

## Late Pleistocene marginal marine ostracodes from the southeastern Atlantic coastal plain and their paleoenvironmental implications

### Les ostracodes marins littoraux de la fin du Pléistocène du sud-est de la côte atlantique et leurs habitats

### Die Ostracoden und ihr Habitat der Meeresküsten im Spät-Pleistozän, süd-östliche Atlantik Küste

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Résumé de l'article

Des dépôts du Pléistocène supérieur de 21 sites du Maryland, de la Virginie, des deux Carolines et du nord de la Floride ont fourni 77 espèces d'ostracodes. La très grande majorité d'entre eux vivent actuellement en eaux saumâtre ou salée. On a pu identifier cinq biofaciès du Quaternaire supérieur au moyen de l'analyse en composantes principales, les lagunes, les bords de mer, les estuaires, les bras de mer et les bancs d'huîtres. Pendant le Quaternaire supérieur, les lagunes et les bancs d'huîtres dominaient dans la région de la baie de Chesapeake, alors que le biofaciès de bras de mer caractérisait la région du centre-est de la Caroline du Nord, un biofaciès semblable à celui qui existe présentement dans le bras de mer de Pamlico. Le biofaciès de bords de mer était présent dans le sud-est de la Virginie et le long de la côte de la Caroline du Sud. Le biofaciès estuarien ne se trouvait que dans la région de la baie de Chesapeake. On a pu reconstituer les paléoclimats en comparant la zoogéographie des ostracodes de l'Holocène à ceux de la fin du Pléistocène. Selon toute vraisemblance, le climat qui régnait pendant le Quaternaire supérieur était aussi chaud, et par endroits davantage, que celui des mêmes latitudes aujourd'hui. *Cyprideis margarita*, *Neocaudites atlantica* et *Microcytherura norfolkensis* sont présentés comme étant de nouvelles espèces.

# LATE PLEISTOCENE MARGINAL MARINE OSTRACODES FROM THE SOUTHEASTERN ATLANTIC COASTAL PLAIN AND THEIR PALEOENVIRONMENTAL IMPLICATIONS

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**ABSTRACT** Upper Pleistocene deposits from 21 localities in Maryland, Virginia, South Carolina, North Carolina, and northern Florida yielded 77 ostracode species; virtually all are living today in brackish and marine water. Five late Pleistocene ostracode biofacies signifying lagoonal, oyster bank, estuarine, open sound, and inner sublittoral environments were delineated using Principal Coordinate Analysis. During the late Pleistocene, the Lagoonal and Oyster Bank Biofacies predominated in the Chesapeake Bay area, whereas east-central North Carolina was characterized by an Open Sound Biofacies similar to that in Pamlico Sound today. The Inner Sublittoral Biofacies was present in southeastern Virginia and along the South Carolina coast. The Estuarine Biofacies was found only in the Chesapeake Bay region. Paleoclimates were inferred by a comparison of Holocene and late Pleistocene ostracode zoogeography; apparently the climate during the late Pleistocene was as warm as, and in some areas warmer than at the same latitudes today. Ostracode species are illustrated by scanning electron photomicrographs. *Cyprideis margarita*, *Neocaudites atlantica*, and *Microcytherura norfolkensis* are described as new species.

**RÉSUMÉ** Les ostracodes marins littoraux de la fin du Pléistocène du sud-est de la côte atlantique et leurs habitats. Des dépôts du Pléistocène supérieur de 21 sites du Maryland, de la Virginie, des deux Carolines et du nord de la Floride ont fourni 77 espèces d'ostracodes. La très grande majorité d'entre eux vivent actuellement en eaux saumâtre ou salée. On a pu identifier cinq biofaciès du Quaternaire supérieur au moyen de l'analyse en composantes principales: les lagunes, les bords de mer, les estuaires, les bras de mer et les bancs d'huîtres. Pendant le Quaternaire supérieur, les lagunes et les bancs d'huîtres dominaient dans la région de la baie de Chesapeake, alors que le biofaciès de bras de mer caractérisait la région du centre-est de la Caroline du Nord, un biofaciès semblable à celui qui existe présentement dans le bras de mer de Pamlico. Le biofaciès de bords de mer était présent dans le sud-est de la Virginie et le long de la côte de la Caroline du Sud. Le biofaciès estuarien ne se trouvait que dans la région de la baie de Chesapeake. On a pu reconstituer les paléoclimats en comparant la zoogéographie des ostracodes de l'Holocène à ceux de la fin du Pléistocène. Selon toute vraisemblance, le climat qui régnait pendant le Quaternaire supérieur était aussi chaud, et par endroits davantage, que celui des mêmes latitudes aujourd'hui. *Cyprideis margarita*, *Neocaudites atlantica* et *Microcytherura norfolkensis* sont présentés comme étant de nouvelles espèces.

**ZUSAMMENFASSUNG** Die Ostracoden und ihr Habitat der Meeresküsten im Spät-Pleistozän, süd-östliche Atlantik Küste. Spät-Pleistozän Ablagerungen aus 21 verschiedenen Orten in Maryland, Süd-Karolina, Nord-Karolina und Nord-Florida ergaben 77 Ostracode Arten, welche heute fast alle in Brack- oder Salzwasser leben. 5 Biofacien aus dem Spät-Pleistozän wurden durch die Methode der Haupt-Koordinaten-Analyse identifiziert: Lagunen, Meeresküsten, Mündungen, Meeresarme und Austerbänke. Im Spät-Pleistozän waren die Lagunen und Austerbank Biofacien in der Chesapeake Bay Gegend vorherrschend, während die östlich zentrale Gegend von Nord-Karolina durch eine Meeresarm-Biofacie charakterisiert war, ähnlich dem heutigen Pamlico Sound. Die Biofacie der Meeresküste bestand im Süd-Osten von Virginia und an der Süd-Karolinischen Küste. Die Biofacie der Mündungen bestand nur in der Region der Chesapeake Bay. Man konnte das Paleoklima wiederherstellen, in dem man die Zoo-Geographie der Ostracoden des Holozäns mit denen des Spät-Pleistozäns verglich. Aller Wahrscheinlichkeit nach, war das Klima des Spät-Pleistozäns ebenso warm wie, und in einigen Gegenden wärmer, als in den gleichen Breiten heute. *Cypridus margarita*, *Neocaudites atlantica* und *Micricythrura norfolkensis* sind als neue Arten präsentiert worden.

## INTRODUCTION

Geologic investigations of upper Tertiary and Quaternary deposits of the central and southern Atlantic Coastal Plain have increased significantly in the last two decades. One major reason for this has been the need to determine the timing and location of late Cenozoic crustal warping and faulting and to identify the mechanisms causing these events. Inherently related to the recognition of tectonism is the problem of deciphering the Upper Tertiary and Quaternary geologic history of the region. This history consists of successive marine transgressive-regressive cycles that inundated the outer Coastal Plain to various degrees. Distinguishing glacio-eustatic transgressions from those caused by tectonism is difficult and requires improved refinement and accuracy of dating and correlation techniques for Upper Tertiary and Quaternary deposits as well as detailed lithologic, geomorphologic, and structural studies. Foremost among the dating techniques are biostratigraphy and various radiometric and geochemical dating techniques. Also required are better techniques for paleoenvironmental reconstruction, particularly those for estimating paleo-sea levels, inferring paleoclimates, and recognizing depositional environments in surface and shallow subsurface deposits.

Podocopid ostracodes, a group of small (about 0.5 to 1.5 mm in length), mostly benthic Crustacea, have proved to be extremely useful for many of these purposes. Progressing a calcified shell that is easily fossilized, podocopid ostracodes have evolved rapidly during the last 5 million years. Moreover, various ostracode taxa inhabit freshwater, brackish water, and marine water environments and are, therefore, excellent as paleoenvironmental indicators. Many species also are diagnostic of specific water temperature regimes and thus are useful for paleoclimatic inference. For these reasons, ostracodes are an ideal group of organisms for Coastal Plain regional biostratigraphy and paleoenvironmental reconstruction.

My purposes in the present paper are threefold: 1) to describe and illustrate late Pleistocene ostracodes from southern Maryland to northern Florida; 2) to delineate distinct late Pleistocene ostracode biofacies and to map their geographic distribution; and 3) to determine late Pleistocene paleozoogeography and to infer Atlantic Coastal Plain paleoclimates from these data.

## PREVIOUS STUDIES

### PLEISTOCENE OSTRACODES OF EASTERN NORTH AMERICA

Data on Pleistocene marine ostracodes from eastern North America are scant. However, the results of the few published studies suggest that ostracodes are

common in Pleistocene deposits of the Atlantic Coastal Plain and have excellent potential for paleoenvironmental and biostratigraphic study. In an early work, BRADY and CROSSKEY (1871) studied arctic and subarctic ostracode assemblages from postglacial Champlain Sea deposits from Québec and New York, and also from marine deposits on the coast of Maine. From their limited material, they noted the similarity of the assemblages to those from Pleistocene deposits of Great Britain and to Holocene assemblages from high latitudes in the North Atlantic. Little additional work was done until HALL (1965) studied ostracodes from Pliocene and late Pleistocene deposits from coreholes near Sapelo Island, Georgia. Although Hall had intended to reconstruct the paleoenvironmental history of Sapelo Island, he found that published descriptions and illustrations of ostracodes were inadequate and that there was a confused state of ostracode taxonomy. Further, he found that the lack of ecological data for most species precluded accurate paleoenvironmental reconstruction.

Ostracodes from the Waccamaw Formation of North and South Carolina were studied by SWAIN (1968). Although SWAIN (1978, p. D-1) suggested a "transitional late Miocene to early Pliocene" age for this formation, more recent studies have shown that it is probably early Pleistocene in age (AKERS, 1972; 1973; HAZEL, 1977a; CRONIN and HAZEL, 1979). Swain's study was primarily taxonomic and contained little paleoenvironmental information.

Ostracodes from Pleistocene glacial periods were recovered from Atlantic submarine canyons off New Jersey to Cape Cod and were studied by HAZEL (1969). The assemblages consisted predominantly of cold-temperate species, and Hazel inferred that during glacial times the boundary between cold- and mild-temperate faunal provinces was approximately 800 km south of where it is today. These data were particularly significant because sea level during glacial times was lower than at present and there appears to be no marine record of glacial periods in the onshore record in this region.

VALENTINE (1971) also used Holocene ostracode distribution to infer Pleistocene climatic conditions. Through a detailed comparison of the ostracode assemblage from the Norfolk Formation (upper Pleistocene) of southeastern Virginia with Holocene assemblages from the Atlantic Continental Shelf, Valentine inferred that during the last interglacial period, a warm-temperate climatic zone existed in southeastern Virginia. No such climatic zone exists in this region today because the convergence of cool and warm water masses at Cape Hatteras, North Carolina, forms a major zoogeographic boundary between the mild-temperate

Virginian Province and the subtropical Carolinian Province.

In a study of ostracodes from Champlain Sea deposits, I (CRONIN, 1977a, 1977b) determined, post-glacial [12,500-10,000 yr B.P. (years before present)] climatic conditions of the Champlain Valley of New York, Vermont, and Québec. My results showed that immediately following the Laurentide ice retreat, about 12,500 yr B.P., arctic climates prevailed. By 10,500 to 10,000 yr B.P., a cold-temperate ostracode assemblage had migrated into the region indicating significant climatic warming.

Recently, CRONIN and HAZEL (1979) performed a biostratigraphic study of ostracodes from Pliocene and Pleistocene deposits of the Cape Fear region, North and South Carolina. They found that faunas from the Waccamaw Formation (early Pleistocene) and the Canepatch Formation (lower upper Pleistocene) were distinct from each other in two significant aspects. First, several extinct species that are characteristic of the Waccamaw Formation and older deposits are absent from the Canepatch Formation and apparently became extinct at the end of the Waccamaw transgression. Second, several extant species have their first fossil appearance in the Canepatch Formation of South Carolina. This study and that of HAZEL (1977a) demonstrate the value of ostracodes for regional biostratigraphic correlation of Pliocene and Pleistocene marine deposits of the Atlantic Coastal Plain.

#### HOLOCENE MARGINAL MARINE OSTRACODES, ATLANTIC AND GULF COASTS

Many reports exist on ostracodes from the Atlantic and Gulf coasts of North America. Because most upper Pleistocene ostracode assemblages examined in the present study indicate brackish water, marginal marine environments, I will emphasize in the following review studies dealing with Holocene nearshore ostracodes, particularly those from estuaries, lagoons, and related back-barrier environments. Recent papers containing comprehensive treatments of open-marine ostracode distributions are the studies of HAZEL (1970a) for the Continental Shelf off northeastern North America, VALENTINE (1971) and HAZEL (1975) for the shelf off the central Atlantic Coast, van den BOLD (1978) for the Caribbean Sea, and MADDOCKS (1977) for the Gulf of Mexico and the Caribbean Sea. The reader is referred to these papers and the references in them for details on normal marine ostracode assemblages from eastern North America. Other papers used in the present study that deal primarily with open marine ostracodes are by BLAKE (1929, 1933), BENSON and COLEMAN (1963), CURTIS (1960), HAZEL (1967) TEETER (1975), KONTROVITZ (1976), COLE and FER-

GUSON (1975), SIDDIQUI and GRIGG (1975), CUSHMAN (1906), PURI (1960), and HULINGS (1966, 1967).

Figure 1 shows the geographical regions covered by most studies of marginal marine ostracodes cited in the following discussion. Figure 2 summarizes the results of some of these studies in terms of the various classifications for coastal environments based on the ostracodes which inhabit them. Clearly these previous studies vary in scope, approach, and methodology, and hence Figure 2 shows a variety of classification schemes. Also shown in Figure 2 is the classification adopted in the present study. No single environmental factor was used as a criterion for this classification because ostracode species distributions are controlled by many factors. In general, the Y-axis in Figure 2 represents distance of the environment from shore. A seaward increase in salinity is also a general characteristic of this classification. I will discuss the methodology for biofacies delineation and the environmental classification used in the present paper below.

SWAIN (1955) examined ostracodes from San Antonio Bay, a back-barrier, estuarine-lagoonal complex on the Texas coast in the Gulf of Mexico. On the basis of the distribution of ostracodes, he recognized three "facies" representing prodelta, bay, and open gulf environments. The results indicated that *Cytheromorpha curta* was most abundant in the upper bay near areas of freshwater influx. Predominant throughout most of the bay were *Cyprideis salebrosa*, *Loxoconcha matagordensis*, *Perissocytheridea brachyforma*, *Cytheromorpha newportensis*, *Paracytheridea altita*, and several species of *Cytherura*. *Loxoconcha matagordensis*, and *Cyprideis* were often found associated with oyster reefs.

In a study of ostracodes from Alligator Harbor, on the west coast of Florida, PURI and HULINGS (1957) found a river biofacies consisting of the primarily nonmarine genera *Candona* and *Darwinula*, and a bay biofacies characterized by the genera *Cyprideis*, *Hulingsina*, and others. They also found three depth-related inner neritic biofacies consisting of open marine taxa.

BENDA and PURI (1962) analyzed foraminifers and ostracodes from mangrove swamps and adjacent lagoons of the Cape Romano region on the west coast of Florida. Four ostracode assemblages were recognized. The marsh-river assemblage was characterized by *Candona*, *Cyprideis*, and *Cytherura*, whereas the lagoonal assemblage consisted of *Paracytheroma stephensoni*, *Perissocytheridea brachyforma*, *Perissocytheridea rugata*, *Loxoconcha matagordensis*, *Cytherura forulata*, "*Haplocytheridea*" *setipunctata* and others. The mangrove-island assemblage included *Actinocythereis subquadrata*, *Cyprideis*, *Cytherura*, *Puriana flo-*





FIGURE 1. Areas of previous studies of Holocene marine and marginal marine ostracodes. Area 1) BLAKE (1929; 1933); 2) HAZEL (1970a); 3) CUSHMAN (1906); 4) WILLIAMS (1966); 5) KONTROVITZ and BITTER (1976); 6) KONTROVITZ (1978); 7) VALENTINE (1971) and HAZEL (1975); 8) HULINGS (1966); 9) GROSSMAN (1967); 10) HULINGS (1967); 11) DARBY (1965); 12) HALL (1965); 13) CRONIN, (unpubl. data, 1979); 14) PURI (1960); 15) BENDA and PURI (1962); 16) KEYSER (1975a,

1978); 17) BENSON and COLEMAN (1963); 18) PURI (1960); 19) PURI (1960) and PURI and HULINGS (1957); 20) CURTIS (1960); 21) KONTROVITZ (1976); 22) GARBETT and MADDOCKS (1979); 23) SWAIN (1955); 24) ENGEL and SWAIN (1967); 25) KING and KORNIKER (1970); 26) KRUTAK (1978); 27) ELLIOTT and others (1966).

*Carte de localisation des 27 régions où on a déjà étudié les ostracodes marins et marins littoraux holocènes.*

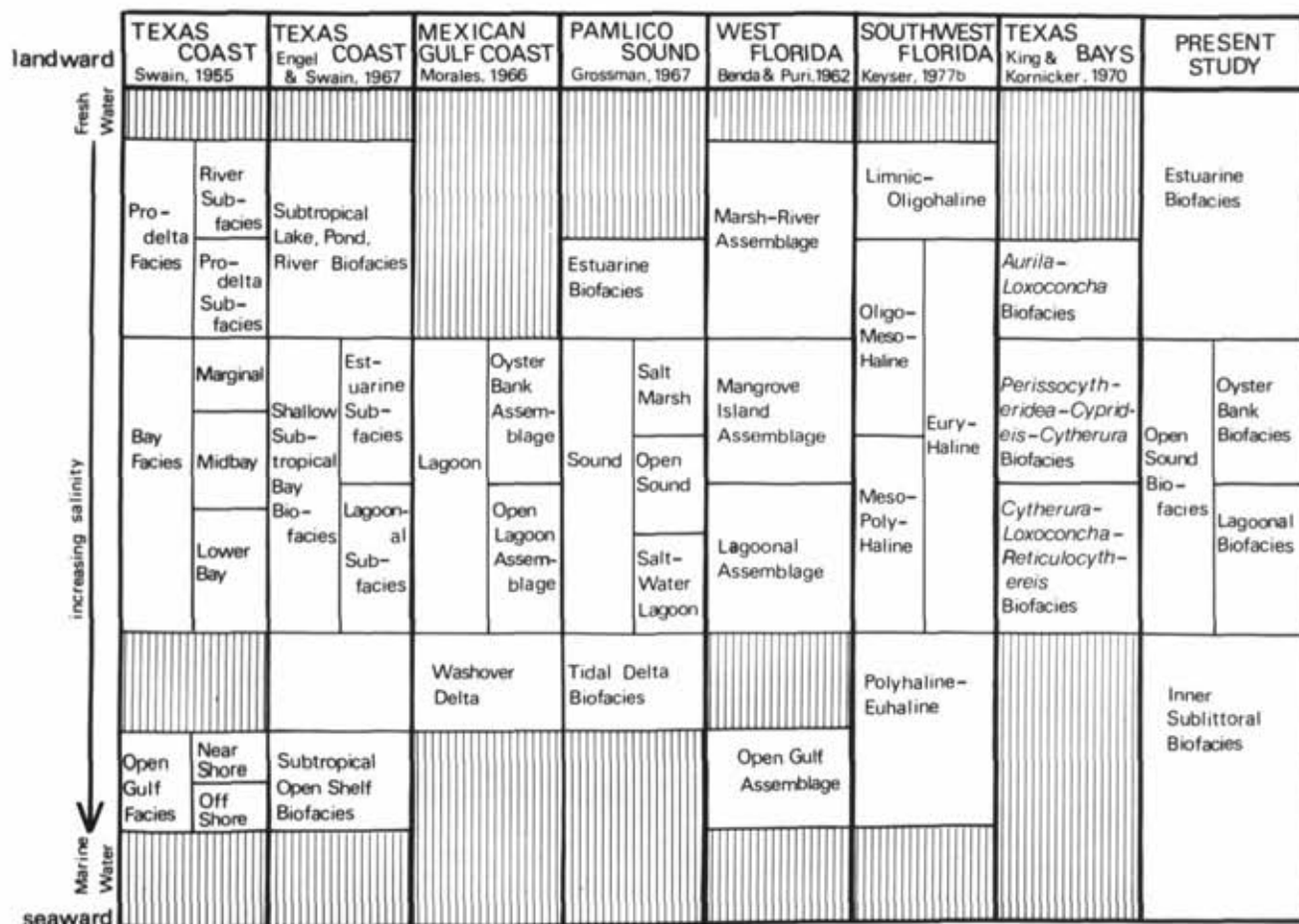


FIGURE 2. Classifications of marginal marine environments used in this study and in previous ostracode studies. Boundaries between biofacies are gradational. This chart schematically depicts a gross correlation of ostracode biofacies and their associated environments.

*ridana*, and *Neocaudites* cf. *N. nevirianii*. The fourth assemblage represented an open gulf environment and contained 39 species.

The ecology, taxonomy, and distribution of ostracodes from Laguna de Terminos in the Gulf Coast of Mexico were studied by MORALES (1966). Three distinct assemblages were recognized and correlated to different habitats. An assemblage dominated by *Cypridels mexicana* and *Perissocytheridea brachyforma* was most common on oyster reefs within the lagoon. "*Haplocytheridea*" *bradyi*, *Loxoconcha matagordensis*, *Paracytheroma stephensoni*, *Perissocytheridea brachyforma*, *Perissocytheridea rugata*, "*Aurila*" *floridana*, *Neocaudites nevirianii*, and several others were found in variable numbers in open lagoonal environments. In the washover-delta environment, *Aurila laevicula* and *Neocaudites nevirianii* were abundant, and most of the species which characterize the lagoonal en-

*La classification des environnements marins littoraux utilisée dans les études sur les ostracodes. Les limites entre les biofacies sont graduelles. Le diagramme établit de façon schématique une certaine corrélation entre les biofacies des ostracodes et leurs habitats respectifs.*

vironment were present in low numbers. Morales suggested that the most suitable environment for ostracode development was near submerged plants, which provided an abundant nutrient supply.

One of the few ostracode studies from marginal marine environments of the northeastern United States was that of WILLIAMS (1966), who examined the distribution of species in Narragansett Bay, Rhode Island. From his data, he could not determine any conclusive relationships between species and various ecological parameters. In general, the fauna was dominated by *Loxoconcha* sp. A, *Loxoconcha sperata*, *Actinocythereis captionis*, *Muellerina canadensis*, and *Loxoconcha rhomboidea*. ELLIOTT and others (1966) studied ostracodes from the Rappahannock River estuary but did not illustrate any specimens.

ENGEL and SWAIN (1967) examined the environmental relationships of ostracodes from the Texas

Gulf Coast. In brief, they found: 1) a subtropical fresh-water biofacies; 2) a subtropical bay biofacies having distinct estuarine and lagoonal subfacies; and 3) a subtropical, open-shelf biofacies, for which they had only a few samples. The estuarine subfacies included the ostracode species *Cyprideis salebrosa*, *Cytheromorpha curta*, *Limnocythere*, and many nonmarine taxa. In lagoons, *Cyprideis*, *Loxoconcha matagordensis*, *Cytherura*, *Perissocytheridea*, *Reticulocythereis*, and "*Aurila*" *floridana* predominated.

GROSSMAN (1967) recognized five ostracode biofacies in southern Pamlico Sound, North Carolina. An estuarine biofacies, represented by only a single sample, contained *Cytheromorpha curta*. The open-sound environment was characterized by *Loxoconcha matagordensis*, *Hulingsina rugipustulosa*, "*Haplocytheridea*" *setipunctata*, and "*H.* *bradyi*", whereas in the salt water lagoonal habitats "*Haplocytheridea*" *setipunctata* and "*H.* *bradyi*" predominated. The saltwater marsh contained "*H.* *setipunctata*", in addition to lower numbers of *Proteoconcha nelsonensis*, *Cytheromorpha newportensis*, *Loxoconcha matagordensis*, and others. The tidal delta biofacies contained most of the species characteristic of the sound and lagoonal biofacies, and also *Cushmanidea seminuda* and low numbers of several open marine species.

A detailed ecologic study of ostracodes in Texas bays and lagoons by KING and KORNICKER (1970) revealed that the abundance of ostracodes is dependent upon availability of food and that salinity may also be a primary factor controlling the distribution of species. Three ostracode biofacies were delineated from the distributional data. On oyster reefs, a *Perissocytheridea brachyforma*-*Cytherura*-*Cyprideis* assemblage was found. A low-diversity bay assemblage contained "*Aurila*" *floridana* and *Loxoconcha matagordensis*. The third biofacies was from upper Laguna Madre and included *Cytherura*, *Loxoconcha matagordensis*, and *Reticulocythereis multicastrata*.

The Holocene distribution of marine ostracodes on the middle Atlantic Continental Shelf was discussed by VALENTINE (1971) and HAZEL (1975). The abundant occurrence data in these studies clearly indicate that several ostracode species that predominate in upper Pleistocene Coastal Plain deposits of the present study are not present in open-marine environments of the Continental Shelf today. These species include *Cyprideis mexicana*, *Cyprideis salebrosa*, *Cyprideis margarita*, *Cytheromorpha curta*, *Cytheromorpha fuscata*, *Paracytheroma stephensoni*, "*Haplocytheridea*" *setipunctata*, *Perissocytheridea brachyforma*, and *Loxoconcha matagordensis* (reported by HAZEL, 1975, from a single shelf locality). All these species are characteristic

of Holocene bays, lagoons, and estuaries of the Atlantic and Gulf Coasts, except for *Cytheromorpha fuscata*, which is known as a fossil from postglacial deposits of Québec and New York (CRONIN, 1977a) and from brackish water environments of northern Europe. It was found in the present study in deposits on the Rappahannock River. When found as fossils, the species listed are extremely reliable indicators of marginal marine, brackish water environments.

KONTROVITZ and BITTER (1976) used cluster analysis on limited data to recognize three ostracode biofacies in the Shrewsbury River estuary, New Jersey. In a later study of the fauna from Great Bay, New Jersey, KONTROVITZ (1978) delineated four biofacies characterized by the following species associations: *Bensonocythere sapeloensis*-*Hulingsina rugipustulosa*; "*Haplocytheridea*" *bradyi*-*Proteoconcha gigantica*; *Cytheromorpha newportensis*-*Loxoconcha* sp. A; and *Leptocythere nikraveshae*-*Cytherura* ssp.

In a recent series of papers, KEYSER (1975a, b, 1977a, 1977b) described the ecology and taxonomy of ostracodes from mangrove swamps of south Florida. He concluded that salinity and substrate were of primary importance in controlling the distribution of species within the area studied. Adopting the following salinity classification: Limnic 0-0.5 ppt (parts per thousand), oligohaline (0.5-5 ppt), mesohaline (5-18 ppt), and polyhaline (18-30 ppt), KEYSER (1977) delineated five salinity-controlled ostracode assemblages. The limnic-oligohaline assemblage consisted of freshwater taxa and the euryhaline species *Cyprideis salebrosa*; the oligohaline-mesohaline assemblage contained almost exclusively freshwater taxa. A euryhaline assemblage consisted of taxa that could tolerate rapid changes in salinity including *Cyprideis beaveni*, the genus *Thalassocypria*, *Perissocytheridea brachyforma*, and "*Aurila*" *floridana*. *Reticulocythereis floridana* and *Reticulocythereis purii*, "*Haplocytheridea*" *setipunctata*, *Loxoconcha matagordensis*, and several species of *Cytherura* dominated the mesohaline-polyhaline assemblage. Polyhaline-euhaline species included *Aurila laevicula*, *Leptocythere nikraveshae*, *Actinocythereis subquadrata*, *Cytheromorpha newportensis*, *Paracytheroma stephensoni*, and *Neocaudites* cf. *N. nevianii*.

GARBETT and MADDOCKS (1979) recently studied ostracodes from bays and lagoons along the eastern Texas Gulf Coast and concluded that salinity and substrate most strongly influenced ostracode biofacies distribution in these environments. In another recent study, KRUTAK (1978) determined the distribution of ostracodes in estuarine, bay, marsh, and sound environments of Bay St. Louis, Mississippi.



## STRATIGRAPHY AND AGE

Ostracodes have proved to be one of the most promising groups of organisms for regional biostratigraphy and several studies have demonstrated their usefulness in the correlation of marine Coastal Plain deposits of Pliocene and early Pleistocene age (HAZEL, 1977a; CRONIN and HAZEL, 1979). Coastal Plain ostracodes are generally quite diverse, they are found in marine and brackish water deposits, and they evolved rapidly. Moreover, many genera have complex and distinctive surface ornaments, the evolution of which can be traced in Pliocene to Holocene assemblages.

Ostracode assemblages of the present study are distinct from those of older deposits in several ways. First, they consist almost entirely of extant species that today inhabit various segments of the Continental Shelf and/or marginal marine environments along the Atlantic and Gulf coasts. However, a particular species may not inhabit the shelf at the same latitude today as it did during the late Pleistocene because the zoogeographical distribution of species has changed in response to climatic and oceanographic changes (see "Paleozoogeography and Paleoclimatology" section). Second, early Pleistocene species are conspicuously absent from assemblages I studied, and many of them apparently have become extinct. HAZEL (1977a) and CRONIN and HAZEL (1979) illustrated many of these diagnostic species. Finally, several species show distinct evolutionary trends in surface ornament throughout the late Tertiary and Quaternary. Representatives of these species in the present material have morphologies very similar to specimens from Holocene collections. Additional radiometric dates and more detailed biostratigraphic and paleozoogeographic study should contribute to a goal of a more accurate late Pleistocene chronology and a more precise age assignment for these Coastal Plain deposits.

The present material was collected from Outer Coastal Plain deposits (*sensu* OAKS and DUBAR, 1974) that have been assigned to several geologic formations. Some of these formations, however, are stratigraphically and geographically poorly known, and thus do not necessarily represent discrete mappable lithologic units. I have tentatively adopted these names pending stratigraphic revision and detailed large scale mapping. The formational name assigned to deposits from each locality is given with the lithologic description of the section in Appendix I.

Late Pleistocene fossiliferous deposits from southeastern Virginia are herein referred to as the Norfolk Formation. The localities north of the city of Norfolk, on the Rappahannock, Piankatank, and Potomac Rivers may represent a distinct, possibly time-equivalent formation, but until detailed study is made, they are

referred to the Norfolk Formation. OAKS and others (1974) suggested a young age for the Norfolk in the type area because of: 1) moderate degrees of limonitic oxidation, clay enrichment, and soil development; 2) weathering characteristics; and 3) uranium-series dates on the coral *Astrangia* from the Norfolk and overlying Kempsville Formation of OAKS and COCH (1963) of 62,000 to 86,000 yr B.P. MIXON and others (1974) report uranium-series dates on the mollusk *Mercenaria* from probable Norfolk-equivalent deposits on the Delmarva Peninsula of 126,000 and 65,000 yr B.P.

VALENTINE (1971) found 82 ostracode species in deposits of the Norfolk Formation, 70 of which he stated are still living on the Atlantic shelf today. However, additional work since Valentine's study suggests that the Norfolk assemblage is even more similar to Holocene assemblages than previously indicated. Of the 12 species that VALENTINE (1971) found were locally extinct, seven (*Bensonocythere* sp. G, *Cushmanidea* sp. C, *Cytheromorpha* sp. A, *Paradoxostoma* sp. G, *Sclerochilus* sp. C, *Sclerochilus* sp. D, and *Leptocythere* sp. A) were present in only one sample in low numbers. *Megacythere* sp. B was found in only two Norfolk samples. *Cytheromorpha* sp. A and *Leptocythere* sp. A are brackish-water taxa and may inhabit poorly studied modern marginal marine environments of the Atlantic Coast. The other five, found in only one sample, are too poorly represented to determine if they were distinct species which have become extinct or if they are aberrant morphotypes of other species. Two other species common in the Norfolk Formation, "*Haplocytheridea*" *setipunctata* and *Paracytheroma stephensoni*, are absent from the shelf but they thrive in brackish waters along the Atlantic and Gulf coasts. Another species, *Hemicythere villosa*, inhabits modern subfrigid to cooler mild-temperate climates of the Atlantic Coast but not the warmer southern part of the mild-temperate climatic zone off Virginia. Only *Paradoxostoma* sp. F was found in many Norfolk samples and seems to be extinct. Virtually all the species examined in the present material from southeastern Virginia are also extant. In summary, ostracode assemblages from the Norfolk Formation consistently show a modern aspect and provide strong evidence for a late Pleistocene age.

Fossiliferous material from the Pamlico Sound region was collected from deposits of the Flanner Beach Formation (DUBAR and SOLLIDAY, 1963). MIXON and PILKEY (1976) mapped the surficial and shallow subsurface deposits of this region and adopted the term Flanner Beach Formation with some restrictions (see MIXON and PILKEY, 1976, p. 9). They proposed the informal term "Beard Creek" member for fossiliferous silty sands and silty clays that contain well-preserved



ostracode assemblages. A middle to late Pleistocene interglacial age was suggested for the Flanner Beach transgressive-regressive cycle.

Although generally yielding ostracode assemblages of low diversity, Flanner Beach deposits at locality 18 yielded a relatively diverse assemblage consisting almost exclusively of well-known, extant species, most of which inhabit Pamlico Sound today. In addition, several distinct species are also found in deposits of the Norfolk Formation but are absent to rare in most other upper Pleistocene Atlantic Coast deposits. These include *Pontocythere* sp. A, *Cytherura* sp. C, *Microcytherura norfolkensis*, *Puriana floridana*, and *Bensonocythere* sp. B. Hence a young age for the Flanner Beach Formation and a gross correlation with the Norfolk Formation are suggested by the ostracode assemblage.

Deposits of the Socastee Formation of DUBAR (1971) of northern South Carolina were assigned a late Pleistocene age. The ostracode assemblages from this formation support this age assignment. Virtually all the species are extant, and distinctive early Pleistocene species that characterize deposits of the Waccamaw Formation (CRONIN and HAZEL, 1979) are conspicuously absent from DuBar's Socastee assemblages.

In central South Carolina, the "Princess Anne and Silver Bluff terrace-formations" are used to describe upper Pleistocene terraces and associated sediments of the Outer Coastal Plain. COLQUHOUN (1974) suggested a probable Sangamonian age for the "Princess Anne" and a late Sangamonian age for the "Silver Bluff." The ostracode assemblages from these formations seem to confirm the late Pleistocene age, however, the degree of biostratigraphic refinement does not yet permit distinction of different transgressions within the last 300,000 yr B.P.

Deposits at locality 10 from the St. Mary's River on the Florida-Georgia border seem to correspond to deposits mapped by HOYT and HAILS (1974) as the late Pleistocene Pamlico Formation. The ostracodes are sparse, but the assemblage contains only extant species.

## OSTRACODE BIOFACIES

### INTRODUCTION

To define the term biofacies, one must consider it within the context of the broader topic of community ecology. BUZAS (1970, p. 101) broadly defined a community as "all the populations of living organisms in a specified area". Of course, to consider all living things in a region is impossible and so ecologists often deal with parts of communities (e.g., epifauna, planktic flora or fauna, benthic fauna, etc.). BUZAS

(1970, p. 102) referred to biofacies as "multispecies assemblages living in a specified area". A biofacies is thus a part of the entire community. In the present study, I am dealing only with the ostracode biofacies. The biofacies concept does not simply encompass an assemblage of species; it also includes the region throughout which the assemblage is distributed. This definition reflects the need to map the areal distribution of biofacies. The criterion of mappability is essential to the biofacies concept, and, in this way, a biofacies is analogous to a lithofacies.

Problems are inherent in working with biofacies in paleontologic data. Non preservation and differential transport of shells are two significant problems that must be addressed. Because all the ostracode taxa treated in this study have hard carapaces that are easily fossilized, preservational problems are minimal. The effect of transport is difficult to assess. Nevertheless, most Holocene ostracode studies that were used in the present study as a modern data base considered only ostracode valves and not the soft parts of the animal. The assemblages discussed in Holocene studies, therefore, do not represent life assemblages (buried *in situ*), but probably indigenous death assemblages which were collected from the same environment in which the ostracodes were living (see RAUP and STANLEY, 1971). The upper Pleistocene assemblages of the present study are also considered indigenous death assemblages, and, except in rare samples containing a few specimens that were clearly washed in from another environment, a fossil assemblage is believed to represent accurately the ostracode assemblage that was living in the area at the time of the burial. Hence, transport of valves was rarely a significant factor in the analysis of the present material. The biofacies delineated below seem to reflect real species assemblages which have similar recent counterparts.

### METHODS AND MATERIALS

Biofacies of Gulf and Atlantic Coast ostracodes have been delineated by a variety of methods, each depending on the scope of the study and purposes of the author. In most qualitative studies, the abundance of each species at each station was determined and presented in a species occurrence chart. The general distributional trends of species were recognized by researchers, apparently through inspecting the data, and the observed groupings were grossly correlated with the environments or with particular environmental characteristics. SWAIN (1955), MORALES (1966), BENDA and PURI (1962), ENGEL and SWAIN (1967), GROSSMAN (1967), and WILLIAMS (1966) apparently used this approach.

More recently, workers have attempted to delineate biofacies quantitatively by using statistical techniques and multivariate analyses. BUZAS (1970) provided a useful, in-depth discussion of various quantitative techniques that are useful for biofacies delineation. VALENTINE (1971) used cluster analysis and the Dice Coefficient to examine the Holocene distribution of ostracodes on the Continental Shelf of the middle Atlantic Coast. KAESLER (1966) and MADDOCKS (1966) used cluster analysis and the Jaccard Coefficient to study the distribution of ostracodes in Todos Santos Bay, California, and off the coast of Madagascar, respectively. KONTROVITZ and BITTER (1976) and KONTROVITZ (1978) also chose cluster analysis and the Jaccard Coefficient to analyze assemblages from New Jersey estuaries and bays. All these workers, except VALENTINE (1971) used R-mode techniques, in which species versus species comparisons are performed to delineate biofacies. Their biofacies, therefore, consisted of groups of species. A major drawback of this approach is that these clusters of species have no areal meaning, that is, they cannot be mapped. BUZAS (1970) and HAZEL (1970b, 1975) advocated Q-mode analyses as an alternative approach. This method gives clusters of samples that are considered biofacies. These clusters can be mapped, and their distribution interpreted in light of the species that predominate in each biofacies. HAZEL (1975) used Q-mode Principal Coordinates Analysis to recognize three ostracode biofacies on the Continental Shelf off Cape Hatteras, North Carolina. Further, Hazel used R-mode cluster analysis of the same data to delineate species groupings which aided in the interpretation of the distribution of the biofacies sample groupings.

In the present paper, my purposes are to delineate late Pleistocene ostracode biofacies, to plot their areal distribution, and to establish their paleoenvironmental significance by comparing the species assemblages of each biofacies to published data on Holocene marginal marine assemblages. A Q-mode Principal Coordinates Analysis (GOWER, 1966; BLACKITH and REYMENT, 1971) was selected as a tool for delineation of the biofacies. In this technique, the correlation coefficient  $r$  is used as a measure of similarity between samples, and is based on the species within each sample. The computer program extracts a selected number of eigenvalues and eigenvectors from a sample-by-sample matrix of coefficients. It also gives the coordinates of the individual samples on the coordinate axes (eigenvectors). The program also gives a plot of the projections of the samples on these axes. The technique is discussed and compared to other multivariate methods in HAZEL (1977b).

The analysis was performed on a matrix of 67 species (species 1-67 in Table I) by 45 samples from 21 localities. The locations and lithologies of these 21 sections are

given in Appendix I. Several species that were found at only one locality were excluded from the analysis. The number of specimens (single valves were counted as one specimen, entire carapaces as two) of each species for each sample was used as input. The advantage of this approach over using presence-absence data stems from the nature of the present material. Compared to the number of ostracode species in normal marine assemblages, relatively few species can tolerate the rigorous brackish water marginal marine environments. Thus, a particular species may be present in several different environments, but it may reach its greatest abundance in only one type of habitat. For example, "*Haplocytheridea*" *setipunctata* (BRADY, 1868) is rarely associated with muddy sediments of lagoonal oyster banks (where it constitutes < 1.0% of the total assemblage), but it is usually the most abundant species (> 50%) in broad open sounds having sandy substrates. Using actual species counts better represents the distribution of the species than does using presence-absence data.

As outlined above, ostracode distributions can be limited by many factors. Therefore, I will interpret the biofacies, their distributions, and their associated species within the context of the general environmental setting of the southeastern Atlantic and Gulf Coastal regions. Specifically, I will use the estuarine-lagoonal, back-barrier complex as a model because, with some variation, it encompasses most of the major marginal marine environments in the study region, and because it serves as a convenient environmental classification for interpretation of the data. Figure 3 schematically depicts this model of coastal environments. The three major environments within this framework are: 1) estuarine/salt marsh (back-barrier); 2) lagoonal/open sound (back-barrier); and 3) inner sublittoral (seaward of the barrier). These environments form a continuum from land to sea but each has its own characteristics. The estuarine environment is characterized by low, fluctuating salinities [0 to 10 ppt (parts per thousand)]. The salt marsh also has great salinity fluctuations and, in addition, is characterized by an abundance of vegetation. The tidal estuarine-salt marsh complex is typified by the Georgia coast.

The typical lagoonal environment is very shallow, less than 1 to 2 m, and has predominantly muddy bottoms. Oyster banks are commonly distributed throughout lagoons, and these serve as major habitats for ostracodes. Salinities in lagoons usually range from about 15 to 30 ppt but are lower near the mouths of estuaries.

Pamlico Sound, on the North Carolina coast, is an excellent example of a broad, back-barrier open sound. This body of water is much larger and is generally deeper than Texas and Mexican coastal lagoons, and

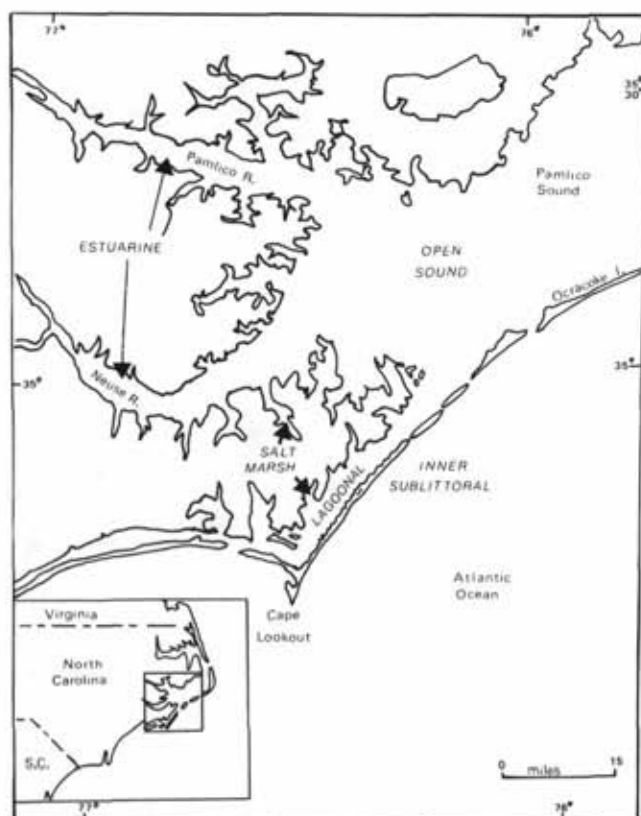


FIGURE 3. Marginal marine environments of the Atlantic Coast. Figure shows southern Pamlico Sound, North Carolina, region (modified from GROSSMAN, 1967). Locations of Estuarine, Salt Marsh, Lagoonal, Open Sound, and Inner Sublittoral Environments are shown.

Les environnements marins littoraux de la côte de l'Atlantique. La carte illustre la région du détroit de Pamlico (Caroline du Nord), d'après GROSSMAN (1967, modifié). La carte montre également la localisation des environnements estuariens, marécageux, lagunaires, de bords de mer et de bras de mer.

its bottom is predominantly sand. Salinities range from about 17 to 35 ppt and are lower near the estuaries.

The inner sublittoral zone, as defined by HEDGPETH (1957), includes the inner part of the Continental Shelf to a depth of 100 m. However, most of the fossil assemblages in the present study indicate water depths of less than 10-20 m. Normal marine salinities (34 to 36 ppt) are present in this environment.

This general classification encompasses several types of coastal morphologies, including the barrier-island complex of Texas, the sea islands of Georgia, the mangrove islands of southwestern Florida, the elongate tidal estuarine-bay complex of Chesapeake Bay, and the broad back-barrier Pamlico Sound. In all these situations, salinity generally increases seaward; this is accompanied by a shift in the fauna from brack-

ish-water to marine assemblages. Other factors, however, such as substrate, vegetation, the presence of oyster banks, water depth, and water temperature contribute to the suitability of the habitat for ostracode populations and these factors vary depending on the type of coastal morphology and the geographic location. The significance of specific factors will be discussed where appropriate in the interpretation of the biofacies. The effect of temperature will be discussed below in the section on "Paleozoogeography and paleoclimatology."

In summary, the biofacies are a means of recognizing various coastal environments of deposition. The biofacies, therefore, provide a valuable aid in the mapping and interpretation of surface and shallow subsurface Quaternary deposits of the Atlantic Coastal Plain. Given the large geographic scope of the present study, and the lack of precise age control within the late Pleistocene, only the large-scale distribution patterns of biofacies could be determined. Nevertheless, the biofacies delineated in this paper represent most major coastal environments and thus provide a framework for recognizing these environments in more detailed mapping studies.

## RESULTS

Of the five axes extracted from the data matrix, axes 1, 2, and 3, which accounted for a total of 57.1% of the variance, yielded meaningful results. Table I gives the sample coordinates for the first five axes, and Figures 4 and 5 show plots of the data for axes 1, 2, and 3. The Principal Coordinates Analysis delineated several sample clusters; those that I consider to be biofacies are circled and labeled in Figure 4. The name given to each biofacies (Table II) is derived from the marginal marine environment that it represents, based on the predominant ostracode assemblages in each. The species occurrence chart in Table III, which groups the samples of each biofacies together, serves as a basis for identifying characteristic species of each sample grouping. The map distribution of biofacies is shown in Figure 6 and will be discussed below.

The faunal characteristics of each biofacies are summarized in Table II. In the following discussion, the term "dominant" means greater than 50% of an assemblage, "common" means between 10% and 50%, and "rare" means less than 10%. In samples of the Oyster Bank Biofacies, *Cyprideis mexicana* is dominant, whereas rare to common species include *Perissocytheridea brachyforma*, *Loxoconcha matagordensis*, *Hulingsina rugipustulosa*, *Cytheromorpha newportensis*, *Cytheromorpha curta*, *Leptocythere nikraveshae*, and *Cyprideis margarita*. The Lagoonal Biofacies is very closely related to the Oyster Bank Biofacies as indicated by their proximity in Figure 4, but differs primarily in containing higher percentages of *Loxoconcha matagor-*



TABLE I  
*Sample Coordinates for first five  
 Principal Coordinate Axes*

Sample No.	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5
41	-0.07606	-0.33900	0.03783	0.19965	-0.03432
40	-0.37194	-0.23197	-0.29102	0.29051	-0.06338
44	-0.49242	0.18431	0.35473	0.03455	-0.08933
42	-0.63431	0.04305	0.26125	-0.14439	-0.06273
43	0.21864	0.33148	0.10199	0.11081	0.19170
25	-0.68446	0.02969	0.26572	-0.11705	-0.04973
26	0.20986	0.31489	-0.36619	-0.28971	-0.19802
6	0.04064	-0.37833	-0.46576	0.47965	-0.06246
WB2	-0.62568	-0.03468	0.21274	-0.05552	0.13797
184	0.53252	-0.40222	0.17505	-0.00956	0.15895
UB3	0.57301	-0.53676	0.18904	-0.01770	-0.22906
UB2	0.57530	-0.44938	0.16299	-0.15741	0.17460
UB1	0.57240	-0.57265	0.17806	-0.08499	-0.14221
71A	-0.52654	-0.04189	0.05222	-0.08499	0.28805
58	0.01111	0.05070	-0.51759	-0.66671	-0.34418
54	0.29429	-0.14650	-0.33832	-0.35783	-0.16351
62	-0.68275	0.00366	0.25304	-0.09733	-0.01945
65A	-0.69619	0.03202	0.25476	-0.09439	-0.00634
65	-0.28821	0.17434	0.24476	-0.05198	0.32671
66	0.33770	0.66776	0.13668	0.21045	-0.15674
67	0.31928	0.52694	0.00224	-0.06480	0.37836
68	0.37545	0.71054	0.04938	0.13049	0.05105
71	0.62508	-0.00531	0.23075	0.19699	-0.33543
72	0.56901	0.31664	0.18587	0.24512	-0.33916
73	0.52337	0.42038	0.15619	0.27124	-0.18135
78	0.23894	0.55881	-0.06984	-0.10111	0.24348
79	0.30481	0.64149	-0.11025	-0.05081	0.01716
141	-0.73383	-0.02179	0.22254	-0.09381	-0.11066
140	-0.70348	-0.06498	0.05496	-0.02767	-0.11968
146	-0.65222	-0.18215	0.02177	0.21159	-0.02321
144	-0.70662	-0.12591	-0.12155	0.17891	-0.07550
145	-0.23457	-0.23431	-0.63695	0.47479	-0.02725
147	-0.73947	-0.05481	0.15365	0.01549	-0.08611
156	0.00774	0.05909	-0.53570	-0.66685	-0.29787
169	-0.25774	-0.09071	-0.60108	0.12124	0.30327
170	-0.73142	-0.02014	0.23975	-0.08604	-0.10409
175	0.16997	0.22380	-0.49819	-0.13956	0.12583
188	0.52745	-0.20182	0.11993	-0.19465	0.37189
183	0.27196	-0.09520	-0.06009	-0.10906	0.62407
185	0.52983	-0.30720	0.19624	-0.08505	0.25819
190	0.61459	-0.35653	0.23192	-0.08943	0.13963
194	0.55698	-0.57779	0.17457	-0.06230	-0.16808
197	-0.11160	-0.18588	-0.62470	0.42651	0.11755
JOI	0.62918	-0.14802	0.24233	0.14114	-0.22462
46	0.32045	0.51636	0.07432	0.26157	-0.19399



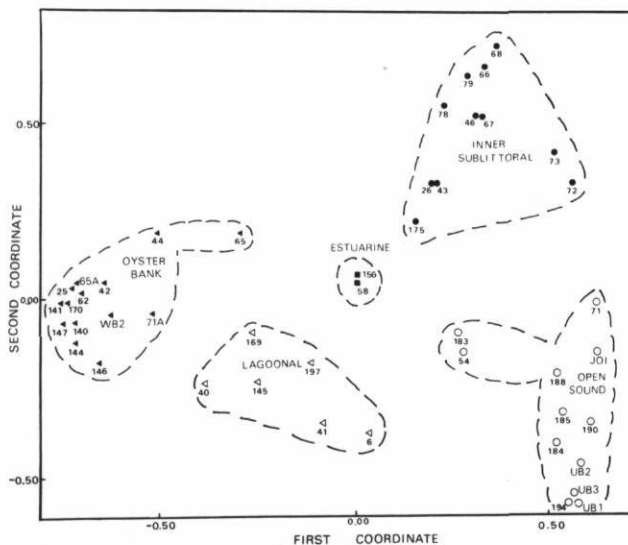


FIGURE 4. Plot of sample coordinates on first and second Principal Coordinate Axes. Samples are labeled and five biofacies are delineated, circled, and labeled.

Diagramme des coordonnées des échantillons sur les premier et deuxième axes des composantes principales. Les échantillons sont identifiés, et cinq biotopes sont délimités, encadrés et identifiés.

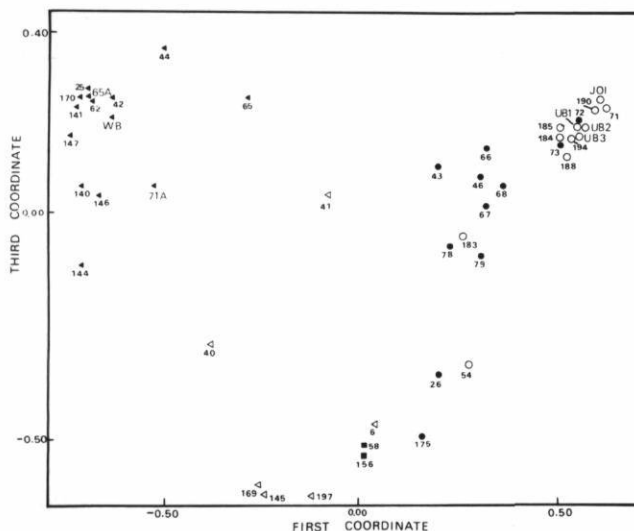


FIGURE 5. Plot of sample coordinates on first and third Principal Coordinate axes.

Diagramme des coordonnées des échantillons sur les premier et troisième axes des composantes principales.

*densis*, "*Haplocytheridea*" *setipunctata*, and *Paracytheridea altia* and lower percentages, but still large numbers, of *Cyprideis mexicana* and *Perissocytheridea brachyforma*. On the basis of the modern distribution of these species, both biofacies signify deposition within a back-barrier lagoon, an environment having a muddy, sometimes oyster-rich substrate and salinities

TABLE II

Ostracode Biofacies Faunal Characteristics

BIOFACIES	DOMINANT SPECIES	SOME OTHER TAXA	COMMENTS
ESTUARINE	<i>Cyprideis salebrosa</i> <i>Cytheromorpha curta</i>	<i>Cytheromorpha fuscata</i>	Very low species diversity
LAGOONAL	<i>Loxoconcha matagordensis</i>	<i>Cyprideis margarita</i> " <i>Haplocytheridea</i> " <i>setipunctata</i> , <i>Cytheromorpha curta</i> , <i>Cytheromorpha newportensis</i> , <i>Leptocythere nikraveshae</i> , <i>Perissocytheridea brachyforma</i>	Larger numbers of " <i>Haplocytheridea</i> " <i>setipunctata</i> than Oyster Bank Biofacies
OYSTER BANK	<i>Cyprideis mexicana</i>	Same as for Lagoonal Biofacies	Larger numbers of <i>Perissocytheridea brachyforma</i> than Lagoonal Biofacies
OPEN SOUND	" <i>Haplocytheridea</i> " <i>setipunctata</i>	Common <i>Hulingsina</i> , <i>Cytherura</i> , <i>Proteoconcha</i> , <i>Cushmanidea seminuda</i>	Lacking <i>Cyprideis</i> , <i>Cytheromorpha curta</i> , and <i>Leptocythere</i>
INNER SUBLITTORAL	" <i>Haplocytheridea</i> " <i>bradyi</i> , <i>Proteoconcha gigantea</i> , <i>Hulingsina rugipustulosa</i>	Rare <i>Bensonocythere</i> , <i>Microcytherura</i> , <i>Cytherura</i> , <i>Pellucistoma</i> and others	Contains many marine taxa; brackish-water species rare to absent; transported specimens common

ranging from 15 to 30 ppt. The distinction between the two biofacies is subtle but significant. *Perissocytheridea brachyforma* is widespread throughout lagoonal environments, but it is most common on oyster banks that fringe lagoons (MORALES, 1966; KING and KORNICKER, 1970; SWAIN, 1955). *Cyprideis mexicana* is commonly associated with *P. brachyforma* in these oyster banks. The data of MORALES (1966), SWAIN (1955), ENGEL and SWAIN (1967), KEYSER (1977), and KING and KORNICKER (1970) indicate that higher numbers of *Loxoconcha matagordensis*, *Paracytheridea altia*, and "*Haplocytheridea*" *setipunctata*, and lower numbers of *Perissocytheridea brachyforma*, signify more open

lagoonal environments and slightly higher salinities (20 to 30 ppt).

Samples of the Estuarine Biofacies are low in species diversity and contain *Cyprideis salebrosa*, *Cytheromorpha curta*, and *Cytheromorpha fuscata*. *Cyprideis salebrosa* is restricted to this biofacies and KEYSER (1977a) found that it was a characteristic species of his limnic-oligohaline assemblage of southwest Florida and that it indicates sandy substrates and water of 0-5 ppt salinities. DARBY (1965) found *Cytheromorpha curta* to be the most abundant species in the restricted salt marsh-estuarine complex behind Sapelo Island, Georgia. *Cytheromorpha fuscata* has been found in postglacial marine deposits of New York and Québec (CRONIN, 1977a). Today it is common along the coasts of northern Europe and in some Canadian lakes (DELORME, 1971) and lives in water of 2-15 ppt salinity.

The Inner Sublittoral Biofacies is characterized by high species diversity, the predominance of normal marine species, and rare occurrences of brackish water species. Species that are common to dominant are "*Haplocytheridea*" *bradyi*, *Hulingsina rugipustulosa*, *Cytherura* sp. B, and *Proteoconcha gigantea*. Rare to common in most samples are *Pellucistoma magniventra*, *Hulingsina* sp. A, *Cytherura forulata*, *Microcytherura* sp. A, *Campylocythere laeva*, and *Proteoconcha tuberculata*. The abundance of marine taxa that are common on the Inner Continental Shelf today (VALENTINE, 1971; HAZEL, 1975) suggests an inner sublittoral environment. At several localities, the presence of inshore genera such as certain *Leptocythere*, certain *Cytheromorpha*, and *Cyprideis*, indicate proximity to shore and possibly some transport from back-barrier environments.

In most samples of the Open Sound Biofacies, "*Haplocytheridea*" *setipunctata* is dominant; *Hulingsina rugipustulosa*, "*Haplocytheridea*" *bradyi*, *Cytherura* sp. B, and *Cushmanidea seminuda* are common in most samples. Other rare species that characterize this biofacies are *Puriana floridana*, *Proteoconcha nelsonensis*, *Hulingsina* sp. E, *Paradoxostoma* ssp., and others (see Table III). This assemblage has distinct similarities to those described by GROSSMAN (1967) from southern Pamlico Sound. Among the most diagnostic species are *Cushmanidea seminuda*, *Proteoconcha nelsonensis*, and "*Haplocytheridea*" *setipunctata*. The environment of deposition was like that of Pamlico Sound — the water was less than 3 to 4 m deep, the salinity ranged from about 15 to 35 ppt and the substrate was sandy.

Figure 6 shows the geographic distribution of ostracode biofacies. Samples from different levels in the same measured section are depicted in their proper stratigraphic sequence. So, for example, at locality 11, near Charleston, South Carolina, the lowest symbol represents sample 65A, the highest sample 68. Descriptions of each locality are in Appendix I.

Clearly, Figure 6 shows distinct trends in the geographic distribution of the biofacies. The poorly represented Estuarine Biofacies was found only in southeastern Virginia along the Rappahannock River, at localities 9 and 16 (samples 58 and 156, respectively). These two samples contain almost identical assemblages, implying a correlation between the two units.

The Oyster Bank Biofacies is most common along tidal rivers that enter Chesapeake Bay, including the Rappahannock, Piankatank, and Potomac Rivers. It was also found in several samples from South Carolina (localities 2, 3, and 11) and in a single sample from the St. Mary's River, Florida (locality 10). The most common lithology associated with these samples is a blue-gray clay matrix containing many specimens of the oyster *Crassostrea virginica*.

In Central North Carolina along the Neuse River, the Open Sound Biofacies was the only biofacies found, except at locality 19 (sample 197), where one sample of the Lagoonal Biofacies was collected. The Open Sound Biofacies assemblage was also present in one sample in the Chesapeake Bay region and in two samples in South Carolina. Samples of this biofacies from the Pamlico Sound area were collected from deposits of the Flanner Beach Formation and consist predominantly of fine to medium sand containing some silt and clay (DUBAR and others, 1974).

The Lagoonal Biofacies assemblages were found in two fossiliferous sections in southeastern Virginia (localities 4 and 15), in both samples from locality 1, in South Carolina, and at locality 19 (sample 197) in North Carolina.

The Inner Sublittoral Biofacies is restricted to South Carolina, except for a single locality in southeastern Virginia (locality 4, sample 175). In South Carolina, most samples of this biofacies were collected from localities that also yielded samples of the Oyster Bank or Open Sound Biofacies from either above or below the Inner Sublittoral samples, indicating that significant environmental changes are recognizable within a single section.

Thus, the geographic distribution of ostracode biofacies strongly suggests that the coastal geomorphology and the environmental setting of the central and southern Atlantic Coast during the late Pleistocene were very similar to those of today. The Chesapeake Bay region today is separated from the open ocean by the Delmarva Peninsula and consists of broad tidal rivers, fringing oyster banks, and generally muddy substrates. Salinities are below those of normal marine conditions and are lowest in the estuaries. During the late Pleistocene, an ancestral Chesapeake Bay apparently was present in this region and included a complex of marginal marine environments such as

TABLE III  
*Species occurrence chart*

[illegible]

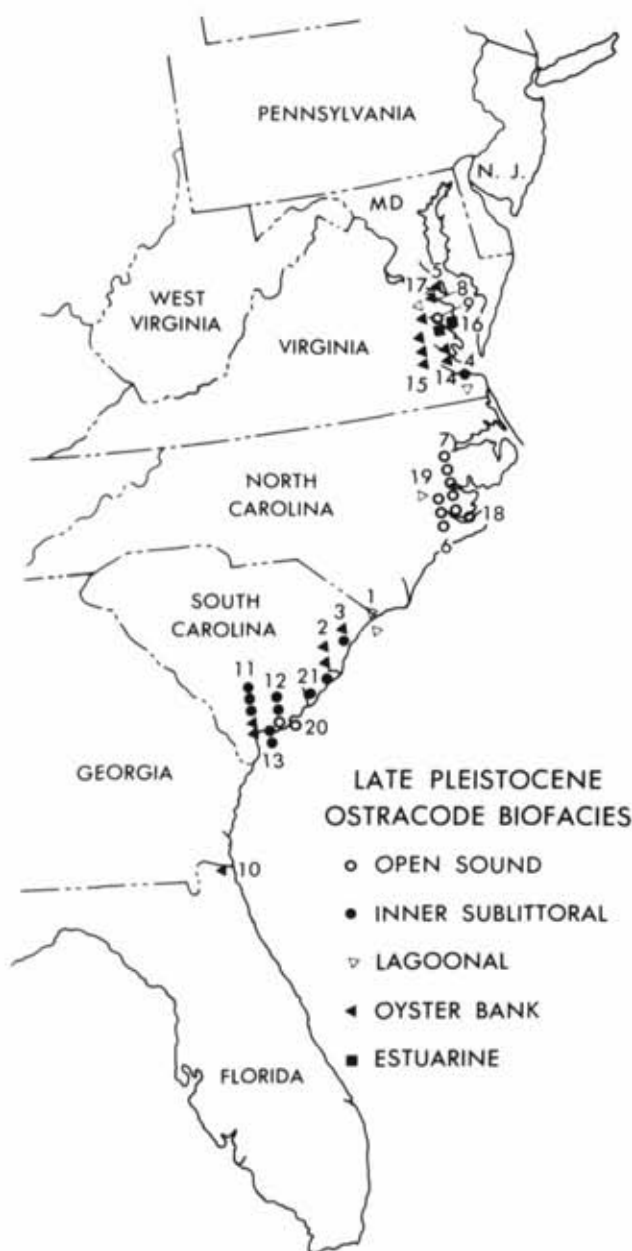


FIGURE 6. Distribution of ostracode biofacies. Symbols are those used in Figure 4. Locality numbers (1-21) are given. Samples from same locality are shown in proper stratigraphic sequence. See Appendix I for details.

Répartition des biofaciès d'ostéocodes. Les symboles sont ceux de la figure 4. Les sites sont identifiés par des numéros (1-21). Les échantillons prélevés sur une même site sont présentés selon l'ordre stratigraphique.

oyster banks, lagoons, and estuaries. Little evidence exists in the ostracode data for normal marine conditions in the Chesapeake Bay region. Rather, brackish water, back-barrier environments were predominant.

Only in the Norfolk, Virginia, region (at locality 4), which is not protected from the open ocean by a barrier such as the Delmarva Peninsula, was the Inner Sublittoral Biofacies found in deposits of the Norfolk Formation. VALENTINE (1971) studied the ostracodes from this unit and his data, and those of the present study, indicate that the Inner Sublittoral Biofacies migrated landward during the last interglacial period into topographically low areas around Norfolk.

In the Pamlico Sound region, late Pleistocene sea-level rise caused the migration of the Open Sound Biofacies landward into the Neuse River area. Today, the Open Sound Biofacies assemblage inhabits Pamlico Sound. Further, the absence of the Inner Sublittoral Biofacies on the central North Carolina coast indicates that a major barrier separated the region from the open ocean during the late Pleistocene. The relatively diverse assemblage in sample 188 (locality 18), however, indicates that nearly normal marine salinities were farther inland during the late Pleistocene than they are today. Today, the Outer Banks separate the Coast and Pamlico Sound from the open ocean.

Several different biofacies were found in South Carolina, of which the Inner Sublittoral Biofacies was the most common. In contrast to the Pamlico Sound and Chesapeake Bay regions, the South Carolina coast is not separated from the open ocean by major barriers such as the Outer Banks or the Delmarva Peninsula (see Fig. 6). Consequently, a late Pleistocene sea level rise brought inner sublittoral environments into submerged lowlying coastal areas. Evidence documenting this marine transgression was found at localities 11 and 12, where samples of the Oyster Bank and Open Sound Biofacies underlie those of the Inner Sublittoral Biofacies. Conversely, a shift from inner sublittoral environments to more restricted oyster bank environments indicates that possible regressional sequences are present at localities 2 and 3. Understanding the detailed environmental history and the precise age relationships of these deposits requires detailed surficial and shallow subsurface mapping and additional absolute dating, however, the recognition of various environments using ostracode biofacies can contribute significantly towards this goal.

## PALEOZOOGEOGRAPHY AND PALEOCLIMATOLOGY

### INTRODUCTION

Whereas the local distribution of ostracode species within marginal marine environments is controlled principally by salinity, substrate, and vegetation, the large-scale zoogeographical distribution of marine species,



that inhabit the continental Shelf, is controlled by bottom-water temperatures. Both the temperature necessary for reproduction and that necessary for survival may be the factors limiting the distribution of a particular species. HAZEL (1970a) discussed the relationship of water temperature and marine ostracode distribution. Usually in the Northern Hemisphere the southernmost occurrence of cryophilic (cold-water) species is determined by warm summer and fall temperatures. For example, the Cape Cod Bay-Massachusetts Bay area is a barrier to equatorward-expanding cryophilic species because of the high summer and fall temperatures in that region (HAZEL, 1970a). Similarly, low winter temperatures of about 3°C in the Cape Cod region form a barrier that stops the poleward expansion of thermophilic (warm-water) species. Hence, many species have limited zoogeographical distributions and are restricted to one or several climatic zones.

#### HOLOCENE ZOOGEOGRAPHY

Figures 7a and 7b depict late Pleistocene and Holocene ostracode zoogeographic provinces and climatic zones, respectively, for the central and southern Atlantic Coast. The reader should refer to Figure 7b for the following discussion.

On the basis of ostracode distribution on the Continental Shelf, HAZEL (1970a) demonstrated that Cape Cod is a major zoogeographical boundary separating the cold-temperate Nova Scotian and the mild-temperate Virginian faunal provinces. VALENTINE (1971) and HAZEL (1975) extended the study of western Atlantic ostracode zoogeography southward and determined that a major faunal break exists at Cape Hatteras, North Carolina, where the mild-temperate Virginian and the subtropical Carolinian faunal provinces converge. No warm-temperate climatic zone exists off the Atlantic Coast today. I have examined ostracodes from 15 bottom samples from the Continental Shelf from South Carolina to the southern tip of Florida and have found that the assemblages of the subtropical Carolinian province reach south of Cape Canaveral, Florida (latitude 28°N.). In this region, the Continental Shelf narrows and winter bottom temperatures, which are warmer than those to the north average 20-22.5°C. Ostracode assemblages from south of Cape Canaveral contain several species characteristic of the Gulf of Mexico, off the west coast of Florida and hence, are distinct from the Carolinian assemblage. Regions off southern Florida have been considered to be in a subtropical climatic zone, and two distinct ostracode faunas have been recognized in the area. The distinct assemblage inhabiting the carbonate platform south and east of Florida (Fig. 7b) has been called a transition

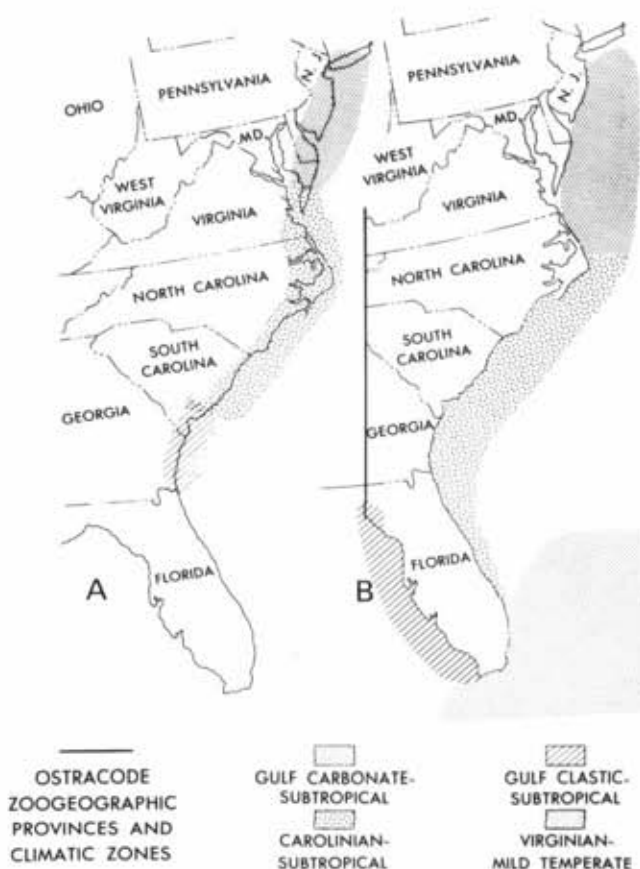


FIGURE 7. Ostracode zoogeography and climatology. 7A) Late Pleistocene zoogeographic provinces and associated climatic zones. Location of boundary between subtropical and temperate zones is assumed and may have been farther north. 7b) Holocene zoogeographic provinces and associated climatic zones. From VALENTINE (1971), van den BOLD (1978), KEYSER (1975a) and Cronin (unpublished data).

*La zoogéographie et la climatologie des ostracodes. 7A) Les régions zoogéographiques de la fin du Pléistocène et les zones climatiques. La limite entre les zones subtropicale et tempérée est estimée et pourrait se situer plus au nord. 7B) les régions zoogéographiques de l'Holocène et les zones climatiques. D'après VALENTINE (1971), van den BOLD (1978), KEYSER (1975a) et Cronin (données non publiées).*

zone between faunas from the Gulf of Mexico and faunas of the Caribbean Sea (van den BOLD, 1978). Off the west coast of the Florida Peninsula, KEYSER (1975a, b) and BENSON and COLEMAN (1963) also recognized an ostracode assemblage characteristic of the carbonate facies and another that they consider characteristic of a clastic facies. This clastic ostracode facies was found mainly in nearshore areas and contains an assemblage very similar to those known from coastal regions around the northern Gulf of Mexico (KEYSER, 1975a, b).

## LATE PLEISTOCENE PALEOZOOGEOGRAPHY

These and other published distributional data on ostracode distribution have been used to infer paleoclimates (HAZEL, 1969; CRONIN, 1977a; VALENTINE, 1971). The ostracode assemblages from the present study also permit paleoclimatic inference for the late Pleistocene. Because the zoogeographical distribution and the temperature tolerances of brackish-water ostracodes from the Atlantic and Gulf coasts are not as well known as those of the marine faunas, I have selected for detailed paleozoogeographical study samples that yielded the most diverse upper Pleistocene marine assemblages from areas in Virginia, North Carolina, and South Carolina. The samples from localities 4, 7, 9, 12, and 18 contain numerous marine species diagnostic of specific temperature conditions and climatic zones. Some brackish-water species that are numerically dominant in many upper Pleistocene samples are excluded from the following discussion because of the limited temperature data available for them. Samples from localities 7 and 18 were treated as one because both are from the Flanner Beach Formation and are only a few kilometers apart. The latitudinal distribution (Fig. 8-11) and the temperature tolerances (Fig. 12-15) for species were plotted for each locality. In addition, the latitude of each locality is indicated in Figures 8-11 by a heavy horizontal line, and the modern winter and summer bottom temperatures for the inner Continental Shelf nearest each locality (from WALFORD and WICKLUND, 1968) are shown in Figures 12-15.

The northernmost locality (locality 9, sample 54) is on the Rappahannock River in southeastern Virginia. The ostracode assemblage consists of some species that today live in the southern part of the Virginian Province and others that inhabit the subtropical Carolinian province and that have not been found north of Cape Hatteras, North Carolina (Fig. 8). The corresponding temperature data (Fig. 12) indicate bottom temperatures during the late Pleistocene of 12.5° to 15°C during the coldest months and 27.5°C during the warmest months. These values are higher than the modern winter and summer water temperatures at the latitude of locality 9 (Fig. 12) and they indicate a subtropical climate.

Locality 4 (sample 175) is near Norfolk, Virginia, at latitude 37° N. The ostracode assemblage is similar to that from locality 9 in having the subtropical species *Cytherura reticulata*, *Loxoconcha matagordensis*, and *Paracytheridea altila*, but it also contains the mild-temperate species *Bensonocythere americana*, *Loxoconcha sperata*, *Neolophocythere subquadrata* and a juvenile specimen tentatively assigned to *Cythere lutea*. The temperature data for this assemblage (Fig. 13) indicates that during the coldest months bottom temper-

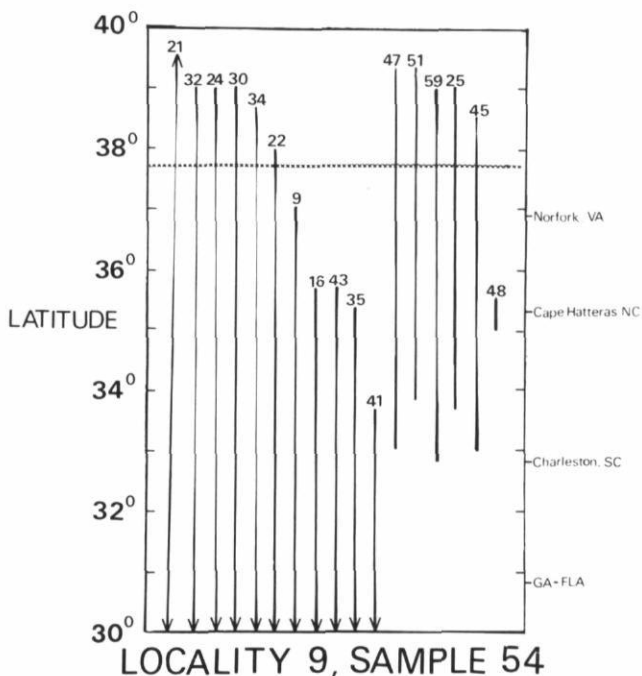


FIGURE 8. Holocene ostracode zoogeography for some species found in sample 54. Vertical line shows latitudinal distribution for each species. Species index numbers are those from occurrence chart Table III. Horizontal line shows the latitude of the fossil sample.

La zoogéographie, à l'Holocène, de quelques espèces d'ostacodes de l'échantillon n° 54. La ligne verticale montre la répartition latitudinale de chacune des espèces. Les numéros des espèces sont les mêmes que ceux du tableau III. La ligne horizontale indique la latitude à laquelle a été prélevé l'échantillon.

atures were 12.5°-15°C, significantly warmer than those of today, whereas summer temperatures were comparable to those of today, about 22.5°-25°C. The ostracode assemblages from localities 4 and 9 resemble those from the Norfolk Formation (upper Pleistocene) (VALENTINE, 1971) in some respects, particularly in the presence of *Paracytheridea altila*, *Pellucistoma magniventra*, *Loxoconcha matagordensis*, *Cytherura reticulata*, and others. The presence of these species at locality 9, except *L. matagordensis*, extends their known late Pleistocene range northward another degree of latitude (to almost 38°N), and signifies warm-water incursions into the Chesapeake Bay region during the late Pleistocene.

However, VALENTINE, (1971) found several other species in the Norfolk Formation, including *Actinocythereis dawsoni*, *Cytheropteron pyramidale*, *Leptocythere angusta*, and *Muellerina* aff. *lienenclausii*, which indicate summer temperatures no higher than 17.5°-10°C, that is, 5° to 10°C cooler than temperatures indicated by the upper Pleistocene assemblages from localities 4

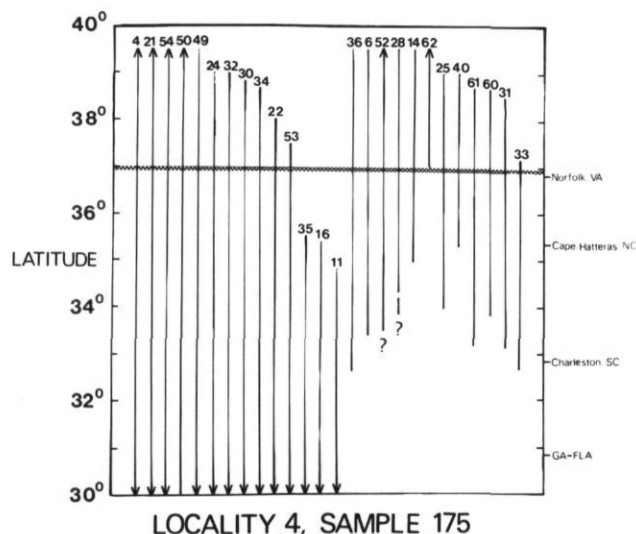


FIGURE 9. Holocene latitudinal distribution for ostracode species found in sample 175. Vertical line shows latitudinal distribution for each species. Species index numbers are those from occurrence chart Table III. Horizontal line shows the latitude of the fossil sample.

La répartition latitudinale, à l'Holocène, des espèces d'ostracodes de l'échantillon n° 175. La ligne verticale montre la répartition latitudinale de chacune des espèces. Les numéros des espèces sont les mêmes que ceux du tableau III. La ligne horizontale indique la latitude à laquelle a été prélevé l'échantillon.

and 9. VALENTINE (1971) inferred that during the last interglacial period a warm-temperate climatic zone existed in southeastern Virginia that was characterized by a narrow annual temperature range of only 7.5°C. The present data indicate that at some time during the late Pleistocene, broader annual temperature ranges existed in southeastern Virginia, and subtropical climates prevailed. In light of the complex climatic changes and sea level fluctuations during the period 200,000 to 60,000 yr B.P. (see FAIRBANKS and MATTHEWS, 1978), it is quite possible that rapid temperature changes and related faunal changes such as those indicated may have taken place within this brief interval. The precise chronology of late Pleistocene marine transgressions in southeastern Virginia awaits more accurate absolute dating.

At localities 7 (sample UB2) and 18 (sample 188), deposits of the Flanner Beach Formation are exposed on the Neuse River, North Carolina. The assemblages from these two localities are treated as one assemblage. The assemblage is similar to those from the upper Pleistocene of southeastern Virginia and consists of predominantly subtropical species (Fig. 10). Summer water temperatures were about 17.5°C (Fig. 14) and were comparable to those on the shelf off North Caro-

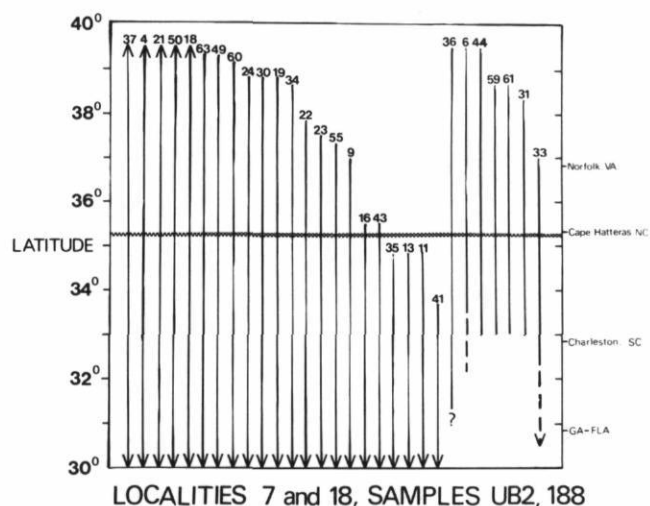


FIGURE 10. Holocene latitudinal distribution for ostracode species found in samples UB2 and 188. Vertical line shows latitudinal distribution for each species. Species index numbers are those from occurrence chart Table III. Horizontal line shows the latitude of the fossil sample.

La répartition latitudinale, à l'Holocène, des espèces d'ostracodes des échantillons n°s UB2 et 188. La ligne verticale montre la répartition latitudinale de chacune des espèces. Les numéros des espèces sont les mêmes que ceux du tableau III. La ligne horizontale indique la latitude à laquelle a été prélevé l'échantillon.

lina and in Pamlico Sound today. Winter temperatures slightly warmer than those of today are indicated by the presence of *Paracytheridea altia*, *Loxoconcha reticulata*, *Neocaudites atlantica*, *Cytherura reticulata*, and *Loxoconcha matagordensis*.

Locality 12 (samples 72, 73) is from the Charleston, South Carolina, area and the ostracode assemblage indicates a subtropical climate similar to that off South Carolina today. Summer water temperatures greater than 27.5°C and winter temperatures of 12.5° to 15°, respectively, were comparable to those of today (Fig. 15). However, some evidence indicates that climates during the late Pleistocene in the Charleston region were slightly warmer than those near Pamlico Sound. First, several subtropical species present at locality 12 near Charleston are absent at localities 7 and 18 in North Carolina. These include *Hulingsina glabra*, *Puriana* sp. A, and *Paracytheridea* sp. A. Further, the presence of two species, *Cytherura nucis* and *Paracytheroma texana*, at localities 12 and 13 suggests warmer water incursion into South Carolina. Today these two species are known to live only in modern Texas bays and lagoons (GARBETT and MADDOCKS, 1979), and their presence in South Carolina during the late Pleistocene suggests a faunal interchange with the Gulf of Mexico sometime during the last 300,000 years.

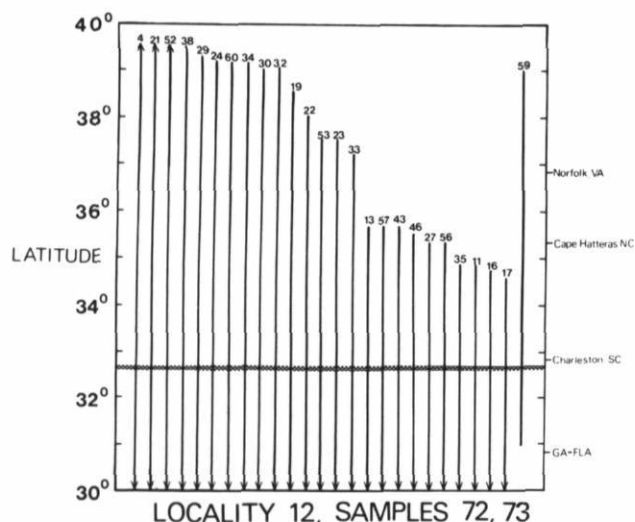


FIGURE 11. Holocene latitudinal distribution for ostracode species found in samples 72 and 73. Vertical line shows latitudinal distribution for each species. Species index numbers are those from occurrence chart Table III. Horizontal line shows the latitude of the fossil sample.

La répartition latitudinale, à l'Holocène, des espèces d'ostracodes des échantillons n°s 72 et 73. La ligne verticale montre la répartition latitudinale de chacune des espèces. Les numéros des espèces sont les mêmes que ceux du tableau III. La ligne horizontale indique la latitude à laquelle a été prélevé l'échantillon.

Evidence also indicates that water temperatures in the Florida-Georgia border area were slightly higher than those of today. The presence at locality 10 (sample 62) of *Reticulocythereis floridana*, a species that is known from northwestern (PURI, 1960) and southwestern (KEYSER, 1977) Florida, but not from eastern Florida, indicates northward migration of this species, perhaps in response to warmer climates of the last interglacial.

In order to summarize the ostracode distributional data, I have attempted to map late Pleistocene zoogeographical provinces and their associated climatic zones (Fig. 7). Deposition at all localities was not necessarily synchronous, and several distinct transgressions may be represented. Deposition, however, probably occurred during sea level rises of the last 300,000 years. Many samples certainly represent deposition during a global high stand of sea-level that occurred at about 125,000 yr B.P. (see, for example, MATTHEWS, 1973; MARSHALL and THOM, 1976; FAIRBANKS and MATTHEWS, 1978).

The paleoenvironmental reconstruction in Figure 7a clearly indicates a late Pleistocene climate that was warmer than that of today; for comparison, modern climatic zones are shown in Figure 7b. Although the

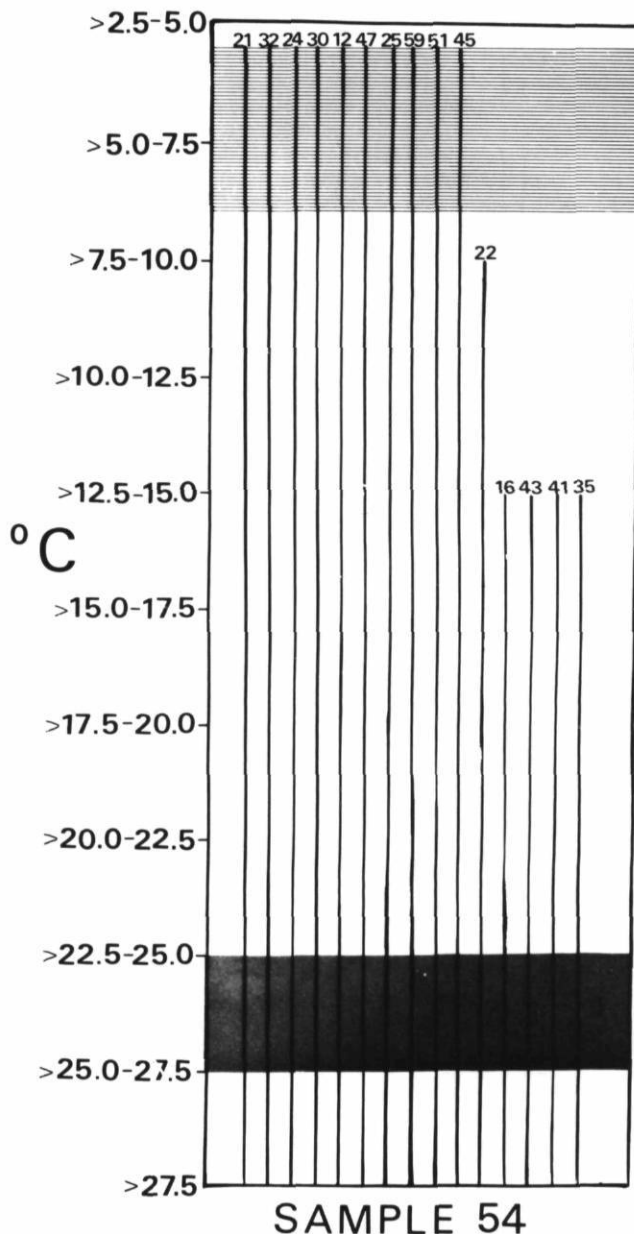


FIGURE 12. Holocene temperature ranges for ostracode species found in sample 54. Data from VALENTINE (1971). Striped and shaded regions indicate modern average bottom-water temperatures during coldest and warmest months, respectively, for waters at same latitude as fossil locality. Temperature data from WALFORD and WICKLUND (1968). Species index numbers are from occurrence chart, Table III.

Les variations de température de l'eau, à l'Holocène, pour les espèces d'ostracodes de l'échantillon n° 54. Les données sont de VALENTINE (1971). Les zones hachurée et en gris donnent les températures moyennes actuelles du fond de l'eau pendant les mois les plus froids et les plus chauds à la même latitude que les sites étudiés. Les données de température sont de WALFORD et WICKLUND (1968). Les numéros des espèces sont ceux du tableau III.



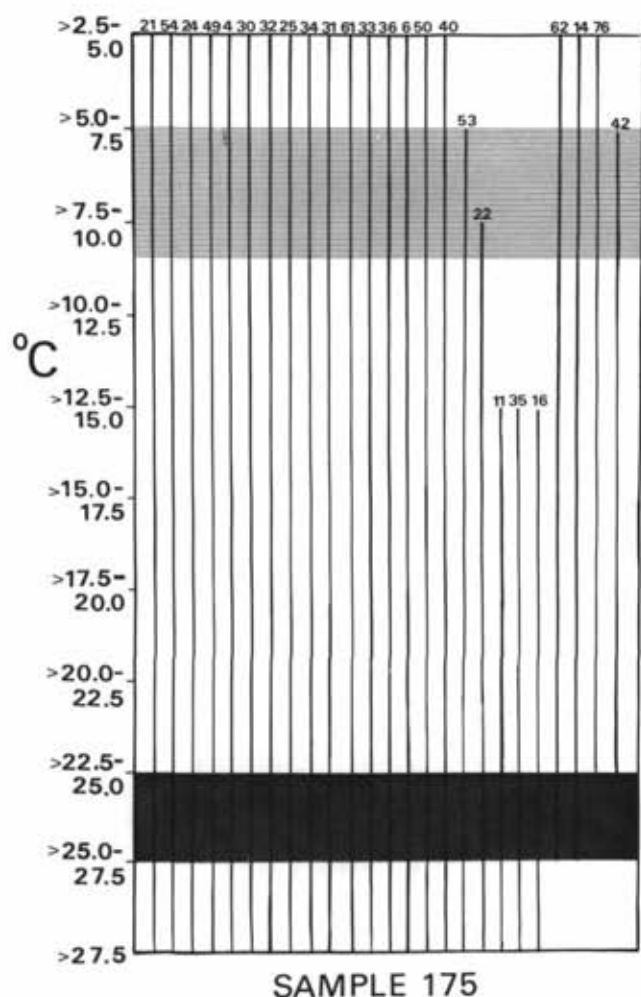


FIGURE 13. Holocene temperature ranges for ostracode species found in sample 175. Data from VALENTINE (1971). Striped and shaded regions indicate modern bottom water temperatures for coldest and warmest months, respectively, for waters at same latitude as fossil locality. Temperature data from WALFORD and WICKLUND (1968). Species index numbers are from occurrence chart, Table III.

*Les variations de température de l'eau, à l'Holocène, pour les espèces d'ostracodes de l'échantillon n° 175. Les données sont de VALENTINE (1971). Les zones hachurée et en gris donnent les températures moyennes actuelles du fond de l'eau pendant les mois les plus froids et les plus chauds à la même latitude que les sites étudiés. Les données de température sont de WALFORD et WICKLUND (1968). Les numéros des espèces sont les mêmes que ceux du tableau III.*

precise location of the boundary between the sub-tropical and temperate zones is unknown, it must have been at least as far north as the northern Delmarva Peninsula, about latitude 38°N. This position is almost 3° in latitude north of the present mild-temperate-subtropical boundary. Whether the climates north of

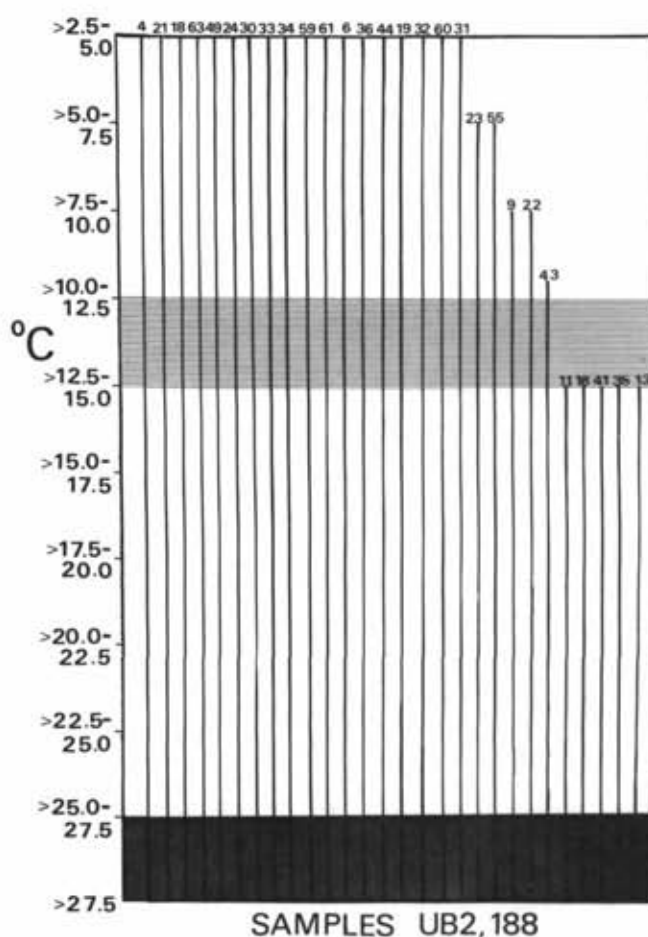


FIGURE 14. Holocene temperature ranges for ostracode species found in samples UB2 and 188. Data from VALENTINE (1971). Striped and shaded regions indicate modern bottom water temperatures for coldest and warmest months, respectively, for waters at same latitude as fossil locality. Temperature data from WALFORD and WICKLUND (1968). Species index numbers are from occurrence chart, Table III.

*Les variations de température de l'eau, à l'Holocène, pour les espèces d'ostracodes des échantillons n°s UB2 et 188. Les données sont de VALENTINE (1971). Les zones hachurée et en gris donnent les températures moyennes actuelles du fond de l'eau pendant les mois les plus froids et les plus chauds à la même latitude que les sites étudiés. Les données de température sont de WALFORD et WICKLUND (1968). Les numéros des espèces sont ceux du tableau III.*

38° N were mild-temperate or warm-temperate is unknown.

Inferred late Pleistocene warm-temperate climates in the Norfolk, Virginia, region (VALENTINE, 1971) are intermediate between the Holocene mild-temperate climates of the region and the late Pleistocene sub-tropical climates indicated by the present data. Valentine's data may signify a warming period preceding

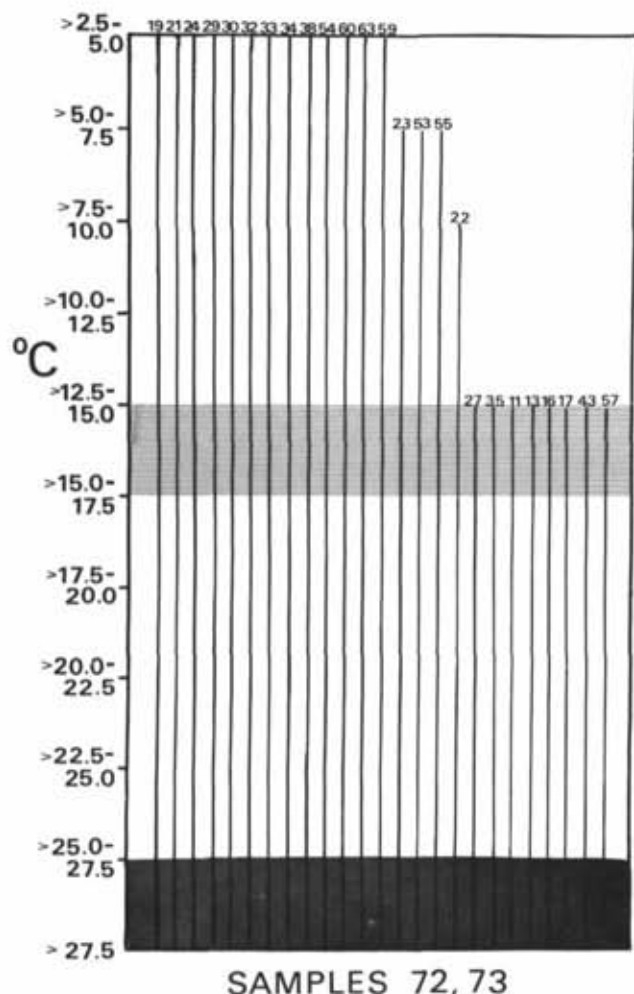


FIGURE 15. Holocene temperature ranges for ostracode species found in samples 72 and 73. Data from VALENTINE (1971). Striped and shaded regions indicate modern bottom water temperatures for coldest and warmest months, respectively, for waters at same latitude as fossil locality. Temperature data from WALFORD and WICKLUND (1968). Species index numbers are from occurrence chart, Table III.

Les variations de température de l'eau, à l'Holocène, pour les espèces d'ostracodes des échantillons n°s 72 et 73: les données sont de VALENTINE (1971). Les zones hachurée et en grisé donnent les températures moyennes actuelles du fond de l'eau pendant les mois les plus froids et les plus chauds à la même latitude que les sites étudiés. Les données de température sont de WALFORD et WICKLUND (1968). Les numéros des espèces sont les mêmes que ceux du tableau III.

a full interglacial, the onset of climatic cooling following a late Pleistocene interglacial climatic maximum, or a late Pleistocene (Sangamonian?, Wisconsinan?) interstadial. The subtropical climates indicated by the material from localities 4 and 9 probably represent a climatic maximum, perhaps at about 125,000 yr B.P.

Additional absolute dates are required to provide a more precise chronology.

The subtropical climate that today characterizes the Carolinian Province reached as far south as the Charleston, South Carolina, region during the late Pleistocene. From Charleston southward to the Florida-Georgia border, slightly warmer subtropical conditions, similar to those from the modern northern Gulf of Mexico, are indicated by the presence in the late Pleistocene of ostracodes characteristic of the modern northern Gulf clastic facies (BENSON and COLEMAN, 1963). The late Pleistocene southern boundary of this province is not yet known and its determination will require study of Pleistocene ostracodes from peninsular Florida.

### SYSTEMATIC PALEONTOLOGY

In the following section I use abbreviated synonymies; for each species I cite only the original species description, and for some species a more recent citation that contains a comprehensive synonymy. Also given in the synonymies are the species names used by VALENTINE (1971), because this reference contains diagnostic zoogeographical and temperature data for numerous species.

Three species are described as new. Many others are left in open nomenclature because they are living and are quite common on the modern Atlantic Continental shelf (see VALENTINE, 1971, and HAZEL, 1975). Formal systematic treatment of most of these species using modern material is presently in preparation.

United States National Museum (USNM) collection numbers were given to all illustrated specimens and these appear in the plate descriptions for each species.

#### Order PODOCOPIDA Sars, 1865

#### Suborder PODOCOPINA Sars, 1865

#### Family BAIRDIIDAE Sars, 1888

#### Subfamily BAIRDIIDINAE Sars, 1888

#### Genus NEONESIDEA Maddocks, 1969

#### *Neonesidea* sp. A

#### Plate 17, figure 9

**Remarks:** Only juvenile specimens were found. They resemble specimens of *N. gerda* (Benson and Coleman, 1963), illustrated by Maddocks (1969, Figure 7a-g), but are more angulate posterodorsally.

**Occurrence:** Rare in several samples from the Inner Sublittoral Biofacies. One sample (71) from the Open Sound Biofacies contained two specimens.

#### Family PONTOCYPRIDAE Muller, 1894

#### Genus ARGILLOECIA Sars, 1866

#### *Argilloecia* sp. A

**Remarks:** A single carapace was found in sample 175.

Genus *PROPONTOCYPRIS* Sylvester-Bradley, 1947  
*Propontocypris edwardsi* (Cushman, 1906)  
 Plate 17, figure 8

1906. *Pontocypris edwardsi* Cushman, Boston Society of Natural History Proceedings, v. 32, no. 10, p. 368, pl. 30, figs. 26-34.

1971. *Propontocypris edwardsi* Cushman, 1906. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 42, 47.

**Occurrence:** Juveniles rare in Inner Sublittoral Biofacies, and in one sample (183) from the Open Sound Biofacies.

**Family CYPRIDAE Baird, 1845**  
 indeterminate genera and species  
 Plate 14, figures 8, 9

**Remarks:** These few specimens, probably representing two genera, suggest proximity to fresh water.

**Occurrence:** Rare in the Oyster Bank Biofacies.

**Family CYTHERIDAE Baird, 1850**  
 Genus *CYTHERE* O. F. Mueller, 1785  
 ? *Cythere lutea* O. F. Mueller, 1785

1785. *Cythere lutea* O. F. Mueller, p. 65, pl. 7, figs. 3, 4.

**Remarks:** A single juvenile was tentatively assigned to *C. lutea*.

**Occurrence:** Sample 175, Inner Sublittoral Biofacies.

Genus *CYTHEROMORPHA* Hirschmann, 1909  
*Cytheromorpha curta* Edwards, 1944  
 Plate 12, figures 6-9

1944. *Cytheromorpha curta* Edwards, Journal of Paleontology, v. 18, no. 6, p. 516, pl. 86, figs. 19-22.

**Occurrence:** Common to dominant in Estuarine Biofacies, absent to common in Lagoonal and Oyster Bank Biofacies, and absent to rare in Inner Sublittoral and Open Sound Biofacies.

*Cytheromorpha fuscata* (Brady, 1869)  
 Plate 13, figures 1-4

1869. *Cythere fuscata* Brady, Linnean Society of London, Transactions, v. 26, no. 2, pl. 7, fig. 8.

**Remarks:** *Cytheromorpha fuscata* is common in brackish waters along northern Europe, but it has been reported from North America only in post-glacial deposits of New York and Québec (Cronin, 1977a, b) and in Canadian Lakes (Delorme, 1971).

**Occurrence:** Common only in Estuarine Biofacies.

*Cytheromorpha newportensis* Williams, 1966  
 Plate 13, figures 5-8

1966. *Cytheromorpha warneri newportensis* Williams, Kansas University Paleontological Contributions, Paper, 11, p. 17, fig. 5, no. 6; fig. 11a-c.

1971. *Cytheromorpha warneri newportensis* Williams, 1966. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 5, 6, 11, 12.

**Occurrence:** Absent to common in Oyster Bank and Lagoonal Biofacies, absent to rare in Inner Sublittoral Biofacies,

absent to rare in Open Sound Biofacies, except in sample 183 where it is dominant.

**Family CYTHERIDEIDAE Sars, 1925**  
**Subfamily CYTHERIDEIDINAE Sars, 1925**  
 Genus *CYPRIDEIS* Jones, 1857  
*Cyprideis mexicana* Sandberg, 1964  
 Plate 1, figures 1-4; Plate 3, figures 1, 2

1964. *Cyprideis mexicana* Sandberg, Stockholm Contributions to Geology, v. 12, p. 125, pl. 11, figs. 11-14; pl. 12, figs. 1-5; pl. 17, fig. 1; pl. 10, figs. 1, 2; pl. 22, figs. 2, 9a-b.

**Remarks:** *Cyprideis mexicana* is characterized by a round to oval mandibular muscle scar (Plate 3, figures 1, 2), fairly straight dorsal and ventral margins, a smooth to weakly pitted surface and a lack of a posteroventral tab. Specimens from upper Pleistocene deposits of the Atlantic Coast are slightly larger than those from the type area off Mexico.

**Occurrence:** Dominant in the Oyster Bank Biofacies, common in the Lagoonal Biofacies, and rare in the Inner Sublittoral Biofacies, where it probably represents transport from more brackish environments.

*Cyprideis salebrosa* van den Bold, 1963  
 Plate 1, figures 5-8; Plate 2, figures 5, 6;  
 Plate 3, figures 3, 4

1963. *Cyprideis salebrosa* van den Bold, Micropaleontology, v. 9, p. 377, pl. 7, figs. 9a-d; pl. 11, figs. 1a-c.

1977. *Cyprideis salebrosa* van den Bold. Keyser, Abhandlungen Verhandlungen naturwissenschaften ver. Hamburg, v. 20, p. 59, pl. 2, figs. 5-7; Text-fig. 6. (with synonymy).

**Remarks:** Keyser (1977a) and Garbett and Maddocks (1979) gave detailed synonymies for this species. The few specimens in the Inner Sublittoral Biofacies were probably transported from estuarine environments.

**Occurrence:** Common in the Estuarine Biofacies, rare in the Oyster Bank and Inner Sublittoral Biofacies.

*Cyprideis margarita* Cronin, n. sp.  
 Plate 1, figures 9, 10; Plate 2, figures 7, 8;  
 Plate 3, figures 5, 6.

1974. *Cyprideis stephensoni* Sandberg. Sandberg and Plusquellec, Geoscience and Man Vol. 6, Ostracoda, p. 23, pl. 1, figs. 12, 18, pl. 2, fig. 6; Text-figs. 7d, 13, 14.

**Differential Diagnosis:** Characterized by very elongate upper mandibular scar, smooth to rarely pitted surface, 7-12 very small anteromarginal denticles, a narrow inner lamella and its distinctive shape. Distinguished from *C. shrewsburyensis* Kontrovitz and Bitter, 1976, by its smaller size, more elongate mandibular scar and smooth surface. Not as high as *C. beaveni* Tressler and Smith, 1948, and possessing a longer mandibular scar than that species. *Cyprideis margarita* differs from *C. stephensoni* Sandberg, 1974 in having a more elongate upper mandibular scar, and a more drawn out posteroventral region, in lacking a posteroventral spine in the right valve and in its smoother surface.

**Remarks:** Sandberg (1964) described *C. stephensoni* from the *Potomides matsoni* zone (Miocene) of Louisiana, as a species characterized by its small size, numerous fine anteromarginal denticles, short posteroventral spine on the right

valve, elongate upper mandibular scar and rounded normal pore canal openings. Sandberg and Plusquellec (1974) assigned Pleistocene and modern specimens from South Carolina and Georgia to *C. stephensoni* noting some variation in valve shape within each sample and the characteristic anteroventral marginal denticles were present. After examining abundant material from locality 2 (South Carolina) I believe Sandberg and Plusquellec's modern and Pleistocene material belongs to *C. margarita* n. sp., a species that is morphologically similar to *C. stephensoni*. Both are relatively small and have small anteroventral marginal denticles, however, *C. margarita* has a more elongate upper mandibular scar, no posteroventral spine, rarely a pitted surface, and a different shape, particularly a more drawn out posteroventral region in males.

**Etymology:** From Greek *margarites* meaning pearl, because of its smooth, pearl-like surface.

**Holotype:** Female left valve (USNM 270049) from upper Pleistocene deposits 300 m west of U.S. Route 17, Sewee Bay, South Carolina (locality 2, sample 44, Appendix I).

**Dimensions:** Holotype: USNM 270049, female left valve, L = 0.76 mm, H = 0.38 mm; Paratypes: USNM 270050, male left valve, L = 0.70 mm, H = 0.35 mm; USNM 270057, male right valve, L = 0.71, H = 0.32 mm; USNM 270058, female left valve, L = 0.71 mm, H = 0.37 mm.

**Occurrence:** Common in Oyster Bank Biofacies in South Carolina, rare in Lagoonal Biofacies of South Carolina. Rare in Inner Sublittoral Biofacies.

Genus "HAPLOCYTHERIDEA" Stephenson, 1936

"*Haplocytheridea*" *bradyi* (Stephenson, 1938)

Plate 2, figures 3, 4

1938. *Cytheridea* (*Haplocytheridea*) *bradyi* Stephenson, Journal of Paleontology, v. 12, p. 129, pl. 23, fig. 22; pl. 24, figs. 5, 6; Text-fig. 10.

1971. *Haplocytheridea bradyi* (Stephenson, 1938). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 42, 46.

1979. "*Haplocytheridea*" *bradyi* Stephenson. Garbett and Maddocks, Journal of Paleontology, v. 53, no. 6, pl. 11, figs. 3-11. (with synonymy).

**Occurrence:** Common to dominant in Inner Sublittoral Biofacies, rare to common in Open Sound Biofacies, absent to rare in Lagoonal and Oyster Bank Biofacies.

"*Haplocytheridea*" *setipunctata* (Brady, 1869)

Plate 2, figures 1, 2

1869. *Cytheridea setipunctata* Brady, Fonds de la Mer, v. 1, Part 1, p. 124, pl. 14, figs. 15, 16.

1971. *Haplocytheridea setipunctata* (Brady, 1869). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 48, 49.

**Occurrence:** Common to dominant in Open Sound Biofacies, absent to common in Lagoonal Biofacies. Absent to rare in Inner Sublittoral Biofacies, except in samples 72 and 73 where it is common. Absent to rare in Oyster Bank Biofacies.

#### Subfamily PERISSOCYTHERIDEINAE van den Bold, 1963

Genus PERISSOCYTHERIDEA Stephenson, 1938

*Perissocytheridea brachyforma* Swain, 1955

Plate 4, figures 7-10

1955. *Perissocytheridea brachyforma* Swain, Journal of Paleontology, v. 29, p. 619, pl. 61, figs. 1a-c, 2a-e, 5a-g; Text-figs. 33a, 39-6a-c.

1977. *Perissocytheridea brachyforma* Swain, 1955. Keyser, Abhandlungen Verhandlungen naturwissenschaften Ver. Hamburg, v. 20, p. 48, pl. 1, figs. 5-7; Text-fig. 2. (with synonymy).

**Remarks:** Keyser (1977) and Garbett and Maddocks (1979) gave comprehensive synonymies for this species and discussed its morphology in detail.

**Occurrence:** Absent to common in Oyster Bank and Lagoonal Biofacies, rare in the Estuarine Biofacies, absent in Inner Sublittoral Biofacies, except for a few isolated specimens.

Genus PUMILOCYTHERIDEA van den Bold, 1963

*Pumilocytheridea* sp. A

**Occurrence:** A single specimen was found in sample 71.

#### Subfamily NEOCYTHERIDEINAE Puri, 1957

Genus PONTOCYTHERE Dubowsky, 1939

*Pontocythere* sp. A

Plate 5, figures 2, 4

1971. *Cushmanidea* sp. B. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 1, figs. 24-27.

**Occurrence:** Absent to rare in all biofacies, but most common in the Inner Sublittoral and Estuarine Biofacies.

Genus SAHNIA Puri, 1952

*Sahnia* sp. A

Plate 6, figure 7

**Remarks:** This species is characterized by faint polygonal reticulation in the posterior region and weak ridges paralleling the antero-dorsal and antero-ventral margins. It is smaller than *Sahnia* sp. B, and lacks the large pits of that species.

**Occurrence:** Absent to rare in the Inner Sublittoral Biofacies, one specimen present in sample 71 of the Open Sound Biofacies.

*Sahnia* sp. B

Plate 6, figure 8

1971. "*Sahnia*" cf. "*S.*" *subulata* (Brady, 1868). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 27, 28.

**Remarks:** This species is characterized by its large, evenly distributed surface pits and its evenly rounded posterior margin. It is probably the same species that Valentine (1971) called "*Sahnia*" cf. "*S.*" *subulata* (Brady, 1868). Additional work on North American *Sahnia* is needed.

**Occurrence:** Absent to rare in the Inner Sublittoral Biofacies, one specimen found in sample 65 of the Oyster Bank Biofacies.

Genus CUSHMANIDEA Blake, 1933

*Cushmanidea seminuda* (Cushman, 1906)

Plate 5, figures 1, 3, 5, 7

1906. *Cytheridea seminuda*, Cushman, Boston Society of



Natural History, Proceedings v. 32, no. 10, p. 374, pl. 33, figs. 62-64; pl. 34, figs. 76, 77.

1971. *Cushmanidea magniporosa* Hall, 1965. Valentine, U. S. Geological Survey Professional Paper 683-D, pl. 1, figs. 41, 42, 45, 46.

**Occurrence:** Absent to common in Open Sound Biofacies, one specimen found in sample 6 of the Lagoonal Biofacies.

Genus *HULINGSINA* Puri, 1958

*Hulingsina* sp. A

Plate 6, figures 1, 3, 5

1971. *Hulingsina* sp. B. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 3, figs. 4, 5, 9, 10.

**Occurrence:** Absent to common in the Inner Sublittoral and Open Sound Biofacies, absent to rare in the Oyster Bank and Lagoonal Biofacies.

*Hulingsina* sp. B

Plate 7, figures 1, 3

1971. *Hulingsina americana* (Cushman, 1906). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 3, figs. 8, 12, 13, 14.

**Occurrence:** Absent to rare in Oyster Bank and Open Sound Biofacies, absent to common in Inner Sublittoral Biofacies.

*Hulingsina glabra* (Hall, 1965)

Plate 6, figure 2

1965. *Cushmanidea glabra* Hall, Four Reports of Ostracode Investigations, no. 4, p. 40, pl. 14, figs. 9-21.

1971. *Hulingsina glabra* (Hall, 1965). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 3, fig. 3.

**Occurrence:** Absent to rare in Inner Sublittoral Biofacies from South Carolina, and present in sample 71 of the Open Sound Biofacies.

*Hulingsina* sp. D

Plate 7, figures 6, 8

1971. *Hulingsina* sp. D. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 3, figs. 1, 2, 6, 7.

**Occurrence:** Absent to common only in Inner Sublittoral Biofacies, except for a new isolated samples from the other biofacies.

*Hulingsina* sp. C

Plate 7, figures 2, 4

1971. *Hulingsina* sp. C. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 3, figs. 19, 20, 23, 24.

**Occurrence:** Absent to rare in Inner Sublittoral and Open Sound Biofacies, found in two samples from the Lagoonal and one sample from the Oyster Bank Biofacies.

*Hulingsina rugipustulosa* (Edwards, 1944)

Plate 5, figures 6, 8; Plate 7, figures 5, 7.

1944. *Cytherideis rugipustulosa* Edwards, Journal of Paleontology, v. 18, no. 6, pl. 86, figs. 5-7.

1971. *Hulingsina rugipustulosa* (Edwards, 1944). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 3, figs. 17, 18, 21, 22, 25, 26, 29, 30.

**Remarks:** Two morphotypes, one having a pustulose surface, the other having nearly smooth surface, are illustrated.

The latter is more common in mild-temperate waters on the Atlantic Shelf, the former in warmer subtropical waters, but additional study is needed to understand these ecophenotypes.

**Occurrence:** Common to dominant in the Inner Sublittoral and Open Sound Biofacies, absent to common in the Oyster Bank and Lagoonal Biofacies.

*Hulingsina* sp. E

Plate 6, figure 4

**Remarks:** This species is smaller and higher than *H. sp. C* and lacks the extremely fine pits and porcelain appearance of that species. *Hulingsina* sp. E differs from *H. rugipustulosa* in that it lacks a sulcus and surface ornament.

**Occurrence:** Absent to rare in Open Sound Biofacies, found in one sample from the Inner Sublittoral Biofacies and two samples from the Oyster Bank Biofacies.

Family CYTHERURIDAE Muller, 1894

Subfamily CYTHERURIDEINAE Muller, 1894

Genus CYTHERURA Muller, 1894

*Cytherura forulata* Edwards, 1944

Plate 8, figures 1-4; Plate 9, figures 7, 8

1944. *Cytherura forulata* Edwards, Journal of Paleontology, v. 18, no. 6, p. 256, pl. 88, figs. 17-20.

1971. *Cytherura forulata* Edwards, 1944. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 25, 26.

- ? 1979. *Cytherura fiscina* Garbett and Maddocks, Journal of Paleontology, v. 53, no. 6, pl. 5, figs. 7-10. (with synonymy).

**Remarks:** Specimens of *Cytherura forulata* have been examined from deposits of Pliocene to Holocene age, from Florida to Maryland, and have great variation in valve size and shape, size of the caudal process, and surface ornament. Even within single populations these features vary greatly. Garbett and Maddocks (1979) proposed the name *C. fiscina* for specimens from Texas bays and lagoons, and suggested that they differ from *C. forulata* Edwards in lacking a caudal process, having a more rounded dorsum, and having parallel radial pore canals. In light of its great morphological variability, I believe a detailed comparative study of fossil and Holocene *C. forulata* from the Atlantic and Gulf Coasts is needed in order to understand the relationships among different populations, and for the time being, I consider *C. fiscina* and *C. forulata* to be synonymous.

**Distribution:** Absent to common in Open Sound and Inner Sublittoral Biofacies, absent to rare in Oyster Bank and Lagoonal Biofacies.

*Cytherura* sp. B

Plate 9, figures 1-5

1971. *Cytherura* sp. D. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 17, 18, 23, 24.

**Occurrence:** Rare to common in Inner Sublittoral and Open Sound Biofacies, absent to rare in other biofacies.

*Cytherura howei* (Puri, 1954)

Plate 14, figure 7

1954. *Kangarina howei* Puri, Florida Geological Survey Bulletin 36, p. 246, pl. 4, fig. 7; Text-figs. 6i, j.

1971. *Cytherura howei* (Puri, 1954). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 1, 7.

*Occurrence:* Absent to common in Lagoonal Biofacies, absent to rare in Oyster Bank, Open Sound, and Inner Sublittoral Biofacies.

*Cytherura nucis* Garbett and Maddocks, 1979  
Plate 10, figures 3-5

1979. *Cytherura nucis* Garbett and Maddocks, Journal of Paleontology, v. 53, no. 6, pl. 6, figs. 1-6; Text-figs. 36a-c.

*Remarks:* Specimens of this distinctive subquadrate species show variation in the development of the surface reticulum.

*Occurrence:* Absent to rare in Inner Sublittoral Biofacies, found in one sample each of Estuarine, Open Sound, and Oyster Bank Biofacies.

*Cytherura sablensis* (Benson and Coleman, 1963)  
Plate 10, figures 1, 2

1963. *Hemicytherura sablensis* Benson and Coleman, Kansas University Paleontological Contributions, Arthropoda, art. 2, p. 33, pl. 6, figs. 6, 8; text-fig. 19.

*Occurrence:* Rare in sample 73, Inner Sublittoral Biofacies.

*Cytherura* sp. A  
Plate 8, figures 7, 8

1971. *Cytherura* sp. A. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 15, 16, 21, 22.

*Occurrence:* Absent to rare in Inner Sublittoral, Open Sound, and Oyster Bank Biofacies.

*Cytherura pseudostriata* Hulings, 1966  
Plate 9, figure 6

1966. *Cytherura pseudostriata* Hulings, Chesapeake Science, v. 7, no. 1, p. 52, fig. 7d.

1971. *Cytherura pseudostriata* Hulings, 1966. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 14, 20.

*Occurrence:* Absent to rare in Inner Sublittoral and Open Sound Biofacies.

*Cytherura* sp. C  
Plate 19, figure 1

1971. *Cytherura* sp. B. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 3, 4, 9, 10.

*Occurrence:* Rare in two samples of the Oyster Bank Biofacies, and one sample each of the Inner Sublittoral and Open Sound Biofacies.

*Cytherura reticulata* Edwards, 1944  
Plate 8, figures 5, 6

1944. *Cytherura reticulata* Edwards, Journal of Paleontology, v. 18, no. 6, p. 525, pl. 88, figs. 13-16.

1971. *Cytherura reticulata* Edwards, 1944. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 5, 6, 11, 12.

*Occurrence:* Absent to rare in all biofacies, except the Estuarine Biofacies.

Genus MICROCYTHERURA Muller, 1894  
*Microcytherura* sp. A  
Plate 10, figure 7

1971. *Microcytherura* sp. A. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 13, 14, 19, 20.

*Occurrence:* Absent to rare in Inner Sublittoral and Open Sound Biofacies, present in one sample from Oyster Bank Biofacies.

*Microcytherura choctawhatcheensis* (Puri, 1954)  
Plate 10, figure 6

1954. *Cytheropteron choctawhatcheensis* Puri, Florida Geological Survey Bulletin 36, p. 242, pl. 5, figs. 1, 2.

1971. *Microcytherura choctawhatcheensis* (Puri, 1954). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 25, 30.

*Occurrence:* Rare in two samples of the Open Sound Biofacies, and in one sample each from the Oyster Bank and Inner Sublittoral Biofacies.

*Microcytherura norfolkensis* Cronin, n. sp.  
Plate 10, figures 8, 9, 10

1971. *Microcytherura* sp. B. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4 figs. 2, 3, 8, 9.

*Differential Diagnosis:* Small, subquadrate *Microcytherura* having evenly rounded anterior and posterior ends; the surface has a fine, very regular reticulum forming distinct polygons containing very fine pits. It is most similar to *M. minuta* Hazel described from deposits of the Yorktown Formation (Pliocene) of Virginia, but it is more quadrate and is larger than that species.

*Etymology:* From deposits of the Norfolk Formation (upper Pleistocene), southeastern Virginia.

*Holotype:* Female left valve (USNM 270118) from deposits of the Norfolk Formation, locality 18, Appendix I, USGS Cenozoic loc. 26181.

*Dimensions:* Holotype: USNM 270118, female left valve L = 0.46 mm, H = 0.23 mm; Paratypes: USNM 270119, female right valve, L = 0.47 mm, H = 0.24 mm; USNM 270120, male left valve, L = 0.43 mm, H = 0.20 mm.

*Occurrence:* Absent to rare in samples of Open Sound and Oyster Bank Biofacies.

Family LOXOCONCHIDAE Sars, 1925  
Subfamily LOXOCONCHIDEINAE Sars, 1925  
Genus LOXOCONCHA Sars, 1866  
*Loxoconcha matagordensis* Swain, 1955  
Plate 11, figures 1, 3, 5, 7

1955. *Loxoconcha matagordensis* Swain, Journal of Paleontology, v. 29, no. 4, p. 629, pl. 63, figs. 9a-b; pl. 64, figs. 1a-b; Text-figs. 366, 39: 7a-b.

1966. *Loxoconcha matagordensis* Swain. Morales, Universidad Nacional Autonoma de Mexico, Institut de Geologia Boletin Mexico, Bulletin 81, p. 66, pl. 6, figs. 4a-d. (with synonymy and discussion).

1971. *Loxoconcha matagordensis* Swain, 1955. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 38, 39, 43, 44.

*Occurrence:* Common to dominant in Lagoonal Biofacies, absent to common in Oyster Bank Biofacies, rare in two samples of the Inner Sublittoral Biofacies and one sample of the Open Sound Biofacies.

*Loxoconcha reticularis* Edwards, 1944  
Plate 12, figures 1, 2, 4

1944. *Loxoconcha reticularis* Edwards, Journal of Paleontology, v. 18, no. 6, p. 527, pl. 88, figs. 26, 27.

**Occurrence:** Absent to rare exclusively in the Inner Sublittoral Biofacies, except in a single sample from the Open Sound Biofacies.

*Loxoconcha* sp. A  
Plate 11, figures 2, 4, 6, 8

1971. *Loxoconcha* aff. *L. granulata* Sars, 1865. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 40, 45.

**Occurrence:** Common in two samples of the Oyster Bank Biofacies, rare in two samples from the Lagoonal Biofacies and in one sample each from the Open Sound and Inner Sublittoral Biofacies.

*Loxoconcha sperata* Williams, 1966  
Plate 12, figure 3

1966. *Loxoconcha sperata* Williams. Kansas University Paleontology Contributions, Paper 11, p. 16, fig. 5, no. 5; Text-figs. 10a-c.

1971. *Loxoconcha sperata* Williams, 1966. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 41, 46.

**Occurrence:** Juvenile specimens only in sample 175 from the Inner Sublittoral Biofacies.

**Family LEPTOCYOTHERIDAE Hanai, 1957**  
Genus LEPTOCYTHERE Sars, 1925  
*Leptocythere nikraveshae* Morales, 1966  
Plate 14, figures 1-6

1966. *Leptocythere nikraveshae* Morales, Universidad Nacional Autonoma de Mexico, Institut de Geologia Boletin 81, p. 62, pl. 5, figs. 2a-b.

1971. *Leptocythere* sp. A. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, fig. 17.

1975. *Leptocythere darbyi* Keyser, Abhandlungen Verhandlungen naturwissenschaften Ver. Hamburg, v. 18/19, p. 257, pl. 20, figs. 1-4; Text-fig. 2. (with synonymy and discussion.)

1978. *Leptocythere domurati* Kontrovitz, Revista Espanola de Micropaleontologia, v. 10, no. 1, p. 38, pl. 2, figs. 1, 4.

**Remarks:** *Leptocythere nikraveshae* varies considerably in the development of surface reticulum and the size of surface pits. The range of variation is illustrated in Plate 14, figures 1-5 in a series of continuous morphologies. Note that, although the thickness of the reticulating ribs and the pit size vary, the pattern of ribs and the position of the pits are constant, indicating their probable homology. Keyser (1975b) discussed previous studies that have confused *Leptocythere* with *Cytheromorpha* (Swain, 1955; Darby, 1965) and suggested that his new species, *L. darbyi*, might actually be synonymous with *L. nikraveshae* Morales. In light of the shell variation in this taxon, I believe they are the same species.

**Occurrence:** Absent to common in Oyster Bank Biofacies and absent to rare in Open Sound, Lagoonal, and Inner Sublittoral Biofacies.

**Family PARACYTHERIDEIDAE Puri, 1957**  
Genus PARACYTHERIDEA Muller, 1894  
*Paracytheridea altia* Edwards, 1944  
Plate 4, figures 1-4

1944. *Paracytheridea altia* Edwards, Journal of Paleontology, v. 18, no. 6, p. 512, pl. 85, figs. 20, 21.

1971. *Paracytheridea altia* Edwards, 1944. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 3, figs. 31-34.

**Occurrence:** Rare to common in Inner Sublittoral Biofacies, absent to common in Lagoonal Biofacies, absent to rare in Oyster Bank and Open Sound Biofacies.

*Paracytheridea* sp. A  
Plate 4, figure 6

1971. *Paracytheridea* sp. A. Valentine, U.S. Geological Survey Professional Paper 683-D, p. D8.

**Occurrence:** Absent to rare in Inner Sublittoral Biofacies, and present in a single sample (71) of Open Sound Biofacies.

*Paracytheridea* cf. *P. rugosa* Edwards, 1944  
Plate 4, figure 5

1944. *Paracytheridea rugosa* Edwards, Journal of Paleontology, v. 18, no. 6, p. 513, pl. 85, fig. 24.

**Remarks:** This species differs slightly from *P. rugosa* in having large pits on the surface and a smaller alae. More material is required to determine if this is a separate species.

**Occurrence:** Only in sample 67 of the Inner Sublittoral Biofacies.

**Family EUCYTHERIDAE Puri, 1954**  
Genus EUCYTHERE Brady, 1868  
*Eucythere gibba* Edwards, 1944  
Plate 15, figure 7

1944. *Eucythere gibba* Edwards, Journal of Paleontology, v. 18, no. 6, p. 513, pl. 85, figs. 25, 26.

1971. *Eucythere gibba* Edwards, 1944. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 40, 41, 44, 45.

**Occurrence:** Rare in one sample each from Open Sound and Inner Sublittoral Biofacies.

*Eucythere triangulata* Puri, 1954  
Plate 15, figure 8

1954. *Eucythere triangulata* Puri (partim), Florida Geological Survey Bulletin 36 (1953), p. 300, pl. 16, fig. 7; Text-fig. 13j; not pl. 16, fig. 8.

**Occurrence:** Absent to rare in Inner Sublittoral Biofacies, rare in one sample each of Open Sound and Oyster Bank Biofacies.

**Family TRACHYLEBERIDAE Sylvester-Bradley, 1948**  
**Subfamily TRACHYLEBERIDINAE Sylvester-Bradley, 1948**  
Genus ACTINOCYTHEREIS Puri, 1953  
*Actinocythereis* sp. A  
Plate 16, figures 1-3

1971. *Actinocythereis* aff. *A. gomillionensis* (Howe and Ellis, 1935). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 1, fig. 39, 40, 44, 48.

**Occurrence:** Absent to dominant in Lagoonal Biofacies, absent to common in Oyster Bank Biofacies, absent to rare in Open Sound and Inner Sublittoral Biofacies.

Genus NEOCAUDITES Puri, 1960  
*Neocaudites atlantica* Cronin, n. sp.  
 Plate 16, figures 4-7

1971. *Neocaudites* sp. A. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 3, figs. 38, 42.

**Differential Diagnosis:** Large rectangular *Neocaudites* having strong, near-parallel median and ventral longitudinal ridges, a produced posterior end, and a pitted surface along the longitudinal ridges. This species is larger than *N. triplistriatus*, and it has a characteristic pit pattern. It differs from *N. nevirianii* Puri, 1960, in lacking the convergence of the ventral and median ridges, in the presence of the pits around the ridges and in the pointed anterior end.

**Etymology:** From its occurrence in Pleistocene (this paper) and Holocene (Valentine, 1971) deposits of the western North Atlantic Ocean.

**Holotype:** Female right valve (USNM 270167) from locality 11, sample 65A, Scanawah Island, South Carolina. (See Appendix I).

**Dimensions:** Holotype: USNM 270167, female right valve, L = 0.64 mm, H = 0.32 mm; Paratypes: USNM 270166, male left valve, L = 0.75 mm, H = 0.35 mm, USNM 270165, juvenile left valve.

**Occurrence:** Absent to rare in Oyster Bank, Inner Sublittoral, and Open Sound Biofacies.

**Subfamily CYTHERETTINAE** Triebel, 1950  
 Genus PROTOCYTHERETTA Puri, 1958  
*Protocytheretta* sp. A  
 Plate 17, figure 7

1971. *Protocytheretta* aff. *P. sahnii* (Puri, 1952). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, fig. 43, 47.

**Remarks:** Cytherettids are very rare in upper Pleistocene deposits and need considerable study. Valentine (1971) referred to a species from the Norfolk Formation (Pleistocene) of Virginia that resembles the present material.

**Occurrence:** Absent to rare in Inner Sublittoral Biofacies and rare in one sample (JOI) from the Open Sound Biofacies.

**Subfamily PTERYGOCYTHEREIDINAE** Puri, 1957  
 Genus PTERYGOCYTHEREIS Blake, 1933  
*Pterygocythereis* sp. A

**Remarks:** Only a few juvenile specimens were found.

**Occurrence:** Rare in sample 73 of the Inner Sublittoral Biofacies.

**Family HEMICYTHERIDAE** Puri, 1953  
**Subfamily HEMICYTHERINAE** Puri, 1953  
 Tribe AURILINI Puri, 1974  
 Genus AURILA Pokorny, 1955  
*Aurila laevicula* (Edwards, 1944)  
 Plate 15, figures 1-4

1944. *Hemicythere laevicula* Edwards, Journal of Paleontology, v. 18, no. 6, p. 518, pl. 86, figs. 27-30.

**Occurrence:** Absent to common in Lagoonal Biofacies, absent to rare in Oyster Bank, Open Sound, and Inner Sublittoral Biofacies.

"*Aurila*" *floridana* Benson and Coleman, 1963  
 Plate 15, figures 5, 6

1963. *Aurila conradi* (Howe and McGuirt) *floridana* Benson and Coleman, Kansas University Paleontological Contributions, no. 31 Arthropoda, art. 2, p. 35, pl. 8, figs. 10-12, 21.

1966. *Aurila floridana* Benson and Coleman, Morales, Universidad Nacional Autonoma de Mexico, Instituto Geologia Boletín 81, p. 56, pl. 5, figs. 5a-d. (with early synonymy).

1971. *Aurila floridana* Benson and Coleman, 1963. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 1, figs. 43, 47.

**Occurrence:** Absent to common in Inner Sublittoral Biofacies, absent to rare in Oyster Bank and Open Sound Biofacies.

Tribe ECHINOCYTHEREIDINI Hazel, 1967  
 Genus ECHINOCYTHEREIS Puri, 1953  
*Echinocythereis* sp. A  
 Plate 17, figure 10

**Remarks:** Only a few juvenile specimens were found.

**Occurrence:** Absent to rare in Inner Sublittoral Biofacies.

Tribe COQUIMBINI Ohmert, 1968  
 Genus MUELLERINA Bassiouni, 1965  
*Muellerina* sp. A  
 Plate 17, figure 3

1971. *Muellerina* aff. *M. lienenklausi* (Ulrich and Bassler, 1904). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 3, figs. 36, 40.

**Occurrence:** Absent to rare in Open Sound, Inner Sublittoral, and Oyster Bank Biofacies.

Tribe THAEROCYTHERINI Hazel, 1967  
 Genus PURIANA Coryell and Fields, 1937  
*Puriana convoluta* Teeter, 1975  
 Plate 16, figure 8

1971. *Puriana* sp. B. Valentine, U.S. Geological Survey Professional Paper 683-D, p. D8.

1975. *Puriana convoluta* Teeter, Belize Shelf — Carbonate Sediments, Clastic Sediments, and Ecology; American Association of Petroleum Geologists, Studies in Geology no. 2, p. 458, figures 14e, 15h-j.

**Remarks:** The Atlantic Coast specimens are slightly larger than the type material from the Gulf of Mexico.

**Occurrence:** Absent to rare in Inner Sublittoral Biofacies.

*Puriana* sp. A  
 Plate 16, figure 9

1971. *Puriana* sp. A. Valentine, U.S. Geological Survey Professional Paper 683-D, p. D8.

**Occurrence:** Rare only at locality 12, samples 71, 72, 73 of the Inner Sublittoral and Open Sound Biofacies.

*Puriana floridana* Puri, 1960  
 Plate 17, figure 10



1960. *Puriana floridana* Puri, Gulf Coast Association of Geological Societies, Transactions v. 10, p. 127, pl. 1, figs. 7, 8; Text-figs. 20, 21.

1971. *Puriana floridana* Puri, 1960. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, figs. 32, 37.

**Remarks:** The illustrated specimen has a smooth surface, whereas some specimens of *P. floridana* are more spinose in the posterior half.

**Occurrence:** Absent to rare in Inner Sublittoral and Open Sound Biofacies.

*Puriana fissipinata* Benton and Coleman, 1963.

1963. *Puriana fissipinata* Benson and Coleman, Kansas University Paleontological Contributions, no. 31 Arthropoda, art. 2, p. 44, pl. 8, figs. 3, 4; Text-fig. 28.

**Occurrence:** A single specimen was found in sample 68 of the Inner Sublittoral Biofacies.

#### Subfamily CAMPYLOCYTHERINAE Puri, 1960

Tribe CAMPYLOCYTHERINI Puri, 1960

Genus CAMPYLOCYTHERE Edwards, 1944

*Campylocythere laeva* Edwards, 1944

Plate 17, figures 4, 5, 6

1944. *Campylocythere laeva* Edwards, Journal of Paleontology, v. 18, no. 6, p. 515, pl. 86, figs. 8-14.

1969. *Campylocythere laeva* Edwards, 1944. Plusquellec and Sandberg, Micropaleontology, v. 15, no. 4, p. 443, pl. 3, fig. 11; pl. 4, figs. 3-6; pl. 5, fig. 6; pl. 6, figs. 8, 16; pl. 8, figs. 2, 10; pl. 9, figs. 1-3, 7, 9, 11; Text-figs. 1, 2a, 3a, 4, 5. (with synonymy.)

1971. *Campylocythere laeva* Edwards, 1944. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 1, figs. 32, 33, 36, 37.

**Occurrence:** Absent to common in Inner Sublittoral and Open Sound Biofacies, absent to rare in Oyster Bank and Lagoonal Biofacies.

Genus PROTEOCONCHA Plusquellec and Sandberg, 1969

*Proteoconcha tuberculata* (Puri, 1960)

Plate 18, figure 10

1960. *Acuticythereis tuberculata* Puri, Gulf Coast Association of Geological Societies, Transactions, v. 10, p. 129, Text-figs. 16, 17.

1971. *Proteoconcha tuberculata* (Puri, 1960). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 48, 49, 53, 54.

**Occurrence:** Absent to common in Inner Sublittoral Biofacies, absent to rare in other biofacies, except Estuarine Biofacies, where it is absent.

*Proteoconcha gigantea* (Edwards, 1944)

Plate 18, figures 6-9

1944. *Basslerites giganticus* Edwards, Journal of Paleontology, v. 18, no. 6, p. 521, pl. 87, figs. 19-23.

1969. *Proteoconcha gigantea* (Edwards, 1944). Plusquellec and Sandberg, Micropaleontology, v. 15, no. 4, p. 455, pl. 4, figs. 1, 2; pl. 5, fig. 3; pl. 7, figs. 2, 3, 8; pl. 10, figs. 3a-g; Text-figs. 2c, 3f, 4, 10. (with synonymy.)

1971. *Proteoconcha gigantea* (Edwards, 1944). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 58-61.

**Occurrence:** Absent to common in Inner Sublittoral and Open Sound Biofacies, absent to rare in Oyster Bank and Lagoonal Biofacies.

*Proteoconcha nelsonensis* (Grossman, 1967)

Plate 17, figure 1

1967. *Acuticythereis nelsonensis* Grossman, Kansas University Paleontological Contributions, Ecology, no. 44, art. 1, part 1, p. 72, pl. 12, fig. 4; pl. 17, figs. 6, 8, 9.

1969. *Proteoconcha proteus* Plusquellec and Sandberg, Micropaleontology, v. 15, no. 4, p. 450, pl. 1, figs. 1-18; pl. 3, figs. 5, 6; pl. 5, fig. 4; pl. 6, figs. 1-4, 17-19; pl. 7, fig. 7; pl. 8, figs. 1, 3, 4, 6, 9, 11; pl. 10, fig. 1a-h; Text-figs. 1-21-m, 4, 7. (with synonymy.)

1971. *Proteoconcha nelsonensis* (Grossman, 1967). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 50, 55.

**Occurrence:** Absent to common in Open Sound Biofacies, absent to rare in Inner Sublittoral, Oyster Bank, and Lagoonal Biofacies.

Genus RETICULOCYTHEREIS Puri, 1960

*Reticulocythereis floridana* Puri, 1960

Plate 17, figure 2

1960. *Reticulocythereis floridana* Puri, Gulf Coast Association of Geological Societies Transactions, v. 10, p. 126, pl. 1, figs. 3, 4; Text-fig. 25.

**Occurrence:** Only in sample 62, locality 10 in the Oyster Bank Biofacies.

Tribe LEGUMINOCYTHEREIDINI Howe, 1961

Genus BENSONOCYTHERE Hazel, 1967

*Bensonocythere americana* Hazel, 1967

Plate 18, figure 2

1967. *Bensonocythere americana* Hazel, U.S. Geological Survey Professional Paper 564, p. 23, pl. 5, figs. 1, 4, 5; pl. 11, fig. 3.

1971. *Bensonocythere americana* Hazel, 1967. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 1, figs. 2, 3, 7, 8.

**Occurrence:** Rare only in samples 6 and 175, locality 4, in Lagoonal and Inner Sublittoral Biofacies.

*Bensonocythere sapeloensis* (Hall, 1965)

Plate 18, figure 1

1965. *Triginglymus sapeloensis* Hall (partim), in Kesling, R.V. and others, Four Reports of Ostracod Investigations, University of Michigan Press, p. 37, pl. 9, figs. 20-23, 25-27; not pl. 9, fig. 24.

1971. *Bensonocythere sapeloensis* (Hall, 1965). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 1, figs. 1, 6, 11, 12.

**Occurrence:** Absent to rare in all biofacies except Estuarine Biofacies.

*Bensonocythere* sp. A

Plate 18, figure 3

1971. *Bensonocythere* sp. E. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 1, figs. 4, 9, 15, 20.

*Occurrence:* Absent to rare in Inner Sublittoral and Open Sound Biofacies, rare in one sample (44) from Oyster Bank Biofacies.

*Bensonocythere* sp. B  
Plate 18, figure 5

1971. *Bensonocythere* cf. *B. sapeloensis* (Hall, 1965). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 1, figs. 28, 29.

*Occurrence:* Absent to rare in Inner Sublittoral, Open Sound, and Oyster Bank Biofacies.

*Bensonocythere whitei* (Swain, 1951)  
Plate 18, figure 4

1951. *Leguminocythereis whitei* Swain, U.S. Geological Survey Professional Paper 234-A, p. 43, pl. 3, figs. 14, 17; (not pl. 3, figs. 16, 18; pl. 4, fig. 1).

1971. *Bensonocythere whitei* (Swain, 1951). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 1, figs. 14, 19.

*Occurrence:* Rare in most samples from Inner Sublittoral Biofacies, rare in one sample each from Oyster Bank and Open Sound Biofacies.

**Family PARADOXOSTOMATIDAE Brady and Norman 1889**  
**Subfamily PARADOXOSTOMATINAE Brady and Norman 1889**  
Genus PARADOXOSTOMA Fischer, 1855

*Paradoxostoma delicata* Puri, 1954  
Plate 6, figures 9, 10

1954. *Paradoxostoma? delicata* Puri, Florida Geological Survey Bulletin 36, p. 288, pl. 15, fig. 3; Text-fig. 12f.

1971. *Paradoxostoma delicata* Puri, 1954. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, fig. 4.

*Occurrence:* Absent to rare in Inner Sublittoral and Open Sound Biofacies.

*Paradoxostoma* sp. A  
Plate 6, figure 6

*Remarks:* Specimens vary in size and shape and more than one species may be present. There is a need for detailed study of Atlantic Coast *Paradoxostoma*.

*Occurrence:* Absent to rare in Open Sound and Inner Sublittoral Biofacies, except in samples 175 and 54, where it is common; rare in sample 65 of Oyster Bank Biofacies.

**Subfamily CYTHEROMATINAE Eloffson, 1941**  
Genus PELLUCISTOMA Coryell and Fields, 1937  
*Pellucistoma magniventra* Edwards, 1944  
Plate 19, figures 7, 9, 10

1944. *Pellucistoma magniventra* Edwards, Journal of Paleontology, v. 18, no. 6, p. 528, pl. 88, figs. 33-35.

1971. *Pellucistoma magniventra* Edwards, 1944. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, fig. 39.

1979. *Pellucistoma magniventra* Edwards, 1944. Garbett and Maddocks, Journal of Paleontology, v. 53, no. 6, p. 864, pl. 2, figs. 1-6; Text-figs. 30a-d. (with synonymy.)

*Occurrence:* Absent to rare in most samples of the Inner Sublittoral and Open Sound Biofacies, rare in three samples of the Oyster Bank Biofacies.

Genus PARACYTHEROMA Juday, 1907  
*Paracytheroma stephensoni* Puri, 1954  
Plate 19, figures 2, 4

1954. *Paracytheroma stephensoni* Puri, Florida Geological Survey Bulletin 36, p. 291, pl. 16, figs. 11, 12; Text-figs. 12g, h.

1971. *Megacythere stephensoni* (Puri, 1954). Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 2, fig. 34.

1979. *Paracytheroma stephensoni* Puri, 1954. Garbett and Maddocks, Journal of Paleontology, v. 53, no. 6, pl. 2, fig. 12; pl. 3, figs. 1-4; Text-figs. 31a-d.

*Occurrence:* Absent to common in Oyster Bank Biofacies, absent to rare in Open Sound, Lagoonal, and Inner Sublittoral Biofacies.

*Paracytheroma texana* Garbett and Maddocks, 1979  
Plate 19, figures 3, 5, 6, 8

1979. *Paracytheroma texana* Garbett and Maddocks, Journal of Paleontology, v. 53, no. 6, p. 871, pl. 3, figs. 5-8; Text-figs. 32a-c.

*Occurrence:* Rare in samples 78 and 79 of the Inner Sublittoral Biofacies.

**Family unknown**

Genus NEOLOPHOCYTHERE Grossman, 1967  
*Neolophocythere subquadrata* Grossman, 1967  
Plate 12, figure 5

1967. *Neolophocythere subquadrata* Grossman, Kansas University Paleontological Contributions, Ecology, no. 44, art. 1, part 1, p. 76, pl. 12, figs. 7-9; pl. 17, figs. 1, 3-5, 7.

1971. *Neolophocythere subquadrata* Grossman, 1967. Valentine, U.S. Geological Survey Professional Paper 683-D, pl. 4, figs. 31, 32, 35, 36.

*Occurrence:* Rare in two samples from the Lagoonal Biofacies, and one sample each from Oyster Bank and Inner Sublittoral Biofacies.

**Suborder PLATYCOPINA Sars, 1866**

**Family CYTHERELLIDAE Sars, 1866**

Genus CYTHERELLOIDEA Alexander, 1928  
*Cytherelloidea* sp. A  
Plate 14, figure 10

*Remarks:* Only a few juvenile specimens were found.

*Occurrence:* Absent to rare in Inner Sublittoral Biofacies, rare in one sample (71) of Open Sound Biofacies.

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- Locality 1.** Little River 7½' Quadrangle, Longitude 78°35'00", latitude 33°51'00". Small sea cliff at end of Tilghmanns Point, on Little River Neck Inlet, South Carolina. Lithostratigraphic unit: "Socastee Formation" (?) of DuBar (1971). Sample 40 (USGS 26140). Orange-brown pebbly, shelly sand with mollusk shells, especially *Crassostrea virginica*, about 0.5 m above low-tide level. Sample 41 (USGS 26141). Tan shelly sand, about 0.5 m above sample 40, with abundant *Mercenaria*.
- Locality 2.** Sewee Bay 7½' Quadrangle, longitude 79°43'15", latitude 32°55'00". West end of sand pit, 300 m west of U.S. Route 17, near Sewee Bay, South Carolina. Lithostratigraphic unit: "Silver Bluff terrace-formation." Sample 44 (USGS 26142). Moderately indurated oyster bank of *Crassostrea virginica* in a sandy matrix, about 1-2 m below ground surface. Sample 42 (USGS 26143). Massive blue-gray clay, with silty, shelly lenses, 0.5 m below sample 44. Sample 43 (USGS 26144). Massive blue-gray clay with sandy lenses and entire mollusk shells, 0.5 m below sample 42.
- Locality 3.** Myrtle Beach 15' Quadrangle, longitude 78°55'30", latitude 33°43'00". Bluff exposed on west bank of Intracoastal Waterway, 100 m south of S.C. Route 501 bridge, west of Myrtle Beach, South Carolina. Lithostratigraphic unit: "Socastee Formation" (?) of DuBar (1971). Sample 25 (USGS 26145). Oyster bank of *Crassostrea virginica* in tan sand matrix, about 3 m above water level. Sample 26 (USGS 26146). Medium to coarse, gray sand with abundant mollusks including *Dinocardium*, *Busycon*, and *Mercenaria*, about 2 m below sample 25.
- Locality 4.** Kempsville 7½' Quadrangle, longitude 76°11'15", latitude 36°48'00". New Light Gravel pit, New Light, Virginia, 1.5 km southeast of intersection of U.S. Route 64 and Indian River Road. Lithostratigraphic unit: Norfolk Formation. Sample 175 (USGS 26147). Pebbly, coarse beach sand, with mollusks, about 8 m below ground surface. Sample 6 (USGS 26148). Grey, mottled, fine-medium silty sand, with articulated bivalves in living position, about 1 m below Sample 175.
- Locality 5.** Point Lookout 7½' Quadrangle, Longitude 76°22'00", latitude 38°04'00". Wailes Bluff on bank of Potomac River, Maryland. Lithostratigraphic unit: Norfolk Formation (?). Sample WB2 (USGS 26149). Oyster bank of *Crassostrea virginica*, about 1.5 m above water level. Collected by J. E. Hazel, 1971.
- Locality 6.** Havelock 7½' Quadrangle, longitude 76°56'45", latitude 34°58'45". Exposures on south side of Neuse River at Flanner Beach, North Carolina. Lithostratigraphic unit: Type locality of Flanner Beach Formation (DuBar and Solliday, 1963). Sample 185 (USGS 26150). Tan to orange, sandy shell hash, about 2 m above low-tide level.

#### APPENDIX I: LOCALITIES

All samples were collected in 1978 by the author, except those indicated. All longitudes are west, all latitudes north.

Sample 183 (USGS 26151). Blue-gray sandy, silty clay; shells moderately common, *Mulinia* the most abundant, 1.0 m below sample 185.

Sample 184 (USGS 26152). Blue-gray sandy, shelly clay, stratigraphic horizon unknown.

**Locality 7.** Upper Broad Creek 7½' Quadrangle, longitude 76°52'45", latitude 35°00'15". Exposures on north bank of Neuse River, near the mouth of Beard Creek, North Carolina.

Lithostratigraphic unit: Flanner Beach Formation (type locality of Neuse Formation of Fallaw and Wheeler, 1969).

Sample 194 (USGS 26153). Compact shelly sandy silt with *Mulinia*, *Ensis*, and other mollusks, about 4 m above low-tide level.

Sample UB3 (USGS 26154). Light grey, moderately indurated clayey silt, with mollusks. Sample collected by Robert Nixon, U.S. Geological Survey, 1970, from about same level as sample 194.

Sample UB2 (USGS 26155). Fine grained quartz sand, grayish-yellow, with mollusks, about 1.5 m below sample UB3. Collected by Robert Nixon, U.S. Geological Survey, 1970.

Sample UB1 (USGS 26156). Fine quartz sand, olive-gray, with abundant mollusks, about 1.0 m below sample UB2. Collected by Robert Nixon, U.S. Geological Survey, 1970.

Sample 190 (USGS 26157). Gray clayey sand, burrowed, with abundant shells of *Busycon*, *Mulinia*, *Dinocardium*, and others, about 0.5 m above low-tide level, probably about the same horizon, or slightly below sample UB1.

**Locality 8.** Kinsdale 7½' Quadrangle, longitude 75°35'30", latitude 38°06'00". Exposures on Potomac River near mouth of Gardiner Creek, Virginia.

Lithostratigraphic unit: Norfolk Formation (?).

Sample 71A (USGS 26158). Oyster bank of *Crassostrea virginica* with sandy, clayey matrix about 1.5 m above water level. Collected by Blake W. Blackwelder, U.S. Geological Survey, 1977.

**Locality 9.** Irvington 7½' Quadrangle, longitude 76°24'30", latitude 37°38'00". Exposures on north bank of Rappahannock River, about 200 m downstream from Norris Bridge, White Stone, Virginia.

Lithostratigraphic unit: Norfolk Formation (?).

Sample 54 (USGS 26159). Blue-gray silty clay with serpulid tubes, decapod chelae and mollusk shells, about 2.5 m above water level.

Sample 58 (USGS 26160). Gray sand with the mollusk *Tagelus* and *Rangia*, about 2 m below sample 54.

**Locality 10.** St. Mary's 7½' Quadrangle, longitude 81°36'45", latitude 30°43'00". Exposures on south bank of St. Mary's River, Florida at Reids Bluff near town of St. Mary's, Florida.

Lithostratigraphic unit: Pamlico Formation equivalent.

Sample 62 (USGS 26161). Oyster bank of *Crassostrea virginica*, in a clayey quartz sand matrix, about 5 m above river level.

**Locality 11.** Edisto Island 7½' Quadrangle, Longitude 80°21'30", latitude 32°33'30". Exposures on Bailey Creek, south side of Scanawah Island, South Carolina.

Lithostratigraphic unit: "Princess Anne terrace-formation."

Samples 68 (USGS 26162), 67 (USGS 26163), 66 (USGS 26164), 65 (USGS 26165), 65A (USGS 26166), in descending order taken at approximately 0.4 m intervals from about 2.5 m of gray

very fossiliferous sands and sandy clays, exposed from low-tide level up to 2.5 m above water level. Sample 65A was taken from an oyster-rich lens at the bottom of the section.

**Locality 12.** Wadmah 7½' Quadrangle, Longitude 80°13'30", latitude 32°41'45". Exposures known as Simmons Bluff on Wadmah River, on the eastern side of Yonges Island, near Oyster House Creek, South Carolina.

Lithostratigraphic unit: "Princess Anne terrace-formation."

Sample 72 (USGS 26167), 73 (USGS 26168), 71 (USGS 26169), in descending order, taken about 0.3 m apart from exposures of very fossiliferous tan, buff sands with articulated bivalves in living position.

**Locality 13.** Edisto Island 7½' Quadrangle, Longitude 80°17'00", Latitude 32°32'00". Spoil piles dredged from irrigation ditches about 1.0 km east of Freedman, Edisto Island, South Carolina.

Lithostratigraphic unit: "Princess Anne terrace-formation."

Sample 78 (USGS 26170). From very shelly light gray sand, west end of spoil pile, with abundant mollusks including *Mulinia*, *Busycon*, *Cyrtopleura*, *Mercenaria*, and others.

Sample 79 (USGS 26171). From east end of spoil pile, 200 m east of sample 78. Both samples dredged from about 1.0-2.0 m below sea level.

**Locality 14.** Wilton 7½' Quadrangle, longitude 76°28'00", latitude 37°31'30". Exposures on Hell Neck, near Cooper Point, south side of Piankatank River, Virginia.

Lithostratigraphic unit: Norfolk Formation (?).

Sample 141 (USGS 26172). Oyster bank of *Crassostrea virginica*, with tan to orange sand matrix, about 3 m above water level.

Sample 140 (USGS 26173). Oyster bank with sandy matrix, about 0.5 m below sample 141.

**Locality 15.** Wilton 7½' Quadrangle, longitude 76°26'00", latitude 37°31'30". Exposures at Holland Point, south side of Piankatank River, Virginia.

Lithostratigraphic unit: Norfolk Formation (?).

Samples 145 (USGS 26174), 144 (USGS 26175), 146 (USGS 26176), in descending order, about 1 m apart, from massive blue-gray clay, with abundant oysters throughout in living position.

Sample 147 (USGS 26177) from flank of oyster bank about 30 m downstream from samples 144, 145, and 146, at about the same stratigraphic level as sample 146.

**Locality 16.** Deltaville 7½' Quadrangle, longitude 76°22'30", latitude 37°30'00". Exposures on north side of Rappahannock River at Mosquito Point, Virginia.

Lithostratigraphic unit: Norfolk Formation (?).

Sample 156 (USGS 26178). Blue-gray sandy clay with the mollusk *Rangia*, about 0.5-1.0 m above water level.

**Locality 17.** Wilton 7½' Quadrangle, longitude 76°28'00", latitude 37°36'45". Exposures on the south side of the Rappahannock River, just upstream from the mouth of Meachin Creek, Virginia.

Lithostratigraphic unit: Norfolk Formation (?).

Sample 169 (USGS 26179). Oyster bank of *Crassostrea virginica* with matrix of blue-gray clay, about 2 m above water level.

Sample 170 (USGS 26180). Oyster bank with sandy clay matrix,

about 1.5 m below sample 169, separated from it by an unfossiliferous sandy clay horizon.

**Locality 18.** Havelock 7½' Quadrangle, longitude 76°53'00", latitude 34°57'00". About 2 km downstream from Locality 6, exposures on south side of Neuse River near Air Force Base, North Carolina.

Lithostratigraphic unit: Flanner Beach Formation.

Sample 188 (USGS 26181). Coarse shelly orange-brown sand with the mollusks *Ensis*, *Dinocardium*, and *Mulinia*, about 1 m above water level.

**Locality 19.** New Bern 7½' Quadrangle, longitude 77°04'30", latitude 35°06'30". Exposures in shopping center excavation, southwest corner of the intersection between U.S. Routes 17 and 70, about 1 km south of New Bern city limits, North Carolina.

Lithostratigraphic unit: Flanner Beach Formation (?).

Sample 197 (USGS 26182). Oyster bed of *Crassostrea virginica* in sandy matrix, about 1.5 m below surface.

**Locality 20.** St. John's Island 7½' Quadrangle, longitude 80°02'40", latitude 32°47'00". Exposure at abandoned railroad crossing, 0.3 km south of U.S. Route 17, 1.3 km southwest of junction of U.S. Route 17 and S.C. Route 7.

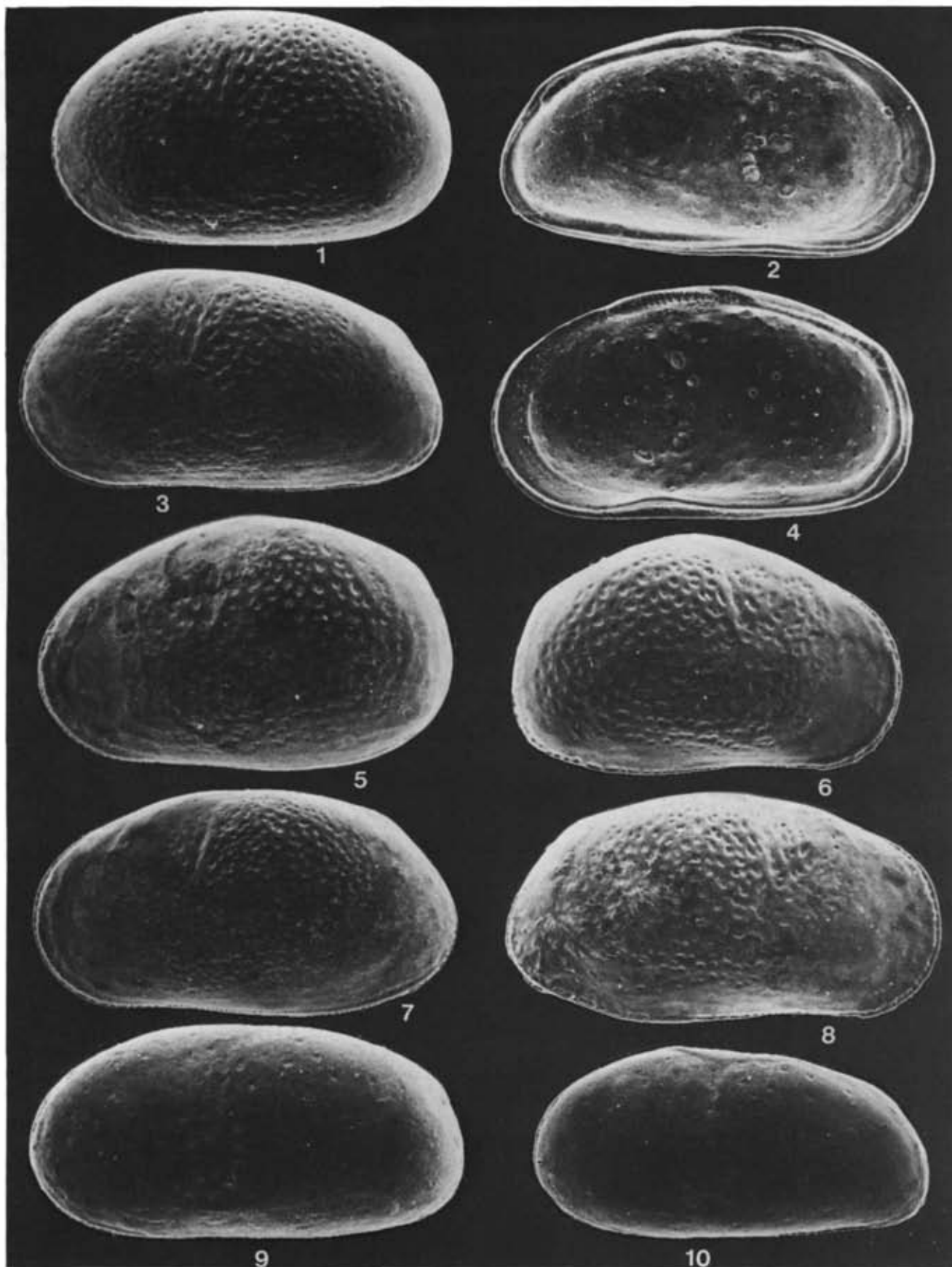
Lithostratigraphic unit: "Princess Anne terrace-formation."

Sample JOI (USGS 26183). Shelly sand from about 1.5 m above sea level. Collected by Brenda Higgins, U.S. Geological Survey, 1975.

**Locality 21.** Fort Moultrie 7½' Quadrangle, longitude 79°50'00", latitude 39°49'15". Venning sand pit, about 1 km east of U.S. Route 17, near the Greater Olive Branch Church, Mount Pleasant, South Carolina.

Lithostratigraphic unit: "Princess Anne terrace-formation."

Sample 46 (USGS 26184). Blue-grey clayey silt about 4 m below land surface, mollusks common.

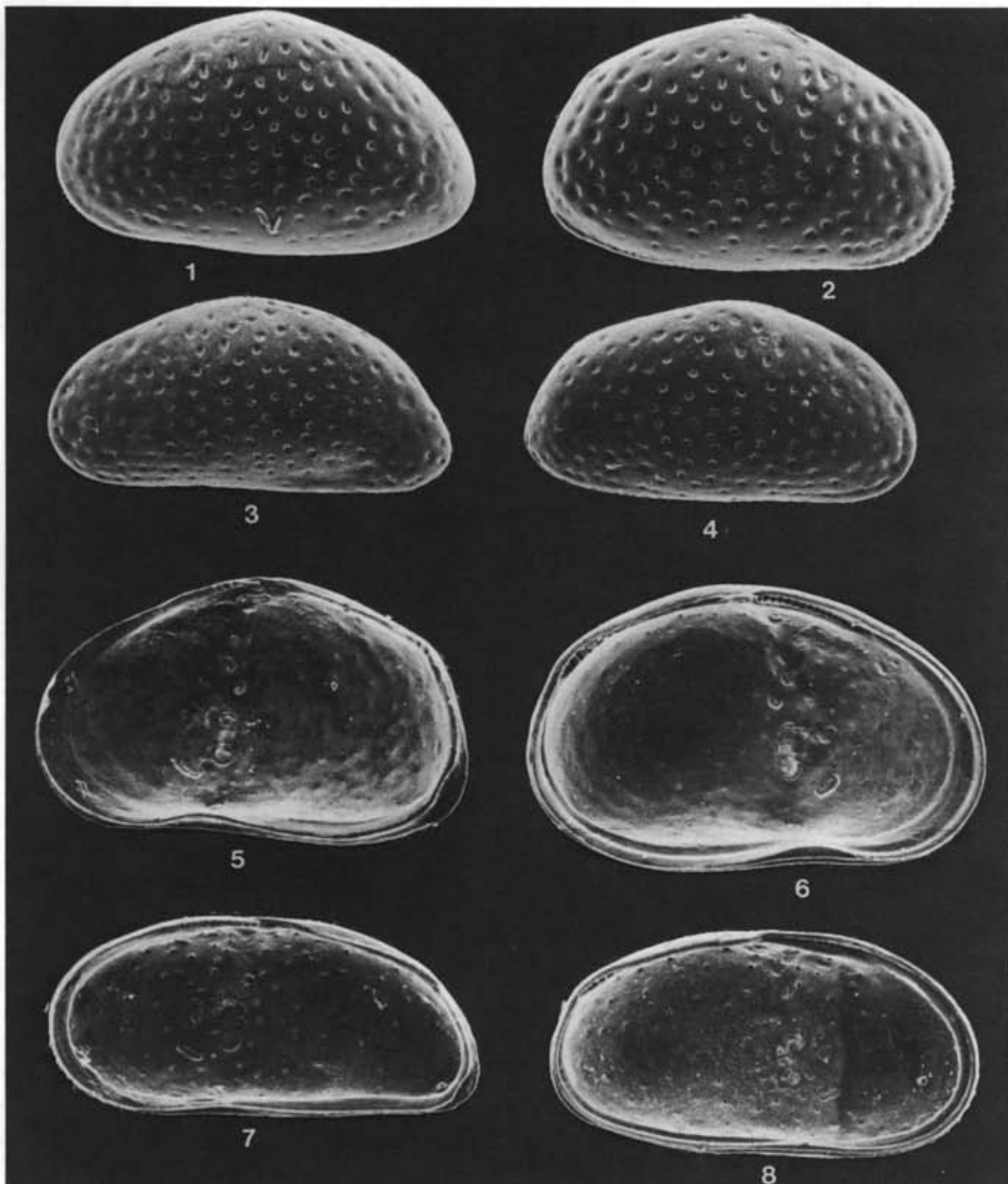


# PLATE 1

FIGURES 1, 2, 3, 4. *Cyprideis mexicana* Sandberg, 1964  
 1) Lateral view, female left valve, loc. 15, sample 147,  $\times 85$ , USNM 270041. 2) Internal view, male left valve, loc. 15, sample 147,  $\times 85$ , USNM 270042. 3) Lateral view, male left valve, loc. 15, sample 147,  $\times 80$ , USNM 270043. 4) Internal view, female right valve, loc. 15, sample 147,  $\times 90$ , USNM 270044. 5, 6, 7, 8. *Cyprideis salebrosa* van den Bold, 1963 5) Lateral view, female

left valve, loc. 16, sample 156,  $\times 70$ , USNM 270045. 6) Lateral view, female right valve, loc. 9, sample 58,  $\times 70$ , USNM 270046. 7) Lateral view, male left valve, loc. 16, sample 156,  $\times 65$ , USNM 270047. 8) Lateral view, male right valve, loc. 9, sample 58,  $\times 70$ , USNM 270048. 9, 10. *Cyprideis margarita* Cronin, n. sp. 9) Lateral view, female left valve, loc. 2, sample 44,  $\times 100$ , Holotype, USNM 270049. 10) Lateral view, male left valve, loc. 2, sample 44,  $\times 100$ , paratype, USNM 270050.

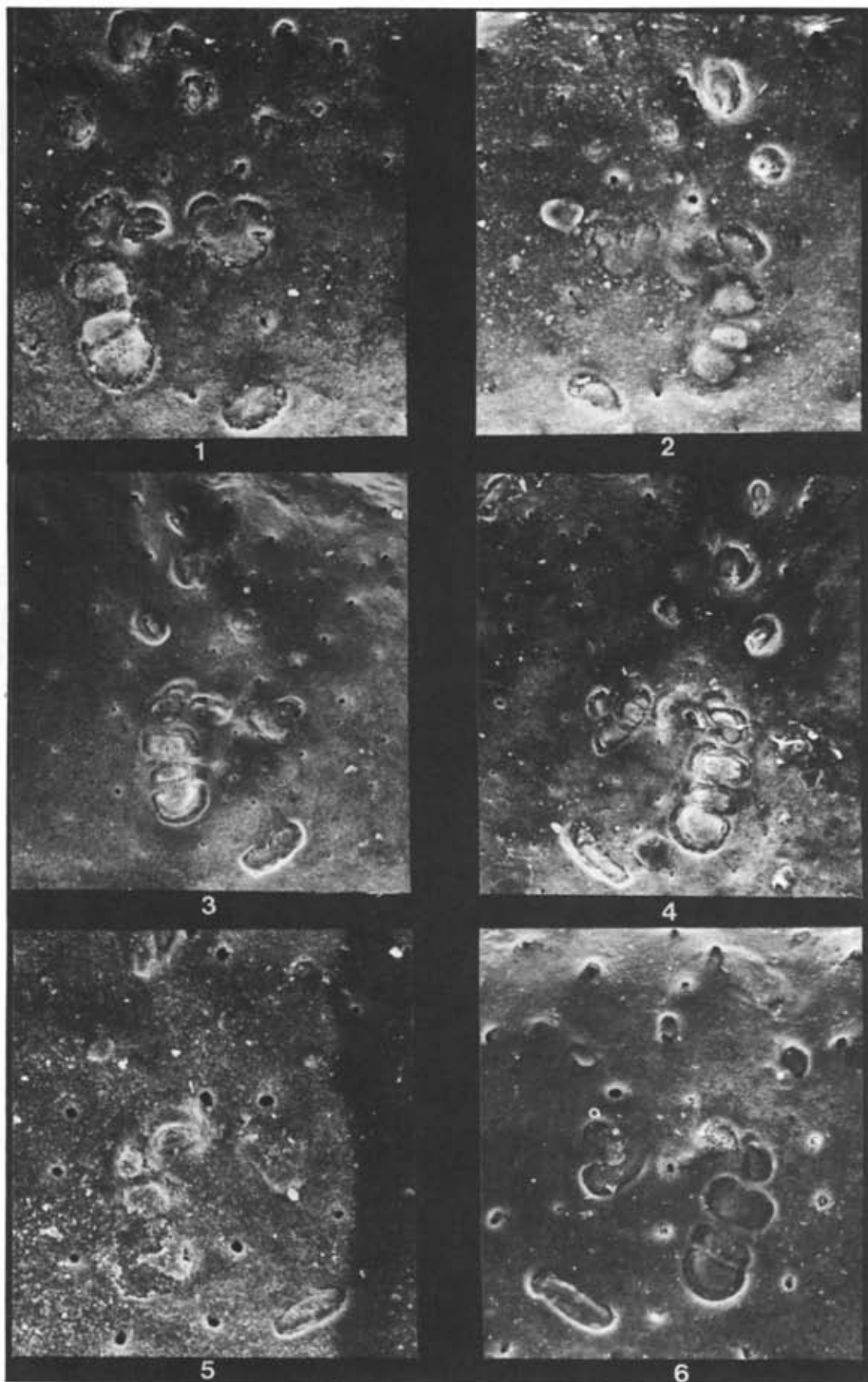




# PLATE 2

FIGURES 1, 2. "*Haplocytheridea*" *setipunctata* (Brady, 1868) 1) Lateral view, male left valve, loc. 2, sample 188,  $\times 75$ , USNM 270051. 2) Lateral view, male right valve, loc. 18, sample 188,  $\times 75$ , USNM 270052. 3, 4. "*Haplocytheridea*" *bradyi* (Stephenson, 1938) 3) Lateral view, male left valve, loc. 2, sample 42,  $\times 100$ , USNM 270053. 4) Lateral view, male right

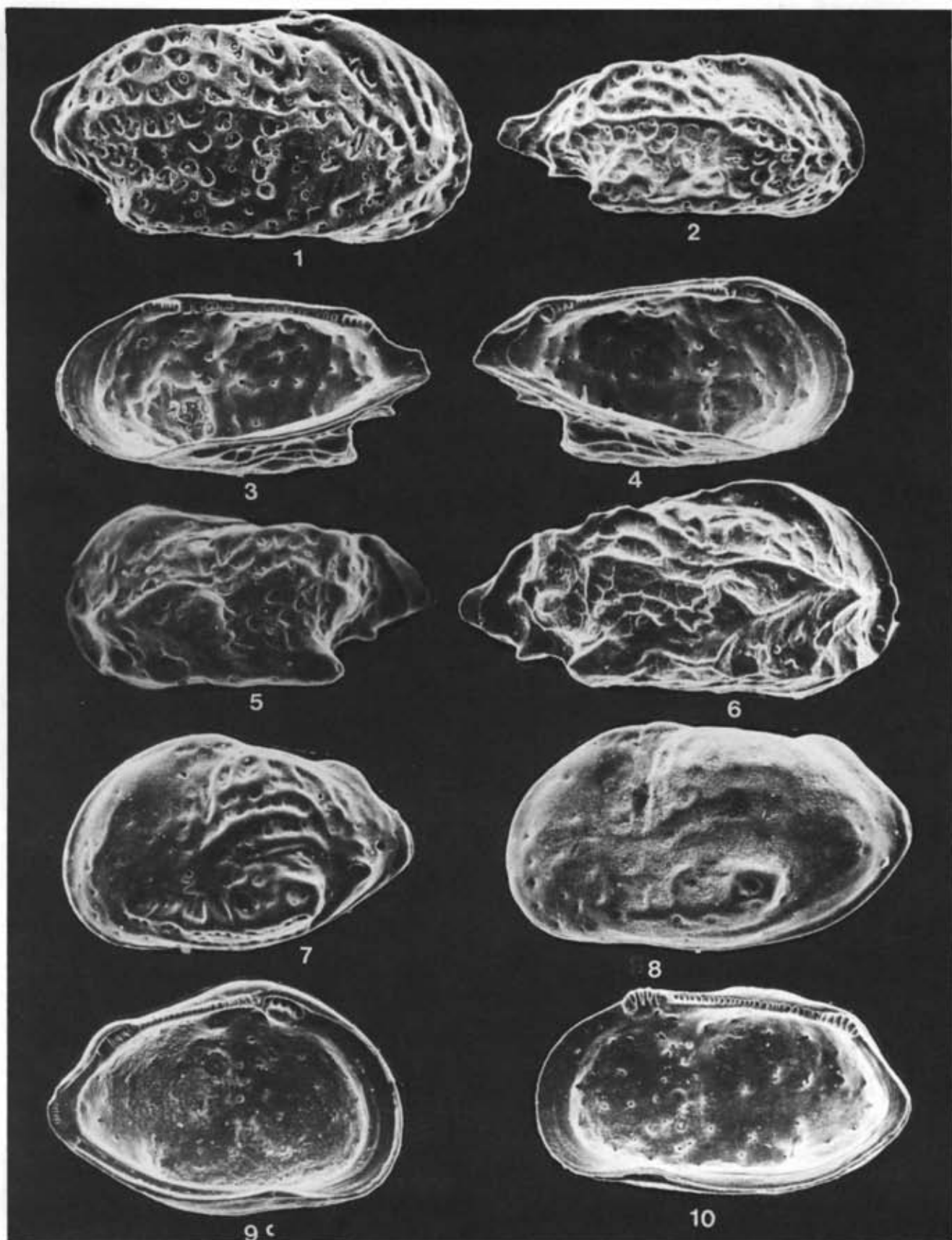
valve, loc. 2, sample 42,  $\times 100$ , USNM 270054. 5, 6. *Cyprideis* *salebrosa* van den Bold, 1963 5) Internal view, female right valve, loc. 9, sample 58,  $\times 75$ , USNM 270055. 6) Internal view, female left valve, loc. 9, sample 58,  $\times 75$ , USNM 270056. 7, 8. *Cyprideis* *margarita* Cronin, n. sp. 7) Internal view, male right valve, loc. 2, sample 44,  $\times 100$ , paratype, USNM 270057. 8) Internal view, female left valve, loc. 2, sample 44,  $\times 100$ , paratype, USNM 270058.



### PLATE 3

FIGURES 1, 2. *Cyprideis mexicana* Sandberg, 1964 1) Internal view of muscle scars, male left valve, loc. 15, sample 147,  $\times 300$ , USNM 270042. 2) Internal view of muscle scars, female right valve, loc. 15, sample 147,  $\times 280$ , USNM 270044. 3, 4. *Cyprideis salebrosa* van den Bold, 1963. 3) Internal view of

muscle scars, female left valve, loc. 9, sample 58,  $\times 200$ , USNM 270056. 4) Internal view of muscle scars, female right valve, loc. 9, sample 58,  $\times 220$ , USNM 270055. 5, 6. *Cyprideis margarita* Cronin, n. sp. 5) Internal view of muscle scars, female left valve, loc. 2, sample 44,  $\times 340$ , paratype, USNM 270058. 6) Internal view of muscle scars, male right valve, loc. 2, sample 44,  $\times 340$ , paratype, USNM 270057.



#### PLATE 4

FIGURES 1, 2, 3, 4. *Paracytheridea altita* Edwards, 1944. 1) Lateral view, female right valve, loc. 11, sample 66,  $\times 150$ , USNM 270059. 2) Lateral view, male right valve, loc. 1, sample 40,  $\times 110$ , USNM 270060. 3) Internal view, male right valve, loc. 1, sample 40,  $\times 110$ , USNM 270061. 4) Internal view, male left valve, loc. 1, sample 40,  $\times 110$ , USNM 270062. 5. *Paracytheridea* cf. *P. rugosa* Edwards, 1944. 5) Lateral view, male?

left valve, loc. 11, sample 67,  $\times 130$ , USNM 270063. 6. *Paracytheridea* sp. A. 6) Lateral view, male right valve, loc. 12, sample 73,  $\times 150$ , USNM 270064. 7, 8, 9, 10. *Perissocytheridea brachyforma* Swain, 1955. 7) Lateral view, female left valve, loc. 1, sample 40,  $\times 130$ , USNM 270065. 8) Lateral view, male left valve, loc. 1, sample 40,  $\times 130$ , USNM 270066. 9) Internal view, female left valve, loc. 1, sample 40,  $\times 130$ , USNM 270067. 10) Internal view, male right valve, loc. 1, sample 40,  $\times 130$ , USNM 270068.

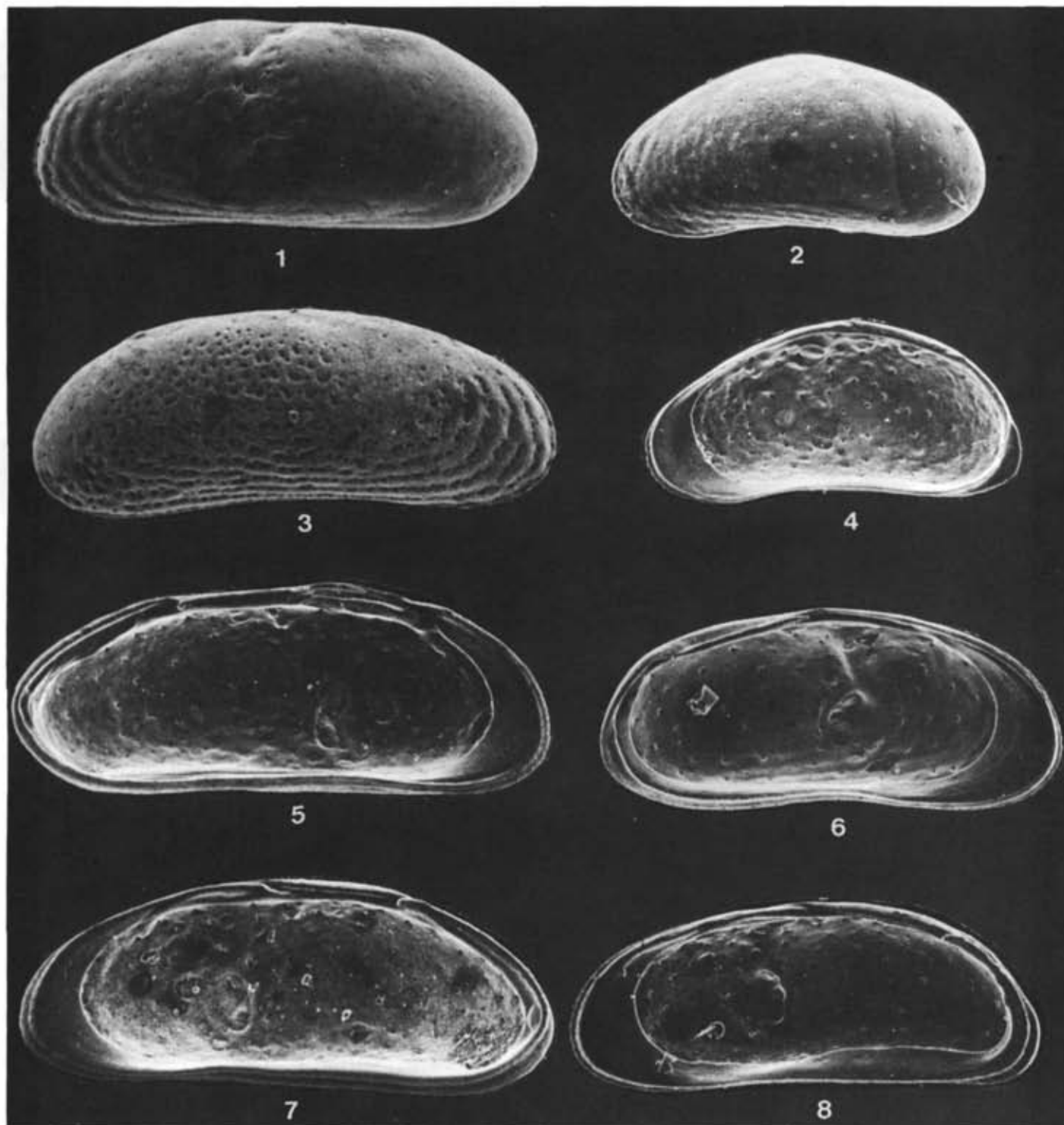
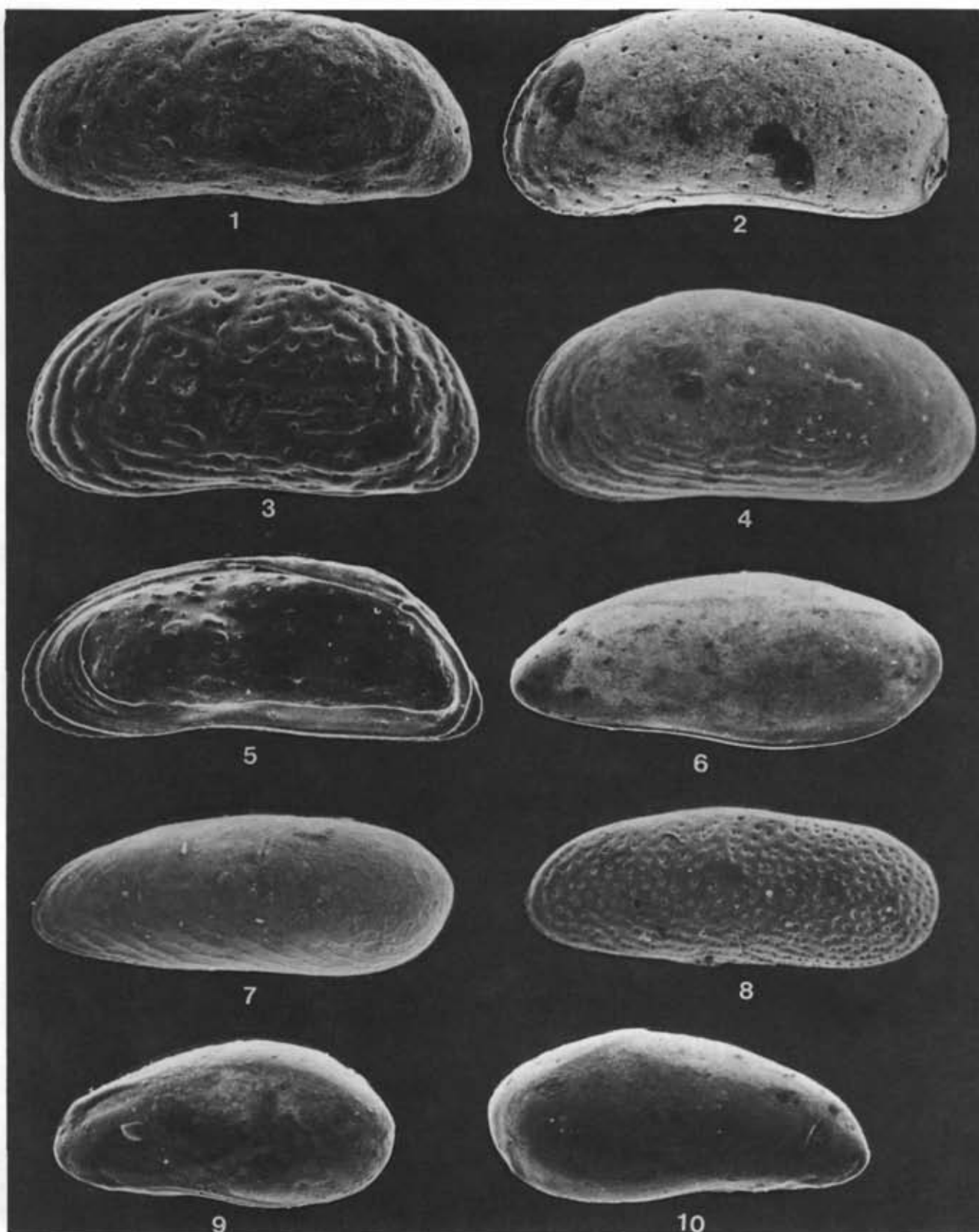


PLATE 5

FIGURES 1, 3, 5, 7. *Cushmanidea seminuda* (Cushman, 1906). 1) Lateral view, male left valve, loc. 7, sample 190,  $\times 100$ , USNM 270069. 3) Lateral view, male right valve, loc. 7, sample 190,  $\times 100$ , USNM 270070. 5) Internal view, male left valve, loc. 7, sample 190,  $\times 100$ , USNM 270071. 7) Internal view, male right valve, loc. 7, sample 190,  $\times 100$ , USNM 270072. 2, 4.

*Pontocythere* sp. A. 2) Lateral view, female left valve, loc. 18, sample 188,  $\times 100$ , USNM 270073. 4) Internal view, female right valve, loc. 18, sample 188,  $\times 100$ , USNM 270074. 6, 8. *Hulingsina rugipustulosa* (Edwards, 1944). 6) Internal view, female left valve, loc. 18, sample 188,  $\times 120$ , USNM 270075. 8) Internal view, male right valve, loc. 18, sample 188,  $\times 120$ , USNM 270076.

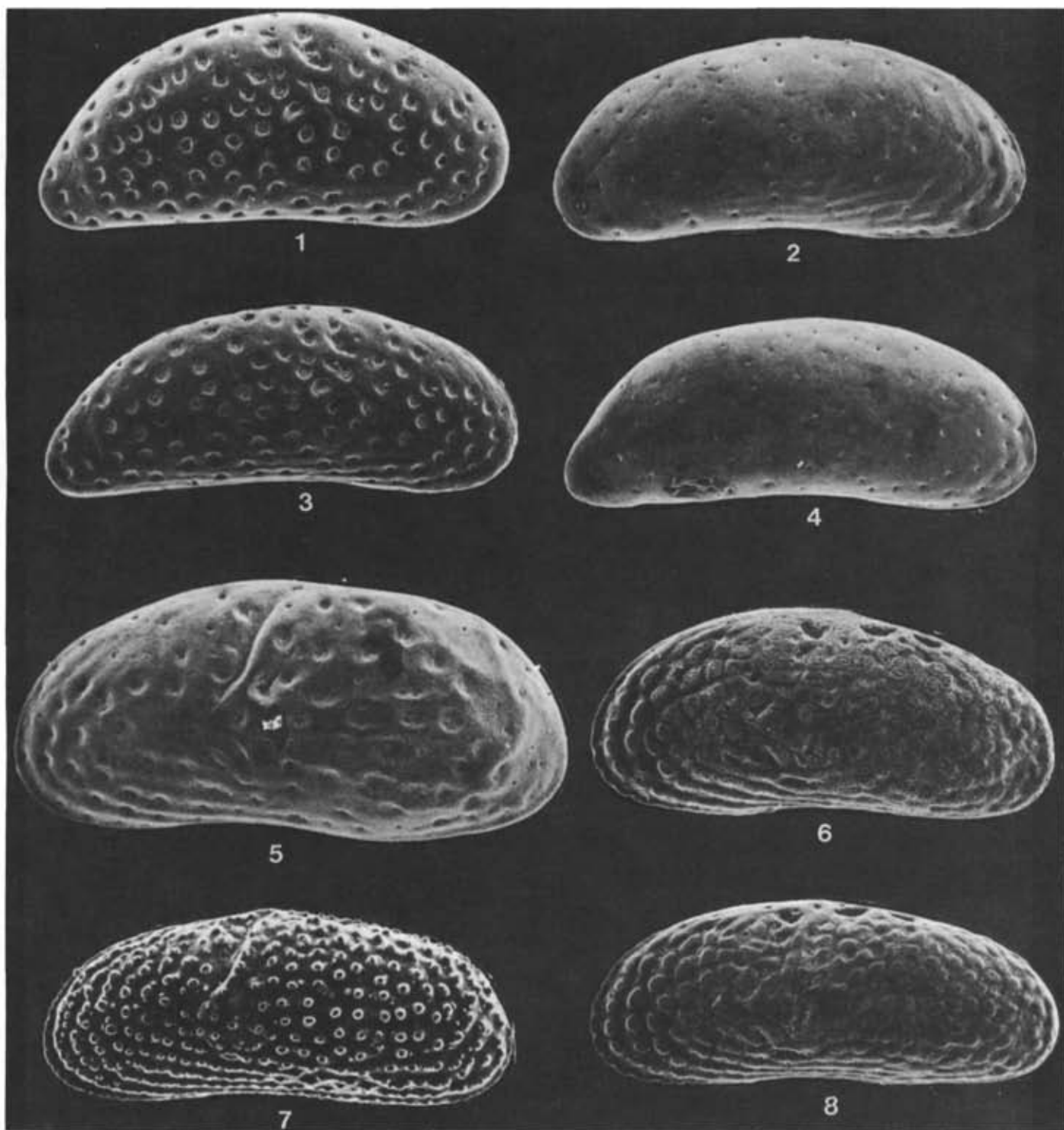




# PLATE 6

FIGURES 1, 3, 5. *Hulingsina* sp. A. 1) Lateral view, male left valve, loc. 18, sample 188,  $\times 145$ , USNM 270077. 3) Lateral view, female left valve, loc. 18, sample 188,  $\times 160$ , USNM 270078. 5) Internal view, male right valve, loc. 18, sample 188,  $\times 145$ , USNM 270079. 2. *Hulingsina glabra* (Hall, 1965). 2) Lateral view, female left valve, loc. 12, sample 73,  $\times 150$ , USNM 270080. 4. *Hulingsina* sp. E 4) Lateral view, female left

valve, loc. 7, sample 190,  $\times 120$ , USNM 270081. 6. *Paradoxostoma* sp. A. 6) Lateral view, female? left valve, loc. 11, sample 54,  $\times 140$ , USNM 270082. 7. *Sahnia* sp. A. 7) Lateral view, left valve, loc. 11, sample 67,  $\times 130$ , USNM 270083. 8. *Sahnia* sp. B. 8) Lateral view, left valve, loc. 11, sample 67,  $\times 110$ , USNM 270084. 9, 10. *Paradoxostoma delicata* Puri, 1954. 9) Lateral view, left valve, loc. 13, sample 78,  $\times 150$ , USNM 270085. 10) Lateral view, right valve, loc. 13, sample 78,  $\times 150$ , USNM 270086.



# PLATE 7

FIGURES 1, 3. *Hulingsina* sp. B. 1) Lateral view, female right valve, loc. 2, sample 44,  $\times 110$ , USNM 270087. 3) Lateral view, male right valve, loc. 2, sample 44,  $\times 100$ , USNM 270088. 2, 4. *Hulingsina* sp. C. 2) Lateral view, female right valve, loc. 18, sample 188,  $\times 100$ , USNM 270089. 4) Lateral view, male right valve, loc. 18, sample 188,  $\times 115$ , USNM 270090. 5. 7.

*Hulingsina rugipustulosa* (Edwards, 1944). 5) Lateral view, female left valve, smooth form, loc. 18, sample 188,  $\times 150$ , USNM 270091. 7) Lateral view, male left valve, pustulose form, loc. 18, sample 188,  $\times 120$ , USNM 270092. 6, 8. *Hulingsina* sp. D. 6) Lateral view, female left valve, loc. 18, sample 188,  $\times 155$ , USNM 270093. 8) Lateral view, male left valve, loc. 18, sample 188,  $\times 140$ , USNM 270094.

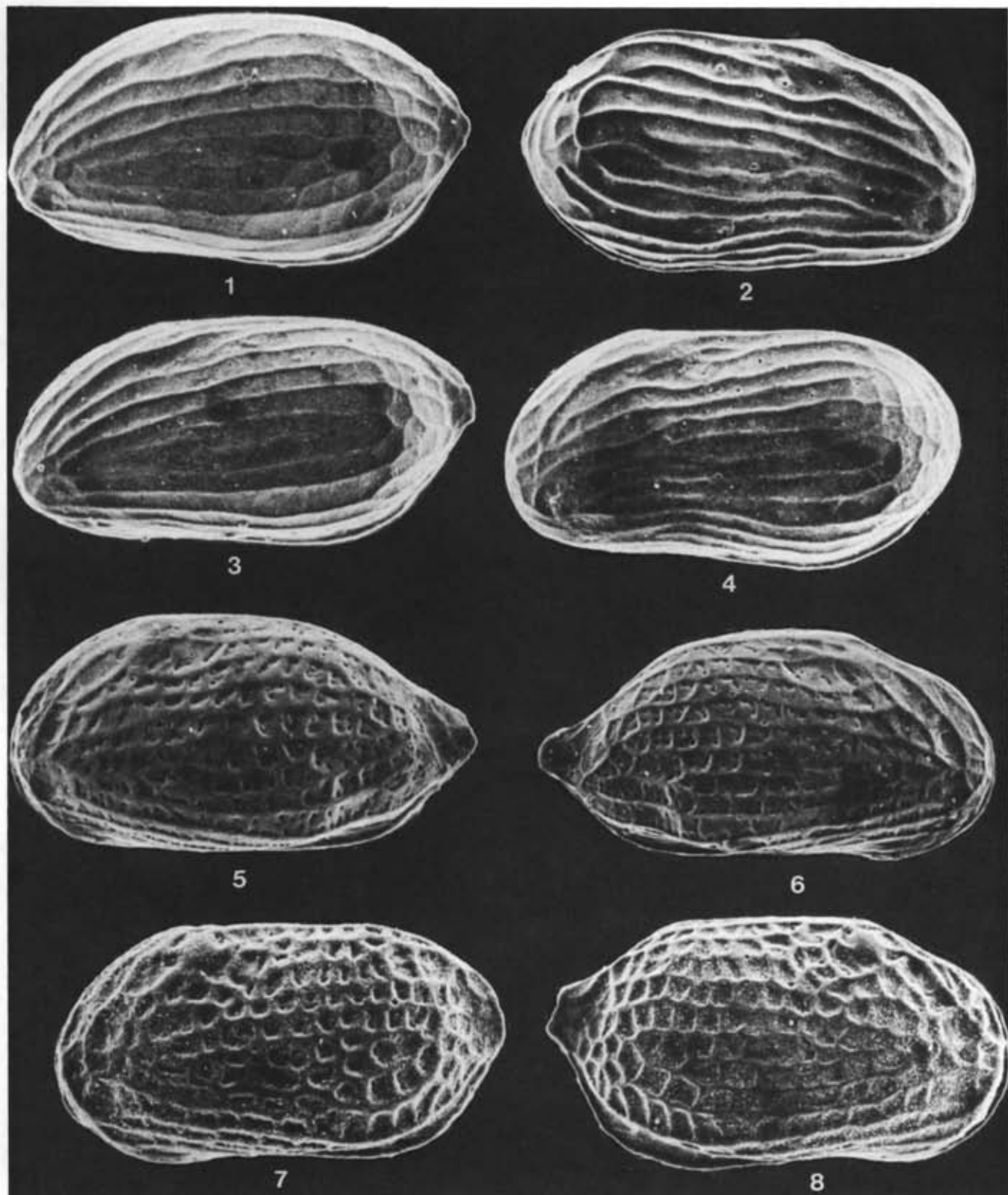
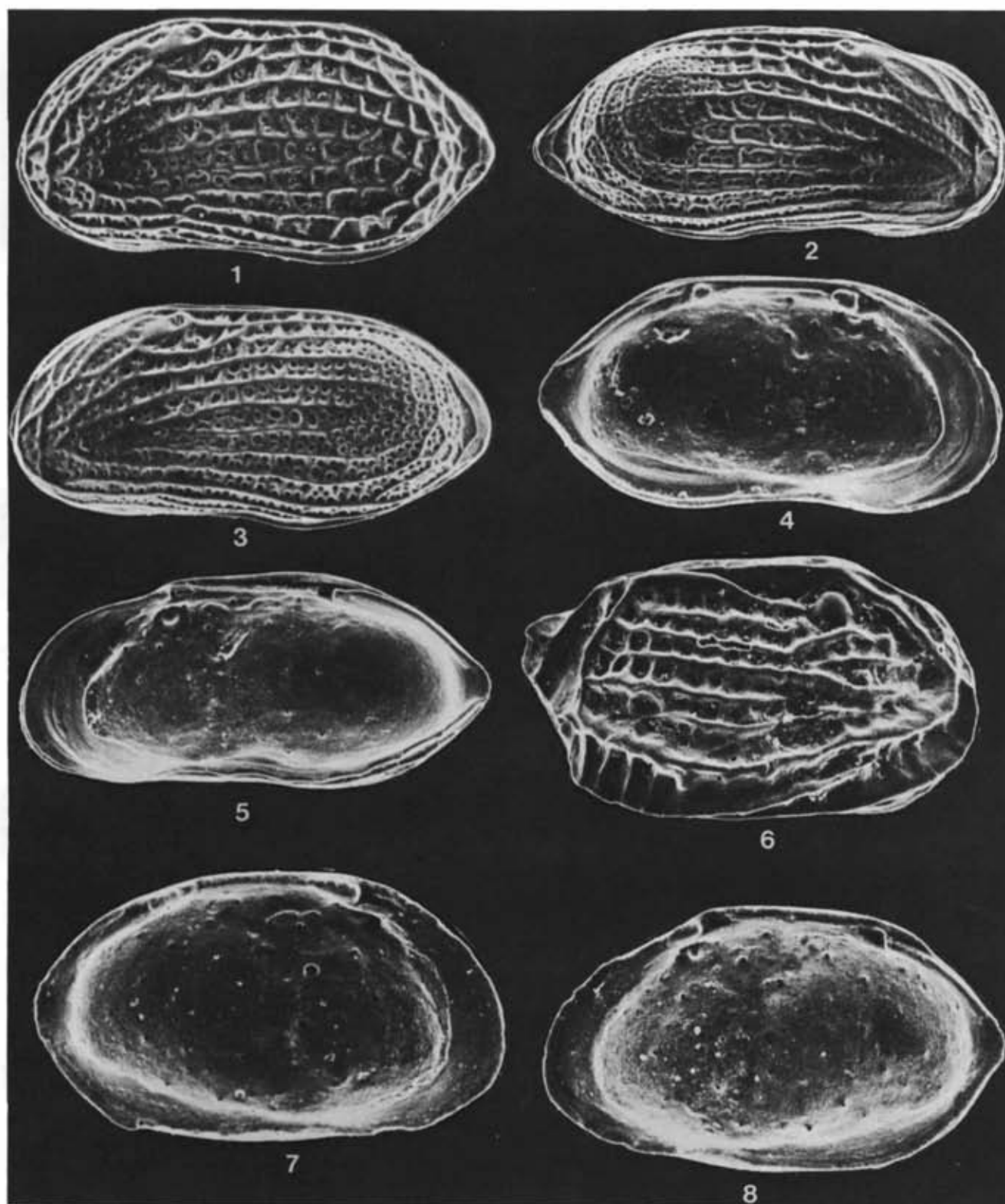


PLATE 8

FIGURES 1, 2, 3, 4. *Cytherura forulata* Edwards, 1944. 1) Lateral view, female left valve, loc. 12, sample 73,  $\times 175$ , USNM 270095. 2) Lateral view, male right valve, loc. 18, sample 188,  $\times 180$ , USNM 270096. 3) Lateral view, male left valve, loc. 12, sample 73,  $\times 170$ , USNM 270097. 4) Lateral view,

female left valve, loc. 18, sample 188,  $\times 180$ , USNM 270098. 5, 6. *Cytherura reticulata* Edwards, 1944. 5) Lateral view, female left valve, loc. 1, sample 41,  $\times 200$ , USNM 270099. 6) Lateral view, female right valve, loc. 1, sample 41,  $\times 185$ , USNM 270100. 7, 8. *Cytherura* sp. A. 7) Lateral view, female left valve, loc. 7, sample UB2,  $\times 200$ , USNM 270101. 8) Lateral view, female right valve, loc. 7, sample UB2,  $\times 215$ , USNM 270102.



# PLATE 9

FIGURES 1, 2, 3, 4, 5. *Cytherura* sp. B. 1) Lateral view, female left valve, loc. 18, sample 188,  $\times 185$ , USNM 270103. 2) Lateral view, male right valve, loc. 18, sample 188,  $\times 165$ , USNM 270104. 3) Lateral view, male left valve, loc. 18, sample 188,  $\times 165$ , USNM 270105. 4) Internal view, female left valve, loc. 18,

sample 188,  $\times 175$ , USNM 270106. 5) Internal view, male right valve, loc. 18, sample 188,  $\times 160$ , USNM 270107. 6) *Cytherura pseudostriata* Hulings, 1966. 6) Lateral view, female right valve, loc. 11, sample 67,  $\times 180$ , USNM 270108. 7, 8. *Cytherura forulata* Edwards, 1944. 7) Internal view, female left valve, loc. 12, sample 73,  $\times 190$ , USNM 270109. 8) Internal view, female right valve, loc. 12, sample 73,  $\times 175$ , USNM 270110.



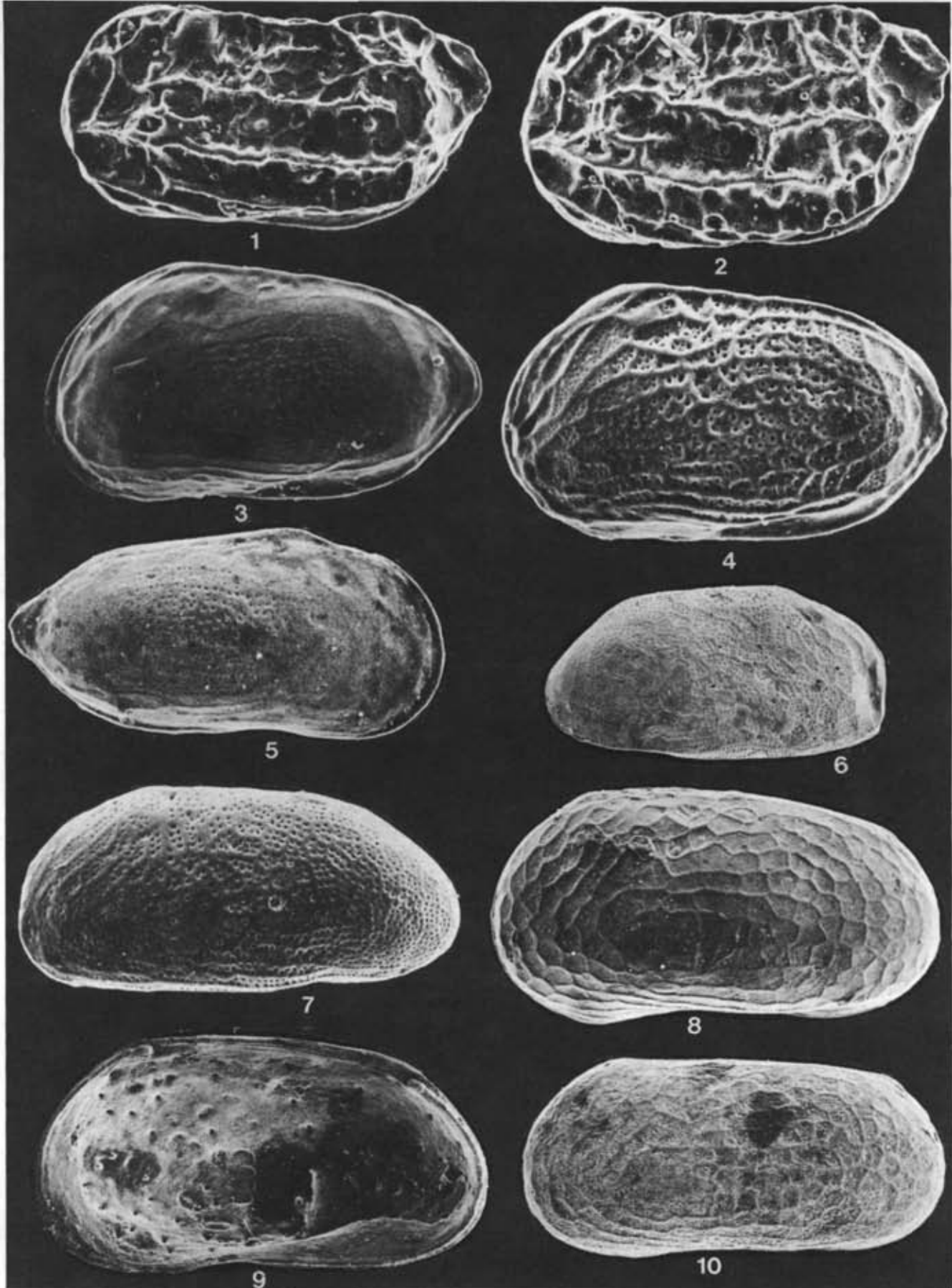


PLATE 10

FIGURES 1, 2. *Cytherura sablensis* (Benson and Coleman, 1963). 1) Lateral view, male left valve, loc. 12, sample 73,  $\times 190$ , USNM 270111. 2) Lateral view, female left valve, loc. 12, sample 73,  $\times 190$ , USNM 270112. 3, 4, 5. *Cytherura nucis* Garbett and Maddocks, 1979. 3) Lateral view, female left valve, loc. 2, sample 43,  $\times 240$ , USNM 270113. 4) Lateral view, female left valve, loc. 2, sample 44,  $\times 275$ , USNM 270114. 5) Lateral view, male right valve, loc. 2, sample 44,  $\times 250$ , USNM 270115.

6. *Microcytherura choctawhatcheensis* (Puri, 1954). 6) Lateral view, female left valve, loc. 18, sample 188,  $\times 110$ , USNM 270116. 7. *Microcytherura* sp. A. 7) Lateral view, male left valve, loc. 13, sample 78,  $\times 180$ , USNM 270117. 8, 9, 10. *Microcytherura norfolkensis* Cronin, n. sp. 8) Lateral view, female left valve, loc. 18, sample 188,  $\times 180$ , Holotype, USNM 270118. 9) Internal view, female right valve, loc. 18, sample 188,  $\times 180$ , paratype, USNM 270119. 10) Lateral view, male left valve, loc. 18, sample 188,  $\times 180$  paratype, USNM 270120.

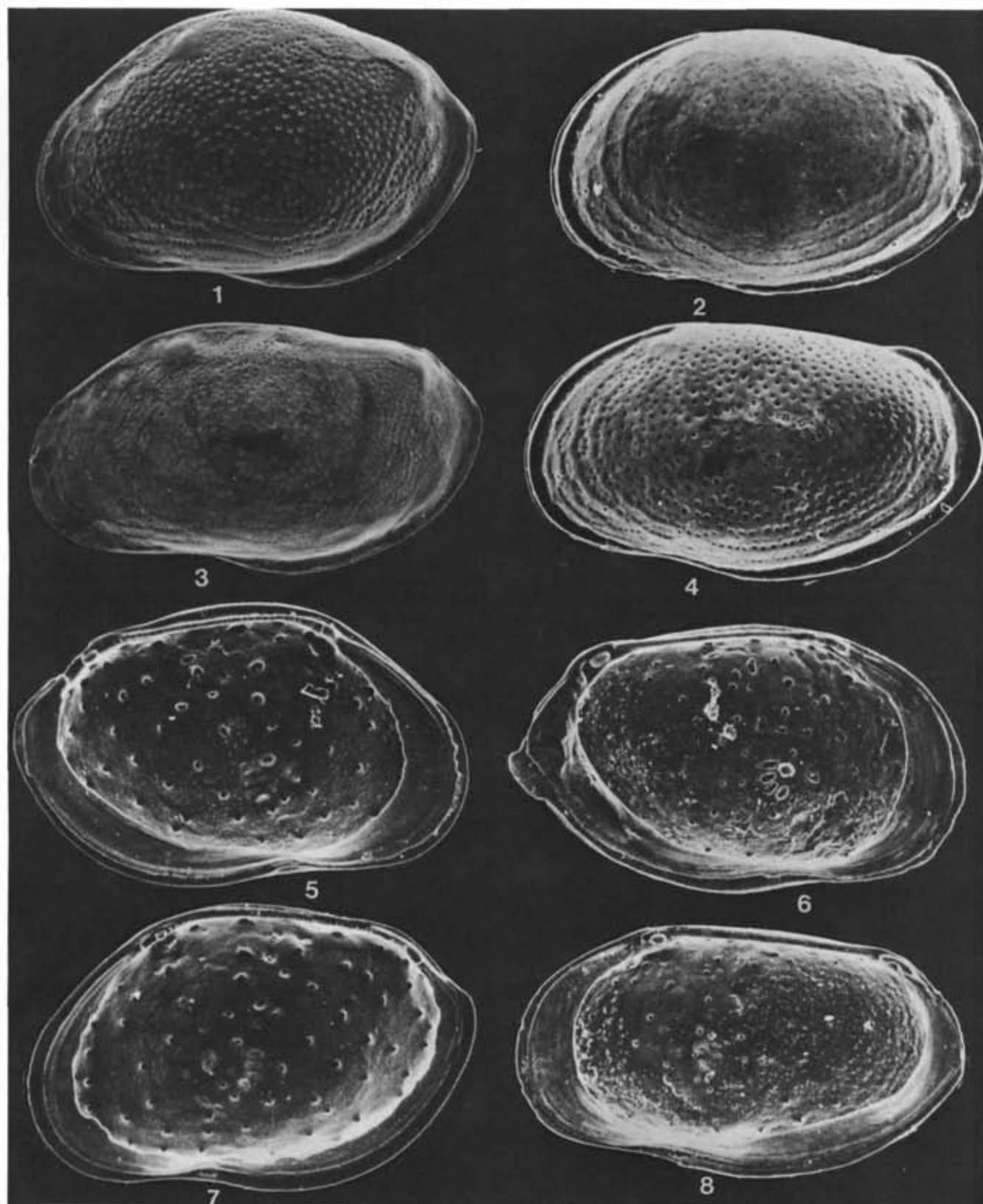


PLATE 11

FIGURES 1, 3, 5, 7. *Loxoconcha matagordensis* Swain, 1955. 1) Lateral view, female left valve, loc. 1, sample 40,  $\times 140$ , USNM 270121. 3) Lateral view, male left valve, loc. 1, sample 40,  $\times 125$ , USNM 270122. 5) Internal view, female left valve, loc. 1, sample 40,  $\times 140$ , USNM 270123. 7) Internal view, female right valve, loc. 1, sample 40,  $\times 140$ , USNM 270124.

2, 4, 6, 8. *Loxoconcha* sp. A. 2) Lateral view, female left valve, loc. 8, sample 71A,  $\times 140$ , USNM 270125. 4) Lateral view, male left valve, loc. 8, sample 71A,  $\times 150$ , USNM 270126. Internal view, female left valve, loc. 8, sample 71A,  $\times 150$ , USNM 270127. 8) Internal view, male right valve, loc. 8, sample 71A,  $\times 140$ , USNM 270128.

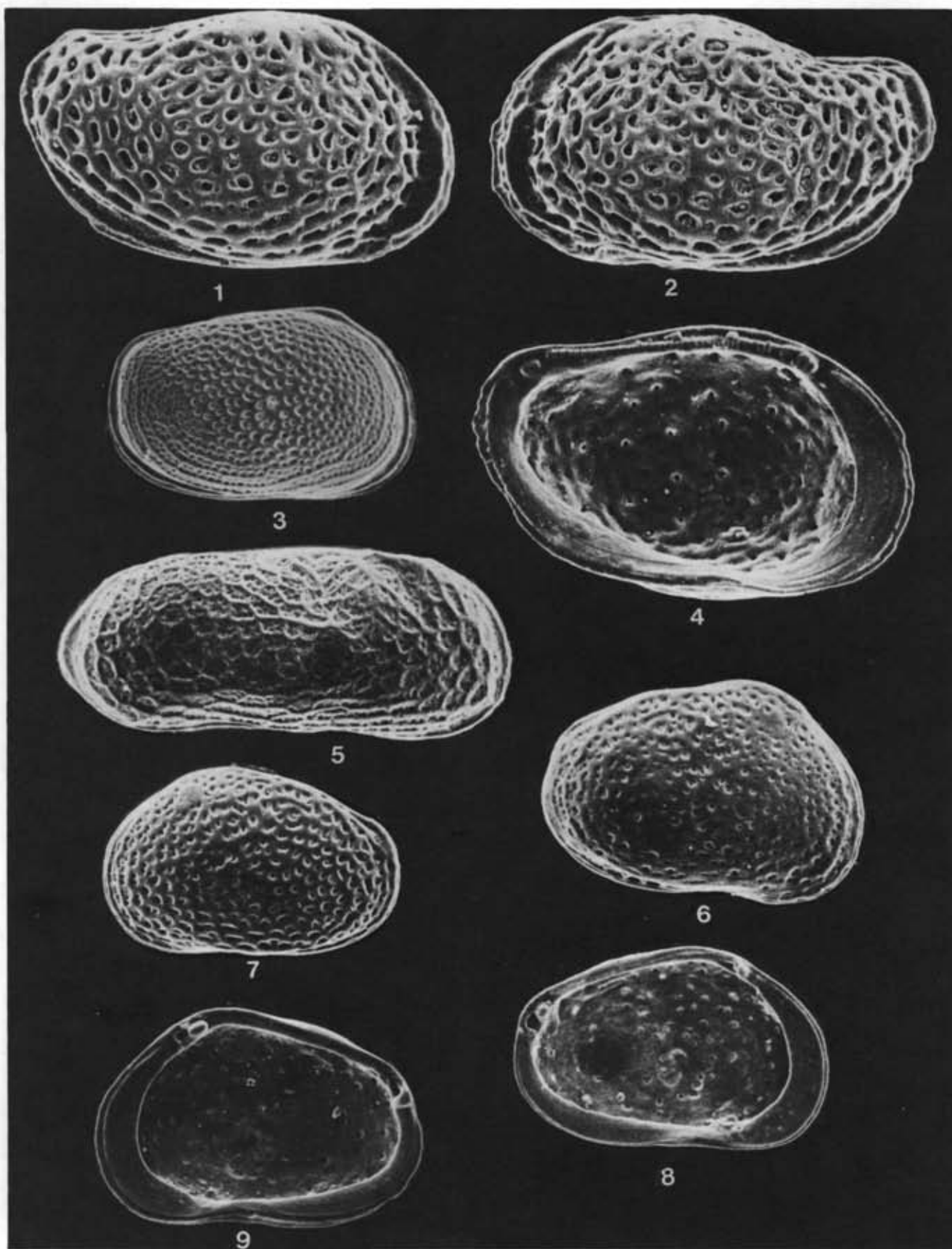


PLATE 12

FIGURES 1, 2, 4. *Loxoconcha reticularis* (Edwards, 1944). 1) Lateral view, right valve, loc. 13, sample 78,  $\times 185$ , USNM 270129. 2) Lateral view, left valve, loc. 13, sample 78,  $\times 195$ , USNM 270130. 4) Internal view, left valve, loc. 13, sample 78,  $\times 190$ , USNM 270131. 3. *Loxoconcha sperata* Williams, 1966. 3) Lateral view, juvenile right valve, loc. 4, sample 175,  $\times 120$ ,

USNM 270132. 5. *Neolophocythere subquadrata* Grossman, 1967. 5) Lateral view, female right valve, loc. 4, sample 175,  $\times 160$ , USNM 270133. 6, 7, 8, 9. *Cytheromorpha curta* Edwards, 1944. 6) Lateral view, right valve, loc. 9, sample 58,  $\times 150$ , USNM 270134. 7) Lateral view, left valve, loc. 9, sample 58,  $\times 150$ , USNM 270136. 8) Internal view, left valve, loc. 9, sample 58,  $\times 150$ , USNM 270168. 9) Internal view, right valve, loc. 9, sample 58,  $\times 150$ , USNM 270135.

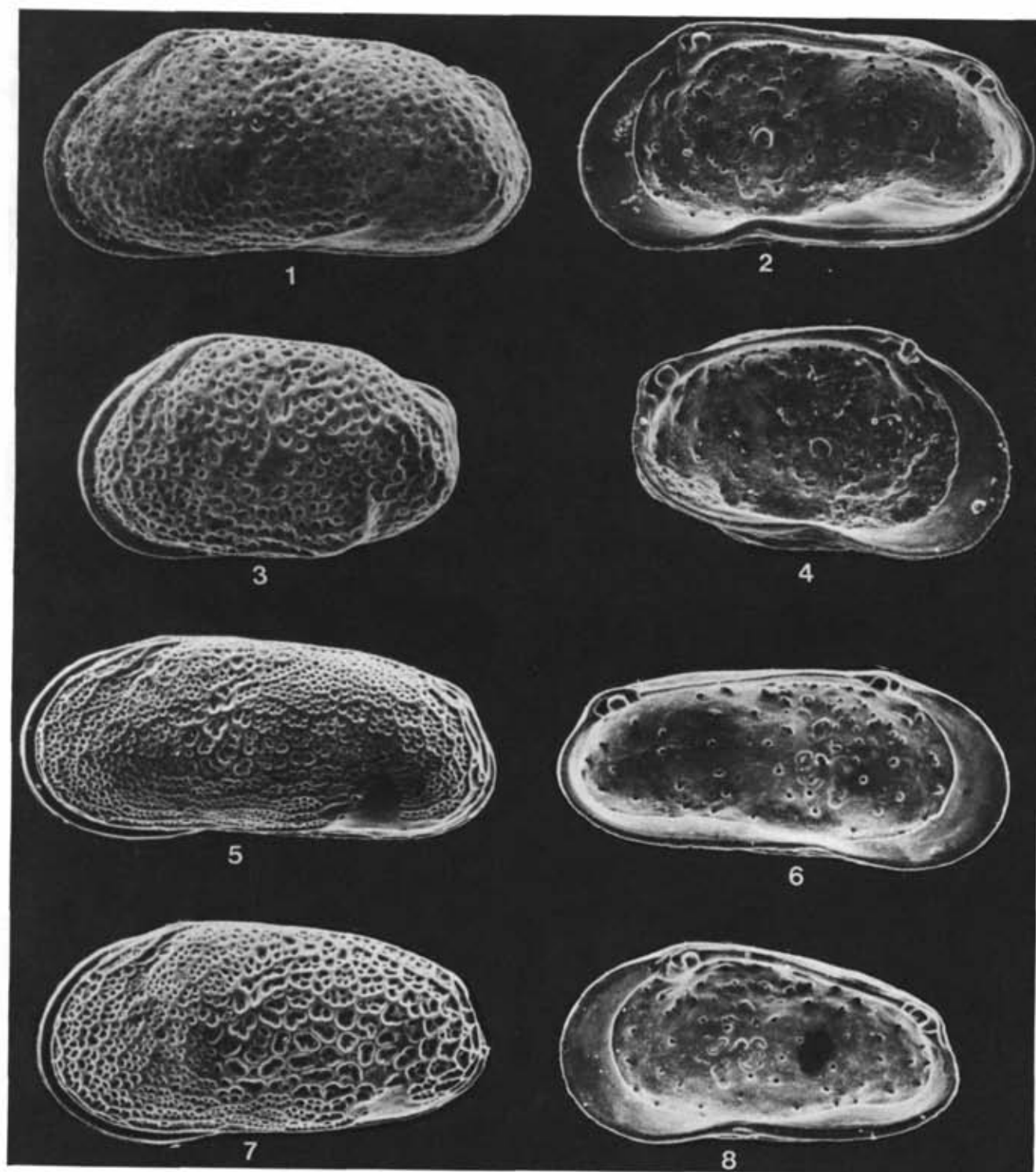


PLATE 13

FIGURES 1, 2, 3, 4. *Cytheromorpha fuscata* (Brady, 1869). 1) Lateral view, male left valve, loc. 9, sample 58,  $\times 130$ , USNM 270137. 2) Internal view, male right valve, loc. 9, sample 58,  $\times 120$ , USNM 270138. 3) Lateral view, female left valve, loc. 9, sample 58,  $\times 130$ , USNM 270139. 4) Internal view,

female left valve, loc. 9, sample 58,  $\times 130$ , USNM 270140. 5, 6, 7, 8. *Cytheromorpha newportensis* Williams, 1966. 5) Lateral view, male left valve, loc. 11, sample 65A,  $\times 150$ , USNM 270141. 6) Internal view, male left valve, loc. 11, sample 65A,  $\times 150$ , USNM 270142. 7) Lateral view, female left valve, loc. 11, sample 65A,  $\times 150$ , USNM 270143. 8) Internal view, female right valve, loc. 11, sample 65A,  $\times 150$ , USNM 270144.



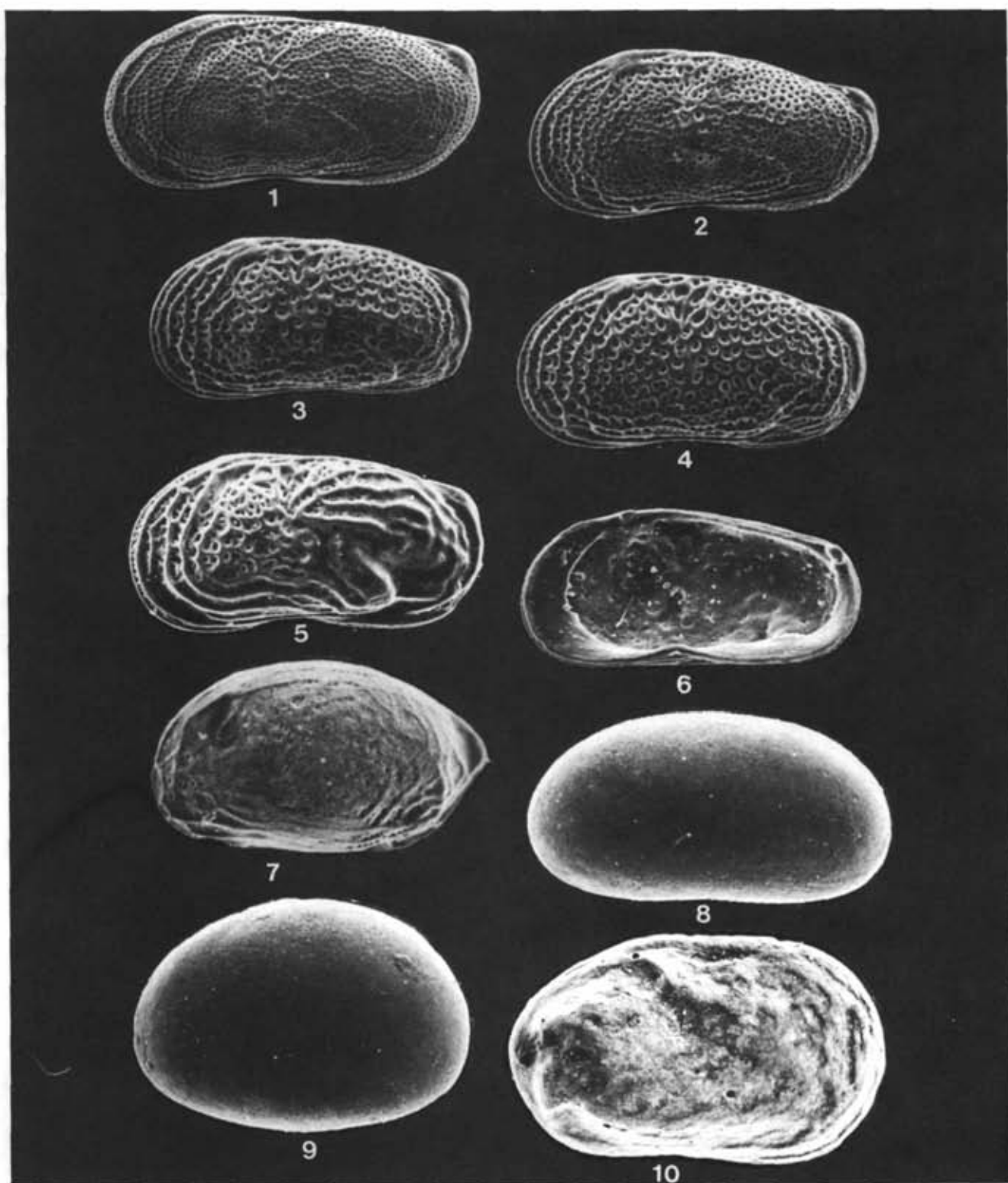
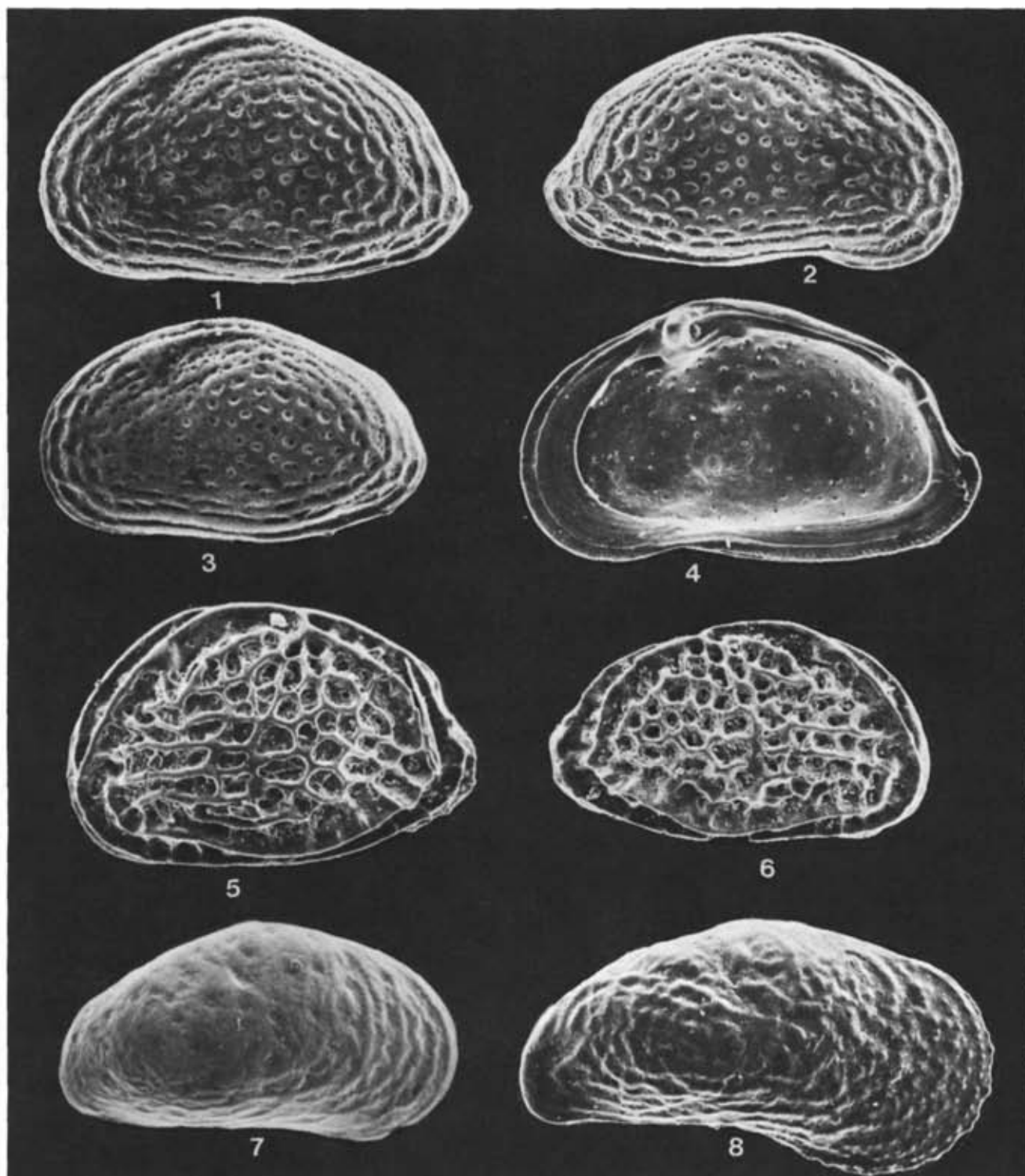


PLATE 14

FIGURES 1, 2, 3, 4, 5, 6. *Leptocythere nikraveshae* Morales, 1966. 1) Lateral view, male left valve, loc. 15, sample 146,  $\times 140$ , USNM 270145. 2) Lateral view, female left valve, loc. 15, sample 146,  $\times 140$ , USNM 270146. 3) Lateral view, female left valve, loc. 9, sample 54,  $\times 140$ , USNM 270147. 4) Lateral view, female left valve, loc. 15, sample 146,  $\times 140$ , USNM 270148. 5) Lateral view female left valve, loc. 5, sample WB2,  $\times 140$ ,

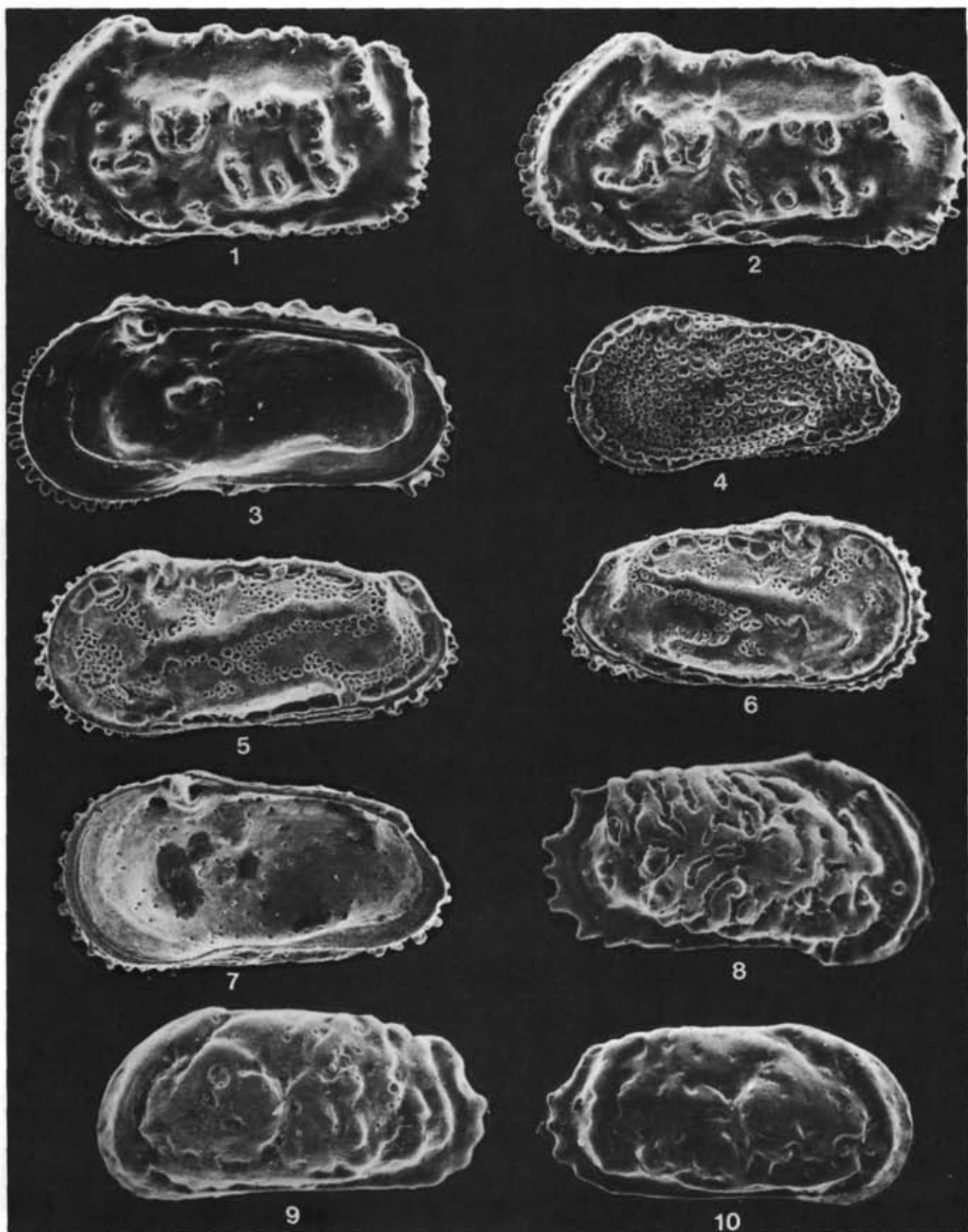
USNM 270149. 6) Internal view, female right valve, loc. 5, sample WB2,  $\times 140$ , USNM 270150. 7) *Cytherura howei* (Puri, 1954). 7) Lateral view, left valve, loc. 15, sample 144,  $\times 120$ , USNM 270151. 8, 9. Unidentified Cypridae. 8) Lateral view, male left valve, loc. 2, sample 44,  $\times 100$ , USNM 270152. 9) Lateral view, female left valve, loc. 2, sample 44,  $\times 100$ , USNM 270153. 10. *Cytherelloidea* sp. A. 10) Lateral view, juvenile right valve, loc. 12, sample 73,  $\times 130$ , USNM 254587.



# PLATE 15

FIGURES 1, 2, 3, 4. *Aurila laevicula* (Edwards, 1944) 1) Lateral view, female left valve, loc. 1, sample 40,  $\times 120$ , USNM 270154. 2) Lateral view, female right valve, loc. 1, sample 40,  $\times 120$ , USNM 270155. 3) Lateral view, male left valve, loc. 1, sample 40,  $\times 120$ , USNM 270156. 4) Internal view, female right valve, loc. 1, sample 40,  $\times 140$ , USNM 270157. 5, 6. "*Aurila*

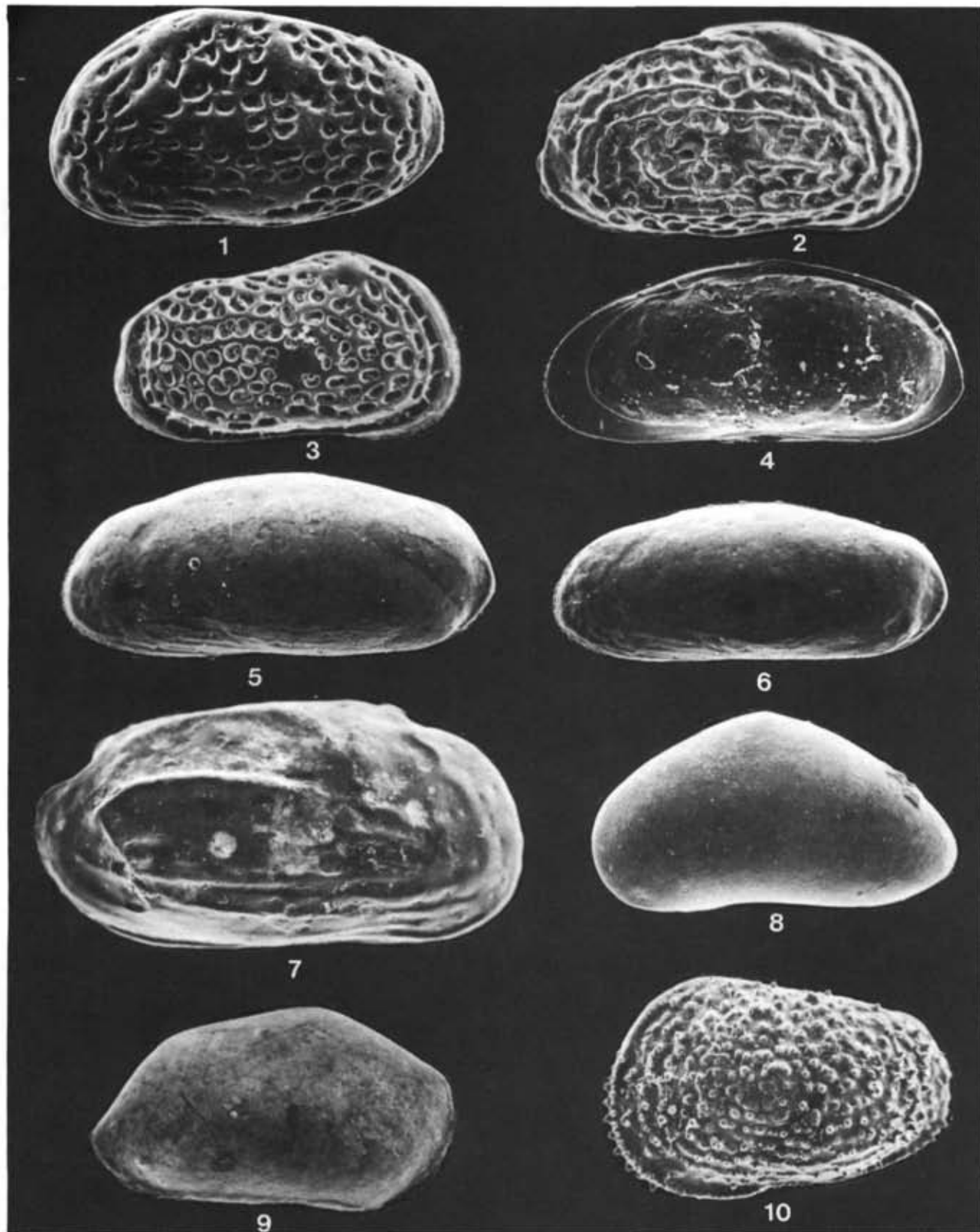
*florldina* Benson and Coleman, 1963. 5) Lateral view, female left valve, loc. 13, sample 79,  $\times 100$ , USNM 270158. 6) Lateral view, male right valve, loc. 11, sample 66,  $\times 100$ , USNM 270159. 7. *Eucythere gibba* Edwards, 1944. 7) Lateral view, female right valve, loc. 3, sample 26,  $\times 86$ , USNM 270160. 8. *Eucythere triangulata* Puri, 1954. 8) Lateral view, male? right valve, loc. 13, sample 79,  $\times 120$ , USNM 270161.



# PLATE 16

FIGURES 1, 2, 3. *Actinocythereis* sp. A 1) Lateral view, female left valve, loc. 1, sample 40,  $\times 100$ , USNM 270162. 2) Lateral view, male left valve, loc. 1, sample 40,  $\times 100$ , USNM 270163. 3) Internal view, male right valve, loc. 1, sample 40,  $\times 100$ , USNM 270164. 4, 5, 6, 7. *Neocaudites atlantica* Cronin, n. sp. 4) Lateral view, juvenile left valve, loc. 11, sample 65A,  $\times 100$ , USNM 270165. 5) Lateral view, male left valve, loc. 11, sample

65A,  $\times 100$ , USNM 270166 6) Lateral view, female right valve, loc. 11, sample 65A,  $\times 100$ , holotype, USNM 270167. 7) Internal view, female right valve, loc. 11, sample 65A,  $\times 110$ , holotype, USNM 270167. 8. *Puriana convoluta* Teeter, 1975 8) Lateral view, female right valve, loc. 12, sample 73,  $\times 120$ , USNM 270169. 9. *Puriana* sp. A 9) Lateral view, left valve, loc. 12, sample 73,  $\times 130$ , USNM 270170. 10. *Puriana floridana* Puri, 1960 10) Lateral view, right valve, loc. 7, sample 194,  $\times 100$ , USNM 270171.



# PLATE 17

FIGURE 1. *Proteoconcha nelsonensis* (Grossman, 1967) 1) Lateral view, female left valve, loc. 18, sample 188,  $\times 120$ , USNM 270172. 2. *Reticulocythereis floridana* Puri, 1960 2) Lateral view, female right valve, loc. 10, sample 62,  $\times 120$ , USNM 270173. 3. *Muellerina* sp. A 3. Lateral view, female right valve, loc. 3, sample 26,  $\times 100$ , USNM 270174. 4, 5, 6. *Campylocythere laeva* Edwards, 1944 4) Internal view, female right valve, loc. 2, sample 43,  $\times 100$ , USNM 270175. 5) Lateral

view, female left valve, loc. 2, sample 43,  $\times 100$ , USNM 270176. 6) Lateral view, male left valve, loc. 2, sample 43,  $\times 100$ , USNM 270177. 7. *Protocytheretta* sp. A 7) Lateral view, female? right valve, loc. 20, sample JOI,  $\times 86$ , USNM 270178. 8) *Pro-pontocypris edwardsi* (Cushman, 1906) 8) Lateral view, left valve, juvenile, loc. 4, sample 175,  $\times 100$ , USNM 270179. 9) *Neonesidea* sp. A 9) Lateral view, juvenile right valve, loc. 13, sample 78,  $\times 120$ , USNM 270180. 10. *Echinocythereis* sp. A 10) Lateral view, juvenile left valve, loc. 13, sample 78,  $\times 100$ , USNM 270181.



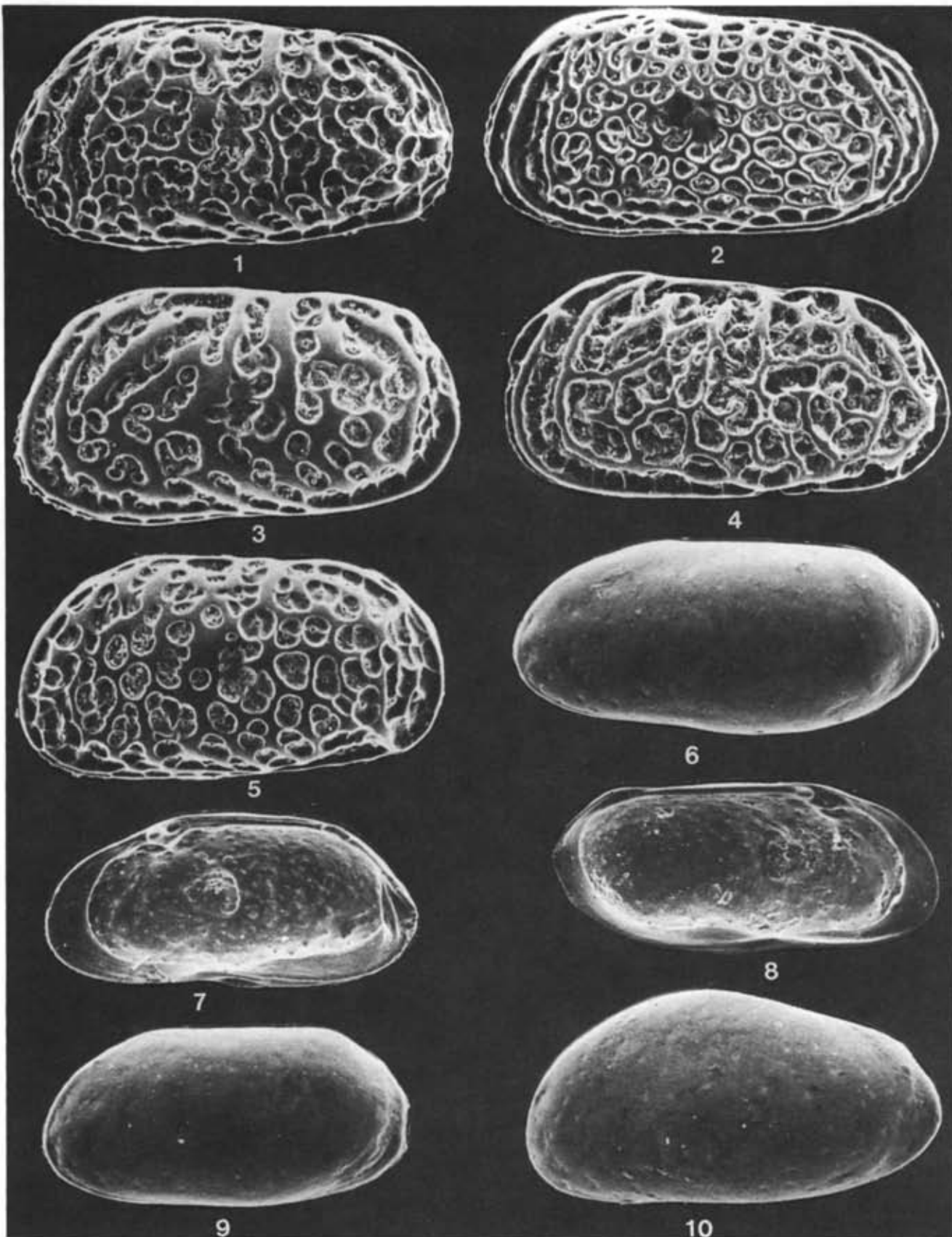
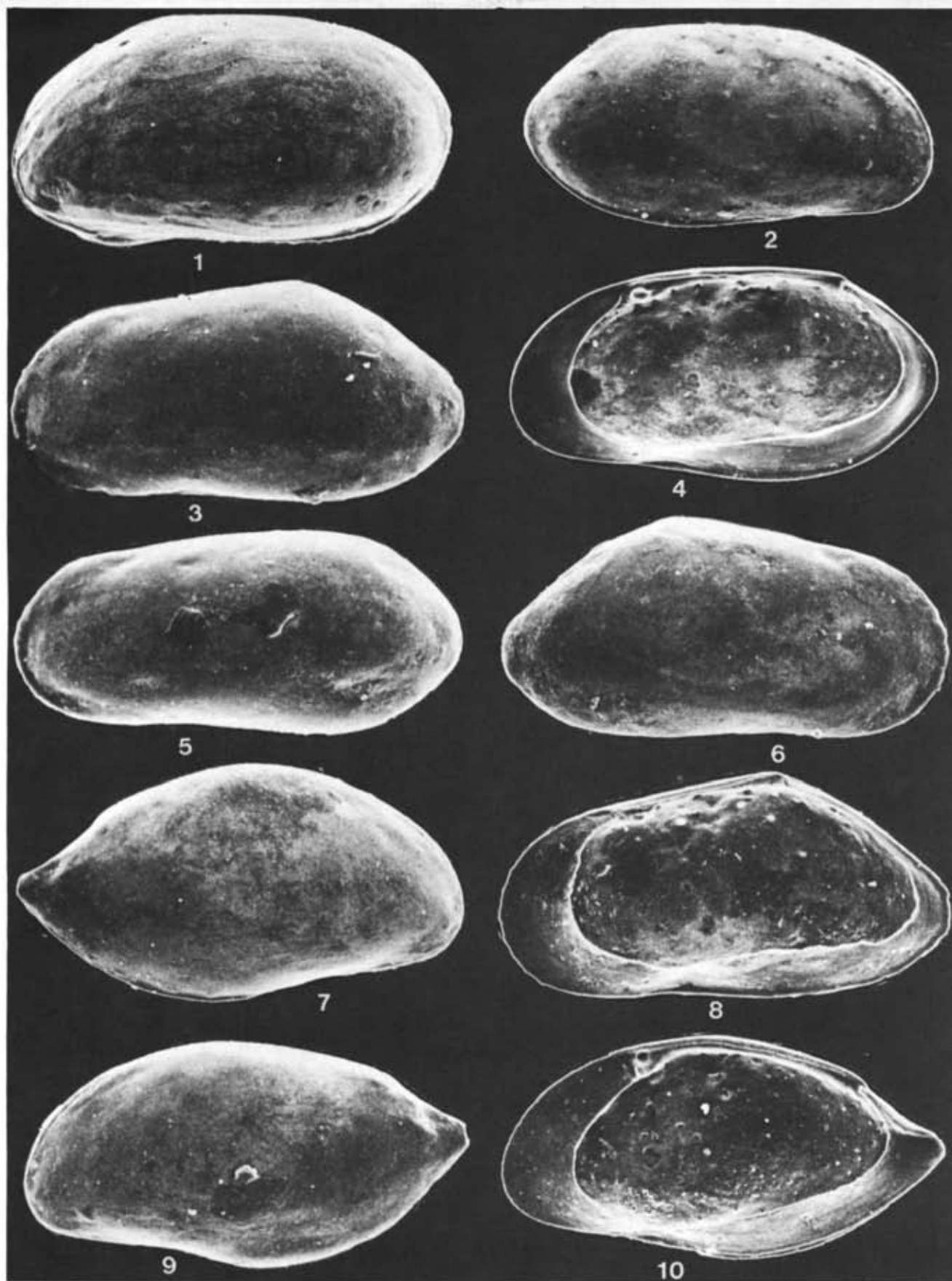


PLATE 18

FIGURE 1. *Bensonocythere sapeloensis* (Hall, 1965) 1) Lateral view, female left valve, loc. 2, sample 43,  $\times 155$ , USNM 270182. 2. *Bensonocythere americana* Hazel, 1967 2) Lateral view, female left valve, loc. 4, sample 175,  $\times 160$ , USNM 270183. 3. *Bensonocythere* sp. A 3) Lateral view, female left valve, loc. 4, sample 175,  $\times 145$ , USNM 270184. 4. *Bensonocythere whitei* (Swain, 1951) 4) Lateral view, male left valve, loc. 11, sample 66,  $\times 140$ , USNM 270185. 5. *Bensonocythere*

sp. B 5) Lateral view, female left valve, loc. 4, sample 175,  $\times 145$ , USNM 270186. 6, 7, 8, 9. *Proteoconcha gigantea* (Edwards, 1944) 6) Lateral view, male left valve, loc. 13, sample 79,  $\times 90$ , USNM 270187. 7) Internal view, female right valve, loc. 13, sample 79,  $\times 90$ , USNM 270188. 8) Internal view, male left valve, loc. 13, sample 79,  $\times 90$ , USNM 270189. 9) Lateral view, female left valve, loc. 13, sample 79,  $\times 90$ , USNM 270190. 10. *Proteoconcha tuberculata* (Puri, 1960) 10) Lateral view, female left valve, loc. 2, sample 43,  $\times 120$ , USNM 270191.



# PLATE 19

FIGURE 1. *Cytherura* sp. C 1) Lateral view, female left valve, loc. 18, sample 188,  $\times 185$ , USNM 270192. 2, 4. *Paracytheroma stephensoni* Puri, 1954 2) Lateral view, female? right valve, loc. 11, sample 65A,  $\times 150$ , USNM 270193. 4) Internal view, female? right valve, loc. 11, sample 65A,  $\times 150$ , USNM 270194. 3, 5, 6, 8. *Paracytheroma texana* Garbett and Maddocks, 1979 3) Lateral view, female left valve, loc. 13, sample 79,  $\times 190$ ,

USNM 270195. 5) Lateral view, male left valve, loc. 13, sample 79,  $\times 170$ , USNM 270196. 6) Lateral view, female right valve, loc. 13, sample 79,  $\times 190$ , USNM 270197. 8) Internal view, female right valve, loc. 13, sample 79,  $\times 190$ , USNM 270198. 7, 9, 10. *Pellucistoma magniventra* Edwards, 1944 7) Lateral view, female right valve, loc. 13, sample 78,  $\times 170$ , USNM 270199. 9) Lateral view, male? right valve, loc. 13, sample 78,  $\times 170$ , USNM 270200. 10) Internal view, male? right valve, loc. 13, sample 78,  $\times 175$ , USNM 270201.