Age and Correlation of the Yorktown (Pliocene) and Croatan (Pliocene and Pleistocene) Formations at the Lee Creek Mine

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ABSTRACT

The fossiliferous beds above the Pungo River Formation (middle Miocene) in the Lee Creek open pit mine in Beaufort County, North Carolina, are approximately 70 feet (21.3 m) thick. This thickness includes 46 feet (14 m) that is correlative with the Yorktown Formation of the type area and is referred to that unit, and, above the Yorktown, a fossiliferous section 23 feet (7 m) thick that is assigned to the Croatan Formation.

The 149 species or subspecies of ostracodes identified were from 16 samples from the Yorktown and Croatan. Coefficients of faunal similarity were calculated for all samples, and the resulting matrix was subjected to unweighted pair-group cluster analysis. Three major faunal groupings were delineated. The principal faunal discontinuity occurs at the Yorktown-Croatan contact about 46 feet (14 m) above the base of the Yorktown. The beds below this level belong to the *Pterygocythereis inexpectata* and *Orionina vaughani* ostracode assemblage zones. Correlation with other Coastal Plain deposits containing planktonic foraminifers indicates that the *Orionina vaughani* assemblage zone is planktonic foraminifer zones N19 and N20 in age and that the *Pterygocythereis inexpectata* assemblage zone may approximate the lowest part of planktonic zone N19 in age. Thus, the Yorktown in the Lee Creek Mine is of early Pliocene age. This is seemingly corroborated by a K/Ar date of 4.4±0.2 my on the *Orionina vaughani* assemblage zone in Virginia.

A third major faunal assemblage is found in the beds of the Croatan Formation, which are referable to the *Puriana mesacostalis* ostracode assemblage zone. The upper part of the Croatan can be correlated with rocks in Florida and North Carolina that have been radiometrically dated by the He/U method at about 1.8 to 1.9 mya. A tentative He/U radiometric date of 2.4 mya was obtained for the lower part of the Croatan at the mine. If a date of about 2.0 mya is used for the Pliocene-Pleistocene boundary, the Croatan as used in the mine spans the Pliocene-Pleistocene boundary.

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Introduction

Texasgulf's Lee Creek open pit phosphate mine is on the south bank of the Pamlico River in Beaufort County, North Carolina. The mine has been the subject of considerable interest since it opened in 1963, not only because of the importance of the primary phosphorite deposits but also because it affords access to an exposure of fossiliferous upper Cenozoic rocks more than 120 feet (36.6 m) thick, an uncommon phenomenon in the Coastal Plain.

This paper is concerned with the ostracodes and their biostratigraphy in the beds of the Yorktown and Croatan formations exposed in the mine walls. This section is interesting not only because of the excellent exposure, but because it is only about 25 miles (40.25 km) north of the Neuse River, the approximate southern limit of the region where the term "Yorktown" is commonly used, and it is in the only area where the term "Croatan" (=James City Formation of DuBar and Solliday, 1963) has been used. South of the Neuse, in the Carolinas and in Georgia, the terms "Duplin" and "Waccamaw" are generally used for rocks considered to be at least in part equivalent to the Yorktown and Croatan. The Duplin is known to contain a warmer water fauna than the Yorktown (for example, Mansfield, 1929); thus, there is also a biogeographic boundary in the vicinity of the Neuse River, although at present this boundary is poorly understood.

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Previous Work

Gibson (1967) made the first study of the fossiliferous rocks in the Lee Creek Mine, assigning them to the Pungo River and Yorktown formations. He measured a 66.4-foot (20.2 m) section of Yorktown in the test pit, in the northeast part of the mine area as shown in Figure 1. Gibson assigned the Yorktown in the mine to the later Miocene, because he concluded that the lowermost beds contained a planktonic foraminifer assemblage consistent with that age. Gibson (1967:638) also pointed out that the presence of

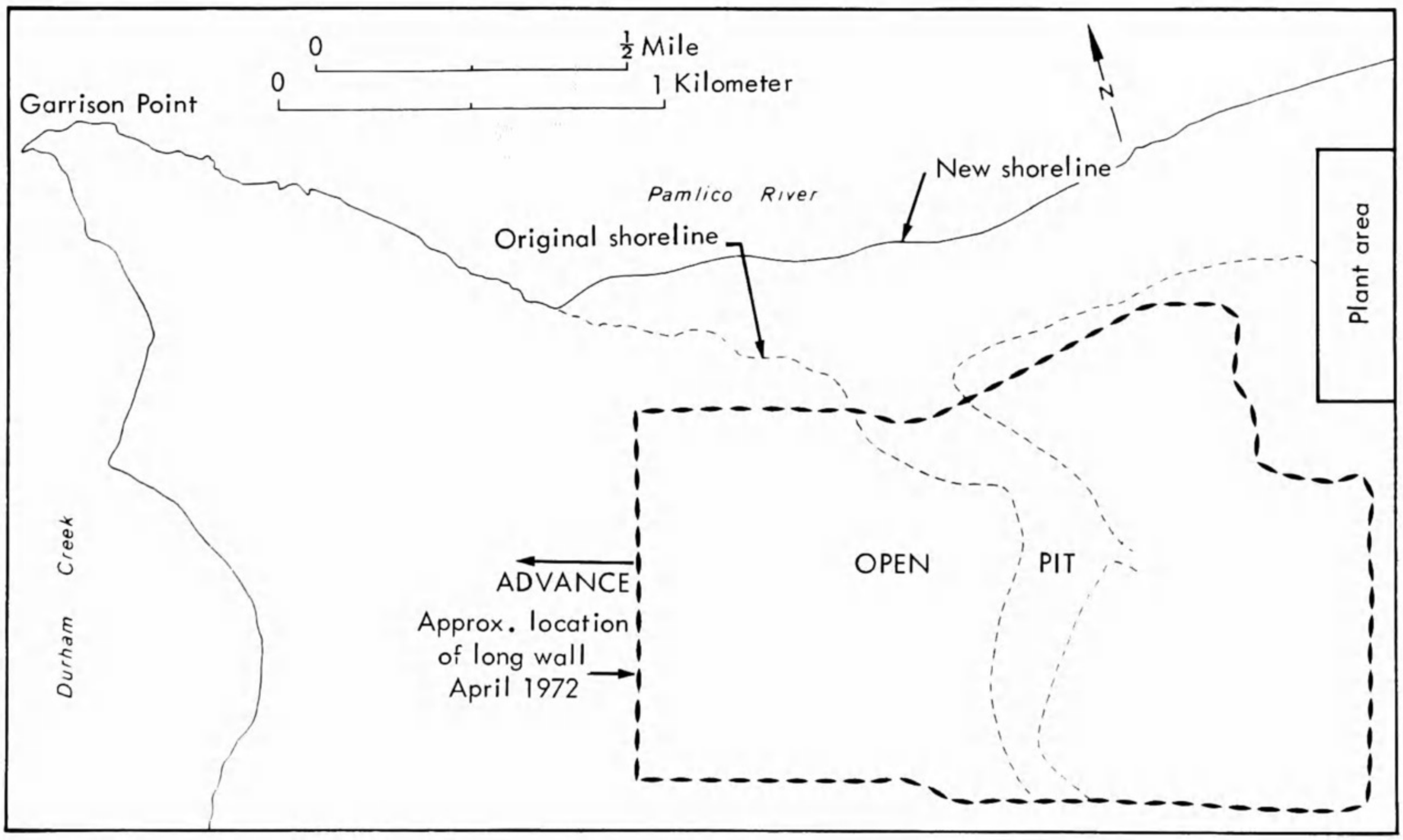

FIGURE 1.—Location of the Texasgulf Inc. Lee Creek open pit phosphate mine near Aurora, North Carolina. The samples used in the present study were taken from the southwestern part of the mine.

Placopecten clintonius (Say) in the lowermost beds indicates correlation with Mansfield's (1929, 1943) *Placopecten clintonius* zone (zone 1) of the Yorktown, and that the presence of *Ostrea sculpturata* in the middle part of the section suggests placement in the lower part of Mansfield's *Turritella alticostata* zone (zone 2). On the basis of foraminifer assemblages, Gibson (1967:647) concluded that the Yorktown in the mine was deposited initially in cool-temperate waters nearly 100 m deep and finally in warmer waters less than 15 m deep.

In 1969, Hazel (1971a:10) referred a 69-foot (21.0 m) section in the southwestern part of the mine to the Yorktown. On the basis of a cluster analysis of 43 Yorktown collections (10 from the Lee Creek Mine), he concluded that the lower few feet of the Yorktown in the mine belonged to the *Pterygocythereis inexpectata* ostracode assemblage zone, and approximately the upper 12 feet (3.7 m) to the *Puriana mesacostalis* assemblage zone; the rest of the accessible section between these two zones was placed in the *Orionina vaughani* assemblage zone. Hazel (1971a:8) assigned the *Puriana mesacostalis* assemblage zone to the Pliocene and suggested that more of the Atlantic and Gulf Coastal Plain deposits traditionally assigned to the upper Miocene could be Pliocene. Hazel (1971b:373) concluded that the early Yorktown assemblage lived under mild or warm-temperate climatic conditions, that warm-temperate conditions prevailed during most of Yorktown time, and that a subtropical marine climate was present in Croatan (his late Yorktown) time.

Swain (1974) studied ostracodes from the Yorktown Formation from various localities in Virginia and North Carolina. Most of the specimens studied by Swain were picked from carbon tetrachloride floats prepared for the study of foraminifers by T.G. Gibson of the U.S. Geological Survey. Few species and specimens were available for study, as Swain indicated in his descriptive section, probably because ostracodes (particularly single valves) do not "float" well. Yorktown samples, 500 to 1000 cm^3 in size, when picked after only washing or after concentrating the carbonate fraction by using a soap float technique (Howe, 1941; Gibson and Walker, 1967), have yielded hundreds and on occasion thousands of ostracode specimens (this study and Hazel, 1971a). Swain (1974), therefore, would have had difficulty in recognizing the assemblage zones established by Hazel (1971a) because he studied only a small number of ostracode specimens. Swain's (1974) study was further impeded when he tried to use the particular species for which Hazel's (1971a) assemblage zones were named as index or guide fossils, despite the fact that Hazel clearly stated that the zones were assemblage zones.

Swain (1974:10) also studied some samples from the Lee Creek Mine and is of the opinion that the large assemblages reported by Hazel (1971a) from the lower part of the Yorktown at the mine are in part reworked from the underlying Miocene Pungo River Formation. The writer has processed several samples from the lower part of the Yorktown at the mine and has found no evidence of reworking of ostracodes from the Pungo River into the Yorktown. T.G. Gibson (pers. comm., 1975) has also studied many samples from the lower part of the Yorktown at the mine, and he, too, finds no evidence of reworking. The Pungo River carries a taxonomically distinct and differently preserved assemblage. Swain (1974:10) stated that these lower beds of the Yorktown in the mine are correlative with the middle or upper part of the Yorktown of the other sections he studied. The ostracodes (Hazel, 1971a, and p. 93 herein) and mollusks (Gibson, 1967:638) indicate an obvious correlation with the lower part of the Yorktown of the type area.

Most of Swain's samples (1974) were from his "lower Yorktown," and some of these at least are actually from the underlying Eastover Formation of Ward and Blackwelder (1980). Specifically, samples from Swain's lower part of the Yorktown at localities 5, 6, 7, 9, 10, and 11 may be partly or entirely from the Eastover Formation. The Eastover is late Miocene (Ward and Blackwelder, 1980:11) and (or) early Pliocene (Andrews, 1980:19) in age.

Swain (1974:9–11) considered the Yorktown Formation to be of late Miocene age; however, he presented no supporting evidence. He assigned the beds at Colerain Landing and near Mt. Gould Landing on the Chowan River to the Pliocene(?). Hazel (1971a) assigned these localities to the Pliocene and placed them in the *Puriana mesacostalis* assemblage zone. Swain's (1974:11) argument that *Puriana mesacostalis* cannot be used as a guide for the Pliocene because it "was described from the upper Miocene Duplin Marl" is circular. There is no evidence that the Duplin is Miocene, but there is considerable evidence that it is Pliocene.

Yorktown Formation

The Yorktown Formation is poorly understood as a lithostratigraphic unit, because the generally recognized Yorktown sediments contain a variety of lithologies. No extensive petrological examinations have been made of the Yorktown, and no extensive detailed mapping has been done at the surface or in the shallow subsurface over any sizable area where the term has been used. Without such a solid physical stratigraphic framework then, it is understandable, if not excusable, that the term "Yorktown" connotes a biostratigraphic, rather than lithostratigraphic, unit to many workers.

In the type area of the Yorktown, which can be defined as the valleys of the York and James rivers and the included peninsula, the Yorktown has generally come to mean the beds containing mollusks referable to Mansfield's (1929, 1943) *Placopecten clintonius* and *Turritella alticostata* zones (the so-called zones 1 and 2, respectively). These two zones are in need of redefinition and revision in the light of modern biostratigraphic thought; nonetheless, the Yorktown has been recognized in an area of about 17,000 square miles (44,030 square kilometers) as a unit of perhaps substage magnitude.

An "ian" ending was added to the Yorktown by Malkin (1953:767), who considered it a substage of the upper Miocene. She did not, however, study much of the Yorktown or discuss the distribution and correlation of this "substage" in any detail. Such nomenclatorial procedures have been followed before (for example, Murray, 1961). However, addition of "ian" endings to ostensibly lithostratigraphic terms in order to make their biostratigraphic use legitimate, although not necessarily confusing, is cumbersome and nomenclatorially undesirable; therefore, it is not followed here.

In North Carolina, rocks younger than the Yorktown of the type area have been included in the Yorktown by Clark et al. (1912), Mansfield (1943), MacNeil (1938), Hazel (1971a), and at the Lee Creek Mine by Gibson (1967) and Hazel (1971a). Gibson (1970) and Swain (1974) have also placed deposits demonstrably older than the classic Yorktown in the Yorktown Formation.

Lithologic units 1–4 of Figure 2 are correlative with the Yorktown Formation of the type area, and their lithologies do not differ from those of beds assigned to the Yorktown in northern North Carolina and Virginia. Therefore, units 1–4 (equivalent to units 1–5 of Gibson, 1967) are assigned to the Yorktown Formation.

Croatan Formation

Units 5–7 (equivalent to Gibson's, 1967, units 6–9) in the mine have been referred to the James City Formation of DuBar and Solliday (1963) by DuBar, Solliday, and Howard (1974:109). The James City was proposed as a substitute for the Croatan Formation of Dall (1892) by DuBar and Solliday (1963:215, 228), because Dall did not adequately define the Croatan Formation in his original work. Dall's collections apparently contained both Pliocene and Pleistocene species, and he did not designate a type section. Mansfield (1928:135) reviewed the situation and restricted the name Croatan "to those beds on or near the Neuse River which are of Pliocene age." According to DuBar and Solliday (1963:223) and DuBar, Solliday, and Howard (1974:106), however, the beds to which Mansfield restricted the name probably represent a Pleistocene unit containing reworked Pliocene fossils.

DuBar and Solliday (1963:228) selected as the type locality of their James City Formation the outcrops on the Neuse River just below the town of James City, which is about 12 miles (19.2 km) from the town of Croatan. Mansfield (1936) had previously included these outcrops in the Croatan but did not tie the name to a type section. However, MacNeil (1938:19) did suggest this locality as the type section for the Croatan. Because this is in the area of the Croatan people (the unit was not named for the town) and MacNeil has indicated a type section, the writer sees no reason not to adhere to the rules of priority and retain the term "Croatan," suppressing the term James City. Attention is called, however, to the clarifying efforts of DuBar and Solliday (1963) and particularly DuBar, Solliday, and Howard (1974).

Dall used the term "Croatan beds," and Mansfield referred to the "Croatan Sand," even though several lithologies are present in the Croatan (see DuBar, Solliday, and Howard, 1974). The writer believes that the unit should be referred to as the Croatan Formation.

Collections and Analyses

The Lee Creek Mine was visited again by the writer in April 1971, and a 69-foot (21.0-m) section of Yorktown was measured in the southwest area of the mine. Collections were made from most of the beds that were inaccessible in the middle part of the formation in 1969 (Hazel, 1971a:10). These and the original collections were supplemented by collections made by L.W. Ward of the U.S. Geological Survey in 1972. The stratigraphic position of the various collections is indicated in Figure 2.

The 149 species or subspecies of ostracodes occurred in the 16 samples used for multivariate analysis. Three Yorktown samples, one from the Croatan, and two from unit 8, which may represent the Flanner Beach Formation (Pleistocene), were barren of ostracodes and are indicated by X in Figure 2. The samples were compared in Q-mode (samples compared on the basis of species content) by calculating Otsuka similarity coefficients between all samples and performing an unweighted pair-group cluster analysis (UPGM) on the resulting matrix. These techniques, as applied to biostratigraphy, have been described by Hazel (1970, 1971a). To minimize environmental or preservational differences between samples, the range-through method of calculation was used (see Cheetham and Deboo, 1963); that is, a species was counted as present in a sample for the purposes of the calculation of the similarity coefficient if it occurred in samples on either side of but not in the sample in question. The Q-mode dendrogram resulting from the cluster analysis is also illustrated in Figure 2.

In order to ascertain which species were primarily responsible for the groupings seen in Q-mode, an R-mode analysis (taxa compared with each other on the basis of the samples in which they occur) using the Otsuka coefficient was performed on all those species or subspecies that occur in more than one sample but not in all samples (a total of 85 taxa). The results of this R-mode analysis are presented in Figure 3.

Alphabetical List of Species

The 149 ostracode species found in the Yorktown Formation at the Lee Creek Mine are listed alphabetically. The number to the left of the name is the computer code number assigned to the species. The numbers to the right of the name indicate occurrences in the samples of Figure 2. The plates and figures illustrating the species are also indicated.

Code	Species	Sample	Illustration
238	*Actinocythereis captionis*	2, 10–16	Pl. 8: figs. 1, 2, 4
241	*A. dawsoni*	1, 3, 5–7, 9	Pl. 9: fig. 1

Code	Species	Sample	Illustration
239	*A. marylandica*	1, 5, 6, 9	Pl. 8: fig. 3
240	*A. mundorffi*, small form	2, 3, 5–8, 16	Pl. 9: fig. 2
243	*Acuticythereis laevissima*	7, 8	
318	*Anchistrocheles* sp. C	11	
9	*Aurila laevicula*	6, 8	Pl. 15: fig. 4
14	*Bairdoppilata triangulata*	1, 6, 8–16	
27	*Bensonocythere blackwelderi*	1, 6, 8, 9, 11–13	Pl. 35: figs. 1, 2, 4; Pl. 37: fig. 4
32	*B. bradyi*	11	Pl. 34: figs. 1, 2; Pl. 38: figs. 2, 4
24	*B. calverti*	1	Pl. 34: fig. 5
19	*B. gouldensis*	4, 8, 9, 11, 15	Pl. 34: figs. 3, 4; Pl. 37: figs. 2, 3
30	*B. ricespitensis*	12, 14	Pl. 33: figs. 1–4
25	*B. rugosa*	3, 8, 10	Pl. 32: figs. 3, 4; Pl. 37: fig. 1
21	*B. trapezoidalis*	1, 5, 9	Pl. 32: figs. 1, 2
18	*B. whitei*	10–16	Pl. 35: fig. 3
33	*Bensonocythere* sp. M	15	
319	*Bensonocythere* sp. OO	11	
320	*Bensonocythere* sp. PP	10, 13	
329	*Bensonocythere* sp. QQ	10	
330	*Bensonocythere* sp. RR	13	
44	*Bythocythere* sp. B	14	
47	*Campylocythere laeva*	5, 6, 9–16	
55	*Caudites paraasymmetricus*	13–15	Pl. 12: figs. 2–4
56	*Cnestocythere?* sp.	16	
217	*Cushmanidea* cf. *C. seminuda*	14	
57	*Cyprideis* sp. B	15, 16	
62	*Cytherella* sp. A	5, 12	
321	*Cytherella* sp. B	1	
63	*Cytherelloidea* sp. A	14, 16	
106	*Cytheridea campwallacensis*	1, 4, 6	Pl. 1: fig. 4; Pl. 2: figs. 1, 3, 4
111	*C. carolinensis*	10–15	Pl. 3
107	*C. virginiensis*	2, 3, 5–15	Pl. 1: fig. 3; Pl. 2: fig. 2
105	*Cytheridea* aff. *C. virginiensis*	3, 6, 7	Pl. 1: figs. 1, 2
250	*Cytheromorpha? curta*	13	
68	*C. incisa*	9, 11, 13	Pl. 21: figs. 1, 2; Pl. 23: figs. 5, 6
70	*C. macroincisa*	11, 15	Pl. 22: figs. 1–5
67	*C. suffolkensis*	9, 11, 12	Pl. 23: figs. 1–4
66	*C. warneri*	1, 5–10	Pl. 22: fig. 6
322	*Cytheromorpha* sp. I	1	
71	*Cytheropteron talquinensis*	1, 2, 5–9, 12	Pl. 9: fig. 4
72	*C.? yorktownensis*	1, 3, 5, 8–12, 14–16	Pl. 9: fig. 3
317	*Cytherura elongata*	1, 3, 9, 15	
132	*C. forulata*	1, 5, 8, 9, 12–15	
75	*C. howei*	1, 5, 8, 12, 13, 15	
77	*C. reticulata*	9, 10, 13–15	
80	*C. wardensis*	6, 9, 15	
193	*Cytherura* sp.	5, 8	
323	*Cytherura* sp. AA	13, 15	
340	*Cytherura* sp. BB	13	
76	*Cytherura* sp. D	1, 3, 5, 7–9	
83	*Cytherura* sp. L	8–10, 14	
84	*Cytherura* sp. M	13, 15	
85	*Cytherura* sp. N	9, 12–16	
194	*Cytherura* sp. U	13	
316	*Cytherura* sp. W	13	

Code	Species	Sample	Illustration
90	*Echinocythereis leecreekensis*	10–12	Pl. 36: figs. 1–3; Pl. 38: fig. 3
89	*E. planibasalis*	1, 5, 6, 8, 9	Pl. 36: fig. 4
91	*Eucythere declivis*	1, 10, 12	
92	*E. gibba*	5, 6, 9, 11–13	
94	*E. triangulata*	11, 13	
96	*Eucythere* sp. F	5	
331	*Hermanites ascitus*	8, 9	Pl. 11: figs. 1–3
115	*Hirschmannia? hespera*	10–12, 14	Pl. 20: figs. 1, 2; Pl. 21: figs. 3, 4
114	*H.? quadrata*	10–14	Pl. 20: figs. 3, 4
23	*Hulingsina americana*	2, 4, 6–14, 16	
156	*H. glabra*	10, 11, 13, 14	
22	*H. rugipustulosa*	1, 9–13, 15, 16	
128	*Hulingsina* sp. C	1, 9, 10, 12–15	
82	*Hulingsina* sp. F	11–15	
41	*Hulingsina* sp. R	5	
61	*Hulingsina* sp. U	7	
121	*Leptocythere nikraveshae*	14	
207	*Leptocythere* sp. E	13	
326	*Leptocythere* sp. F	11	
127	*Loxoconcha edentonensis*	12, 13	Pl. 24: figs. 2, 4
136	*L. matagordensis*	13–16	
126	*L. purisubrhomboidea*	12	
131	*L. reticularis*	6, 8–10, 12, 13	
125	*Loxoconcha* sp. C	1–3, 5, 9	
130	*Loxoconcha* sp. H	3–7, 12–16	
133	*Loxoconcha* sp. M	5, 8, 9	
69	*Loxoconcha* sp. S	1	
216	*Loxoconcha* sp. T	14, 16	
13	*Malzella conradi*, angulate form	8–10	Pl. 14: figs. 1, 2, 4
12	*M. evexa*	1, 3, 5, 6, 8–14, 16	Pl. 14: fig. 3; Pl. 15: figs. 1–3, 5
139	*Microcytherura choctawhatcheensis*	1, 6–16	Pl. 29: fig. 3
140	*M. expanda*	10, 11, 15, 16	Pl. 30: figs. 1–3
149	*M. minuta*	3	Pl. 31: figs. 1–3
138	*M. similis*	9–16	Pl. 29: fig. 4; Pl. 30: fig. 4; Pl. 31: fig. 4
141	*Microcytherura* sp. D	13	
145	*Microcytherura* sp. H	1, 5, 8–10	
147	*Microcytherura* sp. M	12	
257	*Microcytherura* sp. P	15	
312	*Microcytherura* sp. R	10, 11, 15	
151	*Muellerina bassiounii*	10–13, 16	Pl. 16: figs. 1, 4; Pl. 18: fig. 6
153	*M. blowi*	8–13	Pl. 17: figs. 1, 3; Pl. 18: fig. 2
157	*M. canadensis petersburgensis*	1–3, 5–9	Pl. 16: fig. 2; Pl. 18, figs. 1, 3
150	*M. ohmerti*	1, 3, 5, 7–16	Pl. 16: fig. 3
152	*M. wardi*	1, 3, 9–14, 16	Pl. 17: figs. 2, 4; Pl. 18: figs. 4, 5
160	*Muellerina* sp. P	4	
163	*Murrayina barclayi*	7, 9	Pl. 11: fig. 4
162	*M. macleani*	1–5, 7	Pl. 10: figs. 1–4
164	*Murrayina* sp. E	7	
309	*Neocaudites angulatus*	9, 15	Pl. 6: figs. 2–4
328	*N. subimpressus*	8	Pl. 5: fig. 4
166	*N. triplistriatus*	6, 8, 9	Pl. 6: fig. 1
167	*N. variabilus*	11, 12	Pl. 5: figs. 1–3; Pl. 7: fig. 1
172	*Orionina vaughani*	1, 5, 6, 8–16	Pl. 12: fig. 1

Code	Species	Sample	Illustration
54	*Palaciosa minuta*	13	Pl. 13: figs. 1, 3, 4
182	*Paracyprideis* sp. C	5–7, 9	
184	*Paracypris* sp. B	5	
189	*Paracytheridea altila*	1, 6, 9–16	Pl. 28: fig. 4
188	*P. cronini*	5, 6, 8–10, 12, 13	Pl. 28: figs. 1, 2; Pl. 29: fig. 1
223	*P. mucra*	13	Pl. 29: fig. 2
190	*P. rugosa*	13, 15	Pl. 28: fig. 3
327	*Paracytheridea* sp. F	9	
192	*Paracytheroma stephensoni*	13–15	
196	*Paradoxostoma delicata*	13, 15	
198	*Paradoxostoma* sp. E	11	
200	*Paranesidea? laevicula*	13	
201	*Paranesidea* sp. B	8	
98	*Peratocytheridea bradyi*	6, 7, 10–14, 16	
99	*P. sandbergi*	3–7, 9, 10, 12–16	Pl. 4: figs. 1–3
324	*P. setipunctata*	15	Pl. 4: fig. 4
104	*Peratocytheridea* sp. J	14	
143	"*Pontocythere*" sp. I	10, 13, 15, 16	Pl. 38: fig. 1
230	"*Pontocythere*" sp. G	1, 3, 5–7	
155	"*Pontocythere*" sp. J	9, 13	
205	*Propontocypris* sp. D	3, 5, 7	
175	*Proteoconcha gigantica*	13	
173	*P. jamesensis*	9	Pl. 25: figs. 1, 2; Pl. 27: fig. 2
178	*P. mimica*	9	
206	*P. multipunctata*, sensu lato	1, 5, 6, 8–15	
8	*P. tuberculata*	13	
177	*Proteoconcha* sp. Z	1	
215	*Pseudocytheretta burnsi*	1, 2, 4–11, 13–15	Pl. 24: figs. 1, 3
224	*Pterygocythereis inexpectata*	1–7	Pl. 7: fig. 3
227	*Puriana carolinensis*	1, 3, 6–16	Pl. 27: figs. 1, 3, 4
228	*P. convoluta*	10, 13, 14	Pl. 26: figs. 1, 2, 4
229	*P. mesacostalis*	13, 15	Pl. 25: fig. 4
226	*P. rugipunctata*	6, 9, 12, 13	Pl. 25: fig. 3; Pl. 26: fig. 3
165	*Radimella confragosa*	10–16	Pl. 13: fig. 2
236	*Sclerochilus* sp. B	11, 14	
15	*Thaerocythere carolinensis*	12	Pl. 19: figs. 1, 3, 4
78	*T. schmidtae*	10, 12, 14	Pl. 19: fig. 2
16	*Xestoleberis ventrostriata*	10, 11, 13, 14	
169	*Xestoleberis* sp. E	12, 15	

Numerical Computer Code List of Species

Code	Species
8	*Proteoconcha tuberculata* (Puri, 1960)
9	*Aurila laevicula* (Edwards, 1944)
12	*Malzella evexa*, new species
13	*M. conradi* (Howe and McGuirt, 1935), angulate form
14	*Bairdoppilata triangulata* Edwards, 1944
15	*Thaerocythere carolinensis*, new species
16	*Xestoleberis ventrostriata* Swain, 1951
18	*Bensonocythere whitei* (Swain, 1951)
19	*B. gouldensis*, new species
21	*B. trapezoidalis* (Swain, 1974)
22	*Hulingsina rugipustulosa* (Edwards, 1944)
23	*H. americana* (Cushman, 1906)
24	*Bensonocythere calverti* (Ulrich and Bassler, 1904)
25	*B. rugosa*, new species
27	*B. blackwelderi*, new species
30	*B. ricespitensis*, new species
32	*B. bradyi*, new species
33	*Bensonocythere* sp. U
41	*Hulsingsina* sp. R
44	*Bythocythere* sp. B
47	*Campylocythere laeva* Edwards, 1944
54	*Palaciosa minuta* (Edwards, 1944)

Code	Species
55	*Caudites paraasymmetricus*, new species
56	*Cnestocythere?* sp.
57	*Cyprideis* sp. B
61	*Hulingsina* sp. U
62	*Cytherella* sp. A
63	*Cytherelloidea* sp. A
66	*Cytheromorpha warneri* Howe and Spurgeon, 1935
67	*Cytheromorpha suffolkensis*, new species
68	*Cytheromorpha incisa*, new species
69	*Loxoconcha* sp. S
70	*Cytheromorpha macroincisa*, new species
71	*Cytheropteron talquinensis* Puri, 1954
72	*C.? yorktownensis* (Malkin, 1953)
75	*Cytherura howei* (Puri, 1954)
76	*Cytherura* sp. D
77	*C. reticulata* Edwards, 1944
78	*Thaerocythere schmidtae* (Malkin, 1953)
80	*Cytherura wardensis* Howe and Brown, 1935
82	*Hulingsina* sp. F
83	*Cytherura* sp. L
84	*Cytherura* sp. M
85	*Cytherura* sp. N
89	*Echinocythereis planibasalis* (Ulrich and Bassler, 1904)
90	*E. leecreekensis*, new species
91	*Eucythere declivis* (Norman, 1865)
92	*E. gibba* Edwards, 1944
94	*E. triangulata* Puri, 1954
96	*Eucythere* sp. F
98	*Peratocytheridea bradyi* (Stephenson, 1938)
99	*P. sandbergi*, new species
104	*Peratocytheridea* sp. J
105	*Cytheridea* aff. *C. virginiensis* (Malkin, 1953)
106	*C. campwallacensis*, new species
107	*C. virginiensis* (Malkin, 1953)
111	*C. carolinensis*, new species
114	*Hirschmannia? quadrata*, new species
115	*H.? hespera*, new species
121	*Leptocythere nikraveshae* Morales, 1966
125	*Loxoconcha* sp. C
126	*L. purisubrhomboidea* Edwards, 1953
127	*L. edentonensis* Swain, 1951
128	*Hulingsina* sp. C
130	*Loxoconcha* sp. H
131	*L. reticularis* Edwards, 1944
132	*Cytherura forulata* Edwards, 1944
133	*Loxoconcha* sp. M
136	*L. matagordensis* Swain, 1955
138	*Microcytherura similis* (Malkin, 1953)
139	*M. choctawhatcheensis* (Puri, 1954)
140	*M. expanda*, new species
141	*Microcytherura* sp. D
143	"*Pontocythere*" sp. I
145	*Microcytherura* sp. H
147	*Microcytherura* sp. M
149	*M. minuta*, new species
150	*Muellerina ohmerti*, new species
151	*M. bassiounii*, new species
152	*M. wardi*, new species
153	*M. blowi*, new species
155	"*Pontocythere*" sp. J
156	*Hulingsina glabra* (Hall, 1965)
157	*Muellerina canadensis petersburgensis*, new subspecies
160	*Muellerina* sp. P
162	*Murrayina macleani* Swain, 1974
163	*M. barclayi* McLean, 1957
164	*Murrayina* sp. E
165	*Radimella confragosa* (Edwards, 1944)
166	*Neocaudites triplistriatus* (Edwards, 1944)
167	*N. variabilus*, new species
169	*Xestoleberis* sp. E
172	*Orionina vaughani* (Ulrich and Bassler, 1904)
173	*Proteoconcha jamesensis*, new species
175	*P. gigantica* (Edwards, 1944)
177	*Proteoconcha* sp. Z
178	*P. mimica* Plusquellec and Sandberg, 1969
182	*Paracyprideis* sp. C
184	*Paracypris* sp. B
188	*Paracytheridea cronini*, new species
189	*P. altila* Edwards, 1944
190	*P. rugosa* Edwards, 1944
192	*Paracytheroma stephensoni* (Puri, 1954)
193	*Cytherura* sp.
194	*Cytherura* sp. U
196	*Paradoxostoma delicata* Puri, 1954
198	*Paradoxostoma* sp. E
200	*Paranesidea? laevicula* (Edwards, 1944)
201	*Paranesidea* sp. B
205	*Propontocypris* sp. D
206	*Proteoconcha multipunctata*, sensu lato
207	*Leptocythere* sp. E
215	*Pseudocytheretta burnsi* (Ulrich and Bassler, 1904)
216	*Loxoconcha* sp. T
217	*Cushmanidea* cf. *C. seminuda* (Cushman, 1906)
223	*Paracytheridea mucra* Edwards, 1944
224	*Pterygocythereis inexpectata* (Blake, 1929)
226	*Puriana rugipunctata* (Ulrich and Bassler, 1904)
227	*P. carolinensis*, new species
228	*P. convoluta* Teeter, 1975
229	*P. mesacostalis* (Edwards, 1944)
230	"*Pontocythere*" sp. G
236	*Sclerochilus* sp. B
238	*Actinocythereis captionis*, new species
239	*A. marylandica* (Howe and Hough, 1935)
240	*A. mundorffi* (Swain, 1951), small form
241	*A. dawsoni* (Brady, 1870)
243	*Acuticythereis laevissima* Edwards, 1944
250	*Cytheromorpha? curta* Edwards, 1944
257	*Microcytherura* sp. P
309	*Neocaudites angulatus*, new species
312	*Microcytherura* sp. R

Code	Species
316	*Cytherura* sp. W
317	*C. elongata* Edwards, 1944
318	*Anchistrocheles* sp. C
319	*Bensonocythere* sp. OO
320	*Bensonocythere* sp. PP
321	*Cytherella* sp. B
322	*Cytheromorpha* sp. I
323	*Cytherura* sp. AA
324	*Peratocytheridea setipunctata* (Brady, 1869)
326	*Leptocythere* sp. F
327	*Paracytheridea* sp. F
328	*Neocaudites subimpressus* (Edwards, 1944)
329	*Bensonocythere* sp. QQ
330	*Bensonocythere* sp. RR
331	*Hermanites ascitus*, new species
340	*Cytherura* sp. BB

Biostratigraphy at the Lee Creek Mine

Figure 2 shows two major clusters of samples, labelled I and II, and four principal subclusters, labelled A–D (sample 16 tends to cluster at a low level because of relatively low diversity; the same is true to a lesser extent of sample 1). Samples 1–9 from the Yorktown Formation are faunally more similar to each other than to samples 10–16 from the Croatan Formation.

Thus, the major faunal discontinuity is between samples 9 and 10, and the Yorktown-Croatan contact may represent the major hiatus in the section above the base of the Yorktown. This conclusion is contrary to that of Welby and Leith (1969) who stated that the major break in the part of the mine section treated in the present study is between Gibson's (1967) units 2 and 3 of the Yorktown, that is, between samples 6 and 7 of this study.

Clusters A, B, C, and D indicate that recognizable faunal packages are found within each of the major clusters. Samples 1–7 from the lower 12 feet (3.6 m) of the Yorktown (units 1–3 of Figure 2) group together, and samples 8 and 9 from unit 4 from the upper part of the formation form another cluster. The latter two samples are each composites of samples containing similar faunas taken at virtually the same stratigraphic position but at different times. The interval below sample 8 and above sample 7 contained only a few poorly preserved ostracodes, none of which could be identified.

Sample 10 was taken from a 4-foot (1.2-m) interval in a 12-foot (3.6-m) thick bed of differentially indurated burrowed sand (unit 5) assigned to the Croatan; the irregularly shaped, indurated sandstone blocks are scattered throughout the unit but concentrated at the top. This sample groups faunally with those from the lower part (unit 6) of the very macrofossiliferous bed above. Samples from the upper part of this bed (unit 7) form subcluster D. The two parts of the bed are differentiated by the number of large mollusk shells that they contain: the lower part (unit 6) contains many, the upper part (unit 7), few. Small shells are abundant in both, but comminuted shell is more common or predominant in unit 7. The upper few feet of section below nonmarine Pleistocene ("Cherry Point" unit of DuBar, Solliday, and Howard, 1974) is a dark blue unfossiliferous sandy clay (unit 8) in undulating contact with unit 7; its stratigraphic relationship is unclear, and it is questionably referred to the Flanner Beach Formation (upper Pleistocene).

Opposite the R-mode dendrogram in Figure 3, the ranges of the 85 taxa in the 16 samples are given. These taxa, as well as those that occur in all or only one of the samples, are listed alphabetically and by code number (pp.85–90). At the top left of Figure 3 is a dendrogram summarizing the Q-mode results seen in Figure 2. For convenience in discussion, the R-mode subclusters of Figure 3 are labelled A–P, and the major clusters, I–IV Cluster I consists of species that occur chiefly in the Yorktown in the mine, and clusters II and IV are composed of species occurring principally in the Croatan. Cluster III is composed of species that occur in both the Yorktown and Croatan.

Subcluster D consists of species restricted to the samples of Q-mode subcluster A. R-mode subcluster C contains species that mostly occur throughout Q-mode subcluster A and extend into B and, in part, also into C, whereas R-mode subcluster B represents species that are found in the stratigraphically higher samples of Q-mode subclusters A and B.

Subcluster H consists of species that occur

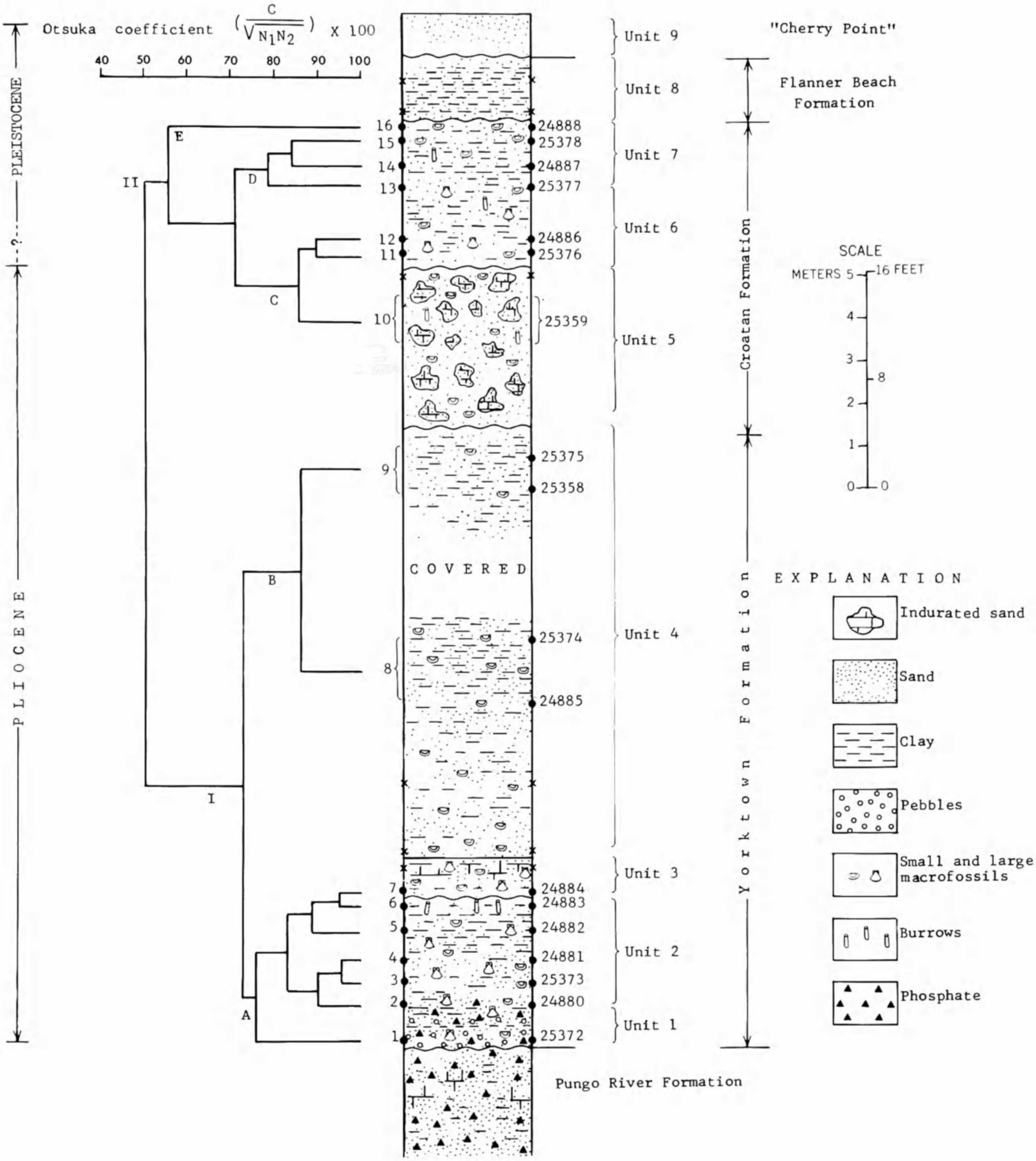

FIGURE 2.—Location of collections, general lithology, and results of Q-mode cluster analysis of the Yorktown and Croatan samples collected in the southwestern part of the Lee Creek Mine. Units 1–9 are the major lithologic units; the 5-digit numbers to the immediate right of the stratigraphic column are USGS Cenozoic locality numbers; the collection points are indicated by dots, except for nonmicrofossiliferous samples, which are indicated by X; the individual and composite samples (1–16) used in the multivariate analysis are indicated to the left of the column. The faunal relationships are indicated by the dendrogram, which was obtained by an unweighted pair-group cluster analysis of a matrix of Otsuka similarity coefficients. This procedure demonstrated two major clusters, indicated by the numerals I and II, and four principal subclusters, A–D, with a less clearly marked subcluster, E.

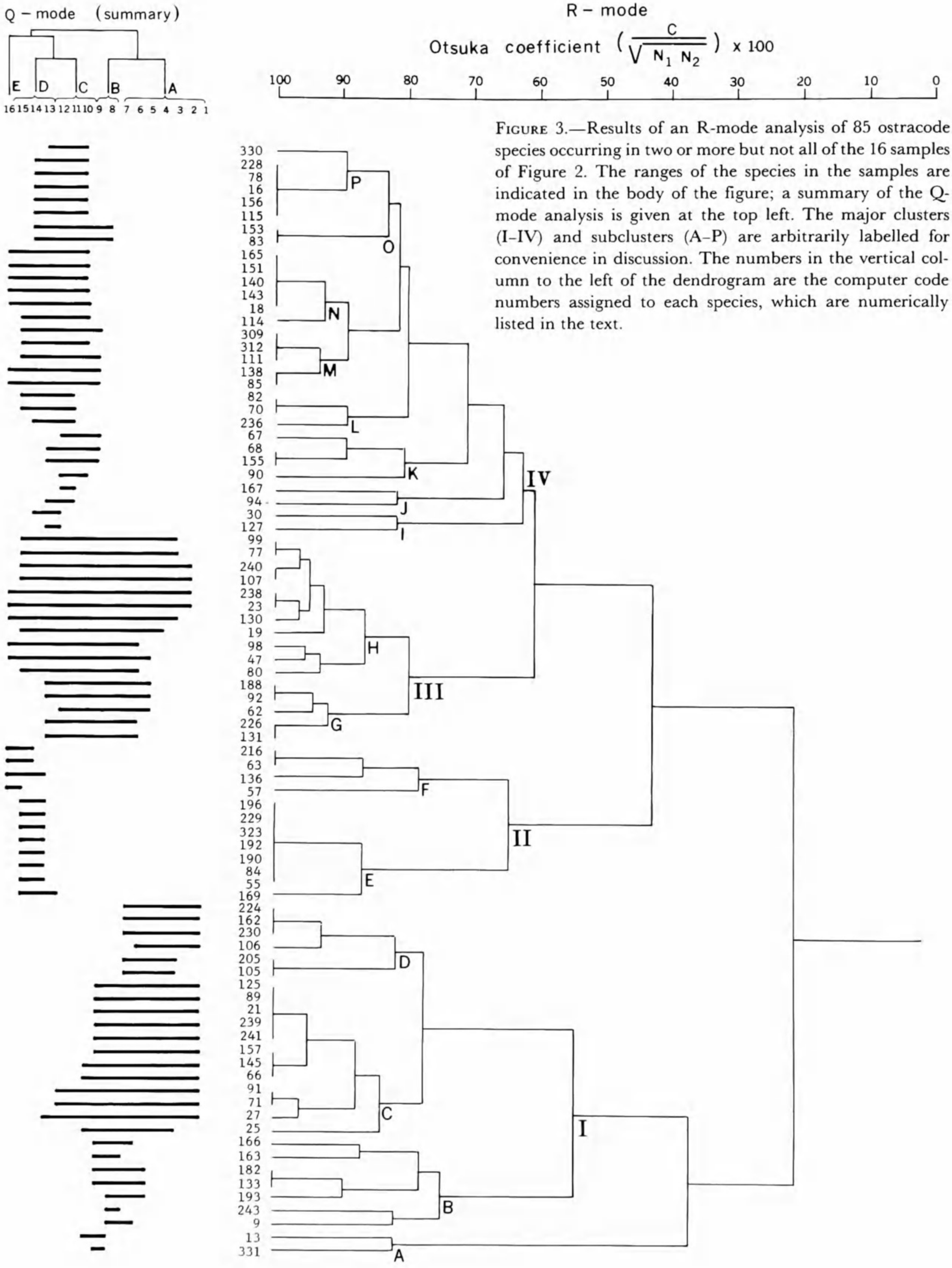

FIGURE 3.—Results of an R-mode analysis of 85 ostracode species occurring in two or more but not all of the 16 samples of Figure 2. The ranges of the species in the samples are indicated in the body of the figure; a summary of the Q-mode analysis is given at the top left. The major clusters (I–IV) and subclusters (A–P) are arbitrarily labelled for convenience in discussion. The numbers in the vertical column to the left of the dendrogram are the computer code numbers assigned to each species, which are numerically listed in the text.

through most of the section in the mine, and subcluster G, those that occur in the upper part of the Yorktown and the Croatan.

Subclusters I through P of cluster IV contain species that are present in the samples of Q-mode clusters C and D, with some occurrences in Q-mode subcluster B. R-mode cluster II comprises species that are largely restricted to the upper part of the Croatan and are, therefore, responsible for Q-mode subcluster D.

Relative Stratigraphic Positions of Lee Creek Beds

Correlations with Localities to the North

Samples from the Yorktown and Croatan formations in the Lee Creek Mine have high similarity values with those from localities farther north in North Carolina and Virginia (Figure 4) and can be assigned to the three assemblage zones proposed by Hazel (1971a).

Samples 1–4 from units 1 and 2 (Figure 2) can be confidently placed in the *Pterygocythereis inexpectata* assemblage zone (Figure 4). The faunal change from the *Pterygocythereis inexpectata* assemblage zone to the younger *Orionina vaughani* assemblage zone is one of gradation, apparently mostly climatically controlled (Hazel, 1971b:372), and samples 5, 6, and 7 are intermediate in composition. For example, they have a combined average similarity of 84.1 with samples 2, 3, and 4, and 81.1 with samples 8 and 9. Samples 5, 6, and 7 cluster with samples 2, 3, and 4 when the Lee Creek samples are analyzed separately, but they cluster with those of the *Orionina vaughani* assemblage zone when Yorktown samples from other areas are added (Hazel, 1971a:2–7).

Samples 8 and 9 from unit 4 represent the *Orionina vaughani* assemblage zone. Sample 9 represents beds not sampled in the previous study (Hazel, 1971a:7). However, the presence of the species *Murrayina barclayi* (McLean, 1957), *Echinocythereis planibasalis* (Ulrich and Bassler, 1904), and *Actinocythereis dawsoni* (Brady, 1870), suggests that unit 4 is no younger than the middle *Orionina vaughani* assemblage zone. The equivalent of the uppermost part of the classic Yorktown of the type area is seemingly missing at Lee Creek.

If sample 10, which is from a 3- or 4-foot (0.9- or 1.2-m) interval in the upper middle part of unit 5, is representative of the assemblage of the entire unit, then this unit is early *Puriana mesacostalis* assemblage zone in age, as based on its faunal similarity with the overlying samples and on the biostratigraphic fidelity values of the contained species (Hazel, 1971a:5, 6). Units 6 and 7 are also placed in the *Puriana mesacostalis* assemblage zone; the distinct cluster (D) formed by samples 13–15 suggests that the assemblage zone is divisible, but this very probably only reflects ecological differences between the upper and lower part of the bed. Units 5–7, as far as is known, are younger than deposits in the type area of the Yorktown, except for the one locality at Yadkin, Virginia, assigned to the Yorktown by Hazel (1971a, fig. 3), which has a *P. mesacostalis* assemblage zone. Also, the beds assigned to the Croatan here are correlated with those cropping out along the Chowan River in North Carolina in the vicinity of Colerain and Mt. Gould landings, which have been assigned to the Yorktown Formation by various authors. The beds along the Chowan River and those of the *Puriana mesacostalis* assemblage zone locality at Yadkin must be investigated further to ascertain which formation(s) is represented. (These beds have recently been assigned to the Chowan River Formation, named by Blackwelder (1981b) after this project had been completed.)

Correlations with Localities to the South

Many Yorktown and Croatan species are present in sediments of similar age to the south, although the ostracode assemblages are in general somewhat different in their overall aspect. Some of these species have limited stratigraphic ranges, and some concurrent range zones are useful in recognizing the chronozones of the three assemblage zones of Hazel (1971a) and in correlating the Yorktown with formations in the Carolinas south of the Neuse River and in Georgia and Florida.

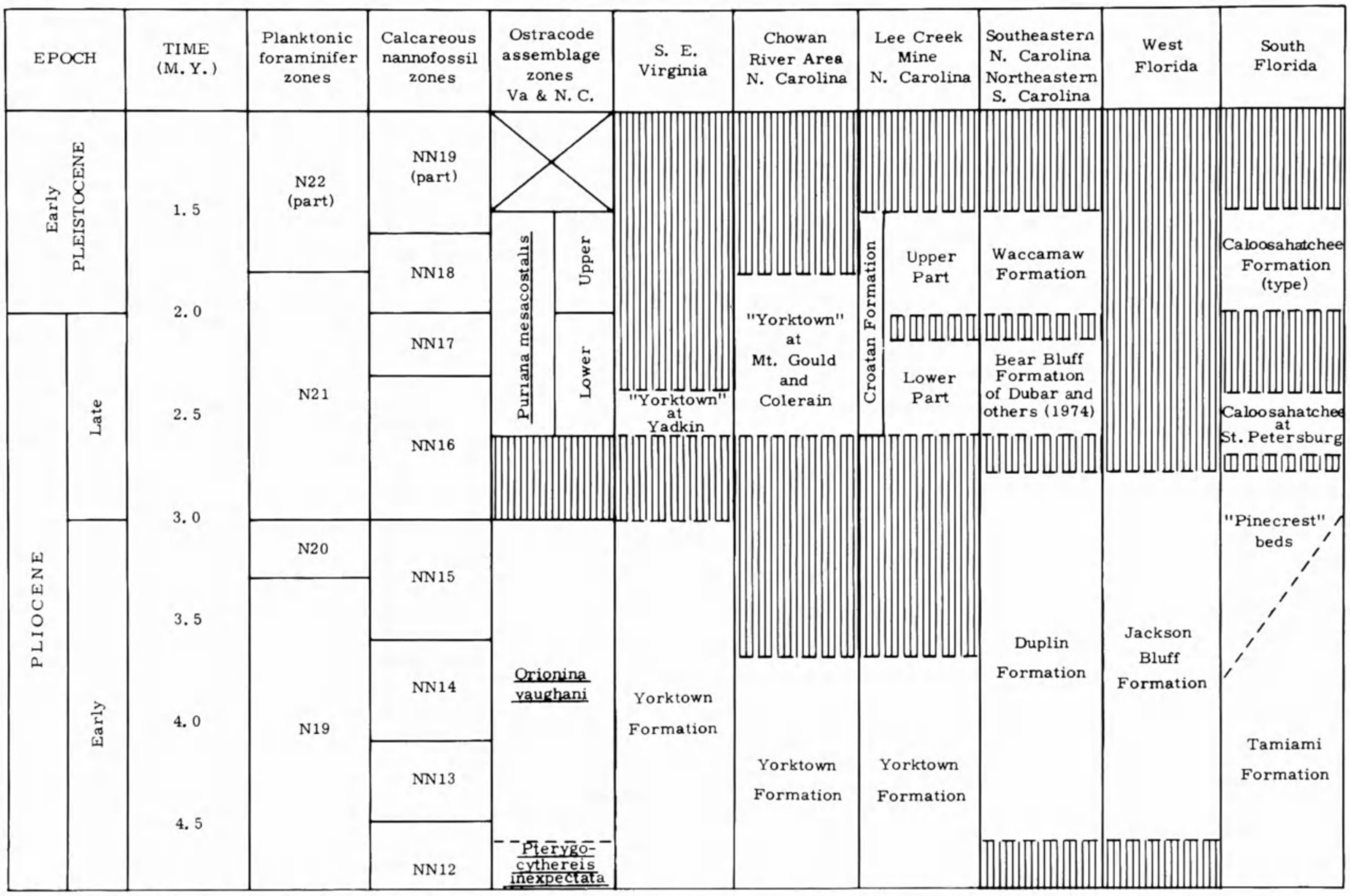

FIGURE 4.—Suggested correlation of the Yorktown and Croatan formations at the Lee Creek Mine with other Coastal Plain lithostratigraphic units and with planktonic foraminifer and nannofossil zonations (time-scale and planktonic organism zones from Berggren and van Couvering, 1974). The planktonic zonations are shown for comparative purposes. Zone-diagnostic planktonic microfossils are generally rare in the formations indicated in the figure.

Care must be taken, however, in using certain kinds of species for the purpose of correlation in the Atlantic Coastal Plain. During Yorktown and Croatan time, the marine climate changed from possible mild-temperate to subtropical conditions in the region of Yorktown and Croatan outcrop (Hazel, 1971b:373), perhaps in response to the closing of the Isthmus of Panama, which would affect the Gulf Stream system (Berggren and Hollister, 1974:158, 175; Emiliani, Gartner, and Lidz, 1972; Casey, McMillen, and Bauer, 1975). A climatic shift in the same direction is to be expected in the southern part of the Atlantic Coastal Plain.

Cryophilic species, then, should be expected to have longer stratigraphic ranges in the north than in the south; the reverse would be true for thermophilic species. Cognizance of the paleoclimatologic framework can be very important in biostratigraphic interpretation.

A large collection of samples from Coastal Plain units to the south has been made, but the studies are incomplete. A multivariate analysis of the data is planned that, it is hoped, will lead to the establishment of regionally useful assemblage zones, such as were proposed for the Virginia-northern North Carolina region (Hazel, 1971a). In addition, work is in progress on a paper delineating the most useful ostracode range and concurrent range zones of the Pliocene and Pleistocene of the middle Atlantic Coastal Plain. This study and those of previous workers (Edwards, 1944; Pooser, 1965; Swain, 1968; Puri, 1953b; Puri and Vanstrum, 1971) suggest certain correlations, which are summarized below.

Beds referable to the *Pterygocythereis inexpectata* ostracode assemblage zone, which in the molluscan zonation of Mansfield (1929, 1943) would approximate the *Placopecten clintonius* zone (zone 1), are either uncommon or difficult to recognize in the southern Atlantic Coastal Plain. The Raysor Marl of Cooke (1936), known from one locality on the Edisto River, South Carolina, and now generally included in the Duplin Formation has been said to contain a fauna of this age. Washings from the original Raysor Marl collection of Cooke (1936) contain *Pterygocythereis inexpectata* (Blake, 1933), *Pseudocytheretta burnsi* (Ulrich and Bassler, 1904), *Malzella evexa*, new species; *Actinocythereis marylandica* (Howe and Hough, 1935), *Cytheropteron? yorktownensis* (Malkin, 1953), *Cytheridea virginiensis* (Malkin, 1953), *Muellerina ohmerti*, new species, *Muellerina wardi*, new species, and other species. This temperate assemblage is of early Yorktown age (chronozone of the *Pterygocythereis inexpectata* assemblage zone or lower *Orionina vaughani* assemblage zone). The Duplin Formation near Magnolia, North Carolina, contains a large ostracode assemblage suggestive of a middle or late *Orionina vaughani* assemblage zone age. It should be noted here that the statement attributed to the writer in Berggren and Van Couvering (1974:125), that the Duplin correlates with rocks containing planktonic foraminifers of zone N12 (middle Miocene), contains an unfortunate typographical error; it should read "N19" (Pliocene) rather than "N12."

Units 3, 4, and the upper part of 2 of the Yorktown in the Lee Creek Mine are placed in the *Orionina vaughani* assemblage zone. In these beds, *Neocaudites triplistriatus* (Edwards, 1944), *Neocaudites angulatus*, new species, and *N. subimpressus* (Edwards, 1944), first appear, and several typical Yorktown forms (subclusters B and C of Figure 3) are last seen. The former all occur farther south, but few of the latter do.

Malzella conradi (Howe and McGuirt, 1935), which ranges as high as the lower part of the *Puriana mesacostalis* assemblage zone, occurs in the lower Duplin, Jackson Bluff, Red Bay, and Tamiami formations. *Murrayina barclayi* McLean, 1957, which occurs in the *Orionina vaughani* assemblage zone and older units, has been traced as far south as Orlando, Florida, where it occurs in rocks of Jackson Bluff age (also see Pooser, 1965:60). *Bensonocythere rugosa*, new species, occurs in the Yorktown and the lower part of the Croatan; in the Duplin Formation, and the Bear Bluff Formation of DuBar et al. (1974:156) in the Carolinas; and the Tamiami Formation in the subsurface of southern Florida.

The equivalent of the Bear Bluff Formation of North and South Carolina of DuBar et al. (1974) is probably represented at Lee Creek by the lower part of the Croatan Formation (unit 5). Ostracodes have been studied from the Bear Bluff Formation at Calabash, North Carolina, and from the subsurface near Bayboro, South Carolina. The Bear Bluff assemblage is very similar to that of the overlying Waccamaw Formation but contains the typical Yorktown-Duplin forms, *Bensonocythere rugosa*, new species, and *Malzella conradi* (Howe and McGuirt, 1935). The two species are known to extend only into the lower part of the *Puriana mesacostalis* assemblage zone. Both occur in sample 10 from the lower part of the Croatan, with an assemblage that is otherwise very similar to that of the upper part of the Croatan.

According to DuBar et al. (1974:156–157) the Bear Bluff occurs primarily in the subsurface and is unconformable with the overlying Waccamaw and possibly with the underlying Duplin Formation, where the latter is present; they indicated that the Bear Bluff macrofauna is transitional between that of the Duplin and Waccamaw formations.

Units 6 and 7 of the Croatan in the Lee Creek Mine are placed in the *Puriana mesacostalis* assemblage zone and contain an evolutionarily advanced form (larger, more elongated) of *Loxocon-*

cha edentonensis (Swain, 1951), which is also known from the Waccamaw Formation. *Caudites paraasymmetricus*, new species (=*C. sellardsi* of Swain, 1968), occurs in unit 7. This distinctive species has been found previously only in the Waccamaw Formation and in its type locality of the Caloosahatchee Formation. It appears then that at least the upper part of the Croatan at the mine correlates with part or all of the Waccamaw and the type Caloosahatchee (DuBar, 1974:220, DuBar et al., 1974:164).

Correlation of the Yorktown and Croatan Formations with a Time Scale

The correlations suggested in the above discussion were based on benthic species endemic to North America. Because none of these taxa occur in stratotypes of the upper Tertiary stages of western Europe, they provide no data for direct correlation with European deposits (Waller, 1969:92). Estimates of age for the Yorktown and Croatan samples, therefore, must be based on (1) finding in these formations more mobile organisms that have a wider distribution and may occur in Europe, or (2) biostratigraphic correlation with rocks that do contain such organisms, or (3) obtaining radiometric dates for the Lee Creek or demonstrably correlative deposits.

Planktonic foraminifers are not diverse in the Yorktown at the Lee Creek Mine above the basal bed (Gibson, 1967:638; Akers, 1972:34). Gibson (1967:637) indicated that the planktonic assemblage from the lowermost beds was of late Miocene aspect; he later (1971:10) concluded that the beds belonged to Blow's (1969) zone N16. This zone, according to Berggren and Van Couvering (1974, figs. 5, 11), is late Miocene in age and lasted from about 10.5 to 8.5 million years ago (mya). However, only one of the species listed by Gibson (1967:637) would be inconsistent with a younger age, and two of the species would be inconsistent with a pre-Pliocene age.

Akers (1972) identified 17 species of planktonic foraminifers from the Yorktown at Rice's pit in Hampton, Virginia (loc. 11 of Hazel, 1971a:11). He placed the Yorktown at the pit in zone N19, pointing out that the assemblage is essentially the same as that of the Jackson Bluff Formation of western Florida. The ostracode assemblage in the Yorktown at Rice's pit indicates placement in the *Orionina vaughani* assemblage zone (Hazel, 1971a, fig. 3). The Tamiami Formation in the subsurface of the Miami area also carries a zone N19 planktonic foraminifer assemblage (identified by M. Ruth Todd, U.S. Geological Survey), as well as ostracodes indicating correlation with the Jackson Bluff Formation (at least the *Ecphora* zone of the Jackson Bluff) and the Yorktown. Present in the Tamiami Formation are common *Orionina vaughani* assemblage zone constituents such as *Malzella conradi* (Howe and McGuirt, 1935), *Malzella evexa*, new species, *Orionina vaughani* (Ulrich and Bassler, 1904), *Bensonocythere rugosa*, new species, *Actinocythereis dawsoni* (Brady, 1870), *Cytheropteron? yorktownensis* Malkin, 1953, and *Puriana rugipunctata* (Ulrich and Bassler, 1904). According to Berggren (1973), zone N19 lasted from about 4.8 to 3.3 mya. The lowermost Yorktown beds at the Lee Creek Mine, however, are clearly older than those at Rice's pit (Hazel, 1971a, fig. 3).

The Red Bay Formation of Puri and Vernon (1964) in western Florida belongs in planktonic zone N17, according to Akers (1972:13). The ostracode and molluscan assemblages of Puri and Vernon's Red Bay Formation (=*Arca* zone of older literature) also indicate that Red Bay is older than the Jackson Bluff Formation. Based on such mollusks as *Chesapecten middlesexensis* (Mansfield, 1929; Ward and Blackwelder, 1975; Druid Wilson, pers. comm., 1973), rocks below the Tamiami Formation in the subsurface of southern Florida can be correlated with the Red Bay and with the Eastover Formation of Virginia, which is stratigraphically below the Yorktown. The ostracode *Otikocythere redbayensis* (Howe and Brown, 1935) is known only from Puri and Vernon's Red Bay Formation and from subsurface deposits on the Eastern Shore of Maryland judged to belong to the lower Eastover Formation. This evidence suggests that the Yorktown is younger than zone N17 which, according to Berggren (1972a, fig. 7; 1973), was about 8.5 to 5.0 mya. Berggren (1973) also presented evidence that the

Miocene-Pliocene boundary is at about 5.0 mya, and that this, for all practical purposes, is equivalent to the base of zone N18. These findings lead to the conclusion that the lowermost beds of the Yorktown at the Lee Creek Mine are at least as young as zone N18 and are therefore Pliocene in age.

Recently, Andrews (1980) has found the diatom species *Thalassiosira oestrupii* (Ostenfeld) in the upper part of the lower Eastover Formation (upper Claremont Manor Member). According to Andrews (1980:20, 22) this indicates that at least the upper part of the Claremont Manor Member and the overlying Cobham Bay Member of the Eastover Formation are also early Pliocene in age.

On the basis of calcareous nannofossils, Akers and Koeppel (1973) concluded that the Yorktown at the Lee Creek Mine was the chronostratigraphic equivalent of planktonic foraminifer zone N20 rather than N19. However, more recent work indicates that N20 is equivalent to upper N19 (for example, Poore, 1979).

Glauconite, from a sample containing an assemblage typical of the *Orionina vaughani* assemblage zone (collected 18 feet (5.5 m) above the beach and 1.3 miles (2.1 km) below the mouth of Grove Creek on the left bank of the James River, James City County, Virginia), gives a K/Ar age of 4.4±0.2 my. This indicates an early Pliocene age for the sample and apparently corroborates the biostratigraphic dating of the Yorktown as early Pliocene (zone N19).

Using the He/U method, Bender (1973) dated corals from the Caloosahatchee Formation of southern Florida. Five of the dates were based on specimens taken from the upper part of the Caloosahatchee (Bee Branch Limestone or Ayers Landing Members of DuBar, 1958) in the type area of the formation, and a sixth was based on a specimen from farther north at St. Petersburg. The five dates from the type area average 1.84 my and have an observed range of 1.78 to 1.89 mya. The upper part of the Croatan in the mine biostratigraphically correlates with the type Caloosahatchee and the Waccamaw Formation. The Caloosahatchee sample from St. Petersburg, which was dated at 2.53 my, contains a molluscan assemblage (Druid Wilson, pers. comm., 1974) indicative of an age younger than the "Pinecrest" beds of Olsson (1964), and several of the distinctive forms found in the Caloosahatchee in its type area are conspicuously absent.

M.L. Bender, University of Rhode Island, in cooperation with the U.S. Geological Survey, has dated corals from the Waccamaw, Croatan, Yorktown, and other upper Cenozoic Coastal Plain units using the He/U technique (see Bender, 1973; Blackwelder, 1981a:17, 24; 1981b:10). The results for some samples are important to the present study. Coral from the lower part of the Croatan (upper part of unit 5 from the north wall of the mine) gives a date of about 2.4 my. Coral from sample 18 of Hazel (1971a:11; fig. 3) from the "Yorktown" near Mt. Gould Landing, North Carolina, gives a date of about 1.91 my.

Hazel (1971a:7) suggested that the "Yorktown" beds near Mt. Gould correlate with what is termed unit 6 in the Croatan Formation in the present study. The fossiliferous beds from the lower part of the exposure at Colerain Landing are younger than the Yorktown Formation of the type area and the Lee Creek Mine, and older than those from near Mt. Gould; therefore, they are most probably correlated with the lower part of the Croatan (unit 5) of the mine.

The radiometric data (Bender, 1973; in litt., 1975) coupled with the biostratigraphy suggest that the Croatan Formation and its correlatives were deposited between about 1.5 and 2.6 mya and that the contact between units 5 and 6 in the mine may approximate 2.0 my. The Yorktown Formation probably was deposited between about 2.6 and 4.8 mya. The youngest part of the Yorktown in the mine is apparently no younger than the middle *Orionina vaughani* assemblage zone. A 3.7- to 4.8-my age range for the Lee Creek Yorktown is not unreasonable.

In connection with the placement of the Pliocene-Pleistocene boundary in the mine, it should be noted that there is considerable controversy as to the radiometric age of the Pliocene-Pleistocene boundary. The Pleistocene should be recognized in a manner similar to all other series of the

Phanerozoic, that is, by correlation of localities with the type area by whatever techniques that give temporally meaningful correlations. There is little logic to the argument that the Pleistocene be recognized by climatic deterioration.

At present, many authors accept the appearance of the planktonic foraminifer *Globorotalia truncatulinoides*, which apparently first appears in the type area of Calabria near the base of the Calabrian Stage, as evidence of the beginning of the Pleistocene. Berggren et al. (1967) presented the results of a study of a deep-sea core from the south-central Atlantic, in which micropaleontologic and paleomagnetic analyses were performed. Berggren indicated that the evolutionary transition from *G. tosaensis* to *G. truncatulinoides* occurred in this borehole and that the first evolutionary appearance of *G. truncatulinoides* was at 500 cm, paleomagnetically dated at 1.85 my. Later refinement by Berggren and others (Berggren and van Couvering, 1974:88) placed this event at 1.8 my, thereby providing the basis for this commonly cited date for the beginning of the Pleistocene.

Parker (1973:280) also studied the foraminifers of the same Atlantic core and opined that at least some of the *G. tosaensis* specimens identified by Berggren were referable to a variant of *G. crassaformis* called "*ronda*." However, *G. tosaensis* and *G. truncatulinoides* occur in the core, and Parker's findings in effect indicate only that the Pliocene-Pleistocene boundary championed by Berggren is some 85 cm below where Berggren (1967) placed it. This suggests a revision of the date for the Pliocene-Pleistocene boundary from 1.8 to 2.0 mya.

Not all workers are willing to accept that *Globorotalia truncatulinoides* is useful in marking the beginning of the Pleistocene or that the Pleistocene began at about 2.0 mya. In open-ocean sediments, however, abundant *G. truncatulinoides* does seem to be a useful criterion, although planktonic foraminifers are generally not abundant in the outcropping sublittoral upper Cenozoic deposits of the Atlantic Coastal Plain.

If the suggested placement of the Pliocene-Pleistocene boundary in Figure 4 is correct, then the unconformity at about 2.8 my in the Atlantic Coastal Plain may correlate with the first cooling event documented in deep-sea cores (Beard, 1969; Berggren, 1972b).

Locality Data

The stratigraphic position and U.S. Geological Survey number of the Lee Creek Mine samples used in this study are indicated in Figure 2. The comparative material from elsewhere in the Yorktown Formation has been given by Hazel (1971a). Comparative material from farther south in the Coastal Plain in North Carolina, South Carolina, Georgia, and Florida consists of more than 300 U.S. Geological Survey collections from the Duplin, Waccamaw, Bear Bluff, Jackson Bluff, Tamiami, and Caloosahatchee formations and Olsson's "Pinecrest" beds (Hazel, 1977; Cronin and Hazel, 1980; Cronin, 1980).

Systematics

Because of the large number of new species involved in the study, the writer has presented the systematic part of the paper as follows: With one exception, *Peratocytheridea setipunctata* (Brady, 1869), only the new species group taxa are treated in formal systematics. For these, a differential diagnosis, but no description as such, is presented. The diagnoses are supplemented by what the writer considers to be generally excellent scanning-electron photomicrographs presented as stereopairs. This approach is taken because the writer believes there is considerable redundant and nondiagnostic information in most ostracode species descriptions. Features that are general characteristics of the genus or family and those that can be clearly observed on photomicrographs need not be described. I believe that the diagnoses presented here, coupled with the illustrations, will be sufficient to indicate my concept of the taxa to other workers.

Most of the species previously described from the Yorktown and Croatan and some that are left in open nomenclature are also illustrated. An alphabetical listing and a numerical computer code list of the taxa used in the computer analyses are presented (pp. 85–90); in the alphabetical list, occurrence data are followed by number of the plate and figure in which each species is illustrated. A checklist of taxa treated formally in this report also follows, reflecting the hierarchic classification used.

Although all the ostracode subfamilies found in the Yorktown and Croatan have been studied and the species delineated by the author, descriptions have not been prepared for some of them; these new taxa are listed in open nomenclature. Major groups in this category are the loxoconchids (except for *Hirschmannia*), and the cytherurids, *Hulingsina*, *Cushmanidea*, *Neocytherideis*, *Leptocythere*.

This study is a contribution from a U.S. Geological Survey program to document the Pliocene and Quaternary ostracodes of the Atlantic continental margin (Hazel, 1967, 1968a, 1970, 1971a, 1971b, 1975a, 1975b; Hazel and Valentine, 1969; Valentine, 1971). The specimens used to illustrate the species were selected from the Yorktown and Croatan formations at the Lee Creek Mine, as well as from various other formations and modern samples. The locality data for the illustrated specimens are given in the figure descriptions. All illustrated specimens are deposited in the USNM collections of the National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Abbreviations used in the tabulations of the dimensions are as follows: N, number of specimens measured; M, mean; sd, standard deviation; OR, observed range; and V, coefficient of variation.

Checklist

Order PODOCOPIDA Müller, 1894
- Suborder PODOCOPA Sars, 1865
  - Superfamily CYTHERACEA Baird, 1850
    - Family CYTHERIDEIDAE Sars, 1925
      - Subfamily CYTHERIDEINAE Sars, 1925
        - Genus *Cytheridea* Bosquet, 1852
          - *Cytheridea campwallacensis*, new species
          - *Cytheridea carolinensis*, new species
        - Genus *Peratocytheridea*, new genus
          - *Peratocytheridea setipunctata* (Brady, 1869)
          - *Peratocytheridea sandbergi*, new species
    - Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948
      - Subfamily TRACHYLEBERIDINAE Bradley, 1948
        - Tribe TRACHYLEBERIDINI Bradley, 1948
          - Genus *Actinocythereis* Puri, 1953
            - *Actinocythereis captionis*, new species
          - Genus *Neocaudites* Puri, 1960
            - *Neocaudites variabilus*, new species
            - *Neocaudites angulatus*, new species
        - Tribe PTERYGOCYTHEREIDINI Puri, 1957
          - Genus *Pterygocythereis* Blake, 1933
            - *Pterygocythereis alophia*, new species
      - Subfamily HEMICYTHERINAE Puri, 1953
        - Tribe AURILINI Puri, 1974
          - Genus *Malzella*, new genus
            - *Malzella evexa*, new species
        - Tribe ECHINOCYTHEREIDINI Hazel, 1967
          - Genus *Echinocythereis* Puri, 1953
            - *Echinocythereis leecreekensis*, new species
        - Tribe ORIONININI Puri, 1974
          - Genus *Caudites* Coryell and Fields, 1937
            - *Caudites paraasymmetricus*, new species
        - Tribe COQUIMBINI Ohmert, 1968
          - Genus *Muellerina* Bassiouni, 1965
            - *Muellerina ohmerti*, new species
            - *Muellerina canadensis petersburgensis*, new subspecies
            - *Muellerina bassiounii*, new species
            - *Muellerina wardi*, new species
            - *Muellerina blowi*, new species
        - Tribe THAEROCYTHERINI Hazel, 1967
          - Genus *Thaerocythere* Hazel, 1967
            - *Thaerocythere carolinensis*, new species
          - Genus *Hermanites* Puri, 1955
            - *Hermanites ascitus*, new species
          - Genus *Puriana* Coryell and Fields, 1953
            - *Puriana carolinensis*, new species
      - Subfamily CAMPYLOCYTHERINAE Puri, 1960
        - Tribe CAMPYLOCYTHERINI Puri, 1960
          - Genus *Proteoconcha* Plusquellec and Sandberg, 1969
            - *Proteoconcha jamesensis*, new species
        - Tribe LEGUMINOCYTHEREIDINI Howe, 1961
          - Genus *Bensonocythere* Hazel, 1967
            - *Bensonocythere bradyi*, new species
            - *Bensonocythere blackwelderi*, new species
            - *Bensonocythere gouldensis*, new species
            - *Bensonocythere ricespitensis*, new species
            - *Bensonocythere rugosa*, new species
    - Family CYTHERIDAE Baird, 1850
      - Subfamily CYTHERINAE Baird, 1850
        - Tribe CYTHERINI Baird, 1850
          - Genus *Cytheromorpha* Hirschmann, 1909
            - *Cytheromorpha incisa*, new species

Cytheromorpha macroincisa, new species
Cytheromorpha suffolkensis, new species
Genus *Microcytherura* Müller, 1894
Microcytherura minuta, new species
Microcytherura expanda, new species
Family LOXOCONCHIDAE Sars, 1865
Genus *Hirschmannia* Elofson, 1941
Hirschmannia? hespera, new species
Hirschmannia? quadrata, new species
Family PARACYTHERIDEIDAE Puri, 1957
Genus *Paracytheridea* Müller, 1894
Paracytheridea cronini, new species

Genus *Cytheridea* Bosquet, 1852

Cytheridea campwallacensis, new species

PLATE 2: FIGURES 1, 3, 4

Anonocytheridea floridana (Howe and Hough).—Malkin, 1953: 784, pl. 79: figs. 29, 30.
Cytheridea sp. B.—Hazel, 1971a:6, table 1, species 73.—Swain, 1974:14, pl. 1: figs. 11, 12 [not pl. 1: fig. 4].
Cytheridea campwallacensis Hazel, 1977:378, figs. 3, 5f, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Many shallow narrow fossae containing normal pore canals, thus possessing relatively smoother valve surfaces than *Cytheridea virginiensis*. On eight well-preserved specimens of *C. campwallacensis*, very short spines at the anterior and a single short spine in each valve at the posterior were observed. In contrast, *C. virginiensis* has 6 or 7 anterior spines on each valve and 2 spines connected by an extension of the valve between the spines (or a tab with spines at either end) at the posterior only in the right valve. The pattern of fossae is distinct from that shown by *Cytheridea virginiensis* (Plates 1, 2). Sexual dimorphism is strong in *C. campwallacensis* and weak in *C. virginiensis*.

HOLOTYPE.—A female right valve (Plate 2: figure 4), USNM 172619, from the lower part of the *Orionina vaughani* assemblage zone of the Yorktown Formation on the James River, Virginia (sample VA-7 of Malkin, 1953, pl. 79: fig. 29).

ETYMOLOGY.—From Camp Wallace, Virginia, on the James River, where the species occurs commonly.

DIMENSIONS (in microns).—The height statistics are biased toward right valves; 14 of the 18 specimens preserved well enough to measure were right valves.

	Female		Male	
	Length	Height	Length	Height
N	11	11	7	7
M	825	480	879	477
sd	47	32	9	–
OR	775–900	450–550	862–888	450–520
V	5.7	6.7	1.1	–

AGE RANGE.—Early Pliocene.

DISTRIBUTION.—Lower and middle part of the Yorktown, *Pterygocythereis inexpectata* and lower *Orionina vaughani* assemblage zones in Virginia and North Carolina. Thirty-five specimens were found.

Cytheridea carolinensis, new species

PLATE 3

Cytheridea sp. G.—Hazel, 1971a:6, table 1, species 76.
Cytheridea carolinensis Hazel, 1977:376, figs. 3, 5e, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Smaller than *C. virginiensis*, and with a more anterior anterodorsal angle, more weakly pitted surface, and fewer normal pore canals. Much smaller than *C. campwallacensis*, and the arrangement of normal pores is distinctly different. At least 5 anterior denticles; none were observed at the posterior. Three to 4 low ridges parallel the anterior margin in contrast to *C. campwallacensis* and *C. virginiensis*, in each of which there are only two.

HOLOTYPE.—A female left valve (Plate 3: figure 1), USNM 191357, from the *Puriana mesacostalis* assemblage zone of the Croatan Formation at the Lee Creek Mine, North Carolina (sample 15).

DIMENSIONS (in microns).—

	Female		Male	
	Length	Height	Length	Height
N	9	9	2	2
M	617	361		–
sd	23	25		–
OR	588–650	325–400	638–650	350–362
V	3.8	7		–

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—Upper part of the Yorktown Formation in Virginia and the Croatan Formation in North Carolina. More than 20 specimens have been found.

REMARKS.—The surface pits are wider and deeper on the older (early Pliocene) specimens assigned to the species.

Genus *Peratocytheridea*, new genus

Peratocytheridea Hazel, 1977, figs. 3, 7h; table 1 [nomen nudum].

TYPE SPECIES—*Cytheridea setipunctata* Brady, 1869.

DIFFERENTIAL DIAGNOSIS.—In adult specimens, ventral margin is concave in the anterior half; carapace widest in the posterior half; the hinge holomerodont (with reversal of hingement in some species); dorsal adductor muscle scar elongated toward the anterodorsal and posteroventral areas.

REMARKS.—Distinct morphologic differences have been recognized between the North American Miocene to Holocene species referred to *Haplocytheridea* and the early Tertiary and late Cretaceous species referred to the genus (Morkhoven, 1963:278–281; Hazel, 1968b:126). The genus *Peratocytheridea* is proposed to accommodate some of these late Cenozoic species.

The species here referred to *Peratocytheridea* are more broadly rounded at the posterior than those referred to *Haplocytheridea*. They are widest in the posterior half, whereas *Haplocytheridea* is compressed posteriorly. The ventral margin of *Peratocytheridea* is concave in the anterior half and that of *Haplocytheridea*, in the posterior half. The dorsal adductor muscle scar in *Peratocytheridea* is elongated toward the anterodorsal and posteroventral areas. In at least the type species of *Haplocytheridea*, the dorsal adductor is not elongated. Under high magnification small denticles can be seen on the outer margin of the selvage, as well as at the outer margin of the valve at the anterior and posterior. This last characteristic may or may not be diagnostic.

The following species are assigned to *Peratocytheridea*:

Cytheridea setipunctata Brady, 1869; Pliocene to Holocene.
C. (Haplocytheridea) bradyi Stephenson, 1938; Pliocene to Holocene.
C. (H.) wadei Stephenson, 1938; Pliocene.
Cytheridea kirkbii Brady, 1866; Holocene.
C. subovata Ulrich and Bassler, 1904; late Oligocene to Miocene.
Haplocytheridea bassleri Stephenson of Puri (1953b, pl. 3, figs. 1–3); Miocene.
H. placentiaensis Teeter, 1975; Holocene.
H. texana Stephenson, 1944; late Oligocene.
Peratocytheridea sandbergi, new species; Pliocene.

The taxonomic positions of the Miocene Caribbean species assigned to *Haplocytheridea* by van den Bold (1965), the late Oligocene Gulf Coast forms studied by Butler (1963) and Poag (1974), and the younger early Miocene species "*H.*" *mansfieldi* (Stephenson, 1938) and "*H.*" *gardnerae* (Stephenson, 1938) are not clear at present (see Sandberg, 1964b).

The species here assigned to *Peratocytheridea* have a combined chronostratigraphic range of upper Oligocene to Holocene. *Haplocytheridea* is known from the Upper Cretaceous to the upper Eocene and possibly Oligocene (Poag, 1972:68; 1974:49).

The well-known species, *Cytheridea setipunctata* Brady, 1869, is chosen as the type species. The soft parts for *Peratocytheridea setipunctata* have been illustrated by Sandberg (1970, figs. 3, 5, 7, 9).

Peratocytheridea setipunctata (Brady, 1869), new combination

PLATE 4: FIGURE 4

Cytheridea setipunctata Brady, 1869:124, pl. 14: figs. 15, 16.
Cytheridea (Haplocytheridea) ponderosa Stephenson, 1938:133, pl. 23: fig. 10; pl. 24: figs. 1, 2.
Cytheridea (Leptocytheridea) sulcata Stephenson, 1938:139, pl. 23: fig. 2.
Cytheridea puncticillata Brady.—Tressler and Smith, 1948:11 [partim], pl. 1: fig. 2 [two juvenile specimens on USNM slide 87319 are probably *Peratocytheridea setipunctata*; as Sandberg (1964b:362) points out, the male specimen in the collection is a *Cyprideis*].

Haplocytheridea bassleri Stephenson.—Swain, 1955:617 [partim], pl. 59: fig. 9a [not pl. 59: fig. 9b, which is a *Cyprideis americana* (Sharp, 1908)].
[?] *Haplocytheridea bassleri* (Stephenson).—Puri and Hulings, 1957, fig. 11.
Haplocytheridea cf. *H. ponderosa* (Stephenson).—Curtis, 1960:482, pl. 2: fig. 9.
Haplocytheridea ponderosa (Stephenson).—Curtis, 1960:486, pl. 3: fig. 1.
Haplocytheridea bassleri (Stephenson).—Curtis, 1960:486, pl. 3: fig. 2.
[?] *Haplocytheridea ponderosa* (Stephenson).—Puri, 1960:110.
[?] *Haplocytheridea* cf. *H. nodosa* (Stephenson).—Puri, 1960: 110.
Cyprideis floridana Puri, 1960:100, pl. 2: fig. 5.
[?] *Anomocytheridea* cf. *A. floridana* (Howe and Hough).—Benda and Puri, 1962, pl. 3: fig. 32.
Haplocytheridea gigantea Benson and Coleman, 1963:27, pl. 3: figs. 10–14, fig. 14.
Haplocytheridea setipunctata.—Sandberg, 1964a:507, pl. 3: fig. 12; 1964b:361, pl. 1: figs. 10–14, pl. 2: figs. 1–4 [not *Haplocytheridea setipunctata* (Brady)].—Williams, 1966:21, figs. 5–11, 16 [=*Peratocytheridea bradyi* (Stephenson), 1938]. —Morales, 1966:34, pl. 2: figs. 3a–c.—Hulings, 1967:643, fig. 3q.—Grossman, 1967:64a, pl. 11: figs. 4, 7, pl. 16:figs. 13–18 [not *Haplocytheridea setipunctata* (Brady)].—Engle and Swain, 1967:413, pl. 2: fig. 15 [=*Cyprideis americana* (Sharpe, 1908)].—Swain, 1968:7, pl. 1: figs. 5a–c; pl. 7: figs. 1a, b [=*Peratocytheridea sandbergi*, new species].—King and Kornicker, 1970:29, pl. 4: figs. 2a, b, pl. 13: figs. 9, 10, pl. 1b: figs. 7, 8.—Sandberg, 1970, figs. 5, 7, 9 [soft parts].—Krutak, 1971:16, pl. 2: figs. 6a, b.—Valentine, 1971, pl. 2: figs. 48, 49 [not *Haplocytheridea setipunctata* (Brady)].—Swain, 1974:12, pl. 9: fig. 16 [in part].

DIMENSIONS.—The illustrated female right valve is 1010 microns long and 610 high.

AGE RANGE.—Pliocene to Holocene.

DISTRIBUTION.—Chesapeake Bay to Laguna Terminos, Mexico, Puerto Rico, and the Bahamas in the Holocene, primarily in estuaries and lagoons. Pleistocene to Holocene, Virginia-North Carolina region; Pliocene to Holocene in Florida. In the present study, the species is known only by one valve from sample 15 in the Croatan Formation.

Peratocytheridea sandbergi, new species

PLATE 4: FIGURES 1, 2, 3

Haplocytheridea bassleri (Stephenson).—Pooser, 1965:43, pl. 3: figs. 4–9.
Haplocytheridea setipunctata (Brady).—Swain, 1968:7, pl. 1: figs. 5a–c; pl. 7: figs. 1a, b; 1974:12, pl. 9: fig. 16 [in part].
"*Haplocytheridea*" sp. B.—Hazel, 1971a:6, table 1, species 72.
Peratocytheridea sandbergi Hazel, 1977, figs. 3, 7h, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from the closely related *Peratocytheridea setipunctata* by its smaller size, subtle differences in arrangement of normal pores, and shape of the opaque areas of the valves as seen in transmitted light; normal pores of *P. sandbergi* are circular in outline whereas a mixture of circular and elongated pores is found in *P. setipunctata*. The smallest specimens of *P setipunctata* known to the writer occur in upper Pleistocene deposits in North Carolina and Virginia. The females in these samples average about 962 microns in length and the males 1038 microns. Both sexes of the living and fossil *P. setipunctata* from Florida are consistently longer than 1000 microns. *Peratocytheridea sandbergi* females from the *Pterygocythereis inexpectata* assemblage zone and the higher *Orionina vaughani* assemblage zone of the Yorktown Formation average 852 microns in length; males are the same length. In the Croatan Formation, *P. sandbergi* females are about the same size, but the males are somewhat smaller (about 781 microns). The anterodorsal angle in *P. sandbergi* is less acute in both females and males than in *P. setipunctata*.

HOLOTYPE.—A female left valve (Plate 4: figure 1), USNM, 172663, from the Yorktown Formation (sample 4).

ENTYMOLOGY:—Named in honor of P.A. Sandberg, University of Illinois.

DIMENSIONS (in microns).—Pooled data; there are some changes in dimension in the males through time; see above.

	Female		Male	
	Length	Height	Length	Height
N	10	10	9	9
M	844	535	811	457
sd	24	24	41	31
OR	812–875	488–562	750–850	412–488
V	2.8	4.5	5.1	6.7

AGE RANGE.—Early Pliocene to Pleistocene.

DISTRIBUTION.—Upper *Pterygocythereis inexpectata* assemblage zone through *Puriana mesacostalis* assemblage zone in Virginia and North Carolina. Waccamaw and Duplin formations in South Carolina.

Genus *Actinocythereis* Puri, 1953

TYPE SPECIES.—*Cythere exanthemata* Ulrich and Bassler, 1904.

Actinocythereis captionis, new species

PLATE 8: FIGURES 1, 2, 4

Cythereis exanthemata var. *gomillionensis* Howe and Ellis.—Edwards, 1944:521, figs. 31, 32.
Actinocythereis exanthemata.—Puri, 1953a:179, pl. 2: figs. 4, 6; 1953b:252, pl. 13: fig. 7.—Hulings, 1966:55, fig. 8h; 1967:655, fig. 7k.—Swain, 1968:14, fig. 12, pl. 2: fig. 5a–f. [Not *Cythere exanthemata* Ulrich and Bassler.]
Actinocythereis exanthemata gomillionensis (Howe and Ellis).—McLean, 1957:83, pl. 10: figs. 2a-d.—Swain, 1974:31, pl. 4: fig. 22.
Actinocythereis gomillionensis (Howe and Ellis).—Williams, 1966:30, figs. 6a–c, 24.
Actinocythereis sp. B.—Hazel, 1971a:6, table 1, species 42.
Actinocythereis aff. *A. gomillionensis* (Howe and Ellis).—Valentine, 1971, pl. 1: figs. 39, 40, 44, 48.
Actinocythereis exanthemata exanthemata (Ulrich and Bassler).—Swain, 1974:30, [partim], pl. 5: fig. 2.
Actinocythereis captionis Hazel, 1977:379, figs. 3, 8c, table 1 [nomen nudum].—Cronin and Hazel, 1980:18, figs. 6g, h [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Actinocythereis exanthemata* (Ulrich and Bassler, 1904) by its smaller size, characteristic arrangement of bullate tubercles of the ventral and median rows, higher and more evenly rounded posterior, and smoother surface between tubercles. Distinguished from *A. gomillionensis* (Howe and Ellis, 1935) by its smaller size, different arrangement of bullate tubercles in the ventral row, less inflated carapace, and ornamental details of the muscle node. The posterior bullate tubercles of the ventral and median rows in *A. captionis* are set close together and at nearly the same angle, whereas in *A. gomillionensis* they are more *en echelon*.

HOLOTYPE.—A female carapace (Plate 8: figure 1), USNM 172461, from the Holocene Carolinian faunal province off Cape Fear, Holocene sample 2251; lat. 33°42.7′ N, long. 78°45.0′ W, 12 m depth.

ETYMOLOGY.—Latin, *captio*, deception.

DIMENSIONS.—The holotype measures 750 × 400 microns.

AGE RANGE.—Early Pliocene to Holocene.

DISTRIBUTION.—Cape Cod to Florida in the Holocene, common constituent of inner sublittoral Pliocene and Pleistocene assemblages of the Atlantic Coastal Plain from Delaware to Florida. *Actinocythereis captionis* is a mild-temperate to subtropical species.

Genus *Neocaudites* Puri, 1960

TYPE SPECIES.—*Neocaudites nevianii* Puri, 1960 (=male of *N. triplistriatus* (Edwards, 1944).

Neocaudites variabilus, new species

PLATE 5: FIGURES 1–3; PLATE 7: FIGURE 1

Trachyleberis? cf. *T.? triplistriata* (Edwards).—Swain, 1951:37, pl. 6: figs. 2, 3.
Orionina lienenklausi (Ulrich and Bassler).—Puri, 1953b:254, fig. 8d, pl. 12: fig. 14.
Costa sp., aff. *C. triplistriata*.—Hall, 1965:33, pl. 7: fig. 8.
Neocaudites sp. A.—Valentine, 1971, pl. 3: figs. 38, 42.
Neocaudites variabilis Hazel.—Cronin and Hazel, 1980:23, fig. 8h [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Larger, more produced at the posterior, and with a less well-developed ventrolateral carina than *Neocaudites triplistriatus* (Edwards, 1944); surface may vary from nearly smooth to coarsely reticulate, whereas *N. triplistriatus* never has a well-developed reticulum. Distinguished from *Neocaudites subimpressus* (Edwards, 1944) by its larger size, more produced posterior, and absence of the concentric rows of large fossae paralleling the anterior.

HOLOTYPE.—Female right valve (Plate 7: figure 1), USNM 190494, from the Duplin Formation near Magnolia, North Carolina, USGS 23639.

ETYMOLOGY.—Latin, *variabilus*, changeable;

with reference to the variation of the reticulum.

DIMENSIONS.—The holotype measures 650 × 338 microns; a female right valve measures 663 × 338 microns; a male paratype measures 725 × 375 microns.

AGE RANGE.—Pliocene to Holocene.

DISTRIBUTION.—Yorktown, Duplin, Norfolk, Waccamaw formations (Pliocene and Pleistocene) in the North Carolina-Virginia region; Jackson Bluff Formation (Pliocene) in Florida. In the Holocene, the species has been found in 6 samples off North and South Carolina.

REMARKS.—The range of variation in this form is great and more than one species group taxon may well be present in what is here referred to *Neocaudites variabilus*. However, specimens are not common in any one sample, and more material will be required to determine whether there are consistently different morphotypes present and what is their stratigraphic and geographic distribution.

Neocaudites angulatus, new species

PLATE 6: FIGURES 2–4

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Neocaudites triplistriatus* (Edwards, 1944) by its larger size, more prominent ventrolateral carina, and by presence of a few large fossae rather than several small ones at the posterodorsal termination of the median carina.

HOLOTYPE.—Female carapace (Plate 6: figure 4), USNM 172742, from the Waccamaw Formation at Old Dock, North Carolina (locality NC-4 of Swain, 1968).

ETYMOLOGY.—Latin, *angulatus*, with angles; with reference to the pronounced ventrolateral carina, which in end view gives the carapace a more angulate form than is seen in other species.

DIMENSIONS.—The holotype measures 675 × 375 microns; the illustrated right valve measures 725 × 362 microns.

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—Yorktown, Croatan, Duplin, and Waccamaw formations in North Carolina; it is not common in any sample.

Genus *Pterygocythereis* Blake, 1933

TYPE SPECIES.—*Cythereis jonesii* Baird, 1850

Pterygocythereis alophia, new species

PLATE 7: FIGURES 2, 4

Pterygocythereis cornuta americana.—Puri, 1953b:261 [partim], pl. 13: figs. 2, 4

Pterygocythereis sp., aff. *P. americana*.—Benson and Coleman, 1963:22, pl. 5: figs. 2, 3 [partim].—Swain, 1968:19, fig. 18, pl. 2: figs. 7a–d.

Pterygocythereis sp., cf. *P. howei*.—Hulings, 1967:641, figs. 2f, 3m.

Pterygocythereis sp. A.—Valentine, 1971:8.

DIFFERENTIAL DIAGNOSIS.—Distinguished easily from *Pterygocythereis inexpectata* by its smaller size and absence of fluted crests. Distinguished from *P. miocenica* by its smaller size, less sloping dorsal outline, and position, size, and shape of the tab on the posterior of the ala; in *P. alophia*, this structure is small and is a blunt spine, whereas in *P. miocenica* it is a broad thin tab.

HOLOTYPE.—Female right valve (Plate 7: figure 4), USNM 172642, from Holocene sample 1861 in Raleigh Bay off North Carolina, lat. 34°45.6′ N, long. 75°44.6′ W, at 41 m depth.

ETYMOLOGY.—Greek, *lophos*, crest, with the negative prefix *a* with reference to the absence of a crest.

DIMENSIONS.—The holotype is 780 microns long and 415 high.

AGE RANGE.—Early Pliocene to Holocene.

DISTRIBUTION.—*Orionina vaughani* and *Puriana mesacostalis* assemblage zones in North Carolina, Bear Bluff Formation of DuBar et al. (1974:156), and Waccamaw Formation in the Carolinas, Jackson Bluff Formation in west Florida, and Tamiami Formation and "Pinecrest" beds of Olsson (1964) in south Florida. From off Virginia to at least off southwestern Florida in the Holocene.

REMARKS.—Van den Bold (1967) separated the uncrested Miocene and younger Coastal Plain and Caribbean species of *Pterygocythereis* from the crested *Pterygocythereis americana–P inexpectata* lineage, referring the former to his *P. miocenica*. All the Pliocene and younger uncrested specimens seem to belong to one species, *P. alophia*, whereas the upper and middle Miocene forms belong to *P. miocenica*.

Genus *Malzella*, new genus

Malzella Hazel, 1977:376, 379; figs. 3, 6c, d; table 1 [nomen nudum].

TYPE SPECIES.—*Malzella evexa*, new species.

DIFFERENTIAL DIAGNOSIS.—Dorsal precaudal ridge much better developed than in *Radimella* and continuous with the posterior subdorsal ridge. Dorsal ridge, which forms dorsal outline in lateral view, divided into anterior and posterior parts by intersection with short ridge homologous with dorsal end of anterosubdorsal ridge of *Radimella*. Carapace more evenly rounded dorsally and ventrally than in *Radimella*. Internal features as in *Radimella* except that posterior tooth is divided into 2 to 5 lobes. Surface more costate and more coarsely pitted than in *Aurila*; denticulate caudal process consistently present in *Malzella*, variably so in *Aurila*. Size within species quite variable, coefficients of variation near 7.0 common in populations.

REMARKS.—The following species are considered to be representatives of *Malzella*:

"*Aurila*" *bellegladensis* Kontrovitz, 1978; Pleistocene.
Hemicythere conradi Howe and McGuirt, 1935; late Miocene to Pliocene.
Malzella evexa, new species; Pliocene to early Pleistocene.
Aurila floridana Benson and Coleman, 1963, Pleistocene to Holocene.
Aurila conradi littorala Grossman, 1965; Holocene.
"*Aurila*", new species aff. *A. conradi* (Howe and McGuirt, 1935) of Howe and van den Bold (1975); early Holocene.

Malzella is a common constituent of Pliocene, Pleistocene, and Holocene deposits of the middle and southern Atlantic Coast and the Gulf Coast. As a fossil, at least, it extended to Venezuela (*Aurila conradi conradi* of Rodríguez, 1969). The oldest species known is *Malzella conradi* (Howe and McGuirt, 1935), which occurs in rocks as old as late Miocene (Red Bay Formation of Puri and Vernon, 1964, in Florida). Although most commonly found in modern and fossil marine shelf deposits, some species tolerate brackish and hypersaline conditions.

ETYMOLOGY.—*Malzella* is named in honor of Dr. Heinz Malz of the Senckenberg Museum, Frankfurt am Main, Germany.

Malzella evexa, new species

PLATE 14: FIGURE 3; PLATE 15: FIGURES 1–3, 5

Hemicythere conradi.—Edwards, 1944:518, pl. 86: figs. 17, 18.—Swain, 1951:42, pl. 6: figs. 9–12.—Puri, 1953:176, pl. 2: figs. 1, 2.—Brown, 1958:65, pl. 6: fig. 17. [Not *Hemicythere conradi* Howe and McGuirt, 1935.]
Aurila conradi conradi (Howe and McGuirt).—Pooser, 1965:48, pl. 17: figs. 1, 2, 12, 13.—Swain, 1968:23, pl. 5: figs. 7a–i.
Radimella floridana (Benson and Coleman).—Hazel, 1971a:6, table 1, species 9.
Malzella evexa Hazel, 1977:376, 379, figs. 3, 6d, table 1 [nomen nudum].—Cronin and Hazel, 1980:15, fig. 4g [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Malzella conradi* by its more evenly rounded dorsum, more posteroventrally expanded ventrolateral carina, and by details of the arrangement of pores and fossae; distinguished from *M. floridana* by its smaller fossae and wider muri and less expanded ventrolateral carina.

HOLOTYPE.—Female left valve (plate 14: figure 3), USNM 172653, from the *Puriana mesacostalis* assemblage zone of the "Yorktown" near Mt. Gould Landing on the Chowan River, North Carolina, USGS 24897 (sample 20 of Hazel, 1971a).

ETYMOLOGY.—Latin, *evexus*, rounded at the top.

DIMENSIONS.—The holotype measures 738 × 475 microns; the illustrated male left valve measures 675 × 400 microns.

AGE RANGE.—Early Pliocene to early Pleistocene.

DISTRIBUTION.—Yorktown and Croatan formations in North Carolina; Bear Bluff of DuBar et al. (1974), Duplin, and Waccamaw formations in North and South Carolina; "Pinecrest" beds of Olsson (1964) and Jackson Bluff, Tamiami, Caloosahatchee, and Bermont (of DuBar, 1974) formations in Florida.

REMARKS.—Most of the fossil specimens of *Malzella* from other than the Yorktown Formation referred to *M. conradi* are actually *M. evexa*; this apparently has resulted from most workers identifying *M. conradi* by use of Edwards' (1944, pl. 86, figs. 17, 18) illustrations of specimens that represent the early, smaller form of *M. evexa*.

Malzella evexa has not been found north of North Carolina. In table 1 of Hazel (1971a: 6), as the result of a clerical error, this taxon is indicated as occurring in sample 31, which is from the only known outcrop of the *Puriana mesacostalis* assemblage zone in Virginia. The species does not occur in sample 31. The calculations in the paper are not affected.

The specimens illustrated by Swain (1951:42; pl. 6, figs. 9–12) of *Hemicythere conradi* Howe and McGuirt are *Malzella evexa*; however, Swain's (1951:43) unillustrated specimens, USNM 560753 and 560760, represent *M. conradi* (Howe and McGuirt, 1935).

Populations of the species that have large females, such as the holotype, occur in *Puriana mesacostalis* assemblage zone deposits.

Genus *Echinocythereis* Puri, 1953

TYPE SPECIES.—*Cythereis garretti* Howe and McGuirt, 1935.

Echinocythereis leecreekensis, new species

PLATE 36: FIGURES 1–3, PLATE 38: FIGURE 3

Buntonia? cf. *B.? garretti*.—Swain, 1951:39 [partim], pl. 3: fig. 6.
Echinocythereis evax.—Brown, 1958:65, pl. 6: fig. 12.
Echinocythereis garretti.—Swain, 1968:15, fig. 13, pl. 4: fig. 12.
Echinocythereis sp. A.—Valentine, 1971:6, table 1.
Echinocythereis leecreekensis Hazel, 1977:378, figs. 3, 10h, table 1 [nomen nudum].—Cronin and Hazel, 1980:25, fig.. 9f [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—A large, very inflated species with an evenly rounded posterior and, on well-preserved specimens, a prominent posteroventral spine on each valve. Distinguished from *Echinocythereis margaritifera* by its larger size, more evenly rounded posterior, better developed posteroventral spine, and more obvious concentric arrangement of spines. Distinguished from *E. planibasalis* by its spinosity, lack of a reticulum, and absence of the ventrolateral alar-like row of spines present in *E. planibasalis*.

HOLOTYPE.—Female right valve (plate 36: figure 1), USNM 191495, Croatan Formation, USGS 25359 (sample 10).

DIMENSIONS.—The holotype measures 1013 microns in length and 650 in height; the illustrated female left valve measures 1000 × 675, and the illustrated male right valve, 1013 × 575 microns.

AGE RANGE.—Late Pliocene to Holocene.

DISTRIBUTION.—Croatan Formation (*Puriana mesacostalis* assemblage zone) in North Carolina; Bear Bluff of DuBar et al. (1974) and Waccamaw formations in North and South Carolina; Pliocene deposits in cores taken offshore of Jacksonville, Florida. In the Holocene, seemingly conspecific specimens have been found off the Atlantic Coast from the southwest side of the Georges Bank to Florida.

Genus *Caudites* Coryell and Fields, 1937

TYPE SPECIES.—*Caudites medialis* Coryell and Fields, 1937.

Caudites paraasymmetricus, new species

PLATE 12: FIGURES 2–4

Caudites sellardsi (Howe and Neill).—Swain, 1968:22, pl. 6: figs. 2a, b.
Caudites sp.—Puri and Vanstrum, 1971, fig. 4.
Caudites asymmetricus Hazel, 1977:378, 380, figs. 3, 7f, table 1 [nomen nudum].
Caudites paraasymmetricus Hazel.—Cronin and Hazel, 1980:6–22, figs. 2, 8i; table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Caudites sellardsi* (Howe and Neill, 1935) by the asymmetry of the valves in which a well-developed vertically oriented carina, forming a right angle with the ventrolateral carinae, is present in the posterior area in the left valves but not in right valves where the ventrolateral carinae curve upward toward the posterodorsal area, and also by the position of the short dorsolateral carina, which is positioned more dorsally in *C. paraasymmetricus* than in *C. sellardsi*. *Caudites paraasymmetricus* can be distinguished from *Caudites rectangularis* (Brady, 1869), which has a similar valve asymmetry, by the virtual absence of any median carina in the former. *Caudites paraasymmetricus* is very similar to *C. asymmetricus* Pokornyi (1970), but the caudal process is more centrally located than in the latter and the ventral carina extends farther toward the anterior.

DIMENSIONS.—The holotype measures 650 × 325 microns; the illustrated female right valve measures 625 × 312 microns; the illustrated male right valve measures 588 × 300 microns.

AGE RANGE.—Early Pleistocene.

REMARKS.—In some 30 specimens of *Caudites paraasymmetricus* available for study, all the right valves possessed one type of ornamentation and the left valves another. A few of the relatively shorter and more elongated specimens are interpreted to be males; they possess the same valve asymmetry as those that must be the females.

DISTRIBUTION.—Upper part of Croatan Formation and the Waccamaw Formation in North Carolina; Caloosahatchee Formation in Florida.

Genus *Muellerina* Bassiouni, 1965

TYPE SPECIES.—*Cythere latimarginata* Speyer, 1863.

Muellerina ohmerti, new species

PLATE 16: FIGURE 3

Trachyleberis? martini (Ulrich and Bassler).—Swain, 1951:29, pl. 3: figs. 8, 15.

[?] *Trachyleberis* cf. *T.? micula* (Ulrich and Bassler).—Swain, 1951:29, fig. 3L.

Trachyleberis martini (Ulrich and Bassler).—Malkin, 1953:793, [partim], pl. 82: fig. 10.

Murrayina martini (Ulrich and Bassler).—Puri, 1953b:256, fig. 8e, f, pl. 12: figs. 11–13.—McLean, 1957:86, pl. 11: figs. 1a–c, 2a, b, 3a–d; 1966:68, pl. 22: fig. 2.

Murrayina micula (Ulrich and Bassler).—Williams, 1966:31, fig. 18-7, 25a, b.

Murrayina canadensis (Brady).—Hulings, 1966:55, figs. 4f–h, 8g; 1967:654, figs. 4n, 7h.

Muellerina lienenklausi (Ulrich and Bassler).—Hazel, 1967:21, pl. 3: figs. 3–6, 11; pl. 7: figs. 1, 4, 5, 7.—Swain, 1968:16 [partim], pl. 3: figs. 2a, b, ?c, e, f, ?g, h; 3a, c [not figs. 2d, 4a, = *Muellerina bassiounii*, new species; not figs. 3d, 4b, = *M. wardi*, new species; not fig. 3b, = a new species incompletely studied at present].—Hazel, 1968b:1266, table 1.

Muellerina aff. *M. lienenklausi* (Ulrich and Bassler).—Hazel, 1970, table 1.—Valentine, 1971, pl. 3: figs. 36, 40, table 1.

Muellerina sp. A.—Hazel, 1971a:6, table 1, species 28.

Muellerina micula (Ulrich and Bassler).—Swain, 1974:38, pl. 7: figs. 1, 3–8; ?pl. 7: fig. 2.

DIFFERENTIAL DIAGNOSIS.—Distinguished by its broad, evenly rounded anterior, acute anterodorsal angle, and relatively well-developed pair of carinae posterior to the muscle node. Slightly depressed area is located posterocentrally and contains several fossae; depression is open towards the anteroventral area, and a row of fossae extend from the depression to about midlength. *Muellerina ohmerti* is smaller, more quadrate, and more broadly rounded at the anterior than is *M. canadensis* (Brady, 1870). *Muellerina wardi*, new species also possesses a depression in the posterocentral area, but it is not open towards the anteroventral area. *Muellerina ohmerti* is also similar to *M. bassiounii*, new species, which also has a posterocentrally located area of fossae, but which is dissected by short carinae. Shape and distribution of surface fossae also are important in distinguishing *M. ohmerti* from other species. In the anterior part, particularly, the fossae of *M. ohmerti* tend to be circular in outline and discrete. In *M. bassiounii* and *M. wardi*, many of the homologous fossae are coalesced, and others are elongated.

Some of the soft parts of *M. ohmerti* have been illustrated (as *M. lienenklausi*) by Hazel (1967; pl. 7, figs. 1, 4, 5, 7).

HOLOTYPE.—Female left valve (Plate 16: figure 3), USNM 112741, from Holocene (sample 1287 of Hazel, 1967, 1970; Valentine, 1971). This specimen was also illustrated by Hazel (1967, pl. 3: fig. 4).

ETYMOLOGY.—Named in honor of Dr. Wolf Ohmert, the author of the Subfamily Coquimbinae.

DIMENSIONS.—The means for length and height for 22 Holocene female specimens are 682 microns and 377 microns, respectively, with observed ranges of 600–725 and 350–400 microns. The means for length and height for 16 Holocene male specimens are 648 microns and 330 microns, respectively, with observed ranges of 625–675 and 312–362 microns. See also Hazel (1967:21).

AGE RANGE.—Late Miocene (?) and Pliocene to Holocene.

REMARKS.—Prior to 1967, when the writer referred this species to *Muellerina lienenklausi* (Ulrich and Bassler, 1904), specimens of the taxon were being consistently assigned to another species in another family (*Murrayina martini* (Ulrich and Bassler, 1904)). However, although *M. lienenklausi* is undoubtedly congeneric, the type specimen is broken, and the Calvert Formation (lower and middle Miocene) has yielded specimens of more than one species of *Muellerina*. At the present time it cannot be determined with complete certainty which of the Calvert or younger forms is *M. lienenklausi*. Therefore, *M. ohmerti* is proposed for the species referred to by the writer as *M. lienenklausi* in 1967, and *Muellerina* sp. A in 1971.

The specimens of *Muellerina* illustrated by Swain (1968, Pl. 3) are all on a single hole microslide in the National Museum of Natural History. Four species are present on the slide. The queried identifications in the synonymy above result from not being able to determine in all cases which specimen represents which of Swain's illustrations.

DISTRIBUTION.—From the Gulf of Maine to Florida in the Holocene; Virginia to Florida in the Pliocene; Pleistocene in Virginia, North Carolina, and western Atlantic submarine canyons. Specimens possibly referable to *M. ohmerti* have been found in the upper Miocene so-called "St. Marys" Formation of Virginia.

Muellerina canadensis petersburgensis, new subspecies

PLATE 16: FIGURE 2, PLATE 18: FIGURES 1, 3

[?] *Trachyleberis martini* (Ulrich and Bassler).—Malkin, 1953: 793 [partim], pl 82: fig. 11.
Muellerina aff. *M. canadensis* (Brady).—Hazel, 1971a:6, table 1, species 61.
Muellerina canadensis petersburgensis Hazel, 1977:376, figs. 3, 10b, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Muellerina blowi* by details of the reticulum, particularly in the posterocentral area. Fossae in the posterocentral area of the valve in *Muellerina canadensis petersburgensis* are arranged in distinct rows; in *Muellerina blowi*, the pits are more randomly arranged. *Muellerina canadensis petersburgensis* is consistently smaller than its descendant subspecies *M. canadensis canadensis*; otherwise, the two taxa are very similar, and no other consistent morphologic differences have been noted.

Fifteen female specimens of *Muellerina canadensis petersburgensis* have a mean length of 657 microns, whereas the mean length of 22 female specimens of *M. canadensis* is 764 microns (Hazel, 1967:22). The student's t computed in comparing the means is 8.77, with 35 degrees of freedom, a value significant at less than 0.001.

HOLOTYPE.—Female left valve (Plate 16: figure 2), USNM 167408, from the lower part of the *Orionina vaughani* assemblage zone in the Yorktown Formation at Petersburg, Virginia (sample 38 of Hazel, 1971a).

ETYMOLOGY.—From the city of Petersburg, Virginia.

DIMENSIONS (in microns).—

	Female		Male	
	Length	Height	Length	Height
N	15	11	2	2
M	657	344		
sd	34	14		
OR	612–700	323–362	625–675	312–325
V	5.1	4.1		–

AGE RANGE.—Late Miocene to Pliocene.

DISTRIBUTION.—Yorktown and Croatan formations in the *Pterygocythereis inexpectata*, *Orionina vaughani*, and lower part of the *Puriana mesacostalis* assemblage zones in Virginia and North Carolina. Upper Miocene so-called "St. Marys" Formation in Virginia.

Muellerina bassiounii, new species

PLATE 16: FIGURES 1, 4, PLATE 18: FIGURE 6

Muellerina lienenklausi (Ulrich and Bassler).—Swain, 1968:16 [partim], pl 3: figs. 2d, 4a.
Muellerina sp. D.—Hazel, 1971a:6, table 1, species 7.

Muellerina bassiounii Hazel, 1977:378, figs. 3, 10d, table 1 [nomen nudum].—Cronin and Hazel, 1980:19, fig. 6e [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Posterocentral area dissected by 3 or 4 vertically oriented, sinuous carinae; in *M. wardi*, which is morphologically close to *M. bassiounii*, in the same area on the valves there is a spatulate fossa, narrowest dorsally and either open or closed dorsally by bordering carinae. In the lower anterocentral area in *M. bassiounii*, usually 2 fossae coalesce to form a T-shaped compound fossa or a C-shaped fossa open towards the posterior. *Muellerina bassiounii* is also smaller than *M. wardi.*

HOLOTYPE.—Female left valve (Plate 16: figure 4), USNM 167410, from the type locality of the Croatan Formation on the Neuse River, North Carolina.

ETYMOLOGY.—Named in honor of Mohamed el Amin Ahmed Bassiouni of Cairo, Egypt, the author of the genus *Muellerina.*

DIMENSIONS (in microns).—

	Female		Male	
	Length	Height	Length	Height
N	16	16	5	5
M	642	330	602	295
sd	24	13	6	7
OR	588–675	312–350	600–612	288–300
V	3.8	3.9	0.9	2.32

AGE RANGE.—Late Pliocene to early Pleistocene.

DISTRIBUTION.—*Puriana mesacostalis* assemblage zone in the "Yorktown," Croatan, and Waccamaw formations in North Carolina.

Muellerina wardi, new species

PLATE 17: FIGURES 2, 4; PLATE 18: FIGURES 4, 5

Murrayina martini (Ulrich and Bassler).—Brown, 1958:65, pl. 3: fig. 3.

Muellerina lienenklausi (Ulrich and Bassler).—Swain, 1968:16 [partim], pl 3: figs. 3d, 4b.

Muellerina sp. E.—Hazel, 1971a:6, table 1, species 17.

Muellerina wardi Hazel, 1977:376, figs. 3, 10a, table 1 [nomen nudum].—Cronin and Hazel, 1980:19, fig. 6c [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Muellerina bassiounii* by a rather well-defined spatulate fossa located posterocentrally that is either closed or open dorsally (the narrow end); there is either a short isolated carina in the center of the fossa or the carina may be connected with the carina forming the anterior border of the fossa. In *M. bassiounii*, there is no clearly defined fossa in this area of the valve, but several vertically oriented, sinuous carinae. *Muellerina wardi* is significantly larger than *M. bassiounii.*

HOLOTYPE.—Female left valve (Plate 17: figure 4), USNM 167409, from the *Puriana mesacostalis* assemblage zone in the "Yorktown" Formation near Mt. Gould Landing, North Carolina (sample 20 of Hazel, 1971a).

ETYMOLOGY.—Named for L.W. Ward, U.S. Geological Survey, who supplied material used in this study.

DIMENSIONS (in microns).—

	Female		Male	
	Length	Height	Length	Height
N	16	16	2	2
M	683	338	–	–
sd	19	11	–	–
OR	650–725	325–350	625	288–300
V	2.7	3.3	–	–

AGE RANGE.—Pliocene to early Pleistocene.

OCCURRENCE.—*Orionina vaughani* and *Puriana mesacostalis* assemblage zones in Virginia and North Carolina. The species has been found in the Yorktown, Duplin, Croatan, Bear Bluff of DuBar et al. (1974), and Waccamaw formations in Virginia and the Carolinas, the "Pinecrest" beds of Olsson (1964) in south Florida, and Pliocene from cores offshore from Jacksonville, Florida.

Muellerina blowi, new species

PLATE 17: FIGURES 1, 3; PLATE 18: FIGURE 2

Muellerina sp. F.—Hazel, 1971a:6, table 1, species 21.

Muellerina blowi Hazel, 1977:376, figs. 3, 10c, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Differs from *M. ohmerti*, *M. wardi*, and *M. bassiounii* in that the valves are evenly convex in the posterocentral area with no large fossae or prominent carinae present. *Muellerina canadensis* (Brady, 1870) is similar in this respect, but the fossae of that species are aligned in distinct rows in the posterior, whereas in *M. blowi* there is only indistinct alignment of a few of the fossae. In *M. blowi*, fossae are relatively smaller and the intervening murae wider than in other *Muellerina* species. Sexual dimorphism is weak, and sexing of individual specimens is difficult.

HOLOTYPE.—Female left valve (Plate 17: figure 1), USNM 167411, from the *Orionina vaughani* assemblage zone of the Yorktown Formation at Suffolk, Virginia (sample 29 of Hazel, 1971a).

ETYMOLOGY.—Named for Warren Blow, formerly of the U.S. Geological Survey, who supplied valuable material and technical assistance during this study.

DIMENSIONS.—Assumed females range from 625 to 688 microns in length and 325 to 350 microns in height. The assumed males range from 588 to 650 microns in length and 275 to 312 microns in height.

AGE RANGE.—Pliocene to early Pleistocene.

OCCURRENCE.—*Pterygocythereis inexpectata*, *Orionina vaughani*, and *Puriana mesacostalis* assemblage zones in Virginia and North Carolina, Yorktown, "Yorktown," and Croatan formations.

Genus *Thaerocythere* Hazel, 1967

TYPE SPECIES.—*Cythereis crenulata* Sars, 1865.

Thaerocythere carolinensis, new species

PLATE 19: FIGURES 1, 3, 4

Trachyleberis?, cf. *T.? angulata* (Sars).—Swain, 1951:29, pl 3: figs. 9–12.
Hemicythere schmidtae Malkin.—Brown, 1958:66, pl 3: fig. 1.
Thaerocythere sp.—Swain, 1974:40, pl. 7: fig. 16.
Thaerocythere carolinensis Hazel, 1977:377, 378, figs. 3, 6f, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished by the presence of a low, wide, smooth tubercle located in the posterocentral area just behind and above the broad muscle tubercle; posterior termination of the dorsolateral carina is also marked by a large swelling, and another is present in the posterocentral area. In these characteristics, *T. carolinensis* differs from the related species *T. schmidtae* (Malkin, 1953) in which the surface is regularly pitted and there are no prominent tubercles other than the muscle tubercle.

HOLOTYPE.—Female carapace (Plate 19: figure 4), USNM 172657, from the *Puriana mesacostalis* assemblage zone in the "Yorktown" Formation at Colerain Landing, North Carolina (sample 14 of Hazel, 1971a).

DIMENSIONS (in microns).—The data are pooled; the holotype measures 750 × 450 microns.

	Female		Male	
	Length	Height	Length	Height
N	10	10	4	4
M	735	446	679	409
sd	32	19	19	11
OR	700–800	425–488	675–712	400–425
V	4.3	4.4	2.7	2.9

AGE RANGE.—Late Pliocene to early Pleistocene.

DISTRIBUTION.—*Puriana mesacostalis* assemblage zone in the "Yorktown" Formation in the Chowan River area of North Carolina and the Croatan Formation at the Lee Creek Mine. Swain (1974:41) indicated that *Thaerocythere carolinensis* occurs in the type Yorktown Formation in Virginia (his sample S-5), referable to the *Orionina vaughani* assemblage zone. However, the writer has never seen this species in deposits of this age, and it is not present in the original material from collection S-5, which is in U.S. Geological Survey collections.

Genus *Hermanites* Puri, 1955

TYPE SPECIES.—*Hermania reticulata* Puri, 1953.

Hermanites ascitus, new species

PLATE 11: FIGURES 1–3

Hermanites ascitus Hazel, 1977, figs. 3, 6h, table 1 [nomen nudum].—Cronin and Hazel, 1980:19, fig. 6f [nomen nudum].

Differential Diagnosis.—Smaller than *Hermanites reticulatus* and with a less well-developed reticulum, which is nonfoveolate as compared with *H. recitulatus*; median carina traversing posterior half of valves also serves to distinguish the species; in *H. ascitus*, the ventrolateral carina is above the ventral outline in lateral view, whereas in *H. reticulatus*, this carina forms the ventral outline.

Holotype.—Female left valve (Plate 11: figure 1), USNM 172745, from the Duplin Formation on the left bank of the Lumber River, near Lumberton, North Carolina, 1.5 miles (2.4 km) south of intersection of routes 211 and 74. Sample taken 1 foot (0.3 m) below water level in gray shelly sand.

Dimensions.—The holotype is 600 microns long and 350 microns high; the male left valve measures 550 × 288 microns and the female right valve 575 × 312 microns.

Age Range.—Late Miocene to Pliocene.

Distribution.—Known from samples 8 and 9 of the present study, the Duplin Formation of North Carolina near Lumberton and at the Robeson Farm near Tar Heel, Bear Bluff Formation of DuBar et al. (1974) near Bayboro, North Carolina, and the upper part of the so-called "St. Marys" Formation of Virginia.

Genus *Puriana* Coryell and Fields, 1953

Type Species.—*Favella puella* Coryell and Fields, 1937 (= *Cythereis rugipunctata* var. *gatunensis* Coryell and Fields, 1937).

Puriana carolinensis, new species

Plate 27: figures 1, 3, 4

Favella rugipunctata (Ulrich and Bassler).—Malkin, 1953:79, pl. 82, fig. 24.

Puriana mesicostalis (Edwards) [sic].—Swain, 1968:19, pl. 5, fig. 13.

Puriana sp. D.—Hazel, 1971a:6, species 10 (add samples 5, 6, 7, and 19.

Puriana carolinensis Hazel, 1977:376, figs. 3, 8b, table 1 [nomen nudum].—Cronin and Hazel, 1980:15, fig. 4b [nomen nudum].

Differential Diagnosis.—Small, with a relatively strongly convex dorsum and concave venter. Arrangement of carinae and short tubercles on the surface is characteristic. Behind the muscle node is a carina oriented parallel to the length; the ridge may be whole or divided into two parts. Anterior to the muscle node are two intersecting carinae forming a Y. In some populations, the surface carinae in *P. carolinensis* are quite thick relative to the intercarinal areas. Sexual dimorphism indistinct; what are probably males are slightly smaller and slightly more elongated than females. A similar undescribed species is found in the Holocene off the Atlantic Coast, but that taxon is without the carina posterior to the muscle node, and although there is a homologous structure to the Y-shaped compound ridge, the "Y" form is lost; in addition, *P. carolinensis* does not possess undercut ridges in the posterior half of the valves as does the Holocene species. *Puriana mesacostalis* (Edwards, 1944) possesses a carina posterior to the muscle node also, but *P carolinensis* is much smaller and less quadrate.

Holotype.—A female right valve (Plate 27: figure 1), USNM 172469, from the "Yorktown" Formation near Mt. Gould Landing, North Carolina (sample 20 of Hazel, 1971a).

Etymology.—From North Carolina.

Dimensions (in microns).—

	Female		Male	
	Length	Height	Length	Height
N	12	12	2	2
M	554	291	–	–
sd	18	11	–	–
OR	525–575	275–312	500–525	250–275
V	3.2	3.7	–	

Age Range.—Pliocene to early Pleistocene.

Distribution.—*Pterygocythereis inexpectata*, *Orionina vaughani*, and *Puriana mesacostalis* assemblage zones; Yorktown, Croatan, Duplin, and Waccamaw formations in North Carolina; Bear Bluff of DuBar et al. (1974) and Waccamaw formations in South Carolina; *Cancellaria* and *Ecphora* zones of the Jackson Bluff Formation in western Florida; "Pinecrest" beds of Olsson (1964), and Tamiami Formation in southern Florida.

Subfamily CAMPYLOCYTHERINAE Puri, 1960

In 1967, the writer considered the Campylocytherinae Puri, 1960, synonymous with the Leguminocythereididae Howe, 1961, at the subfamily level and placed this taxon in the Hemicytheridae. This is no longer believed to be correct. The Leguminocythereinae and Campylocytherinae are still believed to be closely related, but now the writer considers them as separate tribes within the subfamily Campylocytherinae.

The genera *Campylocythere* and *Acuticythereis*, both proposed by Edwards (1944), and *Proteoconcha* Plusquellec and Sandberg, 1969, were monographed by Plusquellec and Sandberg in a very useful paper. The reader is referred to Plusquellec and Sandberg (1969) for diagnoses and morphologic details of the Campylocytherini. These taxa, plus the less well understood southern forms of *Climacoidea* Puri, 1956, and *Reticulocythereis* Puri, 1960, constitute the North American Campylocytherini.

The genera *Leguminocythereis* Howe and Law, 1936, *Triginglymus* Blake, 1951, *Anticythereis* van den Bold, 1946, and *Bensonocythere* Hazel, 1967, constitute the Leguminocythereidini. The last genus is the only representative of the subfamily to occur in the middle Miocene to Holocene interval. *Bensonocythere* seems to be endemic to the Atlantic Coast of North America, where it is found in sediments deposited in cold-temperate to subtropical waters.

Chrysocythere Ruggieri, 1962, which was included with this general group by the writer in 1967 (p. 26), is actually a thaerocytherine, and *Basslerites* Howe, 1937, is perhaps a buntonid. *Leniocythere* Howe, 1951, which may be a senior synonym of *Pseudocytheromorpha* Puri, 1957, may belong to the Leguminocythereidini but is in need of more study.

Genus *Proteoconcha* Plusquellec and Sandberg, 1969

TYPE SPECIES.—*Proteoconcha proteus* Plusquellec and Sandberg, 1969 (= *Acuticythereis nelsonensis* Grossman, 1967).

Proteoconcha jamesensis, new species

PLATE 25: FIGURES 1, 2; PLATE 27: FIGURE 2

Proteoconcha sp. E.—Hazel, 1971a:6, species 19.

DIFFERENTIAL DIAGNOSIS.—Higher relative to its length than most other species of *Proteoconcha*, except *P. gigantica* (Edwards, 1944), a larger and otherwise distinctive species. More tumid in the posteroventral area than other species of the genus. Males much less acuminate at the posterior than other species, except *P. gigantica* and *P. redbayensis* (Puri, 1953). Surface can be smooth or pitted, the pitting being mainly in the posterior half of the valves. Arrangement of normal pore canals (all sieve type) is most like that seen in *P. nelsonensis* (Grossman, 1967) but differs in detail.

HOLOTYPE.—Female left valve (Plate 25: figure 1), USNM 167377, in the *Orionina vaughani* assemblage zone of the Yorktown Formation, USGS 24622 (sample 32 of Hazel, 1971a).

ETYMOLOGY.—From the James River of Virginia.

DIMENSIONS.—The holotype is 700 microns long and 425 microns high.

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—*Orionina vaughani* and *Puriana mesacostalis* assemblage zones in Virginia and North Carolina.

Genus *Bensonocythere* Hazel, 1967

(= *Prodictyocythere* Swain, 1974)

TYPE SPECIES.—*Leguminocythereis whitei* Swain, 1951.

REMARKS.—When this genus was proposed in 1967, the writer had no idea of its persistence in Miocene to Holocene Atlantic Coast deposits. In that paper, only the northern Holocene assemblages from the Atlantic shelf were studied, and only three species of *Bensonocythere* were recognized. At that time, Miocene, Pliocene, or Pleistocene Atlantic Coast assemblages had not been studied in any detail, and the same was true of Holocene assemblages south of New Jersey.

At least 17 species are present in the Pliocene to Holocene deposits of the Middle Atlantic Coast. Other species, as yet not fully studied, are found in the middle and upper Miocene deposits. *Bensonocythere*, the coquimbine genus *Muellerina*, and the thaerocytherine *Puriana*, characterize and make distinctive the sublittoral fossil and living cold-temperate to subtropical assemblages of the western North Atlantic.

The word "persistence" was used above purposely, because often in contrast to *Muellerina* and *Puriana*, individual species of *Bensonocythere* seldom dominate an assemblage or even number among the abundant forms of it. However, in sublittoral marine to polyhaline assemblages several *Bensonocythere* species are commonly present.

Identification is not easy, as is also the case with the Campylocytherini. Size and shape are, of course, important; however, many species are similar in this respect. The normal pore-canal positions are one very diagnostic feature of *Bensonocythere* species; however, because most species have a coarse reticulum, the pores are not readily discernible at normal working magnifications in incident or transmitted light. Furthermore, the fossae on fossil and Holocene specimens often are filled with sediment. Fortunately the fossae themselves are covariant with the normal pores; thus, these can be homologized from specimen to specimen to delineate species. The height and width of the muri between the pits are variable, but the positions of these are also consistent among conspecific individuals.

The recently proposed genus *Prodictyocythere* (Swain, 1974), is, in this writer's opinion, a synonym of *Bensonocythere.*

Bensonocythere bradyi, new species

PLATE 34: FIGURES 1, 2; PLATE 38, FIGURES 2, 4

Bensonocythere sp. R.—Hazel, 1971a, table 1, species 1.
Bensonocythere bradyi Hazel, 1977:376, figs. 3, 9g, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Bensonocythere ricespitensis* by its larger size and details of the reticulum; for example, the three coalescing fossae immediately anterior to the subcentral tubercle are not present or are ill defined in *B. ricespitensis*; the circular arrangement of pits just below the anterior to the subcentral tubercle is also different in *B. ricespitensis.* In size and shape, *B. bradyi* is similar to *B. gouldensis*, but the pattern of fossae is distinctly different.

HOLOTYPE.—Male right valve (Plate 34: figure 1), USNM 167380, from the *Puriana mesacostalis* assemblage zone on the Chowan River near Mount Gould Landing, North Carolina (sample 17 of Hazel, 1971a).

ETYMOLOGY.—Named for the 19th- and early 20th-century English ostracode worker, G.S. Brady.

DIMENSIONS.—The holotype is 850 microns long by 375 microns high; the illustrated male left valve measures 850 × 400 microns; the illustrated female right valve (interior view) measures 900 × 425 microns.

DISTRIBUTION.—Common in the *Orionina vaughani* and *Puriana mesacostalis* assemblage zones in Virginia and North Carolina and rare in the *Pterygocythereis inexpectata* assemblage zone.

REMARKS.—In the *Puriana mesacostalis* assemblage zone, specimens assigned to this species possess wider muri relative to the fossae than in populations from the older zones. Compare plates 34 and 38.

Bensonocythere blackwelderi, new species

Plate 35: FIGURES 1, 2, 4; PLATE 37: FIGURE 4

Bensonocythere sp. J.—Hazel, 1971a, table 1, species 75.
Bensonocythere sp. K.—Hazel, 1971a, table 1, species 17.
Bensonocythere sp. G.—Valentine, 1971, pl 1: fig. 23, table 1.

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Bensonocythere ricespitensis* by its more evenly rounded anterior and posterior; more convex (particularly in females) rather than straight dorsum; the arrangement of fossae and muri over the surface also distinguishes *B. blackwelderi* from *B. ricespitensis*, particularly that in the posterior half of the valves and in the anteroventral area. *Bensonocythere blackwelderi* is smaller than *B. bradyi*, and the arrangement of fossae is distinctly different.

HOLOTYPE.—Female left valve (Plate 35: figure

4), USNM 167398, from the *Orionina vaughani* assemblage zone in the Yorktown Formation in Virginia near Tormentor Creek, a tributary to the James River in Isle of Wight County, Virginia (sample 33 of Hazel, 1971a).

ETYMOLOGY.—Named in honor of B.W. Blackwelder, formerly of the U.S. Geological Survey.

DIMENSIONS.—The holotype is 781 microns long and 425 microns high.

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—*Pterygocythereis inexpectata* (rare), *Orionina vaughani*, and *Puriana mesacostalis* assemblage zones in Virginia and North Carolina. The forms with particularly wide muri have been found only in the older two zones in the Yorktown Formation. The specimen illustrated by Valentine (1971) as *Bensonocythere* sp. G from upper Pleistocene deposits near Yadkin, Virginia, is probably a reworked *Orionina vaughani* assemblage zone form.

Bensonocythere gouldensis, new species

Plate 34: FIGURES 3, 4; PLATE 37: FIGURES 2, 3

Leguminocythereis whitei Swain, 1951:43 [partim], pl. 3: fig. 18; pl. 4: fig. 1.—Brown, 1958:63, pl. 6: fig. 10.

Bensonocythere sp. B.—Hazel, 1971a, table 1, species 44.

Bensonocythere gouldensis Hazel, 1977:376, figs. 3, 4a, table 1 [nomen nudum].—Cronin and Hazel, 1980:17, fig. 5a [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from the closely related *Bensonocythere blackwelderi* by its less evenly rounded anterior and by the slightly different pattern of fossae, particularly in the posterior half of the valves. In *B. gouldensis*, the first interior carina paralleling the anterior valve margin is close to but distinctly inside the anterior and anteroventral outline, whereas in *B. blackwelderi*, this carina tends to form the outline; the muri are narrower in *B. gouldensis* than in *B. blackwelderi*.

HOLOTYPE.—Female left valve (Plate 37: figure 2), USNM 167385, from the *Puriana mesacostalis* assemblage zone of the "Yorktown" Formation on the Chowan River, North Carolina, near Mt. Gould Landing (sample 19 of Hazel, 1971a).

ETYMOLOGY.—From Mt. Gould, North Carolina.

DIMENSIONS.—The female holotype measures 758 × 375 microns. Females are relatively shorter but absolutely larger; the largest measured female is 875 microns long.

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—Yorktown and Croatan formations in Virginia and North Carolina; Duplin Formation in North Carolina.

Bensonocythere ricespitensis, new species

Plate 33

Leguminocythereis whitei Swain, 1951:43 [partim], pl. 3: fig. 16.

Bensonocythere sp. N.—Hazel, 1971a, table 1, species 79.

Bensonocythere ricespitensis Hazel, 1977:376, figs. 3, 4c, table 1 [nomen nudum].—Cronin and Hazel, 1980:17, fig. 5b [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Bensonocythere bradyi* by its smaller size and characteristic arrangement of fossae, particularly in the area below and slightly anterior to the muscle node where there is a circular pattern of about 6 fossae; three of these are in a row subparallel to the greatest valve length, the anterior fossae slightly higher than the posterior one; below these are 3 or 4 fossae in a semicircle, open dorsally. *Bensonocythere sapeloensis* (Hall, 1965) has a similar arrangement of fossae in this part of the valve, but *B. ricespitensis* is larger, and the fossae pattern in the posterior of the valves is quite different.

HOLOTYPE.—Female left valve (Plate 33: figure 1), USNM 167394, from the *Orionina vaughani* assemblage zone at Mr. William Rice's marl pit in the Yorktown Formation at Hampton, Virginia, USGS 24907 (sample 36 of Hazel, 1971a).

DIMENSIONS.—The female holotype measures 750 × 400 microns. Males are about the same length but not as high.

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—*Orionina vaughani* and *Puriana mesacostalis* assemblage zones in Virginia and North Carolina in the Yorktown and Croatan formations; Waccamaw Formation in North Carolina.

Bensonocythere rugosa, new species

PLATE 32: FIGURES 3, 4; PLATE 37: FIGURE 1

Bensonocythere sp. I.—Hazel, 1971a, table 1, species 51.
Bensonocythere rugosa Hazel, 1977:376, 378, figs. 3, 4b, table 1 [nomen nudum].—Cronin and Hazel, 1980:17, fig. 5c [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Bensonocythere whitei* (Swain, 1951) by its concave dorsum, convex venter, more oblique anterior and details of the reticulum. Distinguished from a morphologically similar undescribed late Pliocene to Holocene species (*Bensonocythere* sp. M. of Hazel, 1971a), which does not occur at Lee Creek, by its larger size, weaker sexual dimorphism, and details of the reticulum, particularly in the posterior part of the valves where the fossae are difficult to homologize. In both *B. rugosa* and *Bensonocythere* sp. M. of Hazel (1971a), the fossae are developed mainly between major vertically oriented muri and separated by minor muri; in *B. rugosa*, these minor muri are more weakly developed.

HOLOTYPE.—Female left valve (Plate 32: figure 4), USNM 167382, from the *Orionina vaughani* assemblage zone of the Yorktown Formation at Petersburg, Virginia, USGS 24909 (sample 39 of Hazel, 1971a).

ETYMOLOGY.—Latin, *rugosus*, wrinkled.

DIMENSIONS.—The holotype measures 688 × 388 microns; the other illustrated female right valve measures 700 × 350 microns; the illustrated male right valve measures 675 × 325 microns.

AGE RANGE.—Pliocene.

DISTRIBUTION.—Yorktown Formation in Virginia and North Carolina; lower part of Croatan and Duplin formations in North Carolina; Bear Bluff Formation of DuBar et al. (1974) in North and South Carolina; Tamiami Formation in Florida.

Genus *Cytheromorpha* Hirschmann, 1909

TYPE SPECIES.—*Cythere fuscata* Brady, 1869.

Cytheromorpha incisa, new species

PLATE 21: FIGURES 1, 2; PLATE 23: FIGURES 5, 6

Cytheromorpha sp. D.—Hazel, 1971a:6, species 48.
Cytheromorpha incisa Hazel, 1977, figs. 3, 9a, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Cytheromorpha macroincisa* by its smaller size, strongly developed reticulum with large fossae, wider but slightly shorter posteroventral incised area, more elongate posterior hinge tooth, and details of normal pore arrangement; distinguished from *Cytheromorpha warneri* Howe by the presence of the posteroventral incised area, which is absent in *C. warneri warneri* Howe and Spurgeon, 1935, and only weakly developed in *C. warneri newportensis* Williams, 1966.

HOLOTYPE.—Female left valve (Plate 21: figure 1), USNM 172560, from the *Puriana mesacostalis* assemblage zone of the "Yorktown" Formation, near Mt. Gould Landing, North Carolina, USGS 24895 (sample 18 of Hazel, 1971a).

ETYMOLOGY.—Latin, *incisus*, cut into, with reference to the posteroventral incised area of the valves.

DIMENSIONS.—The female holotype measures 550 microns long and 300 microns high; the illustrated male measures 563 × 275 microns.

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—Throughout the Yorktown and Croatan formations in Virginia and North Carolina.

Cytheromorpha macroincisa, new species

PLATE 22: FIGURES 1–5

Cytheromorpha macroincisa Hazel, 1977:377, 378, figs. 3, 9c, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Cytheromorpha incisa* by its pitted rather than reticulate surface, by the more narrow but longer incised area in posterior part of the ventrolateral surface of the valves; and by details of normal pore arrangement. Distinguished from *C. suffolkensis* by its more broadly rounded posterior, different arrangement of punctae and small carinae, and the different shape, placement, and angle of the incised area, which is set farther forward in *C. macroincisa.*

HOLOTYPE.—Female left valve (Plate 22: figure 1), USNM 172562, from the *Puriana mesacostalis* assemblage zone of the "Yorktown" Formation near Mt. Gould Landing, North Carolina, USGS 24895 (sample 18 of Hazel, 1971a).

ETYMOLOGY.—Latin, *macro* and *incisus*, long and cut, with reference to the narrow elongated incised area in the valves.

DIMENSIONS.—The holotype is 613 microns long and 325 microns high; the illustrated female right valve measures 600 × 312 microns.

AGE RANGE.—Pliocene.

DISTRIBUTION.—*Puriana mesacostalis* assemblage zone in North Carolina, with one possible occurrence in the *Orionina vaughani* assemblage zone on the Virginia Eastern Shore; "Yorktown" and Croatan formations on the Chowan River in North Carolina.

***Cytheromorpha suffolkensis*, new species**

PLATE 23: FIGURES 1–4

Cytheromorpha sp. C.—Hazel, 1971a:6, species 56.
Cytheromorpha warneri Howe and Spurgeon.—Swain, 1974 [partim], pl 4: fig. 2.
Cytheromorpha suffolkensis Hazel, 1977:376, figs. 3, 9d, table 1 [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Cytheromorpha macroincisa* by its smaller size, differently shaped and positioned incised area on ventrolateral surface, which is set farther to the posterior in *C. suffolkensis.* Surface punctae similar in size to *C. macroincisa*, but the arrangement of punctae and small carina at anterior and posterior is different. Easily distinguished from *C. incisa* by its punctate rather than reticulate surface.

HOLOTYPE.—Female left valve (Plate 23: figure 1), USNM 172551, from the *Orionina vaughani* assemblage zone of the Yorktown Formation at Suffolk, Virginia, USGS 24814 (sample 29 of Hazel, 1971a).

ETYMOLOGY.—From Suffolk, Virginia.

DIMENSIONS.—The holotype is 525 microns long and 275 microns high; the illustrated male right valve measures 550 × 288 microns.

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—*Orionina vaughani* and *Puriana mesacostalis* assemblage zones in Virginia and North Carolina, Yorktown, "Yorktown" on the Chowan River, and Croatan formations.

Genus *Microcytherura* Müller, 1894

(= *Tetracytherura* Ruggieri, 1952)

TYPE SPECIES.—*Microcytherura nigrescens* Müller, 1894.

***Microcytherura minuta*, new species**

PLATE 31: FIGURES 1–3

Microcytherura sp. O.—Hazel, 1971a, table 1, species 84.
Microcytherura minuta Hazel, 1977:376, figs. 3, 5b, table 1 [nomen nudum].—Cronin and Hazel, 1980:21, fig. 7g [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Smaller than other known species of *Microcytherura*; evenly rounded at the anterior and posterior, whereas *M. expanda* is more obliquely rounded and expanded (or inflated) at the posterior; reticulum developed with very fine pits in the fossae, in contrast to *M. expanda*, *M. similis*, and *M. choctawhatcheensis*, which have larger pits in the fossae.

HOLOTYPE.—Female left valve (Plate 31: figure 3) USNM 172750, from the *Orionina vaughani* assemblage zone in the Yorktown Formation at Williamsburg, Virginia (sample 45 of Hazel, 1971a).

DIMENSIONS.—The holotype is 488 microns long and 375 high; the illustrated female right valve measures 525 × 262 microns; and the illustrated male left valve is 513 × 250 microns.

DISTRIBUTION.—Yorktown Formation, *Pterygocythereis inexpectata* (one record) and *Orionina vaughani* assemblage zones, in Virginia and North Carolina; "Yorktown" on the Chowan River, Croatan, and Duplin formations and *Puriana mesacostalis* assemblage zone in North Carolina.

Microcytherura expanda, new species

PLATE 30: FIGURES 1–3

Microcytherura expanda Hazel, 1977:377, 378, figs. 3, 5c, table 1 [nomen nudum].—Cronin and Hazel, 1980:21, fig. 7f [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Microcytherura similis* by its inflated and broadly rounded posterior and better developed reticulum. The intensity of the development of the reticulum is similar in *M. choctawhatcheensis*, but *M. expanda* in general has fewer pits present in the fossae, the positions of the fossae are different, and the posterior is more broadly rounded and inflated. Larger than *M. minuta* and with a higher posterior and pits in the fossae.

HOLOTYPE.—Female left valve (Plate 30: figure 2), USNM 172752, from the "Yorktown" Formation on the Chowan River, North Carolina, near Mt. Gould Landing, USGS 24897 (sample 20 of Hazel, 1971a).

ETYMOLOGY.—Latin, *expando*, spread out.

DIMENSIONS.—The holotype is 575 microns long and 312 high; the illustrated male left valve measures 550 × 300 microns; the illustrated female right valve is 537 × 300 microns.

AGE RANGE.—Late Pliocene to early Pleistocene.

DISTRIBUTION.—"Yorktown" Formation on the Chowan River, North Carolina; Croatan and Waccamaw formations also in North Carolina.

Genus *Hirschmannia* Elofson, 1941

TYPE SPECIES.—*Cythere viridis* Müller, 1785.

Hirschmannia? hespera, new species

PLATE 20: FIGURES 1, 2; PLATE 21: FIGURES 3, 4

Hirschmannia? sp. B.—Hazel, 1971a:6, species 15.

DIFFERENTIAL DIAGNOSIS.—Easily distinguished from *Hirschmannia viridis* by its more elongated valves. Distinguished from *H.? quadrata* by the fact that it is relatively much higher at the anterior than the posterior; the surface is covered with small punctae, whereas the surface of *H.? quadrata* is covered with relatively large fossae with second-order reticulation separated by low muri.

HOLOTYPE.—Female left valve (Plate 20: figure 1), USNM 172575, from sample 14 of the present study.

ETYMOLOGY.—Latin, *hesperus*, western, with reference to this being a western Atlantic member of the genus.

DIMENSIONS.—The holotype is 475 microns long and 250 microns high; the illustrated female right valve (Plate 20: figure 2) measures 488 × 250 microns.

AGE RANGE.—Pliocene.

DISTRIBUTION.—*Orionina vaughani* and *Puriana mesacostalis* assemblage zones in Virginia and North Carolina, Yorktown, "Yorktown," and Croatan formations.

Hirschmannia? quadrata, new species

PLATE 20: FIGURES 3, 4

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Hirschmannia? hespera* by its less tapered posterior, more inturned ventral margin when viewed internally, and presence of a surface ornamentation of fossae with secondary reticulation separated by lower muri. The last characteristic, coupled with a straighter ventral outline, distinguishes the species from *H. viridis*.

HOLOTYPE.—Female left valve (Plate 20: figure 3), USNM 172571, from *Puriana mesacostalis* assemblage zone of the "Yorktown" Formation near Yadkin, Virginia, USGS 24905 (sample 31 of Hazel, 1971a).

ETYMOLOGY.—Latin, *quadratus*, squared.

DIMENSIONS.—The holotype is 475 microns long and 250 microns high; the illustrated male right valve, USNM 172573, measures 488 × 250.

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—*Orionina vaughani* and *Puriana mesacostalis* assemblage zones of Virginia and North Carolina, including the subsurface of the Virginia Eastern Shore.

Genus *Paracytheridea* Müller, 1894

TYPE SPECIES.—*Paracytheridea depressa* Müller, 1894.

Paracytheridea cronini, new species

PLATE 28: FIGURES 1, 2; PLATE 29: FIGURE 1

Paracytheridea nodosa.—Swain, 1951:51 [partim], pl. 3: fig. 22.
Paracytheridea sp. A.—Hazel, 1971a:6, table 1, species 40.
Paracytheridea mucra.—Swain, 1974:20, pl. 1: fig. 23.
Paracytheridea edwardsi Hazel, 1977:376, figs. 3, 7a, table 1 [nomen nudum].—Cronin and Hazel, 1980:23, fig. 8d [nomen nudum].

DIFFERENTIAL DIAGNOSIS.—Distinguished from *Paracytheridea mucra* Edwards, 1944, by its smaller size, narrower posterior, better developed reticulum, and much less well-developed ala. Distinguished from *P. altila* Edwards, 1944, by its less pointed posterior, narrower muri, presence of a weakly developed sulcus, more broadly rounded anterior, and position of and trend of various carinae. Distinguished from *P. rugosa* by its less well-developed reticulum, more rounded posterior, and position of and more weakly developed carinae.

HOLOTYPE.—Female left valve (Plate 29: figure 1), USNM 172759, from the type locality of the Duplin Formation at Natural Well near Magnolia, North Carolina, USGS 23639. (See Edwards, 1944.)

ETYMOLOGY.—Named in honor of T.M. Cronin, U.S. Geological Survey.

DIMENSIONS.—The holotype is 575 microns long and 300 microns high.

AGE RANGE.—Pliocene to early Pleistocene.

DISTRIBUTION.—Yorktown Formation in Virginia and North Carolina, Duplin and Croatan formations in North Carolina, Bear Bluff Formation of DuBar et al. (1974) in South Carolina.

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Plates 1–38

PLATE 1

Cytheridea aff. *C. virginiensis* (Malkin, 1953)

1. Exterior view female left valve, USNM 172518, Yorktown Formation, sample 6 of this study, USGS 24883, × 81.
2. Interior view female left valve, USNM 313688, Yorktown Formation, James City County, Virginia, sample 42 of Hazel (1971a), USGS 24912, × 82.

Cytheridea virginiensis (Malkin, 1953)

3. Exterior view female left valve, USNM 172519, Yorktown Formation, Greenville County, Virginia, sample 27 of Hazel (1971a), USGS 24830, × 93.
4. Interior view female left valve, USNM 172511, Yorktown Formation, James City County, Virginia, sample VA-7 of Malkin (1953, pl. 79: fig. 30), × 93.

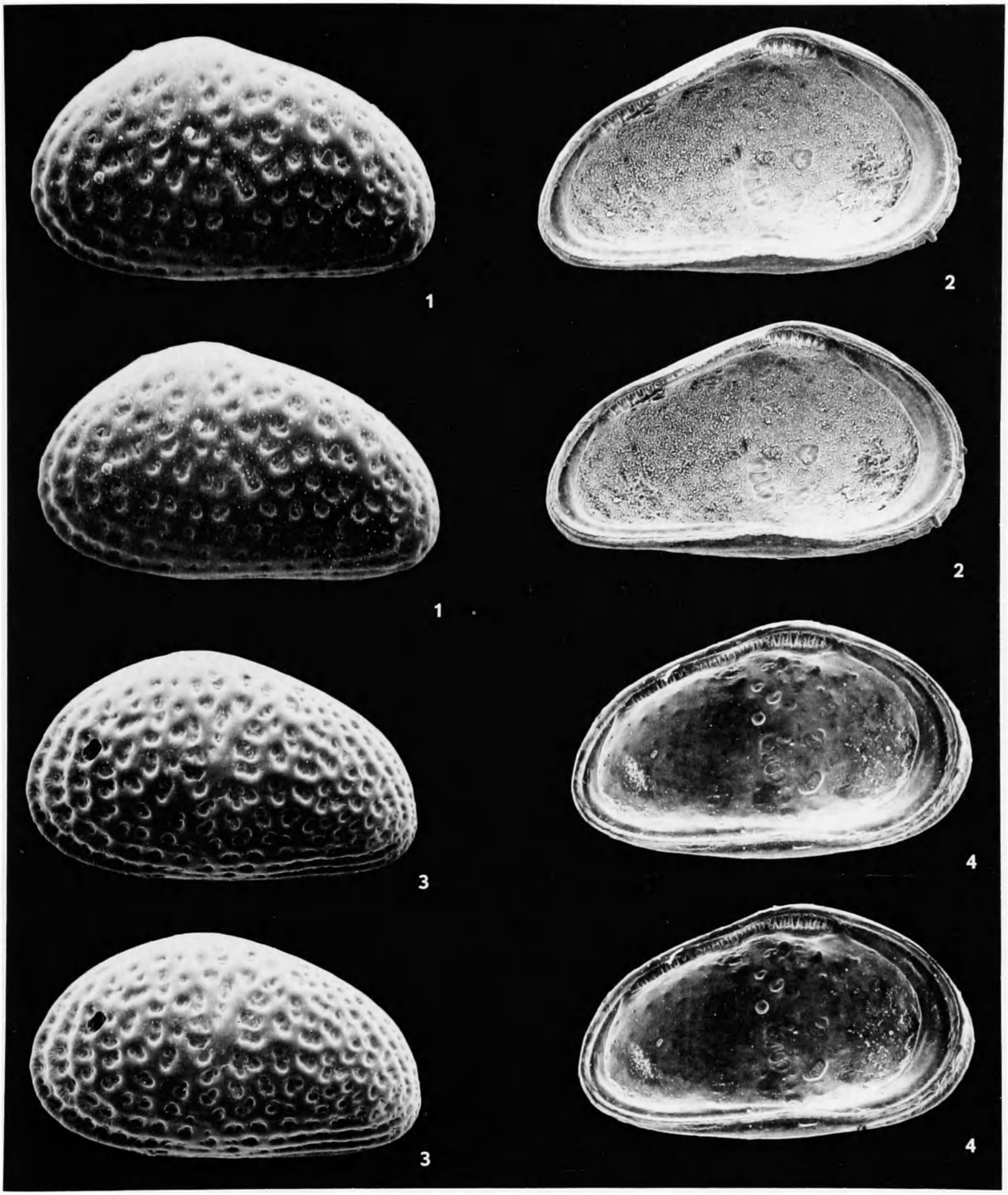

PLATE 2

Cytheridea campwallacensis, new species

1. Exterior view male left valve, USNM 172506, Yorktown Formation, James City County, Virginia, sample 42 of Hazel (1971a), USGS 24912, × 75.
3. Interior view female left valve, USNM 191351, Yorktown Formation, Greenville County, Virginia, sample 27 of Hazel (1971a), USGS 24830, × 90.
4. Exterior view female right valve, holotype, USNM 172619, Yorktown Formation, James City County, Virginia, sample VA-7 of Malkin (1953, pl. 79: fig. 29), × 83.

Cytheridea virginiensis (Malkin, 1953)

2. Interior view female right valve, small form, USNM 191358, Croatan Formation, sample 15 of this study, USGS 25378, × 98.

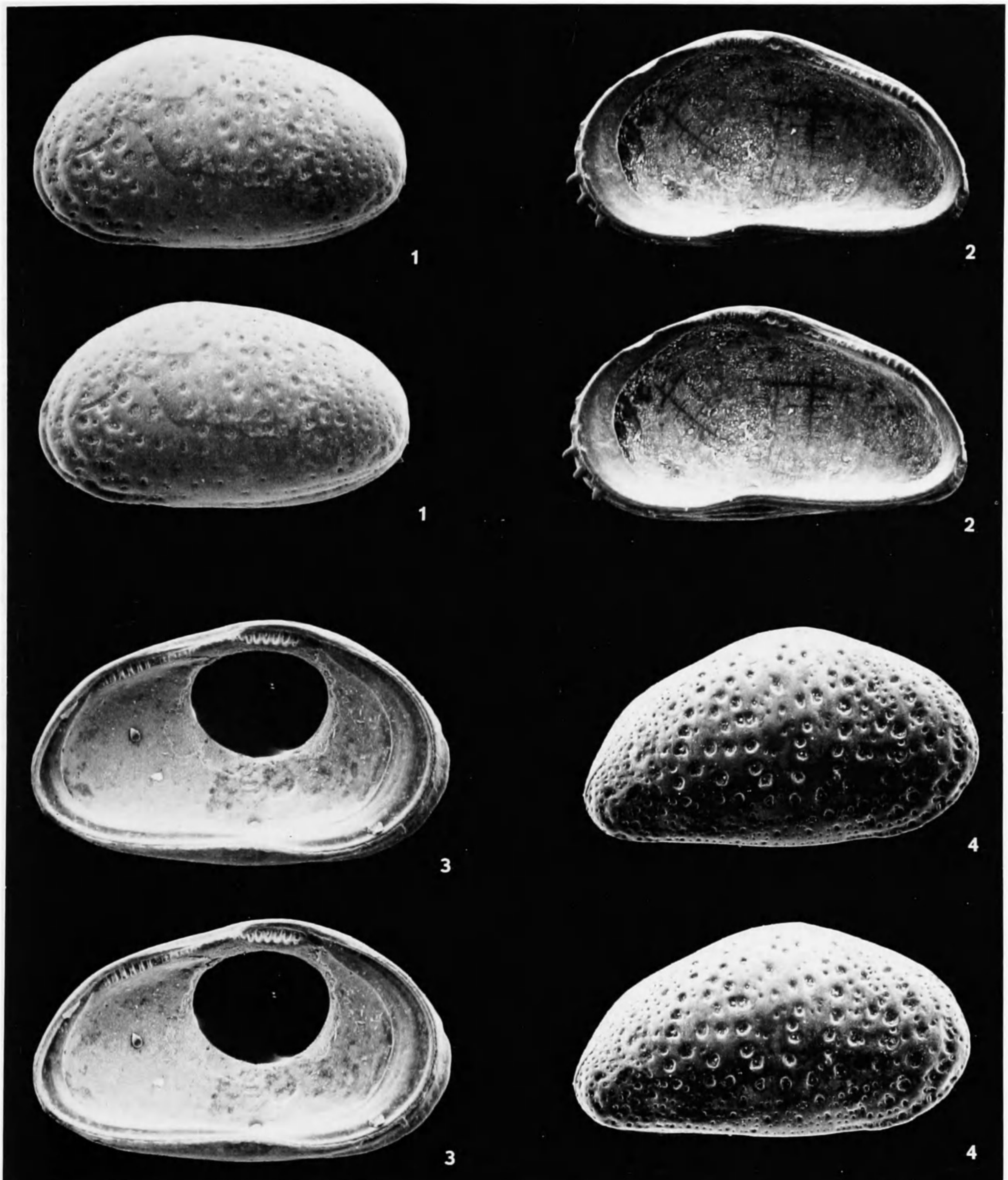
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PLATE 3

Cytheridea carolinensis, new species

1. Exterior view female left valve, USNM 191357, Croatan Formation, sample 15 of this study, USGS 25378, × 106.
2. Interior view female left valve, USNM 191337, Croatan Formation, sample 13 of this study, USGS 25377, × 114.
3. Exterior view female right valve, USNM 191359, "Yorktown" Formation near Colerain, North Carolina, sample 15 of Hazel (1971a), USGS 24892, × 106.
4. Exterior view male left valve, holotype, USNM 172509, Croatan Formation, sample 12 of this study, USGS 24886, × 105.

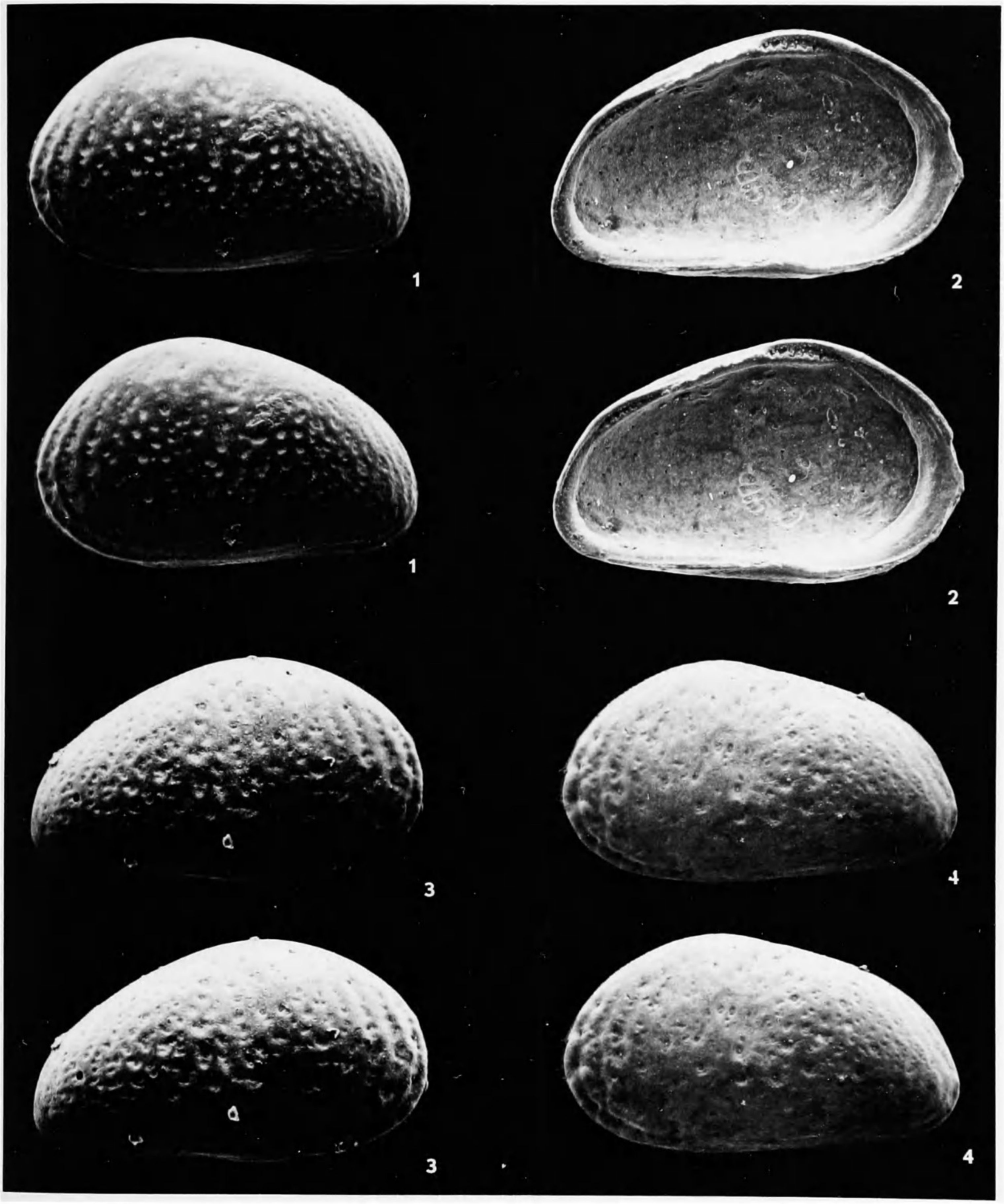

PLATE 4

Peratocytheridea sandbergi, new species

1. Exterior view female left valve, holotype, USNM 172663, Yorktown Formation, sample 4 of this study, USGS 24881, × 87.
2. Interior view male right valve, USNM 172662, Yorktown Formation, sample 4 of this study, USGS 24881, × 87.
3. Exterior view male left valve, USNM 172661, Yorktown Formation, sample 6 of this study, USGS 24883, × 87.

Peratocytheridea setipunctata (Brady, 1869)

4. Exterior view female right valve, USNM 191504, Croatan Formation, sample 15 of this study, USGS 25378, × 74.

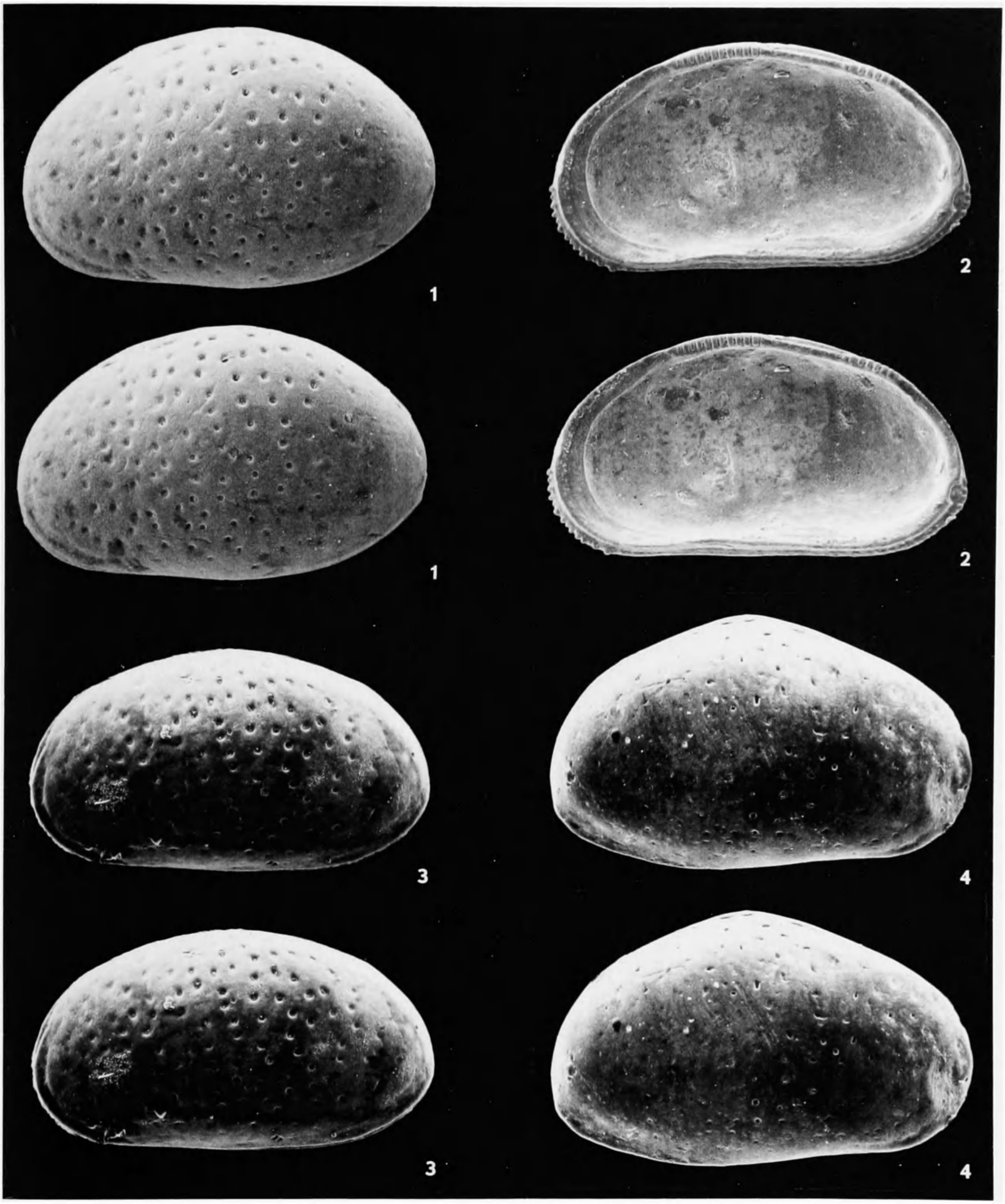

PLATE 5

Neocaudites variabilus, new species

1. Exterior view male left valve, USNM 172745, Norfolk Formation (upper Pleistocene) at Virginia Beach, Virginia, locality P2-1 of Valentine (1971), USGS 23787, × 98.
2. Exterior view female right valve, USNM 191387, Yorktown Formation, Hampton City, Virginia, sample 34 of Hazel (1971a), USGS 24810, × 110.
3. Interior view female right valve, USNM 191386, type locality of the Duplin Formation near Magnolia, North Carolina, USGS 23639, × 120.

Neocaudites subimpressus (Edwards, 1944)

4. Exterior view female left valve, USNM 559432, Duplin Formation, near Lumberton, North Carolina, locality 3 of Edwards (1944, pl. 87: fig. 30), × 109.

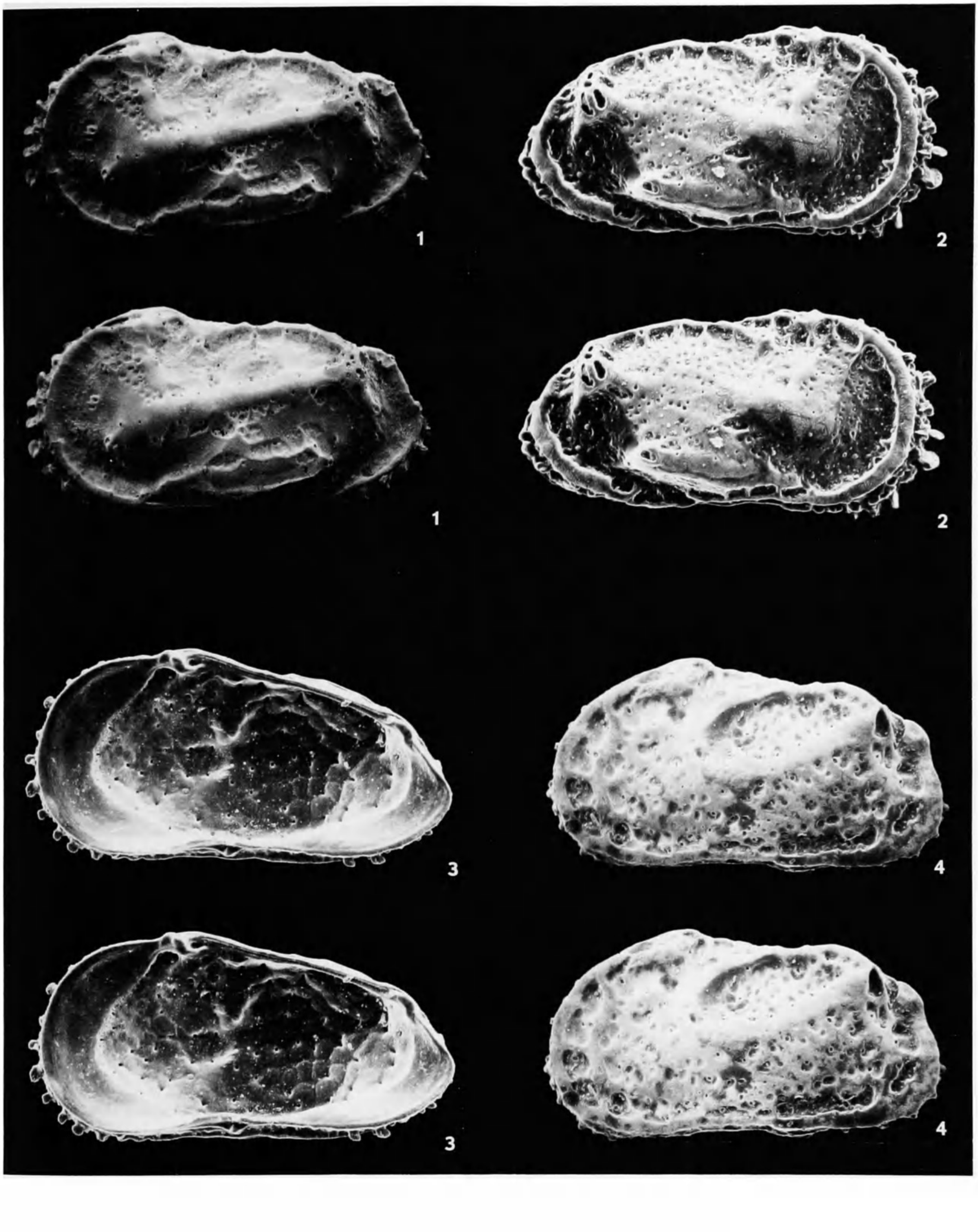
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PLATE 6

Neocaudites triplistriatus (Edwards, 1944)

1. Left exterior view female carapace, USNM 172753, type locality of the Duplin Formation, near Magnolia, North Carolina, locality 1 of Edwards (1944), USGS 23639, × 137.

Neocaudites angulatus, new species

2. Interior view female right valve, USNM 191388, type locality of the Duplin Formation, near Magnolia, North Carolina, locality 1 of Edwards (1944), USGS 23639, × 110.
3. Exterior view male? right valve, USNM 172741, Croatan Formation, near James City, North Carolina, locality 80 of Waller (1969), USGS 25443, × 102.
4. Left exterior view female carapace, holotype, USNM 172742, Waccamaw Formation, near Old Dock, North Carolina, locality NC-4 of Swain (1968), USGS 25445, × 110.

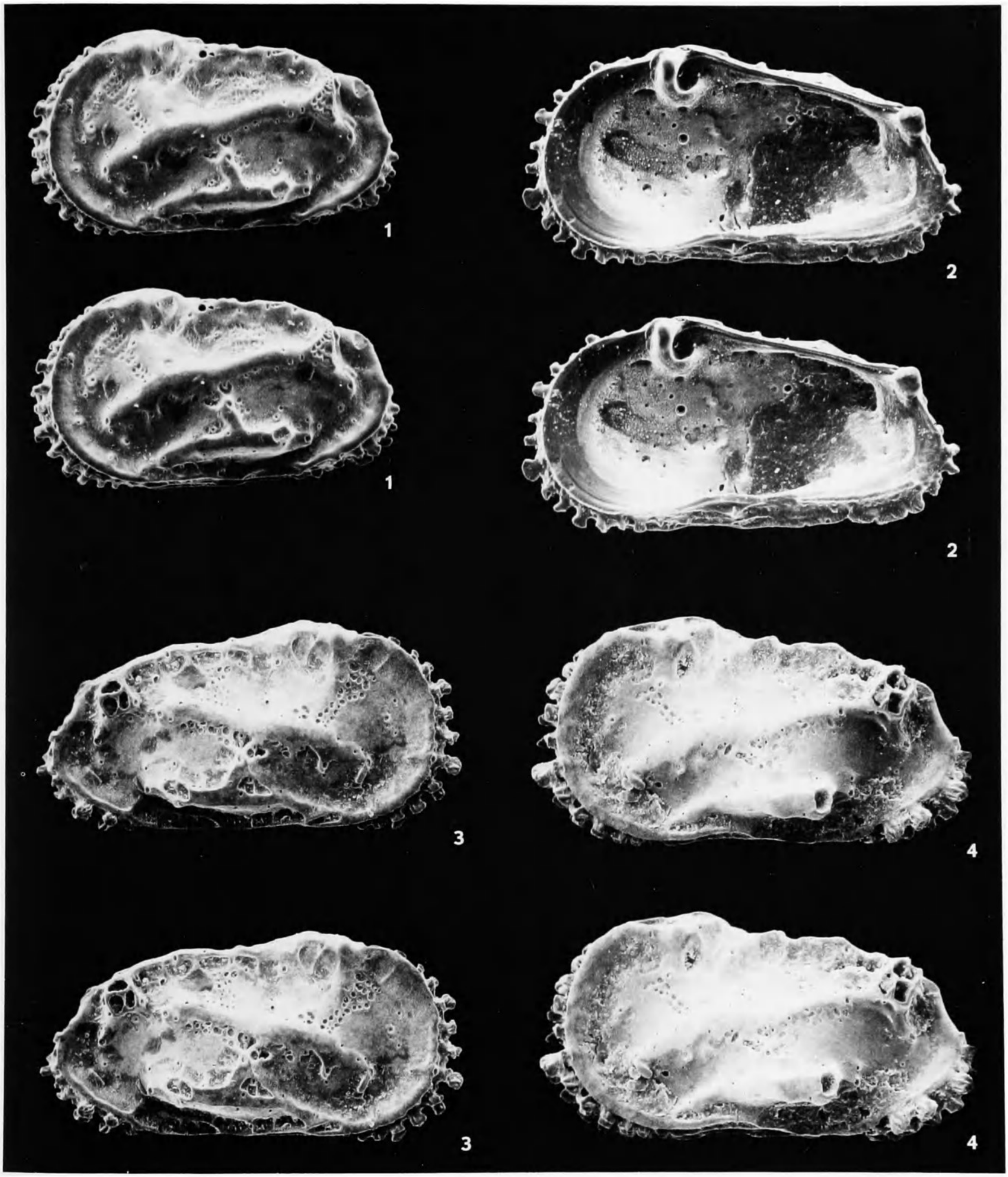
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PLATE 7

Neocaudites variabilus, new species

1. Exterior view female right valve, holotype, USNM 190494, type locality of the Duplin Formation, near Magnolia, North Carolina, locality 1 of Edwards (1944), USGS 23639, × 87.

Pterygocythereis alophia, new species

2. Exterior view male left valve, USNM 191496, "Yorktown" Formation, Colerain Landing, North Carolina, sample 14 of Hazel (1971a), USGS 24891, × 81.
4. Exterior view female right valve, holotype, USNM 172642, Holocene sample 1861 from Raleigh Bay, south of Cape Hatteras, 34°45.6′ N lat., 75°44.6′ W long., 41 meters, × 78.

Pterygocythereis inexpectata (Blake, 1929)

3. Exterior view female left valve, USNM 172748, Yorktown Formation, sample 6 of this study, USGS 24883, × 66.

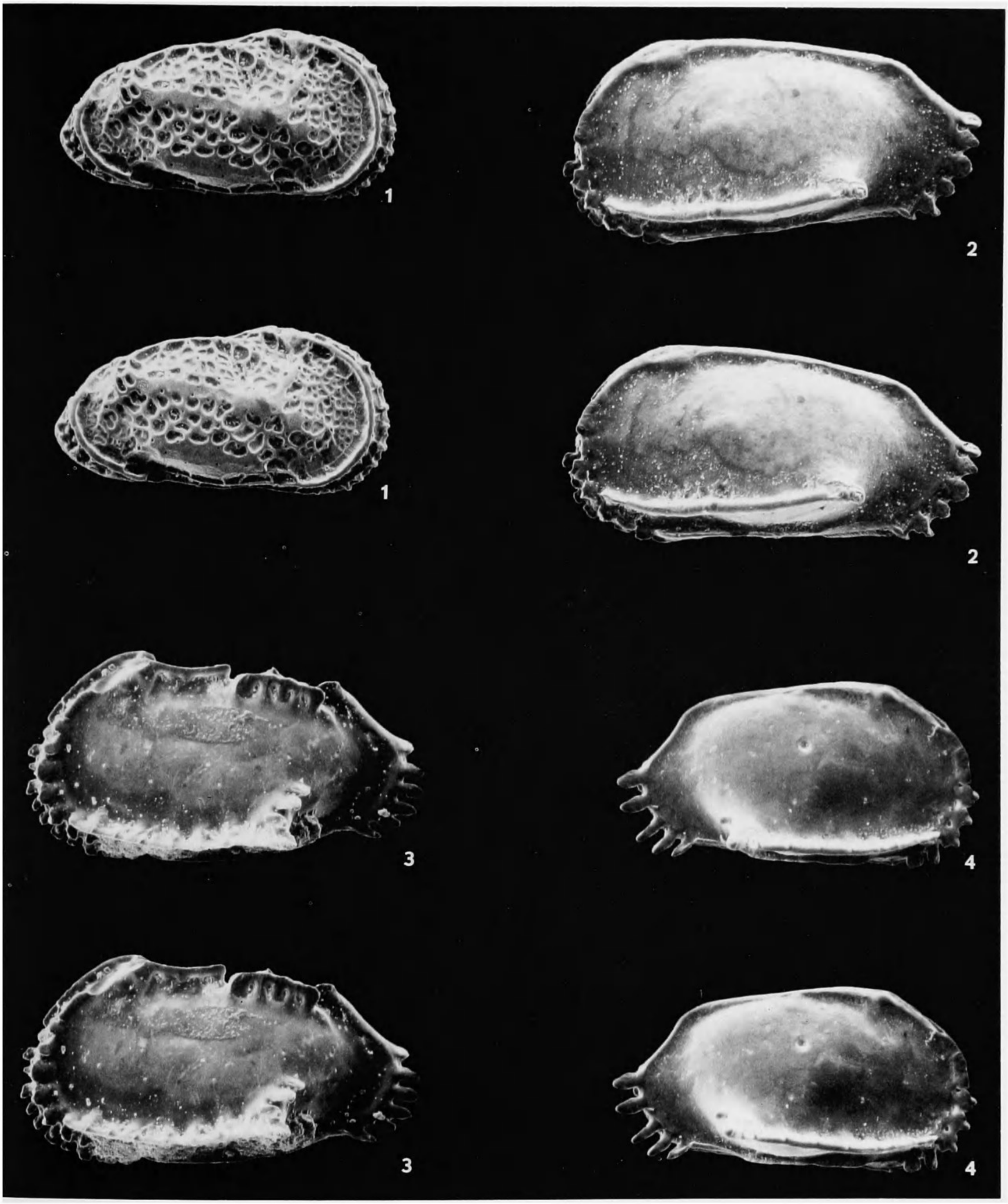
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PLATE 8

Actinocythereis captionis, new species

1. Left exterior view female carapace, holotype, USNM 172461, Holocene sample 2251, southwest of Cape Fear, 33°42.7′ N lat., 78°45.0′ W long., 12 meters, × 85.
2. Left exterior view male carapace, USNM 172463, Holocene sample 2251, southwest of Cape Fear, 33°42.7′ N lat., 78°45.0′ W long., 12 meters, × 90.
4. Interior view male right valve, USNM 191348, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 90.

Actinocythereis marylandica (Howe and Hough, 1935)

3. Exterior view female left valve, USNM 190459, Yorktown Formation, near Palmyra, North Carolina, sample 11 of Hazel (1971a), USGS 24889, × 87.

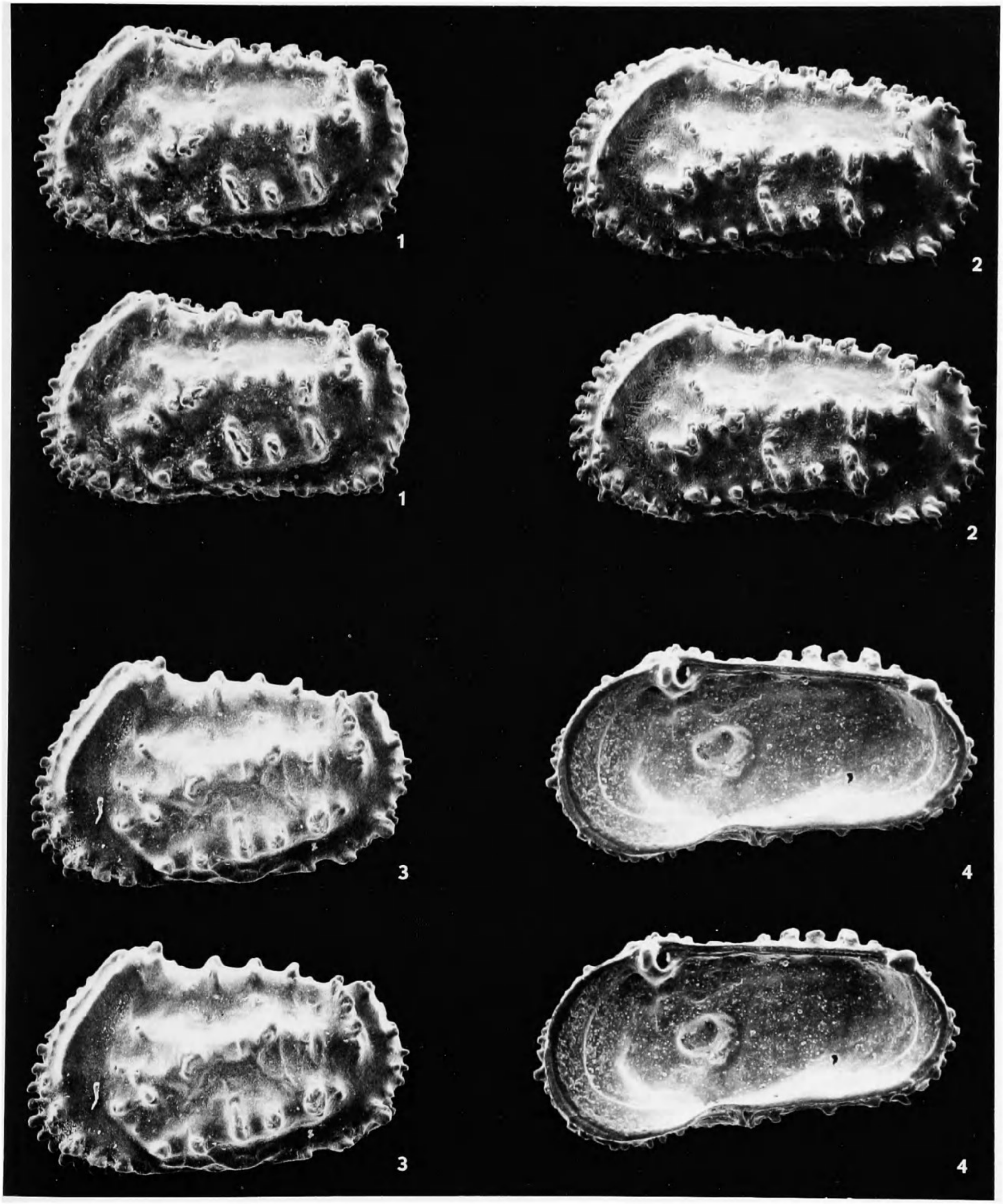
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PLATE 9

Actinocythereis dawsoni (Brady, 1870)

1. Exterior view female left valve, USNM 190458, Yorktown Formation, James City County, Virginia, sample 42 of Hazel (1971a), USGS 24912, × 87.

Actinocythereis mundorffi (Swain, 1951)

2. Exterior view female left valve, small form, USNM 190457, Yorktown Formation, James City County, Virginia, sample 42 of Hazel (1971a), USGS 24912, × 85.

Cytheropteron? yorktownensis (Malkin, 1953)

3. Exterior view female left valve, USNM 190980, Yorktown Formation at Suffolk, Virginia, sample 29 of Hazel (1971a), × 180.

Cytheropteron talquinensis (Puri, 1954)

4. Exterior view female left valve, USNM 190981, Yorktown Formation, Williamsburg, Virginia, sample 44 of Hazel (1971a), USGS 24820, × 137.

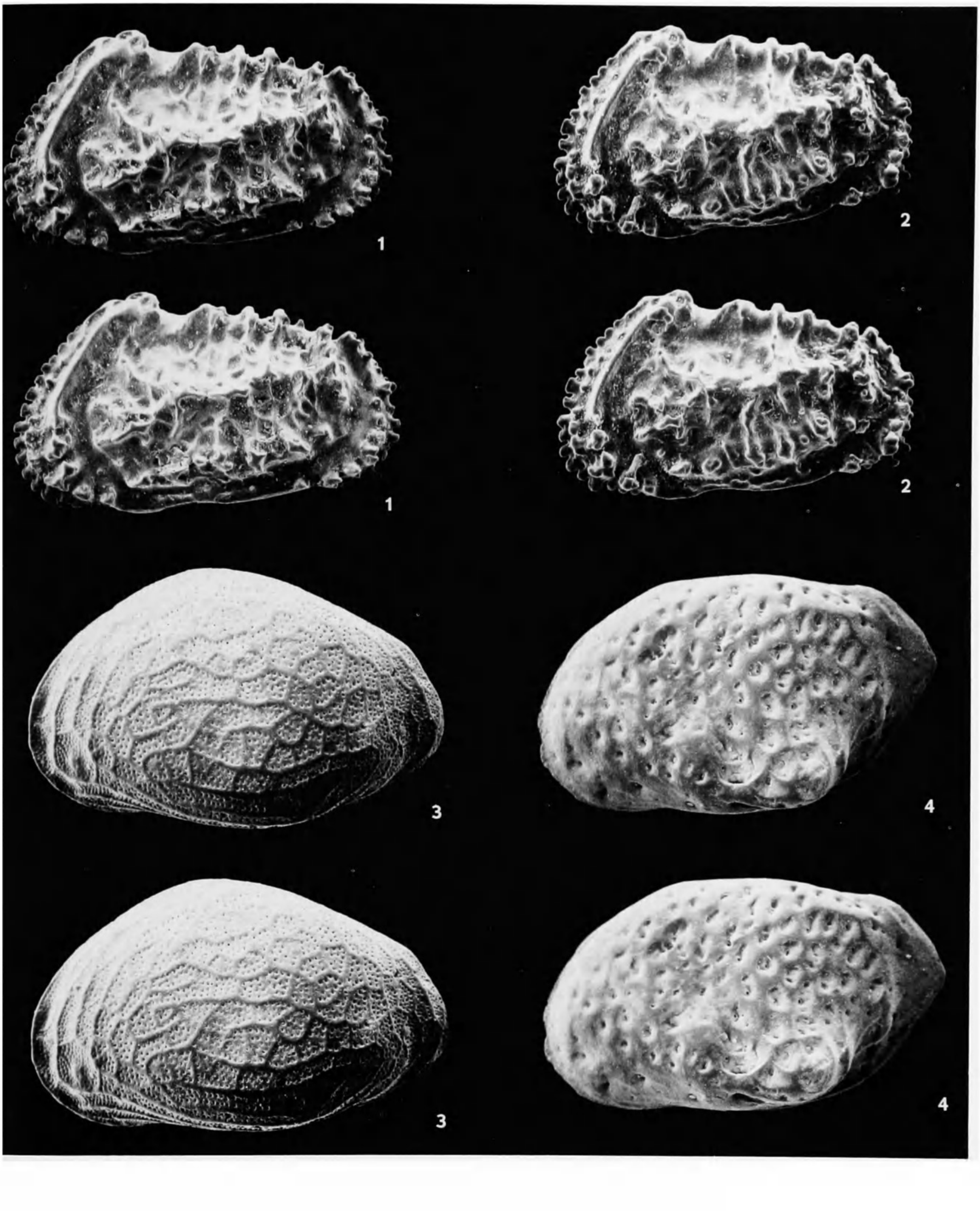
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PLATE 10

Murrayina macleani Swain, 1974

1. Exterior view female right valve, ornate form, USNM 172630, Yorktown Formation, sample 4 of this study, USGS 24881, × 95.
2. Exterior view female right valve, smooth form, USNM 172630, Yorktown Formation, Suffolk, Virginia, sample 28 of Hazel (1971a), USGS 24811, × 95.
3. Exterior view male left valve, ornate form, USNM 191395, Yorktown Formation, Suffolk, Virginia, sample 28 of Hazel (1971a), USGS 24811, × 90.
4. Interior view male right valve, USNM 191394, Yorktown Formation, near Skippers, Virginia, sample 27 of Hazel (1971a), USGS 24830, × 82.

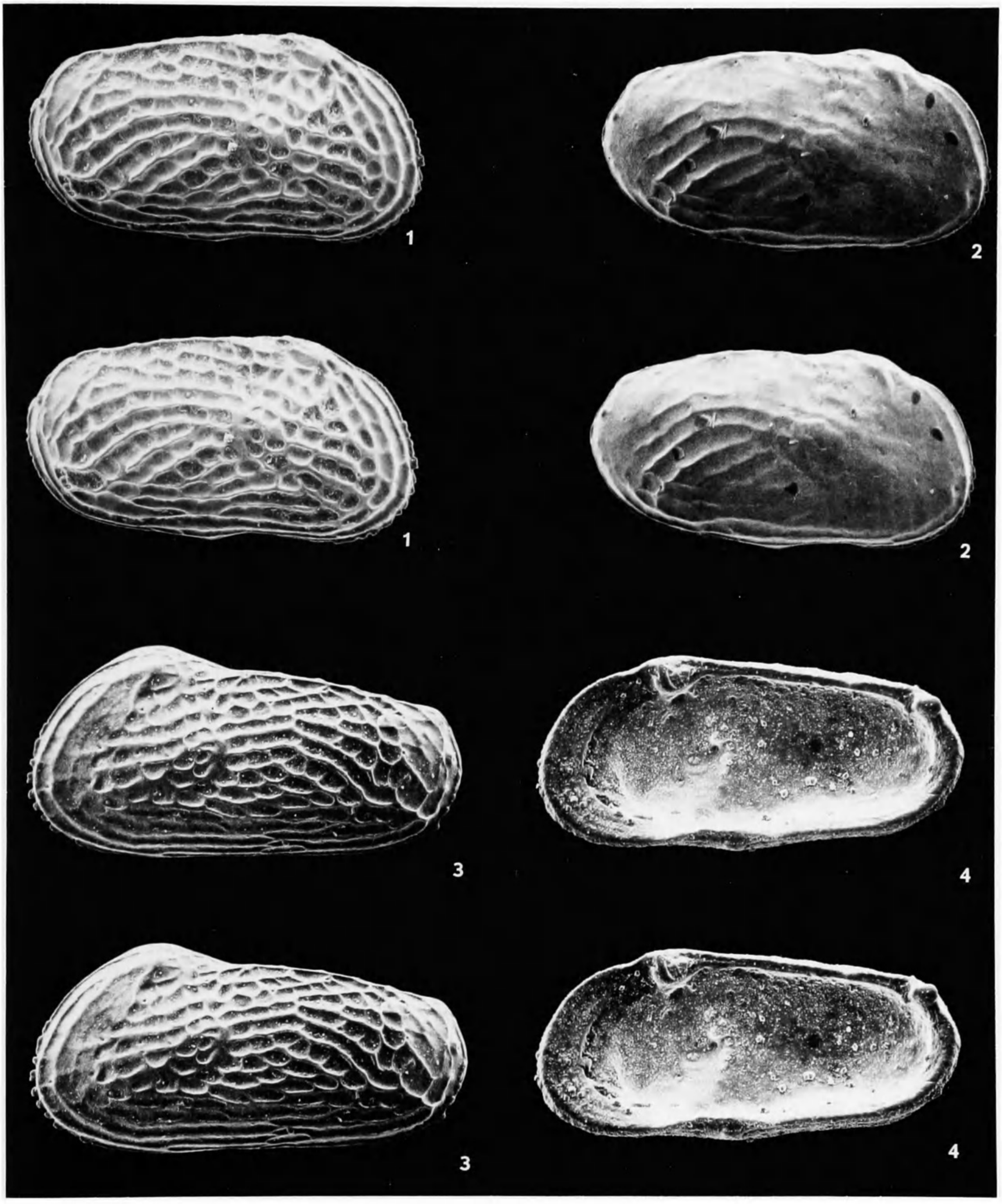
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PLATE 11

Hermanites ascitus, new species

1. Exterior view female left valve, holotype, USNM 172745, Duplin Formation, left bank of Lumber River near Lumberton, North Carolina, USGS 25751, × 122.
2. Interior view female right valve, USNM 191016, Duplin Formation, Robeson Farm near Tar Heel, North Carolina, USGS 25755, × 122.
3. Exterior view male right valve, USNM 191333, Yorktown Formation, sample 9 of this study, USGS 25358, × 127.

Murrayina barclayi McLean, 1957

4. Exterior view female left valve, USNM 172755, Yorktown Formation at Petersburg, Virginia, sample 38 of Hazel (1971a), USGS 24908, × 88.

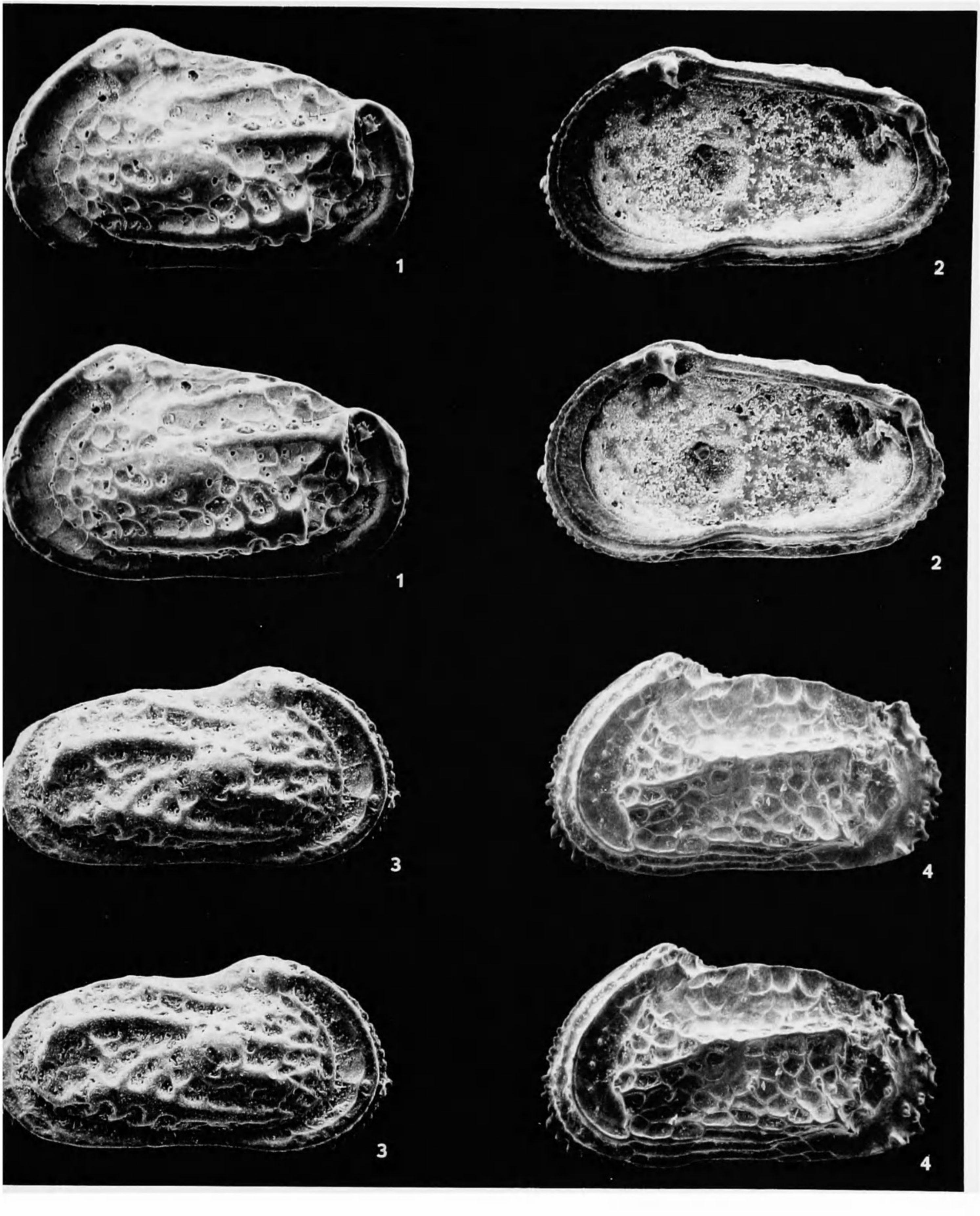

PLATE 12

Orionina vaughani (Ulrich and Bassler, 1904)

1. Exterior view male left valve, USNM 172477, Yorktown Formation at Williamsburg, Virginia, sample 43 of Hazel (1971a), USGS 24821, × 80.

Caudites paraasymmetricus, new species

2. Exterior view female right valve, USNM 172757, Croatan Formation, sample 15 of this study, USGS 25378, × 112.
3. Interior view male right valve, USNM 172740, Croatan Formation, sample 15 of this study, USGS 25378, × 112.
4. Left exterior view female carapace, holotype, USNM, 172756, Croatan Formation, sample 15 of this study, USGS 25378, × 113.

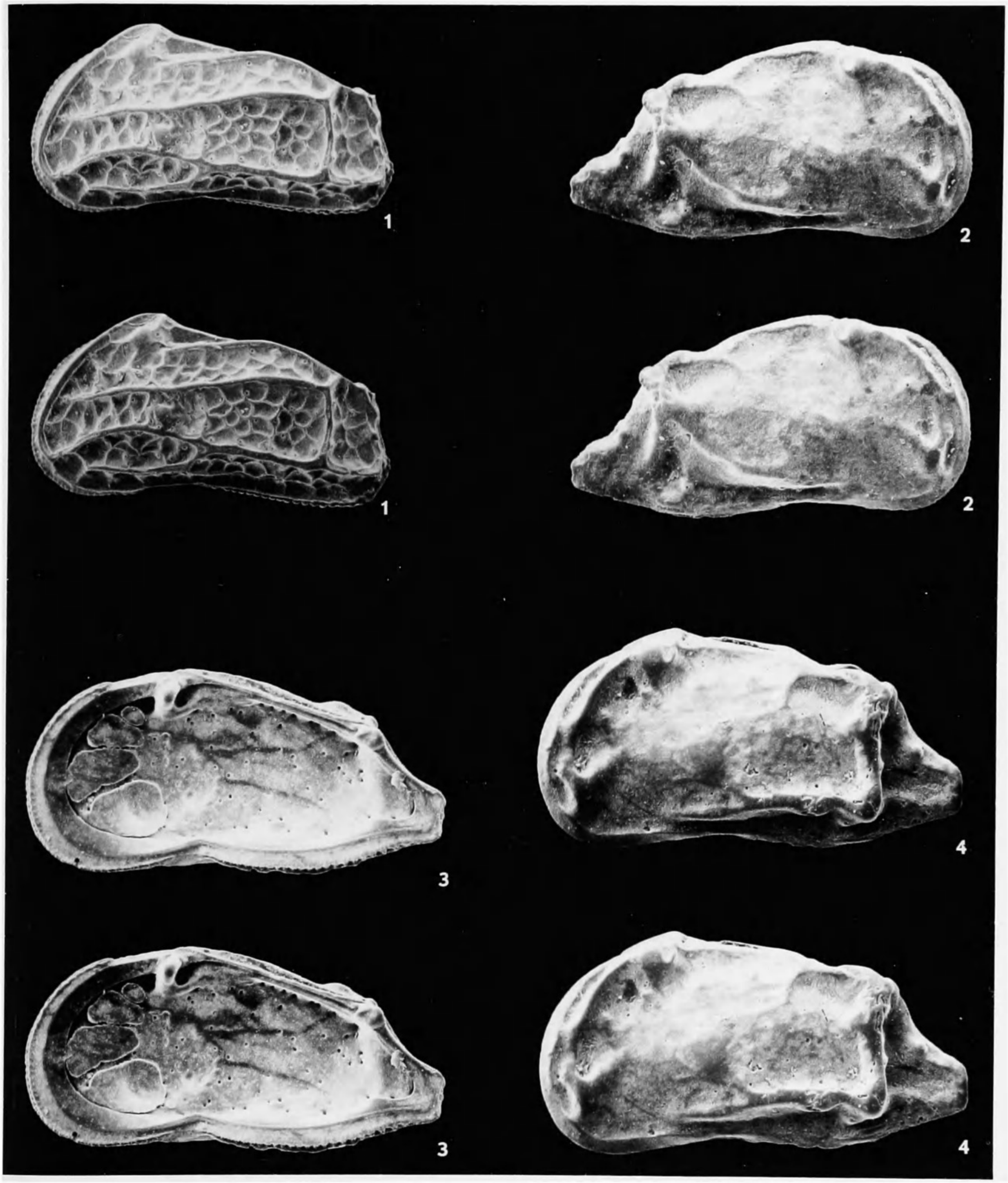
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PLATE 13

Palaciosa minuta (Edwards, 1944)

1. Exterior view male left valve, USNM 167401, Croatan Formation, right bank of Neuse River near James City, North Carolina, USGS 25444, × 115.
3. Interior view female right valve, USNM 167403, Croatan Formation, locality 80 of Waller (1969), USGS 25443, × 144.
4. Interior view right valve of disarticulated holotype of Edwards (1944, pl. 87: figs. 1–3), USNM 559425, Duplin Formation near Lumberton, North Carolina. Note that the small pillars in the anterocentral part of the valve in 3 have become centers of calcite deposition in 4, × 144.

Radimella confragosa (Edwards, 1944)

2. Left exterior view female carapace, USNM 172675, sample 12 of this study, USGS 24886, × 110.

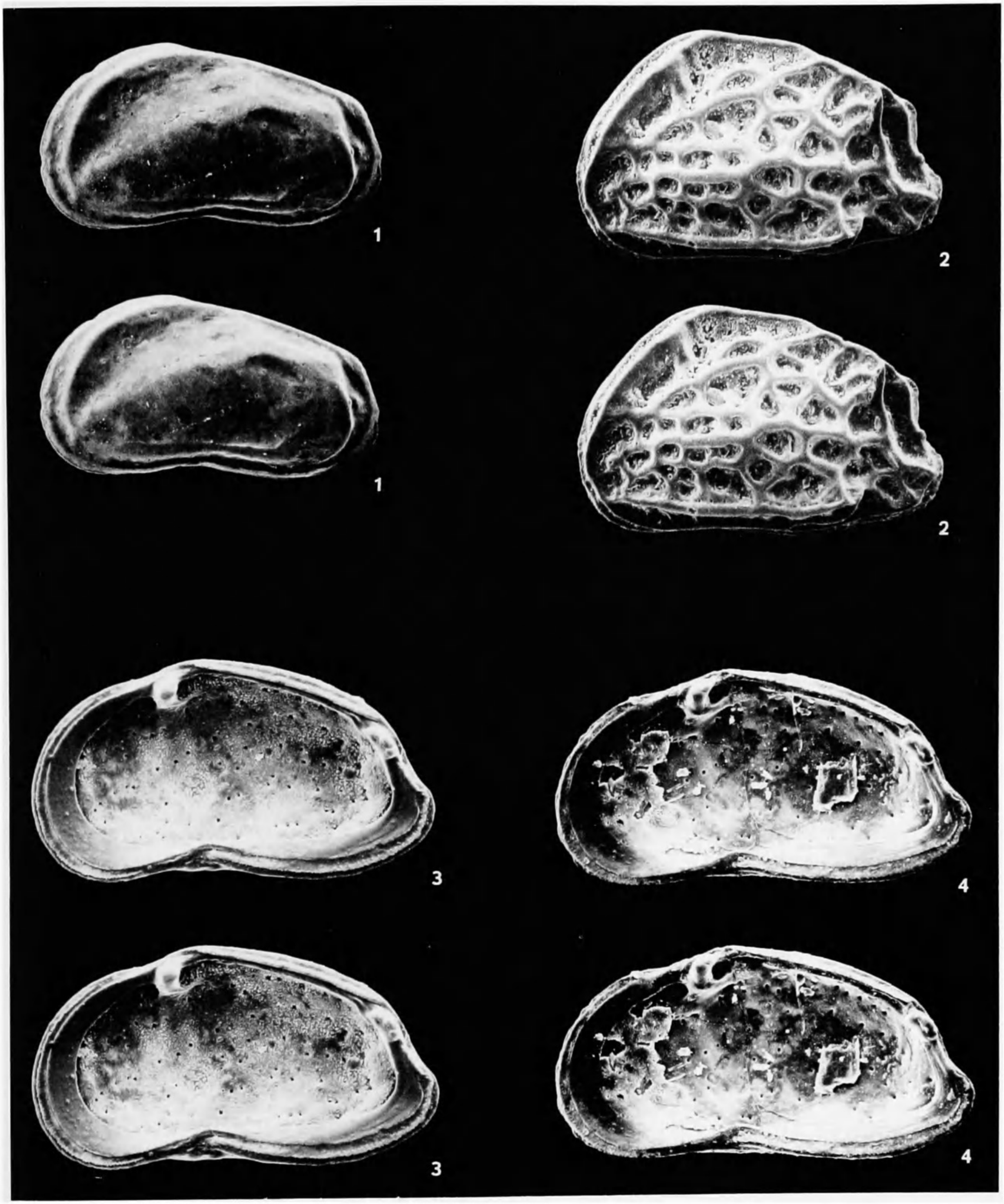

PLATE 14

Malzella conradi (Howe and McGuirt, 1935)

1. Exterior view female left valve, angulate form, USNM 167407, Yorktown Formation at Williamsburg, Virginia, sample 44 of Hazel (1971a), USGS 24820, × 101.
2. Left exterior view female carapace, subquadrate form, USNM 190468, Red Bay Formation of Puri and Vernon (1964), (*Arca* zone), upper Miocene, 1 mile (1.61 km) southeast of Red Bay, Fla., USGS 24709, × 85.
4. Left exterior view female carapace, intermediate form, USNM 190692, Jackson Bluff Formation (*Ecphora* zone), Pliocene, Leon County, Florida, USGS 25158, × 93.

Malzella evexa, new species

3. Exterior view female left valve, holotype, USNM 172653, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 95.

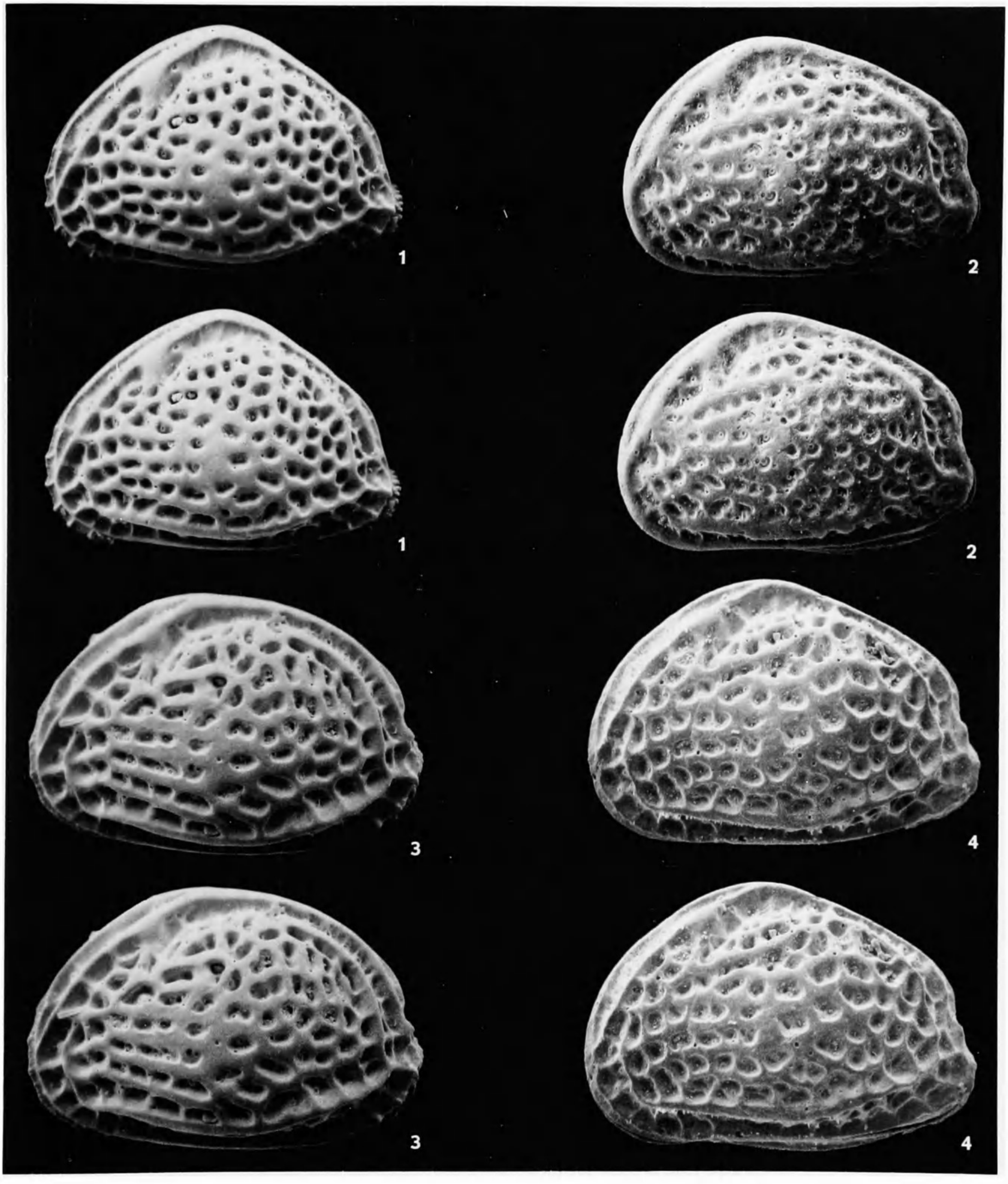
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PLATE 15

Malzella evexa, new species

1. Exterior view male left valve, USNM 313689, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 107.
2. Interior view female right valve showing anterior hinge elements, USNM 191340, Duplin Formation, Cedar Bluff Landing on the Savannah River, Georgia, USGS 23863, × 236.
3. Interior view female right valve, same specimen as figure 2 showing posterior hinge elements, × 236.
5. Exterior view female left valve, Edwards' (1944, pl. 86: fig. 18) specimen, USNM 559759, Duplin Formation, near Magnolia, North Carolina, locality 1 of Edwards (1944), × 122.

Aurila laevicula (Edwards, 1944)

4. Exterior view female left valve, USNM 172491, Yorktown Formation at Petersburg, Virginia, sample 39 of Hazel (1971a), USGS 24908, × 103.

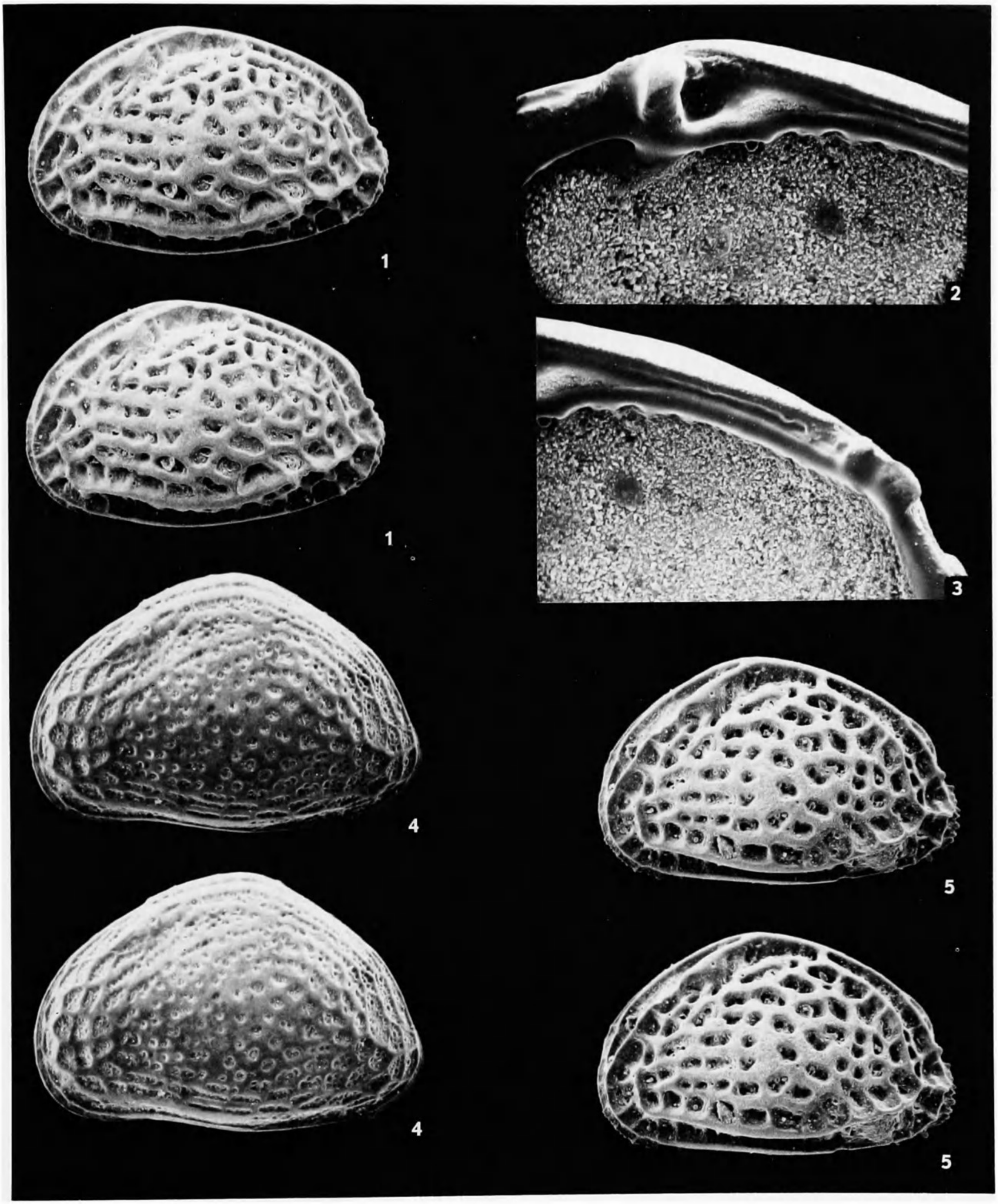
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PLATE 16

Muellerina bassiounii, new species

1. Exterior view male left valve, USNM 172618, "Yorktown" Formation near Mt. Gould, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 115.
4. Exterior view female left valve, holotype, USNM 167410, Croatan Formation at its type locality (MacNeil, 1938; DuBar and Solliday, 1963), near James City, North Carolina, × 103.

Muellerina canadensis petersburgensis, new subspecies

2. Exterior view female left valve, holotype, USNM 167408, Yorktown Formation at Petersburg, Virginia, sample 38 of Hazel (1971a), USGS 24908, × 103.

Muellerina ohmerti, new species

3. Exterior view female left valve, holotype, USNM 112741, Holocene, Atlantic shelf south of Long Island, 40°20′ N lat., 73°15′ W long., 36 meters, sample 1287 of Hazel (1967, 1970), and Valentine (1971), × 95.

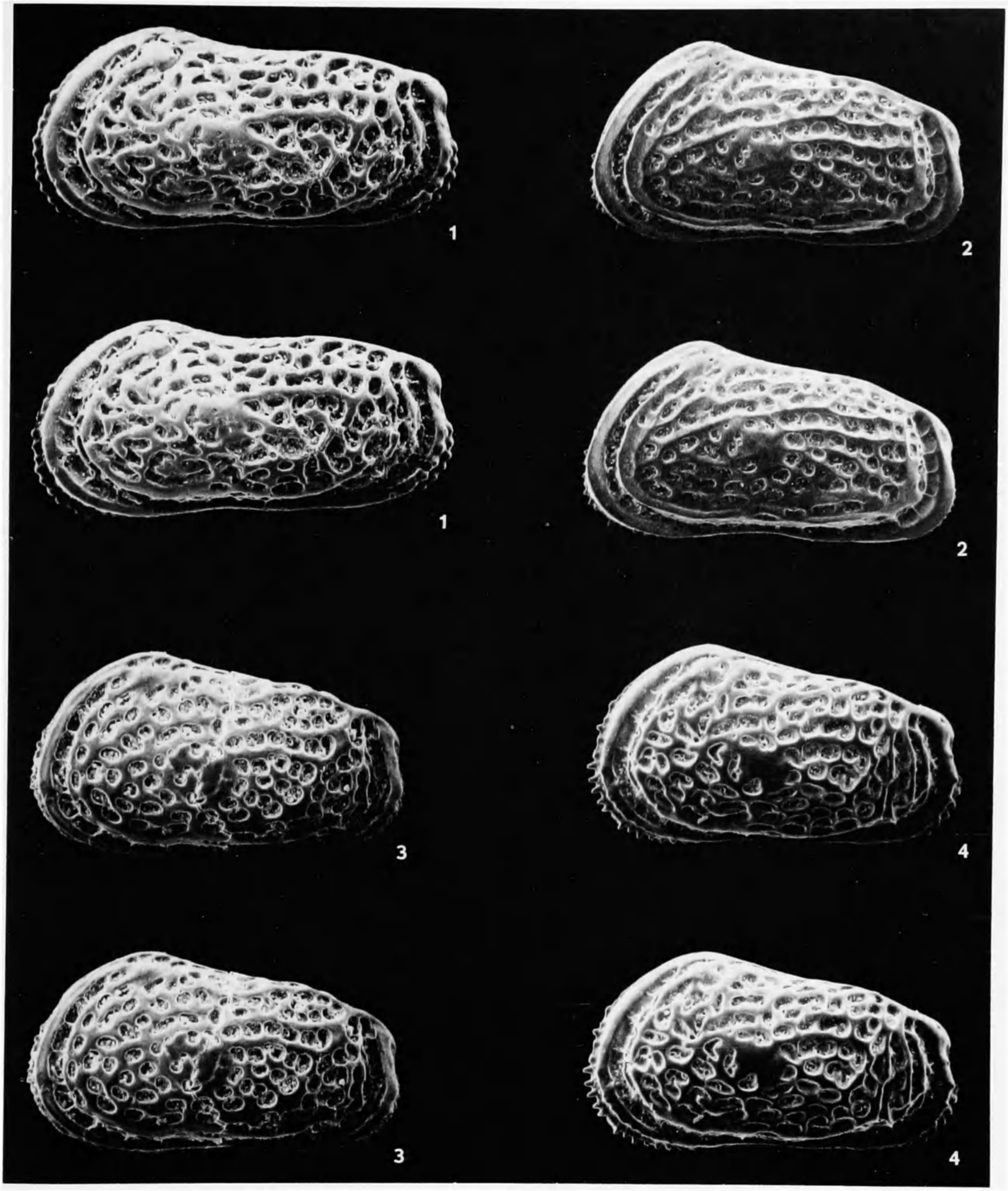

PLATE 17

Muellerina blowi, new species

1. Exterior view female left valve, holotype, USNM 167411, Yorktown Formation at Suffolk, Virginia, sample 29 of Hazel (1971a), USGS 24814, × 92.
3. Exterior view female right valve, USNM 172621, Yorktown Formation at Suffolk, Virginia, sample 29 of Hazel (1971a), USGS 24814, × 98.

Muellerina wardi, new species

2. Exterior view female right valve, USNM 172489, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 90.
4. Exterior view female left valve, holotype, USNM 167409, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 88.

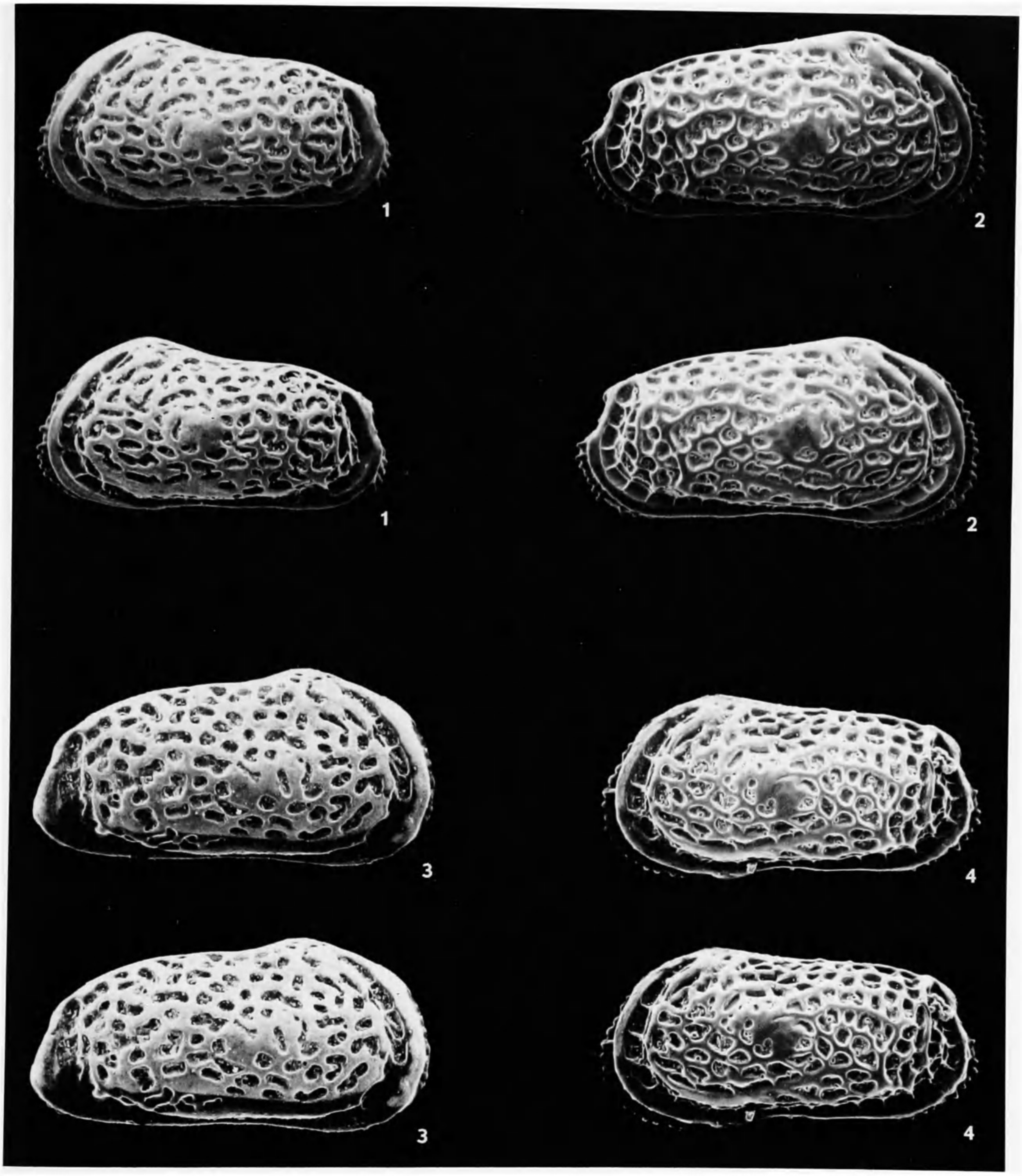
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PLATE 18

Muellerina canadensis petersburgensis, new subspecies

1. Interior view male right valve, USNM 172625, Yorktown Formation at Petersburg, Virginia, sample 38 of Hazel (1971a), USGS 24908, × 89.
3. Interior view female right valve, USNM 172626, Yorktown Formation at Halifax, North Carolina, sample 24 of Hazel (1971a), USGS 24904, × 91.

Muellerina blowi, new species

2. Interior view male right valve, USNM 172720, Yorktown Formation at Suffolk, Virginia, sample 29 of Hazel (1971a), USGS 24814, × 102.

Muellerina wardi, new species

4. Exterior view male left valve, USNM 172632, Yorktown Formation on the Piankatank River, Middlesex County, Virginia, sample 46 of Hazel (1971a), USGS 24801, × 104.
5. Interior view male right valve, USNM 172634, Yorktown Formation in Petersburg, Virginia, sample 39 of Hazel (1971a), USGS 24909, × 116.

Muellerina bassiounii, new species

6. Interior view female right valve, USNM 191402, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 111.


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PLATE 19

Thaerocythere carolinensis, new species

1. Exterior view male left valve, USNM 172658, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 16 of Hazel (1971a), USGS 24893, × 108.
3. Interior view female right valve, USNM 191415, "Yorktown" Formation at Colerain Landing, North Carolina, sample 14 of Hazel (1971a), USGS 24891, × 97.
4. Left exterior view female carapace, holotype, USNM 172657, "Yorktown" Formation at Colerain Landing, North Carolina, sample 14 of Hazel (1971a), USGS 24891, × 90.

Thaerocythere schmidtae (Malkin, 1953)

2. Exterior view male left valve, USNM 172657, "Yorktown" Formation at Colerain Landing, North Carolina, sample 14 of Hazel (1971a), USGS 24891, × 90.

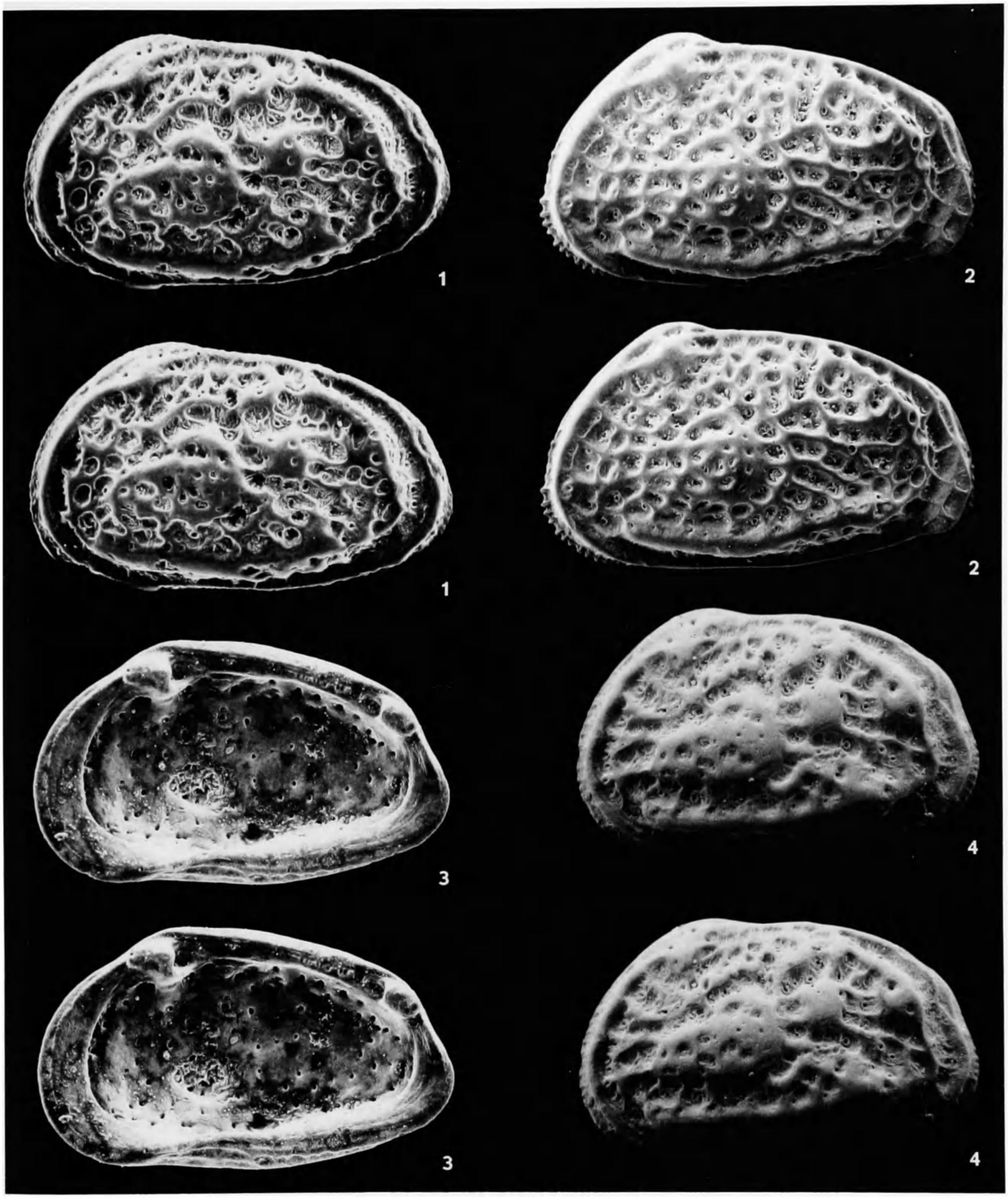

PLATE 20

Hirschmannia? hespera, new species

1. Exterior view female left valve, holotype, USNM 172575, sample 14 of this study, USGS 24887, × 147.
2. Interior view female right valve, USNM 172576, sample 14 of this study, USGS 24887, × 147.

Hirschmannia? quadrata, new species

3. Exterior view female left valve, holotype, USNM 172571, "Yorktown" Formation near Yadkin, Virginia, sample 31 of Hazel (1971a), USGS 24905, × 149.
4. Interior view male right valve, USNM 172573, "Yorktown" Formation near Yadkin, Virginia, sample 31 of Hazel (1971a), USGS 24905, × 166.

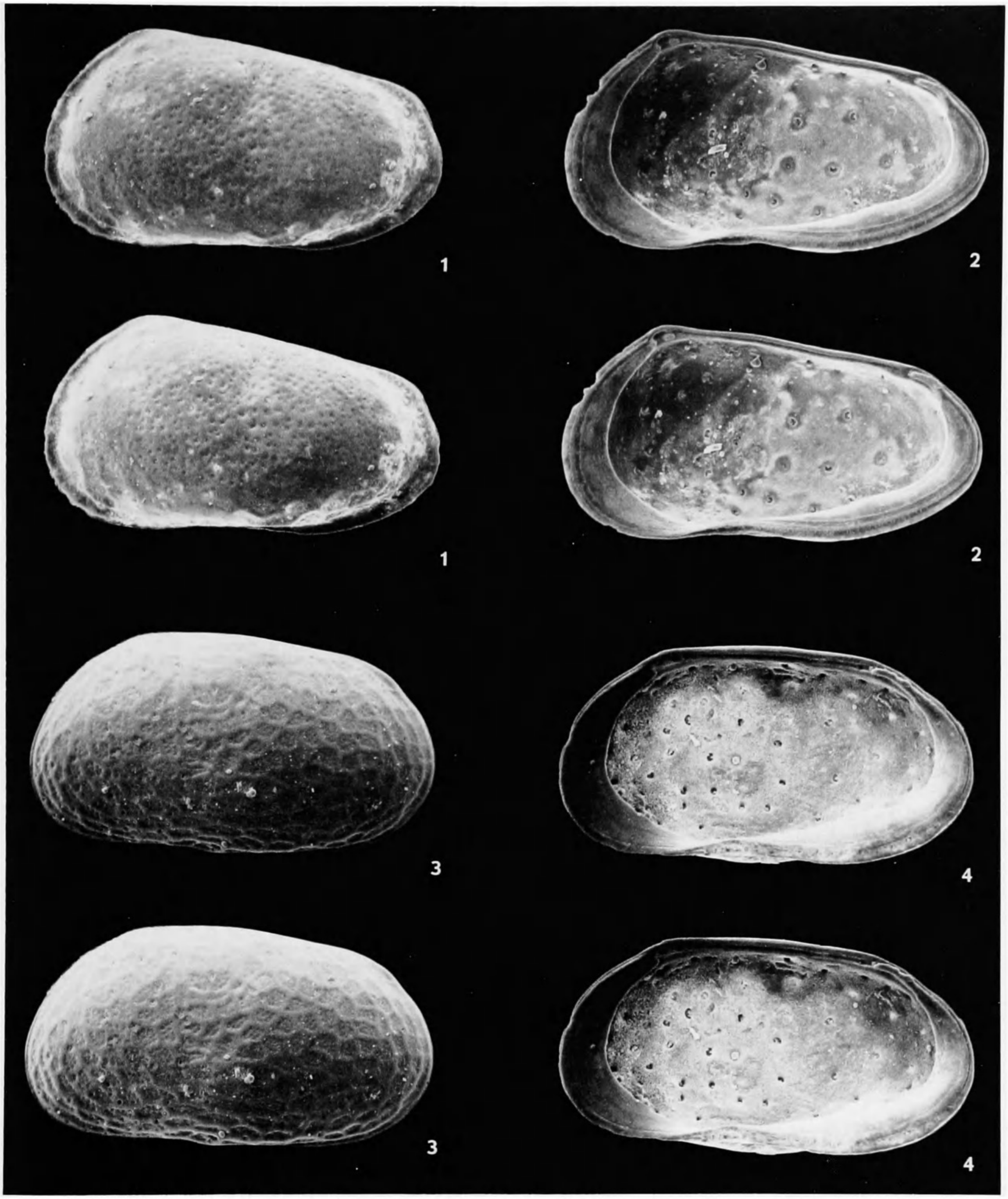
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PLATE 21

Cytheromorpha incisa, new species

1. Exterior view female left valve, holotype, USNM 172560, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 18 of Hazel (1971a), USGS 24895, × 136.
2. Interior view male right valve, USNM 172559, "Yorktown" Formation, Colerain Landing, North Carolina, sample 15 of Hazel (1971a), USGS 24892, × 136.

Hirschmannia? hespera, new species

3. Exterior view male left valve, USNM 172574, Croatan Formation, sample 14 of this study, USGS 24887, × 168.
4. Interior view female right valve, USNM 172577, Croatan Formation, sample 14 of this study, USGS 24887, × 154.

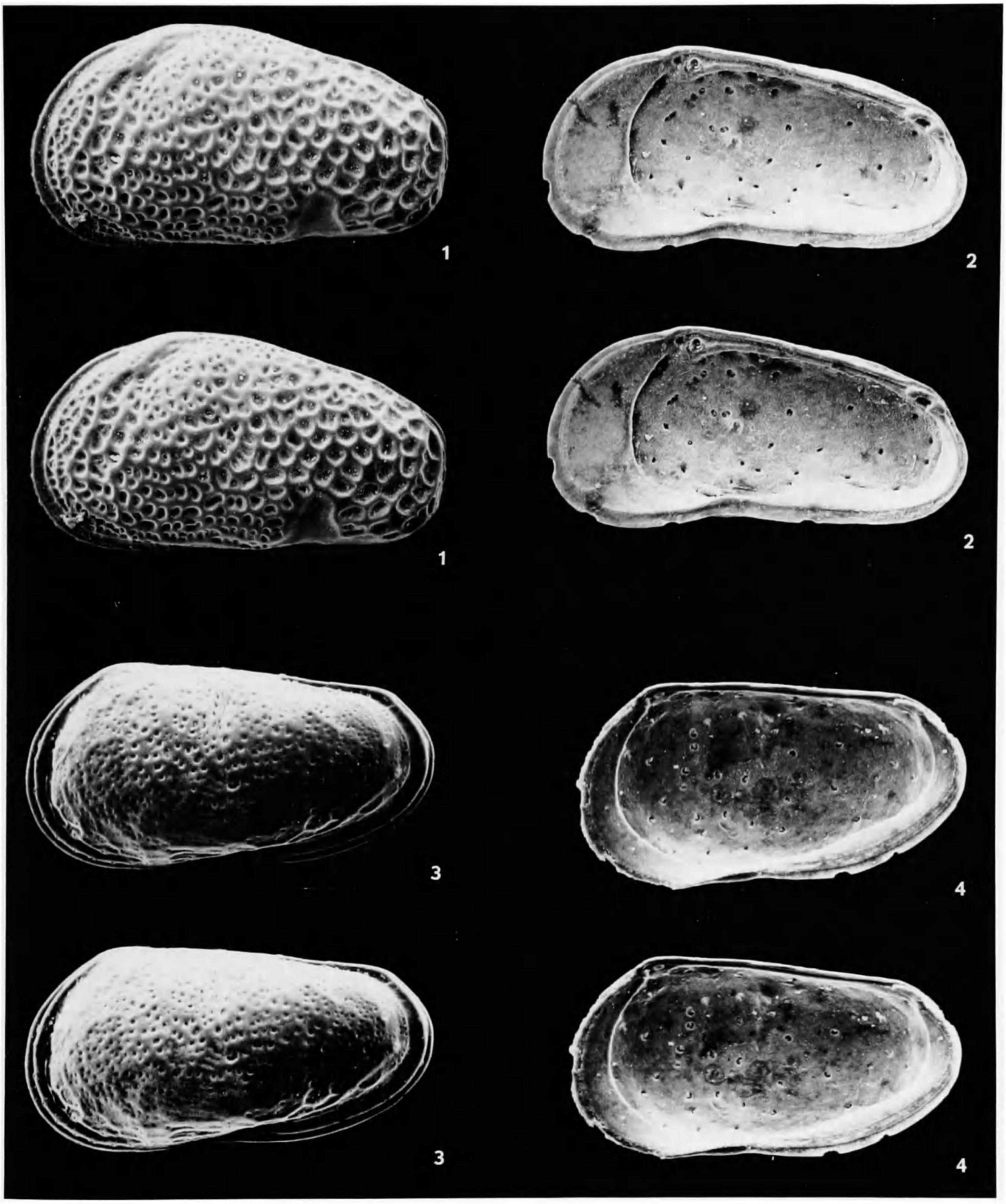
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PLATE 22

Cytheromorpha macroincisa, new species

1. Exterior view female left valve, holotype, USNM 172562, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 18 of Hazel (1971a), USGS 24895, × 116.
2. Interior view female right valve, USNM 172561, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 18 of Hazel (1971a), USGS 24895, × 118.
3. Interior view female right valve, showing central muscle field, same specimen as figure 2, × 356.
4. Interior view female right valve, showing posterior hinge elements, same specimen as figure 2, × 390.
5. Interior view female right valve, showing anterior hinge elements, same specimen as figure 2, × 390.

Cytheromorpha warneri Howe and Spurgeon, 1935

6. Exterior view female left valve, USNM 172555, Jackson Bluff Formation (*Ecphora* zone), Leon County, Florida, USGS 25158, × 105.

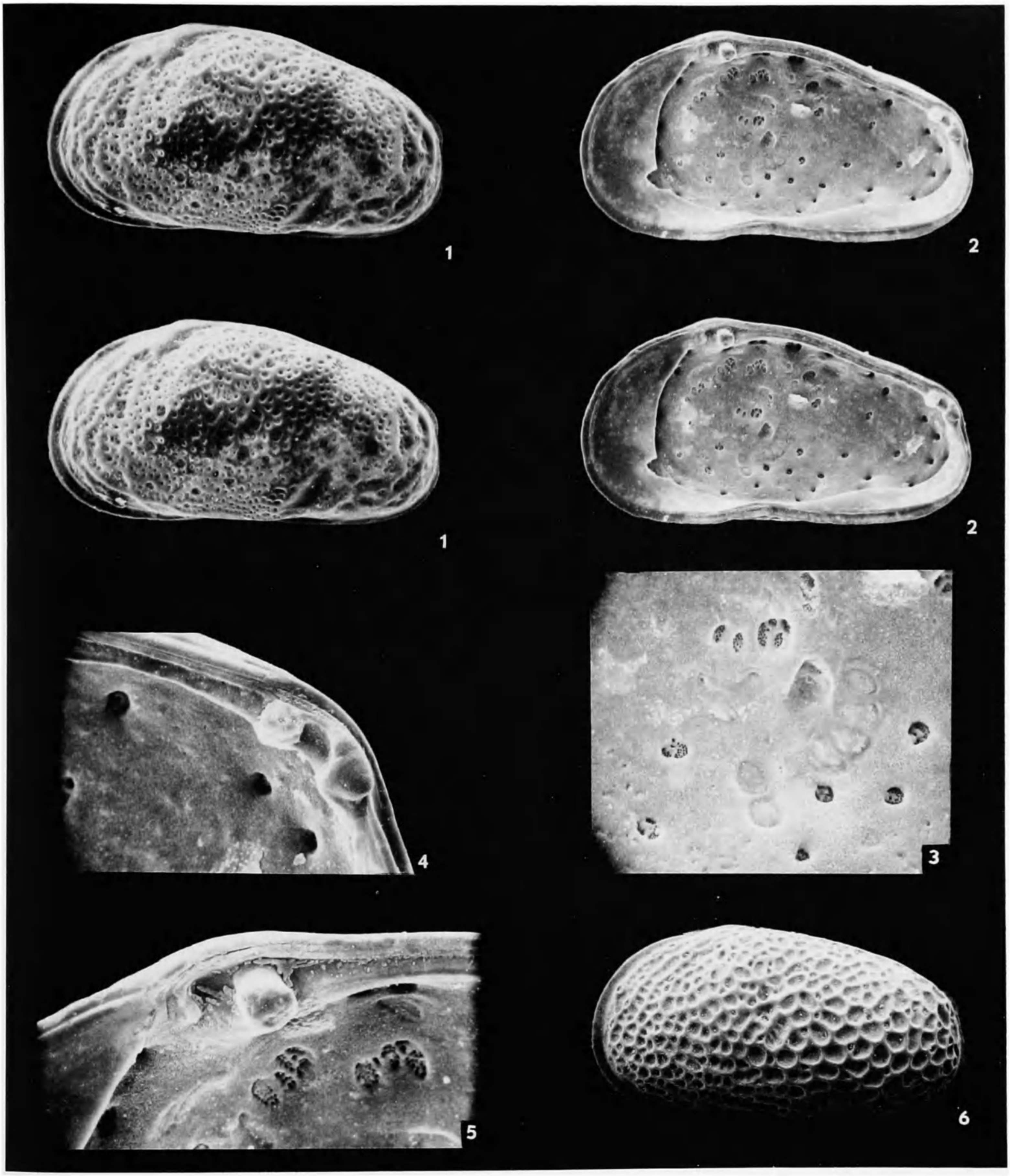
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PLATE 23

Cytheromorpha suffolkensis, new species

1. Exterior view female left valve, holotype, USNM 172551, Yorktown Formation, Suffolk, Virginia, sample 29 of Hazel (1971a), USGS 24814, × 142.
2. Interior view male right valve, USNM 172552, Yorktown Formation, Suffolk, Virginia, sample 29 of Hazel (1971a), USGS 24814, × 142.
3. Interior view male right valve, showing anterior hinge elements, same specimen as figure 2, × 600.
4. Interior view male right valve, showing posterior hinge elements, same specimen as figure 2, × 600.

Cytheromorpha incisa, new species

5. Interior view male right valve, showing anterior hinge elements, USNM 172559, "Yorktown" Formation, Colerain Landing, North Carolina, sample 15 of Hazel (1971a), USGS 24892, × 544.
6. Interior view male right valve, showing posterior hinge elements, same specimen as figure 5, × 544.

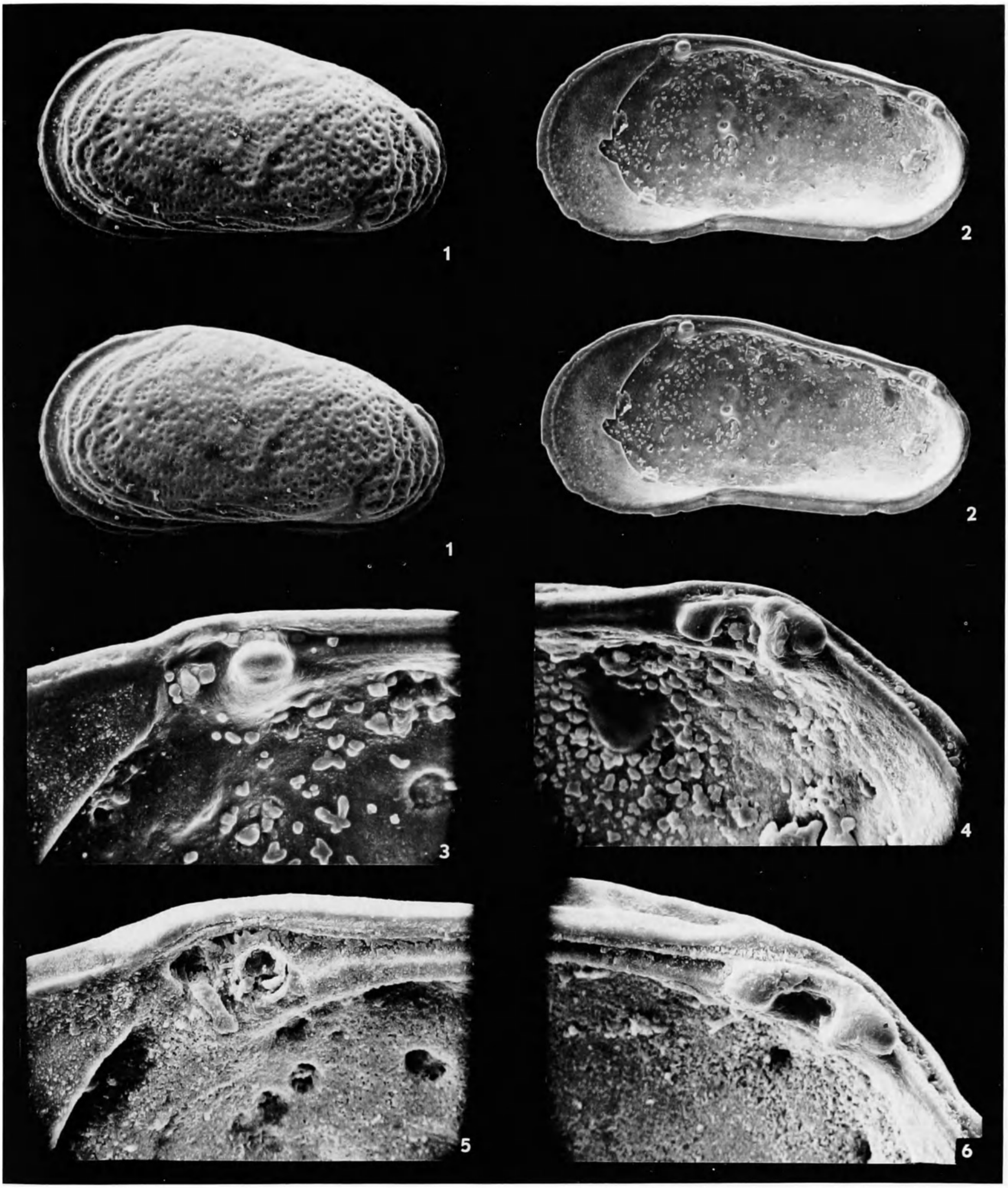
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PLATE 24

Pseudocytheretta burnsi (Ulrich and Bassler, 1904)

1. Exterior view male left valve, smooth form, USNM 172638, Yorktown Formation, Hampton City, Virginia, sample 36 of Hazel (1971a), USGS 24907, × 70.
3. Right exterior view female carapace, pitted form, USNM 172637, Yorktown Formation, Hampton City, Virginia, sample 36 of Hazel (1971a), USGS 24907, × 75.

Loxoconcha edentonensis Swain, 1951

2. Exterior view female left valve, USNM 172603, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 19 of Hazel (1971a), USGS 24896, × 120.
4. Exterior view male left valve, USNM 172604, Croatan Formation, sample 12 of this study, USGS 24886, × 120.

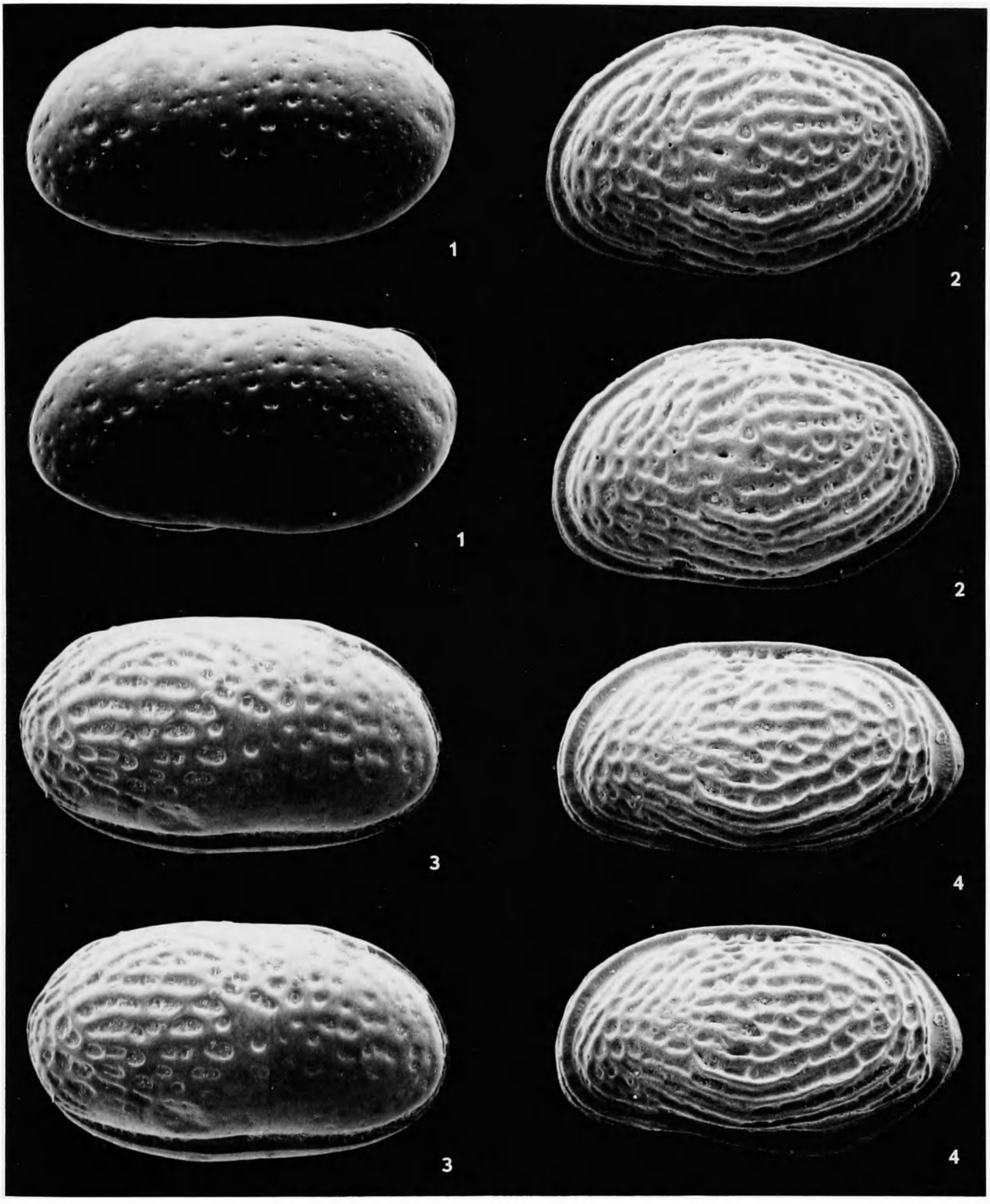
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PLATE 25

Proteoconcha jamesensis, new species

1. Exterior view female left valve, holotype, USNM 167377, Yorktown Formation, Nansemond County, Virginia, sample 32 of Hazel (1971a), USGS 24622, × 90.
2. Interior view female left valve, USNM 191438, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 17 of Hazel (1971a), USGS 24894, × 108.

Puriana rugipunctata (Ulrich and Bassler, 1904)

3. Exterior view female left valve, USNM 172669, Yorktown Formation at Petersburg, Virginia, sample 38 of Hazel (1971a), USGS 24908, × 110.

Puriana mesacostalis (Edwards, 1944)

4. Exterior view female left valve, USNM 172668, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 112.

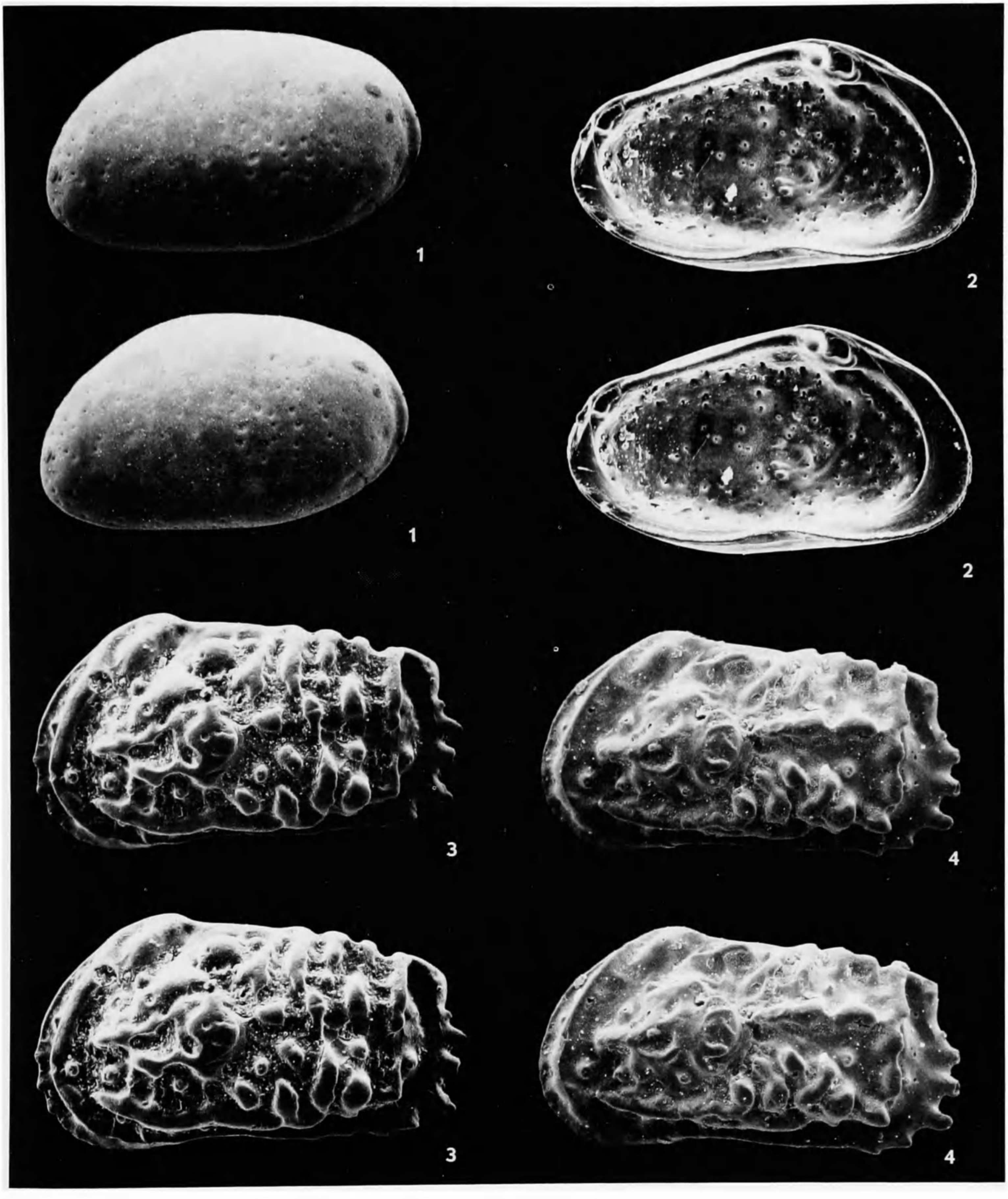
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PLATE 26

Puriana convoluta Teeter, 1975

1. Exterior view male left valve, USNM 191499, Waccamaw Formation, Old Dock, North Carolina, USGS 25445, × 130.
2. Exterior view female left valve, USNM 172651, Holocene sample 1861, Raleigh Bay, south of Cape Hatteras, 34°45.6′ N lat., 75°44.6′ W long., 41 meters, × 115.
4. Interior view female right valve, USNM 172652, Holocene sample 1861, Raleigh Bay, south of Cape Hatteras, 34°45.6′ N lat., 75°44.6′ W long., 41 meters, × 113.

Puriana rugipunctata (Ulrich and Bassler, 1904)

3. Exterior view female right valve, USNM 172478, Yorktown Formation, Williamsburg, Virginia, sample 44 of Hazel (1971a), USGS 24820, × 135.

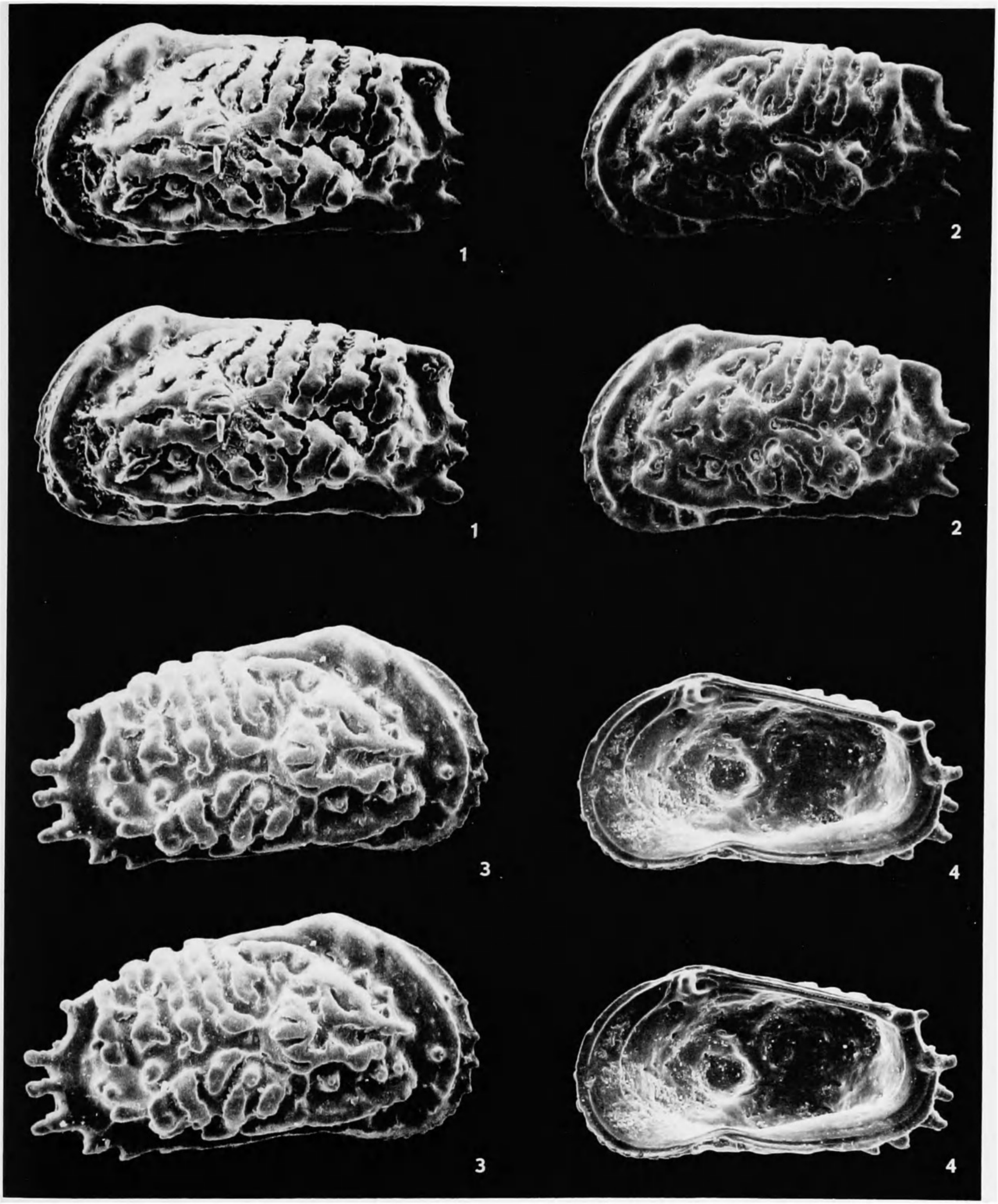

PLATE 27

Puriana carolinensis, new species

1. Exterior view female right valve, holotype, USNM 172649, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 109.
3. Interior view female left valve, USNM 172647, type locality of the Duplin Formation, near Magnolia, North Carolina, USGS 23639, × 150.
4. Exterior view male left valve, USNM 172648, type locality of the Duplin Formation, near Magnolia, North Carolina, USGS 23639, × 150.

Proteoconcha jamesensis, new species

2. Exterior view male left valve, USNM 167379, Yorktown Formation, Hampton City, Virginia, sample 36 of Hazel (1971a), USGS 24907, × 117.

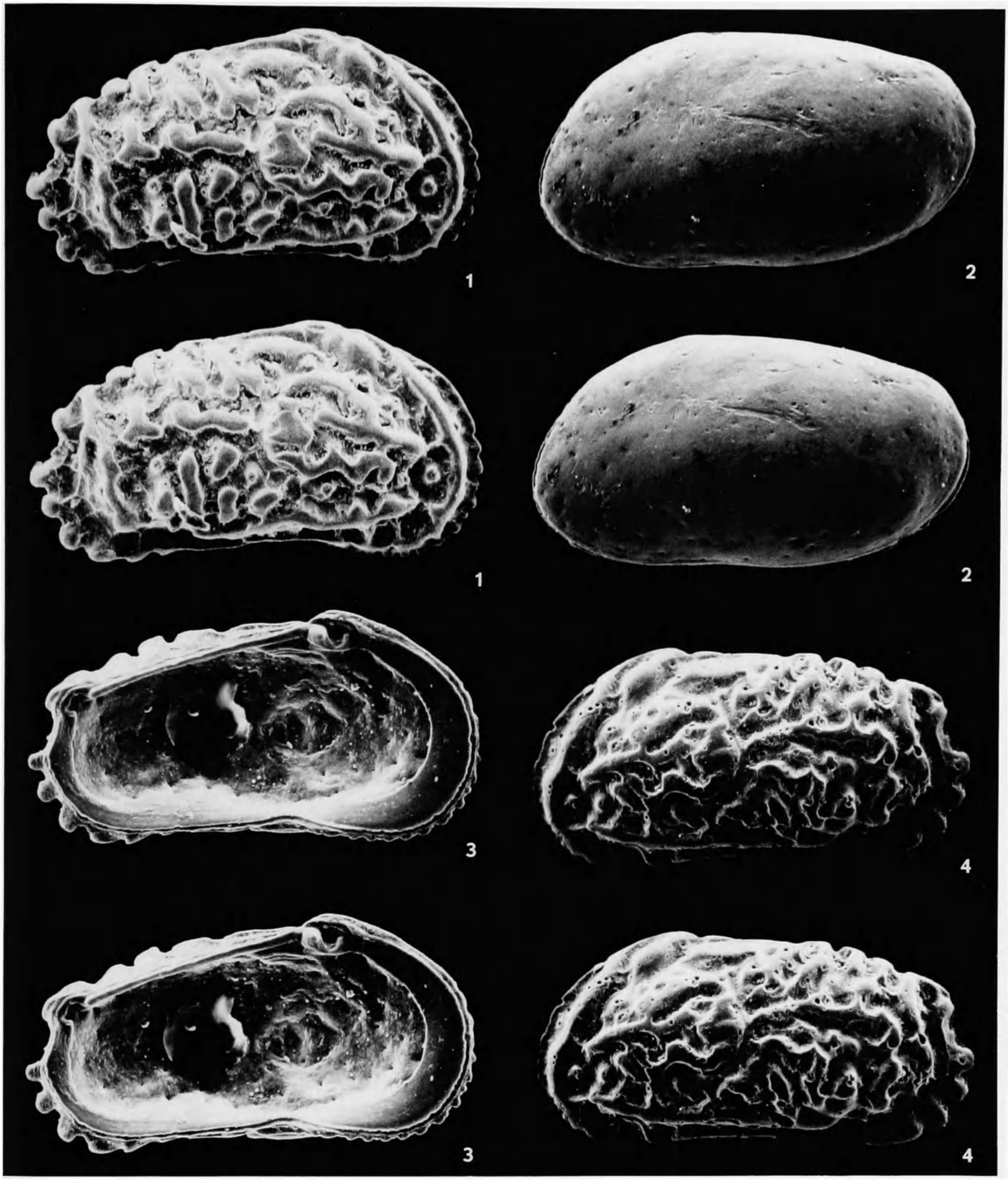

PLATE 28

Paracytheridea cronini, new species

1. Exterior view male left valve, USNM 191428, type locality of the Duplin Formation, near Magnolia, North Carolina, USGS 23639, × 115.
2. Interior view female right valve, USNM 191412, type locality of the Duplin Formation, near Magnolia, North Carolina, USGS 23639, × 118.

Paracytheridea rugosa Edwards, 1944

3. Exterior view female left valve, USNM 191497, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 122.

Paracytheridea altila Edwards, 1944

4. Exterior view female left valve, USNM 191500, Croatan Formation, sample 13 of this study, USGS 25377, × 122.

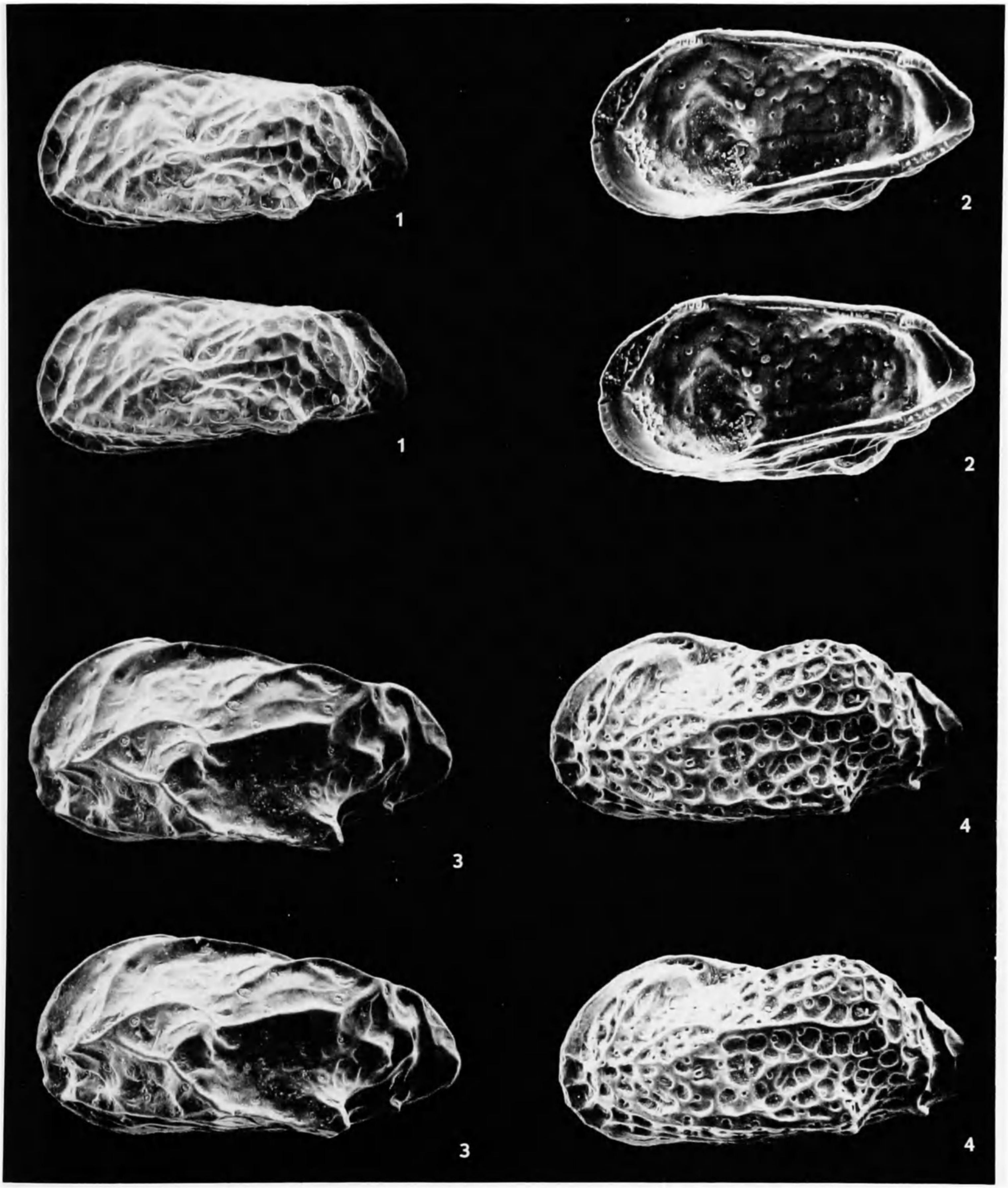
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PLATE 29

Paracytheridea cronini, new species

1. Exterior view female left valve, holotype, USNM 172759, type locality of the Duplin Formation, near Magnolia, North Carolina, USGS 23639, × 113.

Paracytheridea mucra Edwards, 1944

2. Exterior view female left valve, USNM 172758, Yorktown Formation, Suffolk, Virginia, sample 29 of Hazel (1971a), USGS 24814, × 102.

Microcytherura choctawhatcheensis (Puri, 1954)

3. Exterior view male left valve, USNM 191498, Waccamaw Formation, pit near Old Dock, North Carolina, USGS 25445, × 130.

Microcytherura similis (Malkin, 1953)

4. Exterior view female left valve, USNM 172751, Yorktown Formation, Nansemond County, Virginia, sample 32 of Hazel (1971a), USGS 24622, × 117.

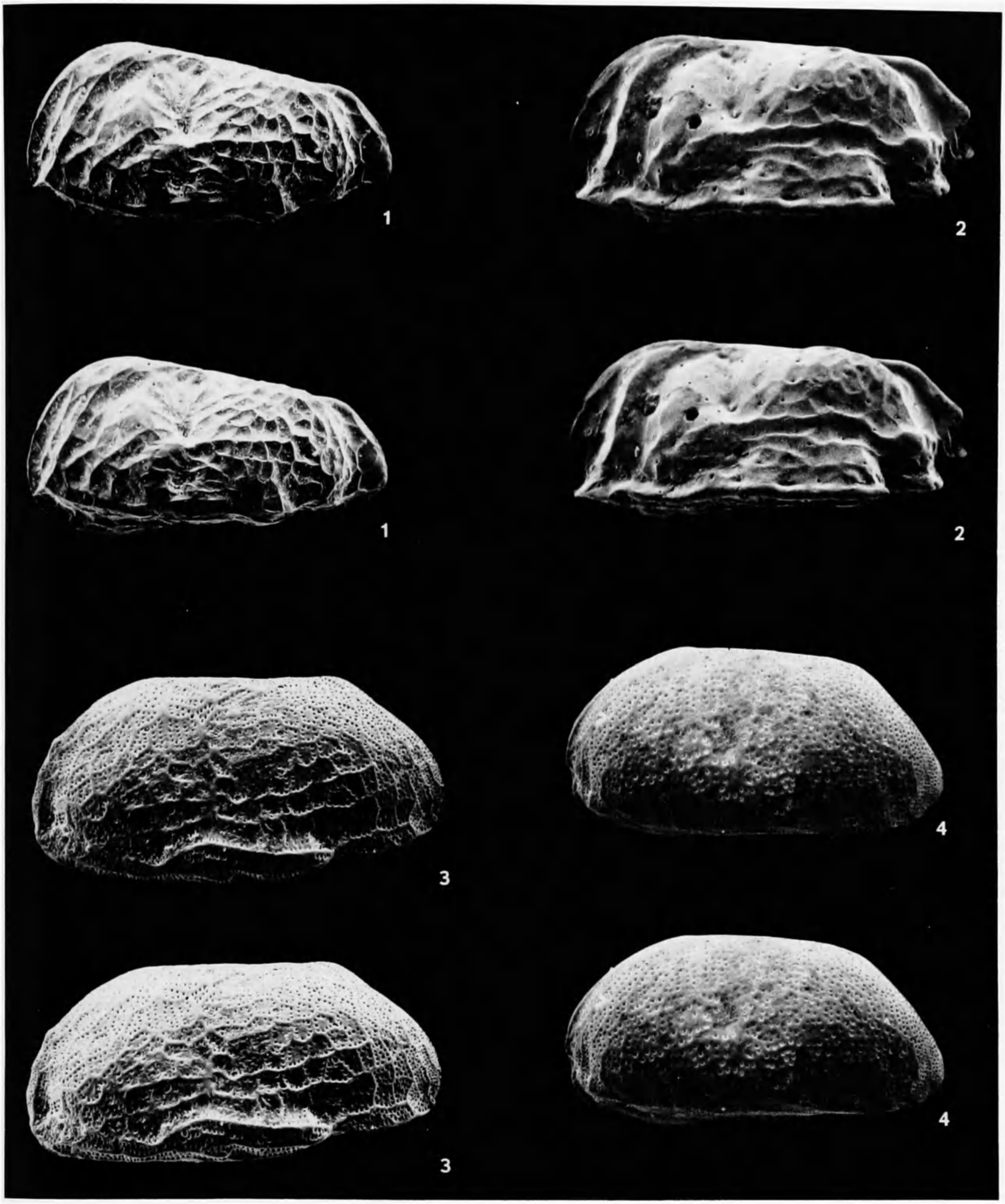

PLATE 30

Microcytherura expanda, new species

1. Exterior view male left valve, USNM 191481, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 123.
2. Exterior view female left valve, holotype, USNM 172752, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 117.
3. Interior view female right valve, USNM 191482, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 20 of Hazel (1971a), USGS 24897, × 117.

Microcytherura similis (Malkin, 1953)

4. Exterior view male left valve, USNM 191483, Yorktown Formation, Nansemond County, Virginia, sample 32 of Hazel (1971a), USGS 24622, × 127.


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PLATE 31

Microcytherura minuta, new species

1. Interior view female right valve, USNM 191484, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 18 of Hazel (1971a), USGS 24895, × 135.
2. Exterior view male left valve, USNM 313690, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 18 of Hazel (1971a), USGS 24895, × 138.
3. Exterior view female left valve, holotype, USNM 172750, Yorktown Formation, Williamsburg, Virginia, sample 45 of Hazel (1971a), × 150.

Microcytherura similis (Malkin, 1953)

4. Interior view female right valve, USNM 313691, Yorktown Formation, Nansemond County, Virginia, sample 32 of Hazel (1971a), USGS 24622, × 154.

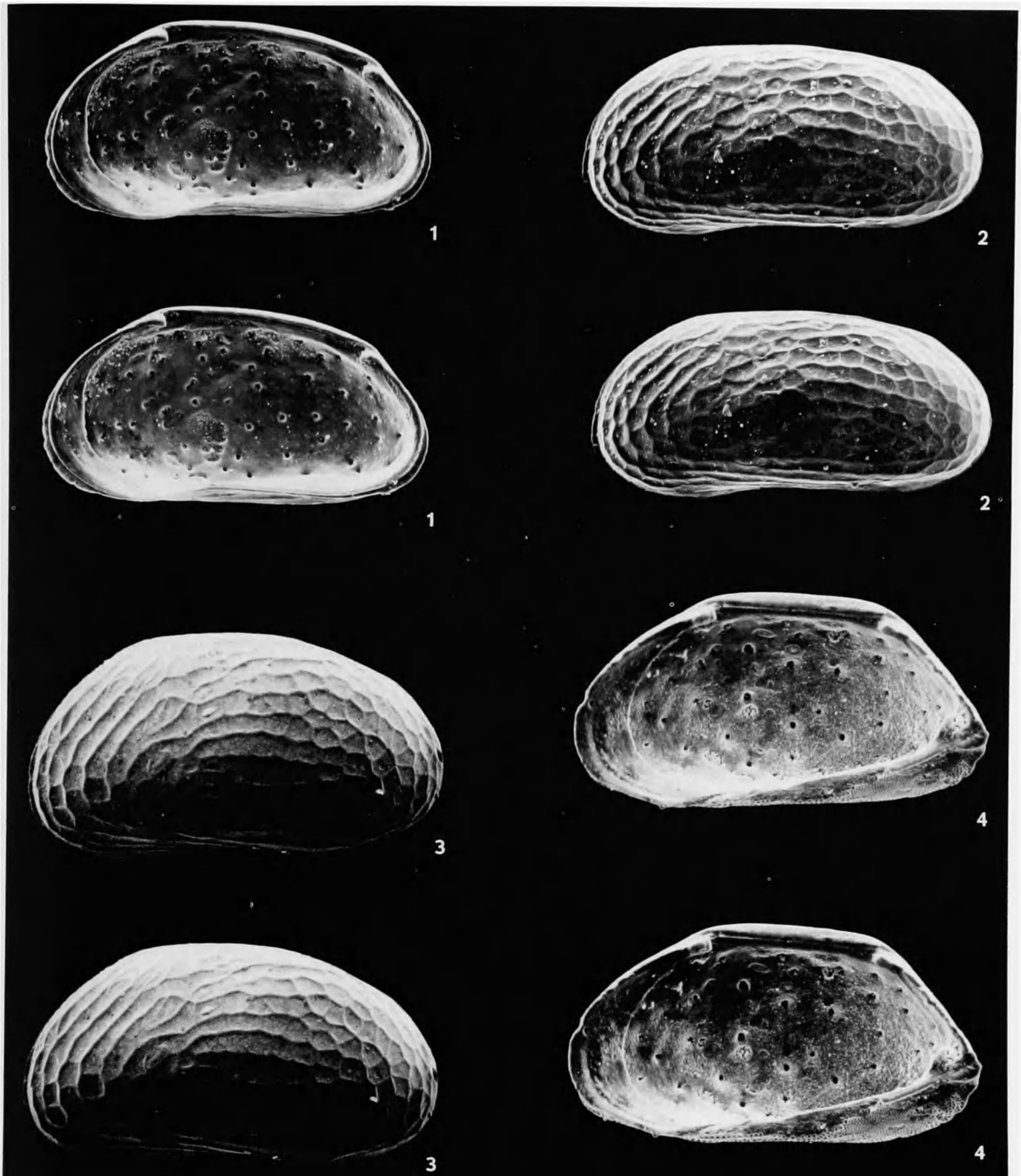
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PLATE 32

Bensonocythere trapezoidalis (Swain, 1974)

1. Exterior view male left valve, USNM 167395, Yorktown Formation, near Palmyra, North Carolina, sample 11 of Hazel (1971a), USGS 24889, × 90.
2. Interior view female right valve, USNM 167396, Yorktown Formation, near Palmyra, North Carolina, sample 11 of Hazel (1971a), USGS 24889, × 113.

Bensonocythere rugosa, new species

3. Interior view female right valve, USNM 167383, Yorktown Formation at Petersburg, Virginia, sample 38 of Hazel (1971a), USGS 24908, × 90.
4. Exterior view female left valve, holotype, USNM 167382, Yorktown Formation at Petersburg, Virginia, sample 39 of Hazel (1971a), USGS 24909, × 86.

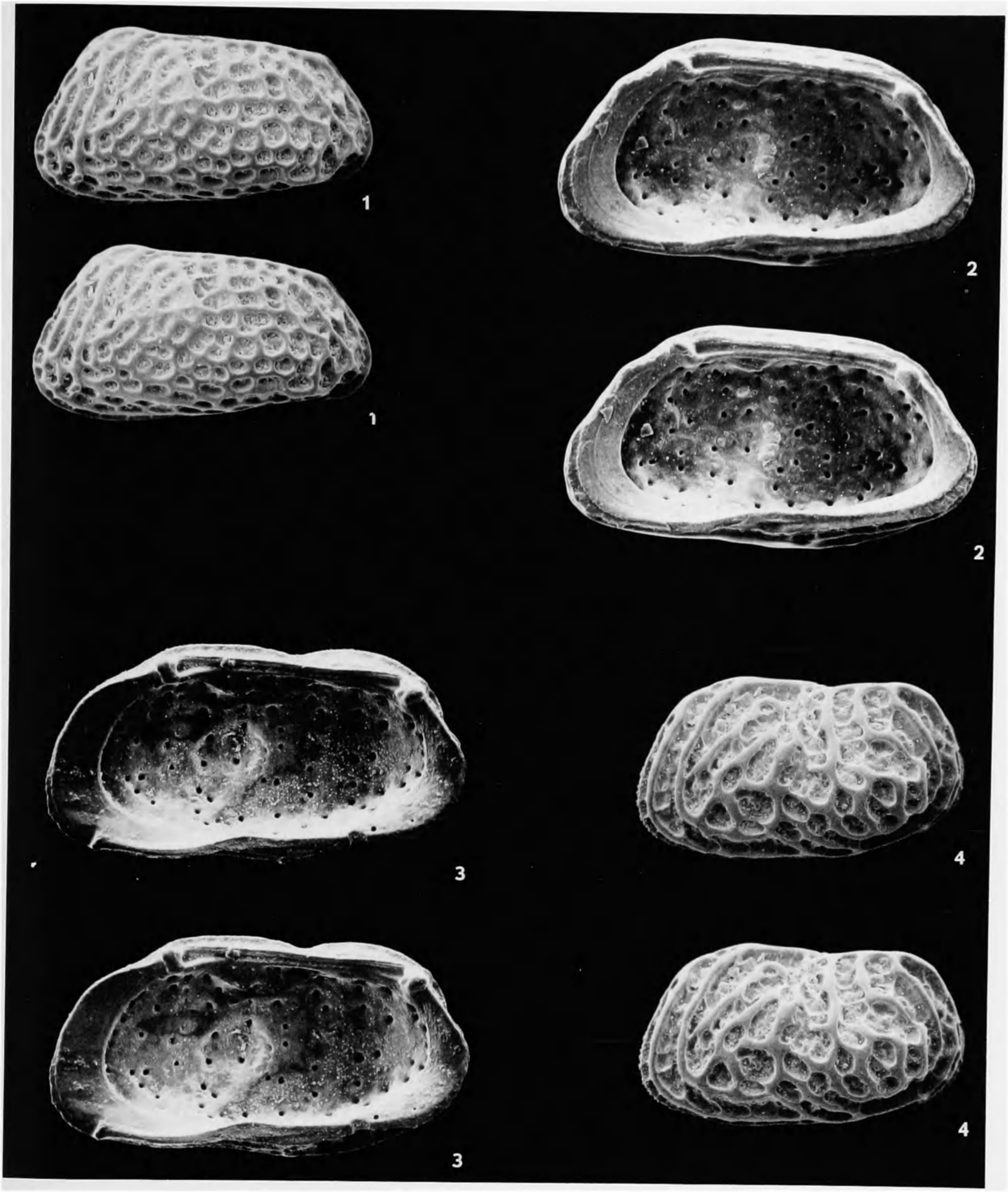
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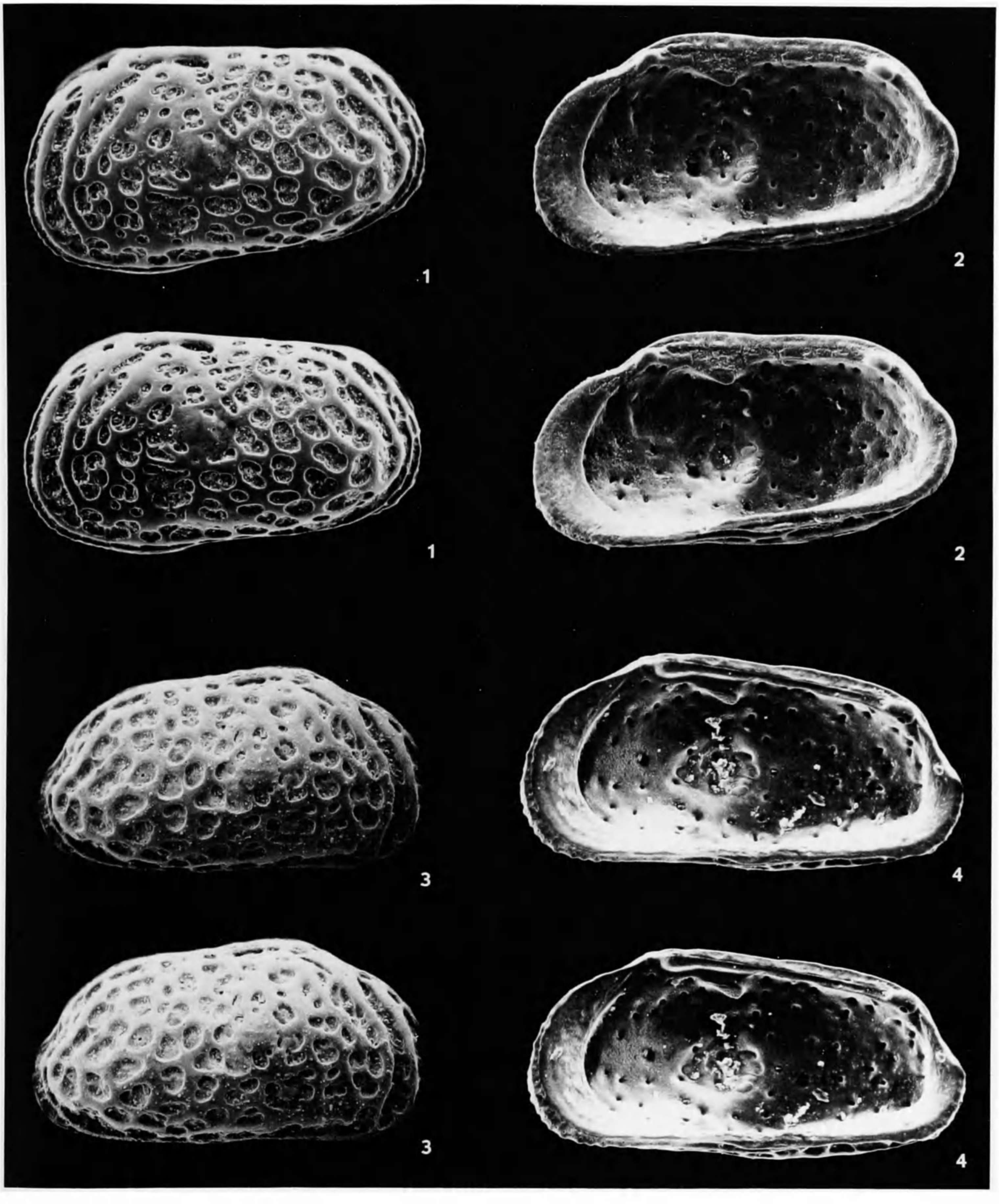
PLATE 33

Bensonocythere ricespitensis, new species

1. Exterior view female left valve, holotype USNM 167394, Yorktown Formation, Hampton City, Virginia, sample 36 of Hazel (1971a), USGS 24907, × 100.
2. Interior view female right valve, USNM 167391, Yorktown Formation, Hampton City, Virginia, sample 36 of Hazel (1971a), USGS 24907, × 98.
3. Exterior view female right valve, same specimen as figure 2, × 98.
4. Interior view male right valve, USNM 191383, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 18 of Hazel (1971a), USGS 24895, × 128.


1
2
1
2
3
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4

PLATE 34

Bensonocythere bradyi, new species

1. Exterior view male right valve, holotype, USNM 167380, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 17 of Hazel (1971a), USGS 24894, × 78.
2. Interior view female right valve, USNM 167381, Yorktown Formation, Hampton City, Virginia, sample 37 of Hazel (1971a), USGS 24805, × 75.

Bensonocythere gouldensis, new species

3. Exterior view male left valve, USNM 167389, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 18 of Hazel (1971a), USGS 24895, × 90.
4. Interior view female right valve, USNM 167388, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 19 of Hazel (1971a), USGS 24896, × 95.

Bensonocythere calverti (Ulrich and Bassler, 1904)

5. Exterior view male left valve, USNM 167387, Yorktown Formation, near Palmyra, North Carolina, sample 11 of Hazel (1971a), USGS 24889, × 68.

PLATE 35

Bensonocythere blackwelderi, new species

1. Exterior view male left valve, USNM 191505, Yorktown Formation, Hampton City, Virginia, sample 37 of Hazel (1971a), USGS 24805, × 110.
2. Interior view male left valve, USNM 172481, Yorktown Formation, Hampton City, Virginia, sample 37 of Hazel (1971a), USGS 24805, × 110.
4. Exterior view female left valve, holotype, USNM 167398, Yorktown Formation, Isle of Wight County, Virginia, sample 33 of Hazel (1971a), USGS 24823, × 90.

Bensonocythere whitei (Swain, 1951)

3. Exterior view female left valve of Swain's holotype, USNM 560640, "Yorktown" Formation, Edenton Naval Air Base, North Carolina, 55 foot (16.8 m) depth in well (downdip stratigraphic equivalent of localities 3 and 4 of Hazel, 1971a), × 109.

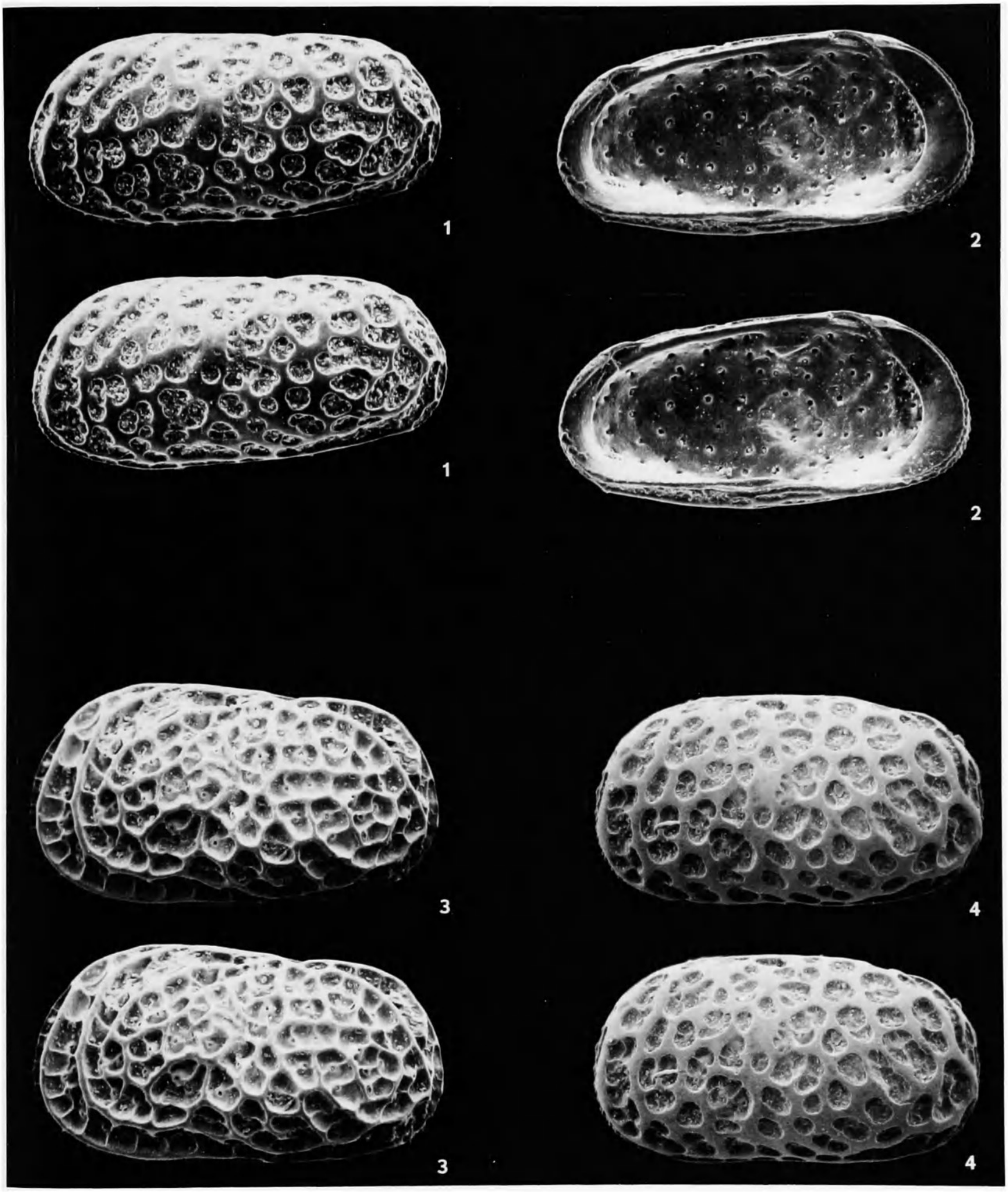

PLATE 36

Echinocythereis leecreekensis, new species

1. Exterior view female right valve, holotype, USNM 191495, Croatan Formation, sample 10 of this study, USGS 25359, × 70.
2. Exterior view female left valve, USNM 191510, Croatan Formation, sample 10 of this study, USGS 25359, × 70.
3. Interior view female right valve, USNM 191508, Croatan Formation, sample 11 of this study, USGS 25376, × 77.

Echinocythereis planibasalis (Ulrich and Bassler, 1904)

4. Exterior view male left valve, USNM 172754, Yorktown Formation near Jamestown, Virginia, sample 41 of Hazel (1971a), USGS 24717, × 70.

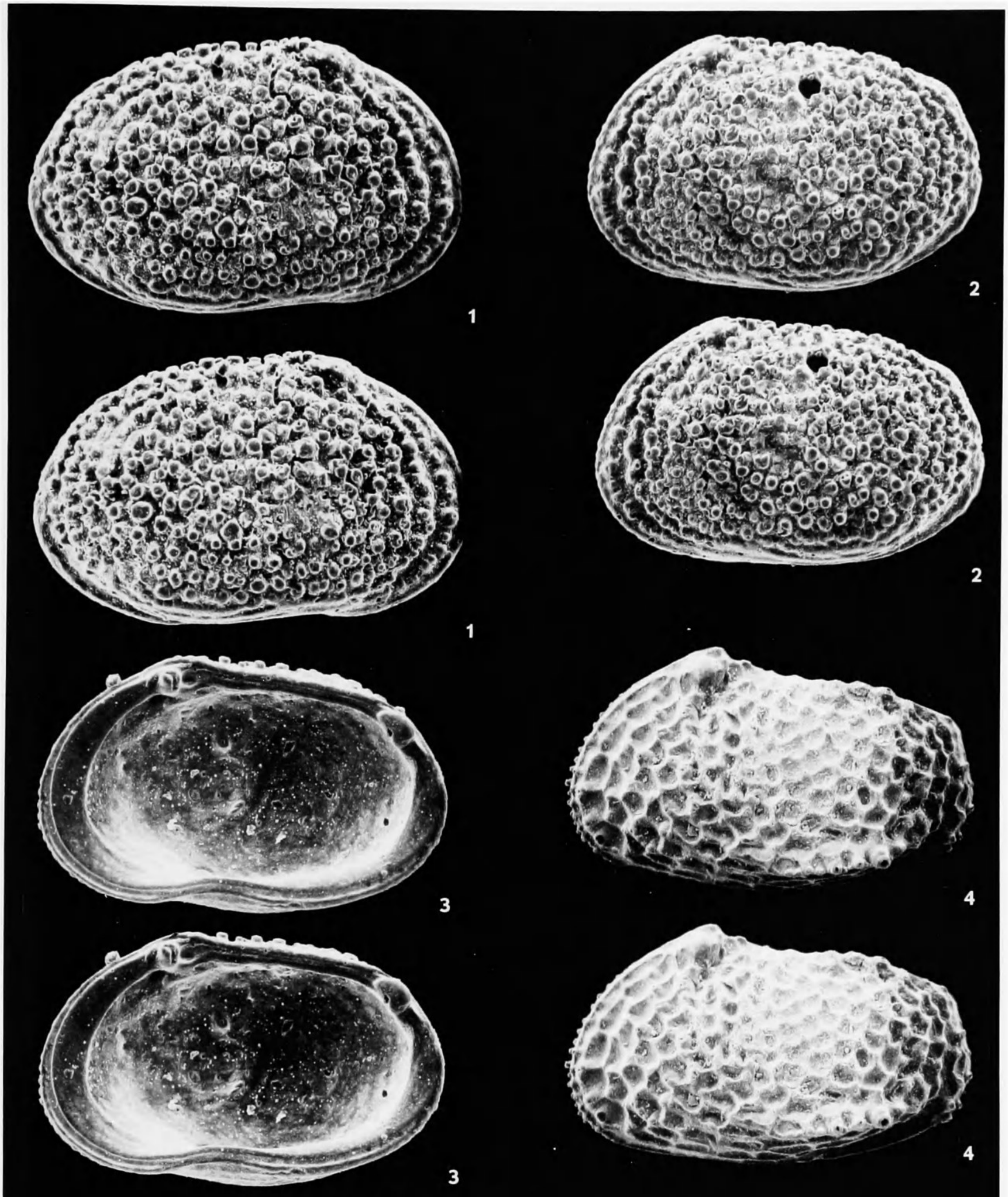

PLATE 37

Bensonocythere rugosa, new species

1. Exterior view male right valve, USNM 167384, Yorktown Formation, Hampton City, Virginia, sample 36 of Hazel (1971a), USGS 24907, × 118.

Bensonocythere gouldensis, new species

2. Exterior view female left valve, holotype, USNM 167385, "Yorktown" Formation, near Mt. Gould Landing, North Carolina, sample 19 of Hazel (1971a), USGS 24896, × 75.
3. Exterior view female left valve, USNM 167390, Yorktown Formation, Hampton City, Virginia, sample 37 of Hazel (1971a), USGS 24805, × 82.

Bensonocythere blackwelderi, new species

4. Exterior view female right valve, USNM 167400, Yorktown Formation, Hampton City, Virginia, sample 36 of Hazel (1971a), USGS 24907, × 112.

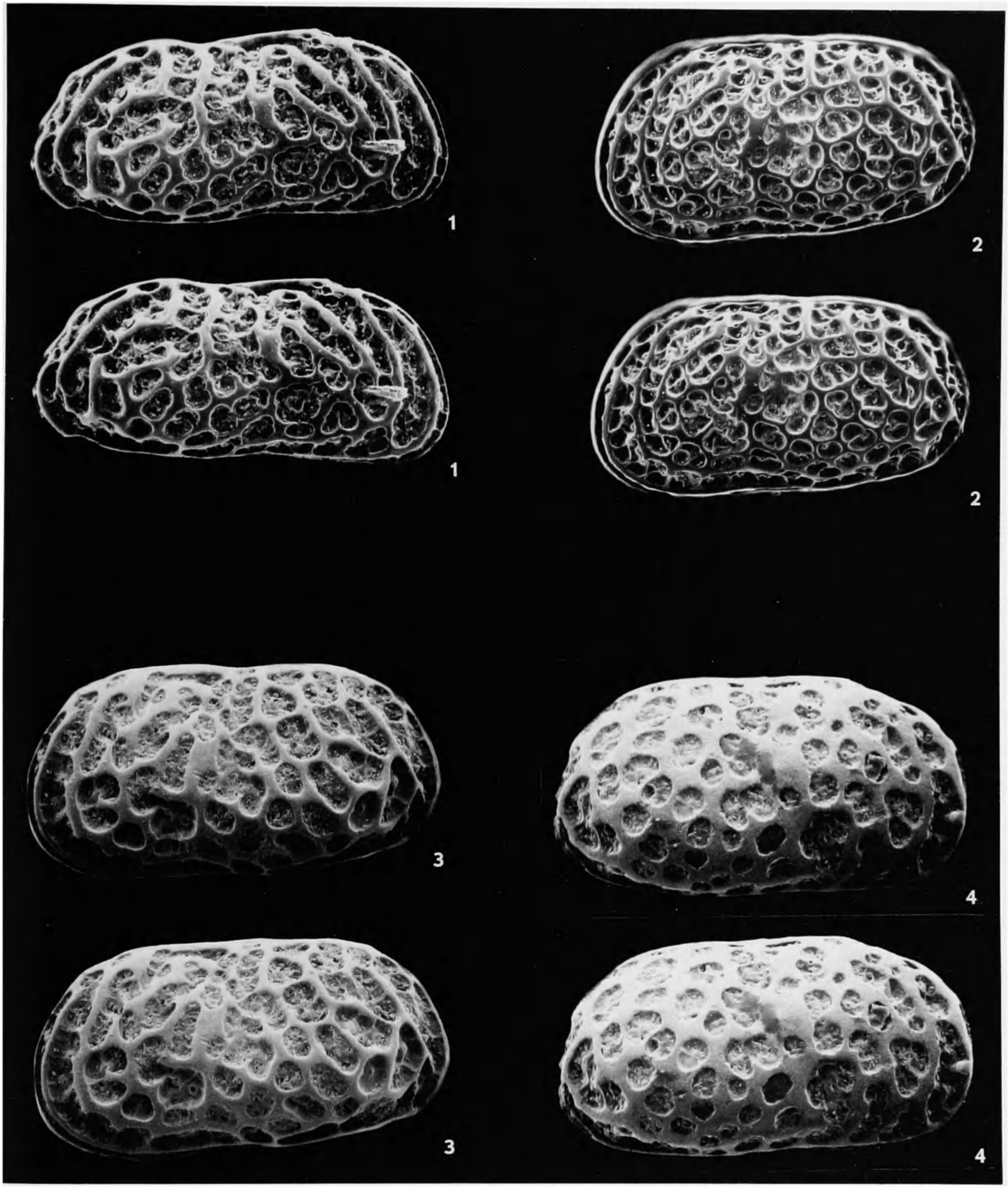

PLATE 38

"Pontocythere" sp. I

1. Exterior view female left vale, USNM 172523, Yorktown Formation, Petersburg, Virginia, sample 38 of Hazel (1971a), USGS 24908, × 90.

Bensonocythere bradyi, new species

2. Exterior view female left valve, USNM 191514, Yorktown Formation, Petersburg, Virginia, sample 38 of Hazel (1971a), USGS 24908, × 80.
4. Exterior view male left valve, USNM 167382, Yorktown Formation, Petersburg, Virginia, sample 38 of Hazel (1971a), USGS 24908, × 93.

Echinocythereis leecreekensis, new species

3. Exterior view male right valve, USNM 191509, Croatan Formation, sample 11 of this study, USGS 25376, × 70.