Phylogeny, Ontogeny, and Morphology of Living and Fossil Thaumatocypridacea (Myodocopa: Ostracoda)

LOUIS S. KORNICKER
and
I. G. SOHN

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ABSTRACT

Kornicker, Louis S., and I. G. Sohn. Phylogeny, Ontogeny, and Morphology of Living and Fossil Thaumatocypridacea (Myodocopa: Ostracoda). *Smithsonian Contributions to Zoology,* number 219, 124 pages, 93 figures, 14 tables, 1976.—A study of the ontogeny of the Thaumatocyprididae revealed that most species in the family have six juvenile growth stages. Each growth stage is described and illustrated. A table is presented for the identification of growth stages by using the number of claws on the caudal furca. Keys are presented for the identification of growth stages of *Thaumatoconcha radiata* and, also, for the identification of genera and species of the Thaumatocyprididae.

A phylogeny is derived for the higher taxa of Ostracoda using the Hennigian system. In this phylogeny the suborders Cladocopina and Halocypridina are referred to a new order Halocyprida.

The following new taxa are described and illustrated: *Thaumatomma piscifrons,* new genus, new species, from the Permian of Idhra, Greece, *Danielopolina carolynae,* new genus, new species, from the South Atlantic Ocean, and *Thaumatoconcha radiata,* new genus, new species, *T. caraionae,* new species, *T. elongata,* new species, *T. hessleri,* new species, *T. polythrix,* new species, *T. punctata,* new species, *T. sandersi,* new species, *T. tuberculata,* new species, and *Thaumatoconcha* species A, from the North Atlantic, South Atlantic, and South Pacific Oceans, and from within the Antarctic Convergence. All species are referred to the ostracode family Thaumatocyprididae (superorder Myodocopa). Supplementary descriptions and illustrations are presented of all previously described living and fossil genera and species of Thaumatocyprididae and some genera and species of the Paleozoic superfamily Entomoconchacea.

It is hypothesized that during the Jurassic period, representatives of the Thaumatocyprididae lived on the continental shelves of what is now Europe; then, after the Jurassic, the group migrated down the continental slope in response to competitive pressures. Their descendants survive today in bathyal and abyssal depths of the world's oceans and, in one instance, in a marine cave in Cuba.

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Contents

Phylogeny, Ontogeny, and Morphology of Living and Fossil Thaumatocypridacea (Myodocopa: Ostracoda)

Louis S. Kornicker and I. G. Sohn

Introduction

This study is based on Ostracoda in the superfamily Thaumatocypridacea. The nominate subfamily, the Thaumatocyprinae Müller, 1906, was established for *Thaumatocypris echinata* Müller, 1906. The species was based on six specimens collected at a depth of 1100 m near Indonesia. Since then, only one additional specimen of the type-species (Poulsen, 1969), one specimen of a new living species (Danielopol, 1972), and Jurassic fossils belonging in two new species (Triebel, 1941; Bartenstein, 1949) have been referred to *Thaumatocypris*. Therefore, it was unexpected, indeed, when more than 2300 specimens of living thaumatocyprids were obtained from 20 benthic samples. These were collected by the research vessels *Atlantis II, Eltanin, Glacier,* and *Vema* during the years 1958–1971, between 32°15′48″N and 70°10′S, and from depths of 587 m to 4758 m in the Atlantic and Pacific Oceans, and from within the Antarctic Convergence (Figure 1). These collections provided us the opportunity to study in detail the morphology, ontogeny, and phylogeny of this interesting group (Figure 2), which Skogsberg (1920:86) considered in many respects to be the most primitive among the halocyprids. In addition, the collections afforded us the opportunity to review the fossil record of the thaumatocyprids and related groups.

Concurrently, we recovered silicified Permian members of this superfamily from Idhra, Greece. Based on this wealth of material, we describe and illustrate ten new species in three new genera, supplement the descriptions and illustrations of the known species, and propose a phylogeny for the Myodocopa, including the Paleozoic superfamily Entomoconchacea (Figure 2).

Methods.—Standard methods of preparation for SEM micrography were used. Most of the specimens of *Thaumatoconcha radiata,* new species, and *T. tuberculata,* new species, were air-dried prior to SEM preparation. The carapaces of most of the other species collapsed on being dried in air because they were poorly calcified, therefore, they were freeze-dried, rather than air-dried. During the freeze-drying process many of the carapaces became distorted, and in some instances, parts of the outer shell layer flaked off (Figure 23). Micrographs of these specimens are mainly for the purpose of documenting the details of the ornamentation on the carapaces. The original shape of each carapace is shown by camera lucida drawings of the undissected specimen immersed in glycerin. Equipment used to collect the samples is listed in the Station Data (p. 21). Holocene specimens have been deposited in the Division of Crustacea, Department

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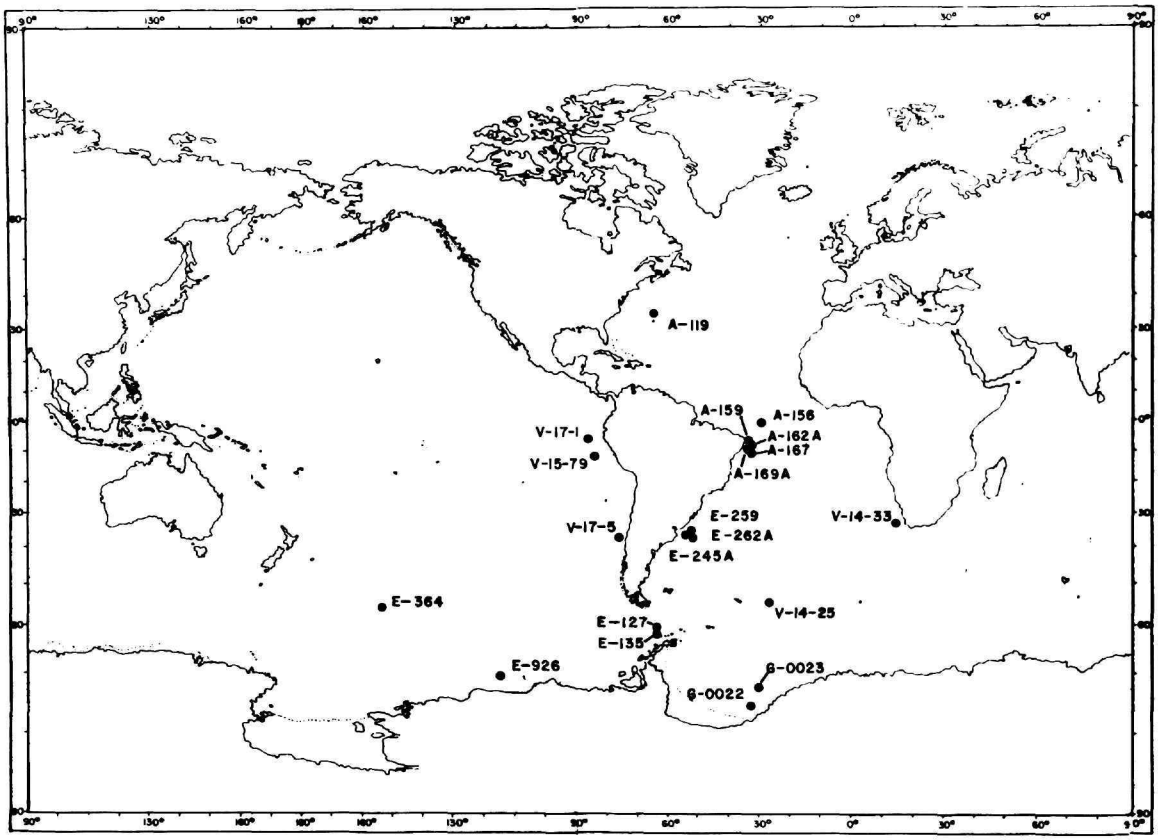


FIGURE 1.—Map showing locations of stations at which new species of living *Thaumatoconcha* and *Danielopolina* were collected. (A = *R. V. Atlantis II*, E = *USNS Eltanin*, G = *USCGC Glacier*, V = *R. V. Vema*)

of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution; Permian specimens have been deposited in the Department of Paleobiology of the same museum (under the acronym USNM for the former United States National Museum).

ACKNOWLEDGMENTS.—We wish to thank Dr. Robert J. Menzies, Florida State University, Dr. Robert Hessler, University of California, Dr. Francisca Elena Caraion, Institute of Biological Sciences, Bucharest, Romania, and Dr. Howard Sanders and Mrs. Susan P. Garner, Woods Hole Oceanographic Institution, for the living thaumatocyprids, and Dr. R. E. Grant, Smithsonian Institution, for the Permian ostracodes. We gratefully acknowledge the assistance of the following colleagues for making available types and duplicates for study and illustrations: Dr. Torben Wolff, Zoological Museum, University of Copenhagen, for the Poulsen material; Dr. D. Danielopol, Osterreische Akademie der Wissenschaften, Limnologisches Institute, Wien, Austria, for unpublished drawings of a species from Cuba; Dr. Heinz Malz, Natur-Museum Senckenberg, West Germany, for a paratype and duplicates of Jurassic species; Dr. R. H. Bate, British Museum (Natural History), London, for specimens of Entomoconchacea; Dr. Peter H. von Bitter, Royal Ontario Museum, Toronto, Canada, for three specimens of *Entomoconchus scouleri* McCoy, 1839, from England; Dr. M. J. Copeland, Geological Survey of Canada, Ottawa, for specimens of Entomoconchacea; Dr. R. S. Laub, Buffalo Museum of Science, for all the specimens of the Oncotechmoninae.

We thank Dr. M. L. Jones and Ms. A. Cohen,

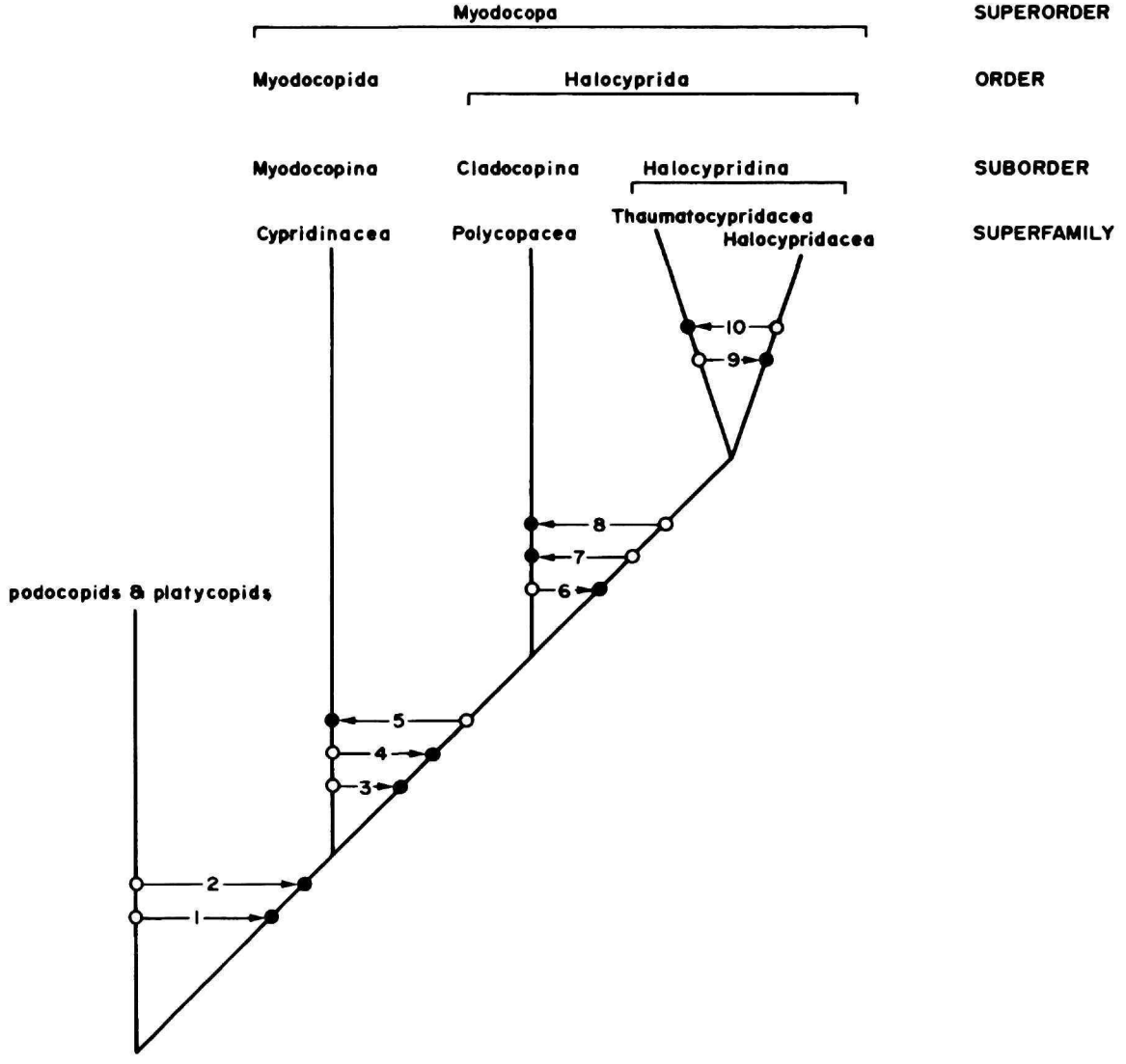


FIGURE 2.—Phylogeny of the superorder Myodocopa. Pleisiomorphic (ancestral) character states are indicated by open circles; apomorphic (derived) character states are indicated by filled-in circles. Numbers refer to numbered morphological characters referred to in text.

Smithsonian Institution, and Dr. J. M. Berdan, U.S. Geological Survey, for reviewing the paper; Dr. Donald R. Whitehead, Smithsonian Institution, for assistance in the Hennigian analysis; Joan Horn, Smithsonian Institution Press, for editing and preparing the manuscript; and W. R. Brown and M. J. Mann, Smithsonian Institution, for taking the scanning electron micrographs. R. H. McKinney, U.S. Geological Survey, took the light photographs of fossil carapaces; the negatives were printed by H. E. Mochizuki, U.S. Geological Survey. Carolyn B. Gast prepared the drawings of the valves and

appendages illustrated in Figures 26–32, 35, 44, 47, 54, 56, 60, 62, 69, 71, and 74; Mr. Paul Mazer and Mr. Jack R. Schroeder prepared the remaining illustrations; freeze-drying of specimens for the SEM was done in the Smithsonian Institution laboratory of Mr. Roland Hower; transmitted light photographs were made by Mr. Victor Kranz, Smithsonian Institution.

Phylogeny

Using the principles proposed by Hennig (1966) we have attempted to derive a phylogeny for the cypridinids, cladocopids, thaumatocyprids, and halocyprids. The selected morphological characters used in the analysis are designated in Figure 2 and are discussed below. The relative recency of a common ancestor is the basis for phylogenetic relationship in the Hennigian system (Kavenaugh, 1972: 119). Evidence of phylogenetic relationship (monophyly) is the possession of the same apomorphic (derived) character state, a condition termed "synapomorphy" as the result of a transformation series. Possession of the same plesiomorphic (primitive) character state, a condition termed "symplesiomorphy," is not evidence of phylogenetic relationship in the Hennigian system. It is not always clear whether a particular character state is plesiomorphic or apomorphic. In general, in this analysis, characters widespread in taxa other than the sister groups being evaluated are considered plesiomorphic; when complex structures are less widespread than simpler ones, they are considered to have been derived from the simpler ones.

We use only a few morphological characters, consequently the proposed phylogeny is necessarily tentative. Many available morphological characters were not used because of the inability to justify a decision whether a character state is apomorphic or plesiomorphic. Additional information is needed to confirm the proposed phylogeny. For example, we conclude that the thaumatocyprids and halocyprids are more closely related to each other than to the cladocopids. But, as discussed on page 5, if the transverse folds on the posterior part of the body of thaumatocyprids (Figure 21) and cladocopids (Müller, 1894, pl. 7: fig. 50) should prove to be apomorphic rather than plesiomorphic, the thaumatocyprids could be more closely related to the cladocopids than to the halocyprids.

Superordinal Dichotomy

1. Telson: The well-developed furcae of the Myodocopa (Cypridinacea, Thaumatocypridacea, Halocypridacea, and Cladocopacea) may represent a telson formed by the extension of the terminal body somite (Bowman, 1971:169). A telson, as defined above, is absent in the platycopids. In the podocopids, it is either absent or represented by a small process, such as that on *Loxoconcha* Sars, 1866 (Bowman, 1971:168, fig. 12). According to Bowman (1971:165), the telson may have been derived from a simple anal flap. Therefore, we consider the well-developed telson of the Myodocopa to be synapomorphic.

2. Uropod: According to Bowman (1971:169) the caudal rami ventral to the anus could be interpreted as uropods, paired appendages of the anal somite. Such uropods are absent on the Myodocopa, but are present on all the platycopids, and with few exceptions on the podocopids. Consequently, we consider the loss of the uropods on the Myodocopa to be synapomorphic, and the loss on some of the podocopids to be convergent. The phylogenetic relationships of the podocopids and platycopids are outside the scope of the present study.

Ordinal Dichotomy

3. Median eye: A median eye is present on all members of the Myodocopida and on most of the Podocopa. Skogsberg (1920:101) considered the presence of a median eye to be primitive. The presence of a median eye is considered herein to be plesiomorphic, and its absence to be apomorphic. The absence of a median eye in the Halocyprida (Cladocopina and Halocypridina, see Figure 2) is treated here as synapomorphic.

4. Male copulatory organ: The male copulatory organ has probably evolved from an appendage (Skogsberg, 1920:77, 96). Appendages of Ostracoda are mostly paired. Therefore, a paired copulatory organ is plesiomorphic and an unpaired copulatory organ is apomorphic. The presence of an unpaired copulatory organ in males of the Halocyprida is treated herein as synapomorphic. The paired copulatory organ of the Myodocopida is plesiomorphic.

5. Sixth limb: The sixth limb of the Halocypridina is elongate, formed of many distinct joints. Skogsberg (1920:68) considered the 6th limb

of the Halocypridacea to be primitive. The elongate 6th limb is considered here to be plesiomorphic. The flat, poorly jointed 6th limb of the Myodocopida is treated herein as apomorphic. The absence of a 6th limb in the Cladocopina (not shown in Figure 2) is also an apomorphic condition, but this condition is considered herein to have evolved after the lineage containing the Halocyprida had diverged from the Myodocopida.

Subordinal Dichotomy

6. Maxilla: Skogsberg (1920:100) stated, "In Polycopidae, especially in a number of forms belonging to this family, we find a maxilla of so simple a type that from it we can quite naturally derive the types found in other families." The maxilla of the Cladocopina is distinctly biramous, a plesiomorphic character state. The uniramous maxilla of the Halocypridina is treated herein as a synapomorphy. Except for having a small exopodite, the maxilla in some families of the Myodocopina (Cypridinidae, Philomedidae) is similar to that of the Halocypridina. We consider this similarity to be convergence. In the myodocopid family Cylindroleberididae the maxilla is uniramous but of different form than that in the Halocypridina.

7. Sixth and seventh limbs: The absence of 6th and 7th limbs in the Cladocopina is clearly apomorphic; their presence in the Halocypridina and the Myodocopina is considered symplesiomorphic.

8. Male copulatory organ: As previously stated in "4," the copulatory organ is paired in the Myodocopida and is single in the Halocyprida. The copulatory organ of the Cladocopina is complex, relative to that of the Halocypridina. We consider the paired copulatory organ to have evolved into a single relatively simple organ from which a single complex organ evolved. Therefore, the more complex copulatory organ of the Cladocopina is apomorphic. The simple copulatory organ of the Halocypridina is considered to be symplesiomorphic.

Superfamilial Dichotomy

9. First antenna: According to Skogsberg (1920: 99) the 1st antenna of the Thaumatocypridacea bears a greater resemblance to that of the podocopids than to the Halocypridacea. The elongate 1st antenna of the Thaumatocypridacea with 7 or 8 joints and the Cypridinacea with 8 joints, is clearly plesiomorphic, compared with the shorter 1st antenna, with fewer than 7 joints, of the Halocypridacea. The 1st antenna of the Halocypridacea is treated herein as apomorphic. The reduction of joints to 4 in the Polycopacea is considered to be convergent.

10. Heart: Skogsberg (1920:75, 101) considered the presence of a heart to be primitive. The presence of a heart in the Halocypridacea is treated as plesiomorphic, and the absence of a heart in the Thaumatocypridacea is treated as apomorphic. Absence of the heart is correlated with small size: platycopids, podocopids, and the Cladocopidina are generally small, as are some of the fossil Thaumatocypridacea. Therefore, the absence of a heart in the podocopids, platycopids, Polycopacea, and the Thaumatocypridacea is considered to be due to repeated convergence.

Characters Not Used

Lateral eye: A lateral eye is absent in the Halocyprida and the deep-sea Myodocopida, but is present in most other Myodocopida. Skogsberg (1920: 101) interpreted the lateral eye of ostracodes to be primitive. Manton (1969b:R23), however, stated that a compound eye would not be expected to occur in the earliest ancestral Crustacea, but she did not specifically mention the Ostracoda. The presence or absence of a lateral eye has not been used in our analysis. The absence of the lateral eye in the Halocyprida, if synapomorphic, would support our proposed classification.

Rostrum: The Thaumatocypridacea and the Cladocopina, as well as the podocopids and platycopids, are without a rostrum. The Halocypridacea and most of the Myodocopida have a rostrum. However, the edge of the valve blends sharply to form the rostrum of the Myodocopida and remains almost straight in the rostral area of Halocypridacea. We agree with Skogsberg (1920:71) that the rostra of these taxa are probably not homologous. Absence of the rostrum is a plesiomorphic condition, and the presence of nonhomologous rostra in Halocypridacea and Myodocopida is due to convergence.

Posterior of body: The posterior of the bodies of both the Thaumatocypridacea and the Cladocopina have transverse folds with spinous edges,

unlike the relatively smooth surface of the posterior of the Myodocopina and the Halocypridacea. The transverse folds are similar to those on the podocopid family Saipanettidae McKenzie, 1967 (McKenzie, 1968), but are not homologous with the "jointing" on the posterior of the body of the platycopids. The paucity of posteriors with transverse folds in taxa outside the Myodocopa suggests that the folds are apomorphic. If the presence of folds on the posterior of Cladocopina and the Thaumatocypridacea were considered as a synapomorphy, then the folds on the posterior of the Saipanettidae would be convergent. However, in this analysis we consider the folds to be plesiomorphic, possibly related to segments that were present in the bodies of the ancestral ostracode. We have not used this character in the formation of Figure 2 because additional data are necessary to resolve the problem. Whichever the apomorphic state may be, it must have arisen twice in the Myodocopa if our proposed phylogeny is correct.

Classification

The primary method recommended by Hennig (1966:185) for the absolute ranking of higher taxa is geologic age, or the time when the group separated from its sister group. The ranks recommended for taxa originating during specific geological ages are as follows (Hennig, 1966:184; Kavanaugh, 1972:125): phylum and subphylum, before the Cambrian; class, between the Cambrian and Devonian; order, between the Carboniferous and the Permian; family, between the Triassic and Early Cretaceous; tribe, between the Late Cretaceous and the Oligocene; genus, after the Miocene. In this system, a fossil species that became extinct at the end of the Permian would be representative of the "ordinal stage," as well as being a species (Hennig, 1966:192). Hennig (1966:190) pointed out that re-evaluation of the Ostracoda using the age criterion would require the elevation to higher rank of many genera. The genus *Bairdia* McCoy, 1844, for example, would require the rank of class because species are recorded as far back as the Devonian. We do not believe that the classification of the Ostracoda should be so drastically revised at this time, but do concur with Sharov (1966:2), Manton (1969a:R13), and Sohn (1972:B2) that the Ostracoda comprise a class.

We concur with Kozur (1972:5) that the Myodocopa, which were already present in the Devonian or earlier, should be treated as a superorder. We have retained the older name Myodocopa Sars, 1866, for the superorder rather than Myodocopamorphes Kozur, 1972. The Myodocopa does not include the Leperditicopida Scott, 1961, which was included by Kozur in the Myodocopomorphes. Sohn (1974) discussed the reasons for excluding the Leperditicopida from the Myodocopa.

We describe in this paper, from the Permian of Greece, the earliest known Thaumatocypridacea. Cladocopacea were also present in the Permian sample, showing that the time of origin of each superfamily was prior to the Permian. Therefore, the lineage containing these taxa must have separated from the Cypridinacea prior to the Permian. Indeed, if we are correct in our hypothesis (Kornicker and Sohn, in press) that the Silurian-to-Mississippian Entomoconchacea was ancestral to the Thaumatocypridacea, the lineage containing the Thaumatocypridacea would have had to diverge from the Cypridinacea in, or prior to, the Silurian. The Halocypridacea are not known before the Cretaceous, but we attribute the lack of earlier fossils to poor preservation of the fragile carapaces of halocyprids. Our proposed phylogeny requires that the Halocypridacea diverge from the Thaumatocypridacea prior to the Permian.

In our classification (Figure 2), the cypridinids are given the superfamilial rank Cypridinacea, the subordinal rank Myodocopina, and the ordinal rank Myodocopida. The cladocopids are given the superfamilial rank Polycopacea (new transfer, *ex* Polycopidae Sars, 1866) and the subordinal rank Cladocopina. The thaumatocyprids are given the superfamilial rank Thaumatocypridacea, and the halocyprids are given the superfamilial rank Halocypridacea. The superfamilies Thaumatocypridacea and Halocypridacea form the suborder Halocypridina. The suborders Cladocopina and Halocypridina form the Order Halocyprida.

The fossil Entomoconchacea may belong in the Halocypridina. We do not deal with the Entomozoacea, doubtfully referred by Sylvester-Bradley (1961:Q388) to the order Myodocopida, because they are poorly known and have no living representatives.

Pokorny (1964:176) considered the Thaumatocyprididae and Halocyprididae to be more closely

related to the Polycopidae (suborder Cladocopina) than to the Cypridinidae (suborder Myodocopina), anticipating our proposed joining of the Cladocopina and Halocypridina to form the order Halocyprida.

Ontogeny of *Thaumatoconcha radiata*, new species

NUMBER OF GROWTH STAGES.—Thirty-seven specimens, including representatives of all size classes, were removed from 1200 specimens of *Thaumatoconcha radiata*, new species, in a single sample (*R.V. Atlantis II* Cruise 60, station 245A). The selected specimens were measured and then dissected. The appearance of appendages and the spacing of clusters of the various sizes of carapaces plotted on a length-height graph (Figure 3) indicate that the sample contained 6 juvenile instars in addition to male and female adults of this species. Examination of all collections containing all the species of *Thaumatoconcha* did not produce any specimens whose carapace size or developmental stage indicated an A–7 growth stage in the genus. Growth factors are shown on Tables 2 and 3. The carapace

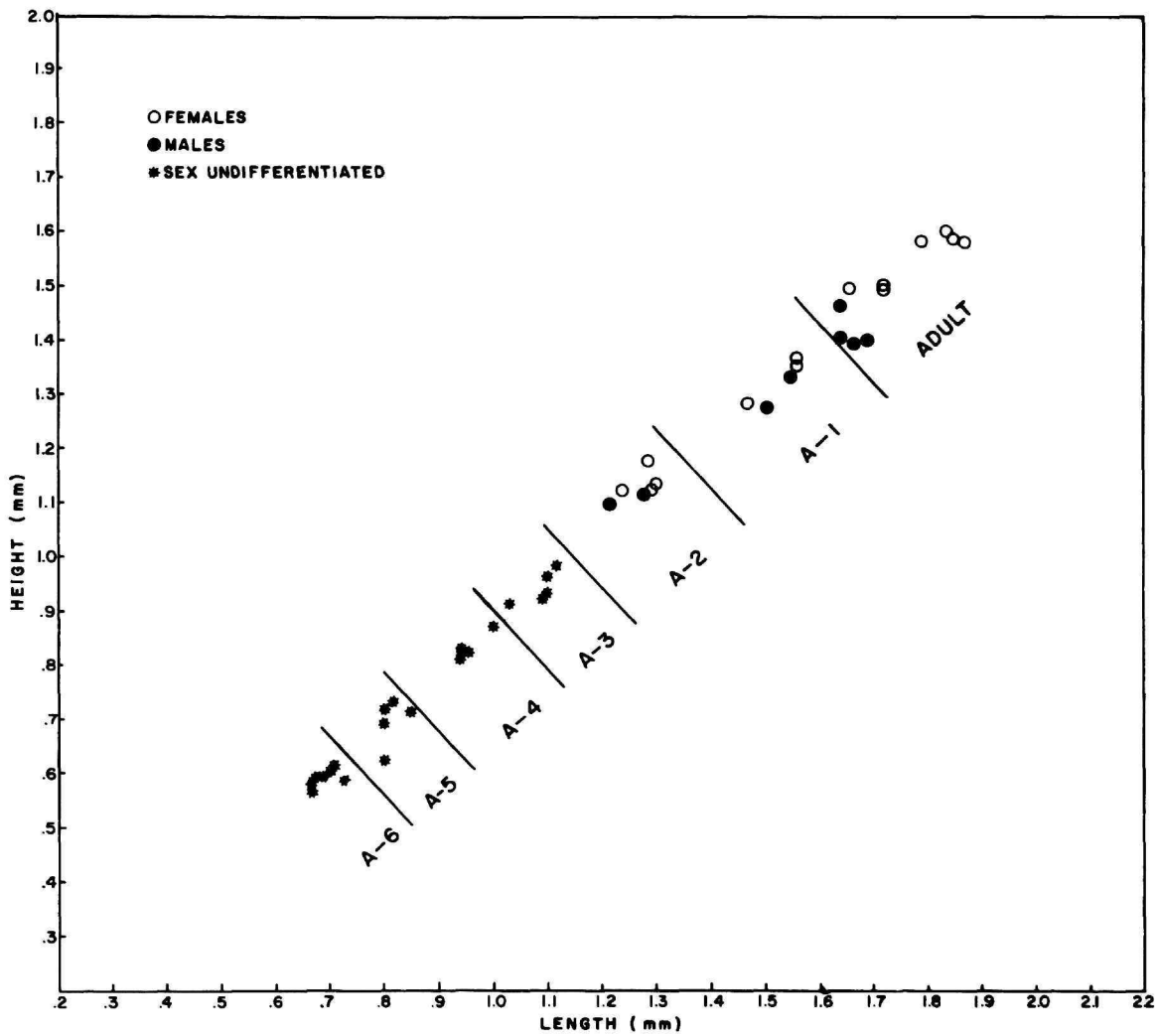


FIGURE 3.—Length-height distribution of growth stages of *Thaumatoconcha radiata*, new species.

TABLE 1.—Relationship between growth stages and number of short claws on each lamella of furcae of species in the THAUMATOCYPRIDIDAE

No. of short claws	Growth Stage	
	Danielopolina orghidani	All other species
0	n.d.	A–6
1	n.d.	A–5
2	n.d.	A–4
3	n.d.	A–3
4	Adult	A–2
5		A–1
6		Adult

n.d. = no data.

TABLE 2.—Average shell dimensions and calculated growth factors for females of *Thaumatoconcha radiata*, new species

Growth stage	Average length (mm)	Growth factor	Average height (mm)	Growth factor	Number of specimens
Adult	1.77		1.55		9
		1.13		1.14	
A–1	1.56		1.36		2
		1.22		1.19	
A–2	1.28		1.14		4
		1.17		1.21	
A–3 •	1.09		0.94		5
		1.14		1.13	
A–4 •	0.96		0.83		4
		1.19		1.20	
A–5 •	0.81		0.69		5
		1.17		1.17	
A–6 •	0.69		0.59		8

•Because males and females could not be distinguished for these early stages, males are also probably included in average dimensions.

length of the smallest specimens of *T. radiata* in the sample from station 245A varied from 0.67 to 0.73 mm, and the height from 0.56 to 0.60 mm. According to Mrs. Susan P. Garner, Woods Hole Oceanographic Institution (letter of 23 July 1973), this sample is from the residue retained on a 0.297 mm screen. Using the growth factor calculated for this species, an A–7 growth stage, if present, would have been retained on the screen. The sample is from a depth of 2707 m, considered to be a low energy, stable environment. Reproduction is assumed to be nonseasonal, and migration negligible. Therefore, we conclude that the 7 stages represent the complete ontogeny of *T. radiata* and, most likely, the other species in the genus.

The furca of living thaumatocyprids bears 2 long anterior claws followed by short claws. Except for *Danielopolina orghidani* (Danielopol, 1972), the furca of adults bears 6 short claws, and the number

TABLE 3.—Average shell dimensions and calculated growth factors for males of *Thaumatoconcha radiata*, new species

Growth stage	Average length (mm)	Growth factor	Average height (mm)	Growth factor	Number of specimens
Adult	1.66		1.41		4
		1.08		1.08	
A–1	1.53		1.30		2
		1.22		1.18	
A–2	1.25		1.10		2
		1.15		1.17	

A–3 to A–6: sex not differentiated and same as in Table 2.

TABLE 4.—Order of appearance of appendages of *Thaumatoconcha radiata*, new species

Growth stage	Rod-shaped organ	First antenna	Second antenna	Mandible	Maxilla	Fifth limb	Sixth limb	Seventh limb	Copulatory appendage (male only)
A–6	x	x	x	x	x	x	absent	absent	absent
A–5	x	x	x	x	x	x	rudimentary•	absent	absent
A–4	x	x	x	x	x	x	reduced	absent	absent
A–3	x	x	x	x	x	x	x	x	absent
A–2	x	x	x	x	x	x	x	x	reduced
A–1	x	x	x	x	x	x	x	x	reduced
Adult	x	x	x	x	x	x	x	x	well-developed

• 6th limb observed on some specimens as a minute lobe (anlage) without bristles.
x = present.

of short claws is decreased by one in each previous growth stage (Table 1). Thus, the number of short claws on each lamella of the furca is diagnostic of the growth stages in living species of the Thaumatocyprididae. The furca of the adult *D. orghidani*, a cave form, bears only 4 short claws; the number of short claws on the furcae of its juvenile is unknown.

DEVELOPMENT OF GROWTH STAGES.—The earliest juvenile, the A–6 instar, does not have the 6th and 7th limbs; this is discussed under the description of *Thaumatoconcha radiata*. The 6th limb of the A–5 instar is a small bare lobe; this limb has many bristles on the A–4 instar. The 7th limb appears on the A–3 instar. The copulatory limb of the male appears on the A–2 instar. The male cannot be recognized in earlier instars. Investigation of juve-

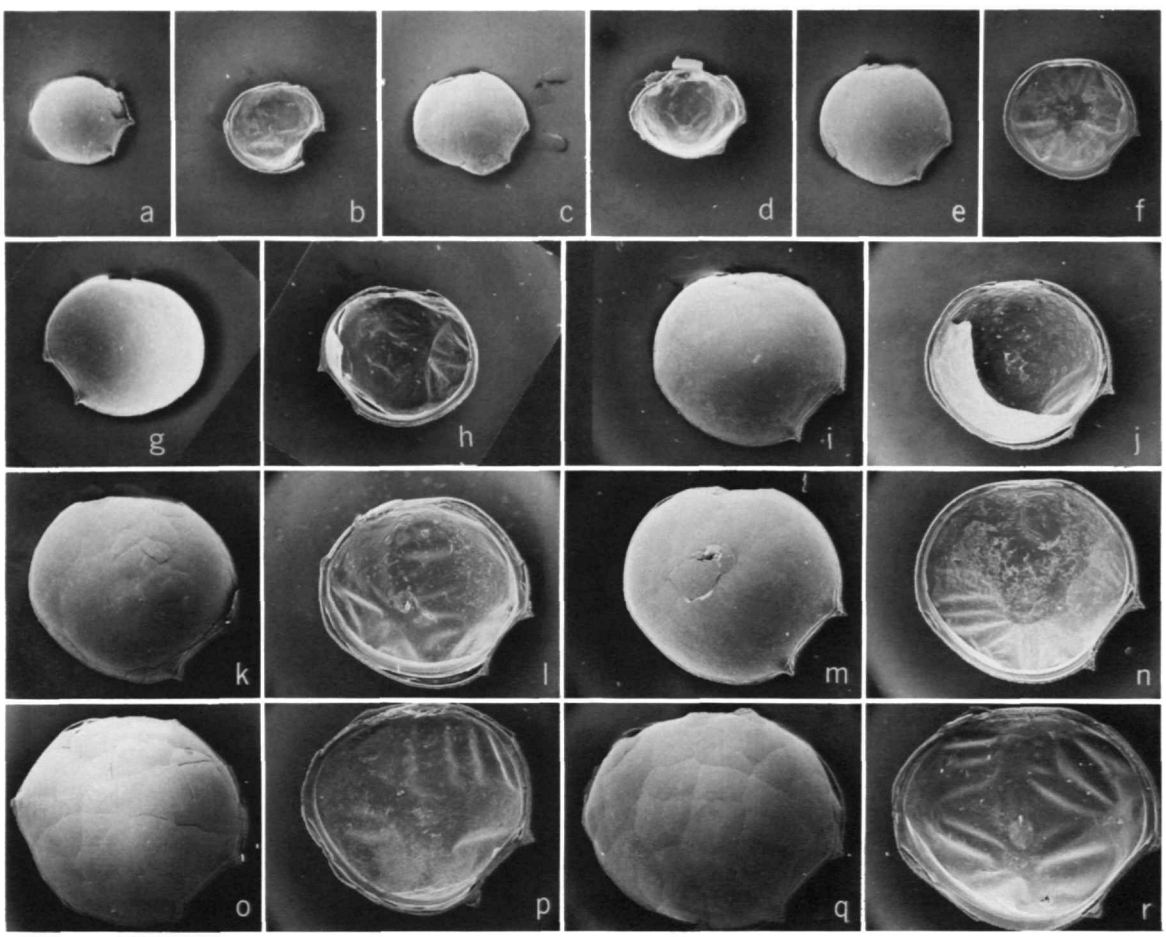


FIGURE 4.—*Thaumatoconcha radiata*, new species, paratypes, growth series: *a,b*, A–6 instar, USNM 143753LL, right valve (outside) and left valve (inside); *c,d*, A–5 instar, USNM 143753QQ, right valve (outside) and left valve (inside); *e,f*, A–4 instar, USNM 143753RR, right valve (outside) and left valve (inside); *g,h*, A–3 instar, USNM 143753II, left valve (outside) and right valve (inside); *i,j*, A–2 female, USNM 143753PP, right valve (outside) and left valve (inside); *k,l*, A–1 male, USNM 143753MM, right valve (outside) and left valve (inside); *m,n*, A–1 female, USNM 143753DD, right valve (outside) and left valve (inside); *o,p*, adult male, USNM 143753JJ, right valve (outside) and left valve (inside); *q,r*, adult female, USNM 143753KK, right valve (outside) and left valve (inside). (All × 50, photos reduced to 42 percent.)

niles selected at random from other species of *Thaumatoconcha* indicates that the order of appearance and general development of limbs conform to those of *T. radiata.*

In general, the morphology of the carapace of the instars is similar to that of the adult (Figures 4–6). It was not possible to differentiate males and females in A–6 to A–3 instars. The average growth factor of the shell excluding the growth factor between the preadult and adult male is 1.17. This estimated factor was obtained by averaging both the length and height factors between male and female instars (Tables 2, 3). The growth factor between the preadult and adult male is quite low, 1.08 for both length and height growth factors.

ORDER OF APPEARANCE OF APPENDAGES (Table 4). —The A–6 instar bears a rod-shaped organ, 1st and 2nd antennae, mandibles, maxillae, and 5th limbs. The 6th limb appears as a small lobe without bristles *(anlage)* on the A–5 instar (this was observed on at least 1 side of specimens examined, but was not always observed on both sides of the same specimen). The 6th limb has many bristles on the A–4 instars. The 7th limb appears on the A–3

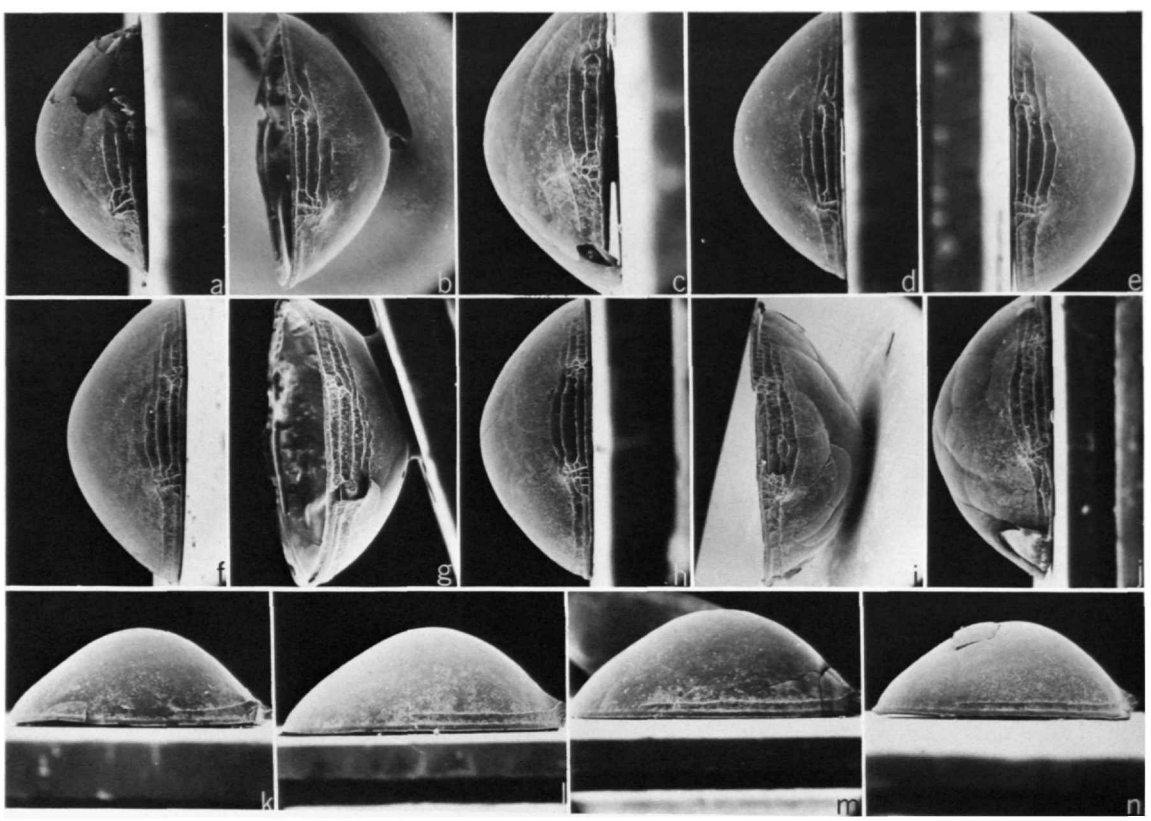


FIGURE 5.—*Thaumatoconcha radiata,* new species, paratypes, growth series. Anterior views: *a,* A–6 instar, USNM 143753LL, right valve, × 150; *b,* A–5 instar, USNM 143753QQ, left valve, × 135; *c,* same, right valve, × 150; *d,* A–4 instar, USNM 143753RR, right valve, × 115; *e,* A–3 instar, USNM 143753II, left valve, × 105; *f,* A–2 female, USNM 143753PP, right valve, × 85; *g,* A–1 male, USNM 143753MM, left valve, × 78; *h,* A–1 female, USNM 143753DD, right valve, × 70; *i,* adult male, USNM 143753JJ, left valve, × 65; *j,* adult female, USNM 143753KK, right valve, × 63. Ventral views: *k,* A–4 instar, USNM 143753RR, right valve, × 100; *l,* A–2 female, USNM 143753PP, right valve, × 80; *m,* A–1 male, USNM 143753MM, right valve, × 60; *n,* A–1 female, USNM 143753DD, right valve, × 60. (Photos reduced to 42 percent.)

instar. The copulatory limb of the male appears on the A–2 instar.

First antenna (Figure 7): This limb contains 8 joints in instars A–6 to A–1 and on adults, but only on the adult male is the 4th joint separated from the 3rd by a distinct suture. The 3rd and 6th joints are without bristles in both instars and adults. Remaining joints have fewer bristles in early instars than in late instars and adults (Table 5). An exception is the 4th joints on female appendages, which

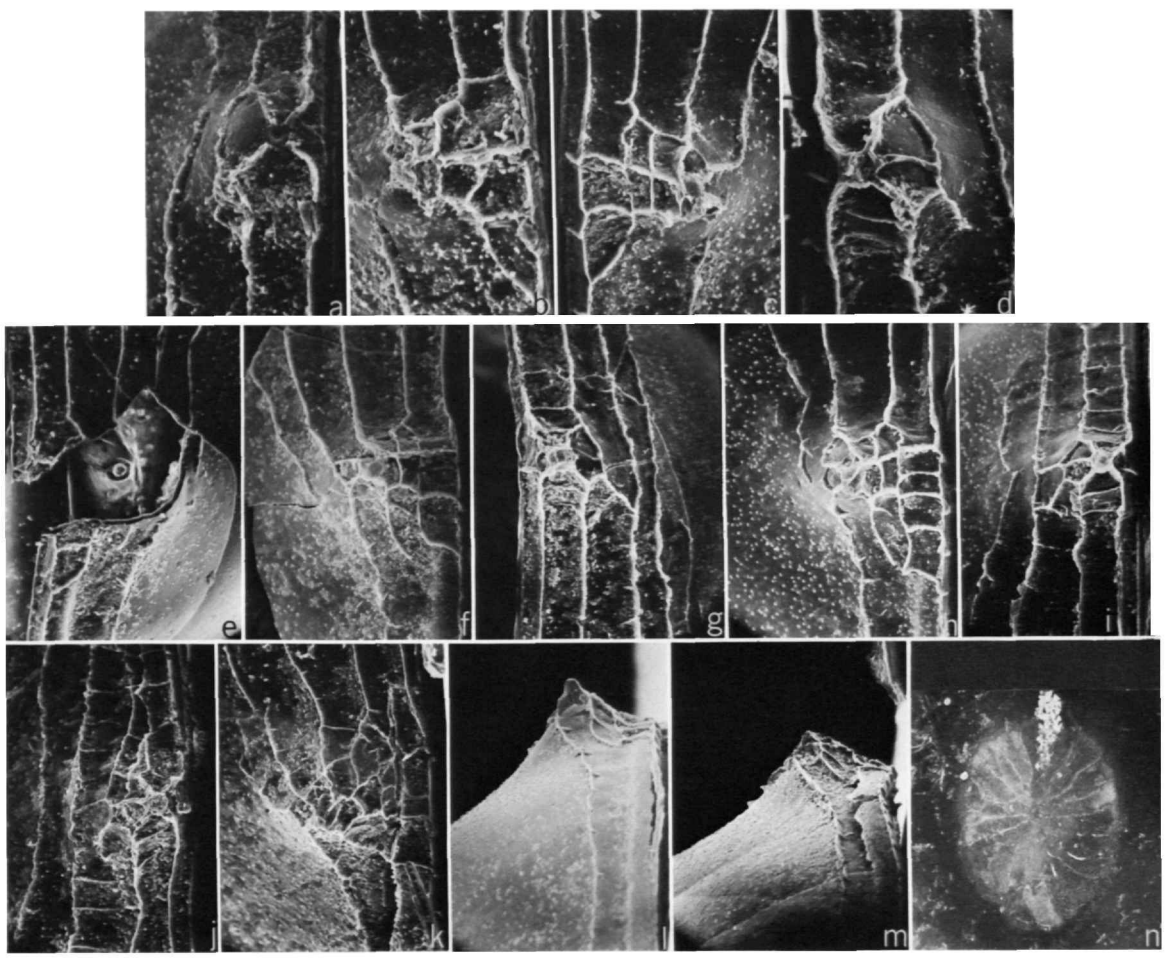


FIGURE 6.—*Thaumatoconcha radiata*, new species, paratypes, growth series, ornamentation: *a*, A–5 instar, USNM 143753QQ, upper anteroventral protuberance of right valve, × 690; *b*, same, lower protuberance, × 690; *c*, A–3 instar, USNM 143753II, lower anteroventral protuberance of left valve, × 470; *d*, same, upper protuberance, × 680; *e*, A–1 male, USNM 143753MM, lower anteroventral protuberance of left valve, × 300; *f*, same, right valve, × 300; *g*, same, upper protuberance of left valve, × 300; *h*, A–1 female, USNM 143753DD, lower anteroventral protuberance of right valve, × 300; *i*, same, upper protuberance, × 300; *j*, adult female, USNM 143753KK, upper anteroventral protuberance of right valve, × 300; *k*, same, lower protuberance, × 300; *l*, A–1 female, USNM 143753DD, anterior end of right valve, ventral view, × 225; *m*, adult female, USNM 143753KK, anterior end of right valve, ventral view, × 235; *n*, same specimen, adductor muscle attachment scars of left valve, inside view, × 320 (white particles in upper middle are debris). (Photos reduced to 45½ percent.)

TABLE 5.—Number of bristles on joints of first antenna of *Thaumatoconcha radiata*, new species

Growth stage	First joint (lateral/dorsal)			Second joint (ventral/dorsal)			Third joint	Fourth joint (ventral)			Fifth joint (ventral)			Sixth joint	Seventh joint (ventral/dorsal)			Eighth joint (terminal)		
	Female	Sex unknown	Male	Female	Sex unknown	Male		Female	Sex unknown	Male	Female	Sex unknown	Male		Female	Sex unknown	Male	Female	Sex unknown	Male
A–6		0/0			0/0		0		0			1		0		1/1			2	
A–5		0/1			0/0		0		0			1		0		1/1			2	
A–4		0/1			0/1		0		0			1		0		2/1			3	
A–3		1/1			0/1		0		1–2			2		0		2–3/1			3	
A–2	1/1		1/1	1/1		1/1	0	1–2		2	3		3	0	2/1		2–3/1	3		3
A–1	1/1		1/1	1/1		1/1	0	1[a]		2[b]	3		3–4	0	2/1		2/1	3		3
Adult	1/1		1/1	1/1		1/1	0	0–1		2	3		3	0	2/1		2/1	3		3

[a] USNM 143753F also with 2 terminal broad flat transparent bristles (left limb only).
[b] One minute inner bristle present on some specimens in addition to 2 longer bristles.

FIGURE 7.—*Thaumatoconcha radiata*, new species, paratypes, developmental stages of the juvenile 1st antenna (rod-shaped organ shown in *a*, *c*, *d*, *g*): *a*, A–6, USNM 143753D, left limb, medial view; *b*, A–5, USNM 143753G, left limb, medial view; *c*, A–4, USNM 143753U, left limb, lateral view; *d*, A–3, USNM 143753L, left limb, lateral view; *e*, A–2 female, USNM 126136B, left limb, lateral view; *f*, A–2 male, USNM 126136A, left limb, lateral view; *g*, A–1 male, USNM 143753MM, right limb, medial view; *h*, A–1 female, USNM 143753F, left limb, medial view. (Scale in micrometers.)

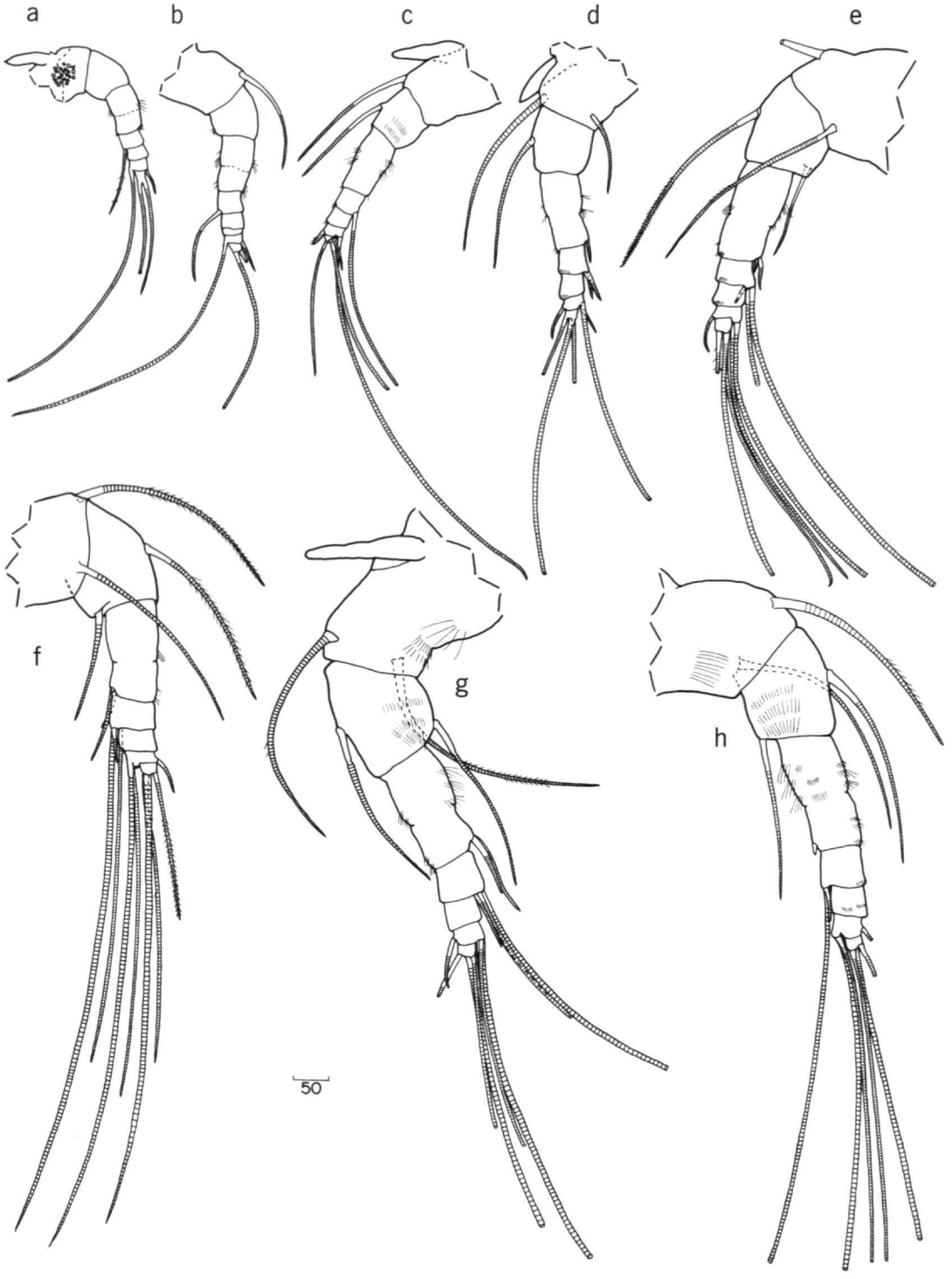

a
b
c
d
e
f
g
h
50

TABLE 6.—Number of bristles on endopodite and 9th exopodite joint of 2nd antenna of *Thaumatoconcha radiata*, new species

Growth stage	Endopodite									Exopodite		
	First joint (ventral/dorsal)			Second joint (lateral/ventral)			Third joint (terminal)			Ninth joint		
	Female	Sex unknown	Male	Female	Sex unknown	Male	Female	Sex unknown	Male	Female	Sex unknown	Male
A–6		0/0			0/1			4			1[b]	
A–5		1/0			0/1			4			1[b]	
A–4		1/0			0/2			4			1[b]	
A–3		1/1			0/3			4			2	
A–2	1/2		1/2	1/4		1/4	4–5		4–5	2		2
A–1	1/2		1/2	1/4		1/4	5		5 (rarely 4)	2		2
Adult	1/2		1/2	1/4		1/4	3 (rarely 2 or 4)		2[a]	3		3

[a] Third joint consists of hook-like process with 2 minute spines (bristles) at tip.
[b] Eighth and 9th joints fused, with total of 2 bristles on fused joints.

TABLE 7.—Number of claws on each lamella of the furca of *Thaumatoconcha radiata*, new species

Growth stage	Long anterior claws	Short middle claws	Posterior process
A–6	2	0	1
A–5	2	1	1
A–4	2	2	1
A–3	2	3	1
A–2	2	4	1
A–1	2	5	1
Adult	2	6	1

TABLE 8.—Characters of the male copulatory appendage of *Thaumatoconcha radiata*, new species

Growth stage	Anterior lobe	Posterior lobe	
	No. of teeth	No. of bristles	Shape
A–2	1	1	sausage
A–1	3–4	3	sausage
Adult	8	3 (hair-like)	styliform

A–6 to A–3, copulatory appendage absent.

have no bristles on instars A–6 to A–4 (sex undifferentiated), at least 1 bristle on instars A–3 to A–1, and may have no bristles on the adult (some adults have 1 bristle). The 2 bristles on the 4th joint of the male appendage are much longer on adults than on instars A–1 and A–2. The male A–1 instars have 4 bristles on the 5th joint of some specimens, whereas the adults have only 3, but this may be the result of intraspecific variability. The presence of more bristles on the 7th joints of A–2 and A–3 instars than on adults may also be attributed to intraspecific variability.

Second antenna (Table 6): Exopodite: The 8th and 9th joints are fused on instars A–6 to A–4 and are separated by a suture on instars A–3 to adults (Figure 27*a*). The fused 8th and 9th joints on instars A–6 to A–4 bear 1 bristle; the 9th joints on instars A–3 to A–1 bear 2 bristles, and the 9th joints on adults bear 3. Endopodite (Figure 8): 3 joints are present on all instars and on adults. Fewer bristles are present on joints 1 and 2 of early instars than on later instars and adults, but the full accompaniment of bristles is reached on instar A–2. The 3rd joint is unusual in that the adult appendage bears

fewer bristles than that of the A–1 instar. This is especially noticeable in the male, because the adult bears on the 3rd joint a hook-like process which might represent a bristle, but could also be an extension of the joint.

Mandible, maxilla, fifth limb: General morphology on all juvenile instars similar to that of the adult female (Figures 28, 29).

Sixth limb: This limb first appears in instar A–5 as a lobe without bristles (Figure 34*d*). It is small, but with numerous bristles on the A–4 instar, and is fully developed on the A–3 instar to adult (Figure 30).

Seventh limb: This limb first appears in the A–3 instar and has 2 bristles like on the adult (Figures 31*a*, 34*i*).

Furca: The claws of the furca may be divided into long anterior claws, short middle claws, and a posterior process (Figure 31*c*). Instars A–6 to adults bear 2 long anterior claws and 1 posterior process. The number of short middle claws increases from 0 on the A–6 instar to 6 on the adult (Figures 31*c*, 34*b,f,n*). One short claw is added in each instar (Table 7).

Rod-shaped organ: This organ is 1-jointed or weakly 2-jointed in instars A–6 to adults (Figures 31*d*, 34*c,e,h,l,p,u,w,aa,bb,ee,ff*). The tip is evenly rounded on adults; however, both rounded and tapered tips were observed on instars.

Posterior of body (Figures 20*a*, 21*a*), lips (Figure 31*e–g*): General morphology similar to that on adults.

Male copulatory appendage: The A–2 instar is the earliest stage on which the copulatory appendage was observed (Figure 34*o,r*). The anterior lobe bears 1 spine-like terminal tooth on the A–2 instar, 3 or 4 minute teeth on the A–1 instar (Figure 34*hh, ii*), and about 8 larger teeth on the adult (Table 8;

Key to the Developmental Stages of *Thaumatoconcha radiata*, new species

1. Furca without short middle claws; 1st joints of 1st antenna and endopodite of 2nd antenna without bristles ..... A–6 instar
1′. Furca with short middle claws; 1st joints of 1st antenna and endopodite of 2nd antenna with at least 1 bristle 2
2(1′). Furca with 1 short middle claw; 2nd joint of 1st antenna without bristles; 2nd joint of endopodite of 2nd antenna with 1 ventral bristle; 6th limb, if present, without bristles ..... A–5 instar
2′. Furca with more than 1 short middle claw; 2nd joint of 1st antenna with 1 dorsal bristle; 2nd joint of endopodite of 2nd antenna with more than 1 ventral bristle; 6th limb with numerous bristles 3
3(2′). Furca with 2 short middle claws; 1st joint of 1st antenna without lateral bristle; 1st joint of endopodite of 2nd antenna without dorsal bristles, 2nd joint with 2 ventral bristles; 7th limb absent ..... A–4 instar
3′. Furca with more than 2 short middle claws; 1st joint of 1st antenna with 1 lateral bristle; 1st joint of endopodite of 2nd antenna with dorsal bristles, 2nd joint with more than 2 ventral bristles; 7th limb present 4
4(3′). Furca with 3 short middle claws; 2nd joint of 1st antenna without ventral bristle; 1st joint of endopodite of 2nd antenna with 1 dorsal bristle, 2nd joint with 3 ventral bristles and no lateral bristle ..... A–3 instar
4′. Furca with more than 3 short middle claws; 2nd joint of 1st antenna with 1 ventral bristle; 1st joint of endopodite of 2nd antenna with 2 dorsal bristles, 2nd joint with 4 ventral bristles and 1 lateral bristle 5
5(4′). Furca with 4 short middle claws ..... A–2 instar
5′. Furca with more than 4 short middle claws 6
6(5′). Furca with 5 short middle claws; 3rd joint of endopodite of 2nd antenna with 5 (rarely 4) terminal bristles; posterior lobe of copulatory appendage of male sausage-shaped ..... A–1 instar
6′. Furca with 6 short middle claws; 3rd joint of endopodite of 2nd antenna of female with 3 terminal bristles (rarely 2 or 4), of male with hook-like process; posterior lobe of copulatory appendage of male tapered, styliform ..... Adult

Figure 18*d–f*). The posterior lobe is sausage-shaped in the A–2 and A–1 instars and styliform on the adult. The tip of the process bears 1 bristle on instar A–2, 3 bristles on instar A–1, and 3 hairs on the adult.

Sex Ratios and Dimorphism

Ratio of Males to Females

Although no attempt was made to determine the exact ratio of males to females of the Thaumatocyprididae, we noted that adult males were plentiful in the samples contáining numerous specimens. Males are sparse in many other marine ostracode species because they die soon after mating.

Sexual Dimorphism of *Thaumatoconcha radiata*, new species

Adult.—Carapaces of males are slightly smaller than females in the same sample (Figure 3); in other characters the carapaces are similar.

First antenna (Figures 26, 32): On the male the 3rd and 4th joints are separated by a distinct suture, they are fused on the female. The ventral margin of the 4th joint on the male bears 2 long bristles whereas the female is either without bristles or bears 1 minute bristle. The longest bristle on the ventral margin of the 5th joint on the male bears abundant marginal hairs, which are absent on this bristle on the female. The setiferous bristle on the male may be equivalent to the sensory bristle located on the same joint of males in the Cypridinacea. The well-defined suture separating the 3rd and 4th joints of the adult male supports our conclusion herein that homologous joints of the female are also 3rd and 4th joints, even though the suture between them is not well defined.

Second antenna (Figures 27, 33): The margins of the 3rd joint of the female endopodite are more-or-less parallel and the joint bears 3 terminal bristles (1 short, 1 medium, 1 long), whereas, the margins of the 3rd joint on the male are convex, and the joint bears terminally a recurved hook-like process with 2 minute spines at the tip (the base of the process projects from the medial side of the distal end of 3rd joint on some specimens).

Copulatory appendage: The males bear a single copulatory appendage (Figure 18*d–f*). No genital pore was discernable on the female.

Remaining appendages, upper lip, and posterior of body: No sexual dimorphism observed.

A–1 instar.—The male carapace may be slightly smaller than that of the female, but an insufficient number of specimens were measured to be certain of this.

First antenna (Figure 7*g,h*): The ventral margin of the 4th joint on the female appendage usually bears 1 minute bristle, whereas, the male appendage bears 2 fairly long bristles in addition to a minute bristle (the latter not present on all specimens).

Second antenna (Figure 8*g,h*): The ventral and dorsal margins of the 3rd endopodite joint on the female are more-or-less parallel, and the joint bears 5 terminal bristles (3 short, 2 medium length). The ventral and dorsal margins of this joint on the male are slightly convex (thumb-like) and the joint bears 5 (rarely 4) short terminal bristles.

Copulatory appendage: Reduced in males (Figure 34*gg*).

Remaining appendages, upper lip, and posterior of body: No sexual dimorphism observed.

A–2 instar.—Carapace of male may be slightly smaller than that of female, but an insufficient number of specimens examined to be certain.

First antenna (Figure 7*e,f*): Ventral margin of 4th joint of female with 1 or 2 short bristles or 1 short and 1 longer bristle; this joint of male with 1 short and 1 longer bristle. Sexes not readily separated by this feature because some specimens of both sexes are similarly armed with bristles.

Second antenna (Figure 8*e,f*): Ventral and dorsal margins of 3rd joint of endopodite of female more-or-less parallel; this joint of male thumb-like (thumb less well defined than that of A–1 male instar).

Copulatory appendage: Male appendage considerably reduced (Figure 34*o*).

Remaining appendages, upper lip, and posterior of body: No sexual dimorphism observed.

A–3 to A–6 Instars.—No sexual dimorphism observed.

Ecology and Biology

Geographic Distribution.—The Permian species, *Thaumatomma piscifrons*, new species, is from the

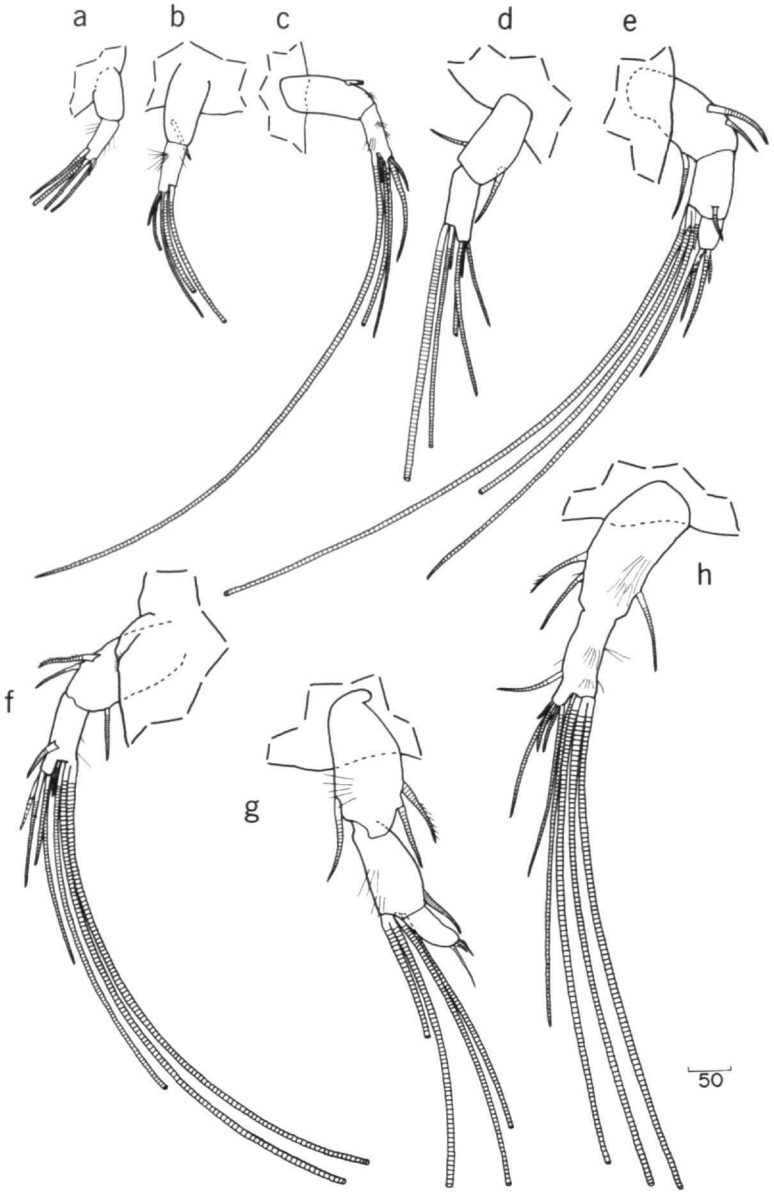


FIGURE 8.—*Thaumatoconcha radiata,* new species, paratypes, developmental stages of the endopodite of the juvenile 2nd antenna: *a,* A–6, USNM 143753D, left limb, medial view; *b,* A–5, USNM 143753G, right limb, medial view; *c,* A–4, USNM 143753U, left limb, medial view; *d,* A–3, USNM 143753L, left limb, medial view; *e,* A–2 male, USNM 126136A, right limb, lateral view; *f,* A–2 female, USNM 126136B, left limb, lateral view; *g,* A–1 male, USNM 143753MM, left limb, medial view; *h,* A–1 female, USNM 143753F, right limb, medial view. (Scale in micrometers.)

TABLE 9.—Species in the family THAUMATOCYPRIDIDAE arranged according to localities

Locality	Species
Indonesia area, Indian Ocean	*Thaumatocypris echinata*
Marine cave in Cuba	*Danielopolina orghidani*
North Atlantic Ocean near the Bermuda Islands	*Thaumatoconcha polythrix*
South Atlantic Ocean	
Off Brazil	*Danielopolina carolynae*
	Thaumatoconcha tuberculata
Off Argentina	*Thaumatoconcha radiata*
	Thaumatoconcha caraionae
South Africa	*Thaumatoconcha hessleri*
South Pacific Ocean	
Off Peru (west edge of Peru-Chile Trench)	*Thaumatoconcha elongata*
Off Chile	*Thaumatoconcha* sp. indet.
Subantarctic region	*Thaumatoconcha punctata*
Antarctic Region (within Antarctic Convergence)	
Drake Passage	*Thaumatoconcha radiata*
	Thaumatoconcha sandersi
Weddell Sea	*Thaumatoconcha radiata*
	Thaumatoconcha species A
	Thaumatoconcha sandersi
Scotia Sea	*Thaumatoconcha radiata*

island of Idhra, off the Argolian coast of Greece. The Early Jurassic species, *Pokornyopsis bettenstaedti* (Bartenstein, 1949), is from northwestern Germany. The Late Jurassic species, *Pokornyopsis feifeli* (Triebel, 1941), is from southwestern Germany. The Holocene species are widespread (Figure 9). As shown in Table 9, the only species of *Thaumatocypris* Müller, 1906, *T. echinata,* is from the Indonesian area where it has been reported twice (Müller, 1906:43; Poulsen, 1969:8). Species of the new genus *Danielopolina* have been reported from two localities: Danielopol (1972:1) reported *D. orghidani* (Danielopol, 1972), from a shallow water, saline cave in Cuba, and we report here a new species, *D. carolynae,* from abyssal depths of the South Atlantic Ocean near the Equator.

The new genus *Thaumatoconcha* is represented by species in the Atlantic and Pacific Oceans, and also within the Antarctic Convergence. Only one species, *T. polythrix,* new species, was collected in the North Atlantic Ocean, from near Bermuda. Four species, all new, were collected in the South Atlantic Ocean: *T. tuberculata* from off the coast of Brazil; *T. radiata* and *T. caraionae,* from off the coast of Argentina; and *T. hessleri,* from off the coast of South Africa. Two species are endemic to the South Pacific Ocean: *T. elongata,* new species, from near the western edge of the Peru-Chile Trench, off the coast of Peru, and *T. punctata,* new species, from the Subantarctic region. Two unidentifiable specimens of *Thaumatoconcha* were collected off the coast of Chile. Two species, in addition to one in open nomenclature, were collected within the Antarctic Convergence (Antarctic region): *T. radiata,* new species, was recorded from the Drake Passage, and the Weddell and Scotia seas; *T. sandersi,* new species, and *Thaumatoconcha* species A were collected in the Weddell Sea.

VERTICAL DISTRIBUTION.—The thaumatocypridids upon which our study is based were collected on the bottom at depths ranging from 587 to 4758 m (Table 10). This range of depth represents both the bathyal and abyssal zones (200–6000 m). Because the boundary between the bathyal zone and the abyssal zone is considered to be 2000 m by some authorities and 3000 m by others (Menzies et al., 1973:73), Table 11 shows the distribution of samples and species within depth zones using the 2000 and 3000 m boundary. For this discussion we use 3000 m as the boundary.

Our samples were collected from the continental slope and the abyssal ocean floor (Table 10). Four samples with thaumatocypridids were collected from the upper slope (maximum depth 1007 m), five samples from the lower slope (1493–2747 m), and 11 samples from abyssal depth (3035–4758 m).

More species were collected in the abyssal zone than in the bathyal zone (Table 11). The upper part of the slope yielded 2 species, the lower part of the slope yielded 5 species, and the abyssal ocean floor yielded 6 species.

Four species, *Thaumatoconcha tuberculata, T. hessleri, T. polythrix,* and *T. caraionae* were collected only in the bathyal zone (200–3000 m); five species, *Thaumatoconcha punctata, T. sandersi, T. elongata, Thaumatoconcha* species A, *Danielopolina carolynae,* were collected in the abyssal zone (3000–6000 m), and only one species, *Thaumatoconcha radiata,* was collected in both zones (species range: 2440–4758 m) (Table 12). The relatively short depth ranges of most of the species indicate that depth is an important factor in their distribution. Similar results have been reported for

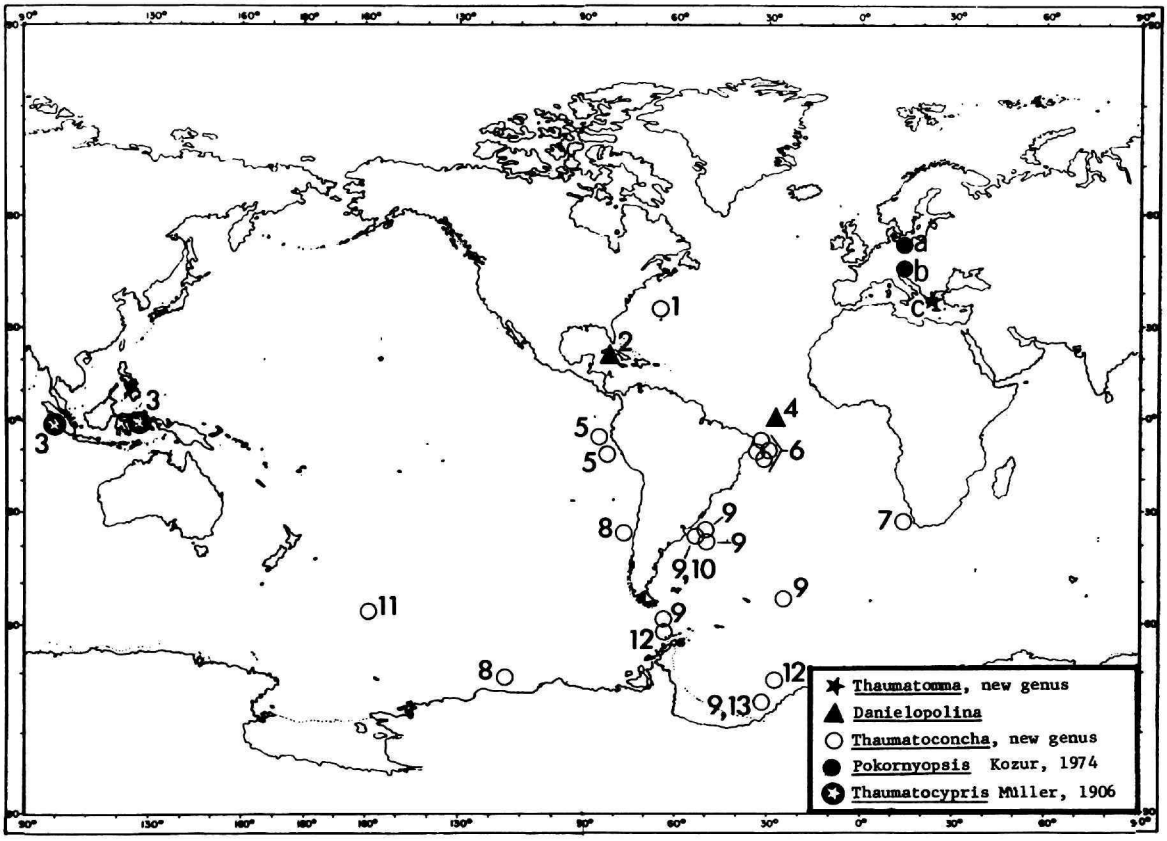


FIGURE 9.—Distribution of living and fossil species of the Thaumatocyprididae. (Fossil species are identified by a letter next to each symbol, living species by a number, as follows: a = *Pokornyopsis bettenstaedti* (Bartenstein); b = *Pokornyopsis feifeli* (Treibel); c = *Thaumatomma piscifrons*, new species; 1 = *Thaumatoconcha polythrix*, new species; 2 = *Danielopolina carolynae*, new species; 3 = *Thaumatocypris echinata* Müller; 4 = *Danielopolina carolynae*, new species; 5 = *Thaumatoconcha elongata*, new species; 6 = *Thaumatoconcha tuberculata*, new species; 7 = *Thaumatoconcha hessleri*, new species; 8 = *Thaumatoconcha* species indeterminate; 9 = *Thaumatoconcha radiata*, new species; 10 = *Thaumatoconcha caraionae*, new species; 11 = *Thaumatoconcha punctata*, new species; 12 = *Thaumatoconcha sandersi*, new species; 13 = *Thaumatoconcha* species A.)

other ostracode taxa and other animals (e.g., Morkhoven, 1972; Belyaeva, 1972; Kornicker, 1975).

The vertical distribution of the fossil species can be inferred from the associated organisms. The Jurassic species are inferred to have lived at depths not deeper than 200 m (Triebel, 1941:377; Bartenstein, 1949:96). A normal marine shelf habitat is postulated by us for the Permian species. According to Briggs (1974:431–434), the representatives of many ancient groups now restricted to ocean depths migrated down the slope from the shelf during the Paleozoic and Mesozoic eras in order to escape competition from newly evolving taxa. Our data suggest that the thaumatocyprids migrated to deeper water during post-Jurassic time.

The environment of caves is similar to deep-water environments in lack of light, scarcity of food, and climatic stability (Poulson, 1971:52). Danielopol (1972:3) noted that the thaumatocyprids should be included among the organisms in-

TABLE 10.—Vertical distribution of species in the family THAUMATOCYPRIDIDAE arranged according to depth at which they were collected

Depth (m)	Location	Species	Source
shallow	Cuban Cave	*Danielopolina orghidani*	Danielopol (1972); herein
587	South Atlantic Ocean	*Thaumatoconcha tuberculata*	herein
717–619	South Atlantic Ocean	*Thaumatoconcha hessleri*	herein
834–939	South Atlantic Ocean	*Thaumatoconcha tuberculata*	herein
943–1007	South Atlantic Ocean	*Thaumatoconcha tuberculata*	herein
1100 (pelagic)	Indian Ocean	*Thaumatocypris echinata*	Müller (1906)
1493	South Atlantic Ocean	*Thaumatoconcha tuberculata*	herein
2000 (pelagic)	Indonesia	*Thaumatocypris echinata*	Poulsen (1969)
2095–2223	North Atlantic Ocean	*Thaumatoconcha polythrix*	herein
2440–2480	South Atlantic Ocean	*Thaumatoconcha radiata*	herein
2707	South Atlantic Ocean	*Thaumatoconcha radiata*	herein
		Thaumatoconcha caraionae	herein
2747	Scotia Sea	*Thaumatoconcha radiata*	herein
3035	Weddell Sea	*Thaumatoconcha radiata*	herein
		Thaumatoconcha species A	herein
3305–3317	South Atlantic Ocean	*Thaumatoconcha radiata*	herein
3459	South Atlantic Ocean	*Danielopolina carolynae*	herein
3569	South Pacific Ocean	*Thaumatoconcha* sp. indet.	herein
3658	Weddell Sea	*Thaumatoconcha sandersi*	herein
3694	South Pacific Ocean	*Thaumatoconcha punctata*	herein
3715–3752	Drake Passage	*Thaumatoconcha sandersi*	herein
3824–3739	South Pacific Ocean	*Thaumatoconcha* sp. indet.	herein
4124	South Pacific Ocean	*Thaumatoconcha elongata*	herein
4460–4449	South Pacific Ocean	*Thaumatoconcha elongata*	herein
4758	Drake Passage	*Thaumatoconcha radiata*	herein

habiting both cave and abyssal environments. Our deep sea collections of thaumatocyprids support Danielopol's observation.

FOOD.—The guts of four specimens (*Danielopolina orghidani*—1, *Thaumatoconcha radiata*—2, *T. tuberculata*—1) were examined. They contained mostly brownish particles that appeared to be organic, some fragments of crustacean appendages, and unidentifiable parts of other organisms. No sediment was observed in the gut. The absence of sediment suggests that the thaumatocyprids, like other halocyprids, are carnivorous, but they could also be detritus feeders capable of excluding particles of sediment from their diet.

TABLE 11.—Bathymetric distribution of thaumatocpyrids (pelagic samples not included)

Depth zone (m)	No. of samples	No. of species
Bathyal		
200–2000	5	2
200–3000	9	5
Abyssal		
2000–6000	15	8
3000–6000	11	6

EGG LAYING.—The absence of eggs within the carapaces of the many adult females we examined indicates that eggs are laid directly on the substrate, and are not brooded. In this respect, this taxon resembles the Cladocopina and most members of the Halocypridacea.

FUNCTIONAL MORPHOLOGY.—Steuer (1910:208) considered the 2 long protuberances of *Thaumatocypris echinata* Müller, 1906, to be buoyancy organs. Skogsberg (1920:118) disputed this, stating:

> That the two pairs of spines in the genus *Thaumatocypris* cannot be explained as adaptations of buoyancy is shown quite clearly by their position, as they are not, as one would expect according to the buoyancy theory, both placed in the horizontal plane in order to bring about an optimal increase in the horizontal projection; only one of them is in this plane—pointing almost straight forward—the other points

TABLE 12.—Depth, depth zone, habitat, and locality of species of THAUMATOCYPRIDIDAE

Species	Depth (m)	Depth zone	Habitat	Locality
Danielopolina orghidani	shallow	shallow cave	unknown	Cuba
Thaumatoconcha tuberculata	587–1493	bathyal	benthos	South Atlantic
Thaumatoconcha hessleri	619–717	bathyal	benthos	South Atlantic
Thaumatocypris echinata	1100–2000	midwater	pelagic	Indian Ocean, Indonesian area
Thaumatoconcha polythrix	2095–2223	bathyal	benthos	North Atlantic
Thaumatoconcha radiata	2440–4758	bathyal-abyssal	benthos	Drake Passage, Weddell Sea, South Atlantic
Thaumatoconcha carnionae	2707	bathyal	benthos	South Atlantic
Thaumatoconcha species A	3035	abyssal	benthos	Weddell Sea
Danielopolina carolynae	3459	abyssal	benthos	South Atlantic
Thaumatoconcha punctata	3694	abyssal	benthos	South Pacific
Thaumatoconcha sandersi	3658–3752	abyssal	benthos	Weddell Sea, Drake Passage
Thaumatoconcha elongata	4124–4449	abyssal	benthos	South Pacific

almost straight downward; moreover, both pairs are concentrated on the anterior side of the shell.

Skogsberg (1920:120) believed that forward and backward movements of the 1st and 2nd antennae during swimming would cause specimens of *Thaumatocypris* to roll backwards if it were not for the spines, especially the anteroventral pair, which act like motionless oars pressed downward by swimming strokes. The absence of the long spines on benthic thaumatocypridids, which have 1st and 2nd antennae similar to those on *T. echinata,* and presumably swim for short distances, suggests that the spines are probably buoyancy organs as suggested by Steuer (1910:208).

The upper lips of thaumatocypridids bear 2 tubular spine-like processes that face the mouth (Figure 31*e,f*). The processes are connected by a tube to a gland within the upper lip. The excretion from the gland is no doubt involved with the feeding process, but its exact role is unknown.

Station Data

HOLOCENE COLLECTIONS

R. V. Atlantis II

Cruise 24, August 1966

Station 119; 19 August 1966; 32°15′48″N, 64°31′36″W to 32°16′06″N, 64°32′36″W; 2095–2223 m; epibenthic trawl; bathyal; North Atlantic.
Thaumatoconcha polythrix, new species: 2 specimens (USNM 143790), 1 specimen (USNM 143792).

Cruise 31, February 1967

Station 156; 15 February 1967; 00°46′00″S, 29°28′00″W to 00°46′30″S, 29°24′00″W; 3459 m; abyssal; South Atlantic.
Danielopolina carolynae, new species: 1 adult ♀ (USNM 143789).

Station 159; 18 February 1967; 7°58′00″S, 34°22′00″W; 834–939 m; epibenthic sled; bathyal; South Atlantic.
Thaumatoconcha tuberculata, new species: 9 specimens (USNM 143854).

Station 162A; 19 February 1967; 8°02′00″S, 34°03′00″W to 7°56′00″S, 34°09′00″W; 1493 m; epibenthic sled; bathyal; South Atlantic.
Thaumatoconcha tuberculata, new species: 27 specimens (USNM 143791).

Station 167; 20 February 1967; 7°58′00″S, 34°17′00″W to 7°50′00″S, ?W; 943–1007 m; epibenthic sled; bathyal; South Atlantic.
Thaumatoconcha tuberculata, new species: 135 specimens (USNM 143853).

Station 169A; 21 February 1967; 8°03′00″S, 34°23′00″W to 8°02′00″S, 34°25′00″W; 587 m; epibenthic sled; bathyal; South Atlantic.
Thaumatoconcha tuberculata, new species: 238 specimens (USNM 143796); 1 adult ♂ (USNM 143852).

Cruise 60, March 1971

Station 245A; 14 March 1969; 36°55′42″S, 53°01′24″W; 2707 m; large epibenthic sled; bathyal; American Quadrant; South Atlantic.
Thaumatoconcha radiata, new species: ca. 1200 specimens (USNM 143753).

Thaumatoconcha caraionae, new species: 1 adult ♀ (USNM 143856), 4 adult ♂♂ (USNM 143855), 4 adult ♀♀ (USNM 143859), 4 specimens (USNM 143860): 1 A–1 ♂ (USNM 143857).

Station 259; 26 March 1969; 37°13′18″S, 52°45′00″W; 3305–3317 m; large epibenthic sled; abyssal; American Quadrant; South Atlantic.

Thaumatoconcha radiata, new species: 49 specimens (USNM 143754).

Station 262A; 27 March 1971; 36°05′12″S, 52°17′54″W; 2440–2480 m; bathyal; South Atlantic.

Thaumatoconcha radiata, new species: 176 specimens (USNM 143799).

USNS Eltanin

Cruise 4, July–August 1962

Station 127; 1 August 1962; 61°45′S, 61°14′W; 4758 m; Menzies trawl; abyssal; American Quadrant; Drake Passage; Antarctic region; Continental subregion. Aliquot: whole.

Thaumatoconcha radiata, new species: 1 adult ♂, 1 A–1 ♂ (both specimens, USNM 127272).

Station 135; 6 August 1962; 62°40′S, 64°06′W to 62°37′S, 63°57′W; 3715–3752 m; Menzies trawl; abyssal; American Quadrant; Drake Passage; Antarctic region; Continental subregion. Aliquot: whole.

Thaumatoconcha sandersi, new species: 1 adult ♂ (USNM 143793), 7 specimens (USNM 127275).

Cruise 11, January 1963–February 1964

Station 926; 17 January 1964; 70°03′S, 114°47′W to 70°02′S, 114°28′W; 3569 m; Menzies trawl; abyssal; Pacific Quadrant; Antarctic region; South Pacific Ocean.

Thaumatoconcha species indeterminate: 1 A–3 instar (USNM 127520).

Cruise 25, October–November 1966

Station 364; 11 December 1966; 56°17′S, 156°13′W to 56°19′S, 156°18′W; 3694 m; Menzies trawl; abyssal; Pacific Quadrant; Subantarctic region; South Pacific Ocean.

Thaumatoconcha punctata, new species: 1 adult ♀ (USNM 143861), 5 specimens (USNM 127289).

USCGC Glacier

International Weddell Sea Oceanographic Expedition (IWSOE) Cruise 2, February–March 1969; collected by J. S. Rankin Jr., K. Clark, C. Biernbaum

Station 0022; 14 March 1969; 73°29′S, 30°24′6″W; 3035 m; epibenthic sled; abyssal; American Quadrant; Weddell Sea; Antarctic; Continental subregion.

Thaumatoconcha radiata, new species: 74 specimens (USNM 126136), 1 adult ♀ (USNM 143794).

Thaumatoconcha species A: 1 adult ♀ (USNM 143851).

Station 0022; same as above except collected with Anchor dredge.

Thaumatoconcha radiata, new species: 1 juvenile (USNM 126139).

Station 0023; 14–15 March 1969; 72°47′30″S, 30°28′18″W; 3658 m; epibenthic sled; abyssal; American Quadrant; Weddell Sea, Antarctic; Continental subregion.

Thaumatoconcha sandersi, new species: 1 adult ♀, 1 adult ♂ (both specimens, USNM 143752).

R. V. Vema

Cruise 14, January–July 1958

Station V–14–25 (LGO 49); 9 March 1958; 56°43′S, 27°41′W; 2747 m; small bottom trawl; bathyal; American Quadrant; Scotia Sea; Antarctic; Continental subregion; Scotia subregion; bottom with some volcanic sand.

Thaumatoconcha radiata, new species: 12 specimens (USNM 143858 A–D).

Station V–14–33 (LGO 55); 6 April 1958; 34°36′S, 16°40′E; 717–695 m; small bottom trawl; bathyal; African Quadrant; South Atlantic.

Thaumatoconcha hessleri, new species: 3 adult ♀ (USNM 143755, 143862, 144006).

Cruise 15, December 1958–January 1959

Station V–15–79; 23 December 1958; 11°12′S, 84°48′W, 4460–4449 m; small bottom trawl; manganese nodules present in trawl; abyssal; South Pacific.

Thaumatoconcha elongata, new species: 1 juvenile ♂ (USNM 144005).

Cruise 17, February–November 1961

Station V–17–1; 26 February 1961; 7°10′S, 85°50′W; 4124 m; small bottom trawl; abyssal; South Pacific.

Thaumatoconcha elongata, new species: 1 adult ♀ (USNM 143967), 1 adult ♂ (USNM 143968).

Station V–17–5; 16 March 1961; 38°15′S, 76°00′W; 3824–3739 m; small bottom trawl; abyssal; South Pacific.

Thaumatoconcha species indeterminate: 1 adult ♀, 1 juvenile (USNM 143969).

PERMIAN COLLECTIONS

Collected by Dr. Richard E. Grant, Department of Paleobiology, Smithsonian Institution, 1968, 1974

USNM locality 9260. Southeastern side of Idhra, just off the Argolian coast, Greece, about ½ km south of the village of Episkopi, weathered block with silicified fossils (Grant, 1972:214, for description).

Thaumatomma piscifrons, new species: 40 specimens (USNM 168167–168187).

Superorder MYODOCOPA Sars, 1866

Kozur (1972:5) proposed the superorder Myodocopamorphes for the orders Cladocopida, Myodocopida, and Leperditiida. We do not include the

Leperditiida in the superorder Myodocopa and have retained the name Myodocopa proposed as a section by Sars (1866:2).

The superorder Myodocopa contains the orders Myodocopida (outside the scope of this study) and Halocyprida.

Key to the Orders of Myodocopa

1. Seventh limb vermiform;[1] medial eye present;[2] 6th limb flat, plate-like ..... MYODOCOPIDA
1′. Seventh limb short with 2 bristles (Halocypridina) or absent (Cladocopina); medial eye absent; 6th limb elongate (Halocypridina) or absent (Cladocopina) ..... HALOCYPRIDA

[1] Seventh limb absent or reduced on males of some species of Sarsiellidae.
[2] Medial eye reduced in genus *Igene* Kornicker, 1975.

Order HALOCYPRIDA Dana, 1853

DIAGNOSIS.—Medial eye absent; 7th limb absent, or short with 2 bristles; 6th limb absent or elongate.

This order contains the suborders Cladocopina and Halocypridina.

Key to the Suborders of Halocyprida

1. Body with 5 pairs of limbs; furca with short conical projection between claws; 1st joint of exopodite of 2nd antenna without ventral bristle ..... CLADOCOPINA
1′. Body with 7 pairs of limbs; furca without short conical projection between claws; 1st joint of exopodite of 2nd antenna with 1 ventral bristle ..... HALOCYPRIDINA

Suborder HALOCYPRIDINA Dana, 1853

HALOCYPRINAE Dana, 1853:1281.
HALOCYPRIFORMES Skogsberg, 1920:555.
HALOCYPRIDINA Kornicker, 1968:439.

This suborder contains the superfamilies Halocypridacea (Cretaceous to Holocene), Thaumatocypridacea (Permian to Holocene), and possibly Entomoconchacea (Lower Silurian to Lower Carboniferous).

DISTRIBUTION.—Halocypridacea: world-wide in Holocene, single fossil from Cretaceous of Czechoslovakia (Pokorny, 1964). Thaumatocypridacea: Holocene, world-wide, mostly southern hemisphere; Jurassic, Germany; Permian, Greece. Entomoconchacea: Lower Silurian to Lower Carboniferous, Europe, northeastern North America.

HABITAT.—Halocypridacea: mostly pelagic, partly benthic. Thaumatocypridacea: fossils benthic; Holocene species both benthic and pelagic. Entomoconchacea: presumably benthic.

DIAGNOSIS.—Fifth and 6th limbs elongate with 2 or 3 bristles on end joint; 7th limb short, 1- or 2-jointed, with 2 long terminal bristles; copulatory limb large, single, on left side of body; with or without heart.

Key to the Superfamilies of Halocypridina

1. Anteroventral margain of carapace straight or slightly concave, anterior margin without incisur or rostrum; radial adductor muscle attachment scar; 1st antenna long, straight; 1st joint of 1st antenna with 1–2 bristles; furcal lamella with 2 long anterior claws followed by 3–7 short claws of similar length; heart absent 2
1′. Anteroventral margin convex; anterior margin with or without incisur or rostrum; non-radial muscle-attachment scar; 1st antenna short, bent downwards distally; 1st joint of 1st antenna without bristles; furcal lamella wih 1 long anterior claw followed by 6–7 smaller claws decreasing in size posteriorly; heart present ..... HALOCYPRIDACEA
2 (1). Specimens large, more than 6 mm in length; adductor muscle attachment scar large, more than one-fourth greatest height ..... ENTOMOCONCHACEA
2′. Specimens small, less than 2.5 mm in length; adductor muscle scars small, less than one-fifth greatest height ..... THAUMATOCYPRIDACEA

Superfamily THAUMATOCYPRIDACEA Müller, 1906

THAUMATOCYPRINAE Müller, 1906:41.
THAUMATOCYPRIDACEA Sylvester-Bradley, 1961:Q397.

DIAGNOSIS.—Because this taxon contains only one family, the diagnosis is the same as that for the family.

This superfamily contains one family, the Thaumatocyprididae.

DISTRIBUTION.—Holocene in Atlantic, Pacific, and Indian oceans, mostly in southern hemisphere; fossils in Europe (Germany, Jurassic; Greece, Permian).

HABITAT.—Benthic and pelagic.

REVIEW OF THAUMATOCYPRIDACEA.—Müller (1906:41) assigned his subfamily Thaumatocyprinae, based on the monotypic genus *Thaumatocypris* Müller, 1906 *(Thaumatocypris echinata* Müller, 1906), to the Halocyprididae Dana, 1853. Triebel (1941) and Bartenstein (1949) referred two Jurassic species, *Thaumatocypris feifeli* Triebel, 1941, and *Thaumatocypris bettenstaedti* Bartenstein, 1949, to Müller's genus. Sylvester-Bradley (1961:Q397) established the superfamily Thaumatocypridacea in the suborder Myodocopina Sars, 1866, to comprise the single family Thaumatocyprididae. Danielopol (1972) referred the second living species, *orghidani,* to *Thaumatocypris.* Oertli (1972, pl. 3: figs. 39–41) referred Jurassic ostracodes to *"Polycope?* sp., *Thaumatocypris?* sp." Kozur (1974:853) proposed the new genus, *Pokornyopsis* and referred to it *Thaumatocypris feifeli* Triebel, 1941, *T. bettenstaedti* Bartenstein, 1949, *"Polycope?* sp., *Thaumatocypris?* sp." (Oertli, 1972), and *Polycope?* sp. D (Oertli, 1972, figs. 37, 38). Kozur (1974) described the new subfamily Pokornyopsinae in the family Polycopidae Sars, 1866, suborder Cladocopida Sars, 1866, for *Pokornyopsis.* Kornicker and Sohn (in press) referred *Thaumatocypris orghidani* Danielopol, *T. feifeli* Triebel, *T. bettenstaedti* Bartenstein and an undescribed living species to the new genus *Danielopolina* (deliberate nomen nudum). We referred to the *Thaumatocyprididae,* two additional new genera (deliberate nomena nuda), *Thaumatoconcha,* containing 8 undescribed living species, and *Thaumatomma,* containing an undescribed Permian species. In an addendum to that paper, we accepted *Pokornyopsis feifeli* (Triebel, 1941) and *Pokornyopsis bettenstaedti* (Bartenstein, 1949) and referred the genus to the Thaumatocyprididae, but removed *Polycope?* sp. D (Oertli, 1972), and *"Polycope?* sp., *Thaumatocypris?* sp." (Oertli, 1972), from the genus *Pokornyopsis* and referred them to the Polycopidae. The subfamily Pokornyopsinae Kozur, 1974, was placed in the synonomy of Thaumatocyprididae, and the superfamilies Thaumatocypridacea and Halocypridacea were united in the suborder Halocypridina, order Myodocopida.

Family THAUMATOCYPRIDIDAE Müller, 1906

THAUMATOCYPRINAE Müller, 1906:41.—Skogsberg, 1920:564, 568.
THAUMATOCYPRIDIDAE Sylvester-Bradley, 1961:Q397.
THAUMATOCYPRIDAE Poulsen, 1969:7.
POKORNYOPSINAE Kozur, 1974:853.

This family contains 5 genera, *Thaumatocypris* Müller, 1906, *Pokornyopsis* Kozur, 1974, *Thaumatoconcha,* new genus, *Danielopolina,* new genus, and *Thaumatomma,* new genus.

DISTRIBUTION (Figure 9).—Holocene: Atlantic Ocean (32°N–73°S); Pacific Ocean (7°S–70°S) and also west of Celebes (2°22′S, 126°58′E); Indian Ocean (0°58′S, 99°43′E). Fossil: Upper Jurassic of southwestern Germany; Lower Jurassic of northwestern Germany; Permian, Idhra Island, Greece.

HABITAT.—Benthic *(Thaumatomma, Thaumatoconcha, Pokornyopsis, Danielopolina)* and bathyal pelagic *(Thaumatocypris).*

DIAGNOSIS.—Carapace small, length less than 2.5 mm; with straight or slightly concave anteroventral margin delimited by terminal protuberances; with or without anterodorsal node on each valve; usually with posterodorsal tubercle on one or both valves; surface smooth, punctate, or reticulate; adductor muscle attachment scars less than one-fifth greatest height. First antenna long with 8 joints; 1st joint with 1 dorsal bristle *(Thaumatocypris),* or with 1 dorsal and 1 lateral bristle *(Thaumatoconcha, Danielopolina).* Each lamella of furca with 2 long anterior claws followed by 3–7 short claws *(D. orghidani* with 3 short claws, remaining species in family with 6 or 7 short claws). Rod-shaped organ well developed only in species of *Thaumatoconcha;* heart absent. Morphology of genera and species is compared in Table 13.

DESCRIPTION.—Each valve with straight or slightly concave anteroventral margin with a short or long protuberance at dorsal and ventral ends; one genus

(Thaumatomma) with anterodorsal node; a small posterodorsal tubercle on one or both valves of some species of *Thaumatomma* and on one species of *Thaumatoconcha (T. tuberculata);* surface smooth, punctate, or reticulate; anteroventral surface with or without thin ridges parallel to valve margin; diameter of adductor muscle attachment scar less than one-fifth greatest height.

First antenna: Elongate, 8-jointed: 1st joint with 1 dorsal bristle; lateral surface with 1 lateral bristle on *Danielopolina* and *Thaumatoconcha,* but without a bristle on *Thaumatocypris;* 2nd joint with 1 dorsal and 1 ventral bristle; 3rd and 4th joints fused except at sclerotized dorsal and ventral margins, especially the former; 3rd joint usually without bristles, but rarely with a ventral bristle; 4th joint of *Danielopolina* and *Thaumatoconcha* usually without bristles, but rarely with a ventral bristle; 4th joint of *Thaumatocypris* with long terminal bristle on ventral margin; ventral margin of 5th joint of *Danielopolina* with 1 or 2 bristles, of *Thaumatoconcha* with 2 or 3 bristles, of *Thaumatocypris* with 3 bristles; 6th joint without bristles, an exception being the presence of a transparent bristle on the specimens of *Thaumatocypris echinata* described by Poulsen (1969:8); ventral margin of 7th joint of *Danielopolina* and *Thaumatoconcha* with 2 bristles, of *Thaumatocypris* with 1 bristle; dorsal margin of *Danielopolina* without bristles, of *Thaumatoconcha* and *Thaumatocypris* with 1 bristle; 8th joint of *Danielopolina* and *Thaumatoconcha* with 3 bristles, of *Thaumatocypris* with 2 bristles.

Second antenna: Protopodite without bristles except for *Danielopolina carolynae,* which bears 1 posterior bristle, not described on any other Myodocopida. Endopodite of *Thaumatocypris* with 2 joints, of *Danielopolina* and *Thaumatoconcha* with 3 joints: ventral margin of 1st joint of *Danielopolina* without bristle, of *Thaumatoconcha* and *Thaumatocypris* with 1 bristle; dorsal margin of 1st joint with 2 bristles, 2nd joint with 1 ventral and 4 terminal bristles, except for *Danielopolina orghidani* which bears 3 terminal bristles and is without a ventral bristle; 3rd joint of *Danielopolina* with 1 terminal bristle, of *Thaumatoconcha* with 2 or 3 terminal bristles. Exopodite with 8 or 9 joints: 1st joint without bristles except for *Danielopolina carolynae* which bears 1 long medial bristle, longer than reported on any other species of Myodocopida; 1st joint divided into a long proximal and short distal part (Figure 10); the 2 parts especially well defined on *D. carolynae* (Figure 10*a*); joints 2–8 with natatory bristles; 9th joint with 2 or 3 bristles.

Mandible: Coxale endite with proximal and distal sets of teeth separated by small space; proximal set consisting of 4 broad teeth plus rounded teeth adjacent to space separating proximal and distal sets of teeth; clusters of densely packed spines medially between each tooth and extending onto medial surface of endite; 1 pointed or blunt spinous

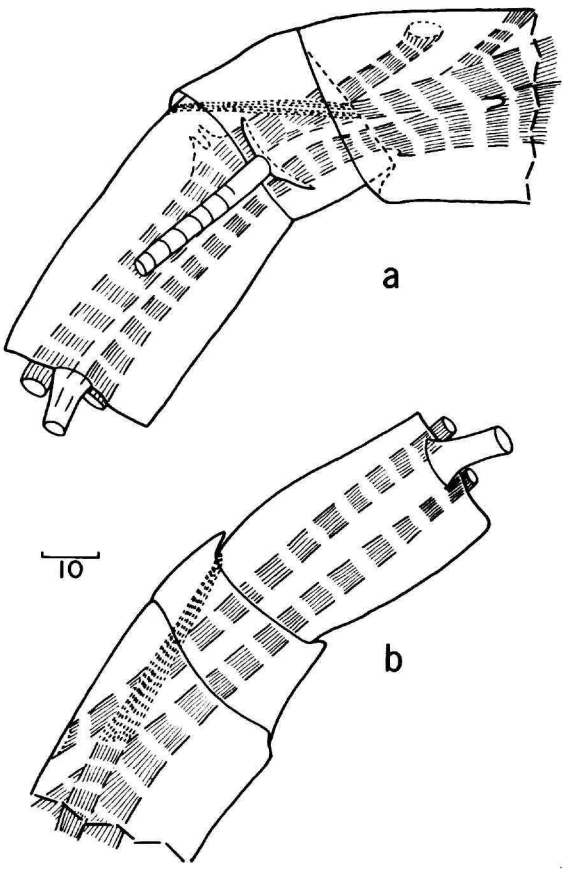


FIGURE 10.—Second joint and distal part of 1st joint of exopodites of 2nd antennae showing proximal parts of bristles, and muscle connected to proximal dorsal corner of 2nd joint and some of the other muscles: *a, Danielopolina carolynae,* adult female, holotype, USNM 143789, right limb, medial view; *b, Thaumatoconcha radiata,* adult female, holotype, USNM 143794, right limb, medial view. (Scale in micrometers.)

TABLE 13.—Summary of morphologic characters

Character	*Thaumatoconcha*						
	radiata		*punctata*	*elongata*		*caraionae*	
	♀	♂	♀	♀	♂	♀	♂
Carapace, length (mm)	1.66–2.02	1.61–1.99	2.22–2.24	2.30	2.00	1.87–1.99	1.74–1.80
No. of anterior ridges	4 or 5	4 or 5	9	8	8	7–11	7–11
No. of muscle segments	19–24	19–24	20	19	19	20–22	20–22
Surface	smooth	smooth	punctate	punctate	punctate	punctate	punctate
Posterodorsal tubercles or spines present (P) absent (A)	A	A	A	A	A	A	A
First antenna (no. of bristles)							
1st joint: dorsal/lateral	1/1	1/1	1/1	1/1	1/1	1/1	1/1
2nd joint: ventral/dorsal	1/1	1/1	1/1	1/1	1/1	1/1	1/1
3rd joint: ventral	0 or 1 (rare)	0	0	0	0	0	0
4th joint: ventral	0 or 1 (rare)	2	0	0	2	0	2
5th joint: ventral	2–3	3	2	3	3	3	3
6th joint	0	0	0	0	0	0	0
7th joint: ventral/dorsal	2/1	2/1	2/1	2/1	2/1	2/1	2/1
8th joint	3	3	3	3	3	3	3
Dorsal margin of 3rd joint longer (L) or shorter (S) than 4th	L	L	L	L	L	L	L
3rd and 4th joints fused (F) separated by suture (S)	F	S	F	F	S	F	F
Second antenna							
Protopodite (no. of bristles)	0	0	0	0	0	0	0
Endopodite (no. of bristles)							
1st joint: ventral/dorsal	1/2	1/2	1/2	1/2	1/2	1/2	1/2
2nd joint: lateral/terminal	1/4	1/4	1/4	1/4	1/4	1/4	1/4
3rd joint	3 (rarely 2 or 4)	0	2	2	0	3	0
Exopodite							
No. of joints	8 (rare) or 9	9	9	8	8	8	8
No. of bristles on joints 1st/9th	0/2 or 3	0/3	0/2	0/2	0/2	0/2	0/2
Mandible							
Basale (no. of bristles)							
Posterior margin (proximal)	2	3	3	3	3	3	3
Anterior margin	1	1	1	1	1	1	1
Lateral side[a]	4 or 5	5	5	5	5	5	5
Medial side	2	2	2	2	2	2	2
Endopodite (no. of bristles)							
1st joint: dorsal	1	1	1	1	1	1	1
2nd joint: ventral/dorsal	3 or 4/2	3/2	4/2	3/2	3/2	3/2	3/2
3rd joint	7	7	7	6	6	6	6
Maxilla (no. of bristles)							
Endite I	c 11	12	12	10	10	nd	10
Endite II	9–11	11	nd	9	nd	nd	c 10
Endite III	c 7	c 6	nd	7	nd	nd	nd
Basale: dorsal/ventral	1/1	1/1	1/1	1/1	1/1	nd	1/1
Endopodite							
1st joint: anterior/posterior	5 or 6/3	5 or 6/?	6/3	5/3 and 6/2[b]	5/3	nd	5/2?
2nd joint	9	8	8	9	8	nd	8

in living species of THAUMATOCYPRIDIDAE

Thaumatoconcha								*Danielopolina*		*Thaumatocypris echinata*	
polythrix		*sandersi*		*tuberculata*		*hessleri*	sp. A	*carolineae*	*orghidani*		
♀	♂	♀	♂	♀	♂	♀	♀	♀	♀	♀ [a]	♀ [b]
1.85–1.94	1.68	1.94–2.00	1.78–1.89	1.61–1.70	1.59–1.67	1.42–1.47	1.46	1.85	0.52–0.59	1.4	1.55
10	10	1–3	1–3	5 or 6	5 or 6	5	4 or 5	3	0	nd	7
16	16	9	9	17–20	17–20	14–17	15	8	9	nd	4?
punctate	punctate	smooth	smooth	smooth	smooth	smooth	smooth	reticulate	reticulate	smooth	smooth
A	A	A	A	P	P	A	A	P	P	P	P
1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1 [c]	1/0	1/0
1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1 [c]	1/1	1/1
0	0	0	0	0	0	0	0	0	0 [c]	0	0
0	2	0	2	0	2	0	0	0–1(minute)	0 [c]	1	1
2	3	3	3	3	3	3	2	2	1 [c]	3	3
0	0	0	0	0	0	0	0	0	0 [c]	1	0
2/1	2/1	2/1	2/1	2/1	2/1	2/1	2/1	2/0	2/0 [c]	1/1	1/1
3	3	3	3	3	3	3	3	3	3 [c]	2	2
L	L	L	L	L	L	S	S	L	S? [c]	S	S
F	S	F	S	F	F	F	F	F	F [c]	F	F
0	0	0	0	0	0	0	0	1	0	nd	nd
1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	0/2	0/2	1/2	1/2
1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	0/3	1/4	1/4
2	0	2	0	3	0	3	2	1	1	no 3rd joint	no 3rd joint
8	8	8	8	9	9	8	8	9	8	9	9
0/2	0/2	0/2?	0/?	0/2	0/2	0/2	0/2	1/2	0/2	0/2	nd
3	3	nd	3	3	3	3	2(1 missing?)	3	2 [c]	2	2
1	1	nd	1	1	1	1	1	1	1 [c]	2	3
5	5	nd	5	5	5	5	5	5	4 [c]	7	5?
2	2	nd	2	2	2	2	2	2	nd	2	2
5 or 6	4 or 5	1	1	1	1	1	1	1	1 [c]	1	1
3/3	3/3	4/2	4/2	3/2	3/2	3/2	4/2	3/2	3/2 [c]	4/2	3/3
6	6	6	6	7	7	6	6	6	6 [c]	7	6
c 11	9	nd	10	nd	10	c 9	nd	10	4 [c]	8	c 9
nd	8	nd	11	9	nd	9	nd	nd	3 [c]	15	nd
nd	6	nd	c 8	7	nd	7	nd	nd	4 [c]		nd
1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1 [c]	0/1	1?/2?
7/2?	7/3	5/3	5/3	6/2?	5/3	5/3	6/3	4/2?	3/3 [c]	4/2	5/2
nd	8	nd	8	9	8	8	8	c 8	5 [c]	6	6

TABLE 13.—Summary of morphologic characters

Character	*Thaumatoconcha*						
	radiata		*punctata*	*elongata*		*caraionae*	
	♀	♂	♀	♀	♂	♀	♂
Fifth limb (no. of bristles)							
Epidopial appendage	14	nd	14	14	nd	nd	14
Protopodite and endopodite	23	nd	22	18	23	21	22
Exopodite							
1st joint: dorsal/ventral	1/7	1/9	1/10	1/9	1/9	1/9	1/7
2nd joint ventral: midventral/terminal	3/0	3/0	3/0	3/0	3/0	3/0	2/0
3rd joint	2	2 (3 rare)	2	2	2	2	2
3rd joint: length of short bristle as % of long bristle	58	nd	50	46	nd	nd	44
Sixth limb (no. of bristles)							
Epipodial appendage	c 15	nd	15	15	nd	nd	15
Protopodite	4	4	4	4	nd	4	nd
Exopodite							
1st joint	4 or 5	4	4 or 5	6	4	3	4
1st joint, process on dorsal corner	3	3	3	3	3	3	3
2nd and 3rd joints: midventral/dorsal	2 or 3/1	2/1	2/1	2 or 3/1	2/1	2/1	2/1
3rd joint: terminal ventral	0	0	0	0	0	0	0
4th joint	2	2	2	2	2	2	2
4th joint: length of short bristle as % of long bristle	83	nd	65	34	nd	40	44
Seventh limb (no. of bristles)	2	2	2	2	2	2	2
Furca (no. of claws): long/short	2/6	2/6	2/6	2/6	2/6	2/6	2/6
Rod-shaped organ							
Elongate (E), absent (A) or reduced (R)	E	E	E	E	E	E	E
Tip tapered (T) or rounded (R)	R	R	T	R	R	R	R
Posterior: single process (P)	P	P	P	P	P	P	P
Male copulatory organ, no. of teeth: long/short	na	1/7	na	na	1/0	na	1/0

[a] From Poulsen (1969).
[b] From Müller (1906).
[c] From Danielopol drawings (in prep.).
[d] Broad spine also present except on *T. echinata*.
[e] Right and left appendage of same individual.
[f] One lamella of unique specimen with 5 short claws, other with 6.
na = not applicable; nd = no data.

bristle present in space between sets of teeth; distal set of teeth consisting of 2 flat teeth; proximal flat tooth consisting of 1 large lateral cusp and 6–10 small pointed cusps; distal flat tooth with about 6 pointed cusps, cusp 2 counting from lateral side longer than others; 1 spinous bristle present on lateral side of base of proximal flat tooth and about half length of adjacent cusp. Basale: teeth of endite with 5 triangular cusps with minute serrations along margins; posterior margin with 1 or 2 proximal bristles and 1 distal short blunt bristle; anterior margin of basale endite of *Danielopolina* and *Thaumatoconcha* with 1 bristle, of *Thaumatocypris* with 2? or 3? bristles; lateral side of endite with flat knife-like process distal to several bristles, 3? to 5 on *Danielopolina*, 6 (rarely 4) on *Thaumatoconcha*, and 7? on *Thaumatocypris;* medial side of basale with proximal mound with 2 long bristles. Endopodite 3-jointed: 1st joint with 1 dorsal bristle except *Thaumatoconcha polythrix*, which has 5 or 6; ventral margin of 2nd joint with 2 or 3 bristles near middle and 1 subterminal; dorsal margin with 2 bristles except *T. polythrix*, which has 3 (the mandible of *Thaumatocypris echinata* illustrated

in living species of THAUMATOCYPRIDIDAE—Continued

Thaumatoconcha								*Danielopolina*		*Thaumatocypris*	
polythrix		*sandersi*		*tuberculata*		*hessleri*	sp. A	*carolineae*	*orghidani*	*echinata*	
♀	♂	♀	♂	♀	♂	♀	♀	♀	♀	♀ [a]	♀ [b]
14	14	nd	nd	nd	nd	nd	14	14	14 [c]	13	nd
23	21	c 15	c 17	nd	18	22	20	18	14 [c]	17	nd
1/10	1/10	1/6	1/11	1/7	1/7	1/7	1/7	1/9	1/5 [c]	1/8	nd
3/0	3/0	nd	3/0	3/0	2/0	2/0	2/0	2/1	2/1	2/0	nd
2	2	2	2	2	2	2	2	2	2 [c]	3	3
24	nd	48	nd	nd	43,47	34	35,38	87	45(65 [d])	na	na
nd	15	nd	15	15	15	nd	15	15	nd	c 12	nd
nd	6 or 7	4	4	4	4	4	4	4	4 [c]	4	nd
8	5 or 6	4	4	4	4	4	4	5	4	4	nd
3	3	3	3	3	3	3	3	2	2	1+spine	nd
3/1	3/1	2/1	2/1	2/1	2/1	2/1	2/1	3/1	1/1	2/1	nd
0	0	0	0	0	0	0	0	1	0	0	nd
2	2	2	2	2	2	2	2	2	2 [c]	3	3
41	nd	nd	41	nd	64–69	18	32	95	32 [c]	nd	nd
2	2	2	2	2	2	2	2	2	2 [c]	2	2
2/6	2/6	2/6	2/6	2/6	2/6	2/6	2/5 or 6 [e]	2/6	2/3 [c]	2/7	2/7
E	E	E	E	E	E	E	E	A	A [c]	R	A
R	R	R	R	R	R	R	R	na	na	na	na
P	P	P	P	P	P	P	P	P	P [c]	P	P
na	1/0	na	1/0	na	1/1	na	na	na	na	na	na

by Müller [1906, pl. 6: fig. 8] bears 3 bristles on the dorsal margin of the 2 endopodial joint, but only 2 are on the specimen described by Poulsen [1969: 11]); 3rd joint with 6 or 7 bristles, 1 or 2 of these much longer and stouter than others.

Maxilla: Number of bristles on endites difficult to discern on some specimens: endite I with 8 to 12 bristles, except *D. orghidani,* which has only 4; endite II with 8 to 11 bristles, except *D. orghidani* which has only 3; endite III with 6 to 8 bristles, except *D. orghidani* which has only 4. Basale with 1 ventral and 1 dorsal bristle except *Thaumatocypris echinata* which may bear an additional bristle on dorsal margin. Endopodite: anterior margin of 1st joint with 3 or 4 bristles on *Danielopolina,* 4 or 5 on *Thaumatocypris,* and 5 or 6 on all species of *Thaumatoconcha* except *T. polythrix* which has 7; posterior margin of 1st joint with 2 or 3 bristles; 2nd joint of *Thaumatocypris* with 6 bristles, of *Thaumatoconcha* and *Danielopolina* with 8 or 9 bristles, except *D. orghidani* which has only 5.

Fifth limb: Epipodial appendage of *Danielopolina* and *Thaumatoconcha* with 14 bristles arranged in 3 groups of 5, 5, and 4; *Thaumatocypris*

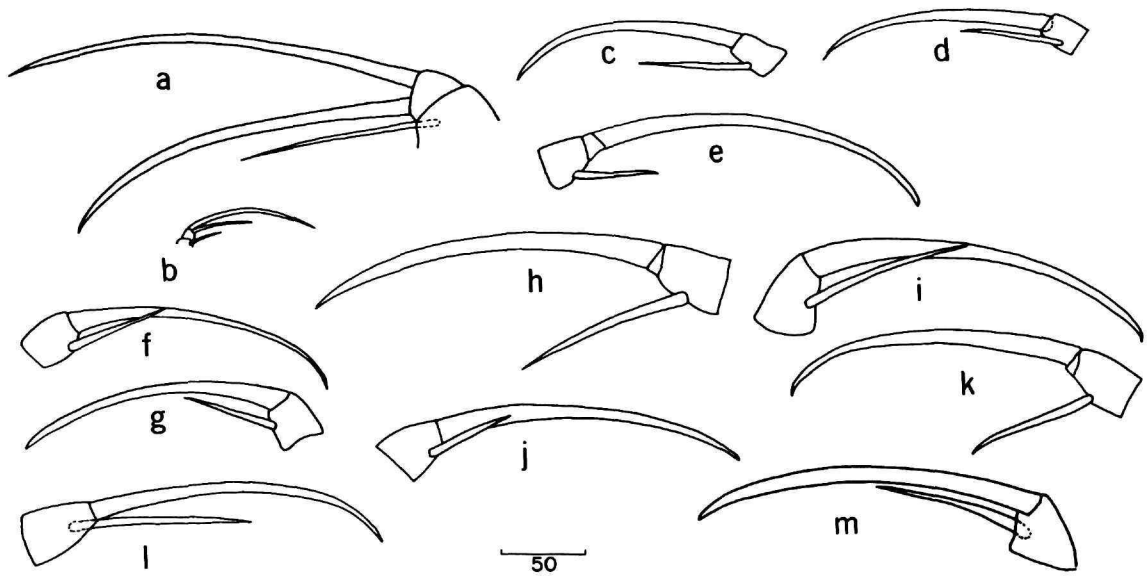


FIGURE 11.—End joint of 5th limb: *a, Danielopolina carolynae,* new species, adult female, holotype, USNM 143789; *b. D. orghidani* (Danielopol, 1972), female; *c, Thaumatoconcha tuberculata,* new species, adult male, paratype, USNM 143796Mb; *d,* same, USNM 143796M; *e, Thaumatoconcha hessleri,* new species, adult female, holotype, USNM 143862; *f,g,* both limbs, *Thaumatoconcha* species A, female, USNM 143851; *h, Thaumatoconcha punctata,* new species, adult female, holotype, USNM 143861; *i, Thaumatoconcha sandersi,* new species, adult female, paratype, USNM 127275C; *j, Thaumatoconcha polythrix,* new species, adult female, paratype, USNM 143790C; *k, Thaumatoconcha caraionae,* new species, adult male, paratype, USNM 143855A; *l, Thaumatoconcha radiata,* new species, adult female, holotype, USNM 143794; *m, Thaumatoconcha elongata,* new species, adult female, paratype, USNM 143967. (Scale in micrometers.)

with 13 bristles arranged in 3 groups of 4, 5, and 4 (Poulsen, 1969:12). The number of bristles on the protopodite and endopodite not clearly discernable on all specimens: the protopodite and endopodite of *Thaumatocypris* with 17 bristles, of *Danielopolina* with 14 to 18 bristles, of *Thaumatoconcha* with 15 to 23 bristles. Exopodite: dorsal margin of 1st joint with 1 bristle; ventral margin of 1st joint of *Thaumatocypris* with 8 bristles, of *Thaumatoconcha* with 7–11 bristles, of *Danielopolina* with 5–8 bristles; ventral margin of 2nd joint of *Thaumatocypris* and *Danielopolina* with 2 midbristles, of *Thaumatoconcha* with 2 or 3 midbristles; ventral margin of 2nd joint of *Danielopolina* with 1 terminal bristles, *Thaumatocypris* and *Thaumatoconcha* without a terminal bristle; 3rd joint of *Thaumatocypris* with 3 bristles, of *Danielopolina* and *Thaumatoconcha* with 2 bristles (Figure 11).

Sixth limb: Epipodial appendage of *Thaumatocypris* with about 12 bristles, of *Thaumatoconcha* and *Danielopolina* with 15. Protopodite with 4 bristles except *Thaumatoconcha polythrix* which bears more (5–7?). Endopodite: process on dorsal corner of 1st joint with 1 bristle and a minute spine on *Thaumatocypris,* 2 bristles on *Danielopolina,* and 3 bristles on *Thaumatoconcha;* 1st joint of *Thaumatocypris* with 4 bristles, of *Danielopolina* with 4 or 5 bristles, of *Thaumatoconcha* with 4–6 bristles, except *T. polythrix* which has 8; dorsal margin of fused 2nd and 3rd joints with 1 bristle; ventral margin of *Thaumatocypris* with 2 bristles, of *Thaumatoconcha* with 2 or 3 bristles (usually 2 except for *T. polythrix*), of *Danielopolina* with 1 *(D. orghidani)* or 4 (*D. carolynae,* 3 midbristles and 1 terminal); 4th joint of *Thaumatoconcha* and *Danielopolina* with 2 bristles, of *Thaumatocypris* with 3 bristles (Figure 12).

Seventh limb: Small with 2 long bristles.

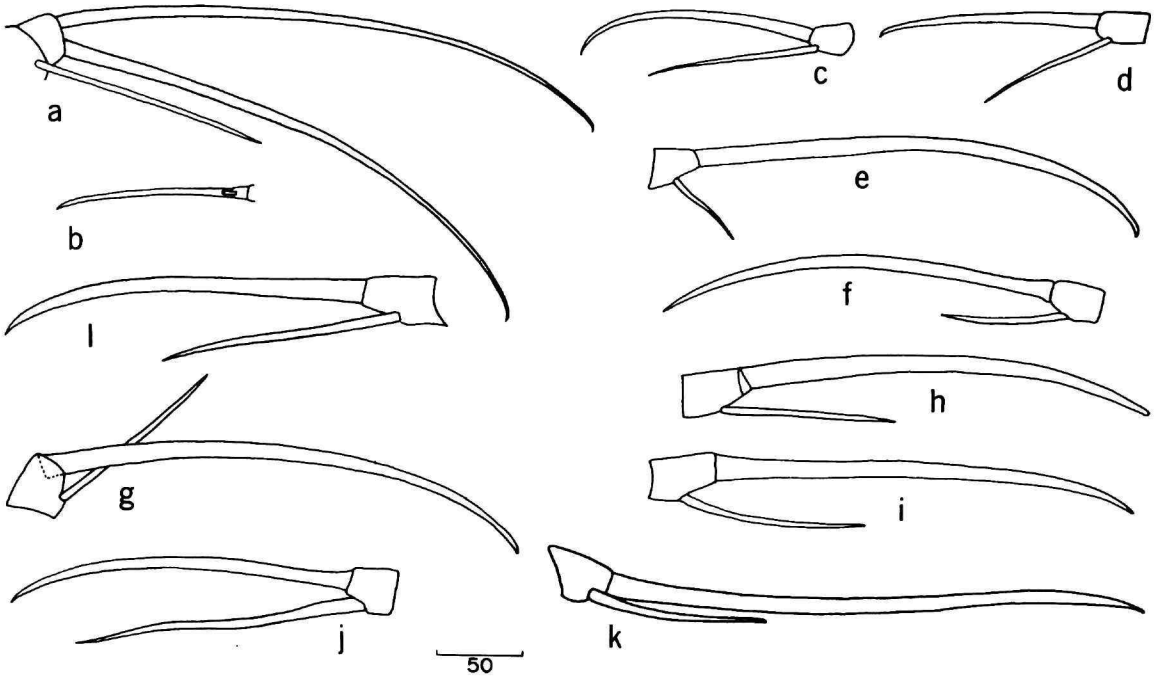


FIGURE 12.—End joint of 6th limb: *a, Danielopolina carolynae,* new species, adult female, holotype, USNM 143789; *b, Danielopolina orghidani* (Danielopol, 1972), female; *c, Thaumatoconcha tuberculata,* new species, adult male, paratype, USNM 143796Mb; *d,* same, USNM 143796M; *e, Thaumatoconcha hessleri,* new species, adult female, holotype, USNM 143862; *f, Thaumatoconcha* species A, adult female, USNM 143851; *g, Thaumatoconcha sandersi,* new species, adult male, holotype, USNM 143793; *h, Thaumatoconcha polythrix,* new species, adult female, paratype, USNM 143790C; *i, Thaumatoconcha caraionae,* new species, adult male, paratype, USNM 143855A; *j, Thaumatoconcha radiata,* new species, adult female, holotype, USNM 143794; *k, Thaumatoconcha elongata,* new species, adult female, paratype, USNM 143967; *l, Thaumatoconcha punctata,* new species, adult female, holotype, USNM 143861. (Scale in micrometers.)

Furca: Each lamella with 2 long anterior claws separated by suture from lamella, followed by short claws joined to lamella: *Thaumatocypris* with 7 short claws; *Thaumatoconcha* and *Danielopolina carolynae* with 6 short claws followed by short process oriented posteriorly; *Danielopolina orghidani* with 3 short claws.

Rod-shaped organ: Missing or represented by minute projection on *Thaumatocypris* and *Danielopolina;* elongate, 1-jointed or weakly 2-jointed on *Thaumatoconcha.*

Posterior of body: Single process on posterior margin proximal to furcal lamellae. Posterior margin of *Thaumatocypris* wrinkled (Poulsen, 1969:12), of *Thaumatoconcha* and *Danielopolina* divided into narrow segments.

Lips: Upper lip (Figure 13): proximal part with triangular sclerotized lateral process on each side oriented anteriorly; distal part with 4 spine-like processes at tip oriented posteriorly; *Thaumatoconcha punctata* and *Danielopolina carolynae* with additional small processes on distal part of lip (Figure 13*d,i,k*). Lower lip consisting of 2 lateral segments, each with sclerotized triangular process at tip oriented anteriorly (Figure 13*a–d,k*). (Details of lip of *Thaumatocypris echinata* are not known, but the illustration of the complete specimen by Müller (1906, pl. 6: fig. 3) suggests that the lips of that species are similar to those of *Danielopolina* and *Thaumatoconcha*).

Heart: We examined several specimens of *Thaumatoconcha radiata* and *Thaumatoconcha tubercu-*

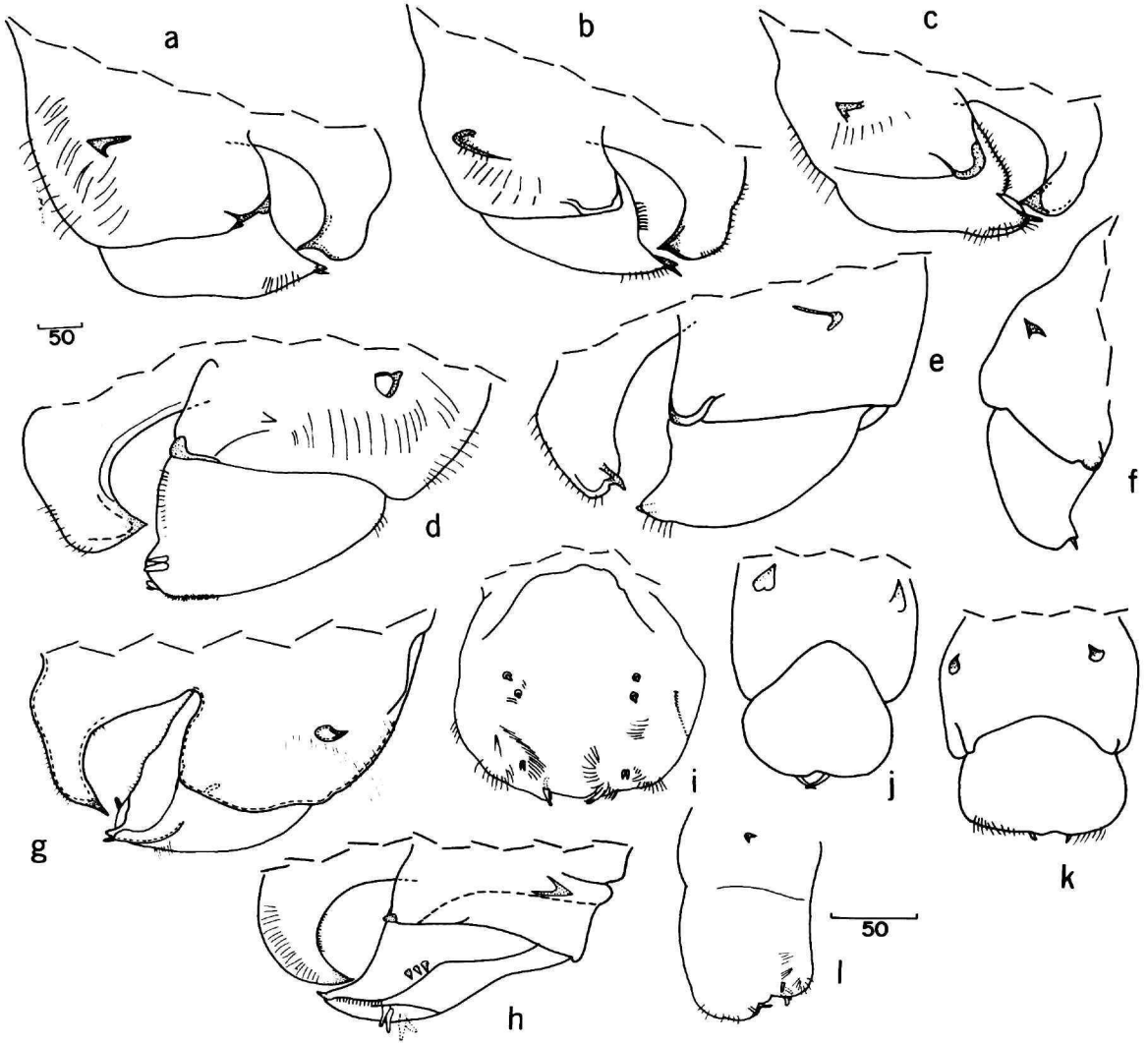


FIGURE 13.—Lips, lateral view: *a, Thaumatoconcha caraionae,* new species, adult female, holotype, USNM 143856; *b, Thaumatoconcha tuberculata,* new species, adult female, paratype, USNM 143796C; *c, Thaumatoconcha polythrix,* new species, adult male, holotype, USNM 143792; *d, Thaumatoconcha punctata,* new species, adult female, paratype, USNM 127289B; *e, Thaumatoconcha sandersi,* new species, adult female, paratype, USNM 127275A; *f, Thaumatoconcha hessleri,* new species (upper lip only), adult female, holotype, USNM 143862; *g, Thaumatoconcha elongata,* new species, adult female, paratype, USNM 143967; *h, Danielopolina carolynae,* new species, adult female, holotype, USNM 143789. Upper lip: *i, Thaumatoconcha punctata,* new species, holotype, USNM 143861, ventral view; *j, Thaumatoconcha hessleri,* new species, adult female, holotype, USNM 143862, anterior view; *k, Thaumatoconcha* species A, adult female, USNM 143851, anterior view; *l, Danielopolina orghidani* (Danielopol, 1972), anterior view (distorted). (Same magnification in micrometers: *a–k; l* is ½ scale of *a–k.*)

lata and one specimen each of *Danielopolina carolynae,* new species, and *Danielopolina orghidani* (Danielopol, 1972), and were not able to find the heart. Therefore, we tentatively have concluded that the thaumatocyprids are without a heart. Thus, they resemble in this character the cladocopes, the podocopes, and the platycopes.

Discussion of Appendages.—First antenna: Müller (1912:54) considered the 1st antenna of *Thaumatocypris echinata* to have 6 joints, but noted an incomplete suture across the 5th joint. Poulsen (1969:9) observed a well-defined suture across the 5th joint as defined by Müller and interpreted that joint to consist of 2 joints, the 5th and 6th; thus, Poulsen considered the 1st antenna to have 7 joints. Poulsen (1969:10) interpreted a long, bare, unringed, bristle on the ventral margin of the 5th joint to be a sensory bristle and cited this to support his belief that the limb had 7 joints. That bristle is absent from the specimen of *T. echinata* illustrated by Müller (1906, pl. 6: fig. 10). The 5th joint is also bare on the specimens of *Thaumatoconcha* and *Danielopolina* that we examined. Therefore, we consider the presence of a bristle on the joint not to be the norm for the *Thaumatocyprididae.* We do, however, agree with Poulsen that the 5th joint described by Müller consists of 2 joints. Poulsen (1969:8) described the 3rd joint of the 1st antenna of *T. echinata* as follows: "The 3rd joint is rather elongate, at about the middle of its dorsal margin is a clear break in the cuticula and off this break on the ventral margin a slight constriction." We have interpreted the "3rd joint" to consist of 2 joints, the 3rd and 4th joints. Thus, the 1st antennae of the *Thaumatocyprididae* have 8 joints, the same number as on other members of the Myodocopina. The presence of a spinous bristle (sensory bristle) on the 5th joint of the adult male of species of *Thaumatoconcha* supports our interpretation that the limb has 8 joints. The 3rd and 4th joints are separated by a well-defined suture on some adult males of *Thaumatoconcha;* unfortunately, adult males are not known for either *Thaumatocypris* or *Danielopolina.*

Second antenna: Müller (1906:41, pl. 6: fig. 9) described and illustrated a 2-jointed endopodite on the 2nd antenna of a juvenile female of *Thaumatocypris echinata* Müller, 1906. Poulsen (1969:10) considered the endopodite of the 2nd antenna of *T. echinata* to be 2-jointed, but stated, "The narrow, distal part of the joint [2nd] is by a weak line or suture divided from the broader, proximal part, and this may indicate that the branch actually has 3 joints (as typical for Myodocopa)." We consider the endopodite of *Thaumatocypris echinata* to be 2-jointed, whereas, the endopodites of *Danielopolina* and *Thaumatoconcha* are 3-jointed.

Mandible: Skogsberg (1920:29) was of the opinion that the small bare verruciform appendage that is situated distodorsally, somewhat medially, on the 2nd protopodite joint that was illustrated by Müller (1906, pl. 7: fig. 7) corresponds to the exopodite. A verruciform appendage was not mentioned by Müller in his description (1906:42) nor does it p-pear in the medial view of the complete mandible he illustrated (1906, pl. 7: fig. 8). Neither was it mentioned or illustrated by Poulsen (1969). A verruciform appendage was not observed on the specimens we examined, but in some of our dissections we have seen stumps of muscles that resemble the structure illustrated by Müller. We conclude that the "verruciform appendage" on Müller's figure 7, which is an illustration of an isolated basale, represents an internal structure, possibly the stump of a muscle.

Key to the Genera of Thaumatocyprididae

1.	Carapace reticulate	2
1′.	Carapace not reticulate	4
2(1).	Carapace with node on anterodorsal part of each valve	***Thaumatomma*** (fossil)
2′.	Carapace without node on anterodorsal part of each valve	3
3(2′).	Reticulations formed by continuous ridges	***Pokornyopsis*** (fossil)
3′.	Reticulations formed by minute subround papillae	***Danielopolina*** (Holocene)
4(1′).	Carapace with long spine-like process at each end of anteroventral margin; 1st joint of 1st antenna with 1 bristle; rod-shaped organ minute	***Thaumatocypris*** (Holocene)
4′.	Carapace with short protuberance at each end of anteroventral margin; 1st joint of 1st antenna with 2 bristles; rod-shaped organ elongate	***Thaumatoconcha*** (Holocene)

Thaumatocypris Müller, 1906

Thaumatocypris Müller, 1906:42.—Skogsberg, 1920: 568.—Poulsen, 1969 [part]:7 [not 12]; [not Danielopol, 1972:1390].

TYPE-SPECIES.—*Thaumatocypris echinata* Müller, 1906. Monotypy.

DISTRIBUTION (Figure 9).—Indian Ocean, 0°58′S, 99°43′E, 1100 m (Müller, 1906:139; Indonesia, 2°22′S, 126°58′E, ca. 2000 m (Poulsen, 1969:8).

HABITAT.—Pelagic at bathyal depths.

Because the genus is monotypic, the diagnosis is the same as that of the species.

Poulsen (1969:12, fig. 2) described and illustrated an empty carapace as *Thaumatocypris* species indeterminate. As discussed on page 121, we do not consider the carapace that of an ostracode.

Thaumatocypris echinata Müller, 1906

FIGURES 14*c,d;* 15

Thaumatocypris echinata Müller, 1906:42, pl. 6: figs. 1–18; 1912:54 [listed].—Poulsen, 1969:7, figs. 1, 2.

HOLOTYPE.—Not designated.

TYPE-LOCALITY.—Valdivia station 190 V, 0°58′S, 99°43′E, southwest of Sumatra, 1100 m (Figure 9). The present location of the syntypes (6 specimens) is unknown.

OTHER LOCALITIES.—Indonesian area, 2°22′S, 126°58′E, about 2000 m (1 specimen) (Poulsen, 1969:12) (Figure 9).

MATERIAL.—We are unable to locate Müller's syntypes. Through Dr. Torbin Wolff we obtained from the Zoological Museum of the University of Copenhagen the specimen described by Poulsen (1969:7).

DIAGNOSIS.—Each valve with upper and lower long anteroventral protuberances (Figure 14*d*); right valve with short posterodorsal tubercle (Figure 14*c*); surface smooth.

First antenna: First joint with 1 dorsal bristle, but without lateral bristle; 7th joint with 2 bristles, 1 ventral, 1 dorsal; 8th joint with 2 bristles.

Second antenna: Two-jointed; 1st endopodial joint with 3 bristles, 1 ventral, 2 dorsal.

Fifth limb: Second exopodial joint without terminal bristle on ventral margin; 3rd exopodial joint with 3 bristles.

Sixth limb: Process on dorsal corner of 1st exopodial joint with 1 bristle and 1 minute spine.

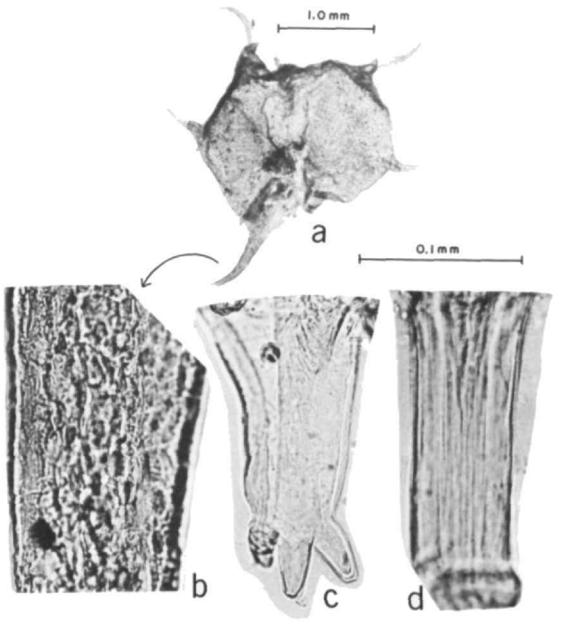


FIGURE 14.—Crustacea? (= *Thaumatocypris* sp. indet. Poulsen, 1969): *a*, outside view of carapace under cover slip in shallow-well glass slide; *b*, detail of spine. *Thaumatocypris echinata* Müller, 1906: *c*, posterodorsal tubercle on right valve, lateral view; *d*, proximal part of anterodorsal spine on right valve, lateral view. (Same magnification: *b–d*. All photographs taken with transmitted light.)

Rod-shaped organ: Minute, cone-shaped.

DESCRIPTION OF APPENDAGES.—First antenna: First joint with 1 dorsal bristle, but without lateral bristle; 2nd joint with 1 ventral and 1 dorsal bristle; 3rd and 4th joints fused except at sclerotized dorsal and ventral margins, especially the former; sclerotized dorsal margin of 3rd joint shorter than sclerotized dorsal margin of 4th joint; 3rd joint without bristles; 4th joint with 1 ventral bristle; 5th joint with 3 ventral bristles; 6th joint without bristles or with transparent ventral bristle; 7th joint with 1 ventral and 1 dorsal bristle; 8th joint with 2 bristles.

Second antenna: Protopodite without a bristle. Endopodite 2-jointed: 1st joint with 1 dorsal and 2 ventral bristles; 2nd joint with 1 lateral and 4 terminal bristles. Exopodite 9-jointed: 1st joint without a bristle, 2nd to 8th joints with natatory setae; 9th joint with 2 bristles.

Mandible: Basale: posterior margin with 2

bristles; anterior margin with 2 or 3 bristles; lateral side with 5 to 7 bristles; knife-like spine may not be present; medial side with 2 bristles. Endopodite: 1st joint with 1 dorsal bristle; 2nd joint with 3 or 4 ventral and 2 or 3 dorsal bristles; 3rd joint with 6 bristles.

Maxilla: Endite I with 8 or 9 bristles; endites II and III with total of 15 bristles. Basale with either 1 bristle or without bristles on dorsal margin and with 1 or 2 bristles on ventral margin. Endopodite: 1st joint with 4 or 5 anterior bristles and 2 posterior bristles; 2nd joint with 6 bristles.

Fifth limb: Epipodial appendage with 13 bristles; prodopodite and endopodite with 17 bristles. Exopodite: 1st joint with 1 dorsal bristle and 8 ventral bristles; ventral margin of 2nd joint with 2 midbristles; 3rd joint with 3 subequal bristles.

Sixth limb: Epipodial appendage with about 12 bristles; prodopodite with 4 bristles. Exopodite: process on dorsal corner of 1st joint with 1 bristle and 1 minute spine; 1st joint with 4 additional bristles; combined 2nd and 3rd joints with 1 dorsal bristle and 2 ventral midbristles; 4th joint with 3 subequal bristles.

Seventh limb: Small with 2 long bristles.

Rod-shaped organ: Absent, or represented by short cone.

Posterior of body: Single process present proximal to furcal lamellae; posterior wrinkled along posterior margin dorsal to process.

Lips: Müller's illustration of the upper and lower lips of this species (1906, pl. 6: fig. 3) indicates that the lips are similar to those of *Danielopolina* and *Thaumatoconcha*.

Discussion of Central Adductor Muscle Attachment Scar.—In his description, Müller (1906: 43) stated that the closing muscle attachments are unclear. The muscle-scars of one of the specimens that he illustrated (1906, pl. 6: fig. 1) consist of 1 large ovoid scar anterior to 3 smaller ovoid scars forming an oblique row. Poulsen (1969) did not describe or illustrate the muscle scars of this species. We restudied Poulsen's specimen for the purpose of determining the muscle scar pattern on *T. echinata*. Unfortunately, the muscles are partly ripped from the shell of Poulsen's specimen so that we could not determine the precise number and the distribution of individual scars. Two adjacent muscle fascicles adhering to the left valve are interpreted to be in position (Figure 15). The position

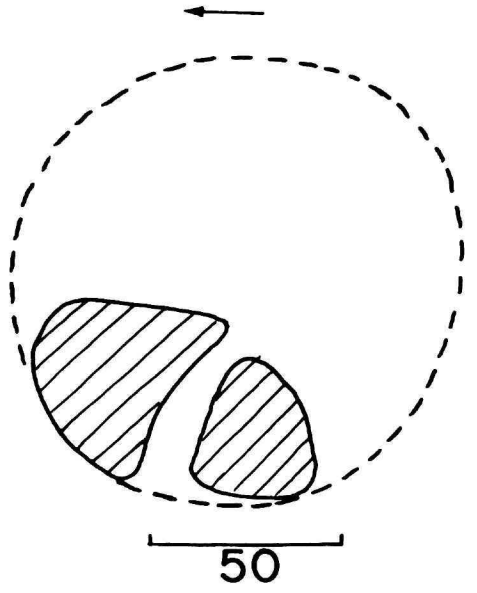


Figure 15.—Camera lucida drawing of terminal ends of 2 adductor muscles on the left valve of Poulsen's *Thaumatocypris echinata*, Zoological Museum of the University of Copenhagen, lateral view. (Scale in micrometers.)

of these two fascicles suggests that all the fascicles are oriented to form a radial group. The two adjacent muscle ends are similar to some of the muscle ends illustrated by Danielopol (1972, fig. B) for *Thaumatocypris orghidani* Danielopol, 1972 (= *Danielopolina*), and also to those we illustrate herein for the male of *Thaumatoconcha sandersi*, new species (Figure 59*b*). Unfortunately, because of the poor condition of Poulsen's specimen we were unable to conclude whether or not all the fascicles were radially arranged. Pending study of additional material, we believe that the muscle-scar pattern of the type-species is radial and not like the pattern illustrated by Müller (1906, pl. 6: fig. 1).

Comparisons.—See Table 13.

Thaumatoconcha, new genus

Type-Species.—*Thaumatoconcha radiata*, new species.

Etymology.—Name derived from a combination of the Greek *thauma* (wonder, marvel) + *konche* (shell).

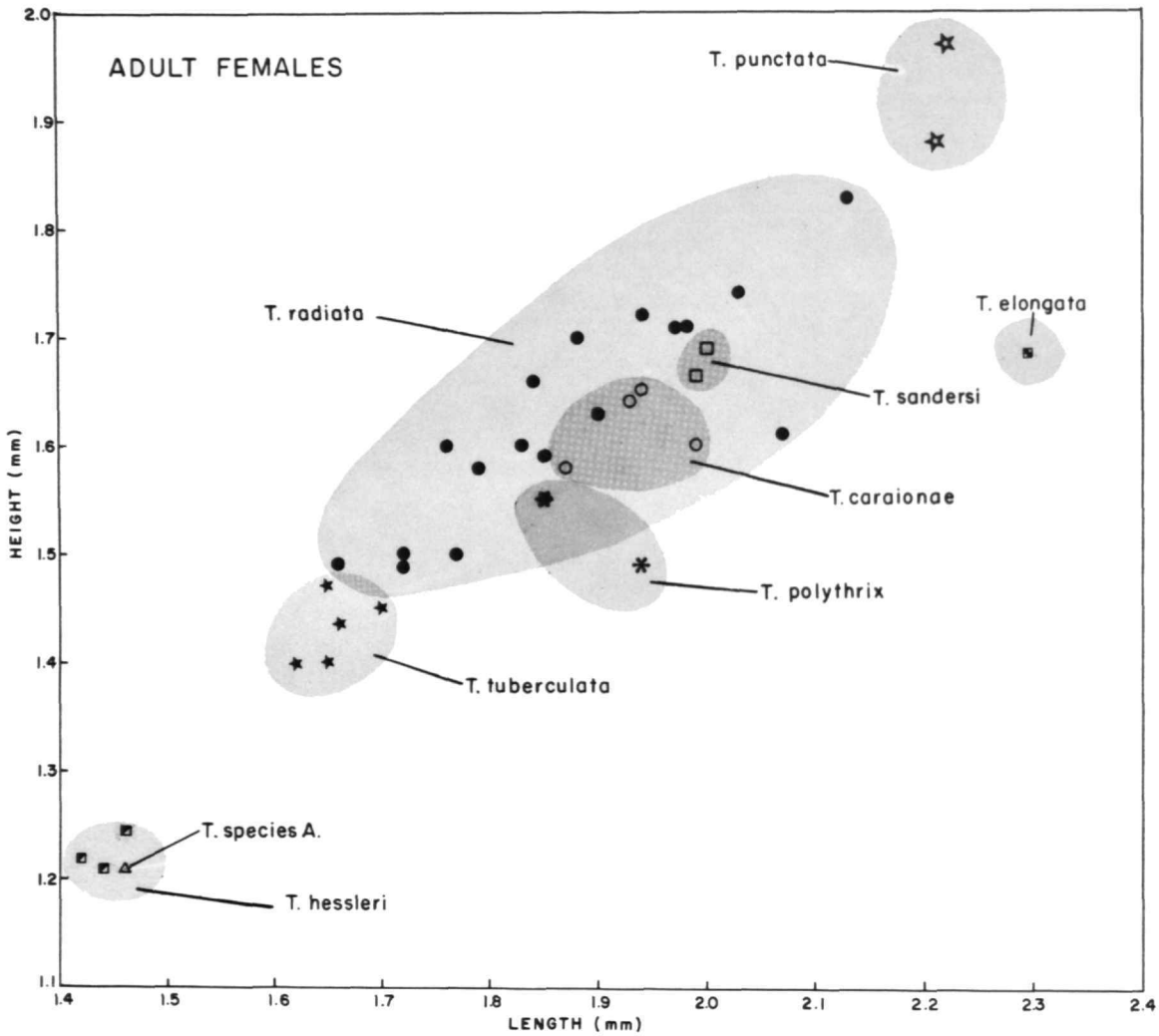


FIGURE 16.—Length-height distribution of adult females of species of *Thaumatoconcha*.
○ *caraionae*, new species
* *polythrix*, new species
□ *sandersi*, new species
■ *elongata*, new species
☆ *punctata*, new species
★ *tuberculata*, new species
◆ *hessleri*, new species
● *radiata*, new species
Δ species A

This genus contains 8 species, all new and one additional taxon in open nomenclature: *T. radiata, T. sandersi, T. hessleri, T. tuberculata, T. caraionae, T. elongata, T. polythrix, T. punctata,* and *Thaumatoconcha* species A.

DISTRIBUTION.—Atlantic Ocean, 32°N to 73°S; Pacific Ocean, 7°S to 70°S (Figure 9).

HABITAT.—Benthic.

DIAGNOSIS.—Carapace with ridges restricted to anteroventral surface of carapace; short anteroventral protuberances crudely reticulated; without posterodorsal tubercles except *T. tuberculata;* 1st antenna with 2 bristles on 1st joint; rod-shaped organ well developed. Surface smooth or coarsely to finely punctate, some species with small pustules visible with SEM; anteroventral surface with 1 to 11 thin ridges parallel to valve margin; cross-ridges on and near anteroventral protuberances; only 1

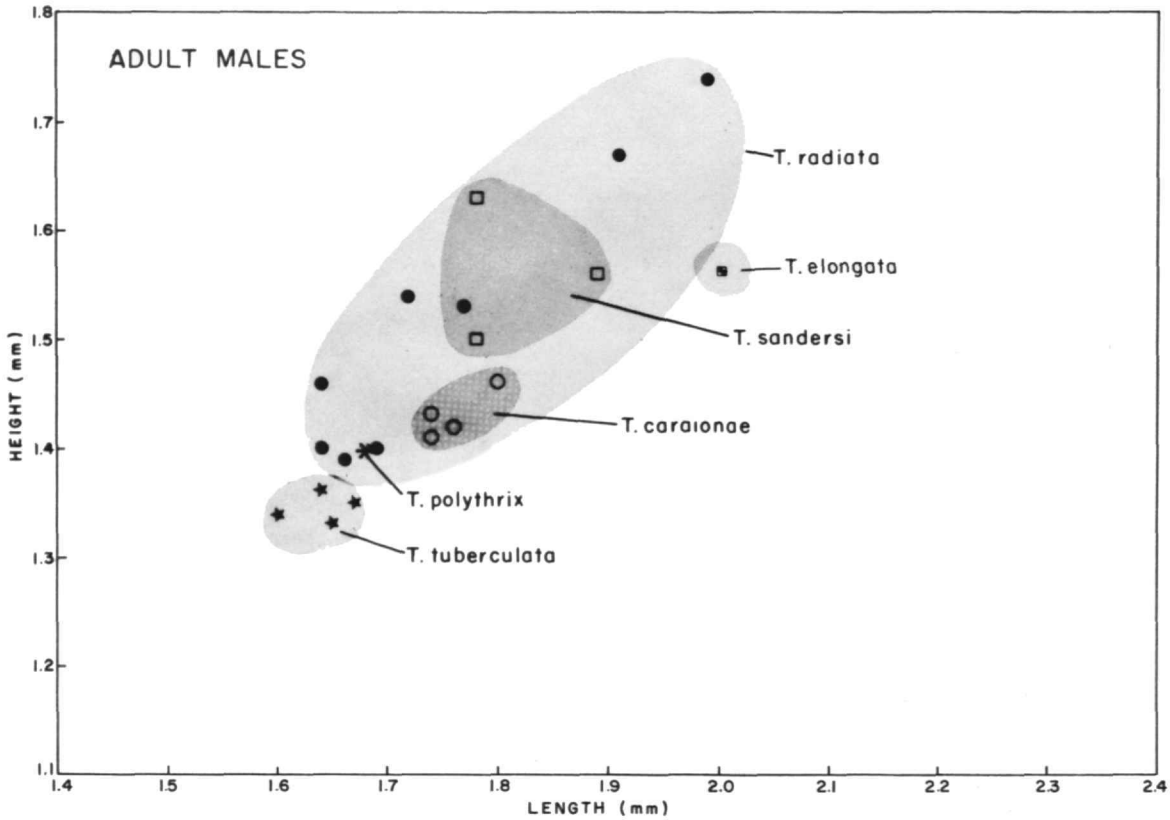


FIGURE 17.—Length-height distribution of adult males of species of *Thaumatoconcha*.
○ *caraionae*, new species * *polythrix*, new species □ *sandersi*, new species
■ *elongata*, new species ● *radiata*, new species ★ *tuberculata*, new species

species, *T. tuberculata*, with minute posterodorsal tubercule on right valve located posterior to similar tubercle on left valve. Dimensions of carapaces are compared in Figures 16, 17.

First antenna: 1st joint with 2 bristles, 1 dorsal, 1 lateral; 7th joint with 3 bristles, 2 ventral, 1 dorsal; 8th joint with 3 bristles.

Second antenna: First endopodial joint with 3 bristles, 1 ventral, 2 dorsal.

Fifth limb: 2nd exopodial joint without terminal bristle on ventral margin; 3rd exopodial joint with 2 (rarely 3) bristles.

Sixth limb: Process on dorsal corner of 1st exopodial joint with 3 bristles; 4th exopodial joint with 2 bristles.

Rod-shaped organ: Elongate with rounded or pointed tip.

DESCRIPTION OF APPENDAGES OF ADULT FEMALE.—First antenna: First joint with 1 dorsal and 1 lateral bristle; 2nd joint with 1 dorsal and 1 ventral bristle; 3rd and 4th joints fused except at sclerotized dorsal and ventral margins, especially the former; segment of dorsal margin of 3rd joint longer than that of 4th joint except for *T. hessleri* and *Thaumatoconcha* species A; 3rd and 4th joints usually without bristles, but rarely with a ventral bristle; 5th joint with 2 or 3 ventral bristles; 7th joint with 3 bristles, 2 ventral, 1 dorsal; 8th joint with 3 bristles.

Second antenna: Protopodite without bristles. Endopodite 3-jointed: 1st joint with 3 bristles, 1 ventral, 2 dorsal; 2nd joint with 5 bristles, 1 ventral, 4 terminal; 3rd joint with 2 or 3 bristles. Exopodite with 8 joints, except *T. radiata, T. punctata,* and *T. tuberculata* which have 9: 1st joint divided into

long proximal and short distal parts, without medial bristle; joints 2 to 8 with natatory bristles; 9th joint with 2 bristles, except *T. radiata* which has either 2 or 3.

Mandible: Proximal flat tooth of distal set on coxale endite with 1 large lateral cusp and 6 or 7 small pointed cusps. Basale: anterior margin of endite with 1 bristle; posterior margin with 3, rarely 2, proximal bristles, and usual blunt distal bristle; lateral side with flat knife-like process and 5, rarely 4, bristles. Endopodite: dorsal margin of 1st joint with 1 bristle, except *T. polythrix* which has 5 or 6 bristles; ventral margin of 2nd joint with 3 or 4 bristles; dorsal margin of 2nd joint with 2 bristles, except *T. polythrix* which has 3 bristles; 3rd joint with 6 or 7 bristles: 3 lateral (middle of these claw-like and longer than others), 3 or 4 medial (1 of these on or near ventral margin).

Maxilla: Endite I with 9–12 bristles; endite II with 8–11 bristles; endite III with 6–8 bristles. Basale with 2 bristles, 1 ventral, 1 dorsal. Endopodite: anterior margin of 1st joint with 5 or 6 bristles, except *T. polythrix* which has 7; posterior margin with 2 or 3 bristles; 2nd joint with 8 or 9 bristles, 1 of these is stout and claw-like, another, with base on posterior margin, is long and stout with short marginal spines.

Fifth limb: Epipodial appendage with 14 bristles arranged in 3 groups—5, 5, and 4. Protopodite and endopodite with 15–23 bristles. Exopodite: dorsal margin of 1st joint with usual single bristle; ventral margin of 1st joint with 6–10 bristles; ventral margin of 2nd joint with 2 or 3 midbristles; 3rd joint with 1 long claw-like bristle and 1 shorter bristle.

Sixth limb: Epipodial appendage with 15 plumose bristles; protopodite with 4 bristles, except *T. polythrix* which has 5 or more. Exopodite: process on dorsal corner of 1st joint with 3 bristles; 1st joint with 3–6 additional bristles, except *T. polythrix* which may have as many as 8; 4th joint with 1 long claw-like bristle and 1 shorter bristle.

Seventh limb: Small with 2 long spinous bristles.

Furca: Each lamella with 2 long anterior claws separated by suture from lamella, followed by 6 short claws joined to lamella; 1 small process oriented posteriorly present following claws.

Rod-shaped organ: Elongate, 1-jointed or weakly 2-jointed with tapered or rounded tip.

Posterior of body: Single process present proximal to furcal lamellae; posterior margin distinctly divided into narrow segments.

Lips: Upper lip: proximal part with triangular sclerotized lateral process on each side oriented anteriorly; distal part with 4 spine-like processes at tip oriented posteriorly; *T. punctata* with additional small processes on distal part of lip (Figure 13*d,i*).

DESCRIPTION OF ADULT MALE.—Similar in shape and ornamentation to that of female but slightly smaller.

First antenna: Joints 1, 2, and 3 similar to those of female, except 3rd and 4th joints separated by well-defined suture on some species (*T. radiata, T. elongata, T. polythrix, T. sandersi);* 4th joint with 2 ventral bristles; 5th joint with 3 ventral bristles, the longer of these with short marginal hairs (sensory bristle); 6th to 8th joints similar to those of female.

Second antenna: Protopodite and exopodite similar to those of female. Endopodite: 1st and 2nd joints similar to those of female; 3rd joint with large curved sclerotized hook-like process with 2 minute spines at tip; surface of hook pustulose near tip; base of process either on medial side of joint or terminal.

Mandible, maxilla, 5th limb, 6th limb, 7th limb, furca, rod-shaped organ, posterior, lips: Similar to those of female, but with few differences in numbers of bristles on mandible, 5th and 6th limbs that could be attributed to interspecific variability (Table 13). An exception might be the 1st joint of the exopodite of the 6th limb of *T. polythrix* with 5 or 6 bristles compared to 8 on female.

Copulatory organ (Figure 18): Single organ consisting of 2 parts present on left side of body: anterior part elongate with either a recurved process, *T. sandersi* (Figure 18*a–c*), a single long tooth-like process, *T. caraionae* (Figure 18*g–i*), *T. elongata* (Figure 18*n–p*), *T. polythrix* (Figure 18*q–s*), a long tooth-like process with a minute tooth at its base, *T. tuberculata* (Figure 18*j–m*), or about 8 teeth, *T. radiata* (Figure 18*d–f*); posterior part shorter than anterior part, tapered, styliform with 3 hair-like bristles at tip.

COMPARISONS.—See Table 13.

SHELL STRUCTURE.—An outer layer of shell flaked off many specimens during the freeze-drying process used prior to SEM micrography (Figures 22*a,c,d;*

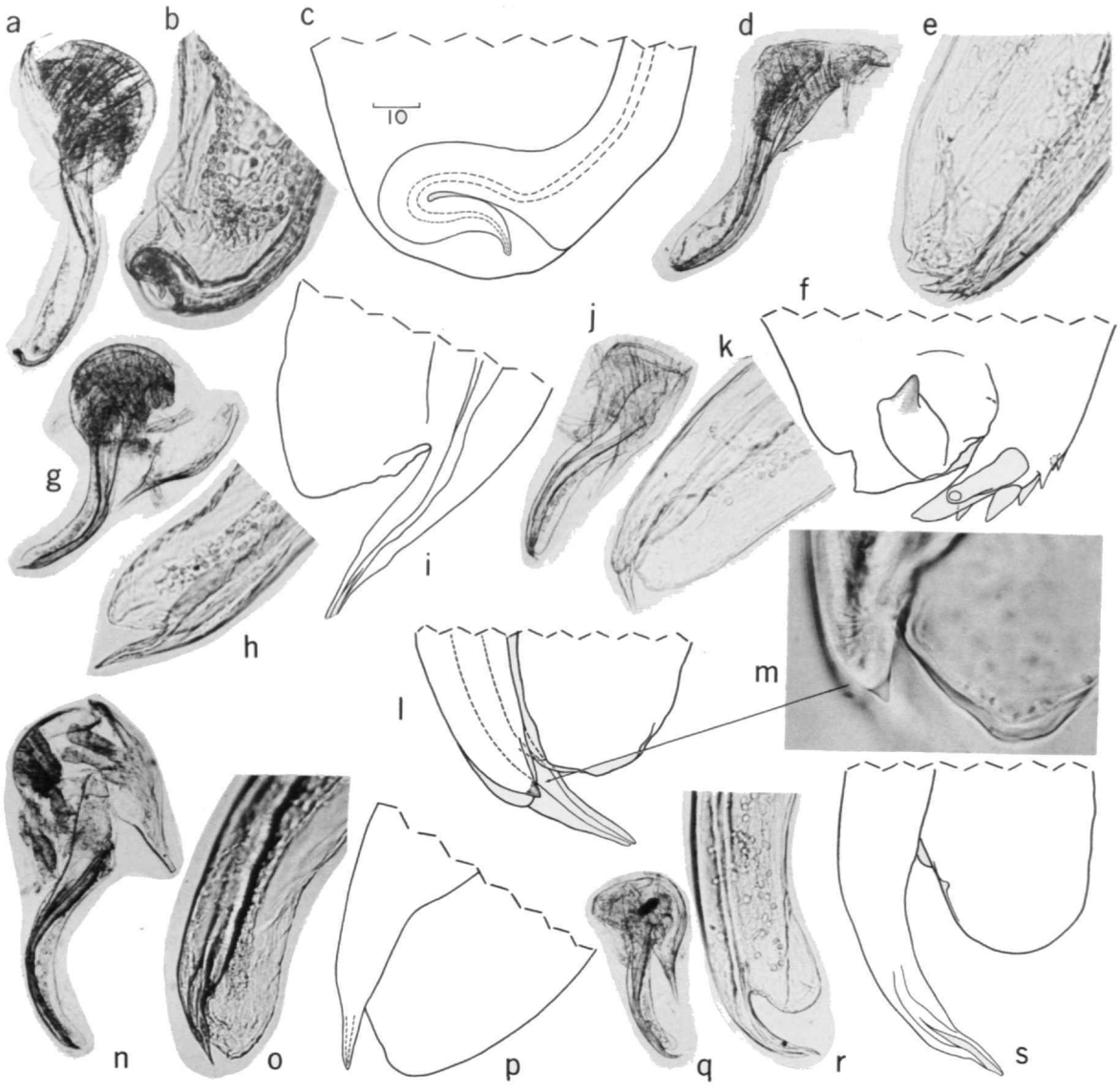


FIGURE 18.—Adult male copulatory organ of species of *Thaumatoconcha*: *a–c, T. sandersi,* new species, paratype, USNM 127275E; *d–f, T. radiata,* new species, paratype, USNM 126136E (arrow in *d* points to styliform lobe); *g–i, T. caraionae,* new species, paratype, USNM 143855A; *j–m, T. tuberculata,* new species, paratype, USNM 143796MY (arrow connects small tooth on *l* and *m*); *n–p, T. elongata,* new species, holotype, USNM 143968; *q–s, T. polythrix,* new species, paratype, USNM 143790B. (Same magnification in micrometers: *c, f, i, l, p, s.*)

23*a,b,d*). We observed that when the outer layer of shell is present, details of the central muscle attachment scar are not visible in reflected light or in SEM micrographs when the shell is viewed from the outside. The scar is visible when the outer layer has flaked off (Figure 23*b*). Hemispherical nodules similar to those described by Sohn and Kornicker (1969:101) from *Vargula hilgendorfii* (Müller, 1890) were observed on a few carapaces of *Thaumatoconcha radiata*.

Key to the Species of *Thaumatoconcha*, new genus

1. Endopodite of mandible with 4–6 dorsal bristles on 1st joint and 3 on 2nd ..... ***T. polythrix***, new species
1′. Endopodite of mandible with 1 dorsal bristle on 1st joint and 2 on 2nd 2
2(1′). Carapace length less than 1.5 mm; surface smooth without posterodorsal processes; 3rd joint of 1st antenna of female shorter than 4th, or about same length; tip of rod-shaped organ rounded 7
2′. Carapace length greater than 1.5 mm; surface smooth or punctate with or without posterodorsal processes; 3rd joint of 1st antenna of female distinctly longer than 4th; tip of rod-shaped organ rounded or tapered 3
3(2′). Carapace coarsely punctate (punctae not visible on all specimens), without posterodorsal processes; tip of rod-shaped organ tapered ..... ***T. punctata***, new species
3′. Carapace smooth or with minute punctae, with or without posterodorsal processes; tip of rod-shaped organ rounded 4
4(3′). Carapace with minute posterodorsal processes (broken off on some specimens); tip of copulatory organ with minute tooth at base of tooth-like processes ..... ***T. tuberculata***, new species
4′. Carapace without minute posterodorsal processes; tip of copulatory organ either with numerous teeth or single tooth-like process 5
5(4′). Carapace smooth, anteroventral surface with not more than 5 ridges parallelling margin; tip of copulatory organ with long straight tooth with numerous short teeth or with long strongly recurved tooth without short teeth 6
5′. Carapace finely punctate, anteroventral surface with more than 5 (usually 8) ridges parallelling margin; tip of copulatory organ with single straight or slightly curved tooth 8
6(5). Tip of copulatory organ straight with numerous short marginal teeth ..... ***T. radiata***, new species
6′. Tip of copulatory organ strongly recurved without short marginal teeth ..... ***T. sandersi***, new species
7(2). Anteroventral margin concave ..... ***T. hessleri***, new species
7′. Anteroventral margin straight ..... ***T.*** species A
8(5′). Length to height ratio of valves 1.29 to 1.39; tip of copulatory organ short, projects just past end of adjacent lobe ..... ***T. elongata***, new species
8′. Length to height ratio of valves 1.18 to 1.24; tip of copulatory organ long, projects well past end of adjacent lobe ..... ***T. caraionae***, new species

Thaumatoconcha radiata, new species

FIGURES 3–8,10*b*, 11*l*, 12*j*, 18*d–f*; 19–23; 24*a–i*; 25–34

HOLOTYPE.—USNM 143794, adult female, some appendages on slides, carapace and some appendages in alcohol.

TYPE-LOCALITY.—*USCGC Glacier* station 0022, 73°29′S, 30°24′6″W, Weddell Sea, 3035 m.

PARATYPES.—USNM 126136, 74 specimens; USNM 127272A, B, 2 specimens; USNM 143753, ca. 1200 specimens; USNM 143754A–C, 49 specimens; USNM 126139, 1 juvenile; USNM 143858, 12 specimens; USNM 143799, 176 specimens. USNM 126136 and 126139 from type-locality.

OTHER LOCALITIES.—USNM 127272 from *USNS Eltanin*, Cruise 4, station 127, 61°45′S, 61°14′W, Drake Passage, 4758 m; USNM 143753 from *R. V. Atlantis II*, Cruise 60, station 245A, 36°55′42″S, 53°01′24″W, South Atlantic, 2707 m; USNM 143754 from *R. V. Atlantis II*, Cruise 60, station 259, 37°13′18″S, 52°45′00″W, South Atlantic, 3305–3317 m; USNM 143858A–D from *R. V. Vema* Cruise 14, station V–14–25 (Lamont Geological Observatory station 49) 56°43′S, 27°41′W, 2747 m;

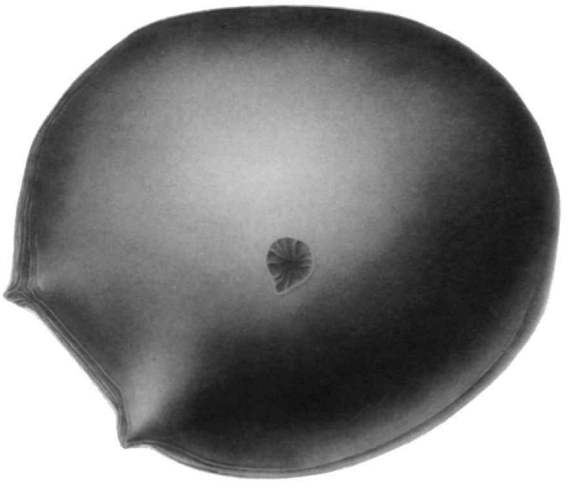


FIGURE 19.—*Thaumatoconcha radiata,* new species, carapace of adult female, paratype, USNM 143753R, length 1.85 mm, anterior to left.

USNM 143799 from *R. V. Atlantis II,* Cruise 60, station 262A, 36°05′12″S, 52°17′54″W, South Atlantic, 2440–2480 m (Figures 1 and 9).

ETYMOLOGY.—The specific name *radiata* is in reference to the radial structure of the adductor muscle attachments.

DIAGNOSIS.—Surface smooth with 4 or 5 anteroventral ridges and straight anteroventral margin; dorsal margin of 3rd joint of 1st antenna longer than dorsal margin of 4th joint; endopodite of mandible with 1 dorsal bristle on 1st joint and 2 on 2nd joint; rod-shaped organ with rounded tip; tip of male copulatory organ with long straight tooth and with numerous short teeth.

DESCRIPTION OF ADULT FEMALE (Figures 4*q,r;* 5*j;* 6*j,k;* 10*b;* 11*l;* 12*j;* 19–22; 24*a–i;* 25–31).—Valves subround, height of anterior margin greater than posterior (Figures 4*q,r;* 19; 20*a;* 21*a;* 22*a–e*); straight anteroventral margin delimited by a dorsal and a ventral forward pointing, short, truncated pro-

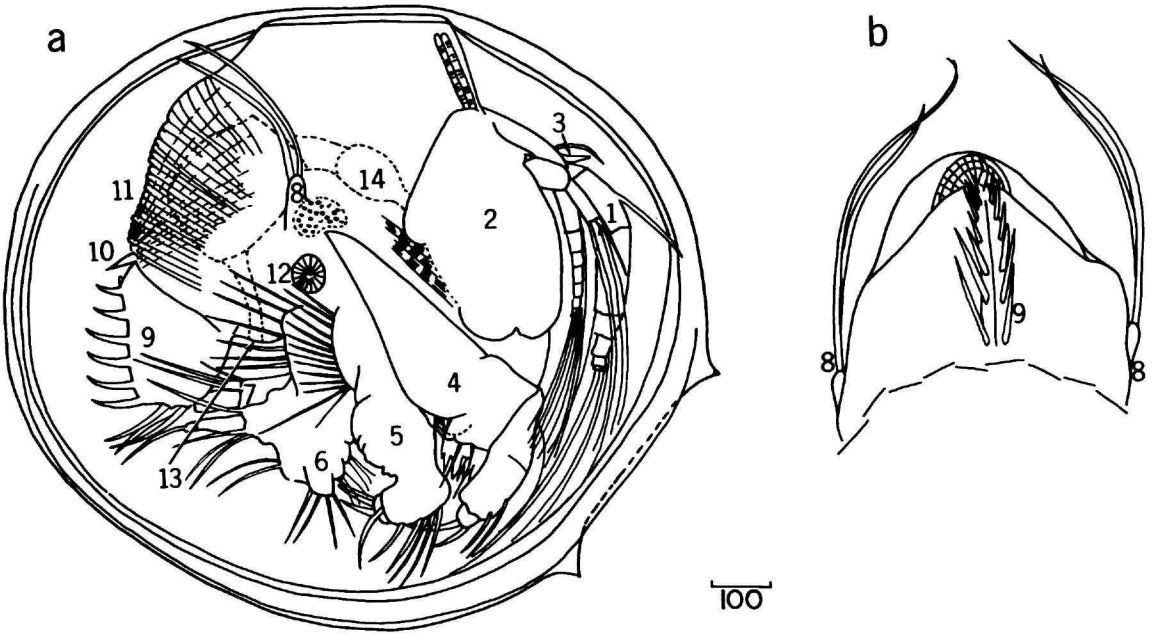


FIGURE 20.—*Thaumatoconcha radiata,* new species: *a,* adult female with right valve removed, paratype, USNM 126136Y, length 1.91 mm, anterior to right; *b,* ventral view of posterior of adult female showing caudal furca and 7th limbs, holotype, USNM 143794. (1 = 1st antenna, 2 = 2nd antenna, 3 = rod-shaped organ, 4 = mandible, 5 = maxilla, 6 = 5th limb, 7 = 6th limb, 8 = 7th limb, 9 = furca, 10 = posterior process, 11 = transverse folds of posterior, 12 = adductor muscle, 13 = anus, 14 = gut. Scale in micrometers.)

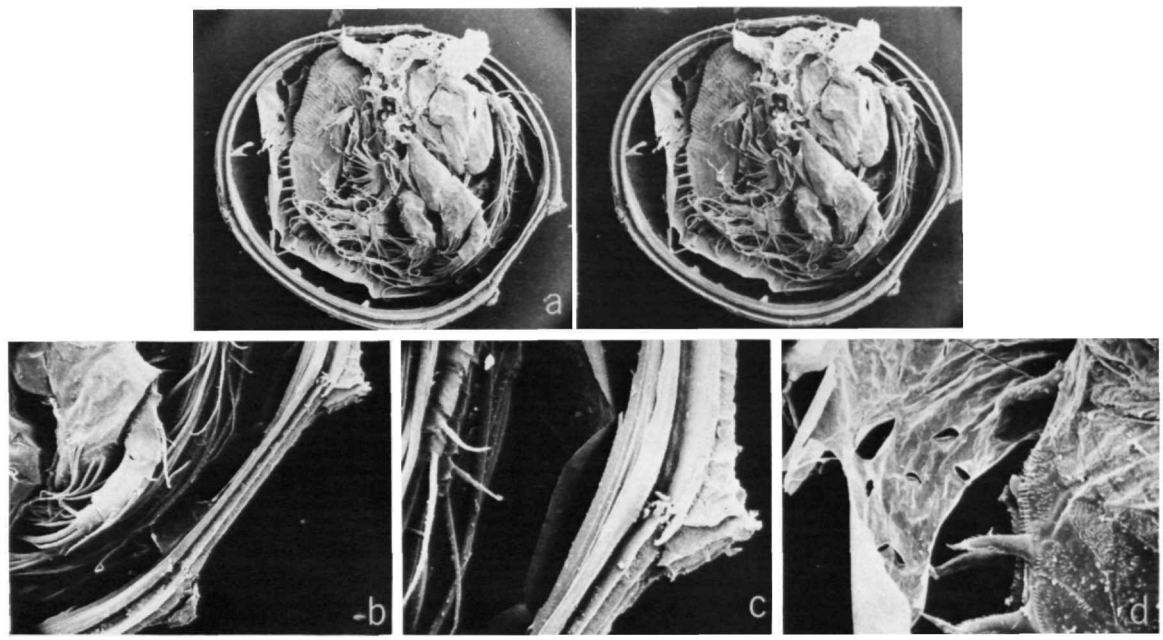


FIGURE 21.—*Thaumatoconcha radiata*, new species, adult female, paratype, USNM 126136Y, specimen with right valve removed: *a*, stereo-pair of body in left valve, anterior margin to right, × 44; *b*, anteroventral edge of left valve and mandible, × 150; *c*, upper anteroventral protuberance of left valve, inside view, × 250; *d*, proximal part of ventral margin of furca and single posterior process (arrow), × 400. (Photos reduced to 54 percent.)

tuberance (Figures 6*j,k;* 22*f,i*); anterodorsal margin broadly convex, merging with short straight dorsal margin at point about one-third greatest length; posterior margin evenly rounded; ventral margin curving gently forward and downward to point approximately below subcentral adductor muscle-scar, then curving upward to join anteroventral margin below protuberance. Dorsal outline subelliptical, greatest width in front of midlength (Figure 22*c*); end outline subelliptical, greatest width slightly below midheight (Figure 22*e*).

Ornamentation: Surface smooth; widely spaced pore-canals with hairs that branch distally observed near anterior margin (Figure 22*g,h*); anteroventral surface with 4 thin ridges parallel to valve margin (some individuals have a discontinuous 5th ridge) (Figure 22*e*); upper protuberance located between the 2 ridges closest to the contact margin, in form of truncated pentagonal pyramid with 5 thin ridges forming corners (Figure 22*f*); ridge on posterior corner perpendicular to contact margin; remaining 4 ridges each join one of the 2 ridges closest to contact margin; cross-ridges form crude reticulations around protuberance; lower protuberance located between 2nd and 4th thin ridges, covered with irregular reticulations formed by cross-ridges and capped by a rimmed pore containing a single hair (Figure 22*i*); 2 of the thin ridges extend along ventral margin, of these, ridge closest to contact margin continues to hinge margin, other terminates at posteroventral margin.

Adductor muscle attachment scar: Scar subcentrally located in area of greatest width; subround, greatest diameter trending towards posterior end of hinge; scar consists of from 19 to 24 subequal wedged-shaped segments more-or-less radially arranged (Figure 19; also see Figure 23*e*, an adult of unknown sex).

Size: USNM 143794 (holotype), left valve, length 1.90 mm, height 1.63 mm; right valve, length 1.88 mm, height 1.67 mm. USNM 126136Y, left valve, length 1.94 mm, height 1.69 mm; right valve, length

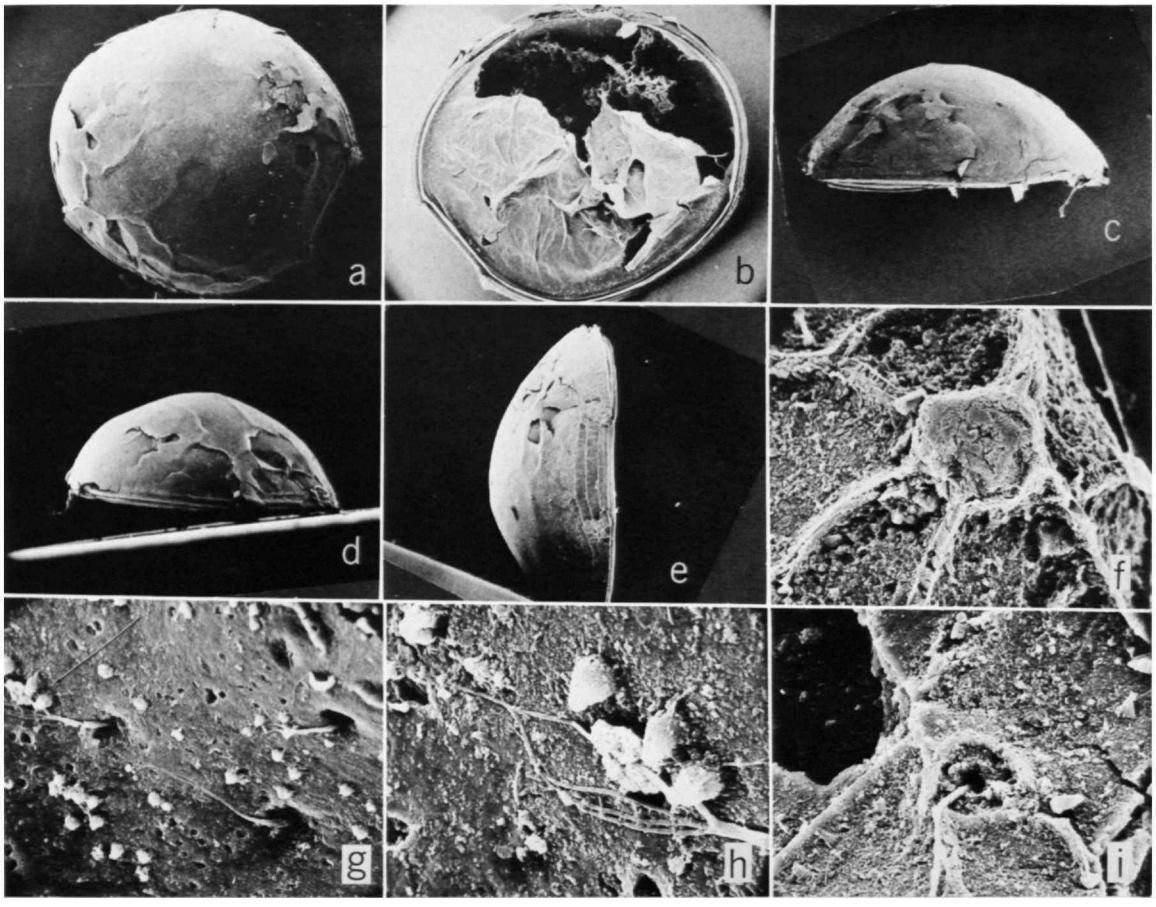


FIGURE 22.—*Thaumatoconcha radiata*, new species, adult female, paratype, USNM 143753W, right valve: *a*, outside, × 42; *b*, inside, × 46; *c*, dorsal view, anterior to left, × 46; *d*, ventral view, anterior to right, × 42; *e*, anterior view, × 46; *f*, upper anteroventral protuberance, × 1250; *g*, outer surface of valve showing branching hairs, pustules, and openings, × 1000; *h*, detail of branching hair, pustules, and openings shown in *g* (arrow), × 3000; *i*, lower anteroventral protuberance, × 1250. (Photos reduced to 66½ percent.)

1.94 mm, height 1.72 mm. USNM 126136Z, complete specimen, length 2.02 mm, height 1.61 mm; USNM 126136G, complete specimen, length 1.97 mm, height 1.71 mm; USNM 126136H, complete specimen, length 1.98 mm, height 1.71 mm. USNM 143753A, left valve only, length 1.72 mm, height 1.50 mm; USNM 143753E, left valve only, length 1.72 mm, height 1.49 mm; USNM 143753N, left valve only, length 1.79 mm, height 1.58 mm; USNM 143753P, complete specimen, length 1.83 mm, height 1.60 mm; USNM 143753R, complete specimen, length 1.85 mm, height 1.59 mm; USNM 143753W, right valve only, length 1.66 mm, height 1.49 mm; USNM 143753KK, disarticulated valves, left valve, length 1.77 mm, height 1.50 mm; right valve, length 1.76 mm, height 1.46 mm; USNM 143753XX, right valve only, length 1.76 mm, height 1.60 mm. USNM 143754A, complete specimen, length 1.88 mm, height 1.70 mm. USNM 143858A, length 2.03 mm, height 1.74 mm; USNM 143858B, length 2.13 mm, height 1.83 mm. USNM 143799A, complete specimen, length 1.84 mm, height 1.66 mm (Figures 3, 16).

First antenna (Figures 7*h*; 20*a*; 21*a*; 24; 25*a*,*b*;

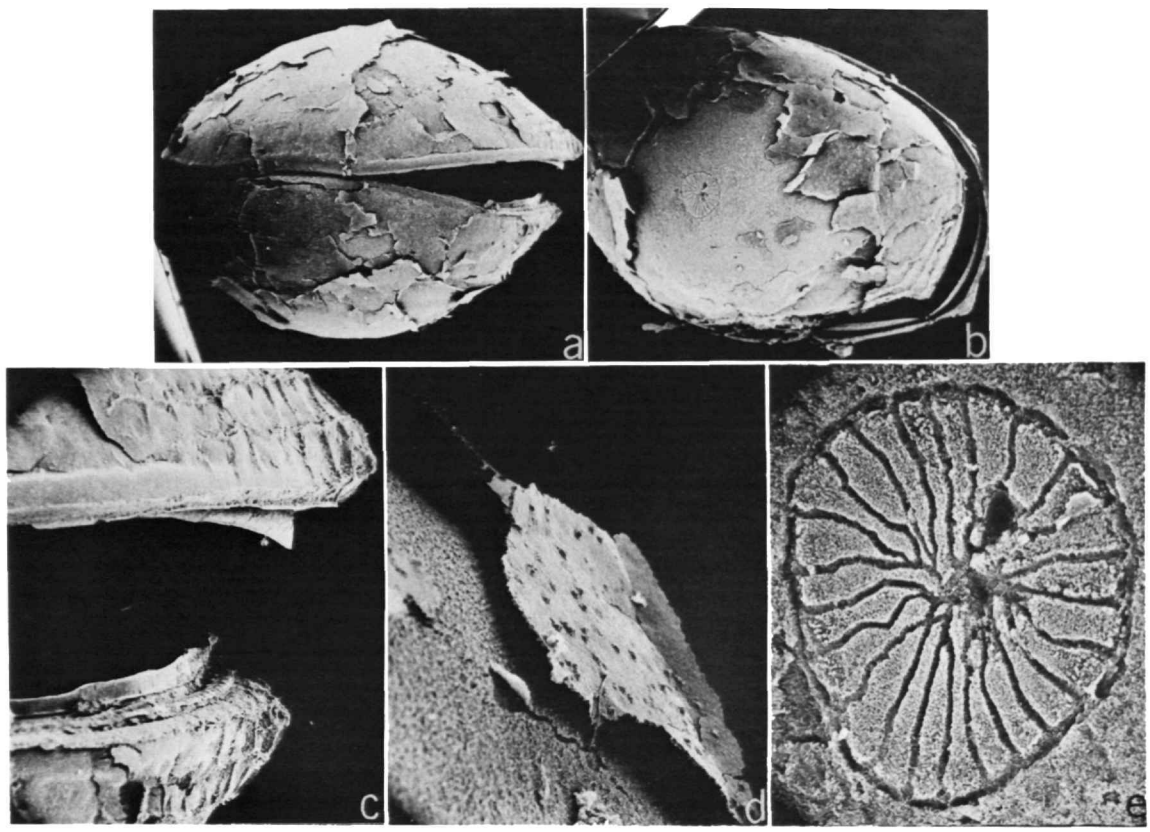


FIGURE 23.—*Thaumatoconcha radiata*, new species, adult specimen, USNM 143753WW, articulated valves: *a*, dorsal view, anterior to right (flaking of shell occurred during freeze-dry operation prior to scanning), × 46; *b*, lateral view of right valve showing adductor muscle attachment scar, × 46; *c*, anterior end of specimen, dorsal view, × 200; *d*, detail of loose flake of shell showing pustules, × 400; *e*, adductor muscle attachment scar on right valve shown in *b* (outer layer of shell not present), × 410. (Photo reduced to 66½ percent.)

26): Limb with 8 joints: 1st joint with minute spines on lateral surface (near distal margin), numerous long spines on medial surface, 1 dorsal bristle with short marginal spines, and 1 spinous lateral bristle on small protuberance; 2nd joint with 1 ventral bristle reaching to or beyond 8th joint and 1 dorsal bristle reaching 5th to 8th joints, both bristles with short marginal spines; 3rd and 4th joints fused except in sclerotized areas on ventral and dorsal margins; 3rd joint distinctly longer than 4th joint; 3rd joint with long spines on ventral and dorsal margins and on medial surface (rarely with ventral bristle); 4th joint with few short marginal spines and rarely with minute terminal bristle on ventral margin (Table 14); 5th joint with few short spines on dorsal margin and with 3 terminal ventral bristles, 1 short (not always present), and 2 long with widely separated short marginal spines; 6th joint with few spines along dorsal margin; 7th joint with 1 short ringed dorsal bristle with short marginal spines and 2 terminal ventral bristles with widely separated short marginal spines; 8th joint with 1 short terminal dorsal bristle with short marginal spines, and 2 long terminal bristles with widely separated short marginal spines.

Second antenna (Figures 8*h*; 10*b*; 20*a*; 21*a*; 25*c*; 27): Protopodite with long hairs forming clusters along ventral margin; lateral surface with numerous

TABLE 14.—Distribution of minute bristles on ventral margin of 4th joint of 1st antenna of *Thaumatoconcha radiata*, new species

USNM	Right limb	Left limb
126136G	1	0
126136H	1	0
126136X	0	0
126136Z	0	0
143753A	0	0
143753E	0	0
143753P	0	0
143753R	1	1
143753T	0	0
143753W	0	0
143753KK	0	1
143754A	1*	1

*3rd joint of right limb unusual, with 1 ventral bristle (Figure 7).

blunt spines on arcuate sclerite proximal to base of endopodite. Endopodite weakly 3-jointed: 1st joint with medial spines, 1 ventral and 2 dorsal bristles, both with short marginal spines; 2nd joint narrower and longer than 1st joint, with medial spines along ventral margin and on medial surface, 1 lateral bristle with short marginal spines, and 4 terminal bristles on ventral half of distal margin, all with widely separated short marginal spines; 3rd joint with 3 terminal bristles (rarely 2 or 4): 1 short, ventral, with closely spaced short marginal spines, and 2 longer, with more widely spaced marginal spines; suture separating 3rd and 4th joints present only on medial side. Exopodite 9-jointed (rarely with 8): 1st joint with suture dividing it into long proximal and short distal parts, with spines along ventral margin and forming row along terminal margin; joints 2–8 each with 1 long bristle with natatory hairs and short spines along ventral margin (number of bristles with spines varies); 9th joint with 3 (only 2 on some specimens) bristles, 1 long and 1 medium with natatory hairs, 1 short with short marginal spines (when short bristle is absent, medium bristle bears only spines); joints without basal spines but with some distal hairs.

Mandible (Figures 20*a;* 21*a,b;* 25*d,e;* 28*a,b*): Coxale endite with proximal and distal sets of teeth separated by small space; proximal set consisting of 4 broad teeth plus rounded tooth near space; about 3 clusters of very densely packed spines present medially between each tooth (bases of cluster extending onto medial surface of endite); 1 pointed or blunt spinous bristle present in space between proximal and distal sets of teeth; distal set of teeth consisting of 2 flat teeth; proximal flat tooth consisting of 1 large lateral cusp and 6 or 7 small pointed medial cusps; distal flat tooth with 6 pointed cusps (cusp 2 counting from lateral side longer than others); 1 spinous bristle present on lateral side of base of proximal flat tooth and about half length of adjacent cusp; medial and lateral surfaces of endite with short spines forming clusters on distal part near teeth. Basale: teeth of endite with 5 triangular cusps with minute serrations along margins; posterior margin of endite with single proximal bristle and distal blunt bristle with minute short tube-like process at tip (process visible at × 1000); anterior margin of endite with 1 bristle; lateral side of endite hirsute with 4 or 5 spinous bristles varying in location on different specimens, and short triangular process with minute teeth on lateral side near anterior margin; medial side of basale with cluster of long hairs near outer edge and mound with 1 long outer bristle with very long proximal hairs and short distal spines, and 1 long inner bristle with short spines. Endopodite 3-jointed with 1st and 2nd joints about same length and 3rd joint shorter; 1st joint with 1 spinous dorsal bristle and spines forming clusters on lateral and medial surfaces and along ventral margin; ventral margin of 2nd joint with 3 or 4 spinous bristles (2 or 3 near middle, 1 terminal); dorsal margin of 2nd joint with 2 claw-like bristles, both with marginal spines (distal bristle slightly broader at base than proximal bristle); terminal end of 3rd joint with 3 lateral spinous bristles (middle of these claw-like and about twice length of others) and 4 medial spinous bristles (1 of these on or near ventral margin).

Maxilla (Figures 20*a;* 21*a;* 25*f;* 28*c*): Endite I with ca. 11 bristles; endite II with 9–11 bristles; endite III with ca. 7 bristles; some endite bristles broad, flat, pectinate. Basale with long dorsal bristle with long proximal and short distal spines; ventral margin of basale with long bristle with short marginal spines (this bristle may be on 1st endopodite joint). Endopodite: 1st joint hirsute, with 5 or 6 slender spinous bristles on anterior (dorsal) margin, 2 terminal spinous bristles and 1 short subterminal

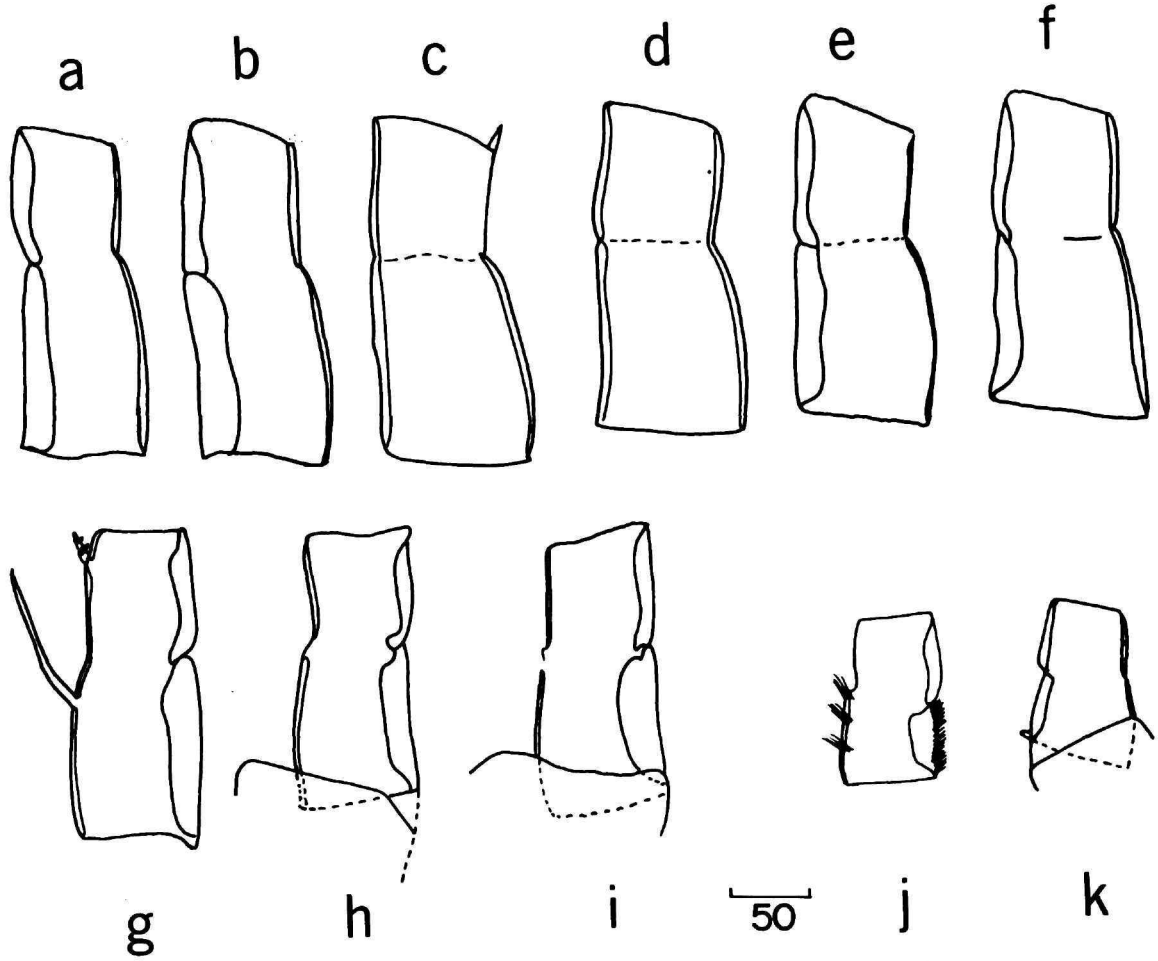


FIGURE 24.—Variation in 3rd and 4th joints of female 1st antenna, *Thaumatoconcha radiata*, new species: *a*, holotype, USNM 143794, left limb, medial view; *b*, same, right limb, lateral view; *c*, paratype, USNM 126136H, right limb, lateral view; *d*, same, left limb, medial view; *e*, paratype, USNM 126136G, right limb, lateral view; *f*, same, left limb, medial view; *g*, paratype, USNM 143754A, right limb, lateral view; *h*, paratype, USNM 143753T, right limb, medial view; *i*, same, left limb, lateral view; *j*, *Thaumatoconcha* species A, USNM 143851, right limb, medial view; *k*, *Thaumatoconcha hessleri*, new species, holotype, USNM 143862, right limb, lateral view. (Scale in micrometers.)

bristle on posterior (ventral) margin, and 1 short proximal spinous bristle with base on medial surface; anterior edge of terminal margin of end joint with 1 stout claw-like bristle with minute blunt teeth along middle of anterior edge, and short spines along middle of posterior edge; terminal margin of end joint with 7 slender bristles, and 1 long stout posterior bristle with short marginal spines; anterior margin of joint with short spines.

Fifth limb (Figures 11*l*; 20*a*; 21*a*; 25*g*; 29): Epipodial appendage with bristles in 3 groups, each with 5, 5, and 4 plumose bristles. Protopodite and endopodite with total of 23 bristles; distal endopodite joint with short triangular tooth-like process. Exopodite 3-jointed: 1st joint with 1 long spinous terminal bristle near dorsal margin, and 7 bristles near ventral margin; 2nd joint hirsute, slender, longer than 1st, with 3 midbristles near or

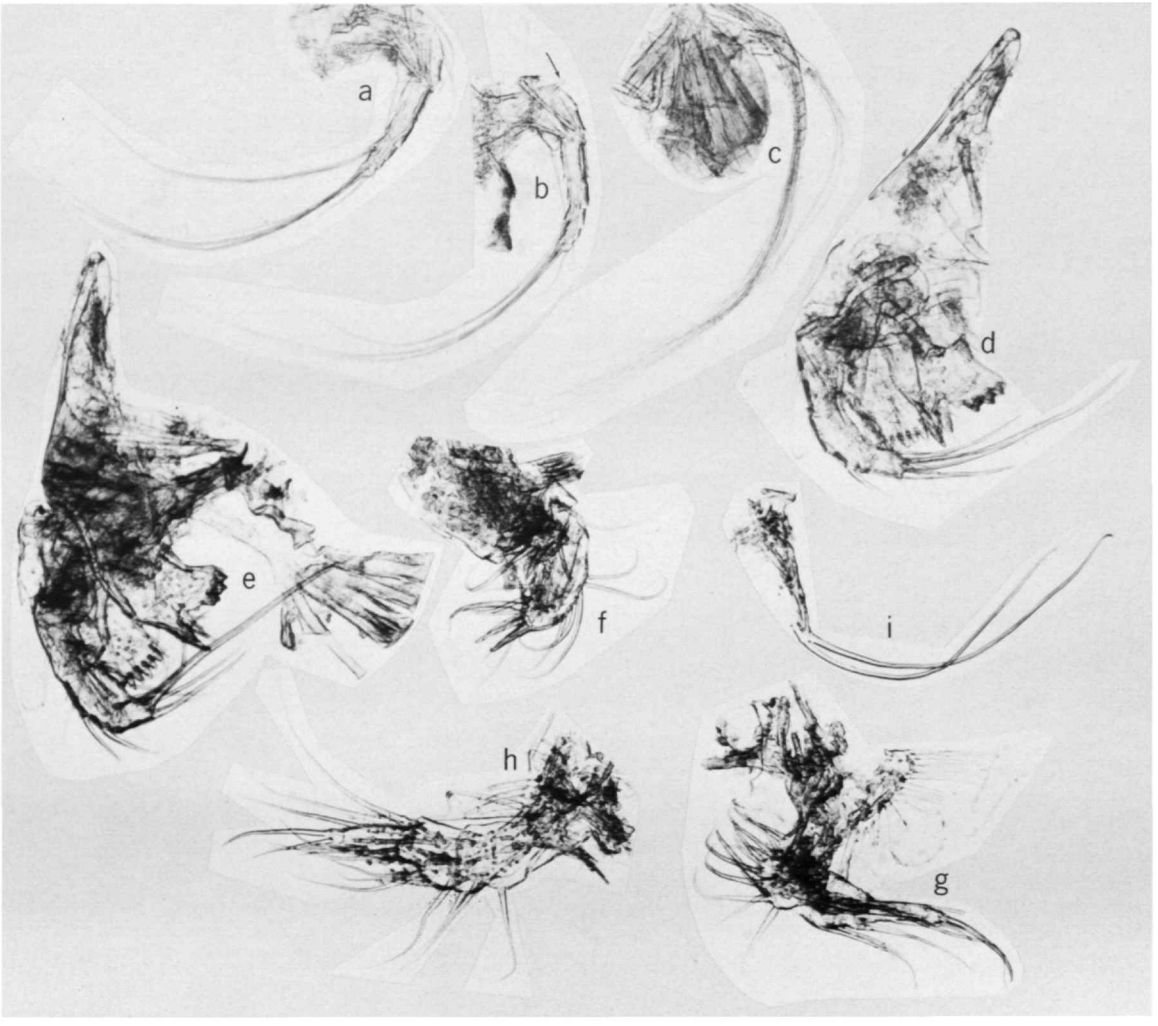


FIGURE 25.—*Thaumatoconcha radiata*, new species, adult female, holotype, USNM 143794: *a*, right 1st antenna, lateral view; *b*, rod-shaped organ (arrow) and left 1st antenna, medial view; *c*, right 2nd antenna, lateral view; *d*, right mandible, medial view; *e*, left mandible and central adductor muscles, lateral view of mandible; *f*, maxilla; *g*, 5th limb; *h*, 6th limb; *i*, 7th limb. (For size of appendages, see Figures 26–31.)

on ventral margin; end joint with 1 short spinous bristle, and 1 long claw-like bristle with spines along ventral margin.

Sixth limb (Figures 12*j*; 20*a*; 21*a*; 25*h*; 30): Epipodial appendage with ca. 15 plumose bristles; protopodite hirsute, unjointed, with 4 bristles near or on ventral margin. Exopodite 4-jointed: 1st joint divided by weak suture into proximal part with 2 spinous ventral bristles, and short distal part with 2 spinous bristles on ventral edge of terminal margin (some variation noted on number and distribution of bristles); small process with 3 plumose bristles present on dorsal corner of terminal margin of 1st joint; 2nd and 3rd joints hirsute, completely fused, with 3 ventral and 1 dorsal bristles, all with long marginal spines; end joint with 1 slender

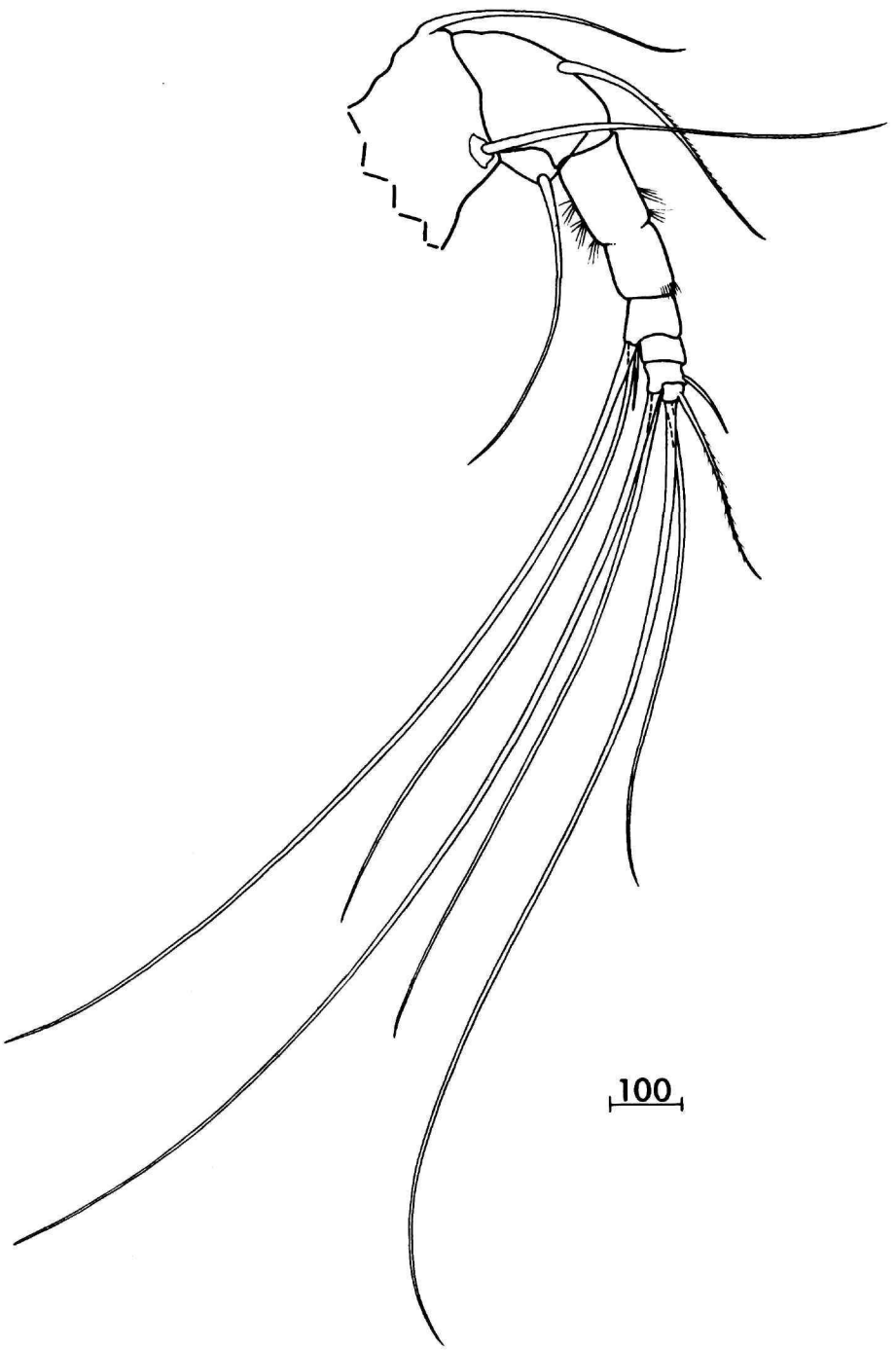


FIGURE 26.—*Thaumatoconcha radiata*, new species, adult female, holotype, USNM 143794, right 1st antenna, lateral view. (Scale in micrometers.)

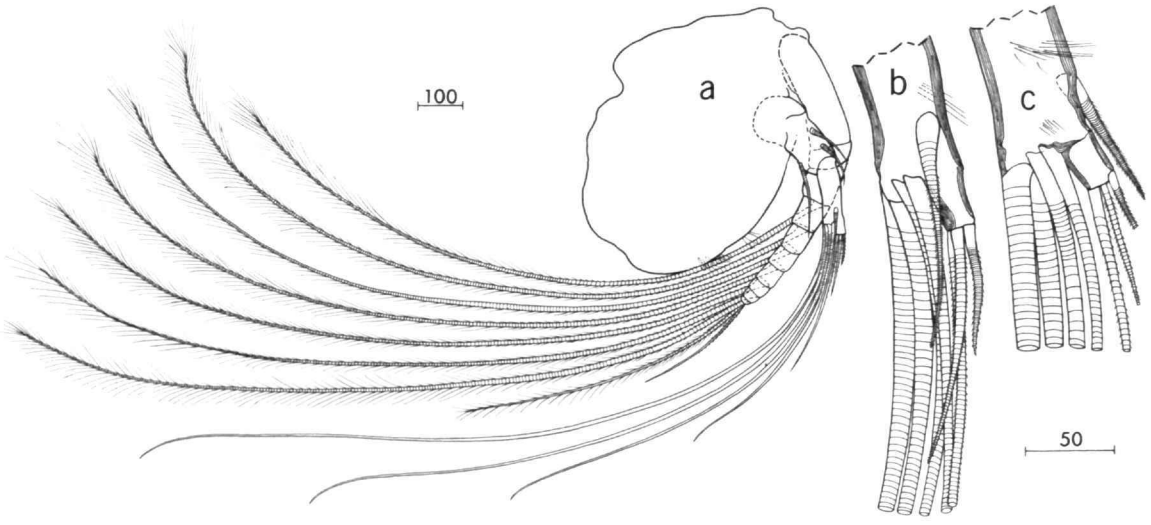


FIGURE 27.—*Thaumatoconcha radiata*, new species, adult female, holotype, USNM 143794, 2nd antenna: *a*, complete right limb, lateral view; *b*, tip of endopodite of right limb, lateral view; *c*, tip of endopodite of left limb, medial view. (Scales in micrometers.)

bristle with short marginal spines, and 1 terminal claw-like bristle with short spines along ventral margin.

Seventh limb (Figures 20; 21*a*; 25*i*; 31*a,b*): Small, tapered, with 2 long spinous terminal bristles.

Furca (Figures 20; 21*a,d*; 31*c*): Each lamella with 2 long anterior claws separated by suture from lamella followed by 6 short claws joined to lamella; 1 small process oriented posteriorly present following other claws; lamellae with spines forming rows; each claw with teeth along anterior and posterior margins.

Rod-shaped organ (Figures 20*a*; 21*a*; 25*b*; 31*d*): Elongate, 1-jointed or weakly 2-jointed with rounded tip, reaching just beyond terminal margin of 1st joint of 1st antenna.

Posterior of body (Figures 20; 21*a*; 31*c*): Single process with minute marginal spines present proximal to furcal lamellae; posterior margin distinctly divided into narrow segments; segmentation becoming less distinct anteriorly.

Lips: Upper lip projecting posteriorly and with 2 short stout outer processes and 2 narrower inner pointed processes which may have glandular opening at tip (Figure 31*e,f*). Lower lip consisting of 2 triangular flaps, each with sclerotized pointed process at tip (Figure 31*g*).

FOOD.—USNM 143753KK with fragments of appendages of myodocopid ostracodes and possibly other crustacea in gut.

DESCRIPTION OF ADULT MALE (Figures 4*o,p*; 5*i*; 18*d–f*; 32; 33).—Similar in shape and ornamentation to that of female but slightly smaller (Figures 4*o,p*; 5*i*; 32).

Size: USNM 143753C, left valve only, length 1.69 mm, height 1.40 mm; USNM 143753V, left valve only, length 1.66 mm, height 1.39 mm; USNM 143753AA, left valve only, length 1.64 mm, height 1.46 mm. USNM 143753JJ, disarticulated valves: left valve, length 1.61 mm, height 1.35 mm; right valve length 1.64 mm, height 1.40 mm. USNM 127272A disarticulated valves, right valve, length 1.99 mm, height 1.74 mm; left valve, length 1.97 mm, height 1.73 mm. USNM 143754B, complete specimen, length 1.77 mm, height 1.53 mm. USNM 143858D, complete specimen, length 1.91 mm, height 1.67 mm. USNM 143799B, complete specimen, length 1.72 mm, height 1.54 mm (Figures 3, 17).

First antenna: Limb with 8 distinct joints; 1st joint similar to those of adult female; 2nd joint

FIGURE 28.—*Thaumatoconcha radiata*, new species, adult female, holotype, USNM 143794: *a*, mandible, right limb, lateral view of coxale, medical view of basale and endopodite; *b*, mandible, left limb, medial view of coxale, lateral view of basale and endopodite; *c*, maxilla. (Scale in micrometers.)

with 1 ventral bristle reaching beyond 8th joint and 1 dorsal bristle reaching to about middle of 4th joint, both bristles with short marginal spines; 3rd joint spinous, much smaller than 2nd; 4th joint smaller than 3rd and with 2 long bare ventral bristles; 5th joint short, with 3 ventral bristles (longest of these with curved hairs along ventral margin, others bare); 6th joint without bristles; 7th joint with 2 long bare ventral bristles and 1 short spinous dorsal bristle; 8th joint with 2 long bare bristles and 1 short spinous bristle.

Second antenna: Protopodite and exopodite similar to those of adult female. Endopodite (Figure 33): 1st and 2nd joints similar to those of adult female; 2nd joint weakly separated from 3rd; 3rd joint with large curved sclerotized hook-like process with 2 minute spines at tip; surface of hook pustulose near tip; base of process either on medial

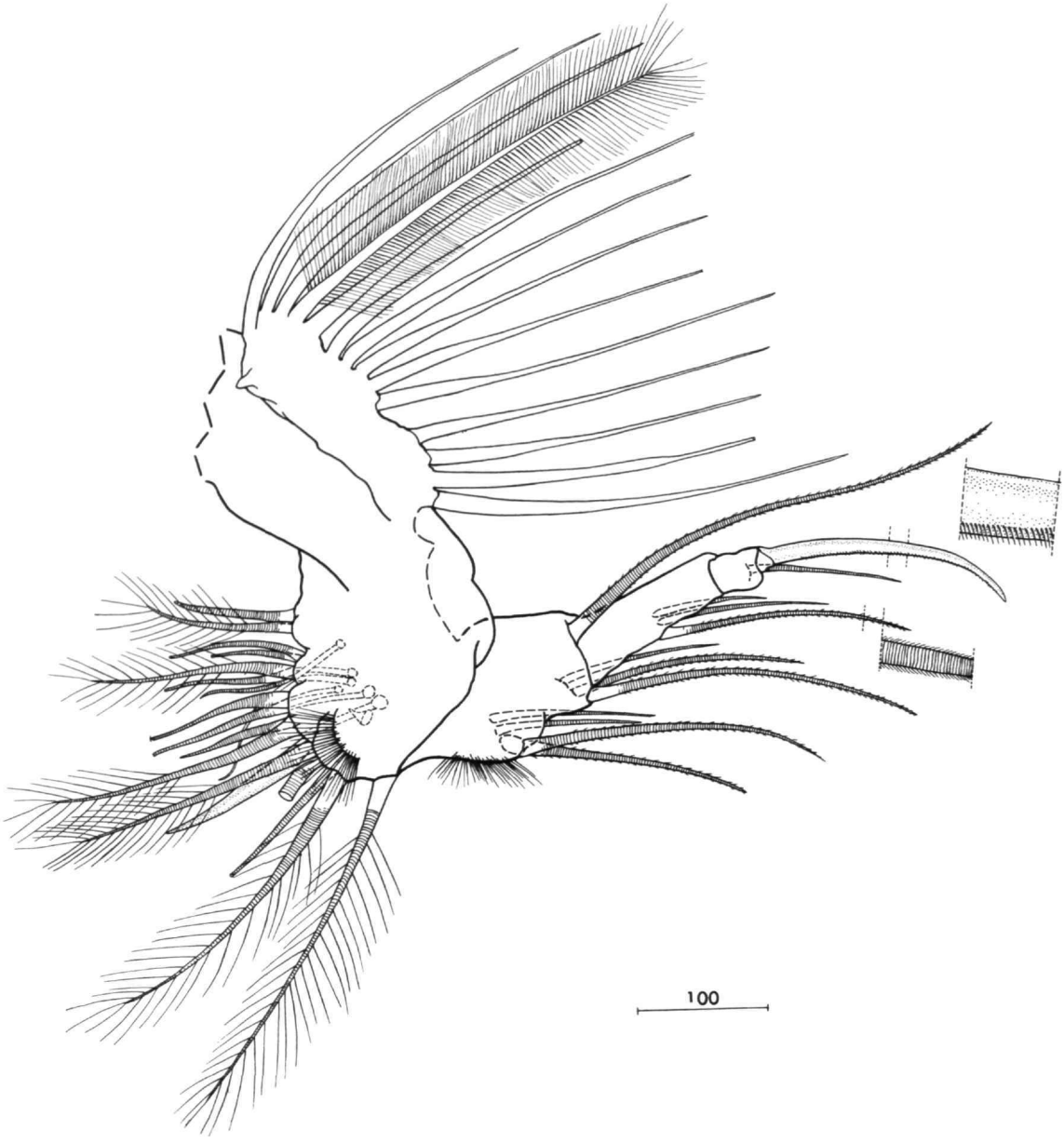


FIGURE 29.—*Thaumatoconcha radiata,* new species, adult female, holotype, USNM 143794, 5th limb. (Scale in micrometers.)

side of joint or terminal. (Length and curvature of hook-like process varies among specimens of the same species and between the left and right appendages of the same specimen.)

Mandible, maxilla, 5th limb, 6th limb, 7th limb, furca, rod-shaped organ, posterior of body; lips: Similar to those appendages on adult female, but with a few differences in number of bristles on mandible, maxilla, 5th and 6th limbs.

Copulatory organ (Figure 18*d–f*): Single organ

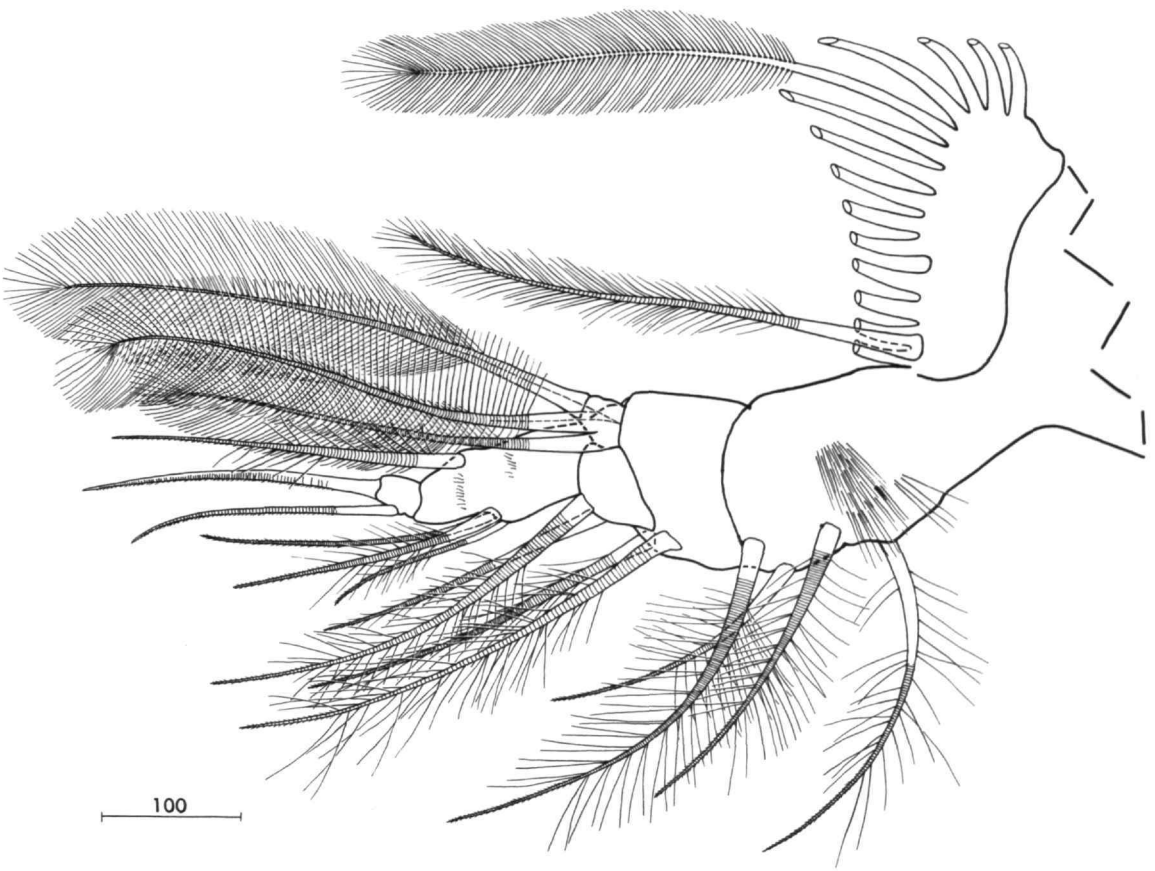


FIGURE 30.—*Thaumatoconcha radiata*, new species, adult female, holotype, USNM 143794, 6th limb. (Scale in micrometers.)

present on left side of animal consisting of 2 parts: anterior part elongate with ca. 8 teeth at tip; posterior part about one-half length of anterior part, tapered, styliform with 3 hair-like bristles at tip.

DESCRIPTION OF FEMALE A–1 INSTAR (Figures 4*m,n;* 5*h,n;* 6*h,l;* 7*h;* 8*h;* 34*x–z,aa,bb*).—Carapace similar in shape to that of adult female (Figures 4*m,n;* 5*h,n;* 6*h,l*).

Size (Figure 3): USNM 143753F, right valve only, length 1.56 mm, height 1.35 mm; USNM 143753DD, complete specimen, length 1.56 mm, height 1.37.

First antenna (Figures 7*h;* 34*x–z*): Limb with 8 joints: 1st joint with long hairs on medial surface and 1 dorsal and 1 lateral bristle similar to those on adult female; 2nd joint with 1 ventral bristle reaching to distal end of 6th joint and 1 dorsal bristle reaching to middle of 5th or 6th joints, both bristles with short marginal spines; 3rd joint with long spines on ventral and dorsal margins and medial surface; 3rd and 4th joints fused; 4th joint with few clusters of marginal spines on ventral and dorsal margins and minute terminal ventral bristle (right limb of USNM 143753F also with 2 terminal broad, flat, transparent bristles, Figure 34*x*); 3rd joint distinctly longer than 4th joint; 5th joint with few short spines along dorsal margin and 3 terminal ventral bristles (1 short inner bristle on lateral side; 2 long outer bristles with widely separated short marginal spines); 6th joint with few clusters of short spines on lateral and medial sides near dorsal margin; 7th and 8th joints similar to those on adult female.

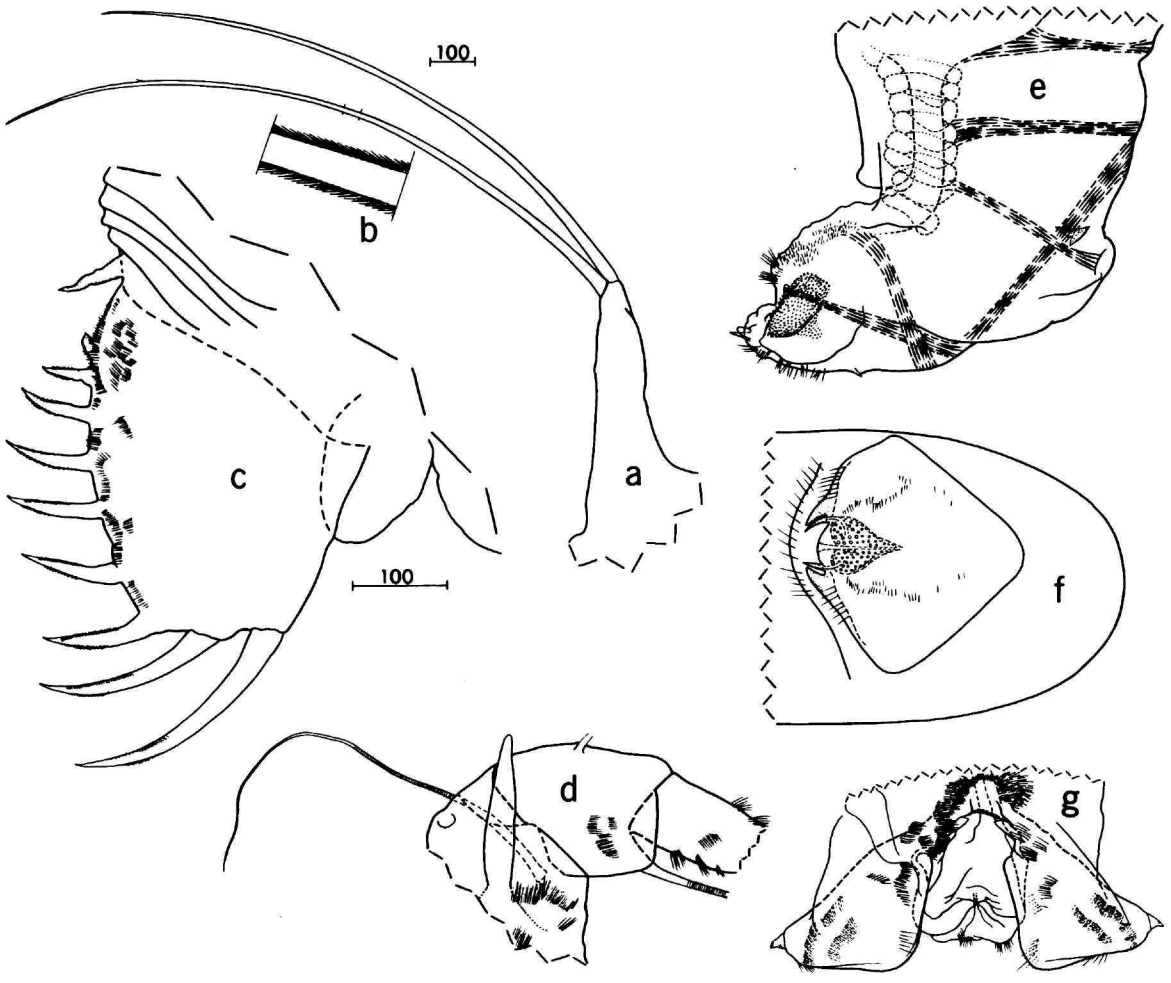


FIGURE 31.—*Thaumatoconcha radiata*, new species, adult female, holotype, USNM 143794: *a*, 7th limb; *b*, detail of spines on bristle of 7th limb; *c*, right lamella of caudal furca and single posterior process; *d*, rod-shaped organ and part of left 1st antenna, medial view (dorsal bristle on joints 1 and 2 missing); *e*, upper lip, lateral view; *f*, upper lip, ventral view; *g*, lower lip, anterior view of lip flattened under cover slip. (Same magnification in micrometers: *a*, *e–g*.)

Second antenna: Similar to that of female adult except 3rd joint of endopodite with 5 bristles, 3 short, 2 medium (Figure 8*h*); terminal joint of exopodite with 2 bristles, 1 long with ventral spines and natatory hairs, 1 medium with only spines.

Mandible, maxilla, 5th, 6th and 7th limbs, posterior of body, and upper lip: General morphology similar to that of adult female.

Furca: Similar to that of adult female except with only 5 short claws.

Rod-shaped organ: Elongate, 1-jointed or weakly 2-jointed; USNM 143753DD with rounded tip similar to that on adult female (Figure 34*bb*); USNM 143753F with tapered tip, unusual for this species (Figure 34*aa*).

DESCRIPTION OF MALE A–1 INSTAR (Figures 4*k,l;*

5*g,m;* 6*e;* 7*g;* 8*g;* 34*cc,ee,gg,ii*).—Carapace similar in shape to that of A–1 female (Figures 4*k,l;* 5*m,g;* 6*e*).

Size (Figure 3): USNM 143753CC, complete specimen, length 1.55 mm, height 1.33 mm. USNM 143753MM, disarticulated specimen, right valve broken; left valve, length 1.50 mm, height 1.27 mm. USNM 127272B, complete specimen, length 1.74 mm, height 1.52 mm.

First antenna (Figures 7*g;* 34*cc*): Similar to limb of A–1 female with following exceptions: ventral margin of 4th joint with 2 fairly long terminal bristles with broad proximal part and 1 minute inner bristle (the latter bristle not present on all limbs); ventral margin of 5th joint with 2 long bristles, 1 short bristle, and 1 minute inner bristle (the latter bristle not present on all limbs).

Second antenna: Similar to limb on A–1 female with following exceptions: 3rd joint of endopodite thumb-like with 5 (rarely 4) short terminal bristles (Figure 8*g*).

Mandible, maxilla, 5th, 6th, and 7th limbs, posterior of body, upper lip: General morphology similar to that of adult female.

Furca: Similar to that of A–1 female.

Rod-shaped organ: Elongate, 1-jointed with rounded tip (Figures 7*g;* 34*ee*).

Copulatory organ (Figure 34*gg*): Shorter than that on adult; anterior part with about 3 minute teeth at tip; posterior part about one-half length anterior part, not tapered or styliform like that on adult, with 3 small bristles at tip.

Description of Atypically Developed Male A–1 Instar (Figure 34*dd,ff,hh*).—Carapace similar in shape to normal A–1 male.

Size: USNM 143753Y, left valve only, length 1.47 mm, height 1.28 mm.

First antenna (Figure 34*dd*): Similar to that on normal A–1 male with following exceptions: ventral margin of 4th joint with 2 short terminal bristles; ventral margin of 5th joint with 3 terminal bristles.

Second antenna: Similar to that on female A–1 instar except shape of 3rd joint on endopodite approaching that of male A–1 instar.

Mandible, maxilla, 5th, 6th, and 7th limbs, posterior of body, upper lip: General morphology similar to that of adult female.

Furca: Similar to that of A–1 female.

Rod-shaped organ (Figure 34*ff*): Bifurcate (abnormality), ventral organ longer and narrower than dorsal organ and with rounded tip; dorsal organ with tapered tip and minute terminal process; both organs with few spines on surface.

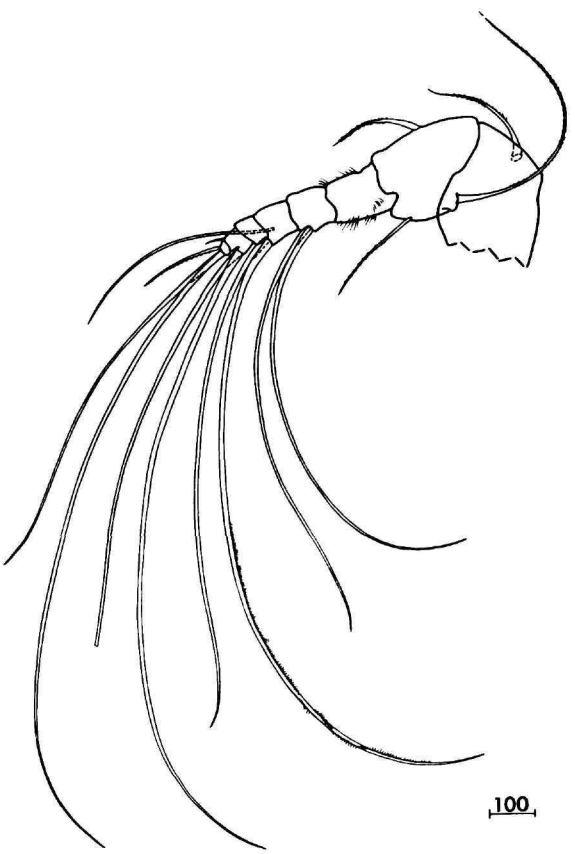


Figure 32.—*Thaumatoconcha radiata,* new species, adult male, paratype, USNM 126136E, left 1st antenna, lateral view. (Scale in micrometers.)

Copulatory organ (Figure 34*hh*): Smaller than that on normal A–1 instar; anterior lobe with 1 long spine or bristle and ca. 4 minute teeth; posterior lobe with 3 bristles somewhat longer than those on normal A–1 instar.

Remarks: This specimen, although having a carapace similar in size to other A–1 instars, bears an endopodite on the 2nd antenna and a copulatory organ that seem to be in degree of development between the A–1 and A–2 instars.

Description of Female A–2 Instar (Figures 4*i,j;* 5*f,l;* 7*e;* 8*f;* 34*s–w*).—Carapace similar in shape to that of adult female (Figures 4*i,j;* 5*f,l*).

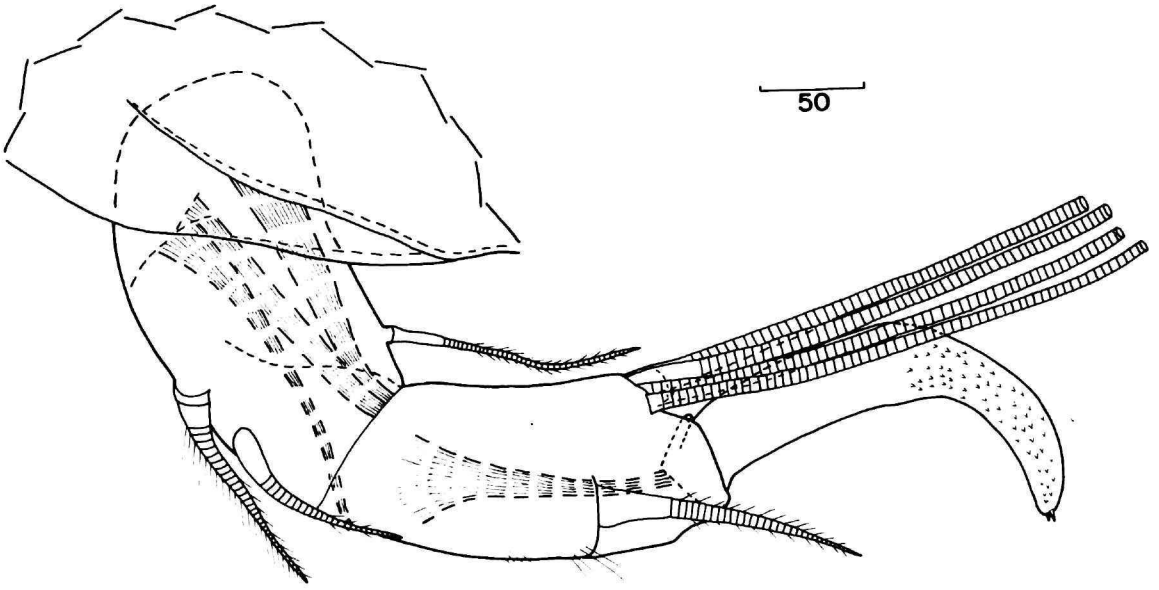


FIGURE 33.—*Thaumatoconcha radiata*, new species, adult male, paratype, USNM 126136E, endopodite of left 2nd antenna, lateral view. (Scale in micrometers.)

Size (Figure 3): USNM 126136B, left valve only, length 1.34 mm, height 1.19 mm. USNM 143753H, right valve only, length 1.29 mm, height 1.12 mm; USNM 143753BB, right valve only, length 1.29 mm, height 1.17 mm. USNM 143753OO, complete specimen, length 1.24 mm, height 1.12 mm. USNM 143753PP, disarticulated valves: right valve, length 1.27 mm, height 1.12 mm; left valve, length 1.30 mm, height 1.13 mm.

First antenna (Figures 7*e;* 34*s,t,v*): Similar to that on A–1 female with following exceptions: ventral bristle on 2nd joint shorter than dorsal bristle; ventral margin of 4th joint with 1 or 2 short terminal bristles or with 1 short bristle and 1 longer bristle reaching past 5th joint; ventral margin of 7th joint with 1 long bristle, 1 medium length bristle, and 1 minute bristle (latter bristle not always present).

Second antenna: Similar to that on female A–1 instar except inner bristle on 2nd joint of endopodite very short and 3rd joint with 4 or 5 bristles (Figure 8*f*).

Mandible, maxilla, 5th, 6th, and 7th limbs, posterior of body, upper lip: General morphology similar to that of adult female.

Furca: Similar to that of A–1 female except with only 4 short claws.

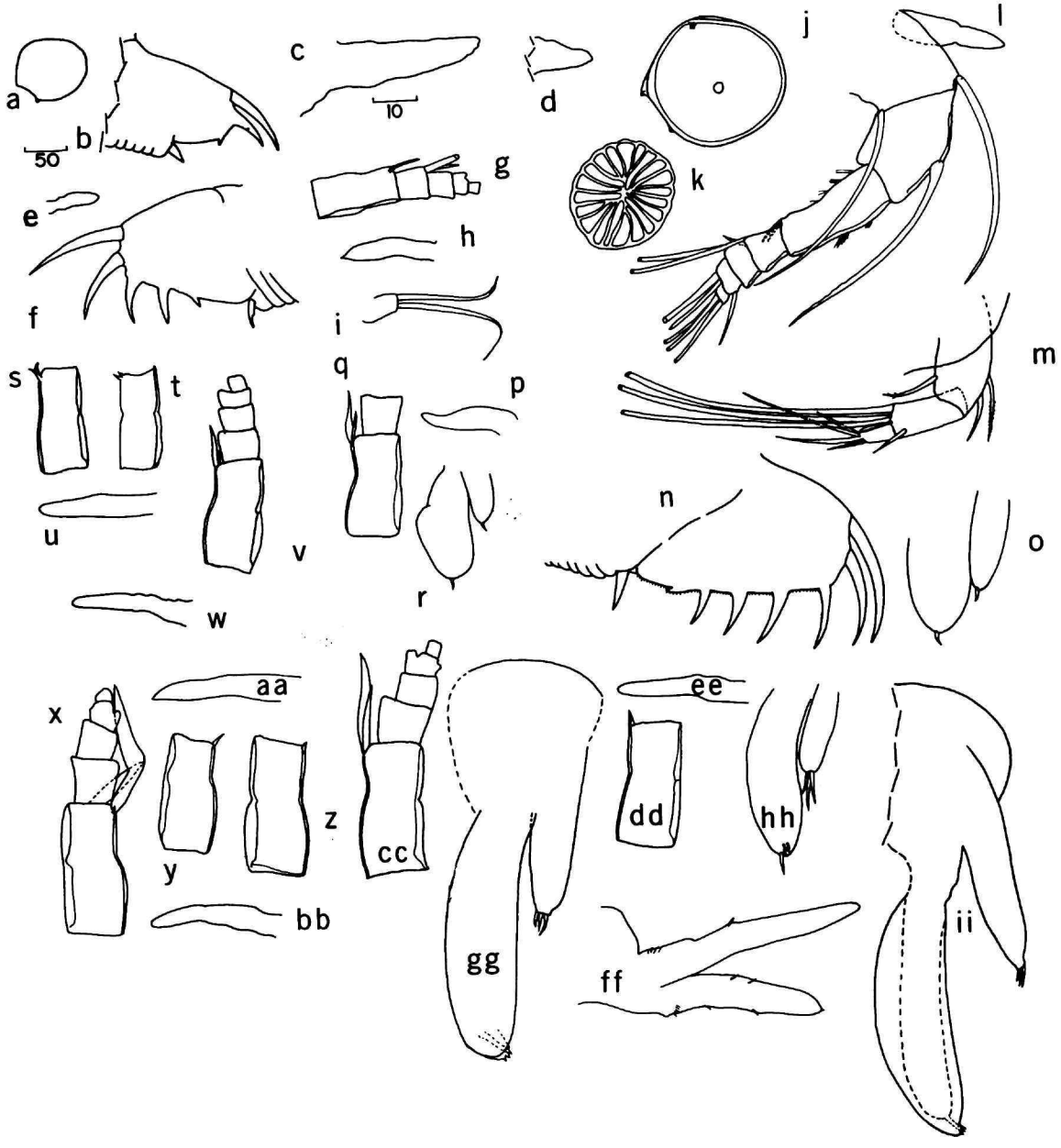
Rod-shaped organ: Elongate, 1-jointed with rounded tip (Figure 34*u,w*).

DESCRIPTION OF MALE A–2 INSTAR (Figures 7*f;* 8*e;* 34*j–r*).—Carapace similar in shape to that of A–2 female (Figure 34*j*).

Size (Figure 3): USNM 126136A, disarticulated valves, right valve, length 1.35 mm, height 1.15 mm; left valve, length 1.37 mm, height 1.15 mm. USNM 126136I, complete specimen, length 1.26 mm, height 1.14 mm. USNM 143753K, complete specimen, length 1.21 mm, height 1.09 mm; USNM 143753X, complete specimen, length 1.28 mm, height 1.11 mm.

First antenna (Figures 7*f;* 34*l,q*): Same as that on A–2 female except ventral margin of 4th joint with 2 bristles: 1 lateral bristle almost reaching or just reaching beyond distal margin of 5th joint; 1 medial bristle about half length lateral bristle. (The female A–2 instar USNM 126136B has bristles on the 4th joint similar to those on the male A–1 instars examined.)

Second antenna (Figures 8*e;* 34*m*): Similar to that on A–2 female except 3rd joint of endopodite



thumb-like (thumb less well defined than that on A–1 male).

Mandible, maxilla, 5th, 6th, and 7th limbs, posterior of body, upper lip: General morphology similar to that of adult female.

Furca: Similar to that of A–2 female (Figure 34*n*).

Rod-shaped organ: Elongate, 1-jointed. USNM 126136A, 143753X, 143753K with tapered tip (Figure 34*l*), the latter with minute process at tip (Figure 34*p*); USNM 126136I with rounded tip.

Copulatory organ: With long anterior lobe with 1 spine-like tooth and shorter posterior lobe with 1 short terminal bristle (Figure 34*o,r*).

Description of A–3 Instar (Figures 4*g,h;* 5*e;* 6*c,d;* 7*d;* 8*d;* 34*g–i*).—No sexual dimorphism observed. Carapace similar in shape to that of A–2

FIGURE 34.—*Thaumatoconcha radiata*, new species, juvenile paratypes. A–6: *a*, right valve, USNM 143753B, length 0.71 mm, inside view; *b*, right furcal lamella, USNM 143753D; *c*, rod-shaped organ, USNM 143753D. A–5: *d*, 6th limb, USNM 143753QQ. A–4, USNM 143753U: *e*, rod-shaped organ; *f*, left furcal lamella. A–3: *g*, joints 3–8 of left 1st antenna, USNM 143753L; *h*, rod-shaped organ, USNM 143753L; *i*, 7th limb, USNM 143753Z. A–2 male, USNM 126136A: *j*, right valve, length 1.37 mm, inside view; *k*, detail of central muscle attachment scars on right valve, medial view; *l*, rod-shaped organ and right 1st antenna, lateral view; *m*, endopodite of right 2nd antenna, lateral view; *n*, right furcal lamella; *o*, copulatory organ. A–2 male: *p*, rod-shaped organ, USNM 143753K; *q*, joints 3–5 of left 1st antenna, USNM 143753X, medial view; *r*, copulatory organ, USNM 143753X. A–2 female: *s*, joints 3 and 4 of right 1st antenna, USNM 143753H, medial view; *t*, same, left 1st antenna, lateral view; *u*, rod-shaped organ, USNM 143753PP; *v*, joints 3–8 of left 1st antenna, USNM 126136B, lateral view; *w*, rod-shaped organ, USNM 126136B. A–1 female: *x*, joints 3–8 of right 1st antenna, USNM 143753F, lateral view; *y*, joints 3 and 4 of right 1st antenna, USNM 143753BB, lateral view; *z*, joints 3 and 4 of left 1st antenna, USNM 143753F, medial view; *aa*, rod-shaped organ, USNM 143753F; *bb*, rod-shaped organ, USNM 143753DD. A–1 male: *cc*, joints 3–8 of right 1st antenna, USNM 143753MM, medial view; *dd*, joints 3 and 4 of left 1st antenna, USNM 143753Y, medial view; *ee*, rod-shaped organ, USNM 143753MM; *ff*, aberrant bifurcate rod-shaped organ, USNM 143753Y; *gg*, copulatory organ, USNM 143753-MM; *hh*, same, USNM 143753Y; *ii*, same, USNM 143753CC. (Same magnification in micrometers: *b,d–z, aa–ii.*)

instars (Figures 4*g,h;* 5*e;* 6*c,d*).

Size (Figure 3): USNM 143753L, complete specimen, length 1.10 mm, height 0.93 mm; USNM 143753Z, left valve only, length 1.03 mm, height 0.91 mm; USNM 143753FF, complete specimen, length 1.09 mm, height 0.92 mm; USNM 143753II, disarticulated valves: right valve, length 1.10 mm, height 0.97 mm; left valve, length 1.11 mm, height 0.96 mm; USNM 143753NN, complete specimen, length 1.12 mm, height 0.98 mm.

First antenna (Figures 7*d;* 34*g*): Similar to that of female A–2 instar with following exceptions: lateral bristle of 1st joint shorter than dorsal bristle; 2nd joint without ventral bristle; ventral margin of 4th joint with 1 or 2 minute bristles, or 1 minute bristle and 1 longer bristle almost reaching distal margin of 5th joint; ventral margin of 5th joint with 2 bristles, 1 long, 1 short (about same length as 5th joint); ventral margin of 7th joint with 1 long terminal bristle, 1 short bristle about twice length of 8th joint, and 1 minute bristle (the minute bristle or both the minute and short bristle not always present).

Second antenna: Similar to that on female A–1 instar with following exceptions: Endopodite (Figure 8*d*): 1st joint with 1 dorsal bristle; 2nd joint without lateral bristle and with 3 terminal bristles on ventral half of distal margin; 3rd joint with 4 bristles. Exopodite: 9th joint minute and not distinctly separated from 8th joint.

Mandible, maxilla, 5th, 6th, and 7th limbs (Figure 34*i*), posterior of body, upper lip: General morphology similar to that of adult female.

Furca: Similar to that of A–2 female except with only 3 short claws.

Rod-shaped organ: Elongate, 1-jointed with slightly or distinctly tapered tip (Figures 7*d;* 34*h*).

Copulatory organ: Not developed.

DESCRIPTION OF A–4 INSTAR (Figures 4*e,f;* 5*d;* 7*c;* 8*c;* 34*e,f*).—No sexual dimorphism observed. Carapace similar in shape to that of A–3 instar (Figures 4*e,f;* 5*d*).

Size (Figure 3): USNM 143753M, complete specimen, length 1.00 mm, height 0.87 mm; USNM 143753U, left valve only, length 0.94 mm, height 0.81 mm; USNM 143753HH, complete specimen, length 0.94 mm, height 0.82 mm; USNM 143753RR, disarticulate valves: right valve, length 0.93 mm, height 0.81 mm; left valve, length 0.95 mm, height 0.82 mm.

First antenna (Figure 7*c*): Similar to that of A–3 instar with following exceptions: 1st joint without lateral bristle; ventral margin of 4th joint without bristles; 5th joint with 1 long ventral bristle, ventral margin of 7th joint with 1 long and 1 very short bristle.

Second antenna: Similar to that on A–3 instar with following exceptions: Endopodite (Figure 8*c*): no dorsal bristle present on 1st joint; 2 terminal bristles on 2nd joint (inner of these very short); medioventral bristle on terminal margin of 3rd joint very short. Exopodite: 1st joint not divided into 2 parts; 8th and 9th joints fused, with 2 bristles, 1 long with natatory hairs and marginal spines, the other medium with only marginal spines (the natatory bristle is considered here to be on the 8th joint and the spined bristle on the 9th).

Mandible, maxilla, 5th limb, posterior of body, upper lip: General morphology similar to that of adult female.

Sixth limb: Reduced but with many bristles.

Seventh limb: Absent.

Furca: Similar to that of A–3 female except with

only 2 short claws (Figure 34*f*).

Rod-shaped organ: Elongate, 1-jointed with rounded or tapered tip (Figures 7*c;* 34*e*).

DESCRIPTION OF A–5 INSTAR (Figures 4*c,d;* 5*b,c;* 6*a,b;* 7*b;* 8*b;* 34*d*).—No sexual dimorphism observed. Carapace similar in shape to that of A–4 instar; 4th thin ridge on anteroventral surface discontinuous (Figures 4*c,d;* 5*b;* 6*a,b*).

Size: USNM 143753G, complete specimen, length 0.80 mm, height 0.62 mm; USNM 143753I, complete specimen, length 0.82 mm, height 0.73 mm; USNM 143753EE, complete specimen, length 0.80 mm, height 0.71 mm, USNM 143753GG, complete specimen, length 0.85 mm, height 0.71 mm. USNM 143753QQ, disarticulated valves: right valve, length 0.79 mm, height 0.69 mm, left valve, length 0.80 mm, height 0.69 mm (Figure 3).

First antenna (Figure 7*b*): Similar to that of A–4 instar with following exceptions: 2nd joint without bristles; ventral margin of 7th joint with 1 long bristle; 8th joint with 2 bristles, 1 medium, 1 long.

Second antenna: Similar to that of A–4 instar except 2nd endopodite joint with only 1 long bristle (Figure 8*b*). (Remarks: USNM 143753G was in process of molting.)

Mandible, maxilla, 5th limb, posterior of body, upper lip: General morphology similar to that of adult female.

Sixth limb: Rudimentary without bristles (Figure 34*d*).

Seventh limb: Absent.

Furca: Similar to that of A–4 female except with only 1 short claw.

Rod-shaped organ: Elongate, 1-jointed with round or tapered tip, some with a minute terminal process.

DESCRIPTION OF A–6 INSTAR (Figures 4*a,b;* 5*a;* 7*a;* 8*a;* 34*a–c*).—No sexual dimorphism observed. Carapace similar in shape to that of A–5 instar; only 3 ridges on anteroventral surface (Figures 4*a,b;* 5*a;* 34*a*).

Size: USNM 143753B, right valve only, length 0.71 mm, height 0.60 mm; USNM 143753D, complete specimen, length 0.69 mm, height 0.59 mm; USNM 143753J, left valve only, length 0.67 mm, height 0.56 mm; USNM 143753O, complete specimen, length 0.67 mm, height 0.58 mm; USNM 143753Q, right valve only, length 0.70 mm, height 0.60 mm; USNM 143753S, complete specimen, length 0.73 mm, height 0.58 mm. USNM 143753LL, disarticulated valves: right valve, length 0.71 mm. height 0.61 mm; left valve, length 0.68 mm, height 0.60 mm. USNM 143753SS, complete specimen, length 0.67 mm. height 0.59 mm (Figure 3).

First antenna: Similar to that of A–5 instar except without bristles on 1st joint (Figure 7*a*).

Second antenna: Similar to that of A–5 instar except no bristles on the 1st endopodite joint (Figure 8*a*).

Mandible, maxilla, 5th limb, posterior of body, upper lip: General morphology similar to that of adult female.

Sixth and seventh limbs: Absent.

Furca: Similar to that of A–3 female except without well-developed short claws, and claw 2 not separated from lamella by suture (Figure 34*b*).

Rod-shaped organ: Elongate, 1-jointed with tapered or irregular tip (Figures 7*a;* 34*c*).

Ontogeny: Summarized on p. 7.

COMPARISONS.—See Table 13.

Thaumatoconcha caraionae, new species

FIGURES 11*k,* 12*i,* 13*a,* 18*g–i,* 35–40

HOLOTYPE.—USNM 143856, adult female; appendages on slides, carapace and some appendages in alcohol.

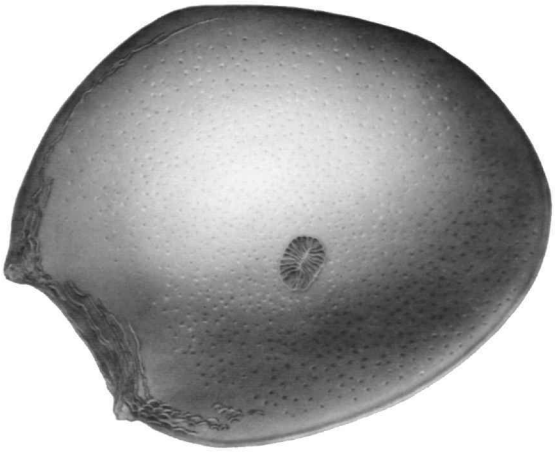


FIGURE 35.—*Thaumatoconcha caraionae,* new species, carapace of adult female, holotype, USNM 143856, length 1.87 mm, anterior to left.

FIGURE 36.—*Thaumatoconcha caraionae*, new species, adult female, holotype, USNM 143856: *a*, left 1st antenna, lateral view; *b*, protopodite and endopodite of right 2nd antenna, medial view; *c*, coxale endite of left mandible, medial view; *d*, basale and endopodite of left mandible, lateral view; *e*, 5th limb; *f*, 6th limb; *g*, 7th limb. (Same magnification in micrometers: *a*, *b*; *c-g*.)

TYPE-LOCALITY.—*R. V. Atlantis II,* Cruise 60, station 245A, 36°55′42″S, 53°01′24″W, South Atlantic, 2707 m.

PARATYPES.—USNM 143855, 4 adult males; USNM 143857, 1 A–1 male; USNM 143859, 4 adult females; USNM 143860, 4 specimens. Paratypes from same sample as holotype (Figures 1, 9).

ETYMOLOGY.—The species is named for Dr. Francisca Elena Caraion.

DIAGNOSIS.—Surface of carapace with shallow punctae and 7 continuous and 3 or 4 discontinuous anteroventral ridges; 6 of the ridges extend along anterodorsal margin to point about halfway between dorsal protuberance and anterior end of hinge; straight anteroventral margin; length of female 1.87 to 1.99 mm, length of male 1.74 to 1.80 mm; dorsal margin of 3rd joint of 1st antenna longer than dorsal margin of 4th joint; endopodite of mandible with 1 dorsal bristle on 1st joint and 2 on 2nd; rod-shaped organ with rounded tip; anterior lobe of male copulatory organ with single tooth-like process.

DESCRIPTION OF ADULT FEMALE (Figures 13*a*, 35, 36).—Valves subround, height of anterior margin greater than posterior (Figure 35); gently concave anteroventral margin delimited by a dorsal and a ventral forward pointing, short, truncated protuberance; anterodorsal margin broadly convex, merging with short straight dorsal margin at about one-third greatest length; posterior margin evenly rounded; ventral margin curving gently forward and downward to a point in front of subcentral adductor muscle-scar, then curving upward to join anteroventral margin below protuberance; dorsal outline subelliptical, greatest width in front of mid-length; end outline subelliptical, greatest width slightly below midheight.

Ornamentation: Surface with shallow punctae, and scattered pore canals with long branched and unbranched hairs; narrow marginal rim around entire periphery of valve except between protuberances; anteroventral surface with 7 continuous and 3 or 4 discontinuous thin ridges subparallel to valve margin; ridges grade into polygonal reticulations in area of protuberances; cross-ridges present on rim between the 2 distal ridges below and behind ventral protuberance, and between 2nd and 3rd ridges in vicinity of dorsal protuberance; 6 ridges extend along anterodorsal margin to point about halfway between dorsal protuberance and anterior end of hinge, and fewer ridges extend for a shorter distance along ventral margin.

Adductor muscle-scar: Scar subcentrally located, subelliptical, greatest diameter trending towards posterior end of hinge; consists of 20–22 subequal pie-shaped segments with inner ends of segments forming wavy ridge that trends along axis of scar.

Size (Figure 16): USNM 143856, complete specimen, length 1.87 mm, height 1.58 mm. USNM 143859, 4 females: complete specimen, length 1.93 mm, height 1.64 mm; complete specimen, length 1.99 mm, height 1.60 mm; right valve, length 1.94 mm, height 1.65 mm; right valve, length 1.93 mm, height 1.64 mm.

First antenna (Figure 36*a*), maxilla, 5th limb (Figure 36*e*), 7th limb (Figure 36*g*), furca, rod-shaped organ, upper-lip (Figure 13*a*), posterior of body: Similar to those of *T. radiata.*

Second antenna (Figure 36*b*): Exopodite with 8 joints; limb otherwise similar to that of *T. radiata.*

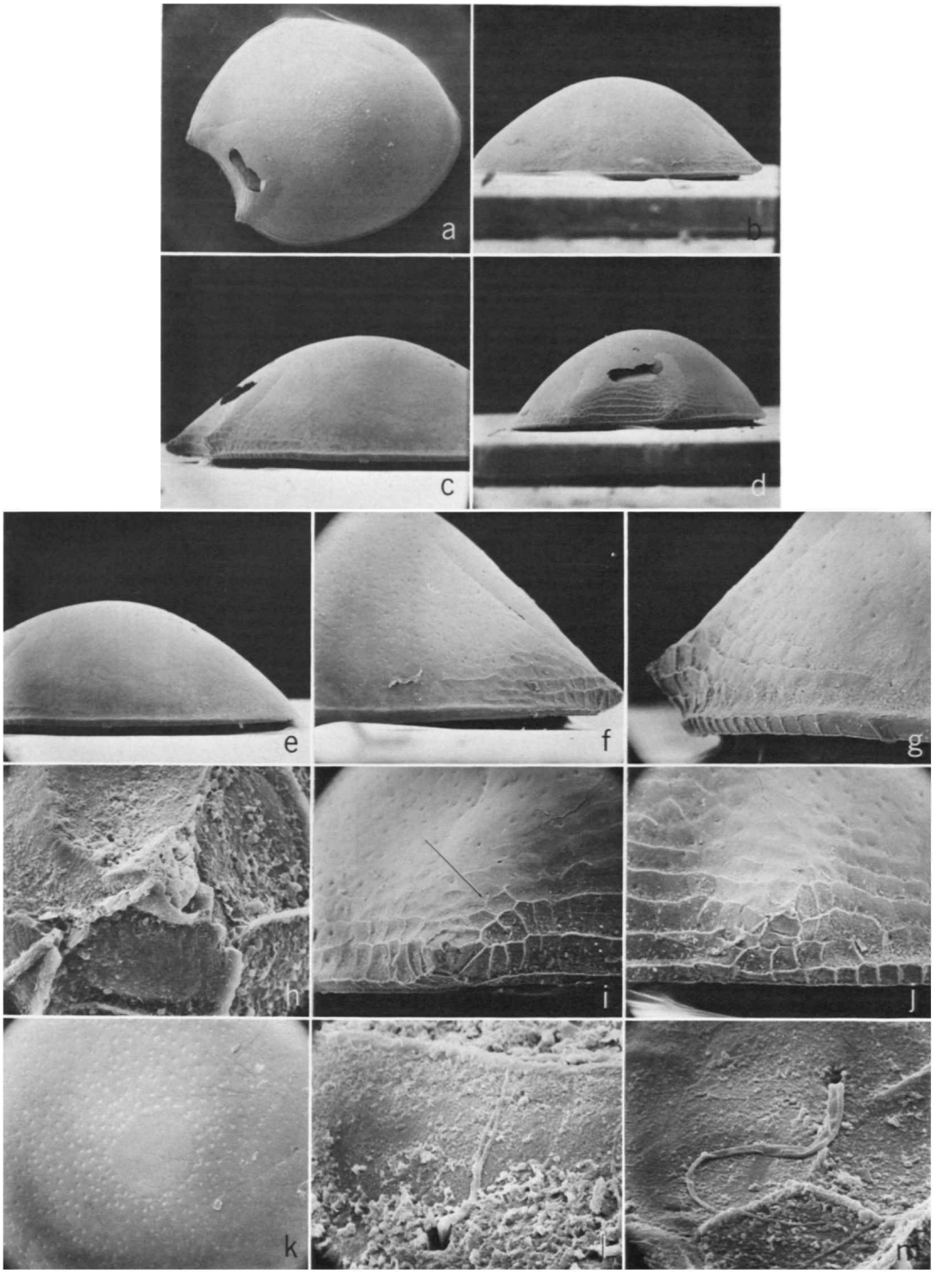
Mandible (Figure 36*c,d*): Third endopodial joint with 6 bristles; limb otherwise similar to that of *T. radiata.*

Sixth limb (Figure 36*f*): Short bristle on 4th exopodial joint of 6th limb, 40 percent length of long bristle; limb otherwise similar to that of *T. radiata.*

DESCRIPTION OF MALE (Figures 11*k*, 12*i*, 18*g–i*, 37–40).—Carapace similar in shape to that of female but smaller (Figures 37, 38).

Size (Figure 17): USNM 143855A, left valve, length 1.74 mm, height 1.43 mm; USNM 143855B, complete specimen, length 1.80 mm, height 1.46 mm. USNM 143855C, 2 specimens: complete speci-

FIGURE 37.—*Thaumatoconcha caraionae,* new species, left valve of adult male, paratype, USNM 143855A: *a*, outside view, anterior to left, × 50; *b*, dorsal view, anterior to right, × 60; *c*, ventral view, anterior to left, × 75; *d*, anteroventral view, ventral margin to right, × 60; *e*, ventral view, posterior to left, × 75; *f*, anterior end of valve, dorsal view, × 160; *g*, anterior end, ventral view, × 280; *h*, lower anteroventral protuberance from *j*, anteroventral view, ventral margin to right, × 1540; *i*, upper anteroventral protuberance, anteroventral view, ventral margin to right, × 300; *j*, lower anteroventral protuberance, anteroventral view, ventral margin to right, × 300; *k*, smooth surface over adductor muscle attachment and minute surface punctae from *a*, × 125; *l*, branched hair from near anteroventral margin of valve, × 2400; *m*, unbranched hair from near upper anteroventral protuberance (for location see arrow in *i*), × 1890. (Photos reduced to 50½ percent.)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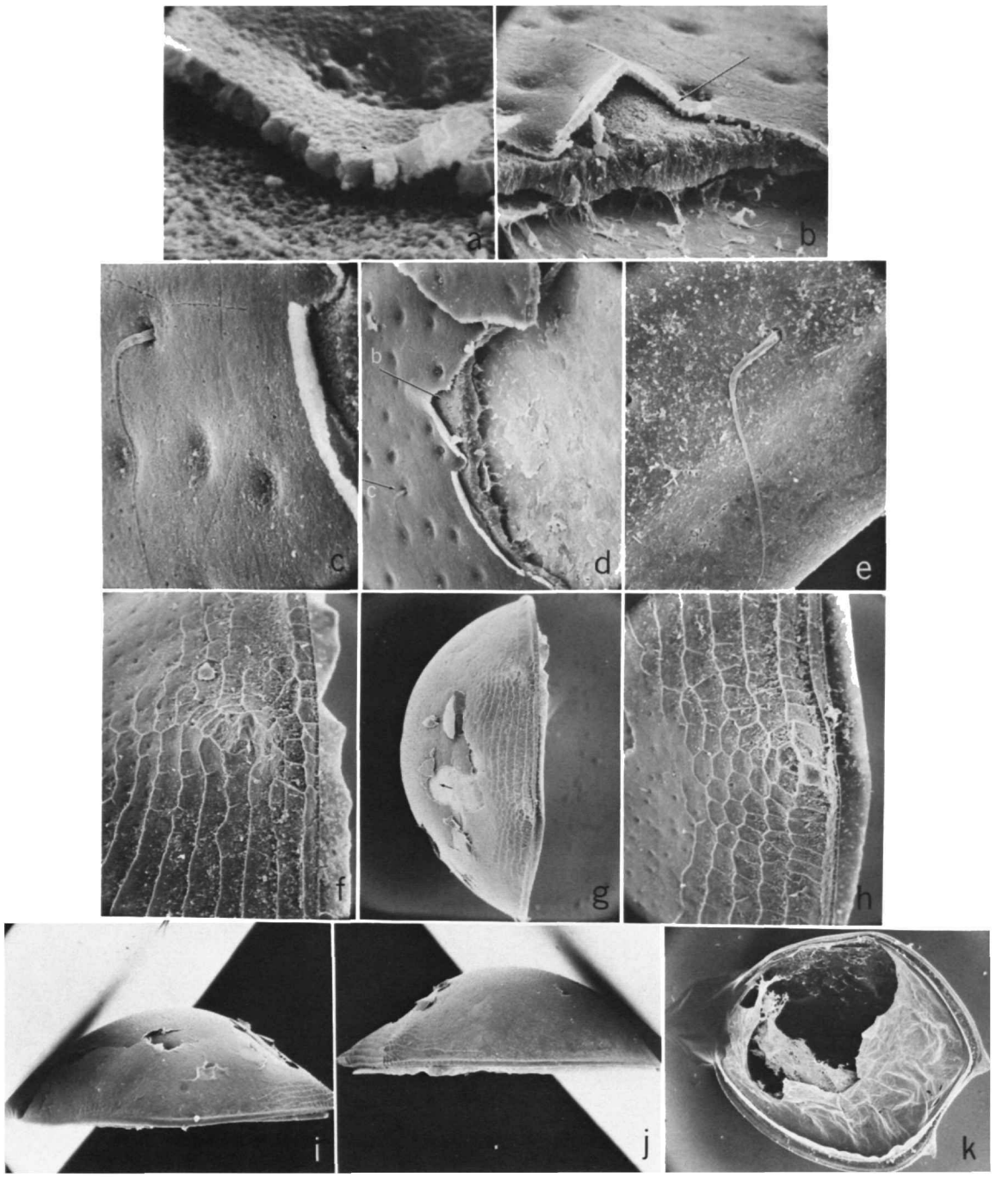

FIGURE 38.—*Thaumatoconcha caraionae*, new species, left valve of adult male, paratype, USNM 143855B; *a*, detail of outer shell layer (for location see arrow in *b*), × 10,000; *b*, cross-section of shell (for location see arrow in *d*), × 2000; *c*, unbranched hair and shallow punctae on surface of valve (for location see arrow in *d*), × 2000; *d*, valve with part of outer layers of shell missing (for location see arrow in *g*), × 700; *e*, unbranched bristle near valve edge, × 1300; *f*, upper protuberance of anteroventral margin, from *g*, × 260; *g*, anteroventral view, ventral margin to bottom, × 70; *h*, lower anteroventral protuberance, from *g*, × 260; *i*, ventral view of valve, anterior to right, × 60; *j*, dorsal view of valve, anterior to left, × 60; *k*, inside view of valve, anterior to right, × 50. (Photos reduced to 55½ percent.)

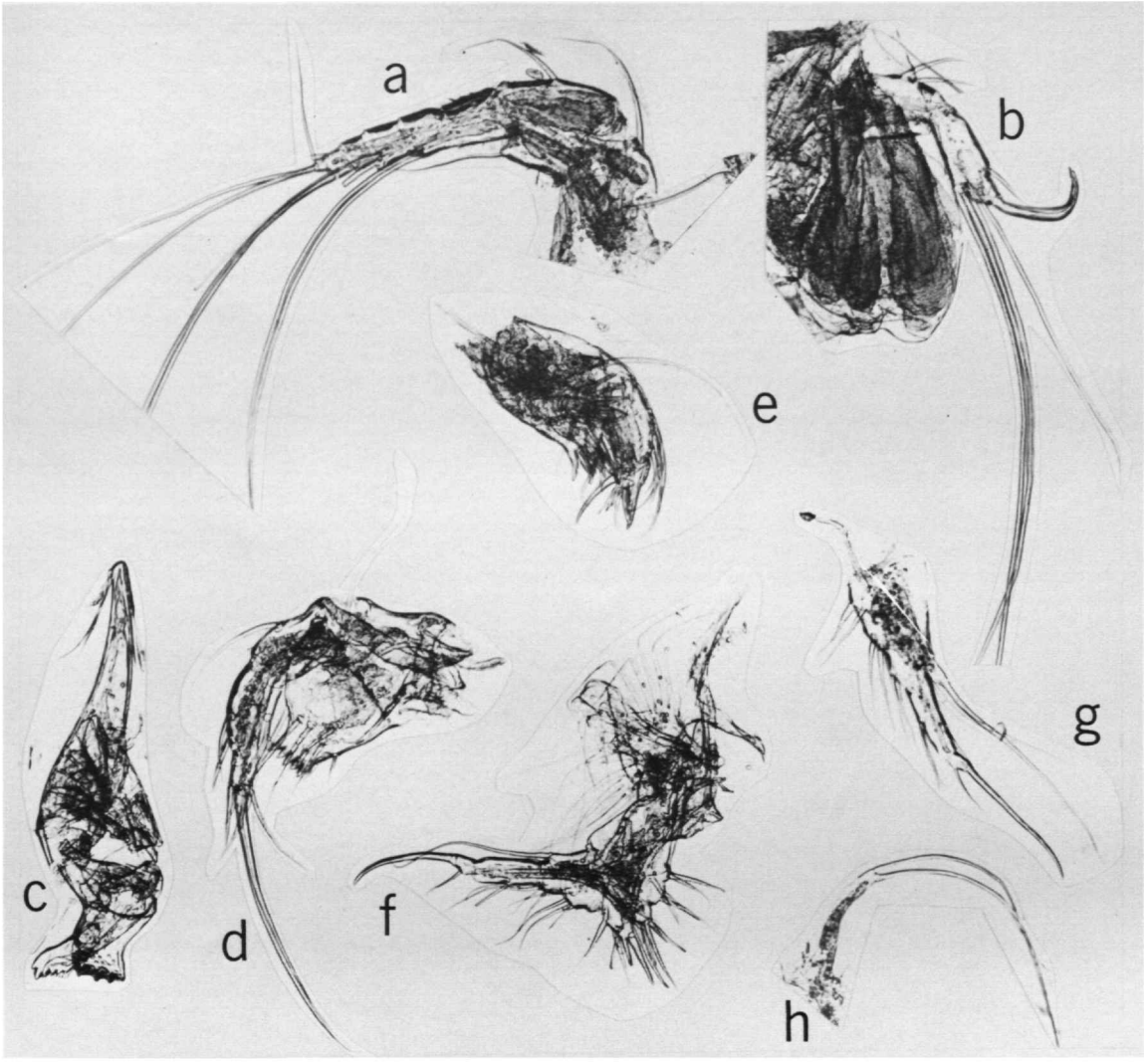

FIGURE 39.—*Thaumatoconcha caraionae*, new species, adult male, paratype, USNM 143855A: *a*, left 1st antenna, lateral view; *b*, part of protopodite and endopodite of left 2nd antenna, medial view; *c*, mandibular coxale; *d*, basale and endopodite of left mandible, lateral view; *e*, maxilla; *f*, 5th limb; *g*, distal part of 6th limb; *h*, 7th limb. (For approximate size of appendages see Figures 36, 40.)

men, length 1.76 mm, height 1.42 mm; left valve, length 1.74 mm, height 1.41 mm.

First antenna (Figures 39*a*, 40*a*): Similar to that of *T. radiata*.

Second antenna (Figures 39*b*, 40*b*): Exopodite with 8 joints; limb otherwise similar to that of *T. radiata*.

Mandible (Figure 39*c–d*), maxilla (Figure 39*e*), 5th limb (Figures 11*k*, 39*f*), 6th limb (Figures 12*i*, 39*g*), 7th limb (Figure 39*h*), furca, rod-shaped organ, posterior of body: Similar to those of female.

Copulatory organ: Tip of anterior lobe with single terminal tooth-like process (Figure 18*g–i*).

DESCRIPTION OF A-1 MALE.—USNM 143857,

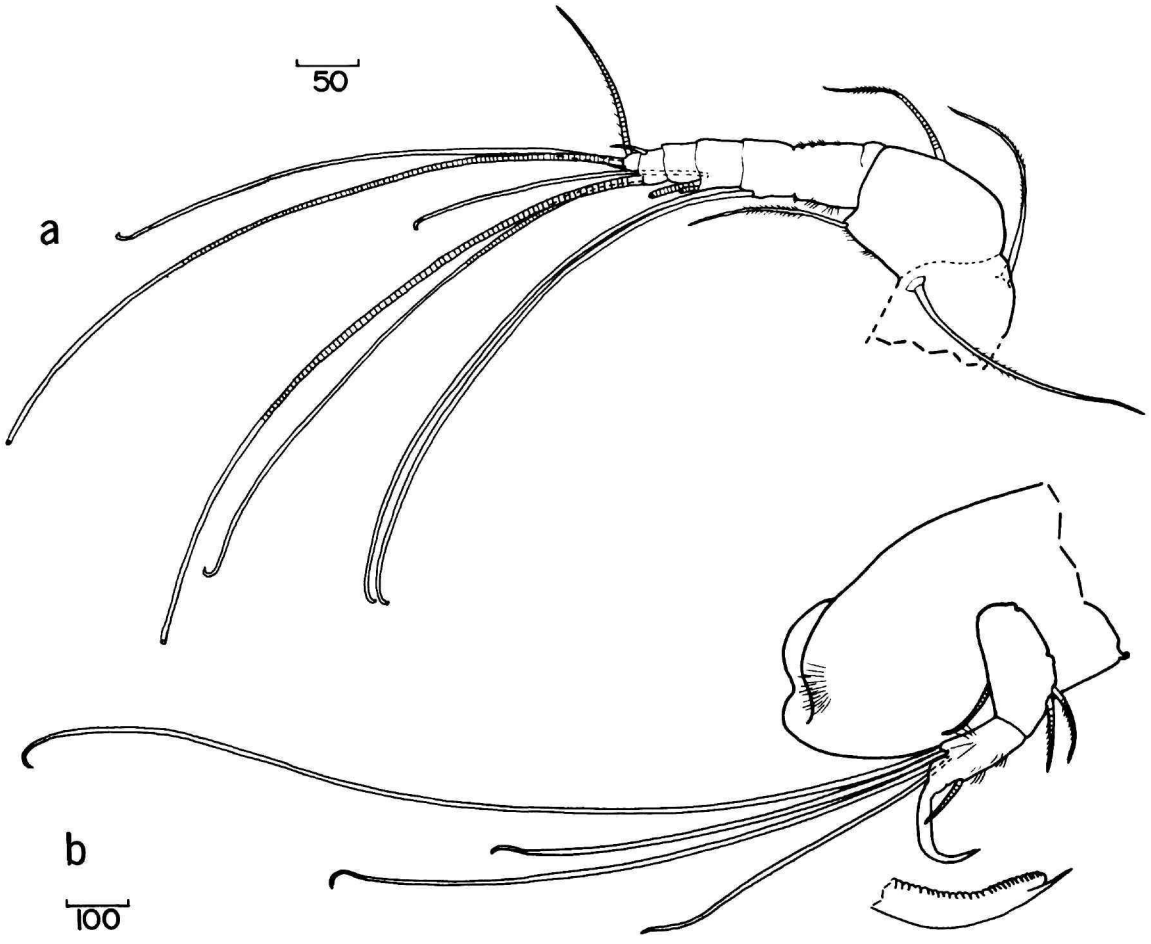

FIGURE 40.—*Thaumatoconcha caraionae,* new species, adult male, paratype, USNM 143855A: *a,* left 1st antenna, lateral view; *b,* part of protopodite and endopodite of left 2nd antenna, medial view. (Scale in micrometers.)

carapace, length 1.52 mm, height 1.29 mm; shape similar to that of adult.

COMPARISONS.—See Table 13.

Thaumatoconcha elongata, new species

FIGURES 11*m*, 12*k*, 13*g*, 18*n–p*; 41–46

HOLOTYPE.—USNM 143968, adult male, appendages on slide, carapace and some appendages in alcohol.

TYPE-LOCALITY.—*R. V. Vema,* Cruise 17, station V-17-1, 7°10′S, 85°50′W, South Pacific, 4124 m.

PARATYPES.—USNM 143967, 1 adult female from same sample as holotype; USNM 144005, 1 juvenile male from *R. V. Vema,* Cruise 15, station V-15-79, 11°12′S, 84°48′W, 4460–4449 m (Figures 1, 9).

ETYMOLOGY.—The specific name is in reference to the elongate carapace of this species.

DIAGNOSIS.—Carapace elongate with scattered shallow pits on surface; anteroventral surface with about 8 ridges; straight anteroventral margin; length of female 2.30 mm, length of male 2 mm;

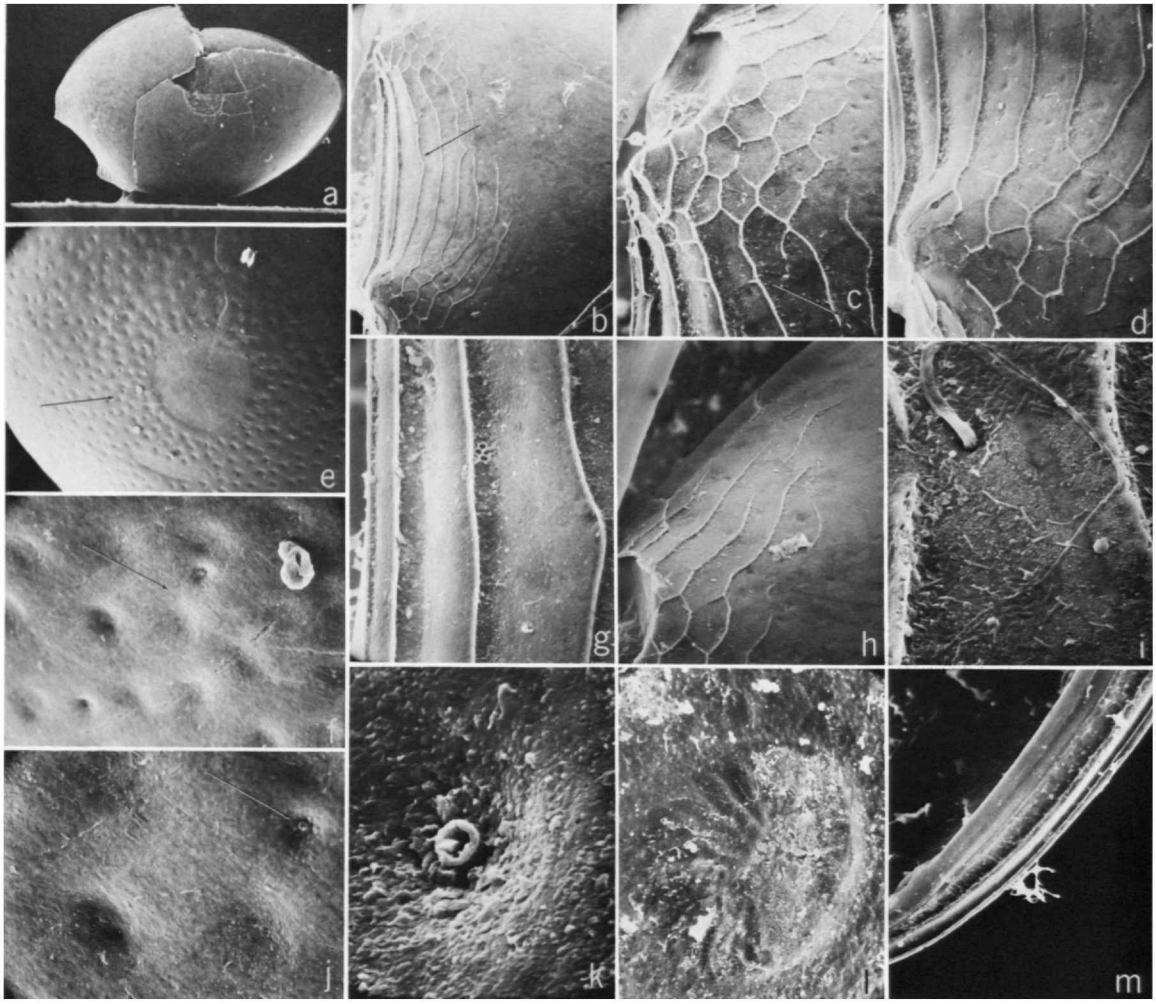

FIGURE 41.—*Thaumatoconcha elongata*, new species, left valve of adult female, paratype, USNM 143967: *a*, outside view (valve cracked during freeze-dry operation), × 40; *b*, anteroventral view, slightly oblique, ventral margin toward bottom, × 135; *c*, upper anteroventral protuberance, from *b*, × 340; *d*, lower anteroventral protuberance, from *b*, × 340; *e*, smooth surface over adductor muscle attachment, and shallow punctae on valve surface, from *b*, × 170; *f*, detail of surface (for location see arrow in *e*), × 1000; *g*, detail of anteroventral ridges (for location see arrow in *b*), × 650; *h*, ridges on anterodorsal valve surface (location is from near top of *c*), × 340; *i*, branching hair on anteroventral part of valve surface (for location see arrow in *c*), × 2400; *j*, detail of shallow punctae (for location see arrow in *f*), × 2000; *k*, detail of punctae with small raised pore (for location see arrow in *j*), × 10,000; *l*, adductor muscle attachment scar as seen from the inside, × 500; *m*, posteroventral margin from inside, ventral margin to right, × 200. (Photos reduced to 48½ percent.)

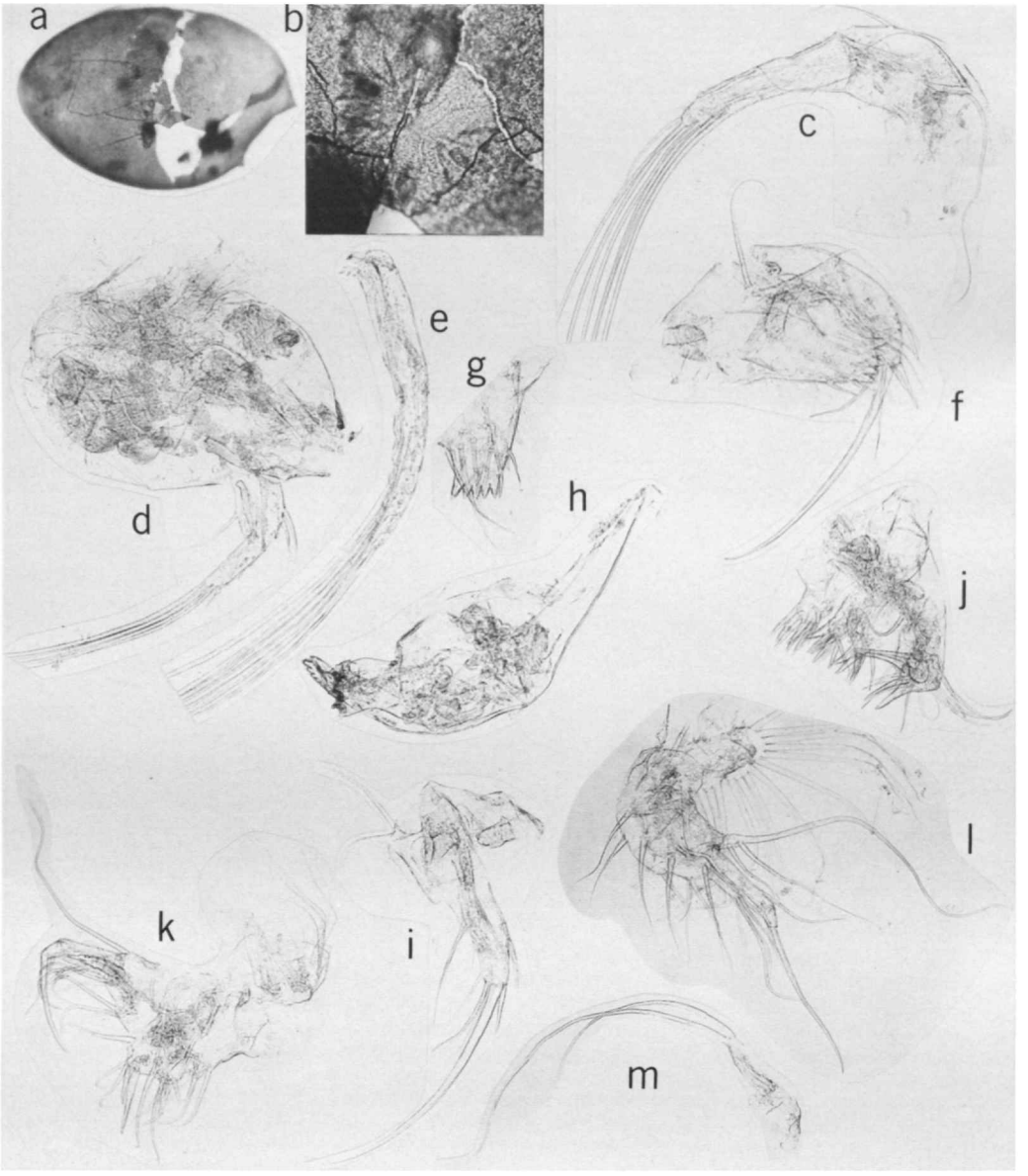

FIGURE 42.—*Thaumatoconcha elongata*, new species, adult female, paratype, USNM 143967: *a*, right valve from outside, anterior to right; *b*, adductor muscle attachment scar of right valve shown in *a*; *c*, right 1st antenna, medial view; *d*, protopodite and endopodite of right 2nd antenna, lateral view; *e*, exopodite of right 2nd antenna, lateral view; *f*, basale and endopodite of left mandible, medial view; *g*, tip of basale of right mandible, lateral view; *h*, mandibular coxale (twisted); *i*, tip of endopodite of right mandible, lateral view; *j*, maxilla; *k*, 5th limb; *l*, 6th limb; *m*, 7th limb. (For size of appendages see Figure 43.)

FIGURE 43.—*Thaumatoconcha elongata*, new species, adult female, paratype, USNM 143967; *a*, complete specimen, length 2.3 mm; *b*, right 1st antenna, medial view; *c*, protopodite and endopodite of right 2nd antenna, lateral view; *d*, mandibular coaxle (twisted); *e*, basale and endopodite of left mandible, medial view; *f*, tip of basale of right mandible, medial view; *g*, tip of endopodite of right mandible, lateral view; *h*, maxilla; *i*, 5th limb; *j*, 6th limb; *k*, 7th limb; *l*, rod-shaped organ. (Same magnification in micrometers: *b*, *c*, *j*, *k*; *a*, *d*, *e*, *g–i*, *l*.)

dorsal margin of 3rd joint of 1st antenna longer than dorsal margin of 4th joint; endopodite of mandible with 1 dorsal bristle on 1st joint and 2 on 2nd; rod-shaped organ with rounded tip; anterior lobe of male copulatory organ with single tapered tooth projecting well past end of adjacent lobe.

DESCRIPTION OF FEMALE (Figures 11*m*, 12*k*, 41–43).—Carapace elongate-ovate; height of anterior margin much greater than posterior (Figures 41, 42*a*, 43*a*); straight anteroventral margin delimited by a dorsal and a slightly smaller ventral cone-like process, each terminating in a forward pointing short, protuberance (in lateral view anteroventral margin appears concave); anterodorsal margin curves gently forward and then strongly downward to upper cone-like process, merging with short straight dorsal margin at point more than about one-third greatest length; in lateral view dorsal outline gently curved; posterior margin curves gently to a point approximately same height as dorsal protuberance, then curves sharply to meet convex ventral margin. Dorsal outline subelliptical, greatest width at midlength; end outline subelliptical, greatest width at midheight.

Ornamentation: Surface with scattered shallow pits; widely spaced pore-canals containing hairs that branch distally observed near anterior margin; narrow marginal rim present except between protuberances; anteroventral surface with 8 thin ridges becoming more convex and discontinuous proximally; ridges grade into polygonal reticulations in area of cone-like processes; ridges terminate posteriorly to cone-like processes.

Adductor muscle-scar: Scar subcentrally located, round, consists of about 19 subequal pie-shaped segments more-or-less radially arranged (Figure 42*a*,*b*).

Size: USNM 143967, length 2.30 mm, height 1.66 mm (Figure 16).

First antenna (Figures 42*c*, 43*b*), maxilla (Figures 42*j*, 43*h*), 5th limb (Figures 11*m*, 42*k*), 7th limb (Figure 42*m*), furca, rod-shaped organ, upper lip (Figure 13*g*): Similar to that of *T. radiata*.

Second antenna: Exopodite with only 8 joints, limb otherwise similar to that of *T. radiata* (Figures 42*d*,*e*, 43*c*).

Mandible: Third endopodial joint with 6 bristles; limb otherwise similar to that of *T. radiata* (Figures 42*f*–*i*, 43*d*–*g*).

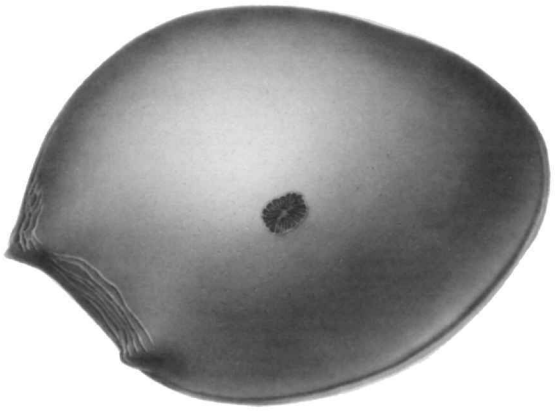

FIGURE 44.—*Thaumatoconcha elongata*, new species, carapace of adult male, holotype, USNM 143968, length 2.00 mm, anterior to left.

Sixth limb (Figures 12*k*, 42*l*, 43*j*): Long bristle of 4th joint about 1½ times length of that of *T. radiata;* limb otherwise similar to that of *T. radiata*.

DESCRIPTION OF ADULT MALE (Figures 18*n*–*p*, 44–46).—Carapace similar in shape to that of female except smaller (Figure 44).

Size: USNM 143968, length 2.00 mm, height 1.55 mm (Figure 17).

First antenna: Similar to that of *T. radiata* (Figures 45*a*, 46*a*).

Second antenna: Exopodite with 8 joints, otherwise limb similar to that of *T. radiata* (Figures 45*b*,*c;* 46*b*).

Mandible (Figures 45*d*,*e;* 46*c*), maxilla (Figures 45*f*, 46*d*), 5th limb (Figure 45*g*), 6th limb (Figure 45*h*), 7th limb (Figure 45*i*), rod-shaped organ (Figure 46*e*), posterior of body: Similar to those of female.

Copulatory organ: Tip long, projecting well past adjacent lobe, without short teeth (Figure 18*n*–*p*).

DESCRIPTION OF JUVENILE MALE.—USNM 144005, carapace, thin, torn, length about 1.39 mm, height about 1.06 mm.

COMPARISONS.—See Table 13.

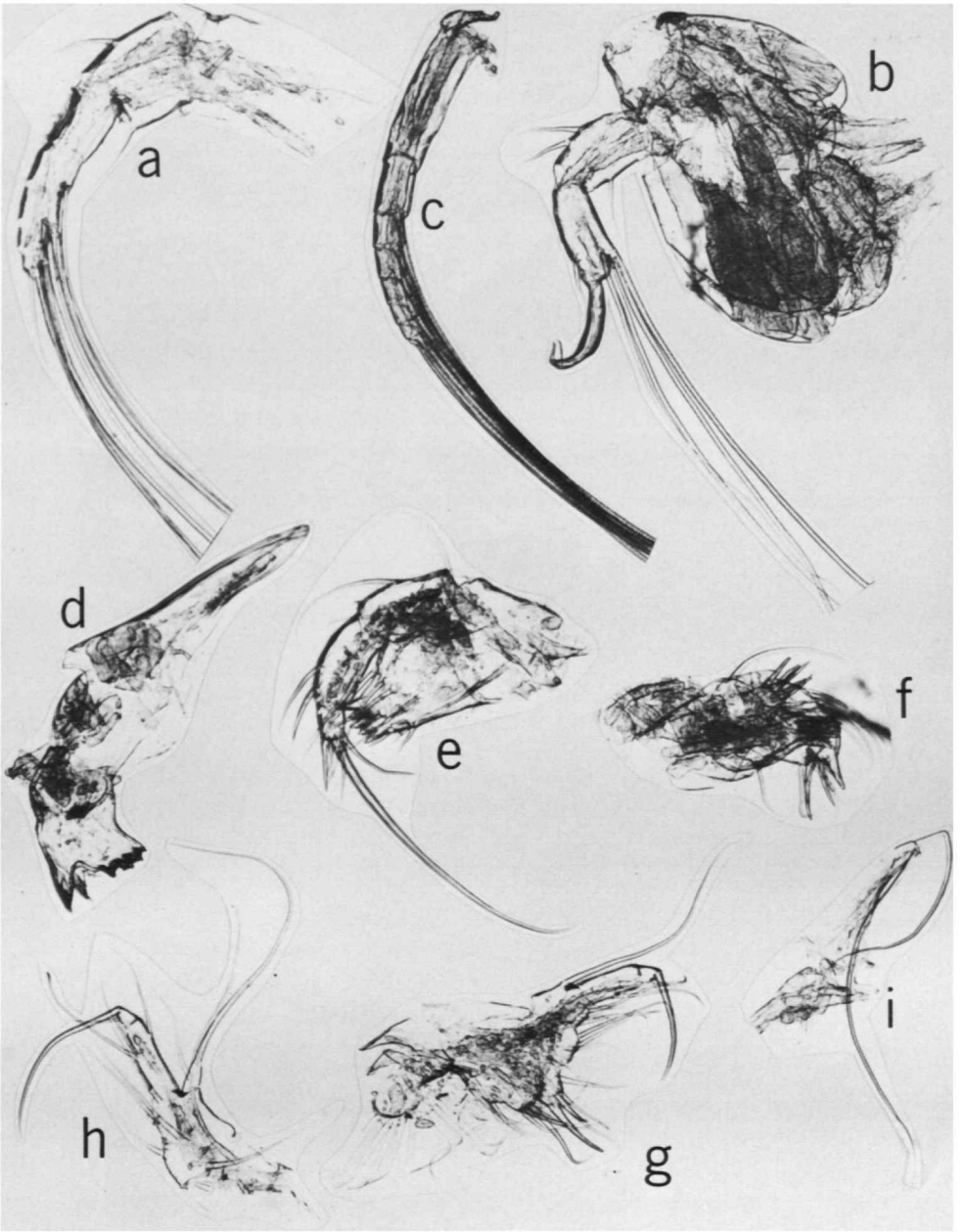

FIGURE 45.—*Thaumatoconcha elongata*, new species, adult male, holotype, USNM 143968: *a*, left 1st antenna, lateral view; *b*, protopodite and endopodite of left 2nd antenna, lateral view; *c*, exopodite of left 2nd antenna, lateral view; *d*, coxale of left mandible, lateral view; *e*, basale and endopodite of left mandible, lateral view; *f*, maxilla; *g*, 5th limb; *h*, distal part of 6th limb; *i*, 7th limb. (For approximate size of appendages see Figures 43, 46.)

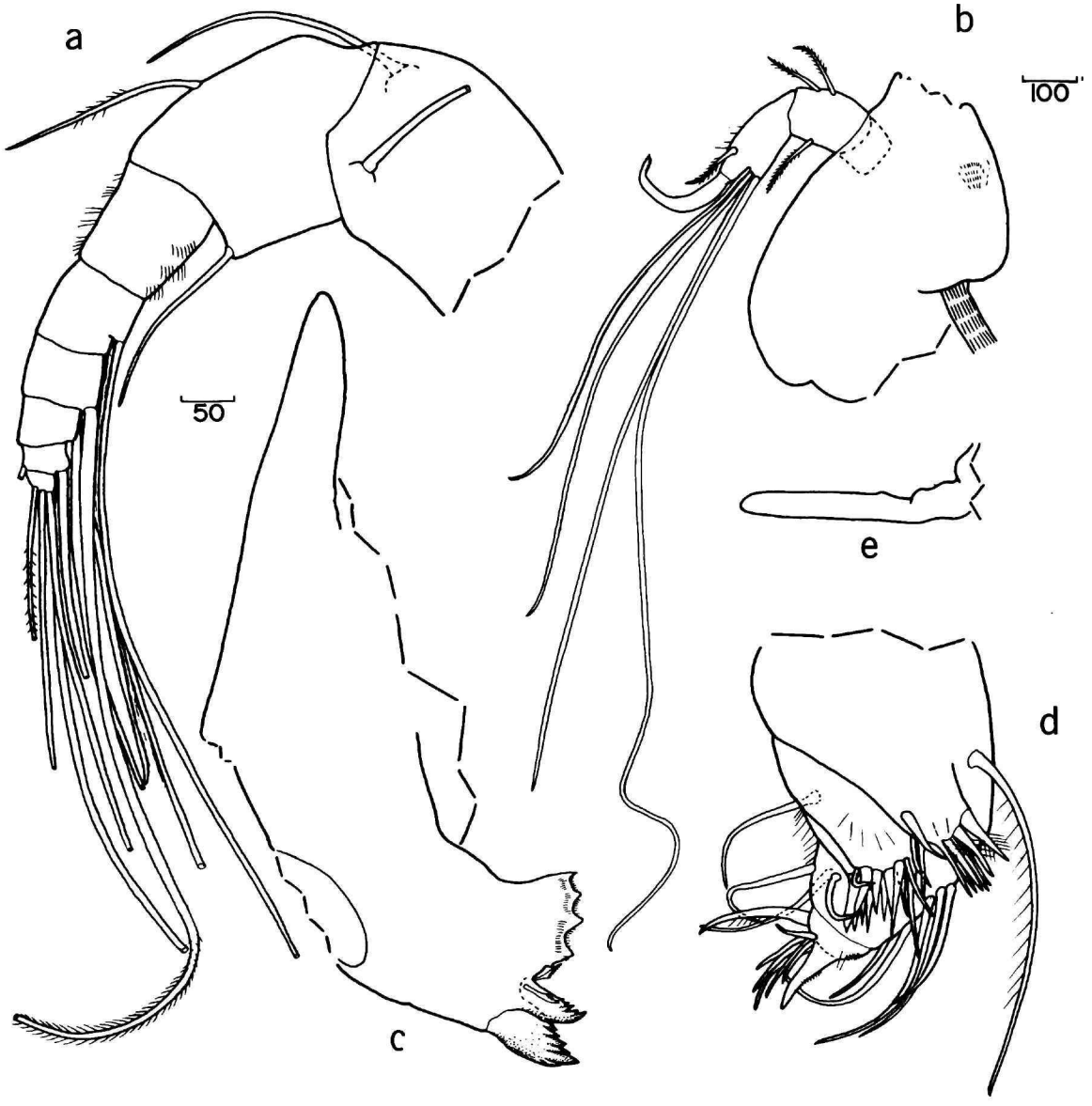

FIGURE 46.—*Thaumatoconcha elongata*, new species, adult male, holotype, USNM 143968: *a*, left 1st antenna, lateral view; *b*, protopodite and endopodite of left 2nd antenna, lateral view; *c*, coxale of left mandible, lateral view; *d*, maxilla; *e*, rod-shaped organ. (Same magnification in micrometers: *a*, *c–e*.)

Thaumatoconcha hessleri, new species

FIGURES 11*e*, 12*e*; 13*f*; 47–51

HOLOTYPE.—USNM 143862, adult female, appendages on slide, valves and remaining appendages in alcohol.

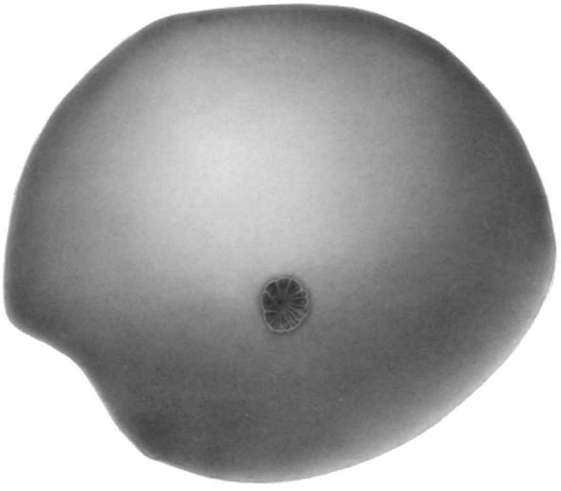

FIGURE 47.—*Thaumatoconcha hessleri*, new species, carapace of adult female, holotype, USNM 143862, length 1.42 mm, anterior to left.

TYPE-LOCALITY.—*R. V. Vema*, Cruise 14, station V-14-33, 34°36′S, 16°40′E, South Atlantic, 717–695 m.

PARATYPES.—Two adult females, USNM 143755, USNM 144006, from same station as holotype (Figure 9).

ETYMOLOGY.—The species is named for Dr. Robert R. Hessler.

DIAGNOSIS.—Surface smooth but with small pustules visible at high magnification (× 2000) and 5 anteroventral ridges; anteroventral profile slightly concave; length of female 1.42 to 1.47 mm; dorsal margin of 3rd joint of 1st antenna shorter than, or about same length as dorsal margin of 4th joint; endopodite of mandible with 1 dorsal bristle on 1st joint and 2 on 2nd; rod-shaped organ with rounded tip.

DESCRIPTION OF ADULT FEMALE (Figures 11*e*, 12*e*, 47–51).—Valves subround, height of anterior margin greater than posterior, concave anteroventral margin delimited by a dorsal and a ventral subdued protuberance (Figures 47–50); anterodorsal margin broadly convex, merging with short straight dorsal margin at point about one-third greatest length; posterior margin broadly convex; ventral margin curving sharply forward and downward to

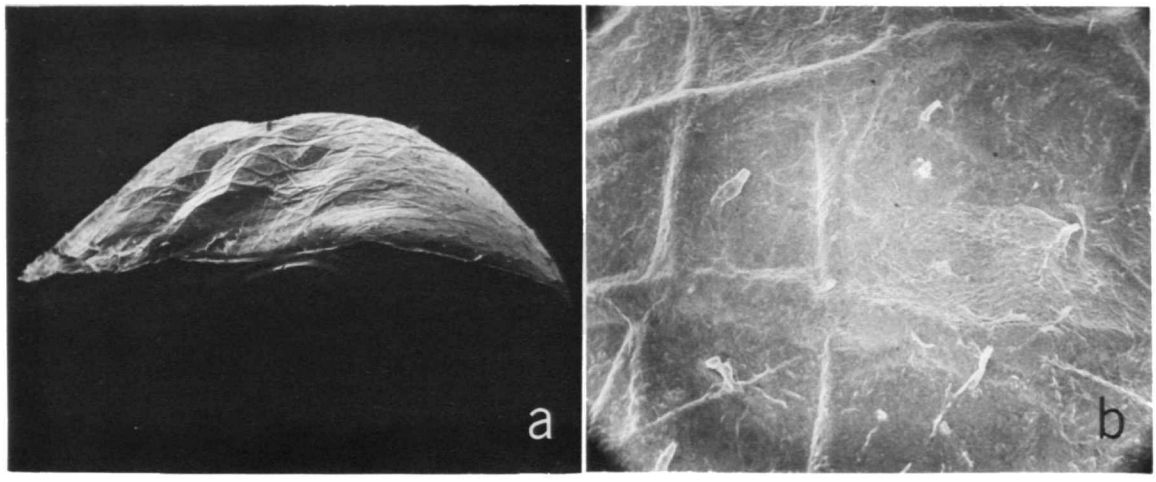

FIGURE 48.—*Thaumatoconcha hessleri*, new species, left valve of adult female, holotype, USNM 143862 (decalcified valve was distorted during freeze-dry operation): *a*, anterior view, ventral margin to right, × 85; *b*, detail of outer surface showing short processes, × 1000. (Photos reduced to 82 percent.)

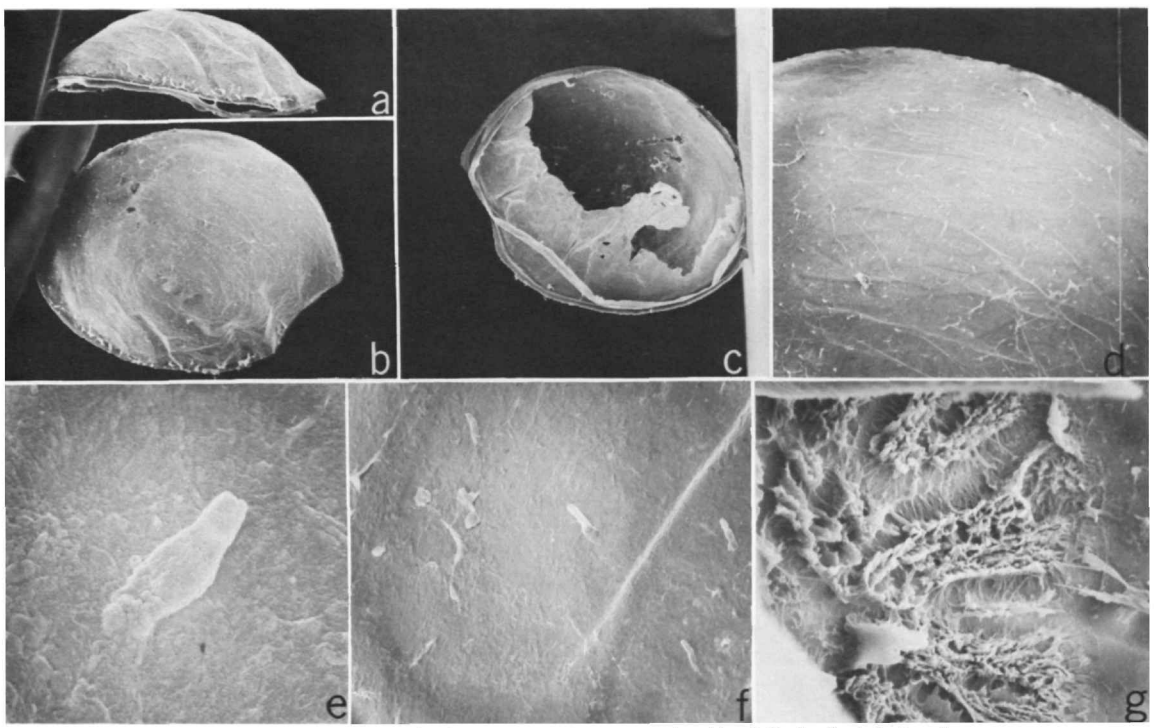

FIGURE 49.—*Thaumatoconcha hessleri*, new species, right valve (decalcified) of adult female, paratype, USNM 143755B: *a*, ventral view, anterior to right, × 50; *b*, outside view, × 50; *c*, inside view, × 50; *d*, outer surface near dorsal margin, anterior to right, × 150; *e*, detail of minute process on outer surface of shell, × 5000; *f*, outer surface of shell showing several processes, × 1000; *g*, part of adductor muscle attachment from inside, anterior end of valve towards top, × 1300. (Photos reduced to 63 percent.)

point approximately below subcentral adductor muscle-scar, then curving upward to join anteroventral margin below protuberance; dorsal outline subelliptical, greatest width subcentral; end outline subelliptical, greatest width subcentral.

Ornamentation: Surface smooth, abundant small pustules observed at high magnification (× 2000); widely spaced pore-canals containing hairs along free margin; anteroventral surface with 5 thin ridges parallel to valve margin, ridges not observed on holotype because it is decalcified; cross-ridges form crude reticulations around protuberances; outermost ridge continuous around all margins.

Adductor muscle-scar: Scar subcentrally located in area of greatest width; subround; scar consists of 14 to 17 subequal wedge-shaped segments more-or-less radially arranged (Figure 47).

FIGURE 50.—*Thaumatoconcha hessleri*, new species, left valve of adult female, paratype, USNM 144006: *a*, inside view (valve distorted), × 65; *b*, outside view (outer layer of shell flaked off during freeze-dry operation), × 60; *c*, anteroventral margin, dorsal margin of valve towards upper right, × 160; *d*, anteroventral view, ventral margin of valve to right, × 100; *e*, lower protuberance of anteroventral margin, ventral margin of valve towards right, × 415; *f*, ridges and surface hairs near upper protuberance of anteroventral margin (for location see arrow in *c*), × 700; *g*, anterior end of valve, dorsal view, × 215; *h*, dorsal view of distorted valve, × 70; *i*, hair near ventral protuberance (see arrow in *e*), × 4150; *j*, outer surface of shell at posterior end of valve (for location see arrow in *b*), × 1000; *k*, ventral view of distorted valve, × 70; *l*, anterior end of valve from inside, × 135; *m*, detail of outer surface of shell (for location see arrow in *j*), × 4000; *n*, outer surface of shell flake from near posterior end of valve (for location see arrow in *b*), × 4000; *o*, inside surface of flake of outer layer of shell shown in *n*, × 4000. (Photos reduced to 50½ percent.)

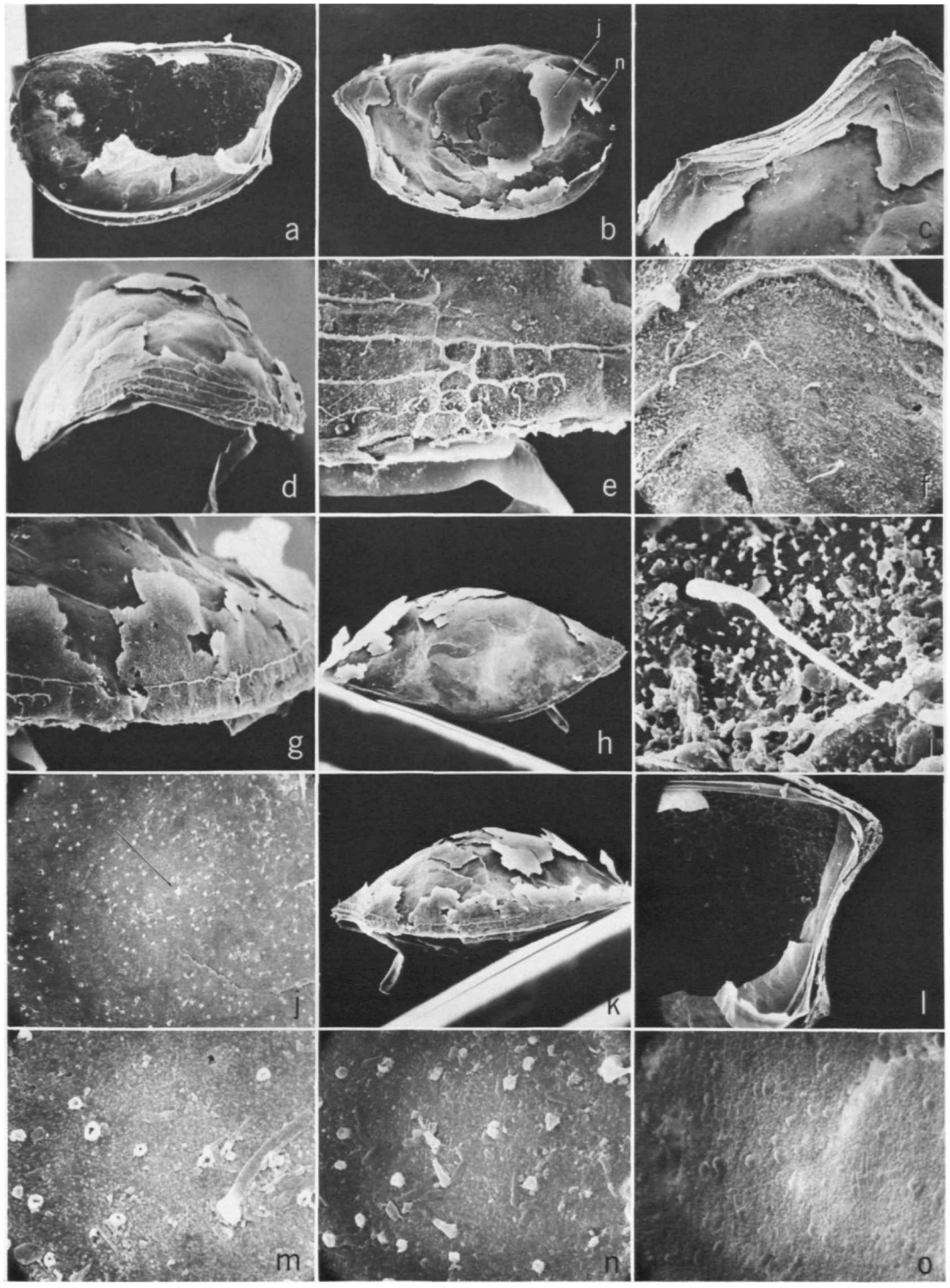
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FIGURE 51.—*Thaumatoconcha hessleri*, new species, adult female, holotype, USNM 143862: *a*, right 1st antenna, lateral view; *b*, right 2nd antenna, medial view; *c*, coxale of left mandible, lateral view; *d*, basale and endopodite of left mandible, lateral view; *e*, maxilla; *f*, 5th limb; *g*, 6th limb; *h*, posterior part of furca showing 5 short claws and small process posterior to them on each lamella, and single posterior process; *i*, rod-shaped organ. (Scale in micrometers.)

Size (Figure 16).—USNM 143862, length 1.42 mm, height 1.22 mm; USNM 143755B, length 1.44 mm, height 1.21 mm; USNM 144006, length 1.47 mm, height 1.28 mm.

First antenna: Dorsal margin of 3rd joint shorter than dorsal margin of 4th joint (Figure 51*a*).

Second antenna: Exopodite with 8 joints; limb otherwise similar to that of *T. radiata* (Figure 51*b*).

Mandible: Third endopodial joint with 6 bristles; limb otherwise similar to that of *T. radiata* (Figure 51*c,d*).

Maxilla (Figure 51*e*), 7th limb, furca (Figure 51*h*), rod-shaped organ (Figure 51*i*), lips (Figure 13*f*), posterior of body: Similar to those of *T. radiata*.

Fifth limb (Figures 11*e*, 51*f*): Short bristle of 3rd exopodial joint about one-third length of long bristle; limb otherwise similar to that of *T. radiata*.

Sixth limb (Figures 12*e*, 51*g*): Short bristle of 4th exopodial joint about one-fifth length of long bristle; limb otherwise similar to that of *T. radiata*.

COMPARISONS.—See Table 13.

Thaumatoconcha polythrix, new species

FIGURES 11*j*, 12*h*, 13*c*, 18*q–s*, 52–55

HOLOTYPE.—USNM 143792, adult male, appendages on slides, carapace and some appendages in alcohol.

TYPE-LOCALITY.—*R. V. Atlantis II*, Cruise 24, station 119, 32°15′48″N, 64°31′36″W to 32°16′06″N, 64°32′36″W, North Atlantic, 2095–2223 m.

PARATYPES.—USNM 143790A,C, 2 adult females from same sample as holotype (Figure 9).

ETYMOLOGY.—The specific name from the Greek meaning many bristles, in reference to the large number of bristles on the dorsal margin of the 1st and 2nd joints of the mandibular endopodite.

DIAGNOSIS.—Surface of carapace smooth to finely punctate with 10 anteroventral ridges; 7 of the ridges continue along ventral margin, decreasing in number posteriorly; 4 ridges continue for short distance along anterior margin dorsal to upper protuberance; straight anteroventral margin; length of female 1.85 to 1.94 mm, length of male 1.68 mm; dorsal margin of 3rd joint of 1st antenna longer than dorsal margin of 4th joint. Endopodite of mandible: dorsal margin of 1st joint with 4–6 bristles; dorsal margin of 2nd joint with 3 bristles; 3rd joint with 6 bristles. Maxilla: anterior margin of 1st endopodial joint with 7 bristles; 5th limb: ventral margin of 1st exopodial joint with 10 bristles; short bristle of 3rd exopodial joint less than one-half length of long bristle. Sixth limb: 1st exopodial joint with 5–8 bristles; rod-shaped organ with rounded tip; anterior lobe of male copulatory limb with single long curved tooth-like process.

DESCRIPTION OF FEMALE (Figures 11*j*, 12*h*, 52, 53).—Valves subround, height of anterior margin greater than posterior (Figure 52); concave anteroventral margin delimited by a dorsal and by a ventral forward pointing protuberance; anterior margin straight or gently curved, slightly longer than anteroventral margin; anterodorsal margin curved, short, merging with straight dorsal margin at point about one-third greatest length; posterior margin convex, evenly rounded; ventral margin curving gently forward and downward to a point approximately below subcentral muscle-scar, then curving outward to join anteroventral margin below protuberance; dorsal outline subelliptical, greatest width at approximately midlength; end outline subelliptical, greatest width slightly below midheight.

Ornamentation: Surface smooth to finely punctate; widely spaced simple pores, some with a hair, and more abundant shallow punctae, 2 or 3 times size of the pores, present on surface except in area of muscle-scar; anteroventral surface with 10 thin ridges subparallel to valve margin; cross-ridges form crude reticulations around subdued protuberances; 7 of the thin ridges continue along ventral margin, decreasing in number posteriorly; 4 of the thin ridges continue for a short distance above the upper protuberance along the anterior margin.

Adductor muscle-scar: Scar subcentrally located, subelliptical, greatest diameter trending toward middle of hinge; scar consists of approximately 16 subequal pie-shaped segments more-or-less radially arranged.

Size (Figure 16): USNM 143790A, complete specimen, length 1.85 mm, height 1.55 mm; USNM 143790C, complete specimen, length 1.94 mm, height 1.49 mm.

First antenna (Figure 53*a*), 7th limb, furca, rod-shaped organ, lips, posterior of body: Similar to those of *T. radiata*.

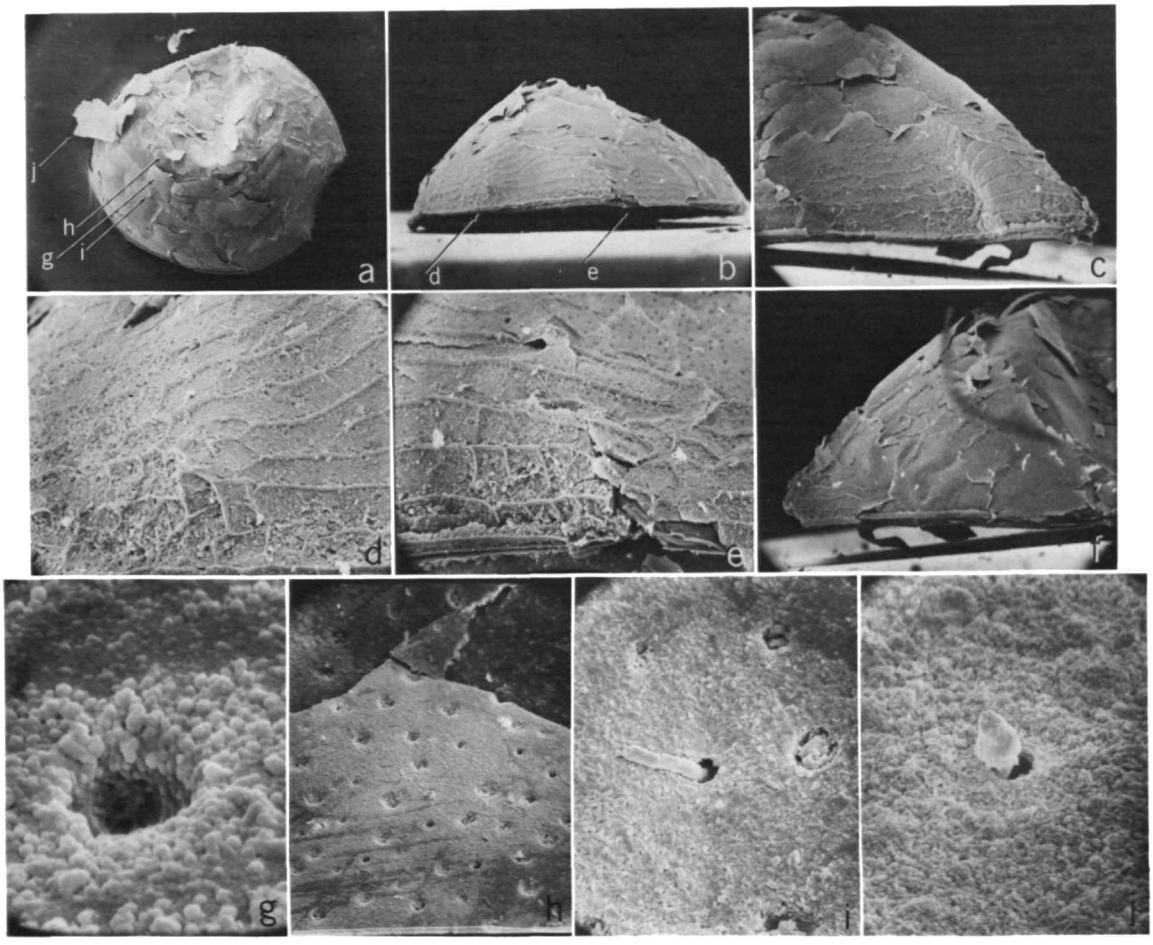


FIGURE 52.—*Thaumatoconcha polythrix*, new species, right valve of adult female, paratype, USNM 143790A: *a*, outside view (cracking and flaking of outer layer of shell took place during the freeze-dry operation), × 40; *b*, anteroventral view, ventral margin to left, × 65; *c*, anterior part of valve, ventral view, × 100; *d*, lower protuberance of anteroventral margin (for location see arrow in *b*), × 295; *e*, upper protuberance (broken) of anteroventral margin (for location see arrow in *b*), × 295; *f*, anterior end of valve, dorsal view, × 100; *g*, detail of puncta (see arrow in *a*); × 16,800; *h*, surface punctae (see arrow in *a*), × 1025; *i*, detail of surface of flake showing broken bristle and punctae (see arrow in *a*), × 3265; *j*, underside of flake showing broadened base of bristle and slightly raised reflections of punctae (see arrow in *a*), × 3200. (Photos reduced to 52 percent.)

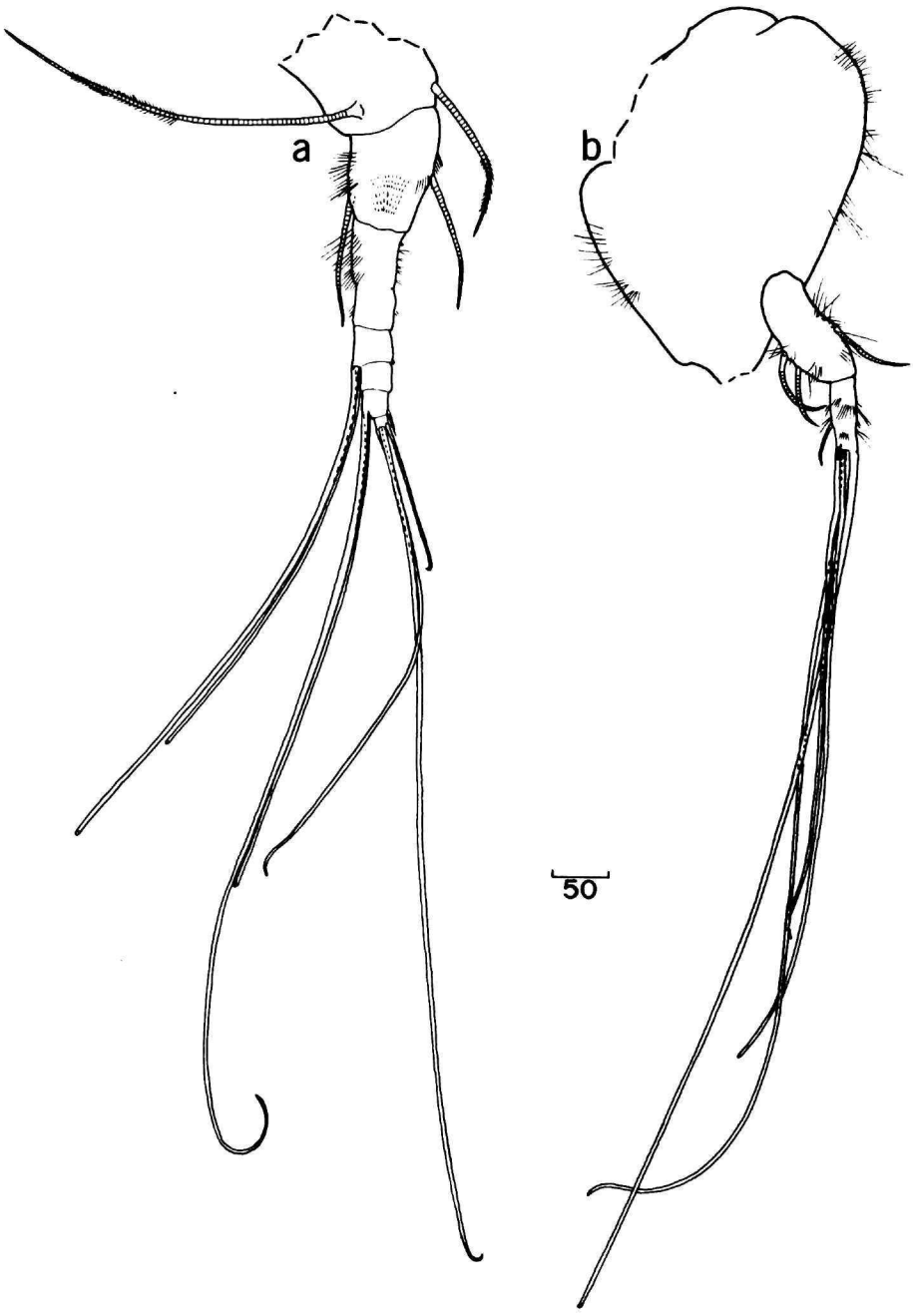


FIGURE 53.—*Thaumatoconcha polythrix*, new species, adult female, paratype, USNM 143790C: *a*, right 1st antenna, lateral view; *b*, protopodite and endopodite of left 2nd antenna, lateral view. (Scale in micrometers.)

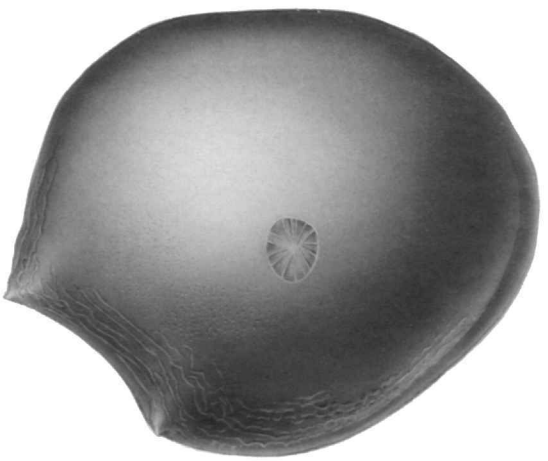


FIGURE 54.—*Thaumatoconcha polythrix*, new species, carapace of adult male, holotype, USNM 143792, length 1.68 mm, anterior to left.

Second antenna (Figure 53*b*): Exopodite with 8 joints and 3rd endopodial joint minute; limb otherwise similar to that of *T. radiata*.

Mandible: Dorsal margin of 1st endopodial joint with 5 or 6 bristles; dorsal margin of 2nd endopodial joint with 3 bristles; 3rd endopodial joint with 6 bristles; limb otherwise similar to that of *T. radiata*.

Maxilla: First endopodial joint with 7 anterior bristles; limb otherwise similar to that of *T. radiata*.

Fifth limb (Figure 11*j*): Frst exopodial joint with 10 ventral bristles; short bristle on 3rd exopodial joint about one-fourth length of long bristle; limb otherwise similar to that of *T. radiata*.

Sixth limb (Figure 12*h*): First exopodial joint with 8 bristles; short bristle of 4th endopodial joint less than one-half length of long bristle; limb otherwise similar to that of *T. radiata*.

FOOD.—USNM 143790A with fragments of crustacean appendages and minute brownish particles in gut.

DESCRIPTION OF MALE (Figures 13*c*, 18*q–s*, 54, 55).—Carapace similar to that of female except smaller (Figure 54).

Size (Figure 17): USNM 143792, complete specimen, length 1.68 mm, height 1.40 mm.

First antenna: Similar to that of *T. radiata* (Figure 55*a*).

Second antenna: Exopodite with 8 joints; limb otherwise similar to that of female (Figure 55*b*).

Mandible (Figure 55*c–e*), maxilla (Figure 55*f*), 5th limb (Figure 55*g*), 6th limb (Figure 55*h*), 7th limb, rod-shaped organ (Figure 55*i*), furca, lips (Figure 13*c*), posterior of body: Similar to that of female.

Copulatory organ: See Figure 18*q–s*.

COMPARISONS.—See Table 13.

Thaumatoconcha punctata, new species

FIGURES 11*h*, 12*l*, 13*d*, 56–58

HOLOTYPE.—USNM 143861, adult female, some appendages on slide, others in alcohol; left valve in alcohol; right valve dry, gold-plated.

TYPE-LOCALITY.—*USNS Eltanin*, Cruise 25, station 364, 56°17′S, 156°13′W to 56°19′S, 156°18′W, South Pacific, 3694 m.

PARATYPES.—USNM 127289B, 1 adult female; USNM 127289C, 1 A–1 female; USNM 127289D–E, 2 A–2 females; USNM 127289F, 1 juvenile, length 1.26 mm, height 1.14 mm (not opened). Paratypes from same sample as holotype (Figure 9).

ETYMOLOGY.—The specific name is in reference to the punctate surface of the carapace (punctae were not observed on juveniles and poorly preserved adults).

DIAGNOSIS.—Carapace surface with irregularly spaced shallow punctae and about 9 anteroventral ridges; straight anteroventral margin; length of female 2.22 to 2.24 mm; dorsal margin of 3rd joint of 1st antenna longer than dorsal margin of 4th joint; endopodite of mandible with 1 dorsal bristle on 1st joint and 2 on 2nd; rod-shaped organ with pointed tip.

DESCRIPTION OF ADULT FEMALE (male unknown) (Figures 11*h*, 12*l*, 13*d*, 56–58).—Valves subround, height of anterior margin almost twice the height of posterior (Figures 56, 57); straight anteroventral margin delimited by a dorsal and a ventral forward pointing very short truncated protuberance; anterodorsal margin broadly convex, merging with short gently curved dorsal margin at point about one-third greatest length; posterior margin gently rounded; forward and downward curving ventral margin joins posterior with slight angulation, curves upward approximately below subcentral ad-

FIGURE 55.—*Thaumatoconcha polythrix*, new species, adult male, holotype, USNM 143792: *a*, left 1st antenna, lateral view; *b*, left 2nd antenna, medial view; *c*, mandibular coxale; *d*, basale and endopodite of left mandible, lateral view; *e*, basale and endopodite of right mandible, medial view; *f*, maxilla; *g*, part of 5th limb; *h*, 6th limb; *i*, rod-shaped organ. (Same magnification in micrometers: *a*, *b*; *c–i*.)

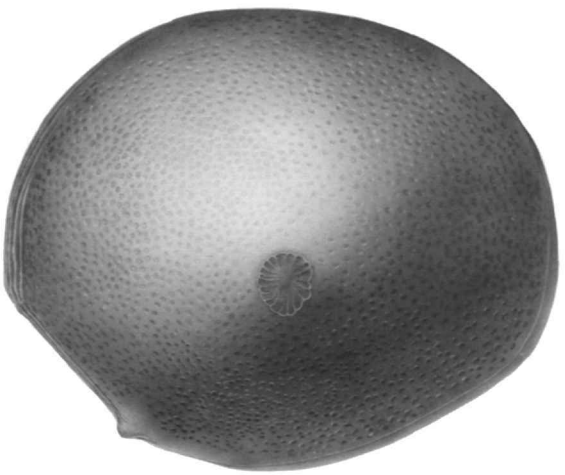


FIGURE 56.—*Thaumatoconcha punctata*, new species, carapace of adult female, holotype, USNM 143861, length 2.22 mm, anterior to left.

ductor muscle-scar to join straight anteroventral margin below protuberance; dorsal outline subelliptical, greatest width slightly in front of mid-length; end outline subelliptical, greatest width slightly below midheight.

Ornamentation: Surface with irregularly spaced shallow punctae and scattered hairs emerging from normal pores; anteroventral surface with 9 low ridges; proximal ridges wavy; practically no cross-ridges present; right closest to contact margin continues around entire valve; next 4 ridges extend dorsally, terminating about half way up anterior margin; proximal ridges progressively shorter than distal ridges.

Adductor muscle-scar: Scar subcentrally located, subovate, greatest diameter trending normal to hinge; scar consists of approximately 20 subequal pie-shaped segments more-or-less radially arranged (Figure 56).

Size: USNM 143861, length 2.22 mm, height 1.88 mm; USNM 127289B, length 2.24 mm, height 1.97 mm (Figure 16).

First (Figure 58*a*) and 2nd antenna (Figure 58*b*), mandible (Figure 58*c,d*), maxilla (Figure 58*e*), 6th limb (Figures 12*l*, 58*g*); 7th limb (Figure 58*h*), furca, posterior of body: Similar to those on adult female of *T. radiata*.

Fifth limb (Figure 11*h*, 58*f*): First exopodite joint of the holotype with 10 ventral bristles. (This joint on holotype of *T. radiata* bears only 7 ventral bristles, but the variability in the number of bristles on this joint was not determined for either *T. radiata* or *T. punctata*, so the observed difference in number of bristles for the 2 species may not be significant).

Rod-shaped organ: Elongate, 1-jointed or weakly 2-jointed, with broad proximal half; distal half strongly tapered with small process at tip (Figure 58*i–j*).

Upper lip: With 4 small processes, otherwise similar to that of *T. radiata* (Figure 13*d*).

DESCRIPTION OF FEMALE A–1 INSTAR.—Carapace similar in shape to that of adult but without punctations (only 1 specimen observed).

Size: USNM 127289C, length 1.85 mm, height 1.49 mm.

Furca: Similar to that on female A–1 instar of *T. radiata*.

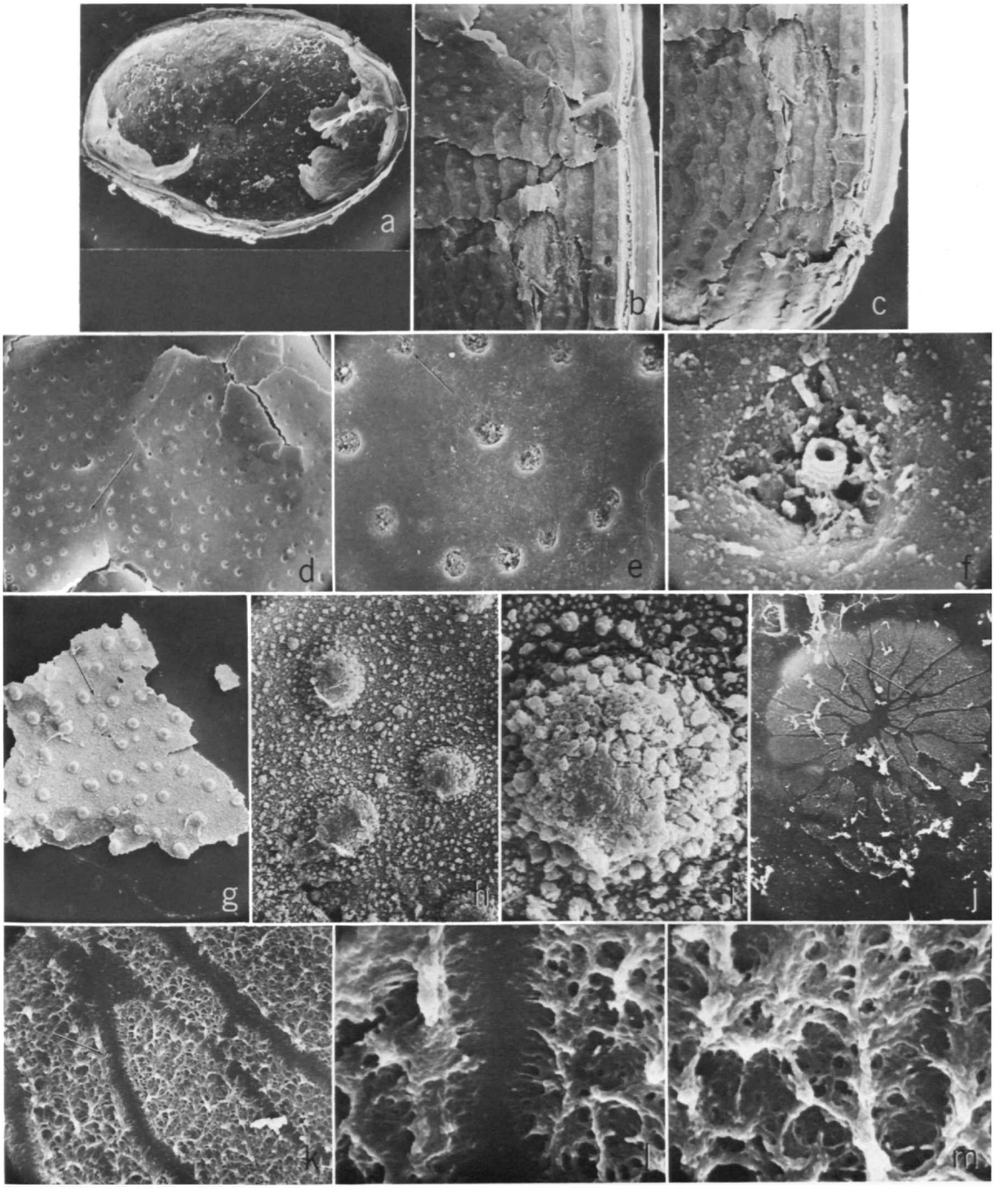
Rod-shaped organ (Figure 58*k*): Elongate, 1-jointed, strongly tapering in distal half.

DESCRIPTION OF FEMALE A–2 INSTAR.—Carapace similar in shape to that of adult but without punctations (only 2 specimens observed).

Size: USNM 127289D, length 1.47 mm, height 1.33 mm; USNM 127289E, length 1.63 mm, height 1.42 mm.

Furca: Similar to that of female A–2 instar of *T. radiata*.

FIGURE 57.—*Thaumatoconcha punctata*, new species, right valve of adult female, holotype, USNM 143861 (valve distorted and part of outer shell layer removed by flaking during freeze-dry operation; valve lost): *a*, inside view, note adductor muscle attachment scar just anterior to valve middle, × 45; *b*, anterior view showing dorsal part of anteroventral margin, × 170; *c*, anterior view showing ventral part of anteroventral margin, × 170; *d*, outer surface of shell just posterior to valve middle showing punctae, × 170; *e*, punctae (for location see arrow in *d*), × 850; *f*, pore with stump of broken bristle (for location see arrow in *e*), × 8500; *g*, inside of flake of outer shell showing convex protuberances that are inner reflections of punctae, × 250; *h*, detail of *g* (for location see arrow in *g*), × 1250: *i*, detail of right protuberance in *h*, × 5000; *j*, adductor muscle attachment scar from inside (see arrow in *a*), × 320; *k*, detail from *j* showing smooth surface between muscle attachments and network-like structure of muscles attached to shell (see arrow in *j* for location), × 2000; *l*, detail from *k* (see arrow in *k*), × 10,000; *m*, detail of adductor muscle attachment from inside, × 10,000. (Photos reduced 54½ percent.)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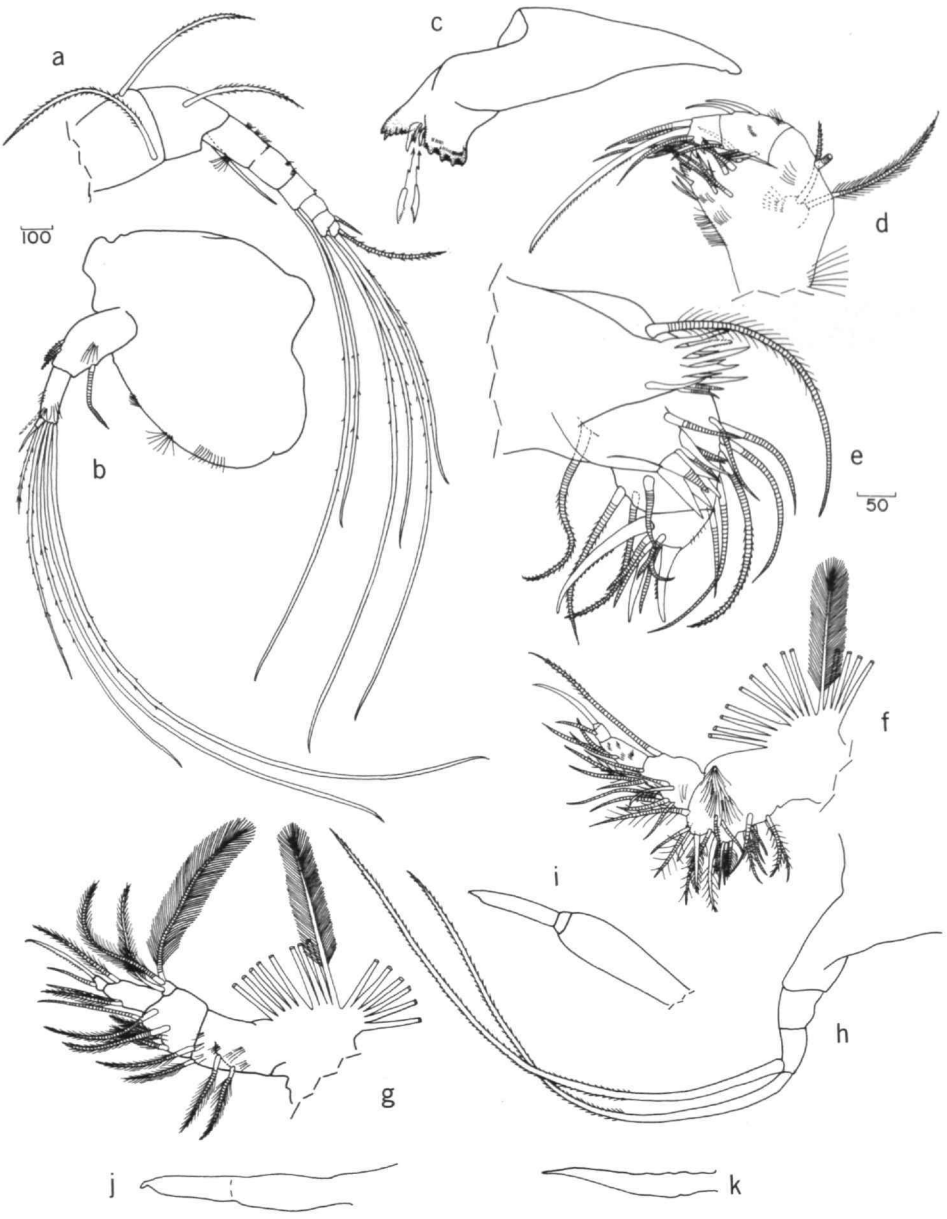


FIGURE 58.—*Thaumatoconcha punctata*, new species. Adult female, holotype, USNM 143861: *a*, right 1st antenna, lateral view; *b*, protopodite and endopodite of right 2nd antenna, medial view; *c*, coxale endite of left mandible, lateral view; *d*, protopodite and basal of left mandible, lateral view; *e*, maxilla; *f*, 5th limb; *g*, 6th limb; *h*, 7th limb; *i*, rod-shaped organ. Adult female, paratype, USNM 127289B: *j*, rod-shaped organ. A-1 female, paratype, USNM 127289C: *k*, rod-shaped organ. (Same magnification in micrometers: *a–d*, *f*, *g*; *e*, *h–k*.)

Rod-shaped organ: Similar to that on A-1 instar but not quite so strongly tapered (observed only on USNM 127289D).

COMPARISONS.—See Table 13.

Thaumatoconcha sandersi, new species

FIGURES 11*i*, 12*g*, 13*e*, 18*a–c*, 59–62

HOLOTYPE.—USNM 143793, adult male, appendages on slides, carapace and some appendages in alcohol.

TYPE-LOCALITY.—*USNS Eltanin*, Cruise 4, station 135, 62°40′S, 64°06′W to 62°37′S, 63°57′W, Drake Passage, 3715–3752 m.

PARATYPES.—USNM 127275, 7 specimens from type-locality (includes 1 adult male and 2 adult females); USNM 143752, 2 specimens (1 adult male, 1 adult female) (Figure 9).

ETYMOLOGY.—Species named for Dr. Howard L. Sanders.

OTHER LOCALITIES.—USNM 143752 from *USCGC Glacier*, station 0023, 72°47′30″S, 30°28′18″W, Weddell Sea, 3658 m.

DIAGNOSIS.—Surface smooth with 1–3 anteroventral ridges and straight anteroventral margin (specimens on hand decalcified); length of male 1.78 to 1.89 mm; dorsal margin of 3rd joint of 1st antenna longer than dorsal margin of 4th joint; endopodite of mandible with 1 dorsal bristle on 1st joint and 2 on 2nd joint; rod-shaped organ with rounded tip; anterior lobe of male copulatory organ with slender recurved terminal process.

DESCRIPTION OF ADULT MALE (Figures 12*g*, 18*a–c*, 59–62).—Valves subround, height of anterior margin greater than posterior (Figures 59*a*, 60); straight anteroventral margin delimited by a dorsal and a ventral forward pointing short protuberance; anterodorsal margin broadly convex, merging with short gently curved dorsal margin at a point about one-third greatest length; posterior margin evenly rounded; ventral margin curving gently forward and downward to point in front of subcentral adductor muscle-scar, then curving upward to join

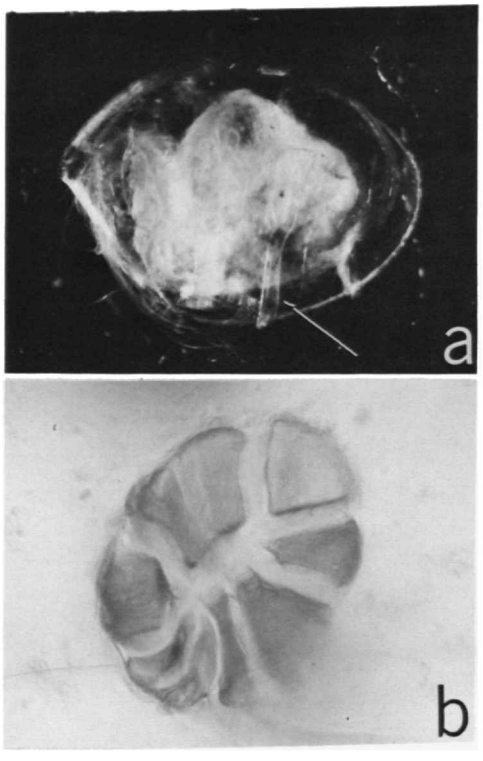


FIGURE 59.—*Thaumatoconcha sandersi*, new species, adult male, holotype, USNM 143793: *a*, complete specimen, anterior to left, note elongate copulatory appendage (arrow), length of specimen 1.78 mm; *b*, detail of adductor muscle attachments of left valve, anterior to left, maximum length of scar 0.21 mm.

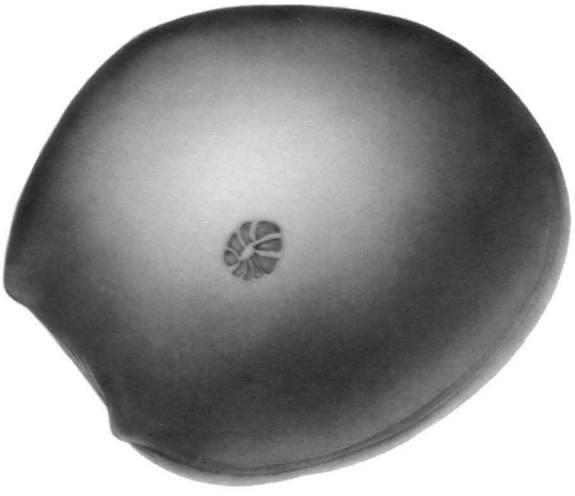


FIGURE 60.—*Thaumatoconcha sandersi*, new species, carapace of adult male, paratype, USNM 127275E, length 1.89 mm, anterior to left.

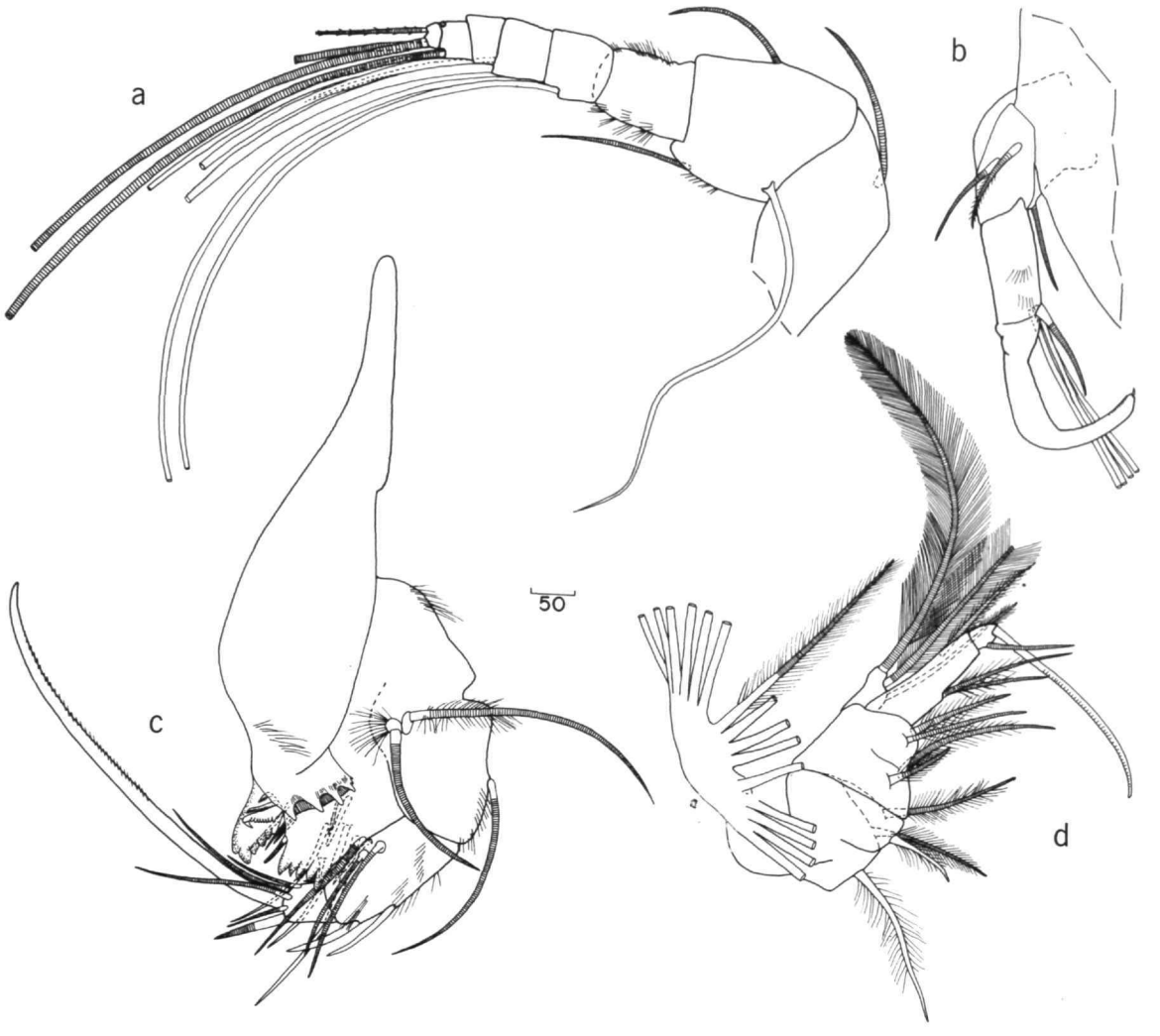


FIGURE 61.—*Thaumatoconcha sandersi*, new species, adult male, paratype, USNM 127275E: *a*, left 1st antenna, lateral view (long bristle usually on 1st joint of 1st antenna, appeared to be on 2nd joint as shown); *b*, endopodite of left 2nd antenna, lateral view; *c*, right mandible, lateral view; *d*, 6th limb. (Scale in micrometers.)

anteroventral margin below protuberance; dorsal outline subelliptical, greatest width at approximate midlength; end outline subelliptical, greatest width slightly above midheight.

Ornamentation: Specimens decalcified; surface smooth; anteroventral surface with 1 to 3 thin ridges parallel to valve margin; protuberances smooth, relatively stout.

Adductor muscle-scar: Scar subcentrally located, subelliptical, greatest diameter trending towards posterior end of hinge; attachment ends consist of 9 subequal pie-shaped segments radially arranged (Figures 59*b*, 60).

Size (Figure 17): USNM 143793, length 1.78 mm, height 1.63 mm, USNM 127275E, length 1.89 mm, height 1.56 mm, USNM 143752B, length 1.78

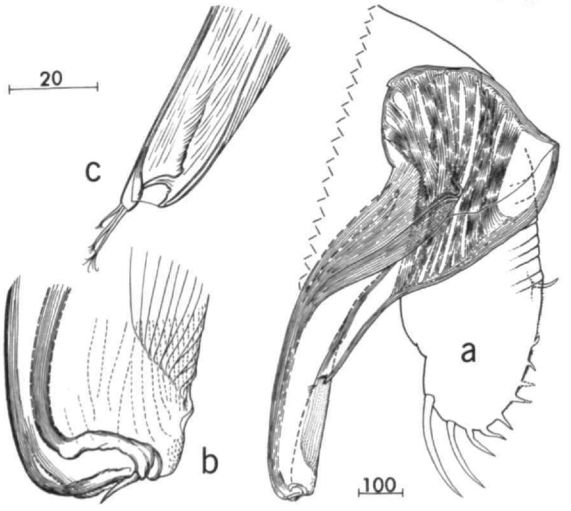


FIGURE 62.—*Thaumatoconcha sandersi*, new species, adult male, paratype, USNM 127275E: *a*, left lamella of furca and copulatory organ; *b*, tip of copulatory organ; *c*, tip of styliform process of copulatory organ. (Same magnification in micrometers: *b*, *c*.)

mm, height 1.50 mm.

First antenna: Similar to that of *T. radiata* (Figure 61*a*).

Second antenna: Exopodite with 8 joints; limb otherwise similar to that of *T. radiata* (Figure 61*b*).

Mandible: Third endopodial joint with 6 bristles; limb otherwise similar to that of *T. radiata* (Figure 61*c*).

Maxilla, 6th limb (Figures 12*g*, 61*d*), 7th limb, furca (Figure 62*a*), rod-shaped organ, lips, posterior of body: Similar to those of *T. radiata*.

Fifth limb: Ventral margin of 1st exopodial joint with 11 bristles; limb otherwise similar to that of *T. radiata*.

Copulatory organ (Figures 18*a–c*, 59*a*, 62): Anterior lobe with slender recurved terminal process.

DESCRIPTION OF ADULT FEMALE (Figures 11*i*, 13*e*).—Carapace similar to that of male but slightly larger.

Size (Figure 16): USNM 127275A, length 1.99 mm, height 1.67 mm; USNM 127275C, length 2.00 mm, height 1.69 mm, USNM 143752A, length 1.94 mm, height 1.65 mm.

First antenna: Similar to that of *T. radiata*.

Second antenna: Exopodite with 8 joints; limb otherwise similar to that of *T. radiata*.

Mandible, maxilla, 6th limb, 7th limb, furca, rod-shaped organ, lips (Figure 13*e*), posterior of body: Similar to those of male.

Fifth limb: Ventral margin of 1st exopodial joint with 6 bristles; limb otherwise similar to that of male (Figure 11*i*).

COMPARISONS.—See Table 13.

Thaumatoconcha tuberculata, new species

FIGURES 11*c,d*; 12*c,d*; 13*b*; 18*j–m*; 63–68

HOLOTYPE.—USNM 143852, adult male, length 1.64 mm.

TYPE-LOCALITY.—*R. V. Atlantis II*, Cruise 31, station 169a, 8°03′00″S, 34°23′00″W to 8°02′00″S, 34°25′00″W, South Atlantic, 587 m.

PARATYPES.—USNM 143796A–D, F–M, ca. 237 specimens, all from same sample as holotype; USNM 143854, 9 specimens; USNM 143791, 27 specimens; USNM 143853, 135 specimens.

ETYMOLOGY.—The specific name is from the Latin *tuberculum* (tubercle), in reference to the minute tubercle present on the posterodorsal margin of the valves.

OTHER LOCALITIES.—USNM 143854 from *R. V. Atlantis II*, Cruise 31, station 159, 7°58′00″S, 34°22′00″W, 834–939 m; USNM 143853 from same cruise, station 167, 7°58′00″S, 34°17′00″W to 7°50′00″S,

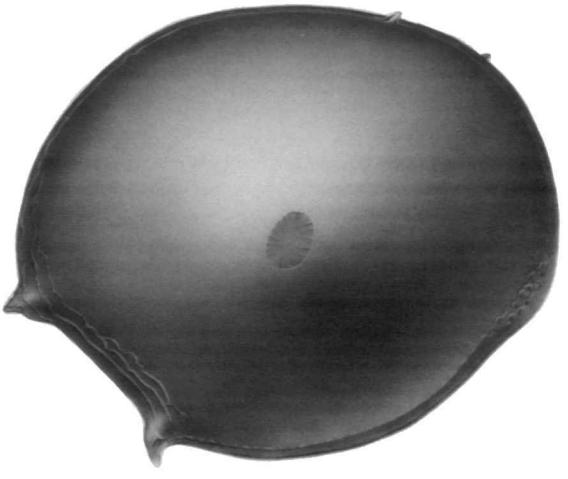


FIGURE 63.—*Thaumatoconcha tuberculata*, new species, carapace of adult male, holotype, USNM 143852, length 1.63 mm, anterior to left.

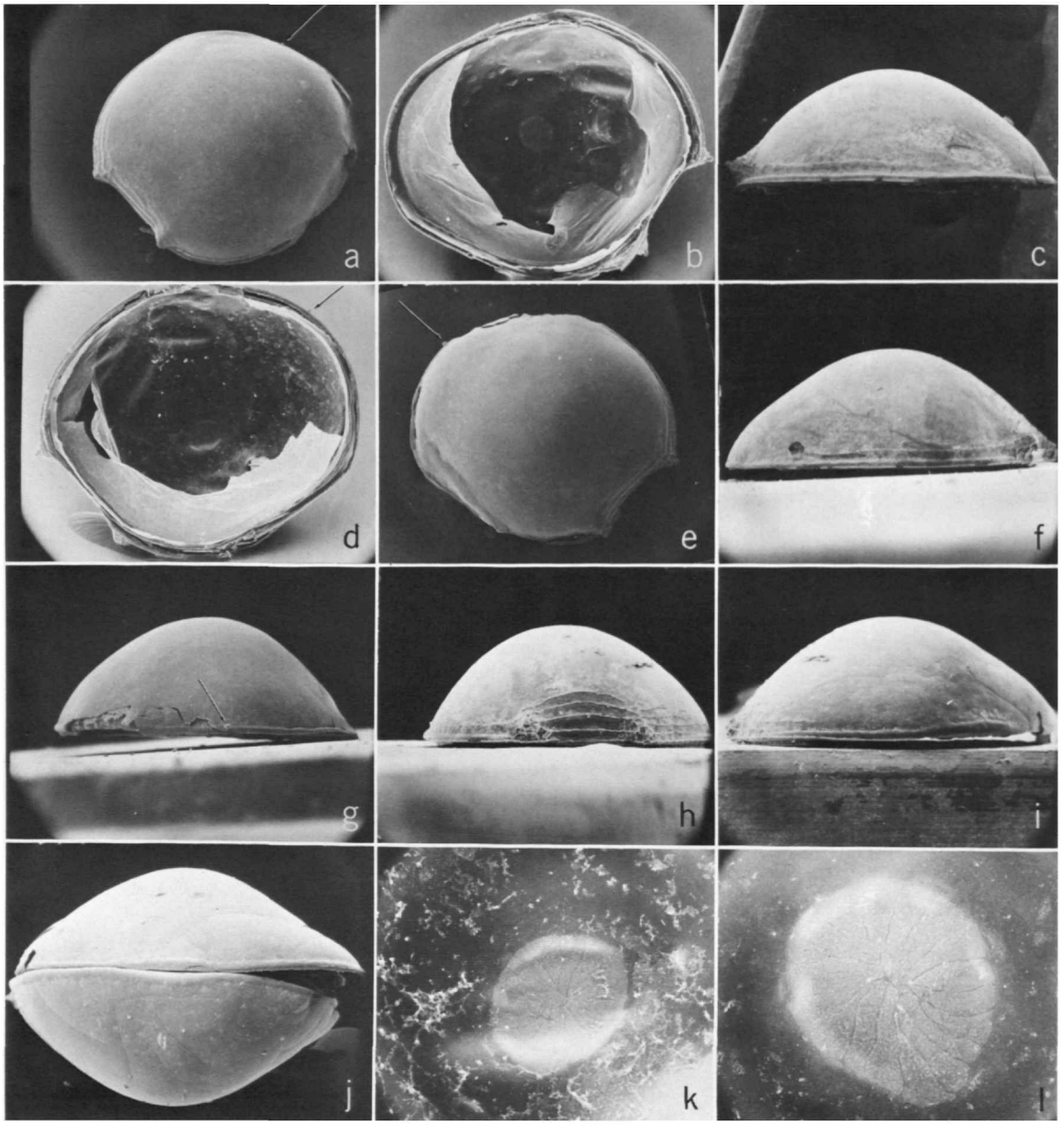


FIGURE 64.—*Thaumatoconcha tuberculata*, new species, paratypes: *a*, adult male, left valve with tubercle (arrow), USNM 143796MY, outside view, × 50; b, adult male, left valve, USNM 143796MW, inside view, × 60; *c*, adult male, left valve, USNM 143796MA, ventral view, anterior to left, × 65; *d*, adult male, right valve with tubercle (arrow), USNM 143796MW, inside view, × 60; *e*, adult male, right valve with tubercle (arrow), USNM 143796MY, outside view, × 50; *f*, adult male, right valve, USNM 143796MA, ventral view, × 65; *g*, adult male, left valve with tubercle (arrow), USNM 143796MY, dorsal view, × 65; *h*, adult male, right valve, USNM 143796MA, anteroventral view, ventral margin to left, × 65; *i*, same valve (remnant of tubercle not visible at this magnification; see Figure 65*k*), dorsal view, × 70; *j*, complete specimen with tubercles missing, USNM 143796MM, dorsal view, anterior to right, × 60; *k*, adductor muscle attachment scar from *d*, inside view, × 240; *l*, same from *b*, inside view, × 360. (Photos reduced to 53½ percent.)

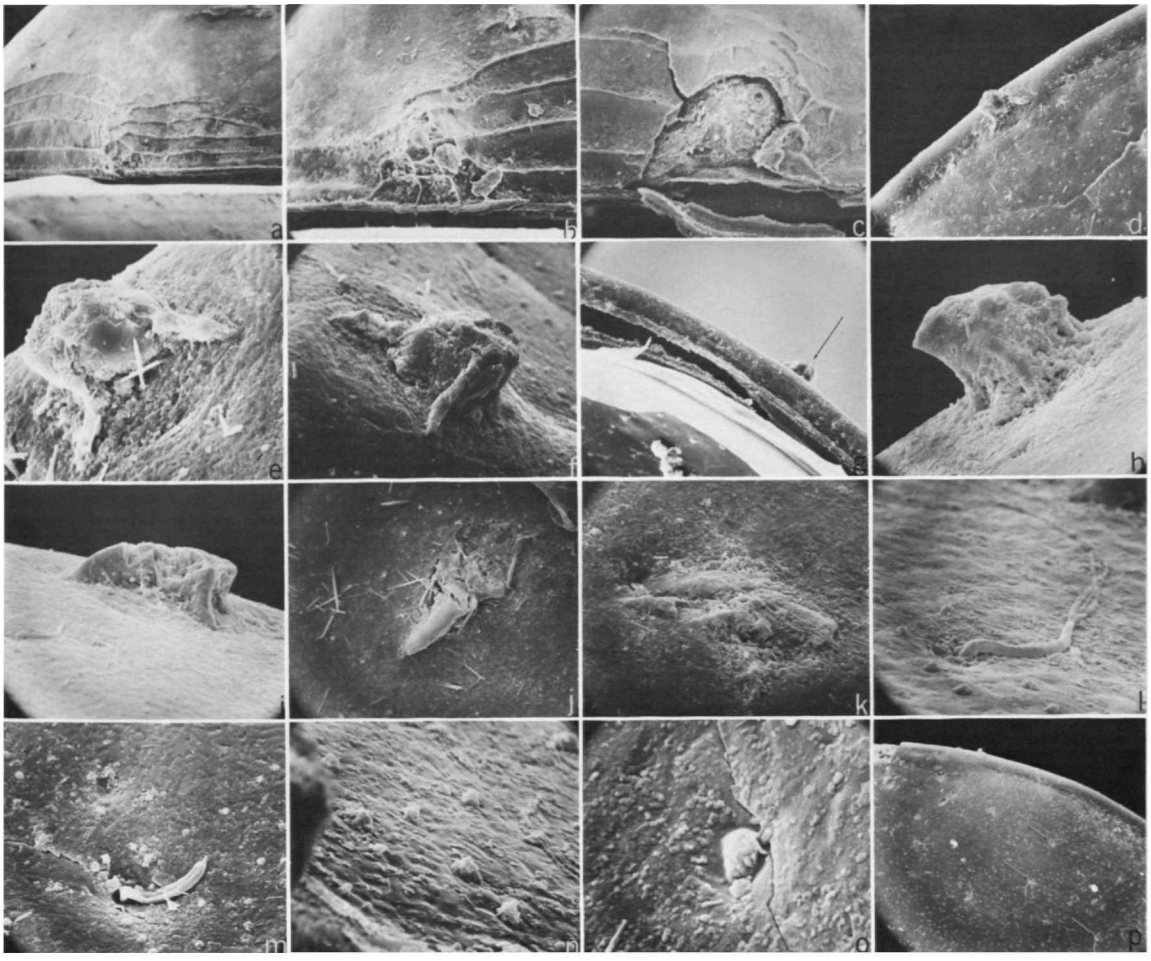


FIGURE 65.—*Thaumatoconcha tuberculata,* new species, adult male paratypes: *a,* upper anteroventral protuberance of right valve, USNM 143796MA, × 170; *b,* same valve, lower anteroventral protuberance, × 265; *c,* upper anteroventral protuberance (broken) of right valve, USNM 143796MY, × 320; *d,* posterodorsal tubercle of right valve, USNM 143796MW, × 500; *e,* protuberance shown in *d,* × 2000; *f,* same, but oblique view, × 1700; *g,* same valve, inside view (protuberance indicated by arrow), × 500; *h,* posterodorsal protuberance of right valve, USNM 143796MY, × 1600; *i,* posterodorsal protuberance of left valve, same specimen, × 1600; *j,* posterodorsal protuberance (remnant) of left value, USNM 143796MA, × 2000; *k,* posterodorsal protuberance (remnant) of right valve, USNM 143796MA, × 2000; *l,* surface near posterodorsal protuberance of left valve showing divided bristle and minute pustules, USNM 143796MY, × 4000; *m,* short bristle? on same specimen, × 2000; *n,* pustules on right valve surface, USNM 143796MW, × 5000; *o,* single pustule on same specimen, × 10,000; *p,* posteroventral part of left valve showing bristle distribution (arrows), USNM 143796MW, × 190. (Photos reduced to 42 percent.)

?W, 943–1007 m; USNM 143791 from same cruise, station 162A, 8°02′00″S, 34°03′00″W to 7°56′00″S, 34°09′00″W, 1493 m (Figure 9).

DIAGNOSIS.—Surface of carapace smooth with 5 or 6 anteroventral ridges and posterodorsal tubercle on each valve; straight anteroventral margin; length of female 1.61 to 1.70 mm, length of male 1.59 to 1.67 mm; dorsal margin of 3rd joint of 1st antenna longer than dorsal margin of 4th joint; endopodite of mandible with 1 dorsal bristle on 1st joint and 2 on 2nd; rod-shaped organ with rounded tip; anterior lobe of male copulatory organ with slender process with minute tooth at its base.

DESCRIPTION OF FEMALE (Figures 13*b*, 68*f*).—Valves subround, height of anterior margin greater than posterior; straight anteroventral margin delimited by a dorsal and a ventral forward pointing protuberance; anterodorsal margin broadly convex, merging with short gently curved dorsal margin at point about one-third greatest length; posterior margin gently rounded; ventral margin slightly convex, with shallow concavity near junction with posterior margin on some specimens. Dorsal outline subelliptical, greatest width in front of midlength; end outline subelliptical, greatest width slightly below midlength.

Ornamentation: Surface smooth; widely spaced pore-canals containing hairs that branch distally, and longer more slender unbranched hairs and more abundant much smaller pustules present; anteroventral margin with 5 thin ridges parallel to valve margin (some individuals with discontinuous 6th ridge); outermost of the thin ridges continues partly around periphery of each valve; 4 remaining ridges continue for a short distance along the upper protuberance and anterior margin, with innermost ridge being shortest; 4th ridge from contact margin continues along ventral margin to point slightly beyond midlength of valve; a wider continuous rim lies just above the thin outermost peripheral ridge, except along the anteroventral margin between protuberances where the rim is absent; cross-ridges present around protuberances and also on ventral margin between outermost thin ridge and contact margin near lower protuberance; a minute tubercle asymmetrically located on posterodorsal part of each valve on the proximal margin of rim; tubercle on left valve located on posterior end of dorsal margin; tubercle on right valve slightly larger and located posterior to tubercle on left valve.

Adductor muscle-scar: Scar located at approximately midlength and slightly below midheight; scar subcentrally located in area of greatest width, subround; greatest diameter trending toward the lower part of the anteroventral protuberance; scar consists of 17 to 20 subequal pie-shaped segments more-or-less radially arranged.

Size: USNM 143796C: left valve, length 1.61 mm, height 1.37 mm; right valve, length 1.62 mm, height 1.40 mm. USNM 143796G: left valve, length 1.65 mm, height 1.46 mm; right valve, length 1.66 mm, height 1.43 mm. USNM 143796H, left valve only, length 1.65 mm, height 1.47 mm; USNM 143796I, left valve, length 1.70 mm, height 1.45 mm; USNM 143796J, left valve, length 1.65 mm, height 1.40 mm (Figure 16).

Second antenna (Figure 68*f*): Similar to that of *T. radiata*.

Other appendages: Similar to those of *T. radiata*.

Food: USNM 143796C with small clear elongate objects of unknown affinity and few crustacean spines in anterior part of gut, and unrecognizable smaller fragments in posterior part of gut.

DESCRIPTION OF MALE (Figures 11*c,d;* 12*c,d;* 18*j–m;* 63–68*a–e*).—Carapace similar to that of female except smaller (Figures 63–65).

Size: USNM 143796A: left valve, length 1.60 mm, height 1.34 mm; right valve, length 1.59 mm, height 1.30 mm. USNM 143852: left valve, length 1.63 mm, height 1.38 mm; right valve length 1.64 mm, height 1.36 mm. USNM 143796D, left valve, length 1.63 mm, height 1.35 mm; right valve, length 1.65 mm, height 1.33 mm. USNM 143796F, left valve, length 1.59 mm, height 1.33 mm; right valve, length 1.57 mm, height 1.36 mm (Figure 17).

First antenna (Figures 66*a*, 67*a*), 2nd antenna (Figures 66*b*, 67*b*), mandible (Figures 66*c,d;* 67*c,d*), maxilla (Figure 67*c,d*), 5th limb (Figures 11*c,d;* 66*e;* 68*a*), 6th limb (Figures 12*c,d;* 66*f*), 7th limb (Figure 68*c,d*), furca (Figure 67*e*), rod-shaped organ (Figure 66*g*), lips, posterior of body: Similar to those on adult male of *T. radiata*.

Copulatory organ (Figures 18*j–m*, 67*f–h*): Tip consisting of proximal and distal lobe, latter with single stout tooth-like process with minute tooth near its base. Organ otherwise similar to that on *T. radiata*.

Food: USNM 143796A with fine brown particles in posterior end of gut.

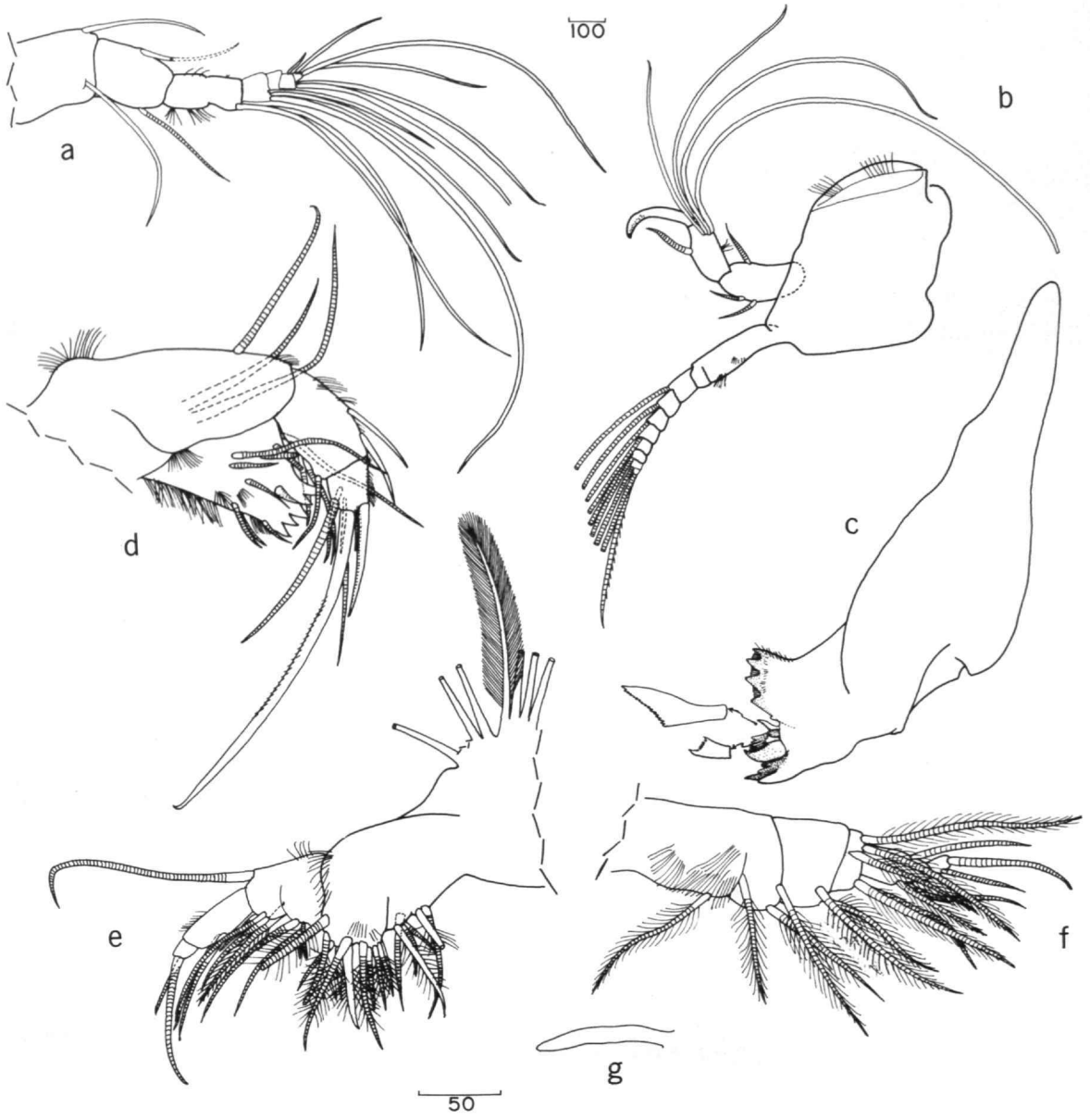


FIGURE 66.—*Thaumatoconcha tuberculata*, new species, adult male, holotype, USNM 143852: *a*, right 1st antenna, lateral view; *b*, right 2nd antenna, lateral view; *c*, coxale of right mandible, lateral view; *d*, basale and endopodite of right mandible, lateral view; *e*, 5th limb; *f*, 6th limb; *g*, rod-shaped organ. (Same magnification in micrometers: *a*, *b*; *c–g*.)

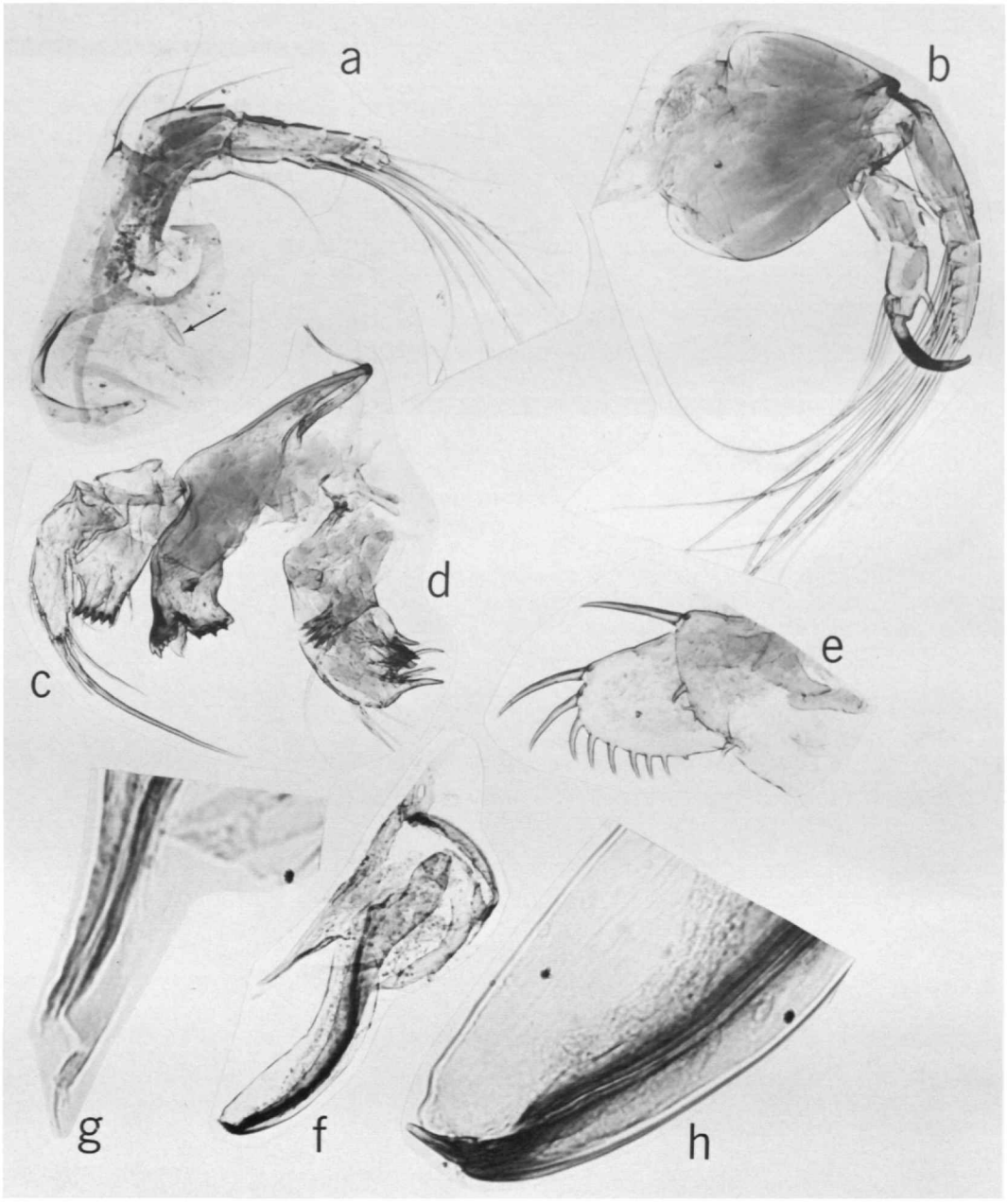


FIGURE 67.—*Thaumatoconcha tuberculata*, new species, adult male, paratype, USNM 143796MB: *a*, left 1st antenna and rod-shaped organ (arrow), medial view; *b*, right 2nd antenna, lateral view; *c*, *d*, right mandible and maxilla, medial view; *e*, caudal furca (left lamella aberrant); *f*, copulatory organ; *g*, tip of styliform lobe of copulatory organ; *h*, tip of copulatory organ. (For approximate size of appendages see Figure 18 *j–m*.)

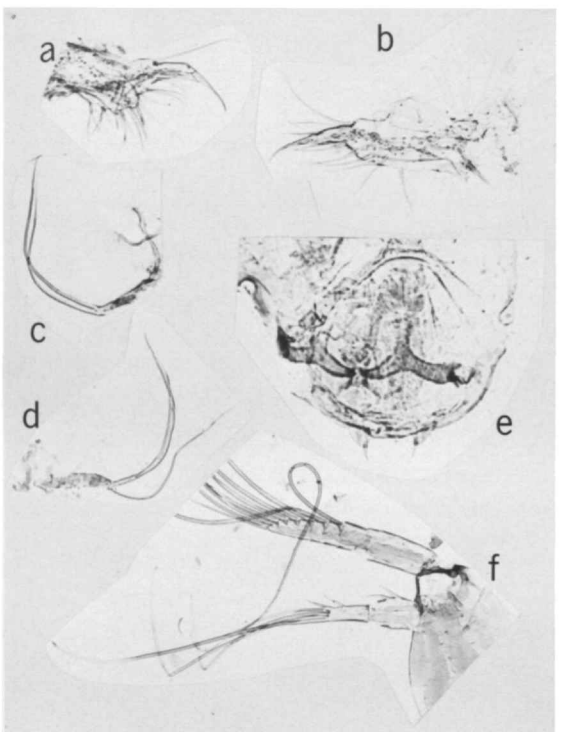


FIGURE 68.—*Thaumatoconcha tuberculata*, new species, paratypes. Adult male, USNM 143796MW: *a*, 5th limb; *b*, 6th limb; *c*, 7th limb. Adult male, USNM 143796MB: *d*, aberrant 7th limb with 3 bristles; *e*, upper lip. Adult female, USNM 143796MO: *f*, left 2nd antenna. (For approximate size of appendages see Figures 13*b*, 66.)

DISCUSSION.—We noted with the light microscope that many of the specimens were without posterodorsal tubercles on either one or both valves of adults of both sexes and juveniles. In order to determine whether or not nontuberculate specimens were the result of breakage of the tubercles, we examined valves with tubercles with the SEM in order to obtain their precise structure and location. We then examined a "nontuberculate" carapace and identified remnants of tubercles on both valves.

COMPARISONS.—See Table 13.

Thaumatoconcha species A

FIGURES 13*k*, 69, 70

MATERIAL.—USNM 143851, adult female, appendages on slide, 1 valve and remaining appendages in alcohol, 1 valve gold-plated and on slide.

LOCALITY.—*USCGC Glacier*, Cruise 2, station 0022, 73°29′S, 30°24′6″W, Weddell Sea, 3035 m (Figure 9).

DIAGNOSIS.—Surface smooth and with 4 or 5 anteroventral ridges; anteroventral profile straight; length of female 1.46 mm; dorsal margin of 3rd joint shorter than, or about same length as, dorsal margin of 4th joint; endopodite of mandible with 1 dorsal bristle on 1st joint and 2 on 2nd; rod-shaped organ with rounded tip.

DESCRIPTION OF ADULT FEMALE (male unknown) (Figures 13*k*, 69, 70).—Differs from *T. radiata* in smaller size of carapace (Figure 69).

Size: USNM 143851, length 1.46 mm, height 1.21 mm (Figure 16).

First antenna: Dorsal margin of 3rd joint shorter than 4th joint; limb otherwise similar to that of *T. radiata* (Figure 70*a*,*b*).

Second antenna: Exopodite with 8 joints; limb otherwise similar to that of *T. radiata* (Figure 70*c*,*d*).

Mandible: Third endopodial joint with 6 bristles; limb otherwise similar to that of *T. radiata*.

Maxilla, 5th limb (Figure 70*e*), 7th limb, rod-shaped organ (Figure 70*a*,*g*), lips, posterior of body: Similar to those of *T. radiata*.

Sixth limb (Figure 70*f*): Short bristle of 4th ex-

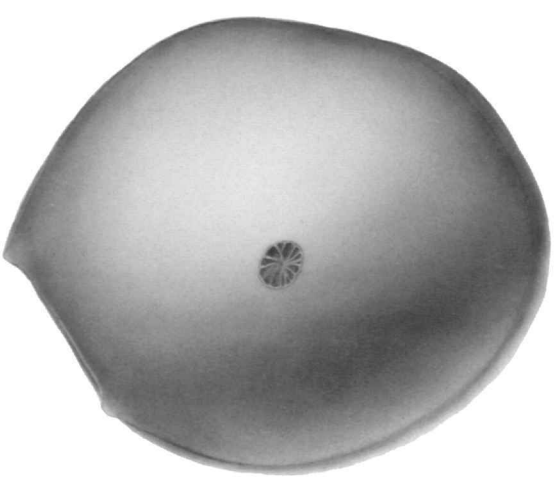


FIGURE 69.—*Thaumatoconcha* species A, carapace of adult female, USNM 143851, length 1.46 mm, anterior to left.

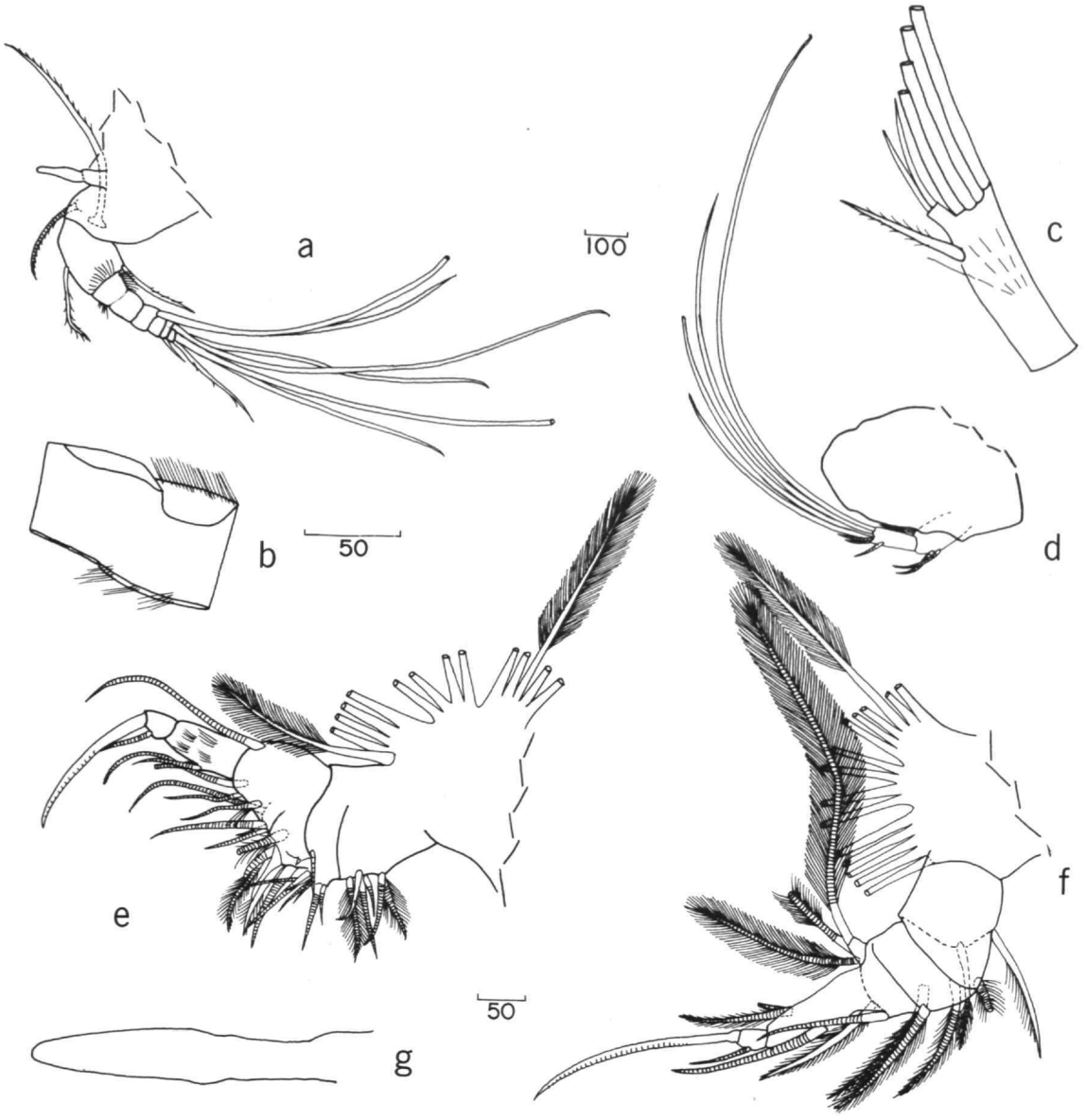


FIGURE 70.—*Thaumatoconcha* species A, adult female, USNM 143851: *a*, rod-shaped organ and right 1st antenna, medial view; *b*, joints 3 and 4 of right 1st antenna, medial view; *c*, joints 2 and 3 of endopodite of right 2nd antenna, lateral view; *d*, protopodite and endopodite of right 2nd antenna, lateral view; *e*, 5th limb; *f*, 6th limb; *g*, rod-shaped organ. (Same magnification in micrometers: *a*, *d*; *e–g*; *b*, *c*.)

opodial joint about one-third length of long bristle; limb otherwise similar to that of *T. radiata.*

COMPARISONS.—See Table 13. Because of inadequate material to evaluate the variability of this species, which differs only slightly from *Thaumatoconcha hessleri,* new species, we have left it in open nomenclature.

Thaumatoconcha species indeterminate

MATERIAL.—USNM 127520, A-3 instar, length 1.21 mm, height 0.96 mm, from *USNS Eltanin,* Cruise 11, station 926; USNM 143969, 1 adult female, length 2.17 mm, height 1.81 mm, and 1 juvenile, length 0.92 mm, height 0.87 mm, from *R. V. Vema,* Cruise 17, station V-17-5. Because several species of *Thaumatoconcha* are identified mainly by the morphology of the male copulatory organ, it was not possible to identify the adult female, USNM 143969. Juveniles of many of the species of *Thaumatoconcha* are difficult to identify, and the above two juveniles, USNM 127520 and 143969, could not be identified. For distribution see Figure 9.

Danielopolina, new genus

Thaumatocypris Müller.—Danielopol, 1972:1390.

TYPE-SPECIES.—*Danielopolina carolynae,* new species.

ETYMOLOGY.—The genus is named for Dr. Dan L. Danielopol.

This genus contains 2 Holocene species, *D. orghidani* (Danielopol, 1972) and *D. carolynae.*

DISTRIBUTION.—A grotto in Cuba and in Atlantic Ocean near equartor at a depth of 3459 m.

HABITAT.—*Danielopolina carolynae,* benthic; *D. orghidani,* presumably benthic. The method of collection in the Cuban grotto is not known, but presumably the water is shallow.

DIAGNOSIS.—Surface reticulate. Boundaries of reticulations formed of closely spaced minute subround papillae.

First antenna: First joint with 2 bristles, 1 dorsal, 1 lateral; 7th joint with 2 ventral bristles, but without dorsal bristle; 8th joint with 3 bristles.

Second antenna: Three-jointed; 1st endopodial joint with 2 dorsal bristles, but without ventral bristle.

Fifth limb: Second exopodial joint with 1 terminal bristle on ventral margin; 3rd exopodial joint with 2 bristles.

Sixth limb: Process on dorsal corner of 1st exopodial joint with 2 bristles; 4th exopodial joint with 2 bristles.

Rod-shaped organ: Absent.

DESCRIPTION.—Surface reticulate, boundaries of reticulations formed by closely spaced minute subround papillae; anteroventral margin bounded by protuberances more spine-like than those of *Thaumatoconcha;* a posterodorsal tubercle on each valve.

First antenna: Joints 1 to 4, 6, and 8 similar to those of *Thaumatoconcha;* 5th joint with 1 ventral bristle *(D. orghidani)* or 2 ventral bristles *(D. carolynae);* 7th joint with 2 ventral bristles, but without dorsal bristle.

Second antenna: Protopodite of *D. carolynae* with bristle on posterior margin; protopodite of *D. orghidani* without bristle. Endopodite 3-jointed: 1st joint with 2 dorsal bristles, but without ventral bristle; 2nd joint of *D. carolynae* with 1 lateral and 4 terminal bristles; 2nd joint of *D. orghidani* without a lateral bristle and with only 3 terminal bristles; 3rd joint with 1 bristle. Exopodite with 8 or 9 joints and with 2 bristles on 9th joint; 1st joint of *D. carolynae* unusual in having long bristle.

Mandible: Similar to that of *Thaumatoconcha.*

Maxilla: Similar to that of *Thaumatoconcha* except with only 3 or 4 anterior bristles on the 1st endopodial joint; *D. orghidani* may have relatively few bristles on endites and on 2nd endopodial joint.

Fifth limb: Similar to that of *Thaumatoconcha* except ventral margin of 2nd exopodial joint with 2 midbristles and 1 terminal bristle.

Sixth limb: Epipodial appendage with 15 bristles; protopodite with 4 bristles. Exopodite: process on dorsal corner of 1st joint with 2 bristles; 1st joint with 4 or 5 additional bristles; combined 2nd and 3rd joints with 1 dorsal bristle; ventral margin of joints 2 and 3 of *D. carolynae* with 3 midbristles and 1 terminal bristle; of *D. orghidani* with only 1 midbristle and without a terminal bristle; 4th joint with 2 bristles.

Seventh limb: Small with 2 bristles.

Furca: Of *D. carolynae,* similar to furca of *Thaumatoconcha;* of *D. orghidani,* with only 3 short claws following the 2 anterior longer claws.

Posterior of body: Similar to that of *Thaumatoconcha.*

Lips: General morphology similar to lips of *Thaumatoconcha.*

Key to the Species of *Danielopolina,* new genus

1. Carapace length less than 1 mm; no bristle on either protopodite or 1st exopodial joint of 2nd antenna; end joint of 6th limb with 1 long and 1 short bristle ..... ***D. orghidani***
1'. Carapace length greater than 1.5 mm; bristle on protopodite and 1st exopodial joint of 2nd antenna; end joint of 6th limb with 2 bristles of equal length .... ***D. carolynae,*** new species

Danielopolina orghidani (Danielopol, 1972)

FIGURES 11*b*, 12*b*, 13*l*, 71–73

Thaumatocypris orghidani Danielopol, 1972:1390, figs. A–D.—Orghidan, et al., 1973, photo 6B [incorrectly spelled *Taumatocypris orghidani*].

HOLOTYPE.—Unique female, length 0.52 mm.

TYPE-LOCALITY.—Grotto in Matanzas, Cuba, 1.5 km from Atlantic Ocean (Figure 9).

MATERIAL EXAMINED.—Five specimens were received from Professor Tr. Orghidan through Dr. Francisca Caraion. The vial contained the following pencilled label, "30 IV 73 MATANZAS GRIETA DU PHARE DE SEBORUCAL / LEG. T. ORGHIDAN et N. VINA." "Grieta" is a vertical cleft in the limestone of a marine terrace giving access to fresh or brackish water (Botosaneanu, 1973:218). The specimens apparently are topotypes collected at a later date. One of the specimens was dissected and appendages were mounted on slides. Slides and specimens were returned to Dr. Caraion.

Dr. Danielopol kindly sent to us copies of illustrations of appendages of the holotype from a manuscript in preparation. These are compared with our samples in the "Supplementary Description," below.

DIAGNOSIS.—Carapace with symmetrically located posterodorsal nodes; length 0.56 to 0.59 mm.

First antenna: Fifth joint with 1 ventral bristle.

Second antenna: Second endopodial joint with 3 terminal bristles and without lateral bristle; exopodite 8-jointed, without bristle on 1st joint.

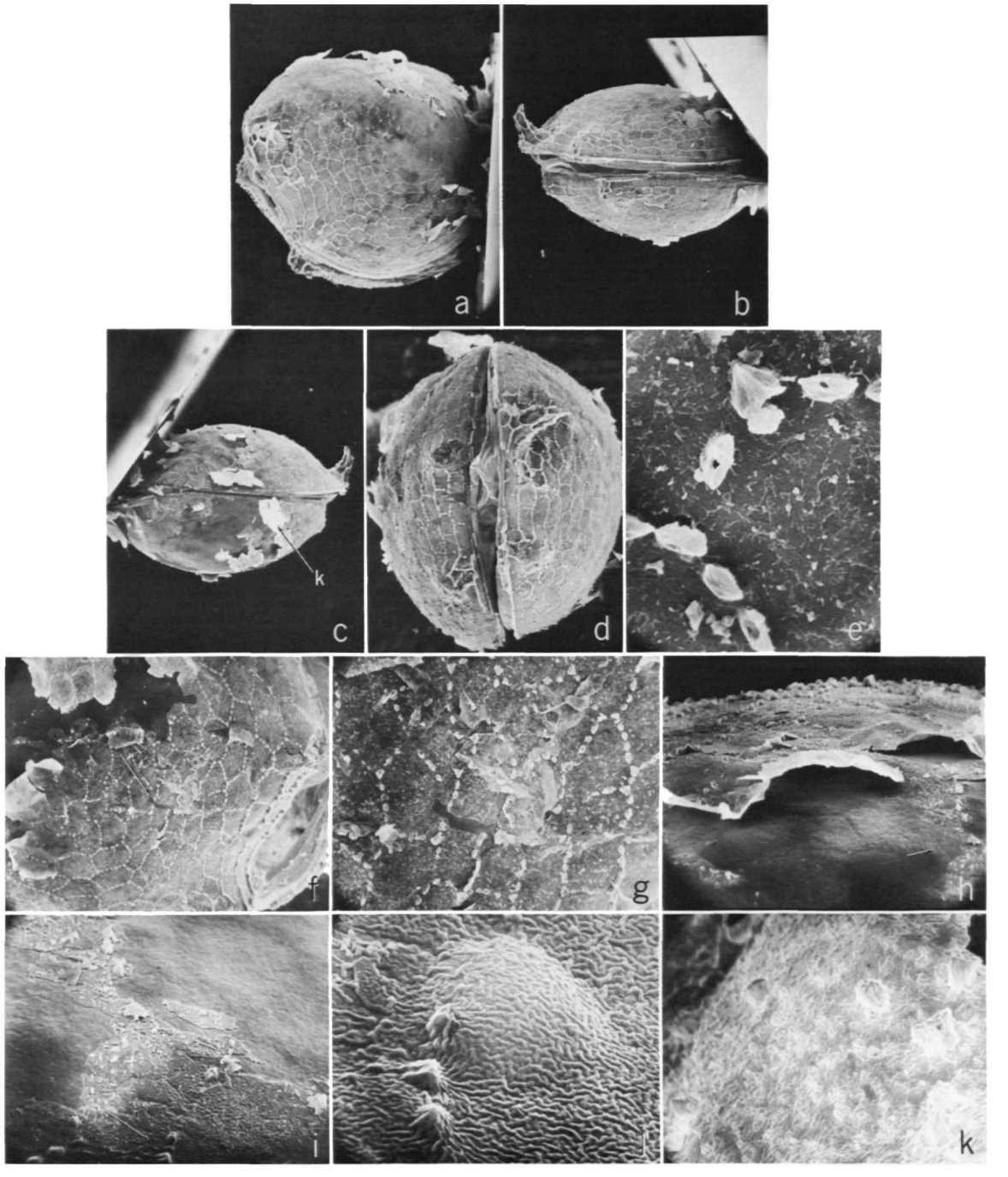
Sixth limb: Third exopodial joint without terminal bristle on ventral margin; short bristle on 4th exopodial joint about one-third length of long bristle.

Furca: Each lamella with 2 long and 3 short claws.

SUPPLEMENTARY DESCRIPTION OF FEMALE (Figures 12*b*, 13*l*, 71–73).—Shell subovate, small, greatest length less than 0.65 mm (Figures 71, 72); height of anterior margin slightly greater than posterior; straight-to-slightly concave anteroventral margin

FIGURE 71.—*Danielopolina orghidani* (Danielopol, 1972), carapace of female, length 0.58 mm, anterior to left.

FIGURE 72.—*Danielopolina orghidani* (Danielopol, 1972), topotype, complete specimen: *a*, outside viewed from left side, anterior to left, × 140; *b*, ventral view, anterior to left, × 140; *c*, dorsal view, anterior to right, × 140; *d*, anterior view, × 200; *e*, pustules forming reticulations on carapace, × 3300; *f*, anteroventral part of right shell showing reticulate surface, anterior to right, × 320; *g*, detail of reticulate surface shown in *f* (see arrow in *f*), × 800; *h*, posterior part of right valve showing height of pustules forming reticulation on outer layer of shell, note absence of pustules on valve surface where outer layer shell is absent, × 950; *i*, surface of right valve near *h* showing outer layer with pustules that form the reticulations, and crinkled surface that might have formed during freeze dry-operation, note smooth surface of valve where outer shell layer is absent (for location see arrow in *h*), × 1900; *j*, detail of *i* (see arrow), × 4650; *k*, underside of flake of outer layer of shell (see arrow in *c* for location of flake), × 5000. (Photo reduced to 55 percent.)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delimited by forward pointing protuberances; dorsoanterior margin gently convex, merging with slightly concave dorsal margin at point slightly in front of position of adductor muscle-scar; posterior and ventral margins evenly rounded; dorsal outline subelliptical with evenly rounded ends, greatest width at approximate midlength; end outline subelliptical, greatest width at or above midheight.

Note: The dorsal margin of the carapace appears to be slightly concave when viewed from the side, we do not know whether or not this may be the result of preservation. The posterodorsal tubercles and ventroanterior processes vary in length with individuals, this variation is probably due to breakage of the distal ends.

Ornamentation: Surface of valves with elongate irregularly shaped reticulations subconcentric to lateral outline, appear to be missing on parts of central area; boundary of reticulations formed by widely spaced, subelliptical papillae; distance between adjacent papillae less than half greatest axis of papillae; anteroventral surface without continuous ridges and cross-ridges, but with subquadrate papillate reticulations; some papillae with minute terminal pores; scattered short hairs emerging from simple pores present within reticulations; conical tubercle symmetrically located on posterodorsal part of each valve, slightly behind and below dorsal margin.

Adductor muscle-scar: Scar approximately sub-

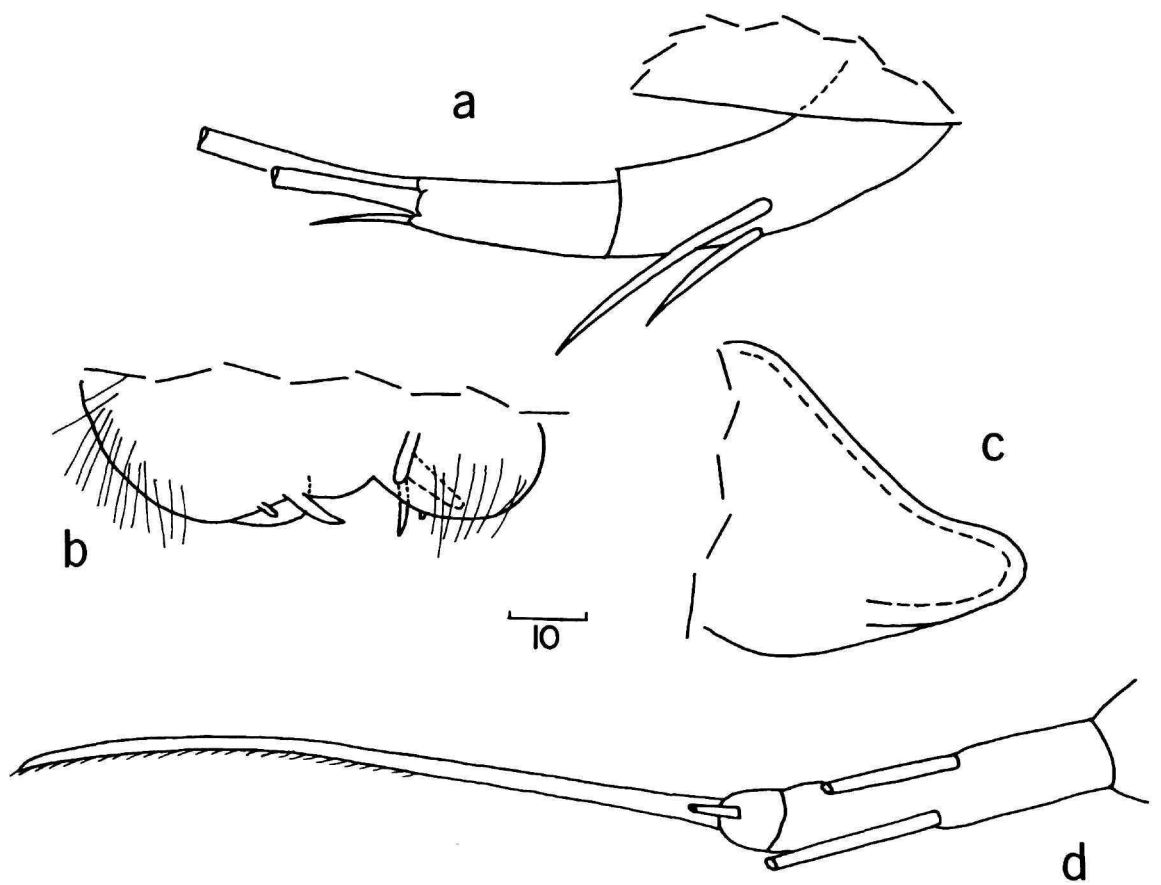


FIGURE 73.—*Danielopolina orghidani* (Danielopol, 1972), adult female, topotype: *a*, endopodite of right 2nd antenna, lateral view; *b*, tip of upper lip, anterior view (distorted under cover slip); *c*, part of lower lip, lateral view; *d*, tip of 6th limb. (Scale in micrometers.)

central; details of scar indistinct, appears to be subelliptical with up to 9 segments, some being pie-shaped and radially arranged (Figure 71).

Size: Danielopol (1972) recorded the length of the holotype as 0.52 mm (measurement did not include anteroventral protuberances). Our measurements of 5 specimens are as follows: length 0.56 mm (with protuberances 0.63 mm), height 0.47 mm (illustrated specimen); length 0.59 mm, height 0.45 mm; length 0.56 mm (with protuberances 0.60 mm), height 0.46 mm; length 0.58 mm, height 0.43 mm; length 0.42 mm, height 0.42 mm (probably juvenile specimen).

Second antenna (Figure 73*a*): 1st joint of endopodite with 2 dorsal bristles; 2nd joint with 3 terminal bristles, 2 long and 1 short (short bristle on minute protuberance on dorsal edge of terminal margin). Exopodite with 8 joints (this supports number found by Danielopol): 1st joint divided by weak suture into long proximal and short distal parts; terminal joint with 1 long and 1 short bristle.

Fifth limb: See Figure 11*b* for distal end.

Sixth limb: The fused 2nd and 3rd exopodial joints on the appendage illustrated by Danielopol bear 2 ventral bristles near the middle; on the single limb we observed, the 2 bristles are widely separated, and the joints could be interpreted as having 1 bristle on the ventral margin and 1 on the dorsal margin (Figures 12*b*, 73*d*).

Lips (Figures 13*l*; 73*b,c*): Not clear on slide, but having general similarity with those of *D. carolynae*.

Remaining appendages: Similar to the illustrations of appendages of holotype supplied by Danielopol (in prep.).

Rod-shaped organ: This organ was not described by Danielopol on the holotype and we did not observe one. The small size of the specimens makes it difficult to ascertain whether a minute rod-shaped organ such as that illustrated by Poulsen (1969, fig. 1j) on *Thaumatocypris echinata* might not be present.

Food: A few unidentified spines and brown particles (plant matter?) in gut.

Comparisons.—See Table 13.

Growth Stage of Specimen.—The similarity in size of the holotype and 4 specimens in the material we studied suggests that they are at the same stage of development. One of the specimens on hand is smaller and presumably younger than the other four. The furca on the holotype has 3 short claws in addition to 2 longer anterior claws. The furca of adults of all other species of Thaumatocyprididae have 6 or 7 short claws in addition to the 2 long anterior claws. The furca on the specimen we examined was fragmented, but seems to have the same number of claws as that on the holotype. The number and distribution of claws on the holotype is similar to that on the A–3 instar of *Thaumatoconcha radiata* (Figure 34*f*). This suggests that the holotype and the material we studied might all be juveniles. The supposition, however, is refuted by the presence of well-developed, but unextruded, eggs in several of the specimens on hand. Also, Danielopol notes (1972:1392) the presence of ovocytes in the holotype, which indicate that it is an adult, or at least not younger than an A–1 instar. Unextruded small eggs appear in A–1 instars of myodocopids, but large eggs are present only in adults.

Danielopolina carolynae, new species

Figures 10*a*, 11*a*, 12*a*, 13*h*, 74–77

Holotype.—USNM 143789, 1 adult female, right appendages on slide, valves and remaining appendages in alcohol. Unique specimen.

Type-Locality.—*R. V. Atlantis II*, Cruise 31, station 156, 00°46′00″S, 29°28′00″W to 00°46′30″S, 29°24′00″W, South Atlantic, 3459 m (Figure 9).

Etymology.—This species is named for Mrs. Carolyn Gast, Smithsonian Institution.

Diagnosis.—Carapace with posterodorsal tubercle of right valve posterior to that on left valve.

First antenna: Fifth joint with 2 ventral bristles.

Second antenna: Second endopodial joint with 1 lateral and 4 terminal bristles; exopodite 9-jointed, with 1 long medial bristle on 1st joint.

Sixth limb: Third exopodial joint with terminal bristle on ventral margin; 2 bristles of 4th exopodial joint of almost equal length.

Furca: Each lamella with 2 long and 6 short claws.

Description of Adult Female (Figures 10*a*, 11*a*, 12*a*, 13*h*, 74–77).—Valves subround, height of anterior margin greater than posterior (Figures 74, 75*a,b*); straight anteroventral margin delimited by

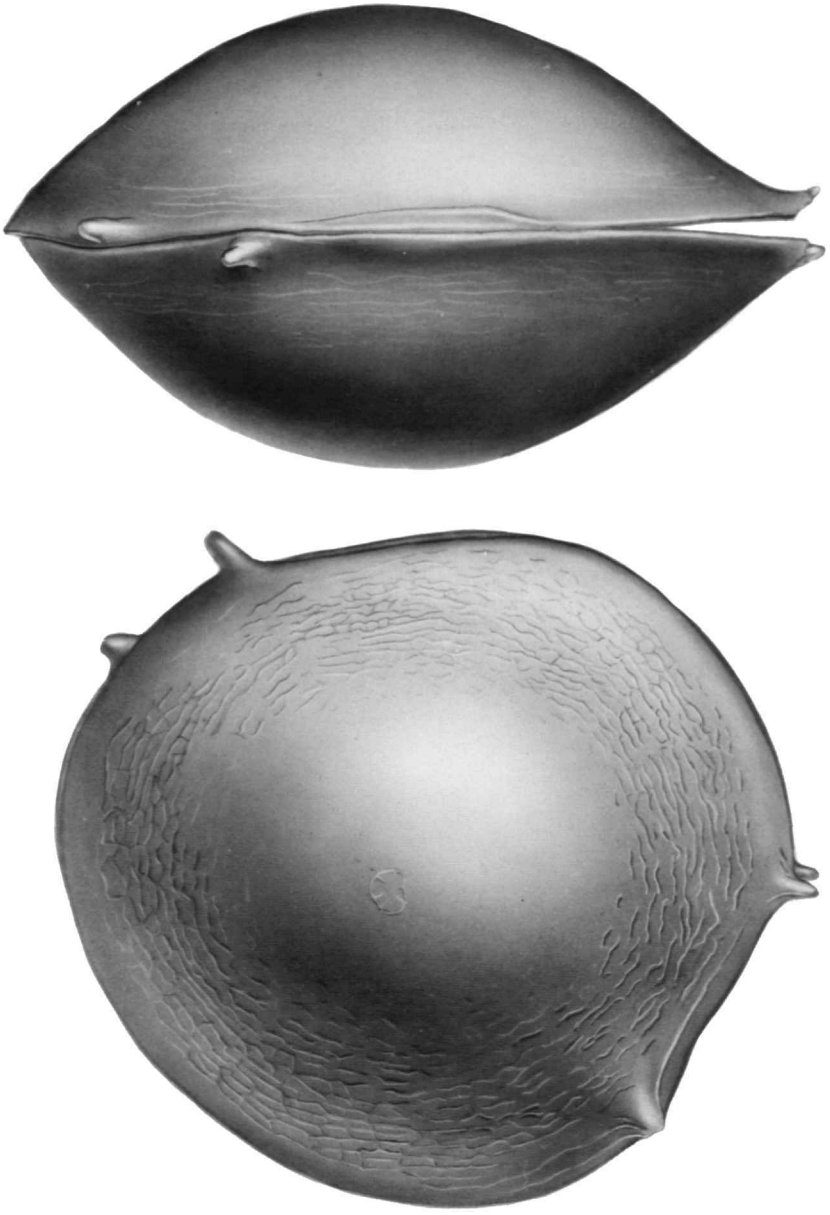


FIGURE 74. *Danielopolina carolynae*, new species, carapace of adult female, holotype, USNM 143789, length 1.85 mm, anterior to right.

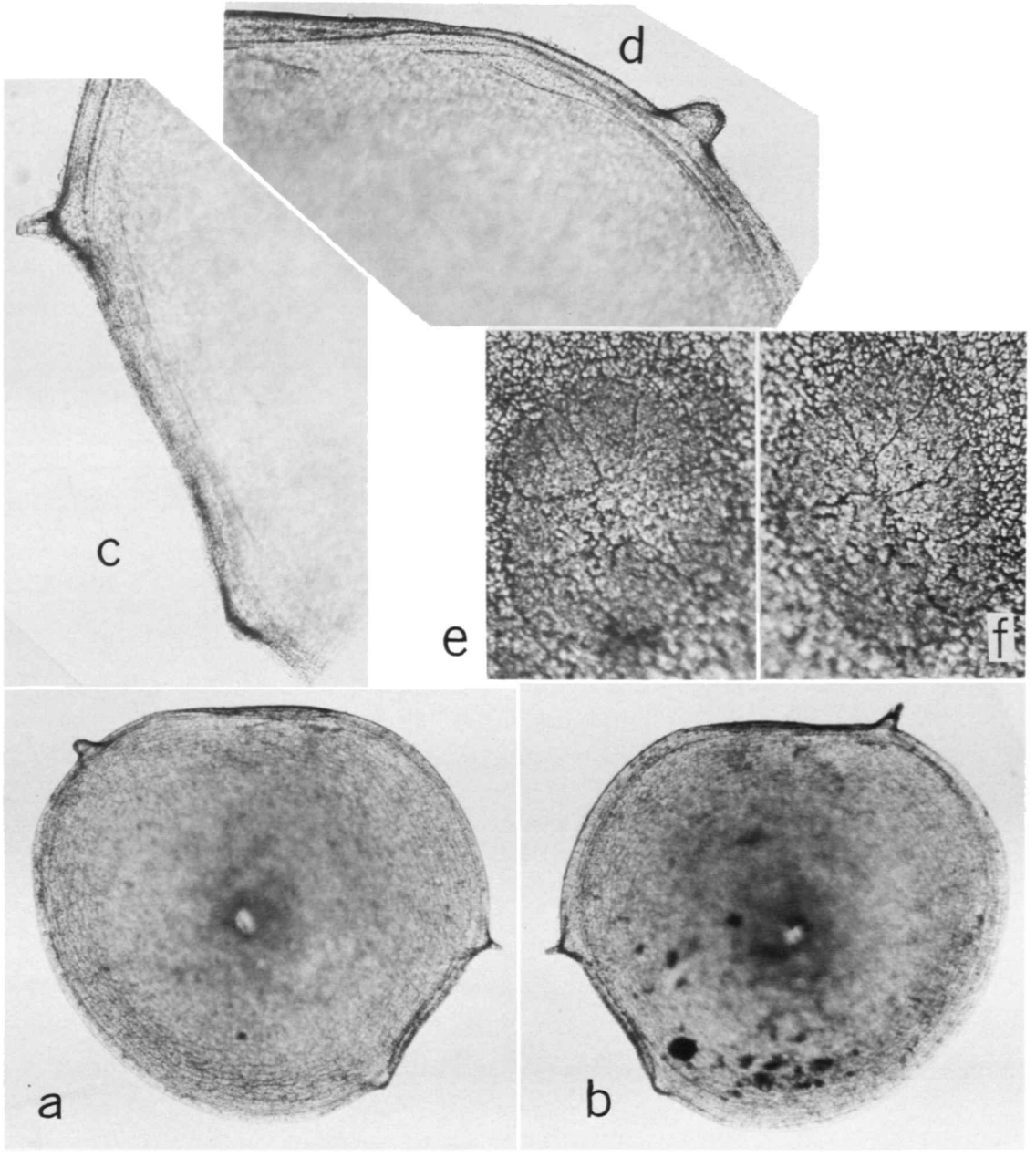


FIGURE 75.—*Danielopolina carolynae,* new species, adult female, holotype, USNM 143789, carapace, length 1.85 mm: *a,* right valve, outside view; *b,* left valve, outside view; *c,* anteroventral margin of right valve, inside view; *d,* posterodorsal corner of right valve showing tubercle, inside view; *e,* adductor muscle attachment scar of left valve, outside view. *f,* same, right valve.

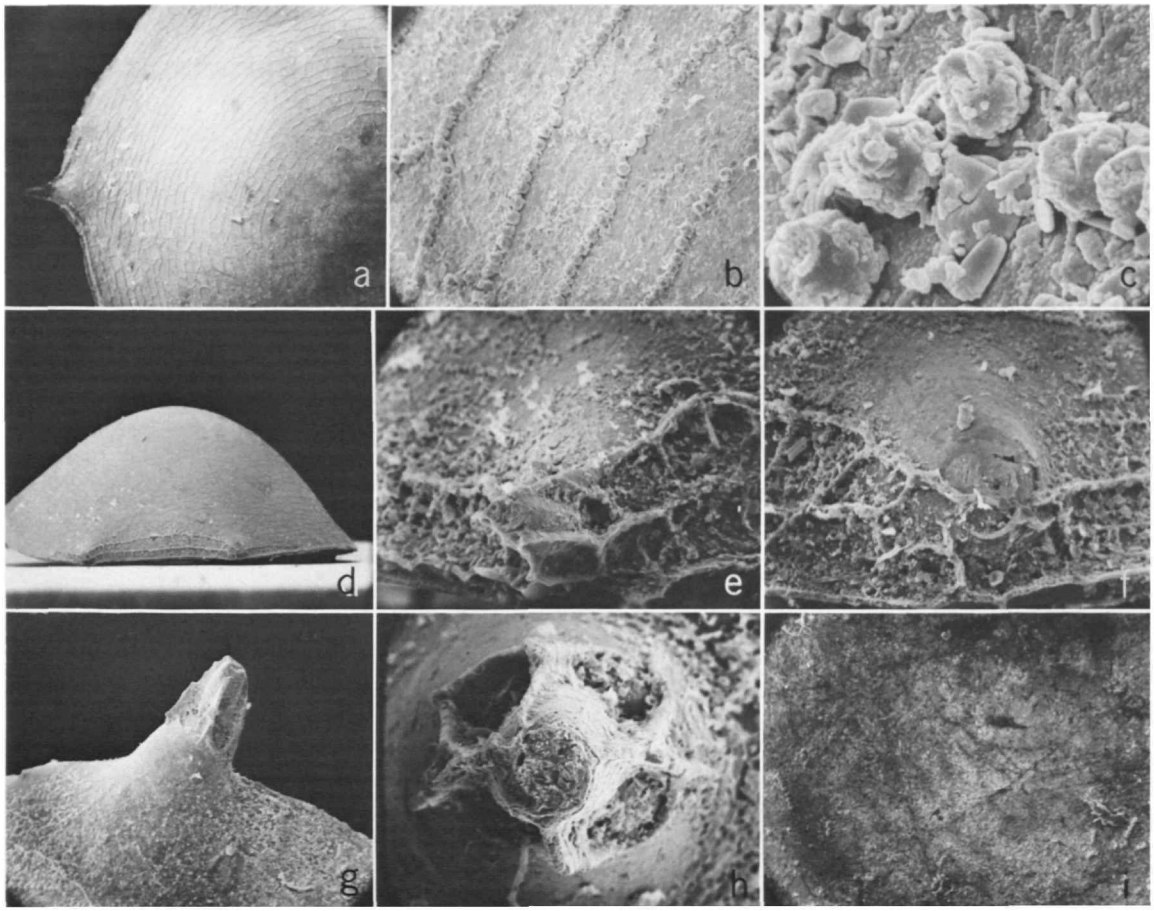


FIGURE 76.—*Danielopolina carolynae*, new species, left valve of adult female, holotype, USNM 143789: *a*, anteroventral part of valve from outside, × 100; *b*, reticulate ornamentation, × 1000; *c*, detail of pustules forming reticulations shown in *b* (much debris between pustules), × 7500; *d*, anteroventral view of valve, ventral margin to right, × 60; *e*, detail from *d* showing upper anteroventral protuberance, × 600; *f*, same, but showing lower anteroventral protuberance, × 600; *g*, posterodorsal tubercle, lateral view, × 320; *h*, same, view perpendicular to tip, × 1200; *i*, nonreticulate area over adductor muscle attachment, lateral view, × 320. (Photo reduced to 55 percent.)

a dorsal and ventral forward pointing conical protuberance (Figures 75*c*, 76*a*,*d*–*f*); dorsoanterior margin broadly convex merging with short, straight dorsal margin at point one-third greatest length; posterior and ventral margins evenly rounded; dorsal outline subelliptical with acuminate ends; greatest width at or behind midlength; end outline subelliptical, greatest width at about midheight.

Ornamentation: Central part of valve smooth (Figure 76*i*), rest with elongate pentagonal and hexagonal reticulations concentrically oriented (Figure 76*a*); boundaries of reticulations formed by closely spaced minute subround papillae (Figure 76*b*,*c*); anteroventral surface with 3 higher nonpapillate ridges parallel to valve margin (Figure 76*d*–*f*); ridge closest to margin continues around valve; 3rd ridge extends dorsally for short distance; 2nd and 3rd ridges extend ventrally for somewhat

longer distance, terminating at distance equal to one-fourth length anteroventral margin; quadrate reticulations formed by nonpapillate cross-ridges; no pore-canals or hairs observed; a conical tubercle asymmetrically located on posterodorsal part of valves (Figures 74; 75*a,b,d;* 76*g,h*); tubercle on left valve located on posterior end of straight dorsal margin, tubercle on right valve located posterior to tubercle on left valve.

Adductor muscle-scar (Figures 74*a,* 75*e,f*): Scar located at approximately midlength and slightly below midheight, its position being below and posterior to a line connecting dorsoposterior tubercle and lower anteroventral protuberance on left valve, and located on a similar line on right valve; scar consists of 8 subequal pie-shaped segments more-or-less radially arranged.

Size: USNM 143789, complete specimen, length 1.85 mm, height 1.72 mm.

First antenna (Figure 77*a*): Limb with 8 joints: 1st joint with long hairs on lateral surface near distal margin, numerous long hairs on medial surface, 1 dorsal bristle with short marginal spines, and 1 spinous lateral bristle on small protuberance; 2nd joint with 1 ventral bristle reaching to 7th joint and 1 dorsal bristle reaching to 4th joint, both bristles with short marginal spines; 3rd joint with long spines and hairs on medial and lateral surfaces and ventral and dorsal margins; 3rd joint fused with 4th except in sclerotized area of dorsal margin; 4th joint about three-fourths length of 3rd, and with few short spines along ventral and dorsal margins, and with either no bristle or with 1 minute bristle; 5th joint with 2 long terminal bristles, lateral of these with small bulge at base and with widely separated short marginal spines, spines possibly on medial bristle, but obscured by debris; 6th joint with few short spines along dorsal margin; 7th joint with 2 long terminal ventral bristles, lateral of these with widely separated minute marginal spines; margins of medial bristle not clearly observable on mounted limb; 8th joint with 1 short terminal dorsal bristle with short closely spaced marginal spines, and 2 long terminal bristles with widely separated minute marginal spines.

Second antenna (Figures 10*a,* 77*b–d*): Protopodite with long hairs along ventral margin and 1 long bare bristle on posteroventral margin. Endopodite considered here to be weakly 3-jointed: 1st joint with distal spines on medial surface along ventral and dorsal margins (more along latter); joint also with 2 dorsal bristles, both with short marginal spines; 2nd joint longer and narrower than 1st joint, with 1 short lateral bristle and 4 long terminal bristles; 3rd joint small, completely fused to 2nd, with 1 short terminal bristle; pore on terminal margin of 3rd joint adjacent to bristle may represent undeveloped bristle. Exopodite with 9 joints: 1st joint with minute spines along ventral margin and distinct suture dividing it into long proximal and short distal parts; medial bristle on distal part reaching just beyond 8th joint, with minute spines along dorsal and ventral margins, more along latter, without natatory hairs; bristles on joints 3–8 with natatory hairs, some also with minute marginal spines; 9th joint with 2 bristles, 1 medium length with short marginal spines, 1 long with natatory hairs.

Mandible (Figure 77*e,f*): Posterior margin of basale endite with 2 short bristles near middle and distal blunt bristle; anterior margin with 1 bristle; lateral surface with 5 bristles; remaining parts of limb similar to limb of *Thaumatoconcha radiata.*

Maxilla (Figure 77*g*): Anterior margin of 1st endopodite joint with 3 bristles near middle and 1 subterminal; limb otherwise more-or-less similar to that of *T. radiata,* but number of small bristles on end joint uncertain.

Fifth limb (Figures 11*a,* 77*h*): Epipodial appendage with bristles in 3 groups with 5, 5, and 4 plumose bristles. Protopodite with 3 bristles on ventral margin proximal to endite I; endite I with 3 bristles; endite II with 5 bristles; dorsal margin of protopodite hirsute. Endopodite with 1 stout bare bristle, 1 stout longer bristle with marginal spines, 3 long slender distal bristles, 1 long slender proximal bristle. Exopodite: dorsal margin of 1st joint with 1 long bristle with short marginal spines; middle of ventral margin with 2 long bristles with long marginal spines and 2 short bristles with short marginal spines; distal end of ventral margin with 3 bristles; middle of distal ends of lateral and medial sides each with 1 bristle; medial side with long hairs forming distal row; 2nd joint with 2 bristles at middle of ventral margin and 1 terminal (base of terminal bristle on medial side of joint); medial surface of joint hirsute; end joint with 2 stout terminal bristles of equal length.

Sixth limb (Figures 12*a,* 77*i*): Epipodial append-

FIGURE 77.—*Danielopolina carolynae*, new species, adult female, holotype, USNM 143789: *a*, right 1st antenna, lateral view; *b*, protopodite and endopodite of left 2nd antenna, lateral view; *c*, same of right 2nd antenna, medial view; *d*, exopodite of right 2nd antenna, medial view; *e*, coxale endite of right mandible, medial view; *f*, basale and endopodite of right mandible, lateral view; *g*, maxilla; *h*, 5th limb; *i*, 6th limb. (Same magnification in micrometers: *a–c*, *d–i*.)

age with bristles in 3 groups with 6, 4, and 5 plumose bristles. Protopodite interpreted to consist of 2 joints: 1st joint with 2 terminal bristles on medial side near ventral margin; 2nd joint with 2 medial bristles near distal margin; suture separating 1st and 2nd joints better defined than suture separating protopodite and exopodite. Exopodite: 1st joint equally divided by weak suture into proximal part with 2 stout plumose bristles, 1 on ventral margin, 1 on medial side, and distal part with 3 bristles, 2 ventral, 1 medial, and short lateral process terminal on dorsal margin; process with 2 bristles; 2nd joint with 2 bristles at middle of ventral margin, 1 bristle distal to middle of dorsal margin, 1 medial bristle near middle, and 1 terminal medial bristle near ventral margin; end joint with 2 bristles of equal length.

Seventh limb: Limb small, elongate, tapered with 2 long spinous bristles.

Furca, posterior of body: Similar to those on *T. radiata.*

Rod-shaped organ: Not observed. (During dissection, when attempting to remove the right 2nd antenna, the right 1st antenna inadvertently was removed with it, resulting in the head area of the specimen being torn. Therefore, it is not certain that a minute rod-shaped organ, such as that illustrated for *Thaumatocypris echinata* by Poulsen (1969:11, fig. 1j), was not present; however, it is reasonably certain that a well-developed rod-shaped organ is absent.)

Upper lip: In general similar to that on *T. radiata,* but with 2 anteroventral spine-like processes and 3 lateral triangular processes on each side (Figure 13*h*).

COMPARISONS.—The new species, *D. carolynae,* differs from *D. orghidani* in being larger, having more delicate reticulations, and in having the posterodorsal process on the left valve lower than the process of the right valve. The 2 bristles on the terminal joint of the 5th limb of *D. carolynae,* unlike those on *D. orghidani,* are equal in length. No other species of Thaumatocyprididae bears a bristle on the distal part of the 1st exopodial joint of the 2nd antenna or on the posteroventral margin of the protopodite. A bristle on the posteroventral margin of the protopodite is unknown for the order Myodocopida. For comparing other morphological characters see Table 13.

Pokornyopsis Kozur, 1974

Thaumatocypris Müller.—Triebel, 1941:376.—Bartenstein, 1949:95.

Pokornyopsis Kozur, 1974:853 [part].

TYPE-SPECIES.—*Thaumatocypris feifeli* Triebel, 1941, original designation.

This genus contains two Jurassic species *P. feifeli* (Triebel, 1941) and *P. bettenstaedti* (Bartenstein, 1949).

DISTRIBUTION.—Lower and Upper Jurassic, Germany.

HABITAT.—Marine, benthonic, maximum depth 200 m.

DIAGNOSIS.—Differs from *Danielopolina* and *Thaumatomma* in character of surface reticulations and from *Thaumatomma* in absence of anterodorsal node.

DESCRIPTION.—Small, less than 1.5 mm in length; subovate, with short straight hinge margin; with 2 anteroventral protuberances and 1 posterodorsal tubercle symmetrically located on each valve. Surface with robust sublongitudinal ribs and 3 or 4 marginal ribs subconcentric with contact margins, finer cross-ridges form reticulated pattern; subcentral subovate pit outlined by rim of same width as surface ribs.

DISCUSSION.—Kozur (1974:853) did not publish a diagnosis under *Pokornyopsis;* he referred to the diagnosis of the subfamily Porkornyopsinae, family Polycopidae. The following additional taxa, which we do not include in *Pokornyopsis,* were referred to it by Kozur: *Polycope?* sp. D (Oertli, 1972, only figs. 37, 38 [Jurassic, Callovian? or Oxfordian, Deep Sea Drilling Project Site 100, Cat Gap, 24°41.2′N, 73°47.94′W]); and *Polycope?* sp., *Thaumatocypris?* sp. (Oertli, 1972 [same core as above]).

Key to the Species of *Pokornyopsis*

1. In end view valve surface slopes sharply from center to margins ..... ***P. feifeli***
1′. In end view valve surface curves gently from center to margins ..... ***P. bettenstaedti***

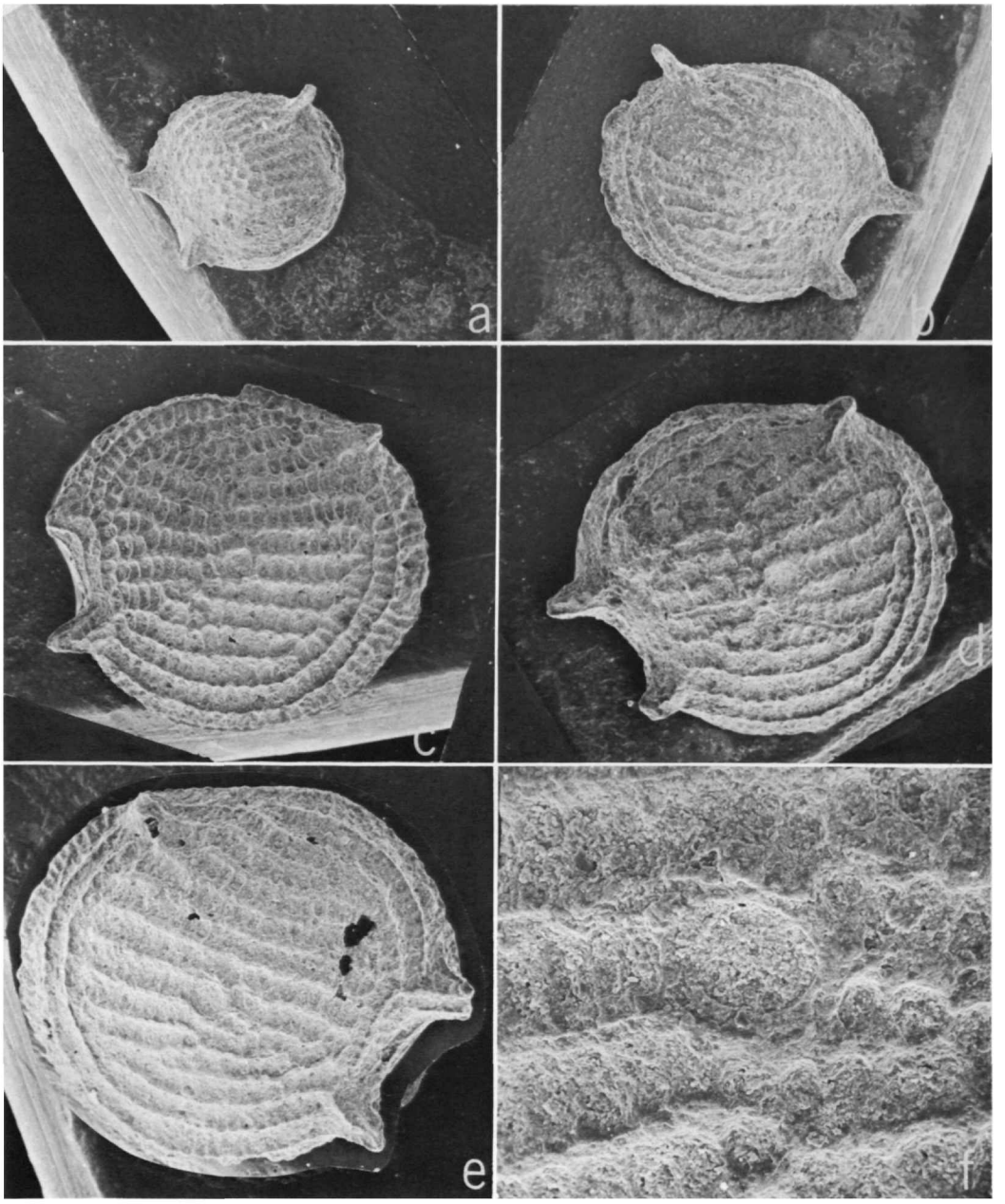


FIGURE 78.—*Pokornyopsis feifeli* (Triebel, 1941), lateral view of topotypes in Natur-Museum Senckenberg: *a*, left valve, specimen lost after examination; *b*, right valve, Xe 10104; *c*, left valve, Xe 10105; *d*, left valve, Xe 10106; *e*, right valve, Xe 10107; *f*, enlargement of adductor muscle attachment area of *e*. (*a–e*, × 75; *f*, × 300; photos reduced to 81 percent).

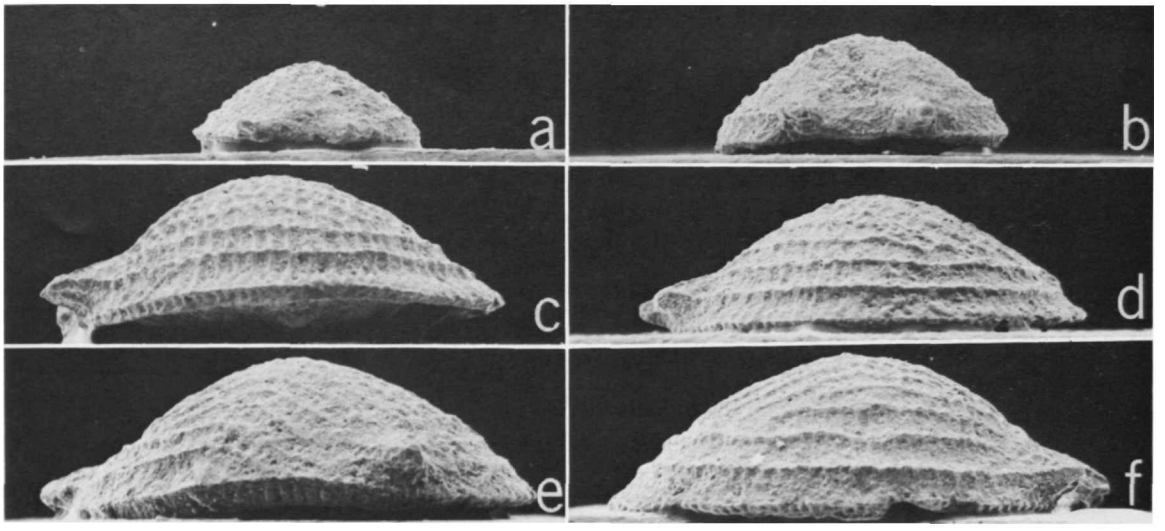


FIGURE 79.—*Pokornyopsis feifeli* (Triebel, 1941), end views of topotypes in Natur-Museum Senckenberg: *a*, anteroventral view, left valve, specimen lost after examination (same as Figure 78*a*); *b*, anteroventral view, right valve, Xe 10104; *c*, ventral view, left valve, Xe 10105; *d*, ventral view, left valve, Xe 10106; *e*, dorsal view, right valve, Xe 10108; *f*, ventral view, right valve, XE 10107. (All × 75, photos reduced to 88 percent).

Pokornyopsis feifeli (Triebel, 1941)

FIGURES 78, 79

Thaumatocypris feifeli Triebel, 1941:376, pl. 12: figs. 140–142.
Pokornyopsis feifeli (Triebel).—Kozur, 1974:853.

HOLOTYPE.—Natur-Museum Senckenberg, Xe 1242.

HABITAT.—Triebel (1941:377) postulated that the heavily calcified shells do not indicate a purely nektonic habit, although the animals could probably swim. Triebel proposed a depth of 100 m to a maximum of 200 m for the type-species.

STRATIGRAPHIC RANGE.—Triebel (1941:377) recorded this species from Malm alpha and beta (Upper Jurassic).

DIAGNOSIS.—Reticulate thaumatocyprid with sharply curved outline in end view.

DISCUSSION.—Triebel adequately described and illustrated this species based on more than 100 specimens. Kozur designated it as the type-species of *Pokornyopsis*. Through the courtesy of Dr. Heinz Malz, we borrowed from the Senckenberg Museum 26 topotype specimens of *P. feifeli*. The valves do not show the adductor muscle attachment scar pattern within the subcentrally located external subovate pit, but the position of adductor muscle attachment scars on the Holocene genera (Figure 19) indicates that the pit on *P. feifeli* probably is the result of the muscle attachment. We attempted to determine the presumed radial pattern of the adductor muscle attachment scar by means of both acetate peels (1 specimen) and SEM photographs (8 specimens), but were not able to discern any details (Figure 78*c–f*). Based on the position of the body within the valves of the Holocene genera (Figures 20, 21), Triebel's orientation is adjusted so that the straight dorsal margin is on top and the two protuberances are in an anteroventral position.

Pokornyopsis bettenstaedti (Bartenstein, 1949)

FIGURE 80

Thaumatocypris bettenstaedti Bartenstein, 1949:95, fig. 1a–c.
Pokornyopsis bettenstaedti (Bartenstein).—Kozur, 1974:853.

HOLOTYPE.—Natur-Museum Senckenberg, Xe 1367.

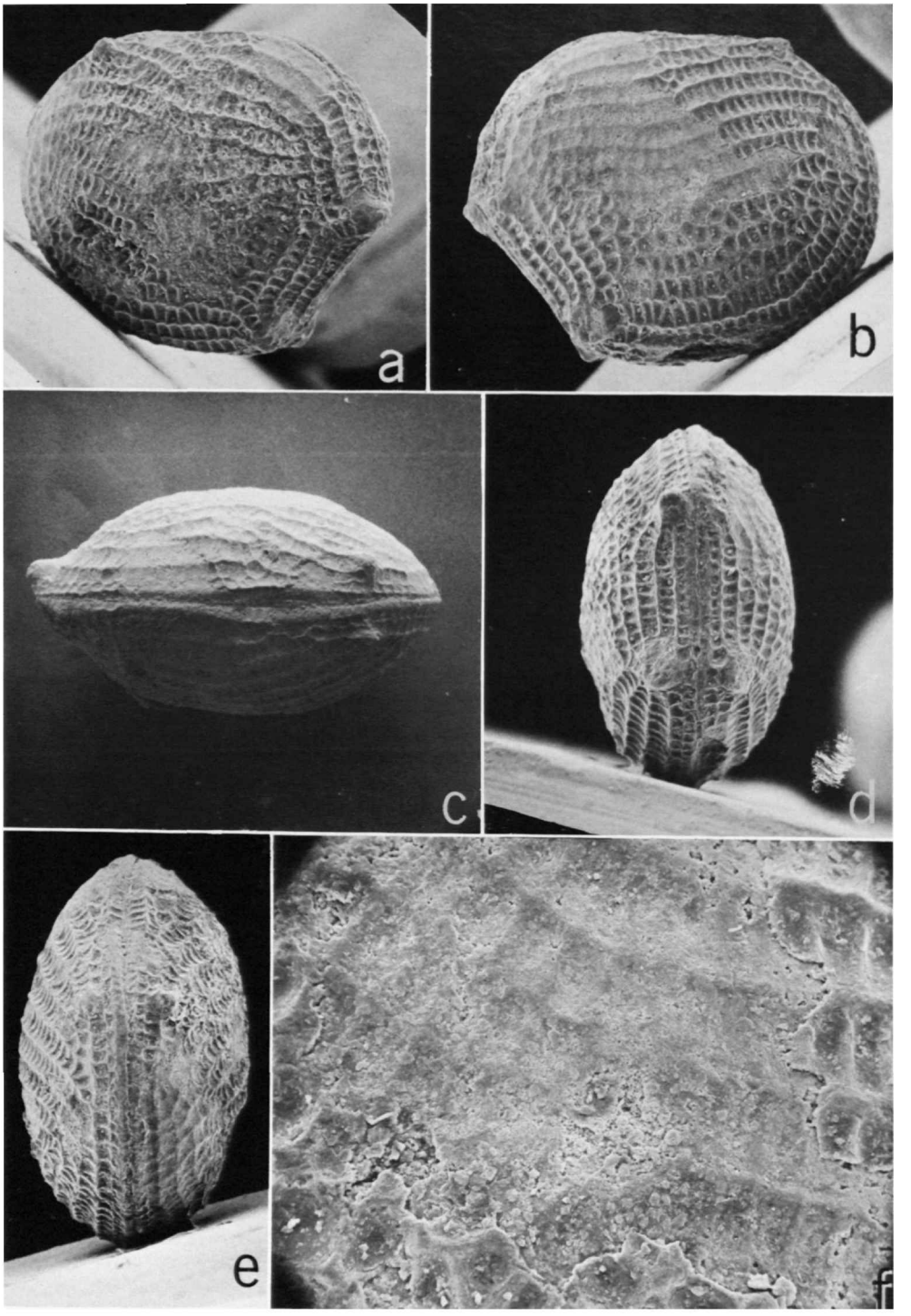


FIGURE 80.—*Porkornyopsis bettenstaedti* (Bartenstein, 1949), paratype, Natur-Museum Senckenberg, Xe 1368: *a*, right valve; *b*, left valve; *c*, carapace, dorsal view; *d*, carapace, anterior view; *e*, carapace, posterior view; *f*, enlargement of adductor muscle attachment area of left valve. (*a–e*, × 75; *f*, × 300; photos reduced to 92½ percent.)

HABITAT.—Bartenstein (1949:96) credited Dr. K. Hoffman-Celle for determining a maximum depth of 200 m for the gray, calcareous claystone in which the 4 specimens were found associated with abundant snail and mollusk fragments, but few foraminiferids, ostracodes, or ammonites.

DIAGNOSIS.—Bartenstein differentiated *P. bettenstaedti* from *P. feifeli* (Triebel) because of its smaller size and more evenly rounded dorsal outline; *P. feifeli* is more convex in dorsal view (compare Figure 79*e* with Figure 80*c*).

DISCUSSION.—Bartenstein adequately described this species and illustrated the holotype from the uppermost Lias (Lower Jurassic) in Lattrum Well no. 2, northwestern Germany. He recorded the length to be from 0.52 mm to 0.96 mm, and stated that in addition to the holotype, he had 3 paratypes (Natur-Museum Senckenberg, Xe 1368). Dr. Heinz Malz sent a pyritised paratype and wrote (letter to Sohn, 19 February 1973) that the second paratype suffered from decay of the pyrite, and that the third specimen is a juvenile.

Thaumatomma, new genus

TYPE-SPECIES.—*Thaumatomma piscifrons*, new species.

ETYMOLOGY.—The generic name is from the Greek *thauma* (marvel) + *omma* (eye).

DISTRIBUTION.—Known only from Permian limestones at Idhra (Hydra), Greece. In addition to the type-species, at least five as yet undescribed species are present in the Permian of Greece.

HABITAT.—Associated brachiopods, rare trilobite fragments, fusuline and other foraminiferids, as well as benthic ostracodes in families including Bairdiidae, Amphissitidae, Kellettinidae, *Roundyella* Bradfield, 1935 (?Scrobiculidae), Hollinellidae, and the presence of growth stages in many of the species indicate a normal marine shelf habitat.

DIAGNOSIS.—Small, subround, reticulate with anterodorsal node.

DESCRIPTION.—Carapace subround; less than 2 mm in greatest length; with straight or slightly convex dorsal margin; valves symmetrical, ornamented by variable patterns formed by ridges and cross-ridges; with more-or-less straight anteroventral margin delimited by 2 protuberances; lower anteroventral protuberance, usually longer than upper, may vary in size on opposing valves, and the distance between it and the contact margin may vary; with slightly inset anterodorsal node on each valve; with or without small posterodorsal tubercle located in the same position on each valve. Overlap slight, apparently right over left on anterior margin, and left over right along posterior margin. Hingement relatively short, straight or curved, apparently without dentition. Dimorphism and adductor muscle attachment scar pattern as yet undetermined.

DISCUSSION.—All the specimens are poorly silicified, obtained by treating limestone with dilute hydrochloric acid. The anterodorsal node is rarely preserved; in most specimens it is represented by a hole in the valve, and in some by a rounded node that is not reticulated. This node, of unknown function, superficially resembles an "eye spot," consequently the name "*Thaumatomma*." The position of the anteroventral protuberances varies in distance from the contact margin, and may possibly be of specific importance. Some species have a stubby posterodorsal tubercle in the same position on both valves; other species have either a spine in the anteroventral area, or do not have any tubercles or spines.

This genus and its type-species are described here in order to document the phylogenetic interpretation. The other species will be described by Sohn at a later date with the rest of the ostracodes from the Permian of Greece.

The presence in the collections of specimens of *Thaumatomma* with diverse morphological characters suggests that some of the observed differences could be due to sexual dimorphism. Dimorphism is ruled out by the fact that each of the morphotypes present has growth stages with the same morphology as the largest specimens. The diversity in *Thaumatomma* species (at least 6) during the Permian of Greece suggests that the genus probably evolved during the Carboniferous or even earlier, but has not yet been recorded.

Thaumatomma piscifrons, new species

FIGURES 81–87

HOLOTYPE.—USNM 168167, left valve of probably A–1 growth stage.

TYPE-LOCALITY.—Southeastern side of Idhra,

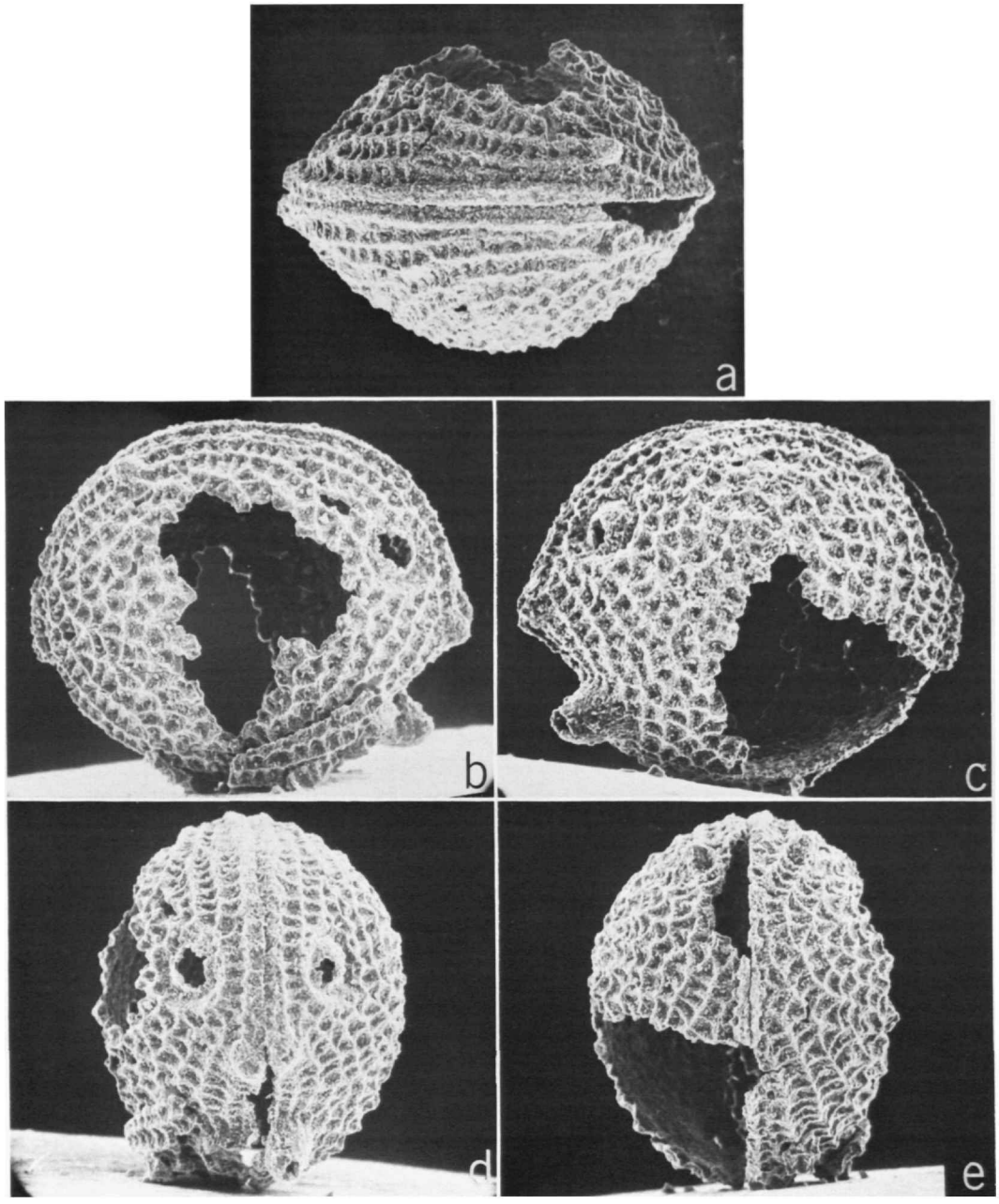


FIGURE 81.—*Thaumatomma piscifrons*, new species, paratype, USNM 168168, broken carapace: *a*, dorsal view; *b*, right view; *c*, left view; *d*, anterior view; *e*, posterior view. Broken fragment of shell adhered to ventral margin of right valve during preparation for SEM as in *d* and *e*. (All approximately × 130; photos reduced to 74½ percent.)

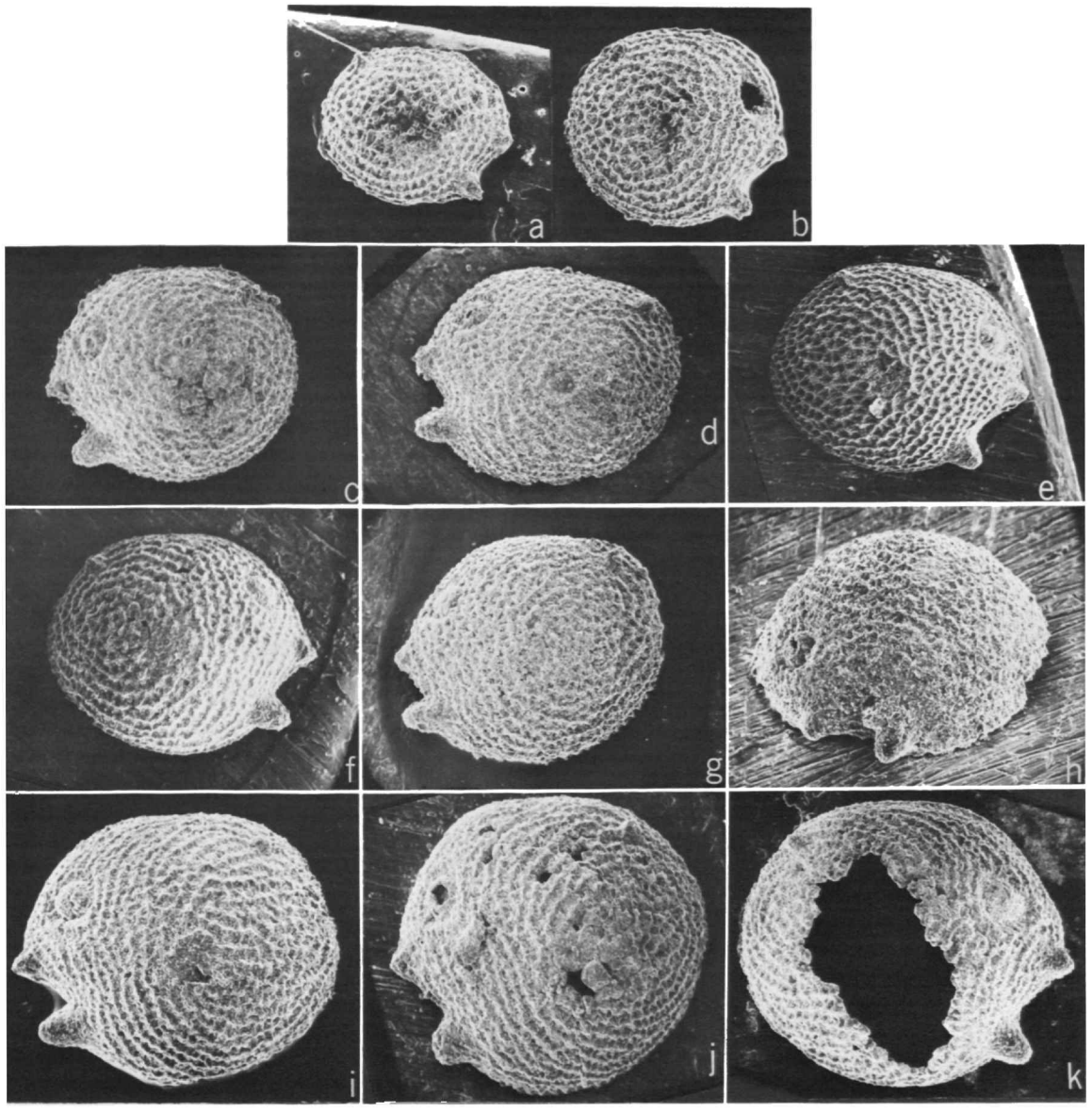


FIGURE 82.—*Thaumatomma piscifrons*, new species, lateral views: *a*, right valve, paratype, USNM 168170; *b*, right valve, paratype, USNM 168171; *c*, left valve, paratype, USNM 168181; *d*, left valve, paratype, USNM 168172; *e*, right valve, paratype, USNM 168173; *f*, right valve, paratype, USNM 168174; *g*, left valve, paratype, USNM 168175; *h*, left valve, oblique view, paratype, USNM 168169; *i*, left valve, paratype, USNM 168176; *j*, left valve, holotype, USNM 168167; *k*, right valve, paratype, USNM 168177. (All approximately × 100, photos reduced to 53 percent.)

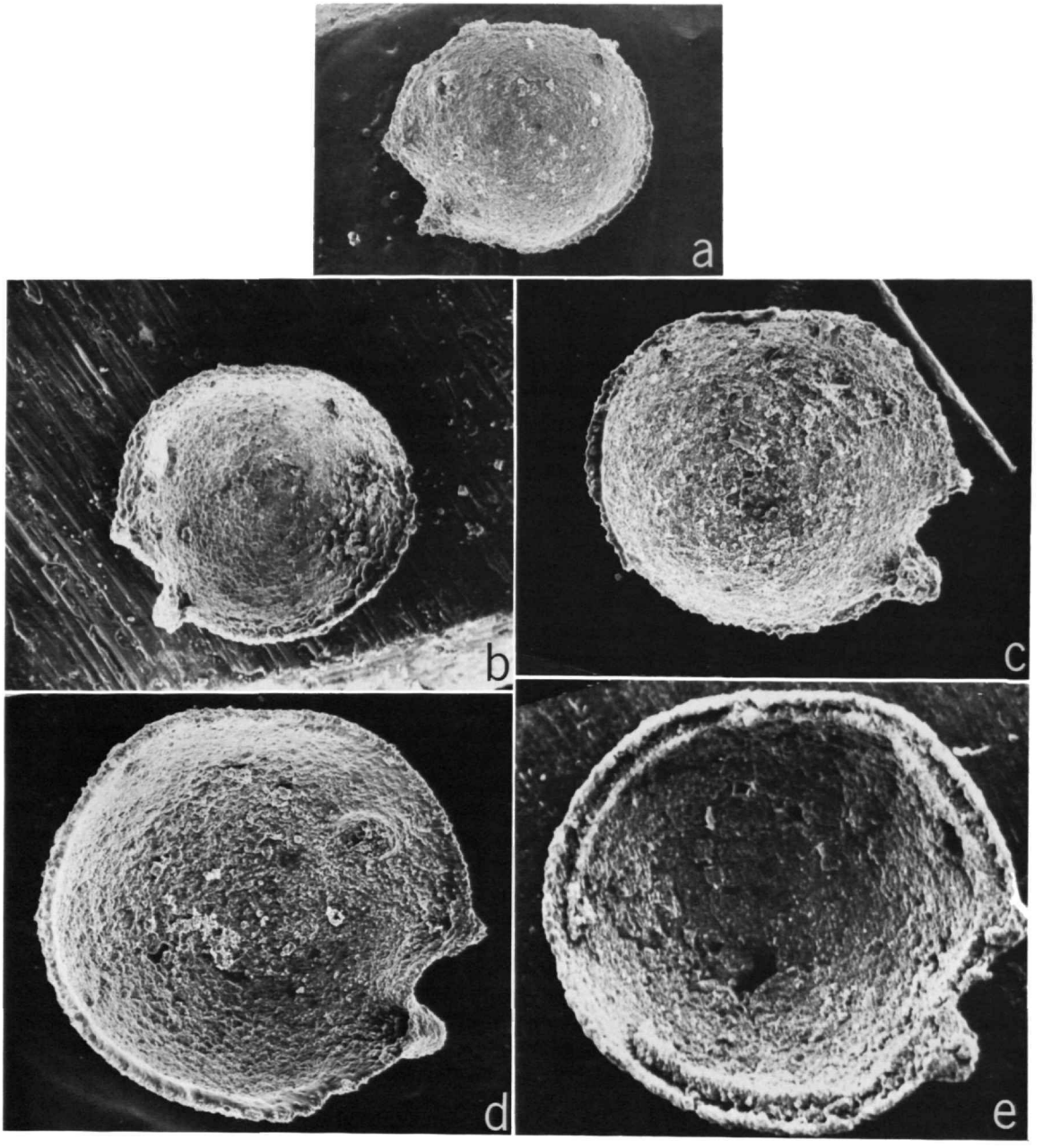


FIGURE 83.—*Thaumatomma piscifrons*, new species, inside views (note location of anterodorsal node, dorsoposterior tubercle, and missing contact margins on *a–d*): *a*, right valve, paratype, USNM 168170; *b*, right valve, paratype, USNM 168171; *c*, left valve, paratype, USNM 168181; *d*, left valve, paratype, USNM 168176; *e*, left valve, holotype, USNM 168167. (*a–d*, approximately × 100; *e*, × 50; photos reduced to 82 percent).

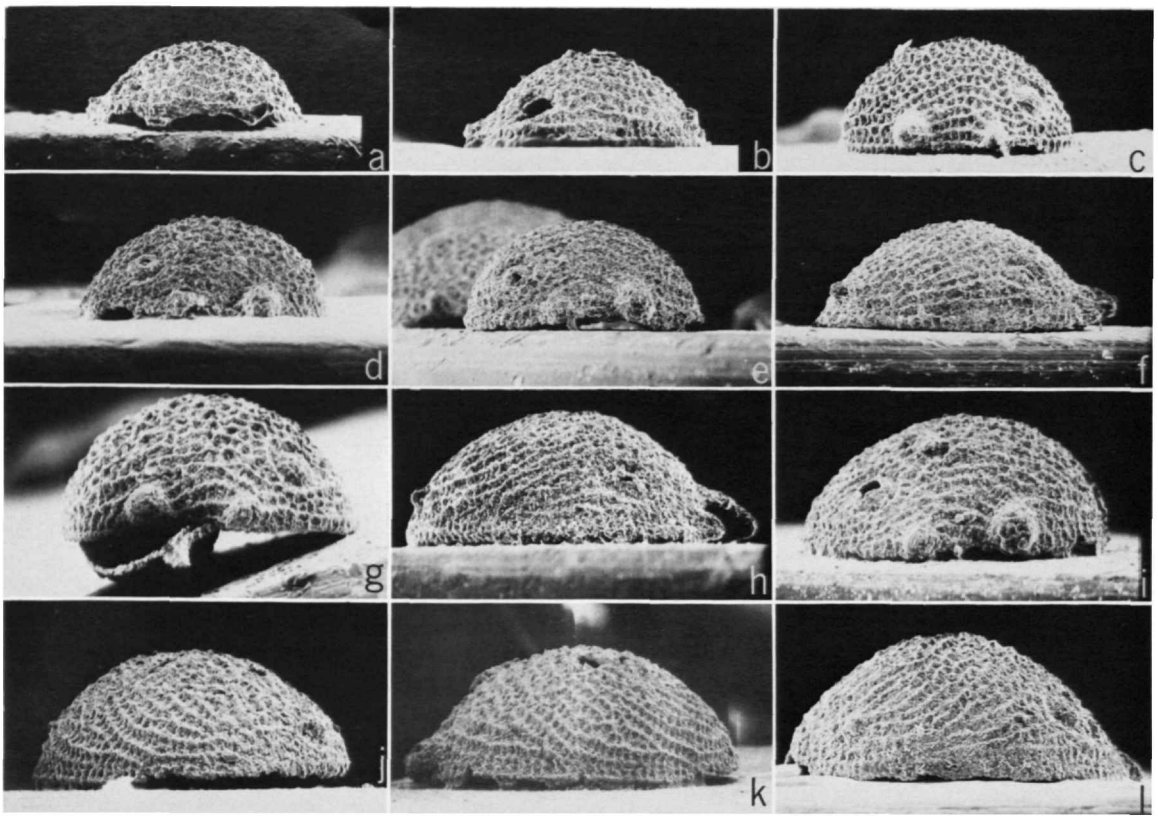


FIGURE 84.—*Thaumatomma piscifrons*, new species: *a*, right valve, dorsal view, paratype, USNM 168170; *b*, right valve, dorsal view, paratype, USNM 168171; *c*, right valve, anterior view, paratype, USNM 168173; *d*, left valve, anterior view, paratype, USNM 168181; *e*, left valve, anterior view, paratype, USNM 168172; *f*, left valve, dorsal view, paratype, USNM 168172; *g*, right valve, anterior view, paratype, USNM 168174; *h*, left valve, dorsal view, paratype, USNM 168169; *i*, left valve, anterior view, holotype, USNM 168167; *j*, left valve, posterior view, with dorsal to right (note tubercle), holotype, USNM 168167; *k*, left valve, ventral view, holotype, USNM 168167; *l*, left valve, dorsal view, paratype, USNM 168176. (All approximately × 100; photos reduced to 54½ percent.)

just off the Argolian coast, Greece, about ½ km south of the village of Episkopi, weathered block with silicified fossils, USNM locality 9260 (see Grant, 1972:214, for description).

TYPE-LEVEL.—"Lattonienkalk" of Renz (1955: 432), Permian (see Grant, 1972:215, for discussion of age).

PARATYPES.—USNM 168168–168187, one poorly preserved juvenile carapace, and 40 right and left valves.

ETYMOLOGY.—The specific name is from the Latin *piscis* (fish) + *frons* (face), because of the appearance in anterior view.

DIAGNOSIS.—*Thaumatomma* with straight dorsal margin; straight anteroventral margin located just below approximate midheight, trends sharply downwards and backwards; lower anteroventral protuberance located lateral to contact margin by less than diameter of upper protuberance; anterodorsal node located below dorsal margin slightly more than one-fourth greatest height, somewhat closer to anterodorsal margin; with posterodorsal

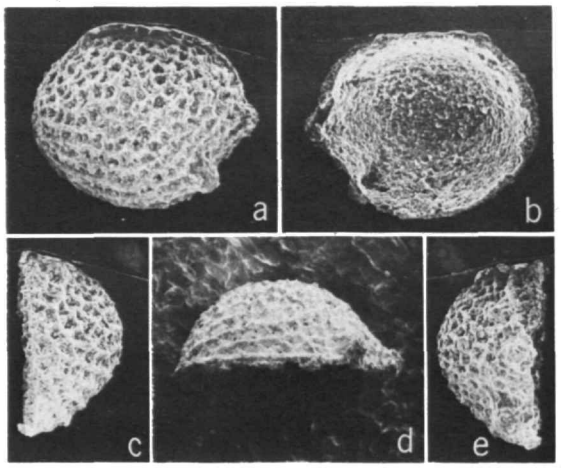


FIGURE 85.—*Thaumatomma piscifrons*, new species, paratype, USNM 168187, smallest specimen, length 0.42 mm, height 0.38 mm; *a*, right valve; *b*, inside view; *c*, posterior view; *d*, ventral view; *e*, anterior view. (All × 100; photos reduced to 76½ percent; because specimen was mounted on its dorsal margin, the dorsal parts of *a* and *b* are retouched.)

tubercle on each valve; surface reticulated, formed by ridges subparallel to free margins, and weaker cross-ridges, ridges subparallel to anterior margin for approximately one-third greatest length, form subconcentric pattern on posterior part of valve.

DESCRIPTION (Figures 81–86).—Valves subovate, dorsal margin straight; anterodorsal margin broadly rounded, extends from approximate anterior quarter of greatest length to approximate mid-height where it merges with the upper smaller anteroventral protuberance; straight anteroventral margin trends downwards and backwards, length of anteroventral margin less than one-fourth the greatest height, makes a distinct angle with larger lower protuberance; ventral margin convex, anterior portion trends downward and backward subparallel to straight anteroventral margin to a point approximately directly below the junction of the dorsal and anterodorsal margins, then curves gently upward to a point opposite lower anteroventral protuberance where it merges with convex posterior margin; posterior margin rounded, merges with dorsal margin slightly in front of dorsoposterior tubercle; dorsal outline subelliptical, greatest width subcentral; end outline subovate; greatest width subcentral, less than greatest height.

Ornamentation: Surface with ridges subparallel to free margin, weaker short ridges form rectangular to subtriangular reticules; subparallel ridges extending approximately one-third valve length from anterior margin, and forming a subconcentric pattern on posterior part of valve. Anterodorsal node with diameter larger than base of lower anteroventral protuberance, subhemispherical, with indented perimeter, located about equidistant from upper anteroventral protuberance and junction of dorsal and anterodorsal margins. Dorsoposterior tubercle small, located about same distance in front of posterior margin and below junction of dorsal and dorsoposterior margins; diameter of base approximately equals distance between three surface ridges. Upper anteroventral protuberance shorter and thinner than lower protuberance, located near contact margin; lower anteroventral protuberance hollow, located lateral to contact margin by distance less than its diameter; distance between protuberance equal to or less than one-fourth greatest height of valve.

Adductor muscle-scar: Unknown.

Size (Figure 87): Because of the poor preservation, many of the valves broke when handled with a wet brush. Consequently, only the greatest lengths and heights on the outside of the valves were measured. The greatest length was measured parallel to the straight hinge margin at the base of the upper anteroventral protuberance, and the greatest height was measured normal to the hinge margin. USNM locality 9260: paratype USNM 168170, length 0.55 mm, height 0.46 mm; paratype USNM 168171, length 0.61 mm, height 0.57 mm; paratype USNM 168172, length 0.74 mm, height 0.64; paratype USNM 168173, length 0.74 mm, height 0.66 mm; paratype USNM 168174, length 0.80 mm, height 0.67 mm; paratype USNM 168175, length 0.75 mm, height 0.67 mm; paratype USNM 168176, length 0.91 mm, height 0.78 mm; paratype USNM 168177, length 0.96 mm, height 0.83 mm; paratype USNM 168168, length 0.66 mm, height 0.56 mm; paratype USNM 168178, length 1.21 mm, height 0.96 mm; paratype USNM 168179, length 1.23 mm, height 0.99 mm; paratype USNM 168180, length 0.42 mm, height 0.38 mm. USNM locality 9261: paratype USNM 168181, length 0.75 mm, height 0.64 mm; paratype USNM 168169, length 0.97 mm, height 0.86 mm; holotype USNM 168167, length 0.92 mm, height 0.89 mm; paratype USNM

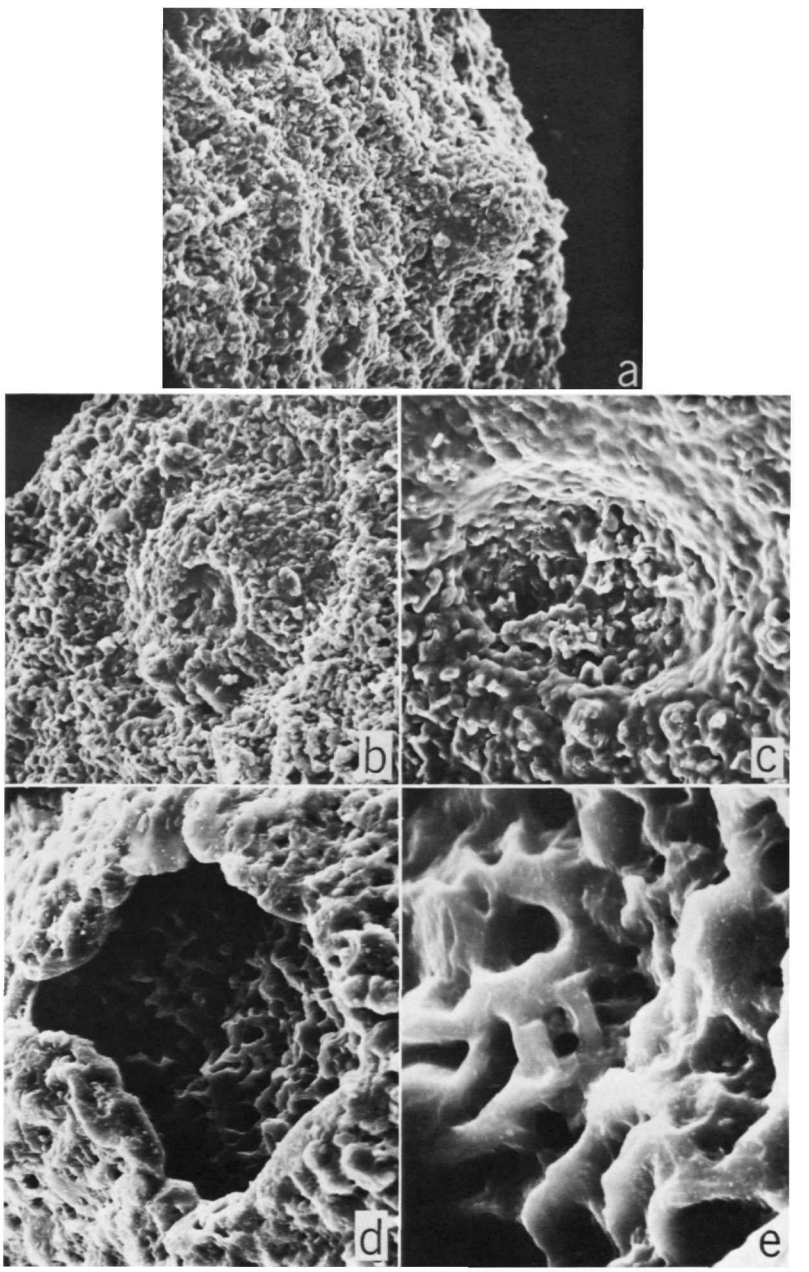


FIGURE 86.—*Thaumatomma piscifrons*, new species: *a*, dorsoposterior tubercle, paratype, USNM 168172, × 500; *b*, lateral view of anterodorsal node, paratype, USNM 168181, × 500; *c*, inside view of anterodorsal node, paratype, USNM 168176, × 500; *d*, lateral view of anterodorsal node, holotype, USNM 168167, × 1200; *e*, detail of inside of *d*, × 4859. (Photos reduced to 69½ percent.)

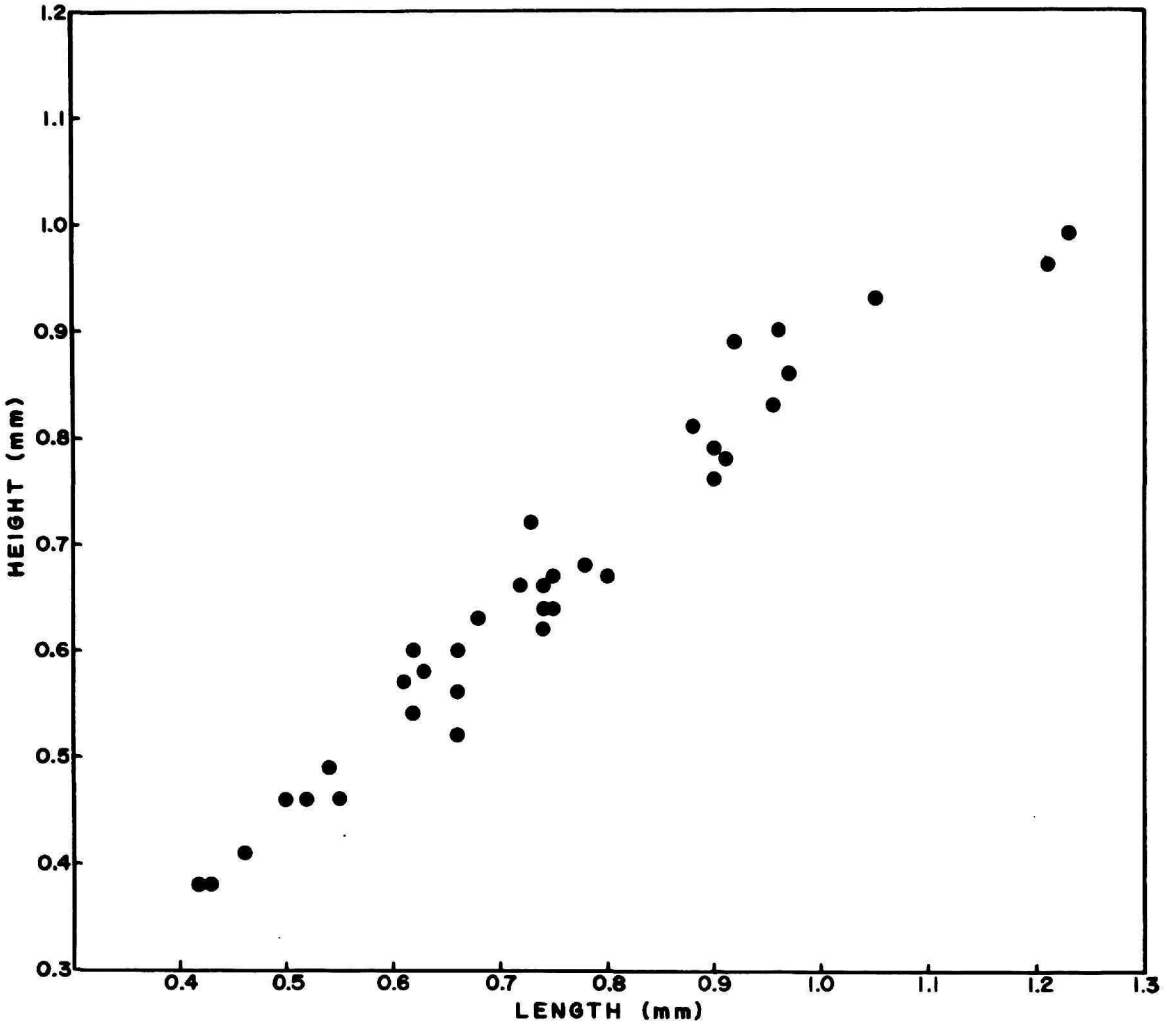


FIGURE 87.—*Thaumatomma piscifrons*, new species, carapace length-height graph.

168187, length 0.42 mm, height 0.38 mm.

DISCUSSION.—The ostracodes were obtained by dissolving, in hydrochloric acid, limestone blocks that ranged in size from approximately 3 × 4 × 6 in (8 × 10 × 15 cm) to as large as 10 × 12 × 24 in (25 × 30 × 60 cm), and each block at the same locality was identified by a number. Because the acid dissolved the specimens from all sides of the block, each ostracode collection represents a mixed assemblage that varies in the time span represented by the thickness of the individual blocks. Any two consecutive growth stages of the same species from the same block may have represented individuals that lived at different times, separated at the maximum by the number of years it took for the thickness of the block to be deposited. The study is further complicated by the fact that the *Thaumatomma* specimens are as a rule poorly preserved, and the majority of the valves have parts of the contact margin missing. A great deal of time was spent in picking the +40 and larger fractions of the etched residue in the hope of finding an adult

individual to serve as a holotype. Only one left valve (Figure 83*e*, USNM 168167), 0.92 mm in greatest length, has a complete contact margin, the other figured specimens (Figures 83*a–d*) have portions of the contact margins missing. Specimens with greatest length of 1.23 mm and fragments of even larger specimens, always less than 2 mm in greatest length were recovered. As can be seen from the length-height graph of *T. piscifrons* (Figure 87), the specimen designated as the holotype probably represents the A–1 growth stage. Figure 87 represents specimens from 5 blocks, with the majority from one block.

Superfamily ENTOMOCONCHACEA Sylvester-Bradley, 1953

Family ENTOMOCONCHIDAE Brady, 1868

Subfamily ENTOMOCONCHINAE Brady, 1868

FIGURES 88, 89

Two genera are included in the Entomoconchinae: *Entomoconchus* McCoy, 1839, and *Elpezoe* Pribyl, 1951 (= *Elpe* Barrande, 1872).

We have examined 4 specimens, all steinkerns, of *Entomoconchus scouleri* McCoy, 1839 (Figures 88, 89) and one specimen of *Elpezoe? borealis* Copeland, 1964.

All the specimens hitherto illustrated in this subfamily are also judged by us to be steinkerns or more or less corroded or abraided specimens because they have a raised radiate adductor muscle attachment scar. If the shell were present, the scars would not be raised. The outside surface of the valves of taxa in this family is as yet unknown. There is no evidence on the specimens examined (Figures 88, 89) and on the published illustrations of specimens that a "siphon" or a "sinus" attributed to this group by Sylvester-Bradley (1953:132, 1961: Q396) is present.

Through the kindness of Dr. Peter H. von Bitter, Department of Invertebrate Paleontology, Royal Ontario Museum, Toronto, Canada, we borrowed 3 specimens of *Entomoconchus scouleri* McCoy, 1839, all steinkerns of single valves. SEM photographs of one of these are illustrated in Figure 89. A steinkern of a specimen of *E. scouleri* (In.-192) was obtained from the British Museum (Natural History) through courtesy of Dr. R. H. Bate. SEM photographs of this specimen are illustrated in Figure 88.

Subfamily ONCOTECHMONINAE Kesling, 1954

FIGURES 90–92

Kesling (1954) adequately described and illustrated *Oncotechmonus chemotus* Kesling, the type-species of *Oncotechmonus* Kesling, 1954, and *Checontonomus cophus* Kesling, the type-species of *Checontonomus* Kesling, 1954. Through the cooperation of Professor R. V. Kesling, University of Michigan, and Dr. R. S. Laub, Buffalo Museum, we have examined the types of both species, and suggest the following emendations:

ORIENTATION.—According to Kesling's orientation, the greatest width is above the midheight, and the anterior margin is straight. Based on our knowledge of the living Thaumatocyprididae, in which the widest part of the carapace is below the midheight, and the anteroventral margin is straight, we consider it likely that the original orientation should be changed so that the ventral margin becomes the dorsal margin and the straight anterior margin represents the anteroventral margin. See, however, the discussion under "Anterior Region."

POSTEROVENTRAL GAPE.—We examined the posteroventral area on the holotype of *O. chemotus* (Figure 92*c*) and cannot exclude the possibility that the "gape" described by Kesling (1954:576) represents missing parts of the ventral edges of both valves. On the hypotype of *O. chemotus*, later described and illustrated by Kesling (1955), this area of the valve is missing.

ANTERIOR REGION.—Kesling stated that the anterior region of the carapace is flat or depressed. Our examination of the holotype of *C. cophus* reveals that parts of the anterior of both valves are not in contact with each other (Figures 90*d,f*; 91). It is not possible to know whether this is the result of missing shell material, or represents an original opening in the carapace. The anterior of the holotype and of the hypotype of *O. chemotus* is partly covered. We are unable to determine whether there is shell material below the covering matrix. If, indeed, both genera have an opening in this area, two possible interpretations can be postu-

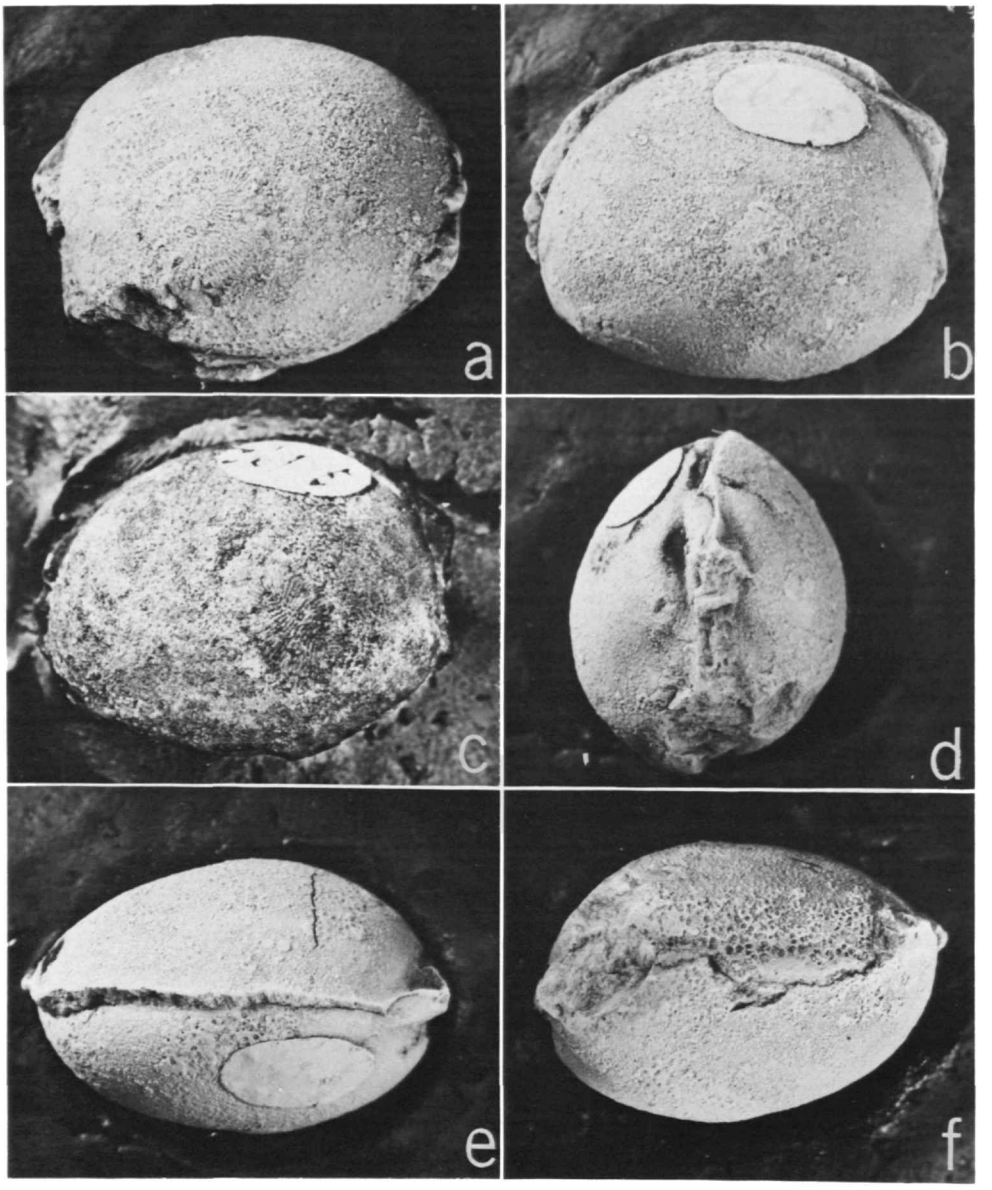


FIGURE 88.—*Entomoconchus scouleri* McCoy, 1839, steinkern, British Museum (Natural History), In-192, Carboniferous Limestone, Bolland, Yorkshire: *a*, left view; *b*, *c*, right view; *d*, anterior view; *e*, dorsal view; *f*, ventral view. (*a*, *b*, *d–f*, coated with ammonium chloride; *c*, uncoated; all approximately × 3.)

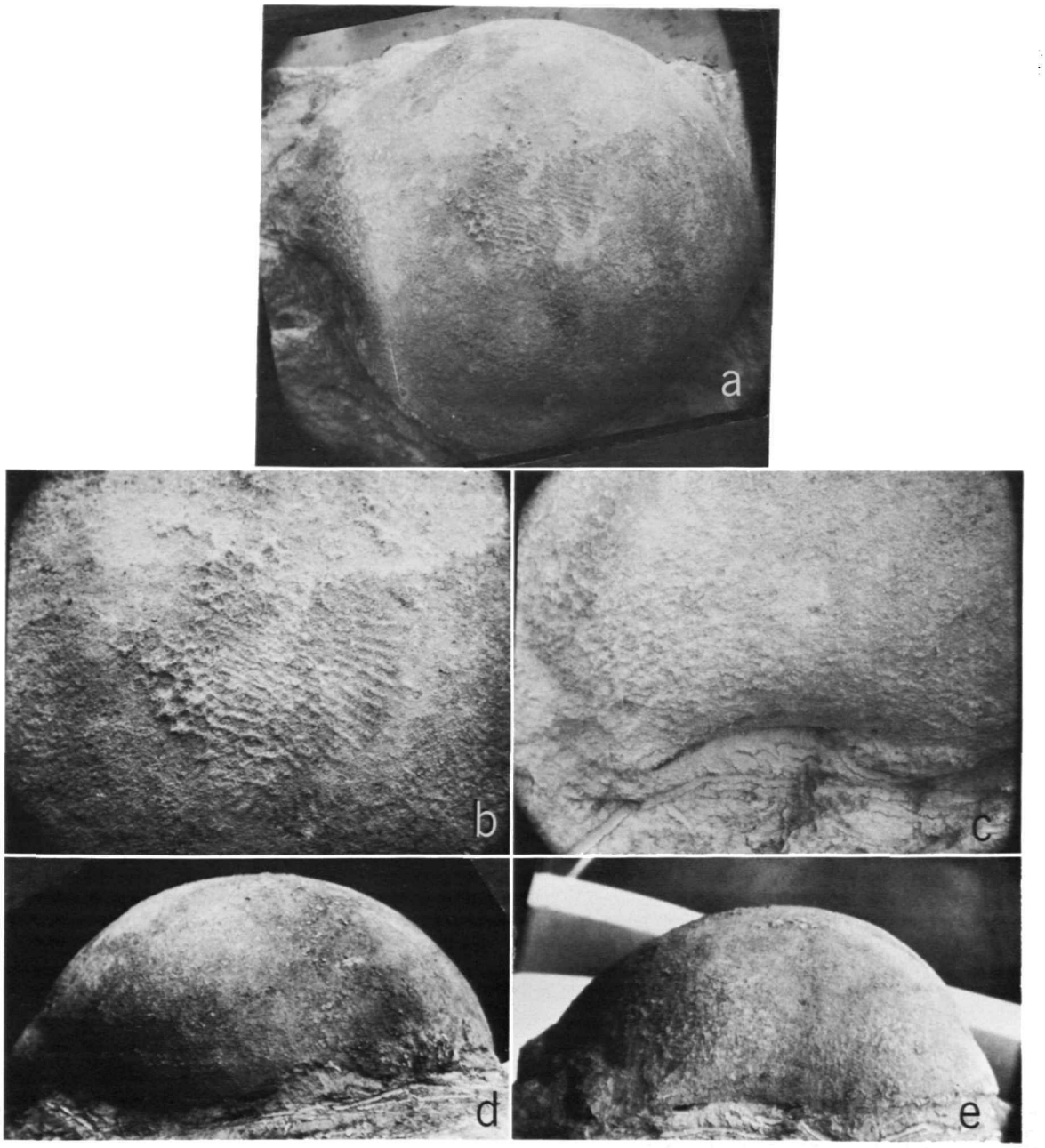
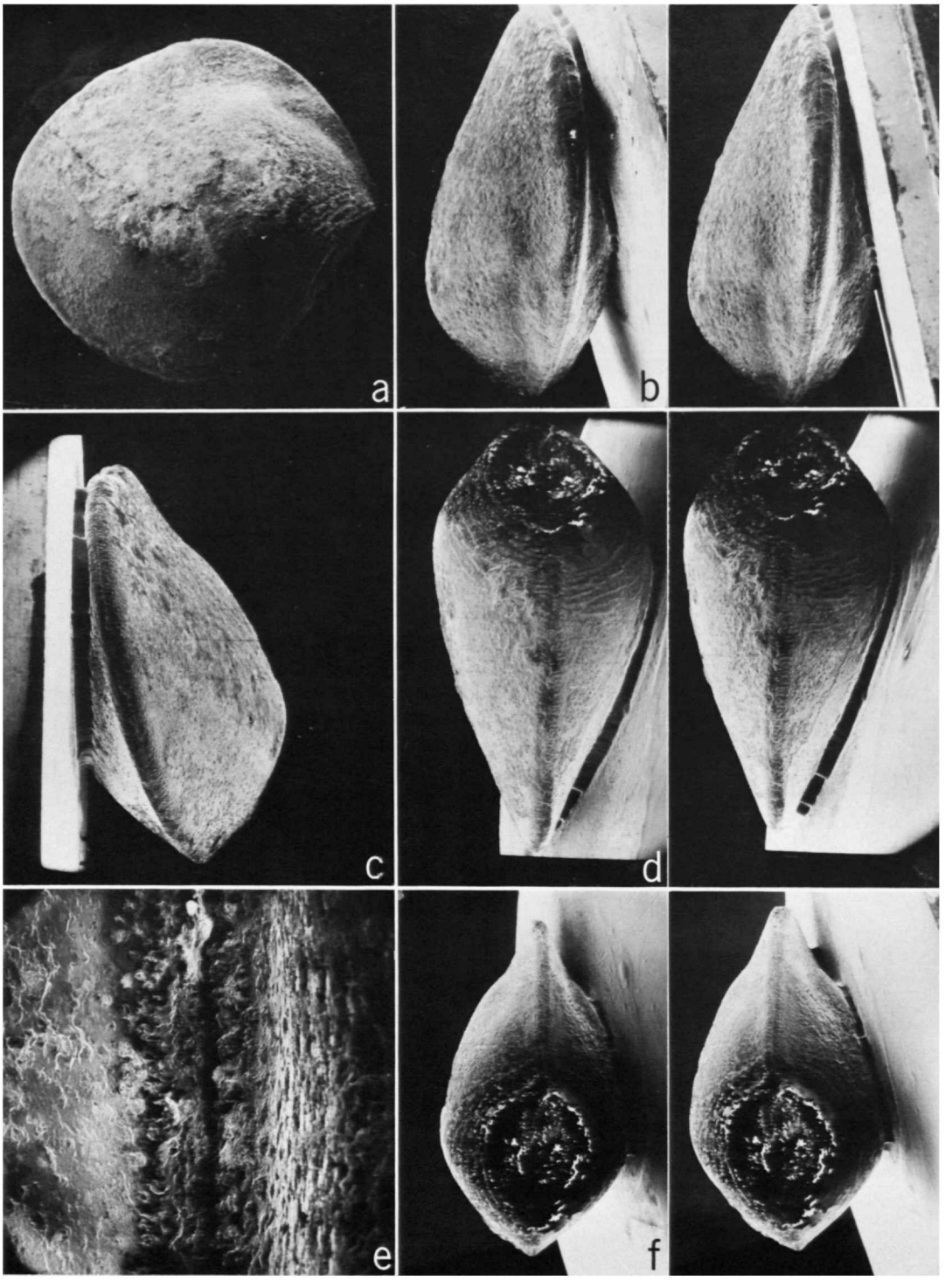


FIGURE 89.—*Entomoconchus scouleri* McCoy, 1839, steinkern, Royal Ontario Museum, no. 2529CB, Carboniferous, Wetton, England: *a*, lateral view of left valve, greatest length, 8.5 mm; *b*, detail of adductor muscle attachment scar; *c*, anteroventral margin, dorsal margin to the left; *d*, ventral view; *e*, anteroventral view to show convexity.


a
b
c
d
e
f

←—FIGURE 90.—*Checontonomus cophus* Kesling, 1954, holotype, Buffalo Museum, No. E15871, length 5.9 mm, height 5.8 mm, width 3.0 mm; *a*, right lateral view, approximately × 13; *b*, dorsal view, stereo-pair (anterior towards bottom); *c*, posteroventral view (ventral margin towards bottom); *d*, anteroventral view, stereo-pair; *e*, detail of hinge area along dorsal margin shown in *b*, orientation same as *b*; *f*, anterodorsal view, stereo-pair. (See discussion on page 118 for alternate orientations; photos reduced to 58 percent).

lated. One, the opening represents the equivalent of the incisur of many myodocopids; or two, the "anterior" is really the posterior, and the opening end is either a siphon, such as is present in some myodocopids, or it represents an aperture through which the body of a crustacean other than an ostracode protruded. We have not been able to determine from the published record or from examination of Devonian Crustacea in the National Museum of Natural History collections the taxon in which the Oncotechmoninae belong, if they are not ostracodes. Most living ostracodes are widest posterior to midlength. The position of the widest part of the Oncotechmoninae suggests that the straight portion of the shell represents the posterior of the carapace.

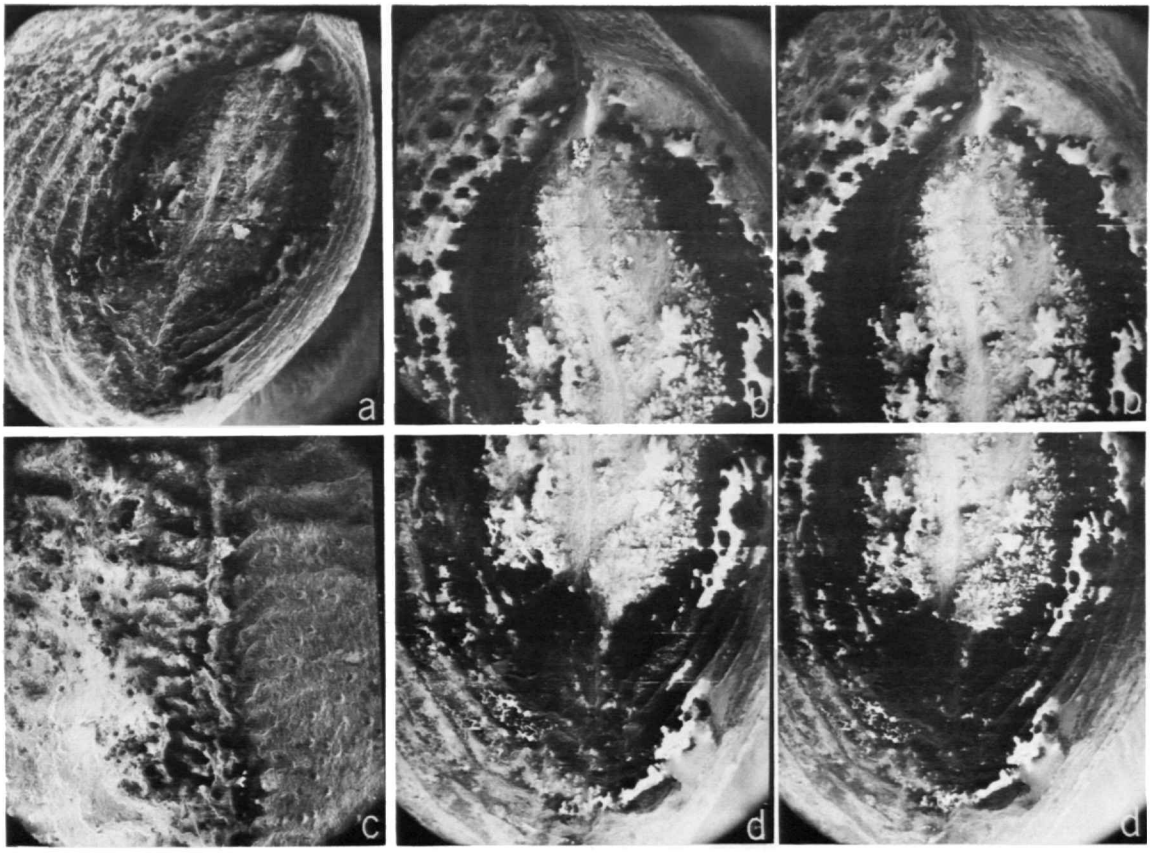


FIGURE 91.—*Checontonomus cophus* Kesling, 1954, holotype, Buffalo Museum No. E15871: *a*, oblique anterior view, approximately × 34; *b*, upper part of *a*, stereo-pair; *c*, detail of ventral contact near middle of valves shown in Figure 90*d*; *d*, lower part of *a*, stereo-view. (Photos reduced to 58½ percent).

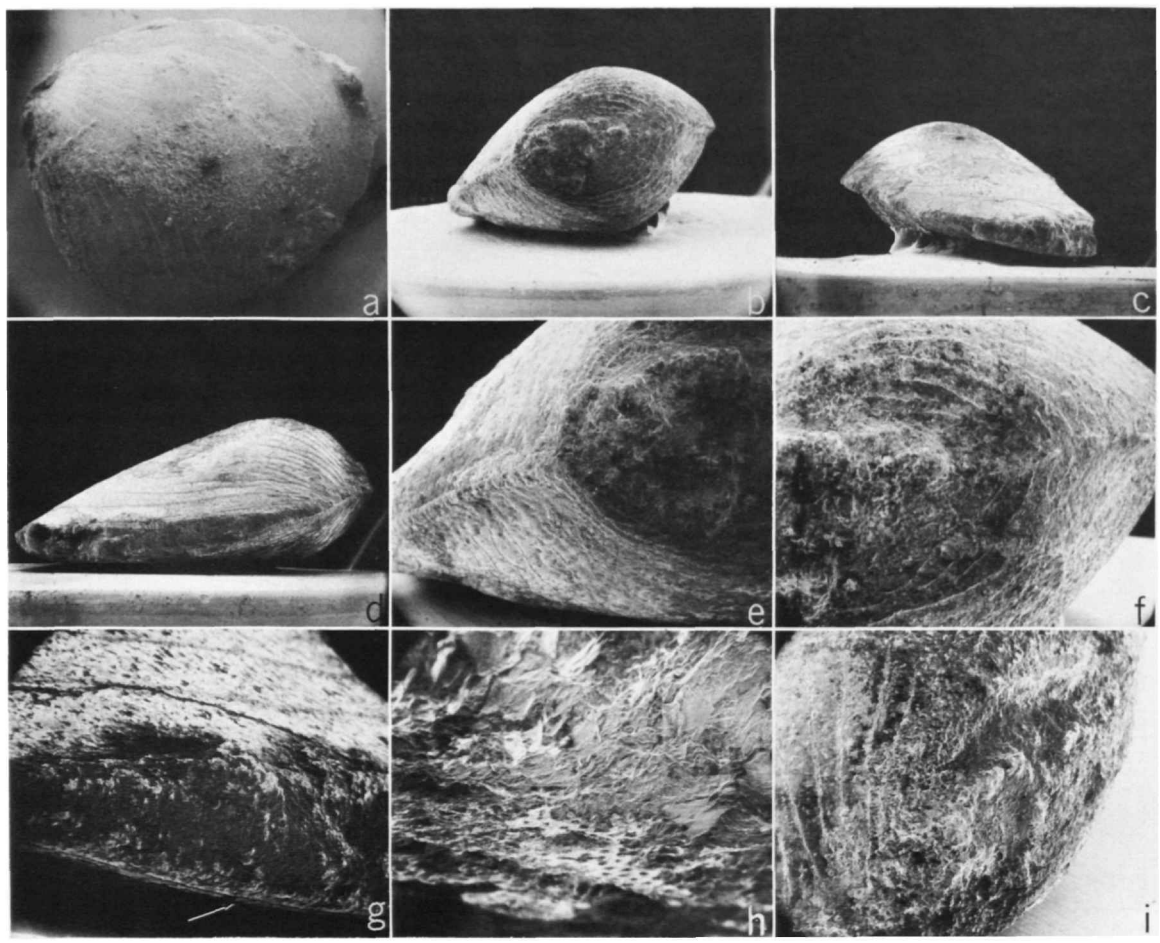


FIGURE 92.—*Oncotechmonus chemotus* Kesling, 1954, holotype. Buffalo Museum No. E14292a, length 7.4 mm, height 6.0 mm, width 3.2 mm *a*, left lateral view, approximately × 13; *b*, anterior view, ventral margin towards right; *c*, posteroventral view; *d*, dorsal view; *e*, dorsal part of anterior shown in *b*; *f*, ventral part of anterior shown in *b*; *g*, detail of posterior edge shown in *c*; *h*, detail of lower edge shown by arrow in *g*; *i*, oblique anterior view.

The available material does not permit conclusions regarding the correctness of any of the three possibilities enumerated above. Lacking conclusive evidence to the contrary, we leave open the question of whether or not the Oncotechmoninae are ostracodes.

Family CYPROSINIDAE Whidborne, 1890

The family Cyprosinidae Whidborne, 1890, was referred to the Entomoconchacea by Sylvester-Bradley (1953:132, 1961:Q397). This family is based on the monotypic genus *Cyprosina* Jones, 1881 (type-species *C. whidbornei* Jones, 1881, Middle Devonian, southern England): The genus, depending upon shell orientation, is either rostrate or has a posterior siphon, and has either a dorsal or a ventral sulcus (Sylvester-Bradley, 1953, pl. 8: figs. 1–3; Whidborne, 1889, pl. 4: figs. 1a, 2a, b). Zanina (1960:329) correctly referred the genus *Cyprosina* to the Cypridinidae Baird, 1850. The only other reference to this genus is by Chapman (1904:312,

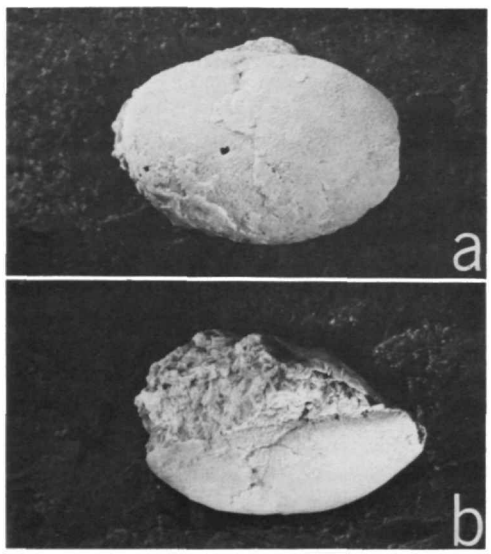


FIGURE 93.—*Cyprosina whidbornei* Jones, 1881, topotype, British Museum (Natural History), In-25911, Devonian, Lummaton near Torguan, Devon, South England: *a*, left valve; *b*, dorsal view. (Approximately × 3.)

pl. 16: fig. 4, pl. 17: fig. 1) who described and illustrated *Cyprosina* sp. from the Silurian of Victoria, but this reference is based on poorly preserved material. Chapman had also classified the genus in the Cypridinidae.

Through the courtesy of Dr. R. H. Bate, we have obtained from the British Museum (Natural History) a left valve (In-25911) of the type-species here illustrated (Figure 93). The specimen is an abraded valve showing a shallow sulcus near the dorsal margin in front of midlength. The posterior part of the valve is missing (Figure 93*b*); consequently, we could not examine the structure previously interpreted as either a rostrum or posterior siphon. We believe, however, that the specimen should be oriented with the sulcus near the top.

Crustacea?

FIGURE 14*a,b*

Thaumatocypris sp. indet.—Poulsen, 1969:12, fig. 2.

Through Dr. Torben Wolff we obtained for examination from the Zoological Museum of the University of Copenhagen the empty carapace described by Poulsen (1969) as *Thaumatocypris* sp. indet.

We were unable to detect on the carapace any indication of a hinge line such as the one shown on the specimen figured by Poulsen (1969, fig. 2). Creases are present on the specimen in the area where a hinge line should appear, but a sufficiently large area is free of creases to ascertain the absence of such a line (Figure 14*a*). Because of the absence of a hinge line we doubt that the carapace is that of an ostracode. Supporting evidence is the absence of muscle-scars, although we rely less heavily on that criterion because of the absence of information concerning the appearance of muscle-scars in molted or partly decomposed thaumatocyprid carapaces. In addition, none of the spines on the specimen has the thick well-defined wall present in the spines of *Thaumatocypris echinata* (compare Figure 14*b* with Figures 14*c,d*). In a brief survey of the literature we noted that some decapod larvae are multispinous, but we did not find any larvae having spines in the precise positions of those on the specimen on hand. These considerations form the basis for our referring the specimen to "Crustacea?."

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