Ordovician Ostracodes with Posterior Domiciliar Dimorphism

By

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ABSTRACT.—Domiciliar dimorphism of the kloedenellid type is definitely recognized in the new Ordovician family *Monotiopleuridae* which includes the genera *Monotiopleura* nov. and *Primitiella* ULRICH, 1897. The family is believed to be the earliest true member of the *Kloedenellacea.* Another new family of Ordovician ostracodes, the *Lomatopisthiidae*, is characterized chiefly by a special type of posterior domiciliar dimorphism, herein termed the lomatopisthid type of dimorphism. Four new lomatopisthid genera are described, viz. *Lomatopisthia* n.gen., *Dibolbopisthia* n.gen., *Bolbopisthia* n.gen., and *Physalidopisthia* n. gen. The family is at present not known outside of North America. Its classification at the superfamily level remains uncertain, and it is herein designated *incertae superfamiliae.* Seven monotiopleurid and lomatopisthid species are described, including the new species *Monotiopleura auriculata* and *Dibolbopisthia arbucklensis.* The terminology and morphology of the kloedenellacean carapace is discussed in some detail.

Contents

Introduction

The presence of domiciliar shell dimorphism of the kloedenellid type in Ordovician ostracodes has previously been reported only in *Primitiella* (KAY 1940, p. 262). During the early stages of the present investigation, GUBER found that another species, originally described as *Primitia* ? (? *Beyrichia*) *parallela* ULRICH (= *Monotiopleura auriculata* n.gen., n.sp.) from the Richmondian rocks of the Cincinnati area, clearly exhibits the kloedenellid type of dimorphism. JAANUSSON observed a similar dimorphism in specimens of *Thomasatia* (= *Lomatopisthia* n.gen.) *simplex* HARRIS which he collected in the Arbuckle Mountains of Oklahoma. A closer examination of *L. simplex* and allied species revealed the presence of a special type of posterior domiciliar dimorphism which is herein termed the lomatopisthid type of dimorphism. Further study of ostracodes found by the present writers in available samples of Ordovician rocks from Oklahoma, Virginia, and Minnesota revealed that Ordovician ostracodes with a posterior domiciliar dimorphism can be grouped into two well-defined divisions of the family-group category. These groups are described herein as the families *Monotiopleuridae* nov., possessing a dimorphism of the kloedenellid type, and *Lomatopisthiidae* nov. which includes velate ostracodes with the lomatopisthid type of dimorphism. The monotiopleurids are regarded as true kloedenellaceans whereas the classification of the lomatopisthids at the superfamily level must remain uncertain until more is known about the details of shell morphology in certain ordinary palaeocopes.

The monotiopleurid species from the Cincinnati area was one of several Richmondian palaeocope species treated by GUBER in a thesis which was supervised by Professor H. W. SCOTT and submitted as a partial fulfillment for the degree of Doctor of Philosophy at the University of Illinois. The present paper was prepared at the Palaeontological Institute of the University of Uppsala. GUBER's visit to Uppsala was made possible by a postdoctoral fellowship from the National Science Foundation, Washington, D.C.

The authors are indebted to Professor I. HESSLAND, University of Stockholm, for generously placing some of his samples from Oklahoma and Virginia at the authors' disposal; to Professor H. B. WHITTINGTON, Harvard University, for lending the writers the holotype of *Primitiella constricta varicata* HARRIS; to Dr. D. J. McLAREN, Geological Survey of Canada, for information concerning the present depository of the specimen figured by ULRICH (1889) as *Primitia*? (? *Beyrichia*) *parallela*; to Dr. J. BERDAN, United States Geological Survey, for making possible the examination of several described and undescribed ostracode specimens pertinent to the present study; to Dr. F. ADAMCZAK, Warszawa University, for demonstrating the structure of the hinge in several species of *Poloniella*; and to Dr. A. MARTINSSON, Uppsala University, for help and advice.

All specimens figured in this paper are deposited in the Museum of the Palaeontological Institute, University of Uppsala (series NA).

Terminology and Discussion of Morphology

The terminology of the carapace used in this paper, excepting the additions discussed below, is that summarized by JAANUSSON (1957).

STRAGULAR PROCESSES.—In the beginning of this investigation, it was found that a proper term did not exist for the dorsal "tooth-like processes" which are characteristic of many kloedenellaceans. Reference to these structures was found to be difficult without applying a special term to them. In the literature, many different denominations have been used for these processes. Some of these are the following: "simple articulation processes" and "tooth-like projections" (CORYELL & BLACKMIER 1931, p. 509); "hinge tooth" (SWARTZ 1933); "toothlike apophysis" (CORYELL & SOHN 1938, p. 599); "dorsal tooth" (ADAMCZAK 1961); "toothlike overlap", "toothlike process", and "cardinal teeth" (MOORE *et al.* 1961, pp. Q 180, Q 181, and Q 184, respectively). None of these designations is adequate, and the use of the term "tooth" in this connection is particularly misleading. Comprehensive glossaries of terms of the ostracode carapace (KESLING 1951; MOORE *et al.* 1961) do not list or define these structures.

The term *stragular process* (from Lat. *stragulum*, "saddle") is here proposed for the dorsal flap-like overlap of one valve over the other in the general area of the cardinal corners. The term cardinal corner is, in this connection, defined as the anterior or posterior termination of a straight or slightly convex dorsal contact margin of the valve when the junction between the dorsal contact margin and the free margin forms a distinct angle at both ends. The stragular process has been observed to occur among diverse ostracode groups. It occurs in the bassleratiid genus *Bassleratia*, the hollinid genus *Triemilomatella* (cf. JAANUSSON & MARTINSSON 1956, Pl. I, figs. 1 d, 3 d), and in several kirkbyids, but its presence is more often associated with kloedenellaceans, where the anterior stragular process attains a large size in some genera. It is also present in some genera of cytheraceans, such as *Paracytheretta* and *Protocytheretta*. It must be stressed that the stragular processes, as defined above, are structures connected with cardinal corners. Similar flap-like dorsal overlaps are also present in ostracodes which do not possess differentiated cardinal corners (*e.g.* as in some species of *Cavellina* and *Cytherelloidea*). In such cases as the latter it is at present better to designate the processes with some other term, such as *straguloid processes*.

The simplest form of the stragular process is a small flap-like overlap of the larger valve over the smaller valve with the process being situated immediately in front of the anterior cardinal corner, immediately behind the posterior cardinal corner, or in both areas. When the stragular processes are conspicuous and about equal in size, the result is the glyptopleurid type of dorsal margin. When the posterior stragular process is small or incipient and the anterior stragular process is large, the result is the dizygopleurid type of dorsal margin. No ostracodes have been observed in which the posterior stragular process is large and the anterior stragular process small or absent.

Observations on valves belonging to different kloedenellid genera revealed that an increase in the width (*tr.*) of the anterior stragular process is accompanied by a conspicuous modification in the adjoining part of the dorsal margin of the smaller valve. The portion of the dorsal margin of the smaller valve beneath the anterior stragular process develops a distinct notch, here termed the *substragular notch.* The reason for the development of this notch is rather apparent, because

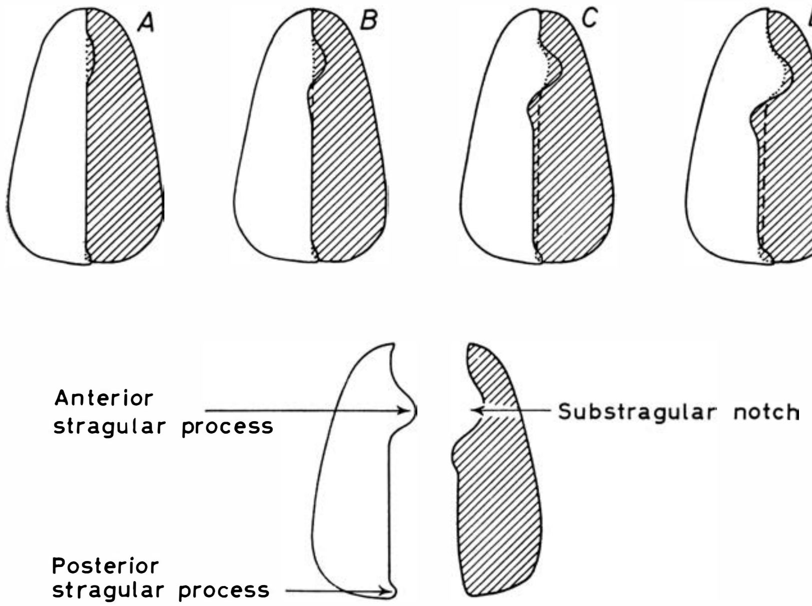

Fig. 1. Diagrammatic dorsal views of carapace of a monotiopleurid (*A*) and a Devonian *Dizygopleura* (*D*) and possible intermediate stages (*B*, *C*) in the development of the anterior stragular process. The dotted line shows the position of the margin of the smaller (right) valve where it is hidden beneath the overlapping larger valve; the dashed line shows the position of the margin of the larger (left) valve where it is overlapped by the smaller valve. The entire area of the smaller (right) valve including the parts overlapped by the larger valve is covered by oblique lines. The size of the posterior stragular process is exaggerated.

without a corresponding accommodation in the margin of the smaller valve, the large, rigid, overlapping flap of the larger valve would render the opening of the carapace impossible. A possible morphological development of the cardinal areas of the carapace from *Monotiopleura*-like ostracodes to forms like *Dizygopleura compsa* Kesling (cf. Kesling 1954, Pl. I & Pl. II, figs. 13–22) is diagrammatically presented in Fig. 1.

The examined material gives the impression that the hinge also may undergo modifications as a result of the varying strength of development of the anterior stragular process. The anterior end of the hinge, defined in a morphogenetical sense, is a point situated just at the posterior end of the anterior stragular process. As the anterior stragular process becomes longer, this point shifts in a posterior direction. As a result of this posterior shift, the hinge shortens, and, in the examined genera at least, an inclination of the hinge, with respect to the ventral margin, develops. This inclination of the hinge may be an adjustment in response to the shifting of the anterior end of the hinge in a posterior direction. In this way, the hinge actually becomes somewhat longer than if it had remained parallel to the ventral margin. However, this possible relation between the length of the hinge line and the inclination of the hinge must be studied on

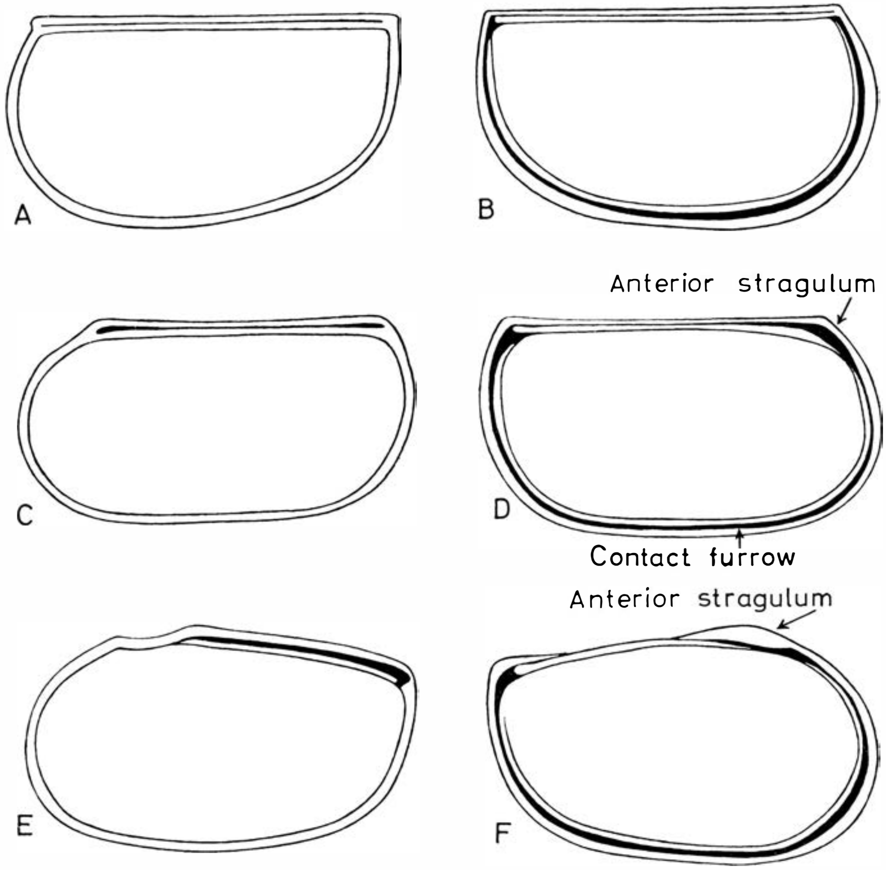

Fig. 2. Diagrammatic drawings of the three different types of hinges discussed in the present paper. Left valves to the right and right valves to the left. *A–B,* hinge of the *Bolbopisthia* type; *C–D,* hinge of the *Primitiella* type (see also Fig. 10); *E–F,* hinge of the *Poloniella* type (see also Fig. 3).

a more representative material than available to the writers, before safe generalizations can be made.

If a carapace has stragular processes at both cardinal corners, its valves cannot be moved relative to each other along the hinge in a longitudinal direction, even when the carapace is open to a certain degree. Apart from the prevention of the movement of valves relative to each other, the function of a strong anterior stragular process is not clear. In species of *Dizygopleura* the interlocking arrangement of a large anterior stragular process and the poststragular dorsal overlap of the smaller valve seems to prevent opening of the carapace more than to a certain degree. However, special studies are needed for attaining of a proper understanding about the exact function of these structures.

HINGEMENT.—The general type of hinge occurring in the ostracodes treated or discussed in this paper is often classified as adont (BOLD 1946) or "simple"

(SYLVESTER-BRADLEY 1956) or referred to as a ridge-and-groove arrangement. Although relatively simple and "toothless", the hinge of these ostracodes includes several well-defined types the distinguishing of which is important for taxonomic and phylogenetic purposes. The hinge has been satisfactorily described from only very few Palaeozoic ostracodes, and in several large groups details of the hinge are still unknown. For this reason it is at present difficult to make safe generalizations about the phylogenetic and morphogenetic significance of different types of hingement within the *Palaeocopa*. An elaborate terminology of different types of hinge has been proposed for post-Palaeozoic ostracodes. For the types of hinge treated in the present paper, it was found desirable to name them provisionally after the genus which best shows the characters of the particular type of hinge. The following three types of hinge pertain to the subject of the present paper:

1. *Bolbopisthia* type (Fig. 2, A–*B*). Both valves possess a longitudinal hinge groove which may be faint to almost absent medially. The anterior end of the groove in the larger valve terminates abruptly and has no connection with the contact furrow. The longitudinal ridges on either side of the hinge groove are approximately equal in size. Provisionally, this type of hinge includes ostracodes in which the hinge furrow of the larger valve has an abrupt termination posteriorly, as well as those which seem to possess a posterior communication between the hinge groove and the contact furrow or a socket-like structure at the posterodorsal end of the contact furrow. In the latter case the ventral hinge ridge always terminates abruptly and has no evident connection with the ridge bordering the contact furrow inside.

The name of this type of hinge must be regarded as provisional, because the available material of *Bolbopisthia carinata* is silicified and does not show all of the details of the hinge clearly. The *Bolbopisthia* type of hinge characterizes large lomatopisthids and probably occurs in several other groups of the *Palaeocopa*.

2. *Primitiella* type (Fig. 2, *C–D*; cf. also Fig. 10). Both valves possess a longitudinal hinge groove which may be faint to almost absent medially. The anterior end of the hinge groove of the larger valve curves anteroventrally and forms a direct continuation of the contact furrow. The ventral hinge ridge of the larger valve has an abrupt posterior termination. Both hinge ridges are about equal in size.

This type of the hinge characterizes the family *Monotiopleuridae*.

3. *Poloniella* type (Fig. 2, *E–F*; cf. also Fig. 3). The larger valve possesses a prominent hinge ridge which abruptly terminates posteriorly. The anterior part of the ridge is bordered dorsally by a continuation of the contact furrow which, in most cases, disappears immediately behind the anterior stragular process, but in some cases it can be observed to continue as a faint groove to the posterior termination of the contact furrow. The smaller valve possesses a deep longitudinal hinge groove. The hinge ridge of the larger valve and the hinge groove of the smaller valve are often slightly curved but are quite straight in some species.

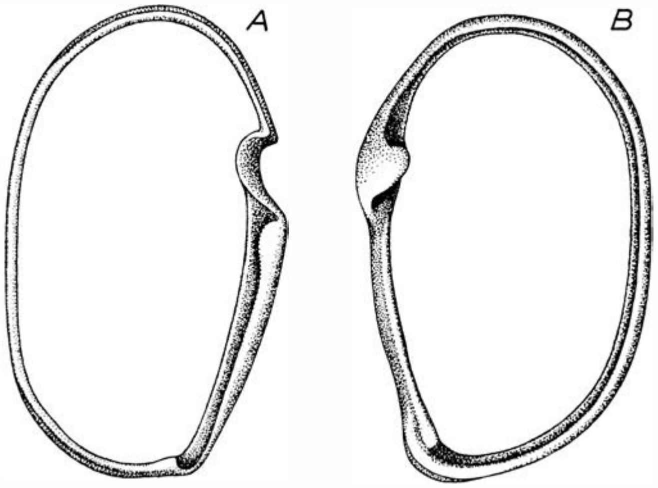

Fig. 3. *Dizygopleura* sp. Diagrammatic drawing of the hinge of the right (*A*) and left (*B*) valves Michigan, Ferron Point Formation. Middle Devonian. Nos. NA 143, 144.

This type of hinge occurs in all examined genera of true kloedenellids. It is termed the *Poloniella* type because its features are distinct and can be well studied in several species of *Poloniella*.

Apparently it is not difficult to derive the *Poloniella* type of hinge from the *Primitiella* type. It is evident that, in the larger valve, the prominent hinge ridge of the kloedenellids corresponds to the ventral hinge ridge of the same valve in the monotiopleurids, and that the hinge groove and the dorsal hinge ridge, as developed in the larger valve of the monotiopleurids, are reduced to a considerable extent in the kloedenellids. A derivation of the *Primitiella* type of hinge from the *Bolbopisthia* type is not as obvious, as there is a morphological discontinuity between these types. This is expressed in the presence of an anterior connection between the hinge groove and the contact furrow in the former type and the lack of such a connection in the latter type.

The term contact margin as used in the present paper denotes the entire inner margin of the valve, viz. the free margin as well as the dorsal margin of the hinge. In velate ostracodes the outline of the contact margin seems to be of a greater significance than that of the lateral margin of the valve. The unequal width of the velar structure, as well as the varying distance between the velar structure and the free margin, causes considerable differences in some cases between the lateral outline of the valve and the outline of the contact margin. Velate ostracodes which differ in lateral outline may have nearly identical outlines of the contact margin.

Discussion of Taxonomy

The occurrence of undoubted kloedenellaceans in pre-Silurian rocks has hitherto been uncertain. Although species referred to kloedenellid genera have occasionally been reported from Ordovician strata, none of them seems to have kloedenellid affinities. *Eukloedenella richmondensis* SPIVEY, 1939, based on a single carapace from the Maquoketa Shale of Iowa, is so different from kloedenellids in its posterior outline and short hinge that its inclusion in the *Kloedenellacea*, in general, and *Eukloedenella*, in particular, is scarcely tenable. It is also difficult to see any kloedenellid affinities in the single incomplete valve described by HESSLAND (1949, pp. 364–365, Pl. X, fig. 8) from the Ontikan ("upper Lower Ordovician") *Raniceps* Limestone of Sweden as *Kloedenella* ? *dorsodepressula* HESSLAND.

Recently, KRAFT (1962) included *Balticella* THORSLUND, 1940 and the new genus *Eokloedenella* from the Champlainian ("Middle Ordovician") Lower Edinburg Formation of Virginia in the family *Kloedenellidae.* The writers have examined numerous specimens of both these genera, and they cannot agree with KRAFT about the kloedenellid affinities of these ostracodes. Neither of these genera shows any indication of possessing a shell dimorphism of the kloedenellid type. In *Balticella* the construction of the hinge is of a general *Bolbopisthia* type which occurs in several other Ordovician ostracodes, but not in kloedenellids. A detailed discussion about the taxonomic position of *Balticella* lies outside the scope of the present paper, but this genus certainly is not a kloedenellacean. *Eokloedenella* is a *Primitia*-like ostracode. It possesses a faint contact furrow on the inside of the left valve close to the free edge and apparently a general *Bolbopisthia* type of hinge. The outline of the valve and the posterior groove suggest that it is a member of *Leperditellidae.*

Primitia ? (? *Beyrichia*) *parallela* ULRICH was referred to by BASSLER & KELLETT (1934, p. 203) as *Beyrichia* (*Kloedenella* ?) *parallela.* In this case, the latter tentative generic assignment could be proven to include a kernel of truth as far as the kloedenellid affinities are concerned. Reinvestigation of an ostracode included in this species by ULRICH and BASSLER & KELLETT from the Richmondian of the Cincinnati area has shown that it possesses several characteristic kloedenellacean features, and that it may be regarded as a true kloedenellacean. This species is described herein as *Monotiopleura auriculata* n.gen., n.sp. and considered to belong to the new family *Monotiopleuridae.* The kloedenellid type of dimorphism was previously described in *Primitiella* by KAY (1940). Examination of several species of this genus revealed the presence of the same general characters as in *Monotiopleura* and strongly suggests that both genera belong to the same family. *Primitiella*-like forms are among the earliest ostracodes, at least in the Balto-Scandian sequence. The taxonomic reference of several of them is still unclear, but some seem to be monotiopleurids. If this is the case, the range of the *Kloedenellacea* should be extended downwards to Lower Ordovician, possibly to the beds comparable to the zone of *Didymograptus hirundo.*

For purposes of comparison with the monotiopleurids, specimens of most kloedenellid genera were examined in connection with this study. This examination resulted in the following diagnosis of the family *Kloedenellidae:*

Kloedenellacea with a long anterior stragular process and characteristically with a dorsal, poststragular overlap of the smaller valve over the larger valve (usually the left valve but occasionally the right valve). Outline of the valve more or less subrhomboidal with a somewhat sinuous ventral margin; dorsal margin usually, but not exceptionally, convergent with the ventral margin in a posterior direction. No velar structure. Larger valve overlaps the smaller valve along most of the free margin and has a distinct contact furrow inside the valve. Hinge of the *Poloniella* type; larger valve with a prominent, mostly slightly curved longitudinal hinge ridge which has an abrupt posterior termination whereas anteriorly it usually merges with the general surface of the inside of the valve ventrally of the anterior stragulum; smaller valve with a deep hinge groove. Distinct domiciliar dimorphism of the kloedenellid type.

The delimitation of the family *Kloedenellidae* as used in the discussions in the present paper agrees with that of SOHN (in MOORE *et al.* 1961). The inclusion of *Oliganisus* in this family, however, needs confirmation and must be considered as uncertain until the hinge of this genus is described. On the other hand, *Poloniella*, as pointed out by ADAMCZAK (1961), is an undoubted member of the family. It is very similar to *Dizygopleura* but its recognition is useful for *Dizygopleura*-like ostracodes with a narrow (*tr.*) anterior stragular process.

The monotiopleurids possess many of the characteristic kloedenellid features, such as the type of dimorphism, shape of the valves, closure of the carapace, and an anterior stragular process. They differ from the kloedenellids mainly by the absence of a dorsal poststragular overlap of the smaller valve, short and narrow anterior stragular process, and the construction of the hinge. It does not appear difficult to derive the kloedenellid characters from those of the monotiopleurids (as to the hinge, see p. 7). The known members of the *Monotiopleuridae* are exclusively Ordovician, whereas the earliest known undoubted kloedenellid (a new genus and species) is from the uppermost Llandoverian beds of Gotland. There is at present no evidence against the probability that the monotiopleurids have been the ancestral stock of post-Ordovician kloedenellaceans, and that they can be classified as a member of the superfamily *Kloedenellacea*.

Another group of Ordovician ostracodes with a domicilial dimorphism is described in this paper as the new family *Lomatopisthiidae*. The dimorphism of these ostracodes differs from that of the kloedenellid type by the heteromorphic inflation of the valve being confined to the posteroventral and posteromedian parts of the postadductorial area, whereas a narrow strip of the valve close to the dorsal margin of the postadductorial area retains its tecnomorphic shape (the lomatopisthid type of dimorphism, cf. p. 23). In addition to the differences in shell dimorphism, the lomatopisthids differ from the monotiopleurids and the other kloedenellaceans by the invariable presence of a velar structure, absence of an anterior stragular process, and a roughly symmetrical construction of the hinge without a direct anterior connection between the contact furrow and the hinge furrow. On the other hand, certain characters suggest that the family may

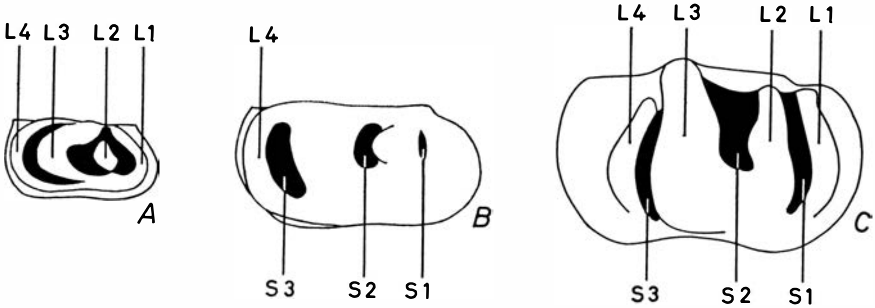

Fig. 4. A comparison of the lobation and sulcation of the tecnomorphic valves of *Lomatopisthia simplex* (*A*), *Monotiopleura auriculata* (*B*), and *Dizygopleura* cf. *swartzi* (*C*).

be related to the *Monotiopleuridae*. The lomatopisthid type of shell dimorphism can, morphologically, be considered as a modification of the kloedenellid type of dimorphism. Small members of the lomatopisthids (*Lomatopisthia* n.gen., *Raymondatia*, *Dibolbopisthia* n.gen.) have a subrhomboidal shape of the valves as in monotiopleurids and most other kloedenellaceans. In these lomatopisthid genera a ridge-like L4 is situated at or near the posterior margin of the valve (cf. Fig. 4 A) and generally projects in a posterior direction as in *Monotiopleura* (cf. Fig. 4*B*). The development of marginal structures and of an anterior recessed area in *Lomatopisthia varicata* (cf. Pl. IV, fig. 1; text-fig. 14) is strikingly similar to corresponding structures of the monotiopleurids. The closure of valves along the free margin as observable in large lomatopisthids agrees with that of the monotiopleurids.

If the lomatopisthids are related to the monotiopleurids, they form a kind of a link between the latter family and the ordinary palaeocopes. The lomatopisthids agree with many palaeocopes in the general construction of their hinge and in the invariable presence of a distinct velar structure which is unknown among true kloedenellaceans. In fact, the presence of the lomatopisthid type of dimorphism is at present the only known well-defined character which distinguishes the lomatopisthids from *Tallinnopsis*-like palaeocopes and their probable relatives. Unfortunately, details of the hinge and of the closure of the valves is still poorly known among the latter ostracodes, and this makes a comparison incomplete and the results inconclusive. Until such details have been described it is difficult to arrive at a motivated decision about the taxonomic position of the *Lomatopisthiidae* within the *Palaeocopa*. For this reason the family is considered here tentatively as *incertae superfamiliae*.

In defining the suborder *Kloedenellocopina*, Scott (in Moore *et al.* 1961, pp. Q 85–86, Q 180) laid particular stress on strong overlap of the smaller valve by the larger around all or a portion of the free margin. The suborder *Beyrichicopina*, on the other hand, was considered to be characterized by subequal valves, both valves being beveled along the free margin so that when closed the valves meet without apparent overreach (SCOTT in MOORE *et al.*, 1961, pp. Q 83, Q 111). However, several genera classified in MOORE *et al.* (1961) as beyrichicopinids have the same type of overlap conditions along the free margin as in the *Kloedenellacea*. Examples of such genera are *Euprimites*, *Oepikella* (cf. JAANUSSON 1957), *Diplopsis* (classified in MOORE *et al.* 1961, Figs. 106:a–b as *Oepikella*), *Hyperchilarina* (regarded by Moore *et al.* 1961, p. Q 189 as synonymous with *Conchoprimitia*, but undoubted members figured as *Aparchites* (Figs. 108: 2f–h, 109: 1a–f)), and *Dilobella*. For this reason it seems that overlap conditions can scarcely be used for defining these order-group taxonomic divisions, and that their significance is at present doubtful for suprafamiliar classification of the lomatopisthids.

The material described in the present paper indicates that kloedenellids may be more closely related to the ordinary palaeocopes than is evident from some recent classifications (POKORNÝ 1958; MARTINSSON 1962). If the lomatopisthids are closely related to the monotiopleurids, the roots of the kloedenellaceans may lie within velate palaeocopes, and it would be difficult to draw a distinct line between these palaeocopes and early kloedenellaceans. If the similarity between the lomatopisthids and the monotiopleurids is due to a homoeomorphic development, the roots of the kloedenellaceans can be sought within *Leperditellacea* (JAANUSSON 1957). However, much more knowledge is needed about the hingement and closure of the valves in early ostracodes before phylogenetic discussions leave the realm of speculation.

Family *Monotiopleuridae* n.fam.

DIAGNOSIS.—*Kloedenellacea* with an incipient anterior stragular process and without a dorsal, poststragular overlap of the smaller valve. Lateral outline of the valve more or less subrhomboidal; hinge line long and parallel to the ventral margin; ventral margin straight to somewhat sinuous; posterior margin straight to somewhat convex. No velar structure. Marginal to admarginal ridges well defined and anteriorly bordering a characteristic, narrow recessed area. Left valve overlaps the right valve along the ventral and posterior free margin and has a distinct contact furrow inside the valve. Hinge of *Primitiella* type; left valve with a longitudinal hinge groove bordered by two longitudinal hinge ridges of about equal size; anteriorly the hinge groove is curved and has a direct continuation into the contact furrow. Distinct domiciliar dimorphism of the kloedenellid type.

GENERA.—*Monotiopleura* n.gen.
Primitiella ULRICH, 1897

A further, new monotiopleurid genus is probably represented by a group of Ordovician *Primitiella*-like ostracodes with a short but distinct S2 (species as *Primitiella fastidiosa* SARV and *P. molli* BONNEMA). This group is at present not known outside Balto-Scandia.

The authors also suspected that the genus *Haploprimitia* ULRICH & BASSLER, 1923 might be a monotiopleurid. An examination of the type of *Primitia minutissima* ULRICH, 1894 in the U.S. National Museum, however, showed that the valve is very small and very likely belongs to an early instar. Its surface and margins are exceedingly corroded, and details of the surface, cardinal corners, and the marginal region are obliterated. The species is not recognizable and ought to be considered a nomen dubium. Thus the genus *Haploprimitia* also becomes a nomen dubium.

DISCUSSION.—The anterior stragular process in the monotiopleurids is a very small and narrow structure, situated just in front of the anterior cardinal corner. It is visible in the dorsal view of a carapace as a faint flexure of the contact margin and is difficult to observe without ink staining. In separate valves the process is often very difficult to recognize as it is commonly worn off in weathered specimens. From this minute structure the long anterior stragulum of the kloedenellids can be easily derived, simply by increasing the length and width of this flange-like overlap.

The main differences between the *Monotiopleuridae* and the *Kloedenellidae* are given in the chapter on taxonomy, but some additional remarks are here deemed necessary. The presence of a marginal structure has not been observed in the kloedenellids, whereas this structure is well developed in the monotiopleurids. Certain post-Silurian ostracodes currently included in the *Kloedenellacea* have been reported to possess a velar structure (HENNINGSMOEN 1953; SOHN in MOORE *et al.* 1961, p. Q 185). Examination of some species of beyrichiopsids revealed, however, that the structure identified as a velar structure is a marginal to admarginal structure comparable to that in monotiopleurids. The presence of a velar structure in these kloedenellaceans has not yet been proven. Another feature of the monotiopleurids is the recessed area along the anterior free margin. This structure is not known to occur in the kloedenellids, but has been observed in certain post-Silurian kloedenellaceans and their probable derivatives. It can be seen that the monotiopleurids have some characters which are present in certain post-Silurian non-kloedenellid kloedenellaceans, but which are lacking in the kloedenellids. Thus the question arises as to whether or not some kloedenellaceans have developed directly from monotiopleurid-like ancestors rather than from the kloedenellids. Without a better knowledge about the structure of the hinge in these post-Silurian ostracodes this problem can scarcely be discussed.

OCCURRENCE.—The earliest *Primitiella*-like ostracodes have been reported from strata roughly corresponding to the zone of *Didymograptus hirundo*. However, at the present state of our knowledge it is difficult to ascertain whether or not they are true monotiopleurids. Ostracodes which seem to be undoubted monotiopleurids occur in beds corresponding to the next following graptolite zone (the British-Scandinavian zone of *Didymograptus bifidus*). The latest known representatives of the family have been found in strata close to the top of the

Ordovician System. No undoubted post-Ordovician monotiopleurids have been seen by the present writers, though the genus *Primitiella* has been recorded to occur in Ordovician to Upper Devonian strata.

Genus *Monotiopleura* n.gen.

Type species.—*Monotiopleura auriculata* n.sp.

Derivation of the name.—From Greek μονάς, one, ὠτίον, small ear, and πλευρά, side, alluding to the ear-like projection of L4.

Diagnosis.—A member of the *Monotiopleuridae* with bi- to trisulcate valves. L4 is situated very close to the posterior margin of the valve and is usually overturned and protrudes in the posterior direction.

Discussion.—The type species and *Primitia* ? (? *Beyrichia*) *parallela* Ulrich, 1889, are the only known species that are referable to the genus.

Monotiopleura differs from *Primitiella* by the distinctly bi- to trisulcate condition of the valves and by the ridge-like, posteriorly protruding L4. In the other respects these genera are very similar. Some other minor differences may be of specific rather than generic value.

Occurrence.—Species here referred to the genus *Monotiopleura* have been reported from the Richmondian (Upper Ordovician) of Indiana, Ohio, Iowa, Wyoming, Manitoba, and Anticosti.

Monotiopleura auriculata n.sp.

Pl. II, figs. 1–15, Pl. III, figs. 1–4; Text-figs. 5–8.

1889 *Primitia* ? (? *Beyrichia*) *parallela* n.sp. — Ulrich, p. 51 (partim) [non Pl. 9, figs. 7, 7a = *Monotiopleura parallela* (Ulrich)].
1890 *Beyrichia* (? *Primitia*) *parallela* Ulrich — Ulrich, p. 125 (partim), Pl. 10, figs. 15a–d.
1908 *Beyrichia parallela* (Ulrich) — Ulrich & Bassler, p. 319, Text-fig. 64.
1915 *Beyrichia parallela* (Ulrich) — Bassler, p. 122.
? 1927 *Beyrichia parallela* (Ulrich) — Twenhofel, p. 343.
? 1929 *Beyrichia parallela* (Ulrich) — Ladd, p. 370.
1934 *Beyrichia* (*Kloedenella* ?) *parallela* (Ulrich) — Bassler & Kellett, p. 203 (partim).
1952 *Primitia* ? *parallela* (Ulrich) — Ellis & Messina (partim) [non Figs. 7, 7a = *Monotiopleura parallela* (Ulrich)].

Holotype.—Heteromorphic carapace, No. NA 79, figured on Pl. II, figs. 1–5.

Type stratum and type locality.—Whitewater Formation of the Richmond Group. From the outcrop along the north bank of the east flowing tributary of Paint Creek and the adjacent outcrop along Ohio Highway 725, 0.75 miles west of city limits of Camden, Ohio, S. E. 1/4, S. E. 1/4, sec. 8, T. 6 N., R. 2 E., Preble County, Ohio, U.S.A.

Derivation of the name.—From Lat. *auriculus* (*-a*, *-um*), small ear, alluding to the ear-like projection of L4.

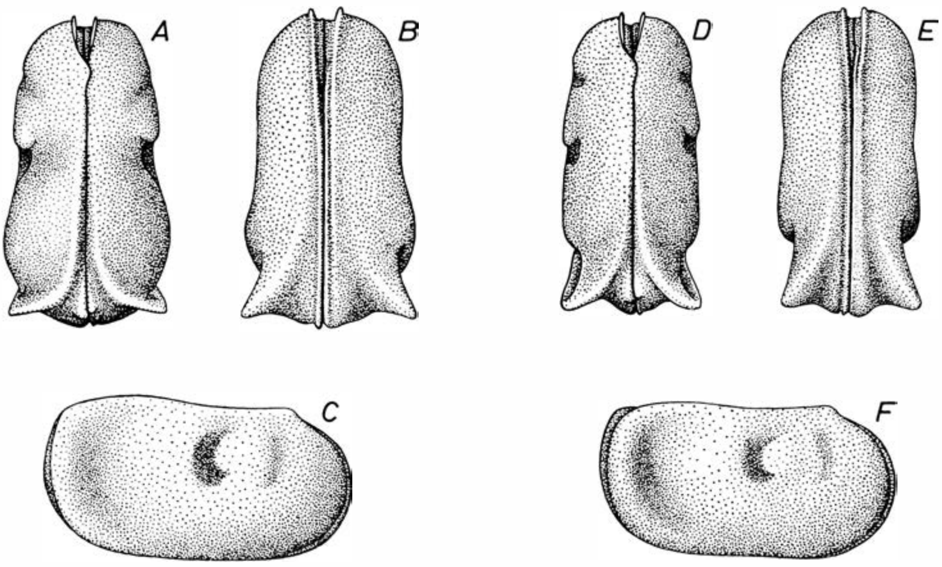

Fig. 5. *Monotiopleura auriculata* n.sp. Diagrammatic drawing of a heteromorphic (*A–C*) and a tecnomorphic (*D–F*) carapace in dorsal (*A*, *D*) and ventral (*B*, *E*) view, and its right valve in lateral (*C*, *F*) view. Magnification about ×40.

DESCRIPTION.—*Adult tecnomorphs.* Outline amplete, anterior margin evenly rounded, ventral margin straight to slightly sinuate, posterior margin broadly rounded to nearly straight. Dorsum epicline in posterior two-thirds, hypocline in anterior third. Valves strongly convex when viewed from anterior. Anterior cardinal angle about 130°, posterior cardinal angle about 100°.

Valves trisulcate. S1 narrow, arcuate, and rather indistinct. S2 deep, gently curves around the preadductorial node. S1 and S2 equally long, both closing ventrally about mid-height. In some specimens, S1 moderately incised and extends two-thirds the valve height from the dorsal margin. S3 wide, crescent-shaped, deeply incised, closing both dorsally and ventrally at points about one-quarter the valve height from each respective border. Preadductorial node very low and poorly defined in its anterior portion. L4, the only well developed lobe, is sharply elevated and represents the highest part of the lateral surface. It is long, narrow, arcuate, and overturned to the posterior. L4 begins slightly anterior of the posterior cardinal corner, curves ventrally, and loses its identity near the ventral border.

Each valve possesses a small marginal or admarginal ridge. The anterior portion of this ridge is a very narrow elevated structure. The ridge begins at the anterior cardinal corner where it is immediately adjacent to the free edge, assuming the position of an admarginal ridge. When this ridge is further traced to the ventral border, it behaves differently on opposing valves. On the left valve, the ridge becomes differentiated into two elements. One element is a narrow ridge which is situated along the free edge. The other element is a considerably wider

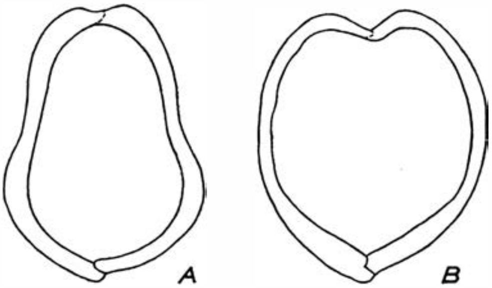

Fig. 6. *Monotiopleura auriculata* n.sp. Two transverse sections through a carapace. Fig. *A* is a section through S2 and Fig. *B* through L3. Details of the contact of the valves are obscure at the hingement owing to recrystallization. Magnification about × 60.

marginal bend of the valve. On the right valve, the ridge maintains its admarginal position around the ventral and posterior borders. The ridge of the right valve continues to the posterior cardinal corner, but the ridge and the marginal bend of the left valve lose their identity as they are traced along the posterior margin. A distinct recessed area is situated along the anterior free edge. This area is distally bounded by the admarginal ridge, and, in ventral view, it assumes the shape of a narrow, flat-bottomed shelf, distinctly indented below the general surface of the valve. This recessed area of both valves becomes narrower and disappears when traced to the ventral border. In a closed carapace, the free edge of the left valve is in contact with the admarginal ridge of the right valve.

Valves unequal in size, the left valve overlapping the right. The contact furrow is deep and farthest from the free edge along the ventral margin. In anterior direction the furrow becomes shallower and the distance between the furrow and the free margin decreases until the contact furrow disappears at a point somewhat ventrally from the mid-height of the valve. The furrow reappears again close to the anterior cardinal corner, somewhat dorsally from the mid-height of the valve, and is well defined at the level of the anterior stragular process. The contact furrow becomes shallower also along the posterior margin of the valve towards the posterior cardinal corner, but details are obscure owing to the state of preservation. Thus the overlap is greatest along the ventral margin of the carapace, seemingly moderate along the posterior margin, slight anterodorsally and anteroventrally, and absent in the area around the mid-height of the anterior margin.

Hinge line long, parallel to ventral margin, and incised along the posterior two-thirds. Details of the hinge structures difficult to observe owing to the state of preservation. The right valve possesses a distinct longitudinal groove which is narrow along the medial portion of the hinge and becomes deeper and broader as the cardinal corners are approached. The groove is bordered dorsally by the valve edge and ventrally by a low ridge. The hinge elements of the left valve are rather obscure because of the poor state of preservation. In the area of the

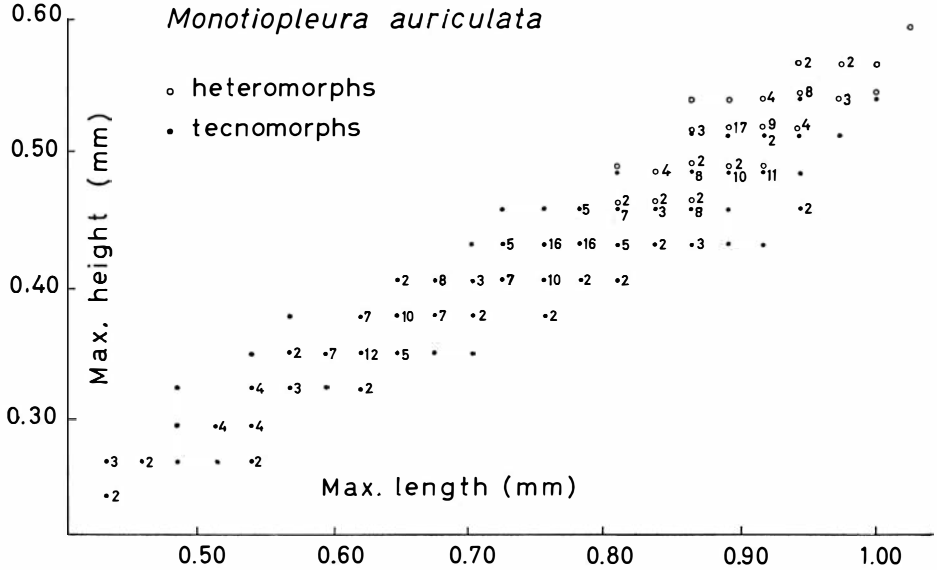

Fig. 7. *Monotiopleura auriculata* n.sp. Size dispersion of left valves in a sample from the type locality. The figures refer to number of valves of the size in question.

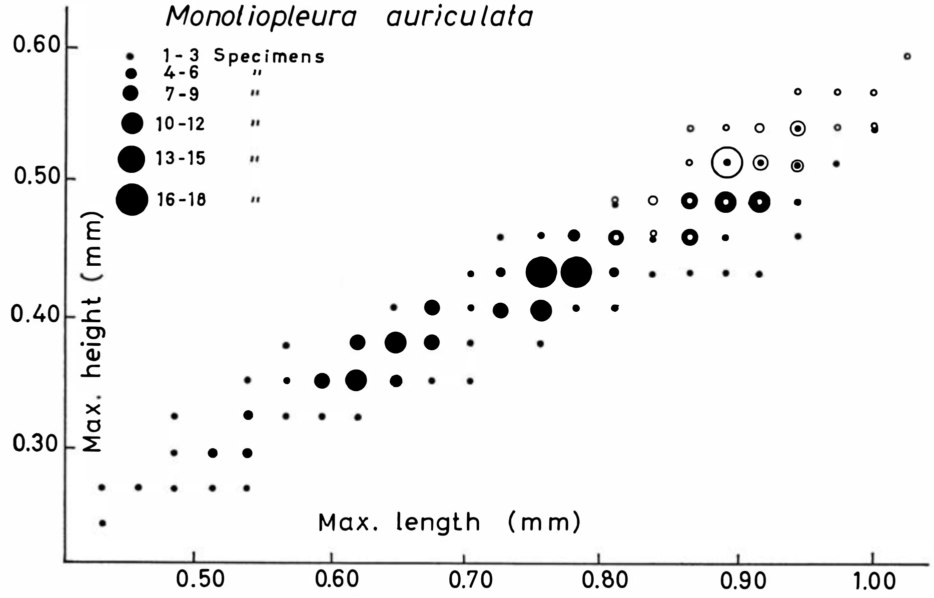

Fig. 8. *Monotiopleura auriculata* n.sp. Size dispersion of left valves according to the data in Fig. 7. Dots refer to tecnomorphs and circles as well as white dots within black dots to heteromorphs.

anterior cardinal corner the contact furrow widens and forms a broad depression which appears to be traceable into a narrow longitudinal groove along the hinge. It should be noted that all of the observable hinge elements of *M. auriculata* agree with those of *Primitiella minima.*

Well preserved valves exhibit a faint pattern of small reticulae.

Heteromorphs. The valves of the heteromorphs are similar to those of the adult tecnomorphs, with the exception of modifications accompanying domiciliar dimorphism.

Area of valves posterior of S2 distinctly inflated. Outline postplete. Ventral border tends to be more sinuate than in tecnomorphs. Posterior inflation almost obliterates S3, reducing it to a shallow, arcuate depression. Definite posterodorsal hump present. Hinge line more strongly incised than in tecnomorphs.

Immature instars. Three possible preadult instars were found. Adult –1 and adult –2 instars similar to adult tecnomorphs, except for size. Adult –3 instar is preplete, S3 not deeply incised, S1 relatively strong with respect to adults.

DIMENSIONS.—See Figs. 7–8.

DISCUSSION.—ULRICH (1889) based the species *Primitia*? (? *Beyrichia*) *parallela* on two imperfect valves from Manitoba and on several isolated valves from Oxford, Ohio. The figure which accompanied the original description of the species was drawn after one of the specimens from Manitoba. ELLIS & MESSINA (1952) designated the locality in Stony Mountain, Manitoba as the type locality. One of the writers (A. L. G.) was fortunate in being able to examine topotype specimens of *M. parallela* which were so kindly made available by Dr. J. BERDAN of the U.S. Geological Survey. Although these specimens were not well preserved, none of them exhibited any indication of an S1 which is invariably present in specimens of *M. auriculata.* In all other observable characters the bisulcate *M. parallela* agrees with the trisulcate *M. auriculata.* It should be noted that well preserved specimens of the bisulcate *M. parallela* also occur in the upper part of the Big Horn Dolomite (Richmondian) of Wyoming.

OCCURRENCE.—Very common in the Whitewater Formation of the Richmond Group (Upper Ordovician) of Indiana and Ohio. Specimens identified as *Beyrichia parallela* (ULRICH) have been reported from the Maquoketa Formation (Upper Ordovician) of Iowa (LADD 1929) and from the Vaureal Formation (Upper Ordovician) of Anticosti (TWENHOFEL 1927), but, because the specimens were not figured, their specific assignment is questionable.

Genus *Primitiella* ULRICH, 1897

TYPE SPECIES.—*Primitiella constricta* ULRICH, 1897.

DIAGNOSIS.—Nonsulcate monotiopleurids, usually with a broad, poorly defined, submedian sulcal depression but without other sulcal or lobal structures. The left valve normally with a faint depressed border paralleling the ventral part of the free margin. In heteromorphs the hinge-line is incised along the posterior part of the dorsal margin and the dorsum distinctly epicline.

Dimorphism, marginal structures, anterior stragular process, and anterior recessed area as in *Monotiopleura.*

DISCUSSION.—The genus *Primitiella* has often been a waste-basket for elongate, nonsulcate or faintly unisulcate early Palaeozoic ostracodes with a long and straight hinge. KAY (1940) improved the definition of the genus, but because he apparently did not have access to closed carapaces, he did not observe or describe some of the diagnostic characters. Such characters are, for instance, the conspicuous overlap of the left valve over the right valve along the free margin, the presence of marginal structures and of an anterior recessed area, and the development of the incipient anterior stragular process. He mentioned the presence of a faint border-like depression along the free margin of the valve, but obviously did not recognize its absence on the right valve (the ventral view of valves of *Primitiella* figured by KAY 1940, Pl. 33, figs. 24, 26, 28, 30, show the left valve exclusively).

An examination of ULRICH's cotypes of *P. constricta* in the collections of the U.S. National Museum showed that, although the specimens figured by him are poorly preserved and do not expose all characters, they are congeneric with the species described by HARRIS (1957) as *Leperditella rex* var. *minima.* This could be further corroborated by a study of abundant material of *Primitiella* from the lowermost Decorah Shale of Minneapolis, Minn., in the Uppsala collections. The latter material, however, does not include any closed carapaces. For this reason *P. minima* (HARRIS) has been chosen to illustrate the generic characters of the genus *Primitiella.* The available material of this species is better preserved than that of *Primitiella* from Minnesota and contains several good closed carapaces. *Primitiella minima* agrees in all essential respects with *P. constricta.*

The characters of the genus *Primitiella* are very similar to those of *Monotiopleura.* The main difference lies in the sulcation, *Primitiella* being nonsulcate and nonlobate and *Monotiopleura* bi- to trisulcate and with a conspicuous L4. Furthermore, in the latter genus the border-like depression along the free margin of the left valve is faint.

The only undoubted members of the genus are at present *P. constricta*, *P. plattevillensis* KAY, 1940, and *P. minima* (HARRIS, 1957). The generic reference of the other species which have been included in *Primitiella* cannot be ascertained without a study of the type material. An examination of the cotypes of *Primitiella limbata* ULRICH, 1897 in the U.S. National Museum showed this species to be based upon so poorly preserved specimens that a safe specific and generic reference is impossible. This species remains for all practical purposes a nomen dubium.

Primitiella minima (HARRIS, 1957)

Pl. I, figs. 1–12; Text-figs. 9–11.

1957 *Leperditella rex* (CORYELL and SCHENK) subsp. *minima* n. subsp. — HARRIS, p. 157, Pl. 3, figs. 3a–3b.

For further synonyms, see HARRIS 1957, p. 157.

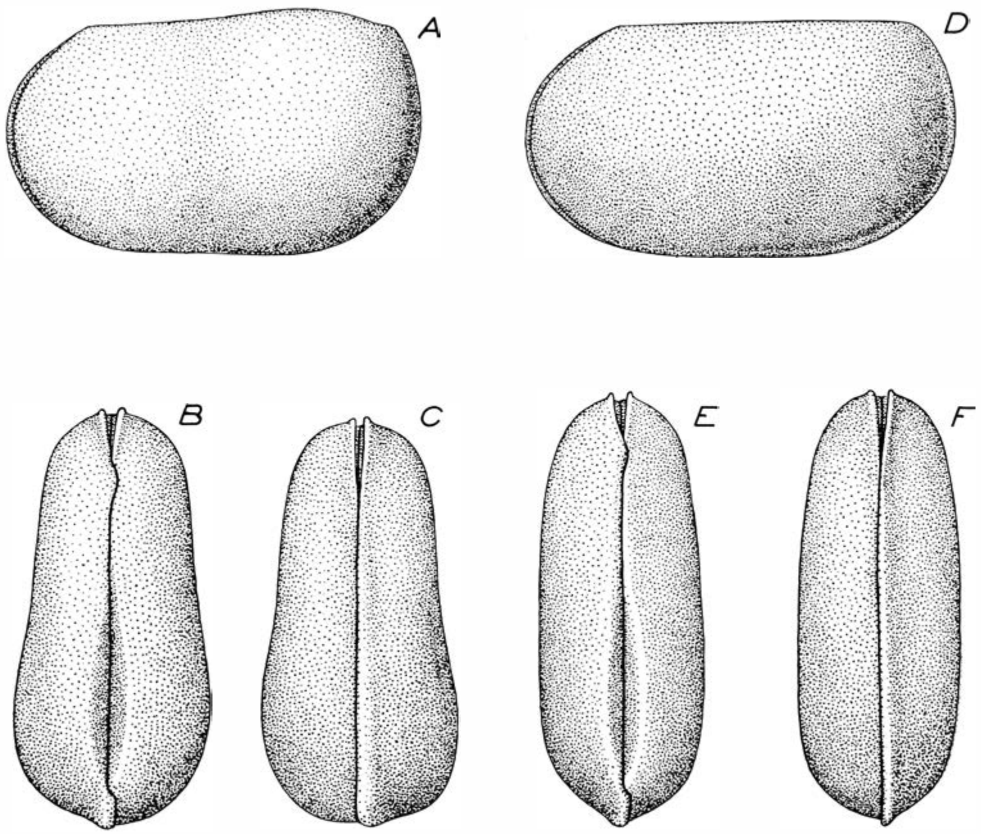

Fig. 9. *Primitiella minima* (Harris). Diagrammatic drawing of a heteromorphic (*A–C*) and a tecnomorphic (*D–F*) carapace in dorsal (*B*, *E*) and ventral (*C*, *F*) view and its right valve in lateral view (*A*, *D*). Magnification about × 80.

Diagnosis.—A species of *Primitiella* with a very poorly defined to obsolete sulcal depression and a well defined dorsum along the postadductorial portion of the dorsal margin in heteromorphs. The ornamentation consists of very faint, scattered pits.

Description.—For type data, see Harris (1957, p. 157). The present description is based on specimens found in a sample from the Pooleville Member at the Rock Crossing locality, Criner Hills, Oklahoma and in two samples from the same member of the roadside excavation, Okla. Highway 99, Arbuckle Mountains (zones 22 and 21–23). The holotype is from zone 24 of the Okla. Highway 99 section.

Tecnomorphs. Outline amplete; anterior margin evenly rounded, ventral margin straight and parallel to dorsal margin, posterior margin faintly curved to nearly straight. Dorsum slightly epicline in posterior two-thirds, hypocline in anterior third. Anterior cardinal angle about 140°, posterior cardinal angle about 110°.

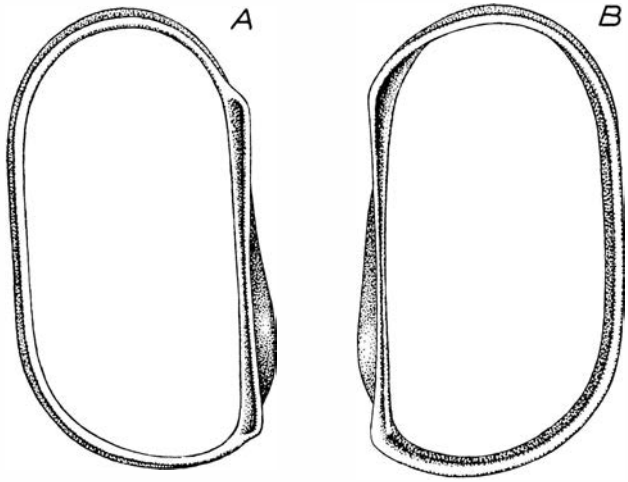

Fig. 10. *Primitiella minima* (HARRIS). diagrammatic drawing of the hinge of the right (*A*) and left (*B*) valves. Magnification about × 80.

Valves smooth with a very faint sulcal depression in some specimens. Lateral sides of the valves in ventral and dorsal view almost parallel to the free margin. A distinct supramarginal depression along the ventral and posterior margin of the left valve serves to delimit a poorly defined convex border-like structure. The extension of this border roughly coincides with the extent of the strong overlap. The right valve lacks this structure.

Marginal structures present on both valves. A narrow admarginal ridge parallels the free edge of the right valve. This ridge is sharp and well defined along the anterior margin, but becomes reduced as it is traced towards the posterior cardinal corner. An admarginal ridge parallels the anterior margin of the left valve. It passes into a marginal bend at an anteroventral position and continues as a bend to the posterior cardinal corner. In a closed carapace the two anterior admarginal ridges are separated by a recessed area which is distinctly indented below the general surface of the valve.

Valves unequal in size. The larger left valve overlaps the smaller right valve along the ventral and posterior margins. A distinct contact furrow inside the left valve is deepest and farthest from the free edge along the ventral margin. Along the posterior margin the furrow is less well defined but distinctly traceable up to the posterior cardinal corner. Anteriorly the contact furrow disappears at a point about one-third the height of the valve from the ventral margin, but it again reappears at a point about one-third the height of the valve from the dorsal margin. At the middle third of the anterior margin the valves do not overlap. In all carapaces studied the left valve seems to overlap the ventral and posterior portions of the admarginal ridge of the smaller right valve, but more material is needed to prove that this is not the result of compression of the carapace.

Hinge long and parallel to ventral margin. The right valve has a distinct

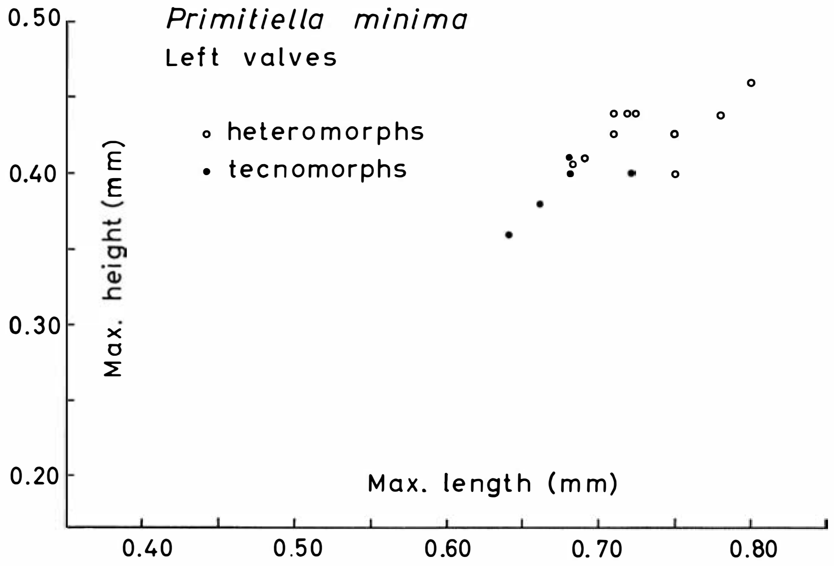

Fig. 11. *Primitiella minima* (Harris). Size dispersion of left valves in a sample from the Pooleville Member of the Rock Crossing locality in Criner Hills, Oklahoma.

longitudinal hinge groove which is narrow and shallow medially, becoming deeper and wider as the cardinal corners are approached. This groove is bounded ventrally by a low ridge and dorsally by the valve edge. The entire hinge area of the right valve appears to be slightly depressed below the level of the free edge of the valve. The hinge of the left valve consists of a narrow groove which broadens anteriorly and continues as an expanded contact furrow under the anterior stragular process. The groove is bounded dorsally by the edge of the valve and ventrally by a low ridge. The posterior termination of the ventral ridge is abrupt and the hinge groove seems to have free communication with the contact furrow around the posterior end of this ridge. Anteriorly the ventral hinge ridge becomes low and poorly defined beneath the anterior cardinal corner. It then continues in an anteroventral direction as a faint ridge forming the inner margin of the contact furrow until it loses its identity together with the anterodorsal portion of the contact furrow.

No undoubted preadult instars were observed.

Heteromorphs. Heteromorphs differ from tecnomorphs in that they possess a conspicuous inflation of the postadductorial portion of the valve. This inflation results in a well defined posterodorsal hump and a strongly epicline dorsum. In all the other characters the heteromorphs agree with the tecnomorphs.

Dimensions.—See Fig. 11.

Discussion.—Harris (1957) included *P. minima* in the genus *Leperditella* apparently on account of the strong posterodorsal hump in the heteromorphs of this species. During the course of the present investigation, the striking similarities between *P. minima* and *P. constricta* were revealed. Both species are very similar in size, shape, dimorphic modifications, development of marginal structures, and in their possession of a small anterior stragular process. The available specimens of *P. constricta* are not as well preserved as those of *P. minima*, but they appear to possess the same type of hinge and overlap conditions as in *P. minima*.

The only striking difference between *P. minima* and *P. constricta* is that *P. minima* is ornamented by small, scattered pits (visible in best preserved specimens only) whereas well preserved specimens identified as *P. constricta* possess a reticulate ornamentation. There is a tendency for *P. constricta* to be more elongate than *P. minima* and to possess a better defined sulcal depression, but these two characters appear to be within the range of variation of *P. minima*.

OCCURRENCE.—*Primitiella minima* is known only in the Pooleville Member of Oklahoma (for its range in different sections, see HARRIS (1957)).

Family *Lomatopisthiidae* n.fam.

DIAGNOSIS.—Ostracodes with a solid, mostly ridge-like velar structure and characteristically with a special type of posterior domiciliar dimorphism. Heteromorphic valves are posteriorly inflated except for a narrow area along the dorsal or dorsomedian part of the postadductorial region that retains its tecnomorphic shape and is often separated from the inflated area by a distinct furrow; in some genera the inflation involves only the area corresponding to S3 in tecnomorphs. Where known, the left valve overlaps the right valve along the free margin.

GENERA.—*Lomatopisthia* n.gen.
Raymondatia KAY, 1934
Dibolbopisthia n.gen.
Bolbopisthia n.gen.
Physalidopisthia n.gen.

Bellornatia KAY, 1934 and *Thomasatia* KAY, 1934 possibly belong to this family also.

DISCUSSION.—The genera included in the *Lomatopisthiidae* exhibit a special type of domiciliar dimorphism which is here termed the lomatopisthid type. This type of dimorphism can be characterized as an inflation of the posterior part of the carapace in which the dorsalmost or dorsomedian part of the postadductorial area is only slightly or not at all involved. In heteromorphs this dorsal unaffected part of the valve usually retains its tecnomorphic shape and convexity. The dorsal boundary between the inflated and the uninflated postadductorial area of the valve is often sharp and defined by a distinct furrow. In contrast to the lomatopisthid type of dimorphism, the domiciliar inflation of heteromorphs in the monotiopleurids, kloedenellids, cavellinids, and cytherellids involves the whole posterior part of the carapace, and, in the monotiopleurids at least, a dorsal hump is developed in the area corresponding to the unaffected area of the lomatopisthids.

The lomatopisthid type of dimorphism manifests itself differently both among and within various lomatopisthid genera, not so much because of changes in the basic pattern of inflation, but because the inflation is superimposed over varying patterns of lobation and sulcation. In *Lomatopisthia* the L3 of tecnomorphs extends ventrally from the connecting lobe to the dorsal margin or dorsal ridge, and it exhibits few changes in width and convexity throughout its length. In heteromorphs most of the medial part of L3 is inflated and widened at the cost of S3. In some species (*L. bromidensis* and *L.* n.sp. from the lowermost Decorah of Minnesota) the inflated part terminates dorsally in a rounded knob. In *L. varicata* the surface of L3 bears two rounded knobs. In all species of *Lomatopisthia*, however, the dorsalmost or dorsomedial part of L3 retains its tecnomorphic shape and convexity, and in some species (*L. auricula*, *L. simplex*, cf. Text-fig. 12*B*) the uninflated part of L3 is separated from the inflated part by a distinct furrow.

In tecnomorphs of most species of *Lomatopisthia* the summit of L4 is situated at a conspicuously lower level than that of L3 (cf. Text-figs. 12*C*, 14*B*) whereas in heteromorphs the summits of L3 and L4 are at the same level (cf. Text-figs. 12*A*, 14*A*) because the posterior inflation widens the valves in the area of L4 and causes L4 to be elevated relative to L3. In these cases the adult dimorphs are readily distinguishable in dorsal and ventral view by the relative widths of the valves in the area of L4. In tecnomorphs of *L. bromidensis* L4 forms a high ridge, the summit of which lies at a much higher level than that of L3. In heteromorphs of this species the inflation of the domicilium in the area of L3 and S3 decreases the difference in the level of the summits of L3 and L4, but the latter lobe still remains higher, and the width of the posterior end of the valve is about equal to that of tecnomorphs. As a result of these heteromorphic changes in *L. bromidensis* the inflation of the domicilium is scarcely noticeable in dorsal and ventral view, but the dimorphs are readily distinguishable from the shape of L3 in lateral view.

The dimorphic features of *Raymondatia gonioglypta* are somewhat similar to those of *Lomatopisthia bromidensis*. In tecnomorphs of the former species (No. NA 130; cf. also MOORE *et al.* 1961, Fig. 72, 3c) L3 is expanded near the dorsal ridge forming a low rounded knob, and S3 is broad and deep. The summit of L4 is higher than that of L3. In heteromorphs (Nos. NA 131, 132; cf. MOORE *et al.* 1961, Fig. 72, 3a, 3d) the dorsal knob of L3 is considerably expanded and its summit lies at about the same level as that of L4. S3 is shallow and a distinct rounded knob is developed within its posteroventral portion (the figures referred to do not convey a correct impression about the relative depth of S3). The dimorphic inflation of the domicilium thus involves S3 and the dorsal knob of L3. The posterior width of the valve in the area of L4 does not seem to increase conspicuously in heteromorphs.

In tecnomorphs of *Dibolbopisthia arbucklensis* n.sp. L4, together with the posterior part of the connecting lobe and the posterior part of the dorsal ridge, forms a continuous high ridge around the posterior periphery of the valve. This ridge surrounds a depressed area formed by a broad (*long.*) S3 and a low L3. In heteromorphs L3 does not seem to change significantly, and the main inflation takes place in the area of S3. The dorsal part of S3 is partly occupied by a large rounded knob, and the floor of the remaining part of S3 lies at a considerably higher level than in tecnomorphs. The knob gives a quinquelobal appearance to the heteromorphic valves. As the heteromorphic inflation is apparently restricted to the depressed area within the peripheral ridge, no widening of the heteromorphic valve is noticeable in dorsal or ventral view.

In the trilobal and the unisulcal genera, *Bolbopisthia* and *Physalidopisthia*, respectively, dimorphism is well defined by a conspicuous inflation of the postadductorial lobe. A dorsal to dorsomedian area of the lobe retains its tecnomorphic shape and is separated from the inflated part of the lobe by a distinct furrow.

In spite of the numerous variations in the morphology of the valve illustrated above, the basic pattern of dimorphic inflation persists throughout the *Lomatopisthiidae*. The precise relationship of soft part anatomy to the heteromorphic valve inflation may never be definitely ascertained, but some speculation may be in order at this time. In the monotiopleurids the interior of the inflated posterior part of the heteromorphic domicilium was very probably used for egg-care, as is the case in the cytherellids and probably also in the cavellinids and kloedenellids. It is probable that the inflated part of the heteromorphic domicilium served the same function in the lomatopisthids. It is interesting to note that the rounded knob-like elevations in heteromorphs of *Lomatopisthia varicata*, *Raymondatia gonioglypta*, and *Dibolbopisthia arbucklensis* resemble similar structures in heteromorphs of many species of *Cytherelloidea.*

The lomatopisthid dimorphism conveys the impression of being more elaborate than the simple inflation of the posterior part of the carapace as in the monotiopleurids, kloedenellids, cavellinids, and cytherellids. The sharp dorsal delimitation between the inflated and the noninflated areas of heteromorphic carapaces in some lomatopisthid species is especially noteworthy. A furrow marks this boundary in *Lomatopisthia simplex*, *Bolbopisthia carinata*, and *Physalidopisthia marginovelata*, and it is in direct continuation with the posteroventral margin of S2. If morphology of the valve is reflecting soft part anatomy in the heteromorphs of the above mentioned species, then it is possible that the posteroventral inflation represents the posterior mantle cavity, that the uninflated posterodorsal area represents a posterior extension of the body cavity, and that the furrow represents the boundary between the two cavities. Only the posterior mantle cavity would be involved in egg-care and subject to dimorphic inflation. The area dorsal of the inflated mantle cavity, *i.e.* the body cavity, would not be involved in egg-care, and any inflation of this area would be unnecessary. These sexual modifications affecting the posterior mantle cavity but not the posterodorsal extension of the body cavity could easily be reflected in the valves as the lomatopisthid type of dimorphism. It should be noted, however, that such a posterodorsal boundary between the body and mantle cavities is unknown among Recent ostracodes and would imply unexpected anatomical differences between lomatopisthids and not only Recent myodocopes, platycopes, and podocopes, but also fossil groups with a kloedenellid type of dimorphism. In Recent ostracodes the posterior boundary between the mantle and body cavities, on the inside of the valve, roughly corresponds to the posterior boundary of S2 or lies slightly behind it dorsally (cf. MÜLLER 1926, Text-fig. 349; TRIEBEL 1941, Text-fig. 2; JAANUSSON 1957, Text-fig. 9) For this reason, the above explanation concerning the significance of the sharp dorsal boundary of the lomatopisthid heteromorphic inflation must remain uncertain until further corroborative evidence is obtained. At present, however, the writers are unable to find another more satisfactory explanation for this phenomenon.

The genera herein included in the *Lomatopisthiidae* have previously been placed in the *Bassleratiidae*. An examination of specimens of *Bassleratia typa*, however, showed that this species probably is not related to the lomatopisthids. The right valve of *B. typa* possesses a small anterior stragular process which suggests that, at the cardinal corners at least, the right valve is larger than the left valve. No definite indication of dimorphism has been observed. The ridge surrounding the lobate area is constructed differently from that of the quadrilobate lomatopisthids, and it is difficult to visualize how the posterior shape of this ridge can be associated with dimorphism of the lomatopisthid type.

Thomasatia KAY, 1934 and *Bellornatia* KAY, 1934, previously included in the *Bassleratiidae*, are herein questionably placed in the *Lomatopisthiidae*. *Thomasatia falcicosta* KAY differs from other lomatopisthids in that its L4 is posteriorly interrupted, and none of the examined specimens exhibited any clear evidence of lomatopisthid dimorphism. A new species of *Thomasatia* from the Pooleville Member in the Arbuckle Mountains also failed to reveal any indication of dimorphism. *Bellornatia* differs from other lomatopisthids in its major features of lobation. All specimens available to the writers possess two knob-like swellings in the general area of L3, and these specimens may represent heteromorphs with the lomatopisthid type of dimorphism. The specimen figured by KAY (1940, Pl. 34, Fig. 26) may represent a tecnomorph, but until more specimens are examined, it is best to questionably assign this genus to the *Lomatopisthiidae*.

For a comparison with the family *Monotiopleuridae*, see the chapter on taxonomy.

OCCURRENCE.—The known members of the family are exclusively North American. The rich contemporaneous ostracode faunas of Balto-Scandia contain no known ostracodes which could be suspected to possess the characters of a lomatopisthid. Undoubted lomatopisthids have been recorded from the post-Oil Creek Champlainian ("Middle Ordovician") rocks of Iowa, Minnesota, Oklahoma, Ontario, and Virginia.

Genus *Lomatopisthia* n.gen.

TYPE SPECIES.—*Thomasatia simplex* HARRIS, 1957.

DERIVATION OF THE NAME.—From Greek λώμα, border and ὀπίσθια, back, alluding to the ridge-like projection of L4 posteriorly.

DIAGNOSIS.—Valves small, quadrilobate; lobes connected ventrally by a connecting lobe and dorsally by a dorsal crest of varying strength. L1 and L4 reaching the dorsal margin; L3 in tecnomorphs joined to dorsal crest; L2 usually a knob not reaching the dorsal crest; L4 ridge-like, situated near or at posterior margin of the valve and projecting posteriorly. Lobate area bordered, at least anteriorly and ventrally, by a narrow extralobal area. Velar structure entire, developed as a narrow ridge. In heteromorphs the valves are inflated posterior of S2 except for a narrow area posterodorsally; L3 widened at the cost of S3, its dorsomedian or dorsal part retaining tecnomorphic shape.

SPECIES.—*Thomasatia simplex* HARRIS, 1957
Thomasatia auricula HARRIS, 1957
Thomasatia bromidensis HARRIS, 1957
Primitiella constricta subsp. *varicata* HARRIS, 1957
Bassleratia rectangulata KRAFT, 1962

Uppsala collections include specimens of two new species of *Lomatopisthia*, one from the Lower Edinburg Limestone of the Shenandoah Valley, Virginia, and the other from the lowermost Decorah Shale of Minneapolis, Minnesota.

DISCUSSION.—Species of this genus with well-developed lobes were included by HARRIS (1957) in *Thomasatia.* An examination of specimens of *Thomasatia falcicosta* and *T.* n.sp. (Pooleville Member, Arbuckle Mountains) revealed distinct and evidently constant differences between *Thomasatia* and *Lomatopisthia.* In *Thomasatia* L4 disappears before reaching the posterior cardinal corner, and a peculiar extension of the dorsal crest in posterior direction occupies the place of the dorsal end of L4. This gives the posterior end of the valve an appearance which is quite different from that of *Lomatopisthia.* In front of S3, however, the lobation of *Thomasatia* agrees not only with *Lomatopisthia* but also with several species of *Tallinnopsis.*

Raymondatia differs from *Lomatopisthia* mainly by the lack of an extralobal area and by the inflation of S3 rather than L3 in heteromorphs. *Dibolbopisthia* has a narrow extralobal area like that of *Lomatopisthia*, but heteromorphs give an impression of being quinquelobate on account of the inflation of the tecnomorphic S3 into two rounded, knob-like structures.

Dimorphism in *Lomatopisthia* is known at present in *L. simplex*, *L. auricula* (specimens Nos. NA 91, 92), *L. bromidensis* (Nos. NA 117, 118) and *L. varicata. Lomatopisthia* n.sp. from the lowermost Decorah of Minnesota is represented only by heteromorphic valves (No. NA 119) and *L.* n.sp. from the Lower Edinburg of Virginia by tecnomorphic valves (No. NA 129). Both species seem to be rare. The specimen of *L. rectangulata* figured by KRAFT (1962, Pl. 15, figs. 19a, b) appears to be a tecnomorph.

The intensity of lobation varies within wide limits in *Lomatopisthia.* Most species have high lobes, whereas in *L. simplex* the lobes are low and rounded and in *L. varicata* L1 and L3 are distinguishable only on well-preserved specimens as very low and poorly defined elevations. The most persistent lobal and sulcal structures are L2, S2, and L4. The posterior portion of L4 is always ridge-like and posteriorly protruding, even in species with otherwise very low relief, such as *L. varicata*. From *L. varicata* the step towards velate, but otherwise *Primitiella*-like forms, is not great.

The unsatisfactory state of preservation of the available specimens of most species of *Lomatopisthia* made observations on the development of the marginal structures difficult. In some specimens of *L. varicata*, however, the marginal and admarginal ridges are well developed (cf. Pl. IV, fig. 1). This species also possesses a narrow recessed area of the type which occurs in *Monotiopleura auriculata*.

Unfortunately no specimen of *Lomatopisthia* was found which clearly showed details of the hingement and the closure of the valves. Some closed carapaces suggest that the left valve slightly overreaches the right valve along the free margin, but the evidence is inconclusive.

OCCURRENCE.—The genus is at present known only from the Champlainian ("Middle Ordovician") strata of Oklahoma (post-Oil Creek and pre-Corbin Ranch; for the range of known species, see HARRIS 1957), Minnesota (lowermost Decorah Formation), and Virginia (lower and middle part of the Edinburg Formation).

Lomatopisthia simplex (HARRIS, 1957)

Pl. III, figs. 5–15; Text-figs. 12–13.

1957 *Thomasatia simplex* n.sp. — HARRIS, pp. 248–249, Pl. 8, figs. 15, 17a, b.
For further synonyms, see HARRIS 1957, p. 248.

DIAGNOSIS.—A species of *Lomatopisthia* with broadly rounded lobes. In tecnomorphs L3 much longer than S2, and S3 forms a narrow, deep, crescentic furrow. In heteromorphs S3 poorly defined, and the inflated part of L3 dorsally bordered by a distinct furrow.

DESCRIPTION.—For type data, see HARRIS (1957, p. 248). The present description is based on numerous specimens found in a sample collected by JAANUSSON in 1959. The sample was taken at the approximate level of HARRIS' zone 35 from the roadside excavation along Oklahoma Highway 99, 3 miles south of Fittstown Arbuckle Mountains, Oklahoma. This is the type locality of the species.

Tecnomorphs. Lateral outline and the outline of contact margin amplete. Valves somewhat rhomboidal in lateral view with an almost straight posterior margin and a moderately curved anterior margin; ventral margin almost straight and parallel to the dorsal margin. Quadrilobation distinct. L1 reaches the dorsal margin, is of uniform width, and curved parallel to the anterior margin of the valve; L2 developed as an elongated knob, separated from the connecting lobe by a shallow furrow; L3 broad (*long.*), crescentic, reaches the dorsal margin and protrudes slightly beyond the hinge-line; L4 narrow, ridge-like, forms a regularly curved arch, and protrudes in posterior direction, in some cases somewhat

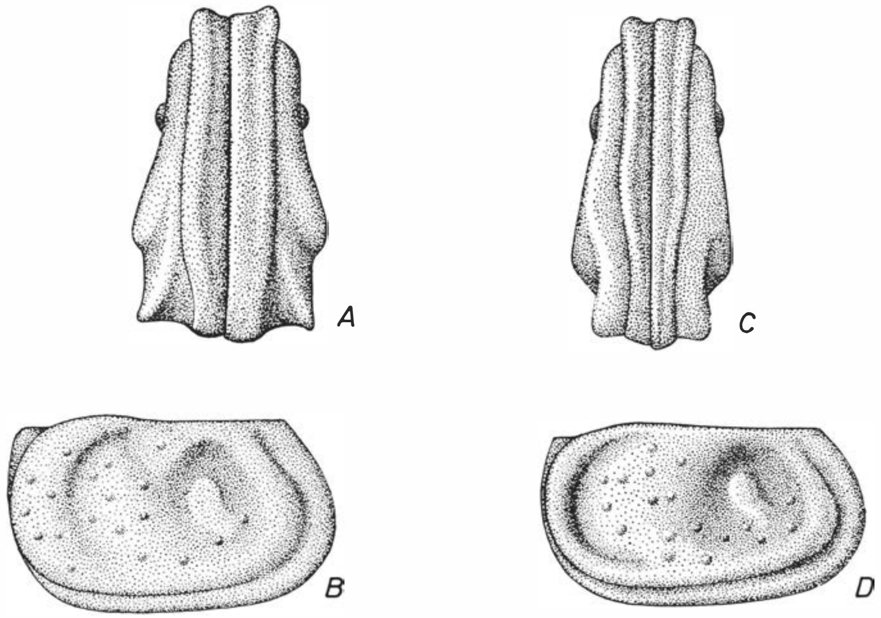

Fig. 12. *Lomatopisthia simplex* (HARRIS). Diagrammatic drawing of a heteromorphic (*A–B*) and a tecnomorphic (*C–D*) carapace in ventral view (*A*, *C*) and its right valve in lateral view (*B*, *D*). Magnification about × 80.

beyond the free edge. S3 forms a narrow, deep, crescentic furrow bordering L4. Highest point of the valve close to the posteromedial part of L3.

The lobate area is bordered anteriorly and ventrally by a narrow, furrow-like extralobal area which continues as a depression between L4 and the velar ridge on the steep posterior surface of the valve. The width of the extralobal area is more or less uniform except along the posterior margin of the valve where it becomes reduced to a narrow strip. The velar ridge is narrow but well defined along the entire free margin; it protrudes only slightly beyond the subvelar field. In ventral view, the subvelar field is moderately high anteriorly and the velar ridge parallel to the free margin to about mid-length of the valve; posterior of this point the velar ridge curves slightly towards the free margin, and the height of the subvelar field decreases slightly towards the posterior margin of the valve.

The specimens are small, and corrosion has obliterated some of the finest structures. As a result of these factors the development of marginal structures either could not be observed or the observations were of inconclusive value.

In all available closed carapaces, the left valve slightly overlaps the right valve along at least the ventral margin (the Text-figs. 12*A*, *C* are reconstructed accordingly). However, some of these carapaces are demonstrably compressed laterally and in others the existence of some lateral compression is not excluded. On the inside of the left valve no groove for the accommodation of the free edge of the right valve has definitely been observed, but this may be due to the state of pre-

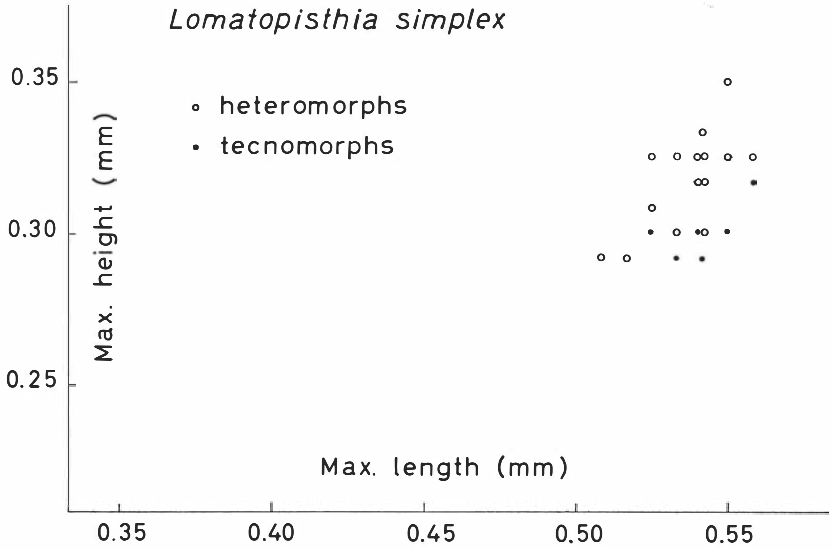

Fig. 13. *Lomatopisthia simplex* (HARRIS). Size dispersion of the valves in a sample from zone 35 of the type locality.

servation. The evidence pertaining to the closure of carapace is, therefore, still inconclusive in this species.

The hinge is long and straight, but details are obscure because of the state of preservation.

The ornamentation consists of a small number of scattered, fairly large tubercles.

No preadult instars have been observed in the available samples.

Heteromorphs. The area of the valves posterior of S2 is considerably inflated. The summit of L4 is as high as that of L3 or is only slightly lower, whereas in tecnomorphs the summit of L4 is considerably lower than that of L3. The high posterior end of the valve slopes almost perpendicular to the sagittal plane of the carapace. L4 is flattened and broad (*long.*), its anterior border occupying a position roughly corresponding to the anterior border of S3 in tecnomorphs. S3 is mostly shallow and occasionally poorly defined. L3 is narrower than in tecnomorphs, its dorsal part is separated from the rest of the lobe by a distinct furrow which extends in a posterodorsal direction and near the dorsal margin of the valve the furrow is continuous with S3. The part of L3 dorsal of this furrow is conspicuously less convex than the main part of the lobe. The velar structure is weakly developed along the posterior margin of the valve. The anterior part of the valve agrees with that of the tecnomorphs.

DIMENSIONS.—See Fig. 13.

DISCUSSION.—*Lomatopisthia rectangulata* (KRAFT) resembles *L. simplex* more than any other described species of the genus. It has low, rounded lobes and a broad (*long.*) L3, but differs from *L. simplex* by L3 being separated from the

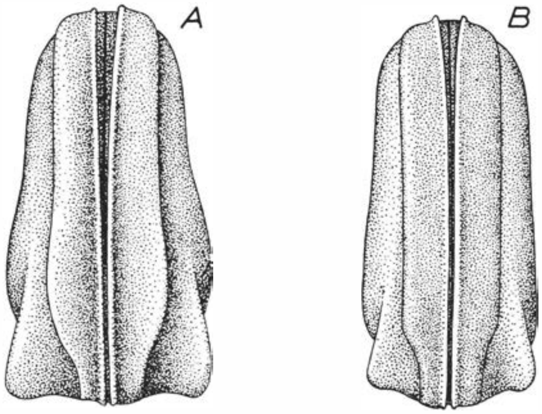

Fig. 14. *Lomatopisthia varicata* (HARRIS). Diagrammatic drawing of a heteromorphic carapace (*A*) and a tecnomorphic carapace (*B*) in ventral view. Magnification about × 80.

connecting lobe by a furrow, L2 being fused with the connecting lobe anteroventrally, and by a rounded shape of L2. In *L. auricula* L3 is high and prominent in tecnomorphs as well as in heteromorphs, and the velar ridge has a strong upwards curvature at the middle of the ventral margin. In *L. bromidensis* L3 is narrow and ridge-like in tecnomorphs and expanded in the middle into a prominent knob-like structure in heteromorphs.

OCCURRENCE.—*Lomatopisthia simplex* is known at present only from the Simpson Group in Oklahoma (for its range in different sections, see HARRIS 1957).

Lomatopisthia varicata (HARRIS, 1957)

Pl. IV, figs. 1–11; Text-figs. 14–15.

1957 *Primitiella constricta* ULRICH subsp. *varicata* n. subsp. — HARRIS, pp. 187–188, Pl. 6, figs. 2a–b.

DIAGNOSIS.—A species of *Lomatopisthia* with low, poorly defined lobes of which the small, rounded knob-like L2 and the posterior part of L4 are best developed. In heteromorphs L3 forms two low, rounded, knob-like structures.

DESCRIPTION.—The holotype (Mus. Comparative Zoölogy, Harvard University, No. 4577) is a right heteromorphic valve figured by Harris 1957, Pl. 6, figs. 2a, 2b, from zone 24 of the Oklahoma Highway 99 section. Harris' figures do not give any details of lobation which are clearly visible on the examined holotype. The present description is based on the holotype and on numerous specimens found by the present writers in four different samples from the Pooleville Member of Oklahoma (two samples from the Rock Crossing locality in Criner Hills, and two samples from the Oklahoma Highway 99 section, 3 miles S of Fittstown, zones 22 and 21–23).

Tecnomorphs. Outline of the valves as in *L. simplex.* The quadrilobal pattern of lobation is not readily discernible without staining with ink or coating with ammonium chloride; only L2 and the posteriorly protruding part of L4 can usually be clearly observed on untreated specimens. On weathered specimens all traces of L1 and L3 are often obliterated. On specimens with a well preserved surface the quadrilobal pattern is distinct. All lobes are flattened; L1 is narrow, reaches the dorsal margin, is of uniform width, and curves parallel to the anterior margin; its ventral part is often poorly defined. L2 forms a small, rounded knob, with its ventral margin situated at about the mid-height of the valve. L3 and the ventral part of the connecting lobe are very low and occasionally scarcely distinguishable. The posterior part of L4 protrudes somewhat in a posterior direction, whereas the anterior part merges with the general surface of the valve without any distinct delimitation. S3 scarcely developed.

The extralobal area is fairly well defined and is similar to that of *L. simplex* but less pronounced. The shape of the velar ridge also agrees with that of *L. simplex* except that the ridge curves more abruptly towards the free margin at a position about one-fourth of the valve length from the posterior margin.

Both valves possess a distinct admarginal ridge which lies very near to the free edge on the posterior half of the valve. In closed carapaces the admarginal ridges of adjacent valves do not meet each other but are separated by a very narrow recessed area which becomes broader in the anterior direction. The latter is due to the divergence of the admarginal ridges from the free edges in the anterior direction.

The carapace appears to be virtually equivalved, the contact edges of both valves meeting each other along the free margin. No contact furrow could be observed, but details of the closure of the carapace are difficult to observe owing to the state of preservation, and better material is needed for confirming the above observations.

Details of the hingement are obscure in the available material. The right valve appears to possess an extremely narrow furrow along the hinge and a socket-like pit below the posterior cardinal corner. Corresponding structures on the left valve could not be resolved because of the corroded condition of the available specimens.

The ornamentation consists of a small number of scattered, fairly large tubercles.

No unquestionable preadult instars have been observed in the available samples.

Heteromorphs. The area of the valves posterior to S2 is distinctly inflated. The area of L3 is slightly lower than the summit of L4 in tecnomorphs, whereas in heteromorphs the summit of L3 is situated slightly higher than that of L4. L3 forms two low, rounded kuob-like structures (Pl. IV, fig. 9) reflected internally as two conspicuous, broad pits (cf. Pl. IV, fig. 11). The area between the dorsal knob and the dorsal ridge is slightly but conspicuously depressed. The anterior part of the valves agrees with that of the tecnomorphs.

DIMENSIONS.—See Fig. 15.

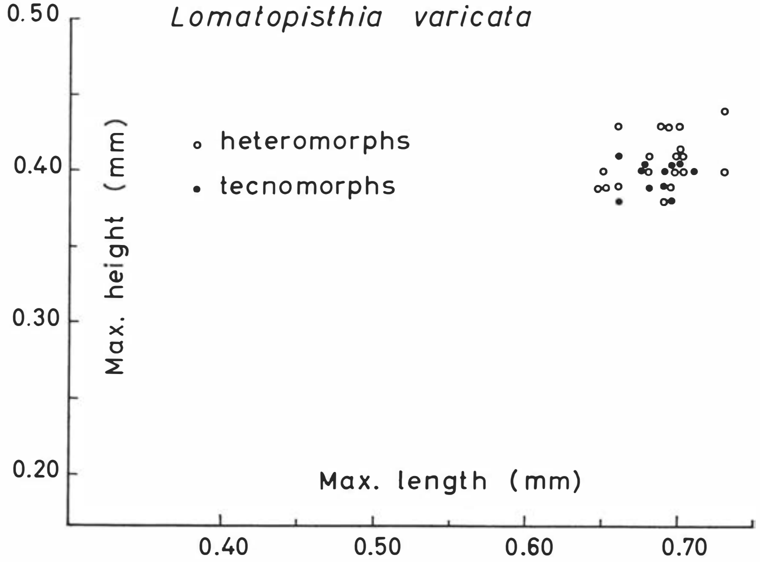

Fig. 15. *Lomatopisthia varicata* (Harris). Size dispersion of the valves in a sample from the Pooleville Member of the Rock Crossing locality in Criner Hills, Oklahoma.

Discussion.—*Lomatopisthia varicata* distinctly differs from the other species of the genus by its poorly developed lobation and by the small size of the rounded, knob-like L2. The observable pattern of lobation and other characters, except for the development of two knob-like structures on L3 in heteromorphs, agree with the other known species of *Lomatopisthia.* Harris' reference of this species to *Primitiella* is difficult to understand.

Occurrence.—*Lomatopisthia varicata* is known only from the Pooleville Member of Oklahoma (for its range in different sections, see Harris 1957).

Genus *Dibolbopisthia* n.gen.

Type species.—*Dibolbopisthia arbucklensis* n.sp.

Derivation of the name.—From Greek δύο, two, βολβος, bulb, and ὀπίσθια back, alluding to the two bulb-like structures in S3 of the heteromorphs.

Diagnosis.—Valves small, quadrilobate; lateral surface surrounded by a continuous, ridge-like elevation which corresponds to L1, the dorsal ridge, L4, and the connecting lobe in *Lomatopisthia.* L2 confluent with the dorsal ridge and not with the connecting lobe; S3 long (*long.*) and deep in tecnomorphs, inflated and provided with two knob-like elevations in heteromorphs; heteromorphic valves, therefore, with a quinquelobal appearance. Extralobal area narrow but well-defined. Velar structure as in *Lomatopisthia.*

Discussion.—The genus is at present monotypic. *Dibolbopisthia* resembles *Raymondatia,* particularly with respect to the confluence of L2 with the dorsal ridge and not with the connecting lobe and with respect to the changes in S3

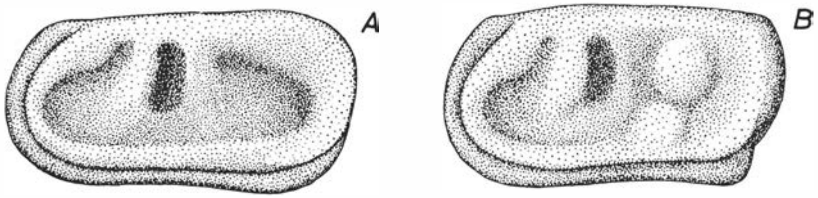

Fig. 16. *Dibolbopisthia arbucklensis* n.sp. Diagrammatic drawing of the left valve of an adult tecnomorph (*A*) and a heteromorph (*B*). Magnification about ×80.

due to dimorphism. However, *Raymondatia* lacks an extralobal area, and the dimorphic changes are not confined to S3 and the area posterior to it but also conspicuously involve the dorsal part of L3.

Dibolbopisthia also resembles, at least superficially, *Saturnites* LEVINSON, 1961 from the approximately contemporaneous beds of Oklahoma. An examination of the holotype of *S. harrisi* in the U.S. National Museum showed, however, that this species lacks a velar structure, L2 is not joined with the dorsal ridge, and that some other features are also not quite consistent with the general morphology of the lomatopisthids. The affinities of *Saturnites* are at present obscure, and more material of the type species must be studied before the characters of the genus are understood.

OCCURRENCE.—See the type species.

Dibolbopisthia arbucklensis n.sp.

Pl. V, figs. 9–12; Text-fig. 16.

HOLOTYPE.—Left heteromorphic valve, No. NA 141, figured on Pl. V, figs. 11–12.

TYPE STRATUM AND LOCALITY.—Bromide Formation, Pooleville Member, Harris' zones 21–23. Oklahoma State Highway 99, roadside exposure 3 miles S. of Fittstown.

DESCRIPTION.—*Dibolbopisthia arbucklensis* is at present the only known species of the genus, and hence its diagnosis agrees with that of the genus.

Adult tecnomorphs. Lateral outline amplete, subrhomboidal, with a slightly convex posterior margin and a somewhat stronger convex anterior margin. Ventral margin distinctly sinuous.

The lateral surface of the valve is surrounded by a distinct ridge which is highest posteriorly and lowest anteroventrally. Compared with *Lomatopisthia* the anterior part of the ridge corresponds to L1, the ventral part to the connecting lobe, the posterior part to L4, and the dorsal part to the dorsal ridge. Anterodorsally (corresponding to the dorsal part of L1) the ridge is slightly widened. L2 narrow, ridge-like, continuous with the dorsal ridge but not with the connecting lobe; L3 poorly defined, continuous with the dorsal ridge but almost obsolete before reaching the connecting lobe; the summit of L3 is considerably below the summit of the adjacent part of the dorsal ridge. S1 and S2 deeply impressed; S3 forms a deep crescentic depression. The highest point of the valve is situated at the posterior end of L4.

Velar ridge entire, solid, narrow in lateral view, fairly thick in ventral view. It has a slightly curved course in ventral view, the subvelar field being somewhat higher at the middle of the ventral margin than anteriorly and posteriorly (cf. Pl. V, fig. 10).

Details of hingement and of marginal features cannot be observed owing to the poor state of preservation of these parts in the available material.

Ornamentation seems to consist of a few, scattered tubercles.

Heteromorphs. Posterior width of the valve almost equal to that of adult tecnomorphs. However, the area corresponding to S3 in tecnomorphs has become considerably inflated. The inflation does not involve the high ridge (posterior part of the dorsal ridge, L4, and posterior part of the connecting lobe) which surrounds S3, and for this reason the inflation is not observable in ventral and dorsal view. The dorsal part of S3 is largely filled by a well-defined, rounded knob, the summit of which lies at about the same level as that of L4. Another knob-like elevation is developed anteroventrally of the main heteromorphic knob, and its ventral half merges with the connecting lobe. L3 is somewhat better defined than in adult tecnomorphs, and its summit is not much lower than the adjacent part of the dorsal ridge.

At the middle of the ventral margin the velar ridge shows a distinct curvature upwards, and the distance there between the velar ridge and connecting lobe is much less than in adult tecnomorphs. In other words, in ventral view the velar ridge of adult tecnomorphs is roughly parallel to the free margin, while the velar ridge of heteromorphs is parallel to the connecting lobe. Posteriorly the velar ridge terminates abruptly just before reaching the posterior end of the valve; in its posterior termination the velar ridge is somewhat expanded. In tecnomorphs the velar ridge continues without change in the shape up to the posterior cardinal corner.

Preadult instars. Only one fragmentary preadult instar was found. All of its observable characters agree with those of the adult tecnomorph.

DIMENSIONS.—All measured specimens are from the roadside exposure along Oklahoma Highway 99, 3 miles S. of Fittstown. The specimens 1 to 4 are from the general level of Harris' zones 21 to 23 and the specimens 5 and 6 from the zone 22.

	Maximum length (mm)	*Maximum height (mm)*
1. Right tecnomorphic valve (figured)	0.56	0.30
2. Left heteromorphic valve (holotype)	0.56	0.29
3. Left heteromorphic valve	0.53	0.31
4. Right heteromorphic valve	0.54	0.29
5. Left heteromorphic valve	0.55	0.30
6. Right heteromorphic valve	0.55	0.29

OCCURRENCE.—See type data.

Genus *Bolbopisthia* n.gen.

TYPE SPECIES.—*Thomasatia carinata* KRAFT, 1962.

DERIVATION OF THE NAME.—From Greek βολβος, bulb, and ὀπίσϑια, back.

DIAGNOSIS.—Valves medium-sized, trilobate with an oval, knob-like L2 and a broad postadductorial lobe (Lp). Carinal flange extends along the anterior and ventral margin of the valve. Distinct dimorphism of the lomatopisthid type: Lp is considerably wider in heteromorphs than in tecnomorphs, except for its dorsalmost part which in heteromorphs retains its tecnomorphic convexity and is separated from the rest of Lp by an oblique furrow.

DISCUSSION.—The genus is at present monotypic. It is related to *Physalidopisthia* n.gen. from which it differs by being trilobate, and by having a distinct carinal ridge and a longer S2. These two genera are easily distinguishable in the youngest known instars, and until morphologically transitional forms have been found, the gross differences are best to be regarded as significant at the generic level.

Thomasatia falcicosta KAY is a small ostracode (length 0.65–0.83 mm according to KAY 1934, p. 338) if its size is compared with *Bolbopisthia carinata* (length of adult valves 1.32–1.44 mm). It is distinctly quadrilobate, L4 disappears before reaching the posterior cardinal corner, and a peculiar extension of the dorsal ridge in posterior direction occupies the place of the dorsal end of L4.

OCCURRENCE.—See the type species.

Bolbopisthia carinata (KRAFT, 1962)

Pl. VI, figs. 1–9; Text-fig. 17.

1961 *Thomasatia* sp. — MOORE *et al.*, Fig. 72g–l.

1962 *Thomasatia carinata* n.sp. — KRAFT, pp. 51–52, Pl. 14, figs. 11–21, Pl. 15, figs. 1–5, Text-figs. 10 m, 12 e–g.

DESCRIPTION.—*Adult tecnomorphs.* Lateral outline amplete; outline of the contact margin distinctly preplete with the greatest height at the level of the anterior end of L2. Outer margin of the velar flange describes a smoothly curved line. The contact margin, on the other hand, is almost straight posteriorly (forming a posterior cardinal angle of 75 to 90°), often somewhat sinuous ventrally, and broadly rounded anteriorly. The dorsal end of Lp projects beyond the hinge line and forms a fairly high, epicline dorsum.

Lateral surface of the valve trilobate with a narrow L1, an oval and knob-like L2, and a long (*long.*), broadly rounded Lp. The distance between the dorsal end of L2 and the dorsal margin equals to about half the height of L2. The dorsal end of Lp forms an anteriorly projecting rounded bulb-like structure. The posterior flank of the dorsal part of Lp possesses three to four depressions. S1 shallow; S2 long, somewhat sigmoidal, its ventral end reaching the carinal ridge. The carinal ridge begins close to the anterodorsal corner of the valve and continues, more or less parallel to the lateral outline of the valve, to the posterior end of Lp, where it terminates in a sharp, posteriorly directed point. The carinal ridge is separated from the middle and ventral part of L1 by a distinct furrow. Ornamentation seems to consist of small, low, scattered tubercles.

Velum entire, solid, forming a somewhat convex, moderately broad and thick flange. It terminates at the cardinal corners and is more or less parallel to the free margin ventrally (KRAFT 1962, Pl. 14, fig. 11 b, Pl. 15, fig. 4). Subvelar field moderately high, somewhat concave. Both valves have a narrow ridge-like marginal structure; that of the right valve is conspicuous and lies in an admarginal position; that of the left valve seems to form only a thickened and slightly protruding edge of the free margin and lies in a marginal position.

No closed carapace is available. The left valve has a distinct contact furrow which is best developed anteriorly and posteriorly, being faint in the middle of the ventral margin. The right valve has no such furrow. This suggests that, in a closed carapace, the left valve overlaps the right valve at least anteriorly and posteriorly.

Hinge structures poorly preserved in the available material. Both valves seem to have a median hinge furrow which is usually better developed on the right valve. Other details of the hingement are obscure.

Heteromorphs. In heteromorphs the main part of Lp is considerably swollen in comparison with that of tecnomorphs. The anterodorsal part of Lp, however, retains its tecnomorphic convexity and is separated from the rest of Lp by a distinct, almost straight furrow which slopes anteroventrally. The area posterodorsal of the furrow has a distinct, triangular pit which is also present, in a comparable position, in adult tecnomorphs. The available heteromorphs lack the additional depressions which are present on the posterior flank of Lp of the adult tecnomorphs. Among the specimens figured by KRAFT (1962) two are heteromorphs (KRAFT 1962, Pl. 14, figs. 16, 19). These specimens show depressions also on the swollen part of Lp.

Immature instars. Four to five preadult instars can be recognized in the available material (Text-fig. 17). The carinal ridge is present in the smallest available specimen (Pl. VI, fig. 8; 0.47 mm long), but it is there developed along the ventral margin only. In these small specimens L1 is not distinguishable, but L2 is prominent and S2 has about the same shape as in adults. The valves are comparatively short and broad, and S2 lies somewhat behind the transverse mid-line of the valve. In the valve 0.73 mm long (Pl. VI, fig. 6), the essential characters of the adult valves are already developed except that the carinal ridge is weak or absent anterodorsally and L1 is low, rounded, and poorly defined. S2 is situated at about the mid-length of the valve. Still larger valves do not differ significantly from the adult tecnomorphs.

Among the specimens of *B. carinata* figured by KRAFT (1962) only three seem to be adult valves, viz. those figured on Pl. 14 as figs. 16, 19, and 21. The other valves belong to earlier (mostly penultimate) instars.

DIMENSIONS.—See Fig. 17.

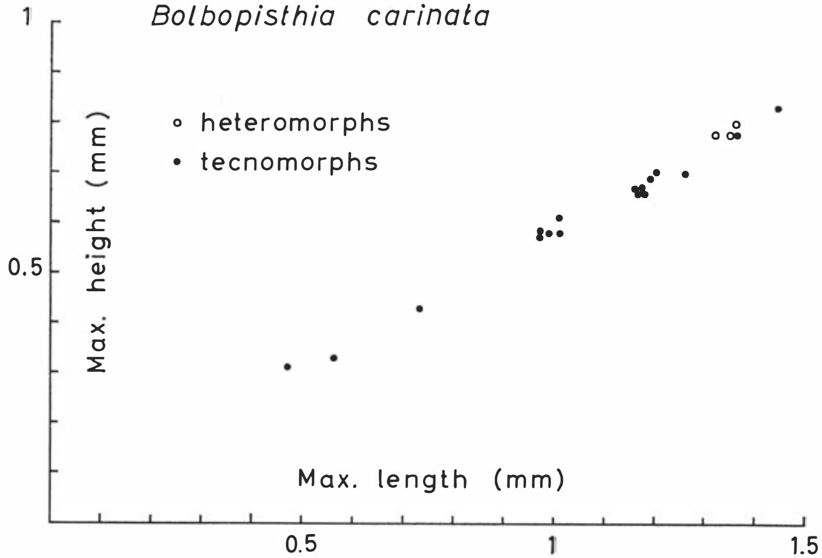

Fig. 17. *Bolbopisthia carinata* (Kraft). Size dispersion of valves in a sample from the Lower Edinburg Formation of Strasburg Junction, Virginia

Occurrence.—Virginia. Lower 15 m of the Edinburg Formation at Strasburg Junction (Kraft 1962, p. 52).

Genus *Physalidopisthia* n.gen.

Type species.—*Physalidopisthia marginovelata* Kraft, 1962.

Derivation of the name.—From Greek φῦσᾰλῐ́ς, bubble, and ὀπίσβια, back.

Diagnosis.—Valves unisulcate with a short, curved sulcus and a distinct, flattened preadductorial node. Velum entire, flange-like, its lateral surface sharply set off from the strongly convex lateral surface of the valve. Adults distinctly dimorphic, the postadductorial area in heteromorphs being conspicuously inflated except for the dorsalmost part which retains its tecnomorphic convexity and is separated from the inflated area by a furrow.

Discussion.—The genus is at present monotypic. For distinguishing characters, see the discussion of the genus *Bolbopisthia.*

Occurrence.—See the type species.

Physalidopisthia marginovelata (Kraft, 1962)

Pl. V, figs. 1–8; Text-figs. 18–19.

1962 *Thomasatia marginovelata* n.sp. — Kraft, p. 51, Pl. 15, figs. 6, 7; Textfigs. 12b–d.

Description.—For type data, see Kraft (1962).

Adult tecnomorphs. Lateral outline amplete, outline of the contact margin

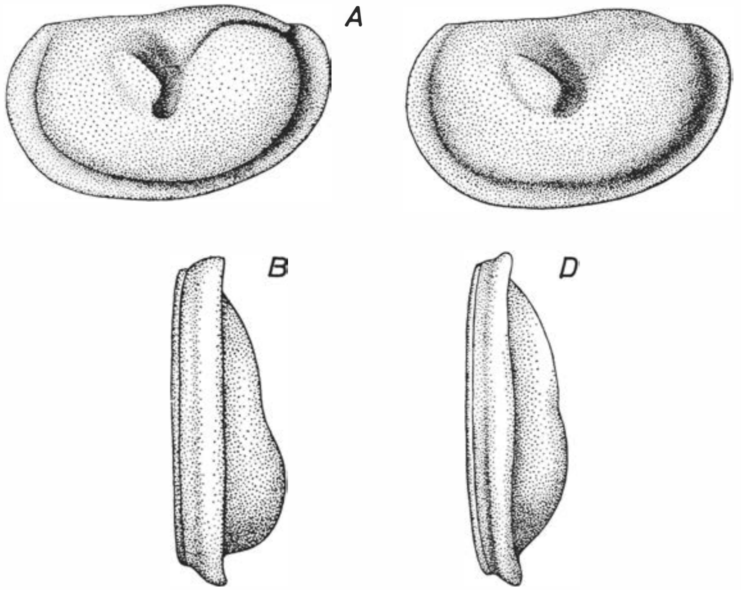

Fig. 18. *Physalidopisthia marginovelata* (KRAFT). Diagrammatic drawing of a left heteromorphic (*A*, *B*) and a left adult tecnomorphic (*C*, *D*) valve in lateral (*A*, *C*) and ventral (*B*, *D*) view. Notice the strongly inflated postadductorial portion of the valve in the heteromorph. Magnification about × 40.

distinctly preplete. The free margin is straight to slightly curved posteriorly and broadly rounded anteriorly; ventrally it is straight to slightly curved with a faint vestige of sinuosity.

Lateral surface unisulcate with a fairly deep, moderately wide, and strongly curved S2; distance between the ventral end of the sulcus and the ventral margin of the valve (incl. velar flange) only slightly greater than that between the ventral end of the sulcus and the dorsal margin of the valve. Preadductorial node large, oval, flattened, not rising beyond the general surface of the valve; its posterodorsal margin in available specimens nearly straight and anterodorsally directed (the specimen figured by KRAFT 1962, as Pl. 15, fig. 6a seems to have a more rounded posterior margin of the node). Postadductorial area more strongly convex than the preadductorial area; maximum convexity lies somewhat behind the posterior end of S2. Postadductorial area dorsally overhangs the hinge line forming a moderately high, epicline dorsum.

Ornamentation seems to consist of a fine granulation over all of the lateral surface; it is, however, difficult to decide how much of the granulation seen on photographs is ornamentation and not a texture of coarse silicification.

Velum entire, developed as a moderately broad, fairly thick, solid, ridge-like flange. The boundary between its lateral surface and the surface of the domicilium is formed by a distinct furrow. Subvelar field moderately high, somewhat concave, of more or less constant height along the ventral margin of the valve.

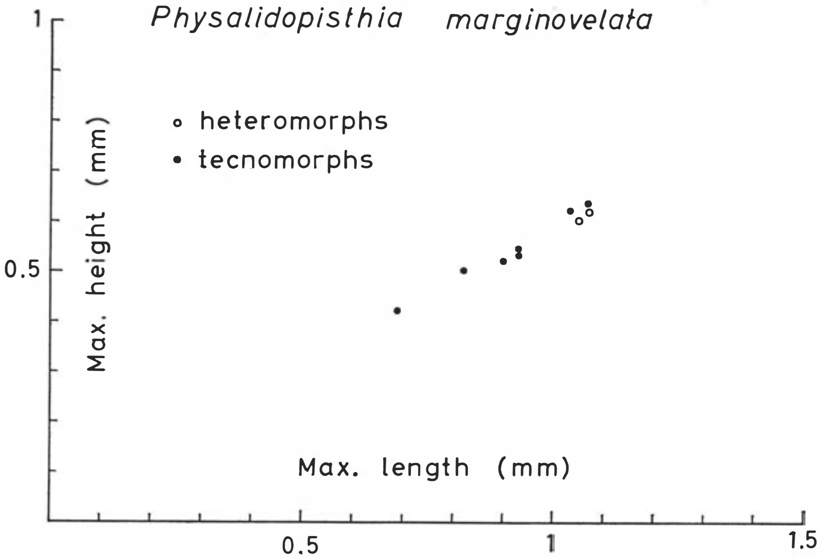

Fig. 19. *Physalidopisthia marginovelata* (Kraft). Size dispersion of valves in a sample from the Lower Edinburg Formation of Strasburg Junction, Virginia.

The development of the marginal ridges seems to be the same as in *Bolbopisthia carinata*, but details are obscure on account of the state of preservation.

Interior of the left valve with a conspicuous contact furrow, developed along the entire free margin. The right valve lacks such a furrow, and in closed valves the contact furrow evidently accommodates the free edge of the right valve. No closed carapaces were available.

The hingement is poorly preserved in the available material. However, traces of a median hinge furrow can be observed on both valves. On the left valve the ventral hinge ridge has an abrupt termination posteriorly.

Heteromorphs. In heteromorphs the postadductorial field is strongly inflated compared to that of tecnomorphs. Only the dorsalmost part of the field retains its tecnomorphic convexity and is separated from the inflated part by a distinct, deep, curved furrow. A faint trace of such a furrow has occasionally been observed on tecnomorphs.

Preadult instars. The smallest available specimen (length 0.79 mm) does not seem to differ significantly from adult tecnomorphs.

Dimensions.—See Fig. 19.

Discussion.—The species is evidently fairly common in some calcarenite beds of the Lower Edinburg Formation at Strasburg Junction, Va, and some 30 specimens were secured during partial examination of the insoluble residue of some limestone samples. Kraft figured one heteromorphic valve (1962, Pl. 15, fig. 6) and a dorsal view of a tecnomorphic valve (1962, Pl. 15, fig. 7), the latter possibly belonging to the penultimate instar.

Occurrence.—Virginia, Strasburg Junction. Lower Edinburg Formation.

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Explanation of plates

The photographs were taken by the authors with the equipment described by MARTINSSON (1962, p. 42). A spotlight was used as the source of illumination. The specimens were faintly stained with ink and coated with ammonium chloride before photographing.

Plate I

Primitiella minima (HARRIS, 1957)

The figured specimens are from the exposure at Rock Crossing of Hickory Creek in the Criner Hills, Oklahoma. Pooleville Member. All figures ×60.

1–3. Heteromorphic carapace in dorsal (fig. 1) and ventral (fig. 2) view and its left valve in lateral view (fig. 3). Museum of the Palaeontological Institute, Uppsala, No. NA 120.
4–6. Technomorphic carapace in dorsal (fig. 4) and ventral (fig. 5) view and its left valve in lateral view (fig. 6). No. NA 121.
7–9. Right heteromorphic valve in lateral (fig. 7), ventral (fig. 8), and internal (fig. 9) view. No. NA 122.
10–12. Left heteromorphic valve in lateral (fig. 10), ventral (fig. 11), and internal (fig. 12) view. No. NA 123.

Plate II

Monotiopleura auriculata n.gen., n.sp.

All figured specimens are from the type locality and the type stratum. Magnification ×40.

1–5. Holotype. Heteromorphic carapace in dorsal (fig. 1), ventral (fig. 2), posterior (fig. 4), and anterior (fig. 5) view and its right valve in lateral view (fig. 3). No. NA 79.
6–8. Tecnomorphic carapace in dorsal (fig. 6) and ventral (fig. 7) view and its left valve in lateral view (fig. 8). No. NA 80.
9–10. Right tecnomorphic valve in lateral (fig. 9) and ventral (fig. 10) view. See also Pl. III, fig. 2. No. NA 81.
11–13. Left heteromorphic valve in lateral (fig. 11), ventral (fig. 12), and internal (fig. 13) view. See also Pl. II, fig. 1. No. NA 82.
14. Left tecnomorphic valve in ventral view. No. NA 83.
15. Right heteromorphic valve in ventral view. No. NA 84.

Plate III

Monotiopleura auriculata n.gen., n.sp.

All figured specimens are from the type locality and the type stratum. Magnification ×40.

1. Left heteromorphic valve in dorsal view. No. NA 82 (see also Pl. II, figs. 11–13).
2. Right tecnomorphic valve in dorsal view. No. NA 81 (see also Pl. II, figs. 9–10).
3. Left tecnomorphic valve in lateral view. No. NA 85.
4. Right heteromorphic valve in lateral view. No. NA 86.

Lomatopisthia simplex (HARRIS, 1957)

The figured specimens are from the exposure along Oklahoma Highway 99, 3 miles S. of Fittstown, Arbuckle Mountains, Oklahoma. Mountain Lake Member, Harris' zone 35. Magnification ×59.

5. Right heteromorphic valve in ventral view. No. NA 90.
6–7. Right tecnomorphic valve in ventral (fig. 6) and lateral (fig. 7) view. No. NA 89.
8–11. Left (fig. 8) and right (fig. 9) valves of a heteromorphic carapace and carapace in ventral (fig. 10) and dorsal (fig. 11) view. No. NA 87.
12–15. Left (fig. 12) and right (fig. 13) valves of a tecnomorphic carapace and carapace in ventral (fig. 14) and dorsal (fig. 15) view. No. NA 88.

Plate IV

Lomatopisthia varicata (Harris, 1957)

The figured specimens are from the exposure at Rock Crossing of Hickory Creek in the Criner Hills, Oklahoma, Pooleville Member. Magnification × 60.

1–4. Heteromorphic carapace in ventral (fig. 1) and dorsal (fig. 2) view and its left (fig. 3) and right (fig. 4) valves in lateral view. No. NA 93.

5–8. Tecnomorphic carapace in ventral (fig. 5) and dorsal (fig. 6) view and its left (fig. 7) and right (fig. 8) valves in lateral view. No. NA 94.

9. Left heteromorphic valve in lateral view showing the two well defined knob-like structures of L3. No. NA 124.

10–11. Right heteromorphic valve in ventral and internal view. No. NA 125.

Plate V

Physalidopisthia marginovelata (Kraft, 1962)

The figured specimens are silicified and are from Strasburg Junction, Shenandoah County, Virginia. Lower Edinburg Formation. Magnification × 40.

1–4. Right heteromorphic valve in lateral (fig. 1), dorsal (fig. 2), ventral (fig. 3), and internal (fig. 4) view. No. NA 133.

5–8. Left tecnomorphic valve in lateral (fig. 5), ventral (fig. 6), dorsal (fig. 7), and internal (fig. 8) view. No. NA 134.

Dibolbopisthia arbucklensis n.sp.

The figured specimens are from the roadside exposure along Oklahoma State Highway 99, 3 miles S. of Fittstown, Arbuckle Mountains, Oklahoma. Pooleville Member, at the general level of Harris' zones 21–23. Magnification × 60.

9–10. Right tecnomorphic valve in lateral (fig. 9) and ventral (fig. 10) view. No. NA 142.

11–12. Holotype. Left heteromorphic valve in lateral (fig. 11) and ventral (fig. 12) view. No. NA 141.

Plate VI

Bolbopisthia carinata (Kraft, 1962)

The figured specimens are silicified and are from Strasburg Junction, Shenandoah County, Virginia. Lower Edinburg Formation. Magnification × 40.

1–2. Right tecnomorphic valve in lateral (fig. 1) and dorsal (fig. 2) view. No. NA 136.

3–5. Right heteromorphic valve in lateral (fig. 3), dorsal (fig. 4), and internal (fig. 5) view. No. NA 135.

6, 7, and 8. Three juvenile left tecnomorphic valves in lateral view. Nos. NA 138, 139, and 140, respectively.

9. Left tecnomorphic valve in internal view. No. NA 137.

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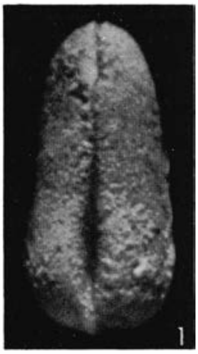
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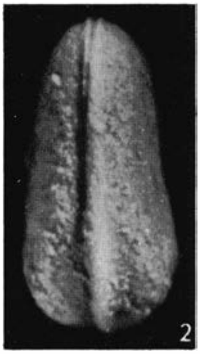
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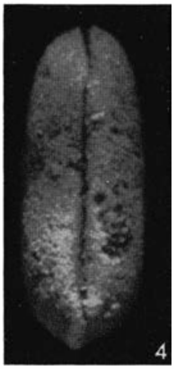
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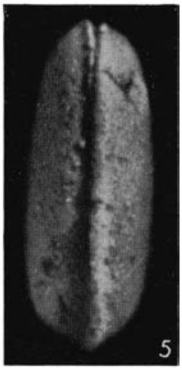
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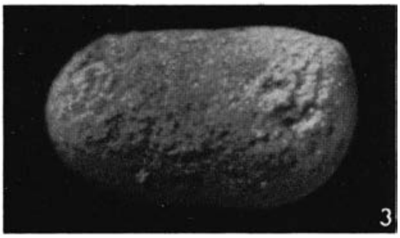
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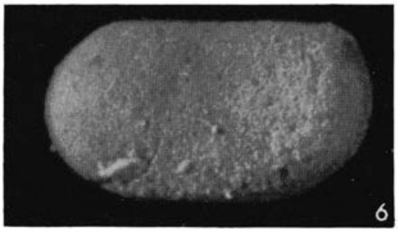
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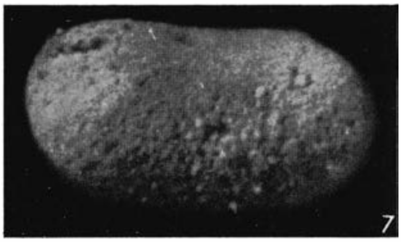
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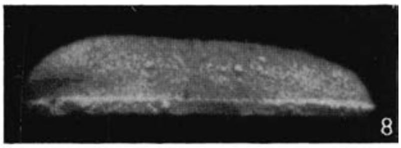
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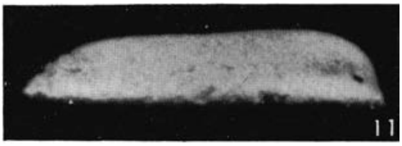
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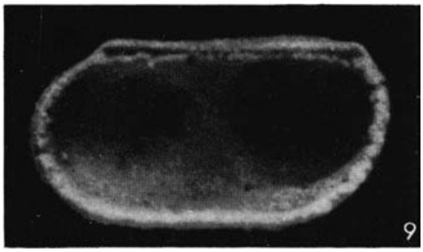
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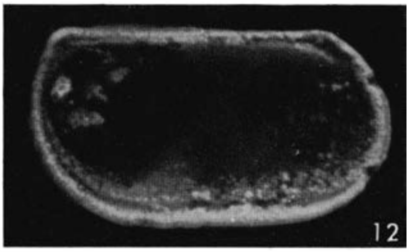
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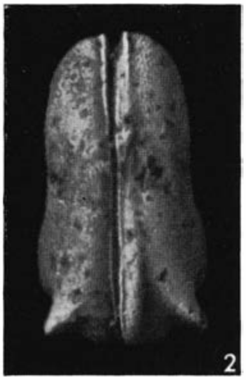
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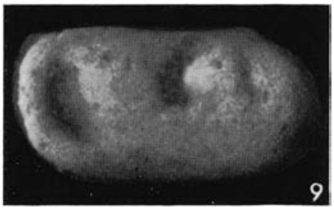
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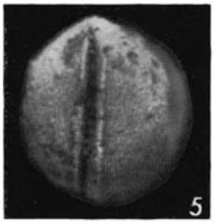
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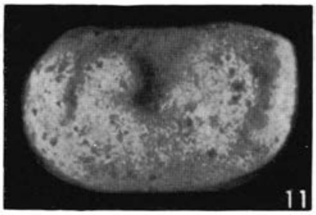
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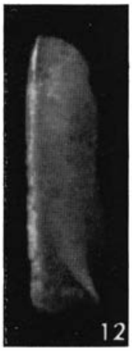
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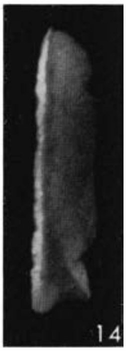
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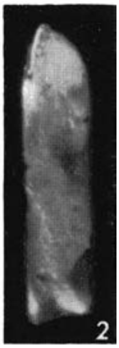
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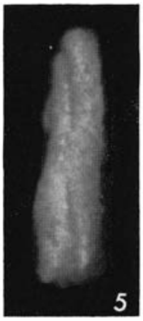
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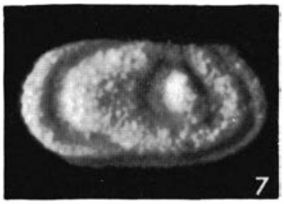
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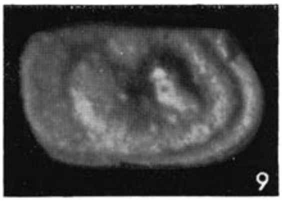
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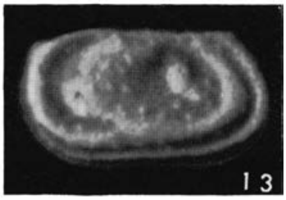
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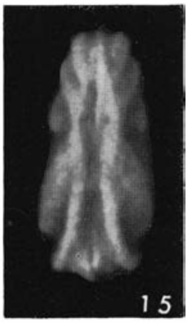
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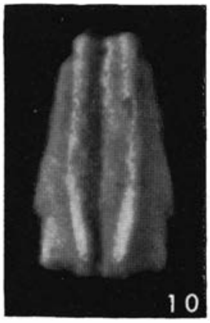
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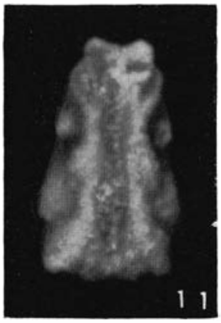
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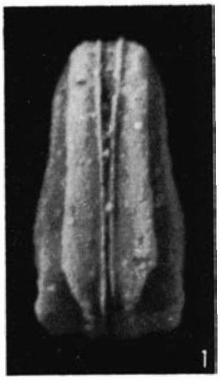
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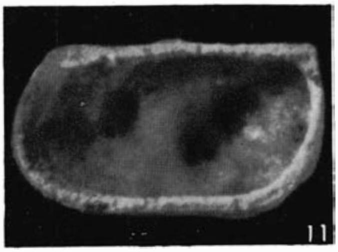
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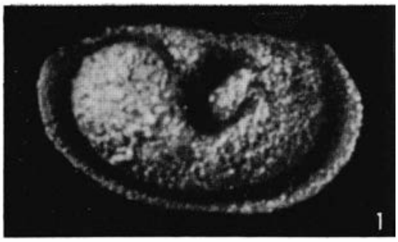
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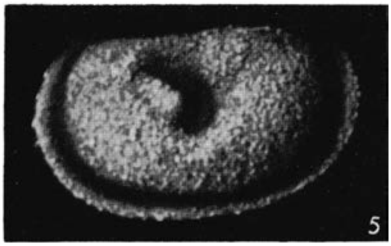
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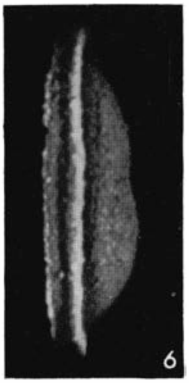
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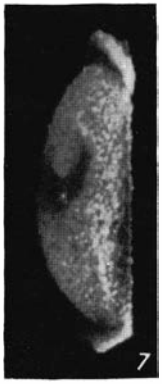
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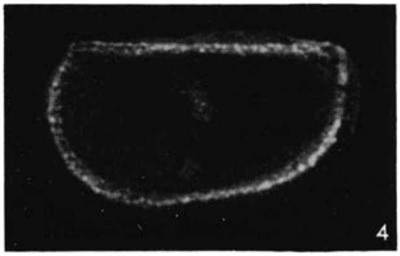
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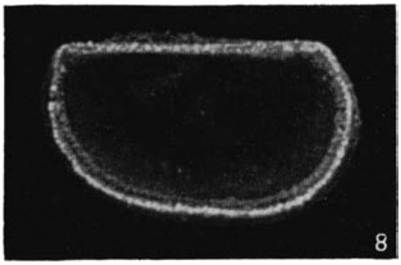
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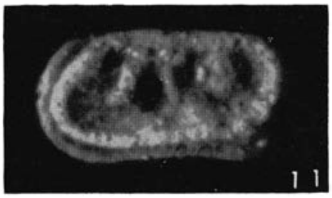
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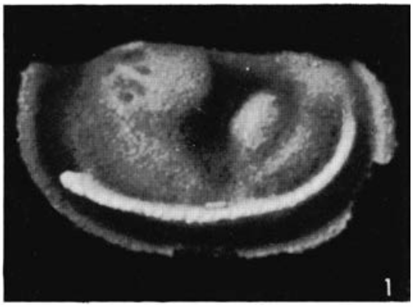
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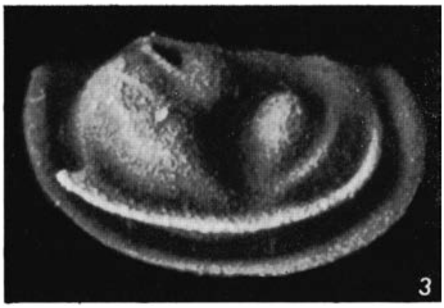
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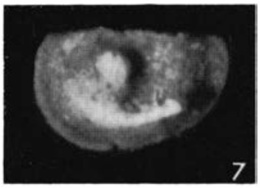
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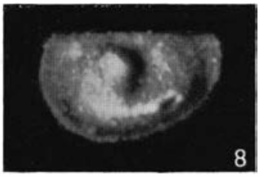
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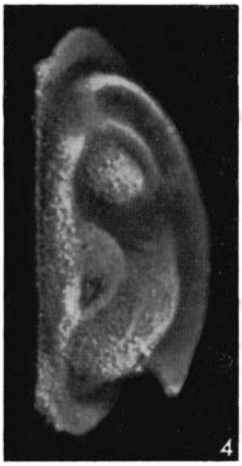
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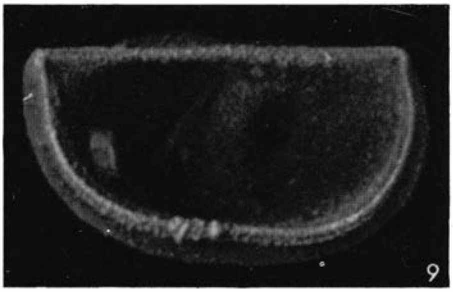
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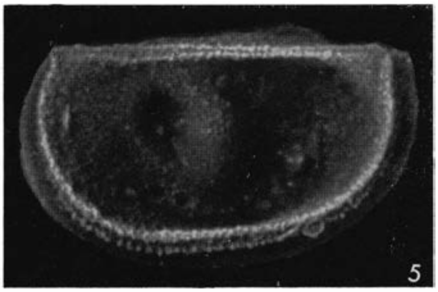
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