Brachiopods and conodonts from the Early Carboniferous of South China

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A sample taken from a detrital limestone lens, presumed to be allochthonous, within the dark coloured argillaceous limestone of the Early Carboniferous Muhua Formation at the Muhua section, Guizhou, South China, yielded numerous, mostly silicified fossils. Ostracodes, which are the most numerous in the sample, were studied by Olempska (1999). Brachiopods and conodonts are described and illustrated in this paper, but other associated fossils are also noted. Among brachiopods the most common are productides, orthotetidines, spiriferides, and orthides. The productoid gen. et sp. indet. 2, *Lambdarina* sp., and rhynchonelloid gen. et sp. indet. most probably represent new taxa, but are described in open nomenclature because of inadequate material. Conodonts are indicative of late Tournaisian age. The fossil assemblage is represented by phosphatic and silicified remnants, the latter being originally calcitic. The pattern of silicification resulted generally in preservation of skeletal morphology in great details.

Key words: Brachiopoda, Conodonta, Early Carboniferous, silicification, China.

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Introduction

The study of the Devonian–Carboniferous rocks widely exposed in South China has been continued for over half a century. Several sections with complete to nearly complete Late Devonian–Early Carboniferous sequences have been found, some of them rich in fossils (Hou *et al.* 1985). Although many papers have been published on the Devonian-Carboniferous invertebrates and fish from these sections there are many groups and faunistic sequences which remain inadequately known. One of the most interesting and important localities where fossils are still poorly known is the section near Muhua village, Guizhou province, South China. Although this locality was proposed as one of the final candidates for the Devonian–Carboniferous Boundary stratotype section (Ziegler & Sandberg 1984; Ziegler *et al.* 1988), its fossil assemblages are not adequately known. This paper deals with silicified and phosphatic fossils revealed in a conodont sample (Mu-42), collected by Jerzy Dzik (Institute of Paleobiology, Warsaw) in 1995 from the limestone lens within argillaceous limestone of the Muhua Formation (Fig. 1, see also Dzik 1997). Although the studied material is generally inadequately represented, it clearly shows that this section merits more detailed palaeontological investigation. Several interesting and most probably new brachiopod and conodont taxa are described here in open nomenclature because the material is inadequate to support formal descriptions. A rich ostracode assemblage from the sample Mu-42 is presented by Olempska (1999).

The studied material is housed at the Institute of Paleobiology of the Polish Academy of Sciences in Warsaw (abbreviated ZPAL).

Remarks on the geological setting and material

The Muhua section (lat. 25°46'0''N, long. 106°23'0''E) is located close to the small village of Muhua, in the southern part of Guizhou province, 50 km south of Huishui, South China (Fig. 1). Late Devonian–Early Carboniferous beds are here well exposed in natural outcrops. The section starts with the Late Famennian Daihua Formation, which consists of ca 3.4 m of thick light-grey bedded limestones with conodonts and ammonoids. The overlying Wangyou Formation starts with the Gedougguan bed which consists of ca 30 cm of light-grey lenticular limestones and yellow grey marlstones. According to Hou *et al.* (1985) and Dzik (1997) this bed represents the *Protognathodus kockeli* Zone. The rest of Wangyou Formation is 3.8 m thick and composed mainly of grey thin to medium bedded nodular limestone. These layers represent the lower part of the Tournaisian.

The section ends with the Muhua Formation which is composed of grey to black medium to thick bedded argillaceous limestones. The sample Mu-42 (ca 1.5 kg in weight), containing the fossils described herein, was taken from a detritic limestone lens which occurs close to the top of the exposure. The lens extends ca 1 m in width and is 10 cm thick. All the studied brachiopods and associated fossils were etched from the sample using a buffered formic acid. The conodonts revealed in this sample are scarce (see Fig. 5); together with ostracode and spore assemblages they suggest late Tournaisian age (see also Olempska 1999).

The fossil assemblage

The percentage composition of the fossil assemblage from sample Mu-42 is shown in Fig. 2. It can hardly be expected that these percentages exactly reflects the composition of the original community. The fossilization process of the Muhua fauna was differential according to the fossilization potential of skeletal remnants and it was additionally modified by silicification. It seems obvious that not all fossil groups are as prone to silicification as are others (Boucot 1981). Although imperfect, the structure of the studied assemblage provides some important data about the biotic and abiotic conditions of the environment (Olempska 1999).

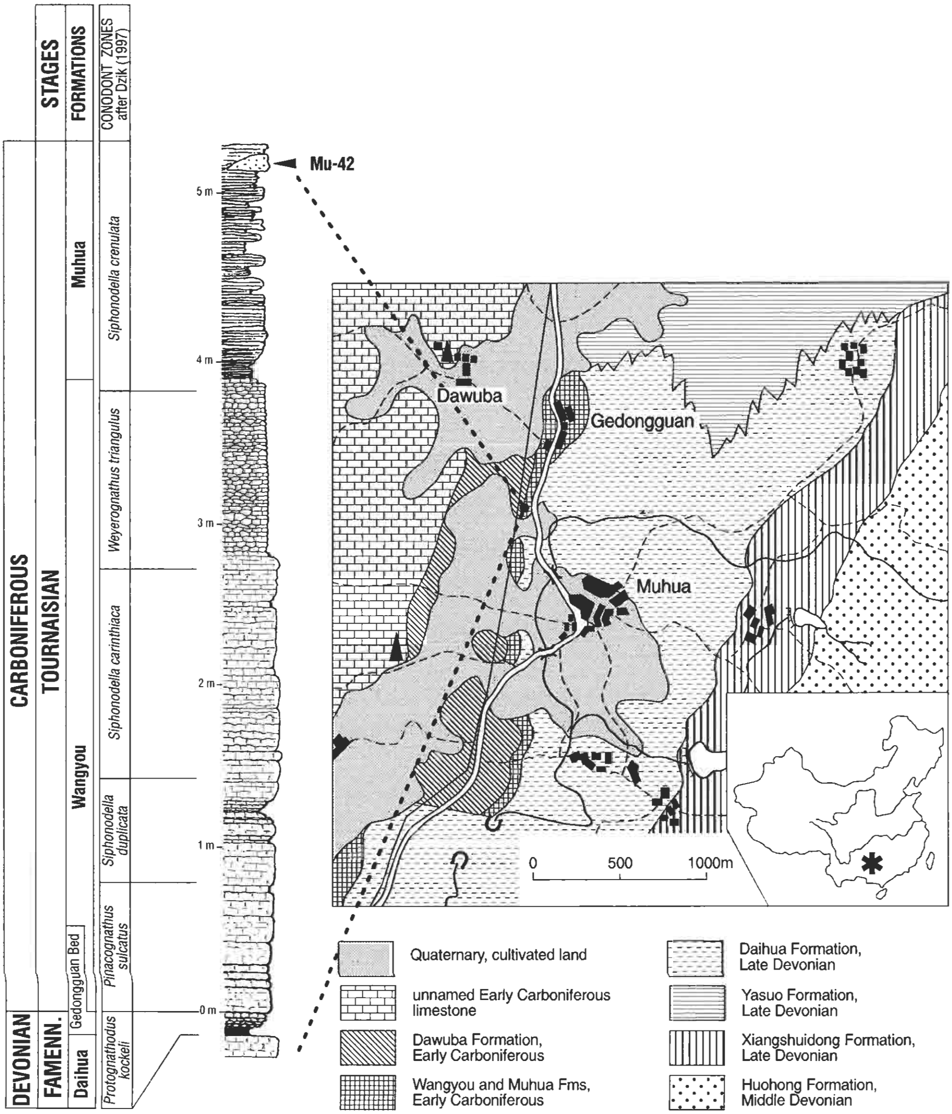

Fig. 1. Lithologic section of the Late Famennian to Tournaisian sequence and its location at Muhua, Guizhou province, south China; location of the Mu-42 sample is marked at the top of the section. After Dzik (1997) and Olempska (1999), modified.

The most characteristic features of the Muhua fauna is the evident disassociation of skeletal parts (e.g., echinoderms, trilobites, brachiopods) and their fragmentation. This indicates some degree of disturbance prior to the burial of the assemblage (Boucot 1981; Olszewski & West 1997). According to Olempska (1999) and Dzik (personal communication) the skeletal debris of the limestone lens was probably transported down slope into a deeper water basin-slope environment.

In the whole collection, which comprises almost five thousands skeletal items, well preserved specimens exceeding 5 mm in size are very rare. The largest are tetracorals

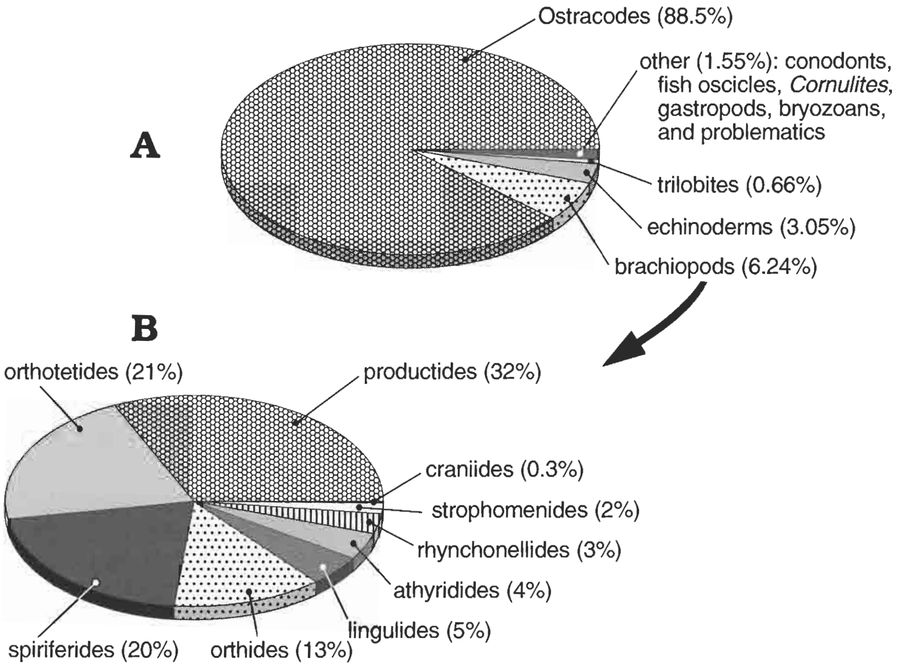

Fig. 2. Relative abundance of groups (**A**) and brachiopod orders (**B**) in the fossil assemblage at Muhua, Guizhou province, South China; estimated by number of specimens.

(9 mm in length) with their robust and durable theca. On the other hand, there are many very well preserved ostracodes and juvenile brachiopods with conjoined valves which are below 3 mm in length. The composition of the fauna suggests that it lived in a marine shelf environment with normal salinities. The most important groups of fossils in the assemblage are, in order of their abundance: ostracodes (88.50%), brachiopods (6.24%), and echinoderms (3.05%). These constitute 97.79% of the assemblage. Subordinate trilobites, conodonts, fish remains, *Cornulites*, tetracorals, bryozoans, gastropods, and problematic fossils constitute 2.21% (Fig. 2).

Among brachiopods the most common are productides, orthotetidines, spiriferides, and orthides (Fig. 2). The first two were well adapted to a soft muddy bottom or, as with the productides, even to a quasi-infaunal mode of life (Rudwick 1970). Also lingulids, which constitute 5% of the brachiopod assemblage were probably infaunal near-shore, or even intertidal dwellers.

The co-occurring ostracodes, especially the presence of bairdiids, together with heavily ornamented forms and large smooth-shelled paraparchitaceans suggest normal marine conditions in a shallow environment (Olempska 1999). Among conodonts, the genus *Mestognathus* is characteristic of harsh, nearshore, shallow-water, hypersaline marine to nearshore brackish-water environments (von Bitter *et al.* 1986). It is noteworthy that the genus was frequently found in downslope transported sediments (Bełka 1983; von Bitter *et al.* 1986). The co-occurring *Cavusgnathus* sp. was also characteristic for carbonate shelf environments (Austin 1976) and was tolerant of a wide range of energy levels (Rexroad 1981).

Review of the brachiopod material

More than three hundred brachiopod specimens have been isolated from the residue of acid digestion. Small specimens dominate the collection and generally they are well preserved as a result of the fine silicification process. Large specimens are always highly fragmented and very poorly represented in the collection, although they are well silicified and frequently display well preserved morphological characters. Because of the fragmentation of specimens they are very difficult to identify taxonomically – the majority are determined only to generic level. Because of their small numbers in the collection the three apparent new forms are described in open nomenclature. These are *Lambdarina* sp., rhynchonelloid gen. et sp. indet., and productoid gen. et sp. indet. 2.

***Lingula* sp.** — Fourteen small fragments of valves belong to the genus *Lingula* (*sensu lato*) (Fig. 3B).

***Acanthocrania* sp.** — One conical dorsal valve (Fig. 3A) with a rather poorly preserved external ornamentation has been found. The valve is 2 mm wide and 0.8 mm high. The ornamentation consists of densely spaced, radially arranged minute spines which show a tendency to produce radial striation. At its periphery the valve shows clear radial ribbing. The presence of minute spines suggests that the valve belongs to *Acanthocrania* Williams, 1943.

***Schizophoria* sp.** — Thirty nine silicified specimens are preserved as small fragments of valves, mostly juveniles. The character of shell ornamentation and internal structures of both valves suggest that these specimens represent the genus *Schizophoria* King, 1850 (Fig. 3C–E).

***Leptagonia* sp.** — One well preserved fragment of dorsal valve showing details of the internal structure (Fig. 3F, G) and four small fragments of broken valves have been found.

***Schuchertella* sp.** — This is one of the commonest species in the assemblage although it is represented almost exclusively by juvenile specimens (Fig. 3H). More than 60 usually incomplete isolated valves have been found. The specimens in the collection rarely exceed 3 mm in length. Interior of the ventral valve without dental plates.

Orthotetidine gen. et sp. indet. — Three small fragments of isolated valves probably belonging to *Schellwienella* have been found. They show strong radial ornamentation and distinct serration of the ribs, but the fragments are too small to identify (Fig. 3R, S). The other three fragments show much weaker ornamentation and it is evident that they represent another species.

***Rugosochonetes* sp.** — This is one of the commonest brachiopod species in the assemblage (Fig. 3M–P). Seventy specimens have been recovered, but usually preserved as incomplete single ventral valves. The largest specimens in the collection attain 12 mm in length. The complete specimens are subrectangular to semi-elliptical in outline and they have short ears. It should be noted, however, that in the studied collection there are also juvenile specimens with a more elongate, semi-circular shell outline (Fig. 3M). Both valves are multicostellate, with numerous bifurcations; commonly 4 to 5 ribs per mm, at 5 mm from the umbo. There are usually up to three pairs of hinge-spines extending posterolaterally at 40 to 65° from the posterior margin.

This species is similar in outline and shell ornamentation to *R. ustulatus* Roberts, 1971 from the Visean of NW Australia (Roberts 1971: pp. 65–67; pl. 7: 15–25); the Chinese specimens, however, have much shorter ears. *R. kruglovi* (Fredericks, 1929) described by Fotiyeva (1985: pp. 26–27; pl. 1: 15–18) from the Tournaisian of the Urals and Timan-Petchorsk province differs from the Chinese form in having more numerous hinge spines and in its smaller shell dimensions.

***Argentiproductus* sp.** — One incomplete ventral valve (Fig. 3J) shows the characteristic radial ribbing, short rows of spines across the umbonal lateral slopes and the median spine bases. The juvenile specimens described below as productoid gen. et sp. indet. 1 may belong to this taxon.

Echinoconchid gen. et sp. indet. — One valve fragment preserves a dense coat of fine, prostrate spines and lamellose bands which suggest an echinoconchid affinity (Fig. 3Q).

Productoid gen. et sp. indet. 1. — There are also about twenty specimens of poorly preserved juvenile productaceans 1 to 2 mm in length. Three of these specimens, however, preserve the morphological details of early ontogenetic stages, one of them is illustrated here (Fig. 3K, L). This shell is 1.8 mm in length (including its protruding pedicle sheath) and 2.0 mm in width and shows the exceptionally well preserved pedicle sheath, median groove and first formed clasping spines. The pedicle sheath of the studied specimens is 0.16 to almost 0.20 mm in length and is postero-ventrally or ventrally directed. Similar structures were described in juvenile productoids by Brunton (1965, 1966), Brunton & Cocks (1996), and Brunton & Mundy (1993), and Brunton's illustrated juvenile ventral umbos attributed to *Argentiproductus* seem almost identical.

Productoid gen. et sp. indet. 2. — Four damaged and one almost complete dorsal valves attain 1.4 to 2.6 mm in length (Fig. 4P, S). This unusual microbrachiopod possesses very characteristic internal structures which are dominated by a pronounced 'W'-shaped submarginal ridge (Fig. 4P, S). The left and right lobes of the ridge are recurved posteriorly near the antero-median valve margin and extend to the valve mid-length. Adductor muscle scars are suboval and elevated. The external ornamentation of the valves is of concentric lamellae.

This very strange form probably represents an unknown stock of tiny productoids (strophalosioids?), although some of its internal characters, such as the sub-marginal ridge and the structure of cardinal process, show some similarity to the plectambonitacean strophomenoids. It should be noted, however, that the stratigraphically youngest representatives of the plectambonitoids are known from the Middle Devonian. The new form shows some similarity in its dorsal valve interior, and especially in the development of the submarginal ridge to the Permian aulostegoid *Cooperina* Termier, Termier, & Pajaud, 1966 (see Cooper & Grant 1975), but this resemblance seems to be superficial. According to Brunton (letter communication) the Chinese form, having postero-ventrally directed cardinal process and characteristic brachial ridge structure, more likely belongs in the Strophalosioidea.

***Lambdarina* sp.** — Only two almost complete and four fragmentarily preserved shells have been recovered (Fig. 4I–O, Q, R). The largest shell attains 1.6 mm in length. The ventral umbo is rather high and averages 24 to 29.5% of the shell length. The umbo is apsacline, i.e. it is slightly inclined ventrally at 25 to 36° away from the plane of the commissure.

The specimens from China differ from the early Visean *L. manifoldensis* Brunton & Champion, 1974, late Permian *L. iota* Grant, 1988, early Carboniferous *L. brownendensis* Morris, 1994, and late Tournaisian *L. glaphyra* Basset & Bryant, 1993 mainly in having wider and shorter lobes. The specimens under study are closest externally to *Lambdarina granti* Nazer, 1983 from the Upper Visean of south-eastern Queensland in having a very similar shell lobation. The former, however, have a weaker median fold in the ventral valve and apsacline ventral area which in the Australian species is distinctly dorsally inclined (Nazer 1983: fig. 1D).

The specimens from China are suggestive of being related to *Hampsia cooperi* Morris, 1994 from the early Carboniferous of North Staffordshire, England, which also has wide lobes and an apsacline ventral area. *H. cooperi* differs in having a strongly convex dorsal valve and more ventrally inclined ventral area, which is flexed at 58° away from the plane of the commissure (measured from Morris 1994: fig. 1G). According to Morris (1994: p. 272) the ventrally inclined ventral umbo of *Hampsia* is unique within the Cardiarinidae. However, this is not the case because an anacline position of the umbo is seen also in some specimens of *Lambdarina manifoldensis* (see Basset & Bryant 1993: fig. 5.3) and *L. glaphyra* (see Basset & Bryant 1993: figs 2.5–2.6). Hoare & Mapes (1997) recently suggested that the Permian *Cardiarina* may have possessed a centronelloidiform loop and they

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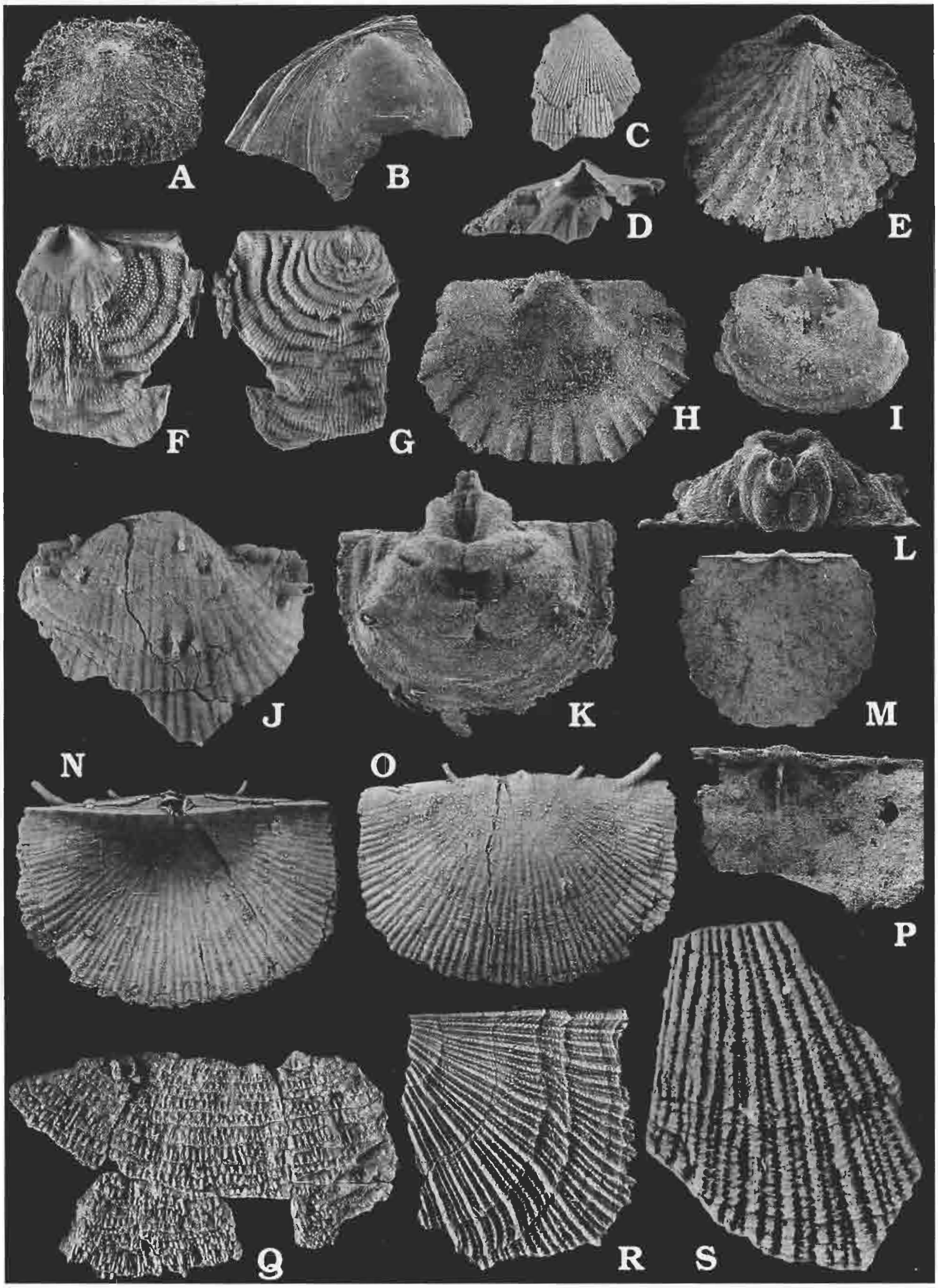
Fig. 3. Silicified brachiopods from the Late Tournaisian of the Muhua section (sample Mu-42), Guizhou province, South China. **A, B, E, H, I, K–M, P,** are SEM micrographs. **A.** *Acanthocrania* sp. Exterior of dorsal valve ZPAL V.XXVI/1, × 15. **B.** *Lingula* sp. Exterior of incomplete dorsal valve ZPAL V.XXVI/2, × 25. **C–E.** *Schizophoria* sp. **C.** Exterior of incomplete ventral valve ZPAL V.XXVI/3, × 2. **D.** Incomplete ventral valve interior, ZPAL V.XXVI/4, × 2. **E.** Juvenile shell in dorsal view, ZPAL V.XXVI/5, × 10. **F, G.** *Leptagonia* sp. Incomplete dorsal valve interior (**F**) and exterior (**G**), ZPAL V.XXVI/6, × 2. **H.** *Schuchertella* sp. Juvenile dorsal valve interior, ZPAL V.XXVI/7, × 25. **I, K, L.** Productoid gen. et sp. indet. 1 (possibly *Argentiproductus* sp.). **I.** Juvenile dorsal valve interior, ZPAL V.XXVI/8, × 12. **K, L.** Juvenile shell in dorsal (**K**) and posterior (**L**) views showing pedicle sheath and a pair of clasping spines, ZPAL



V.XXVI/9, × 20. **J**. *Argentiproductus* sp. Incomplete ventral valve exterior, ZPAL V.XXVI/11, × 3. **M–P**. *Rugosochonetes* sp. **M**. Juvenile ventral valve interior, ZPAL V.XXVI/12, × 12. **N**, **O**. Shell ZPAL V.XXVI/13 in dorsal and ventral views, × 5. **P**. Incomplete ventral valve interior, ZPAL V.XXVI/14, × 12. **Q**. Echinoconchid gen. et sp. indet. Incomplete valve exterior, ZPAL V.XXVI/10, × 12. **R**, **S**. Orthotetidine gen. et sp. indet. Exterior of two fragments of valves, ZPAL V.XXVI/15, × 2.

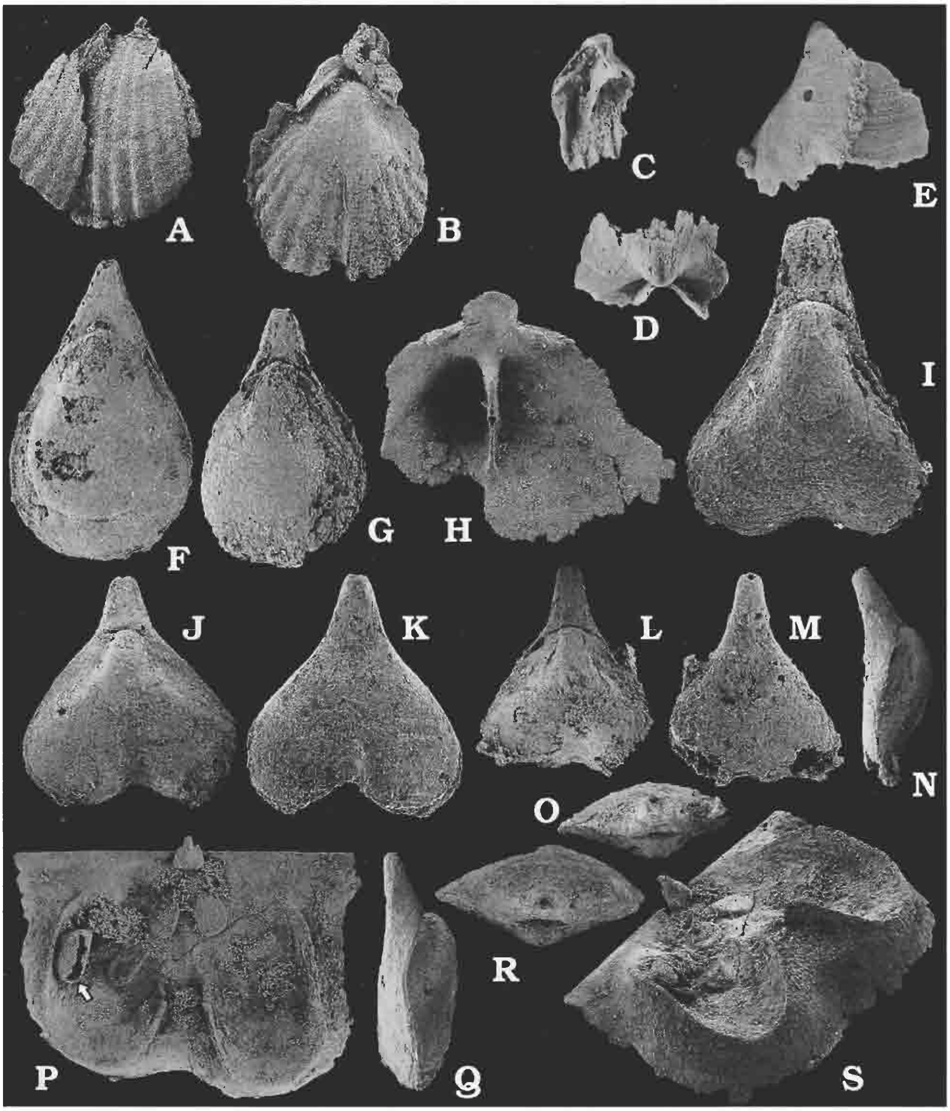


Fig. 4. Silicified brachiopods from the Late Tournaisian of the Muhua section (sample Mu-42), Guizhou province, South China. **A**, **B**, **F**–**S** are SEM micrographs. **A**, **B**. *Hustedia* sp. Ventral (**A**) and dorsal (**B**) views of two incomplete specimens. ZPAL V.XXVI/16 (**A**), ZPAL V.XXVI/17 (**B**), × 15. **C**. *Tylothyris*? sp. Incomplete ventral valve interior, ZPAL V.XXVI/19, × 2. **D**. Phricodothyridine gen. et sp. indet. Posterior view of an incomplete ventral valve ZPAL V.XXVI/20, × 2. **E**. *Cleiothyridina* sp. Incomplete ventral valve exterior, ZPAL V.XXVI/21, × 2. **F**, **G**. Rhynchonelloid gen. et sp. indet. Two shells ZPAL V.XXVI/22 (**F**) and ZPAL V.XXVI/23 (**G**) in dorsal view, × 2. **H**. *Nucleospira*? sp. Incomplete dorsal valve interior, ZPAL V.XXVI/24, × 20. **I**–**O**, **Q**, **R**. *Lambdarina* sp. **I**. Juvenile shell ZPAL V.XXVI/25 in dorsal view, × 40. **J**, **K**, **Q**, **R**. Shell ZPAL V.XXVI/26 in dorsal (**J**), ventral (**K**), lateral (**Q**), and posterior (**R**) views, × 20. **L**–**O**. Slightly damaged shell ZPAL V.XXVI/27 in dorsal (**L**), ventral (**M**), lateral (**N**), and posterior (**O**) views, × 20. **P**, **S**. Productoid gen. et sp. indet. 2. Interior of dorsal valve in two views, ZPAL V.XXVI/28; the small ovoid test (arrowed) on the left side of the valve belongs to ostracode *Gueriechella coeni* Olempska, 1999, × 12.

re-assigned this genus to the Terebratulacea. In consequence, Savage (1996) proposed the new superfamily Lambdarinoidea for the Late Devonian and Carboniferous bilobate micro-rhynchonellids (*Loborina*, *Lambdarina*, *Hampsia*, and *Minysphenia*). *Lambdarina* from the Muhua section seems to be the oldest representative of the genus and is similar to the Famennian loborinid *Loborina* from Poland (Baliński 1982) in its wide, weakly separated lobes.

The species from China cannot be assigned to any described species and the collection is too poor to use as the basis for a new species. Internal shell structure of the Chinese form is unknown.

Rhynchonelloid gen. et sp. indet. — Three almost complete shells have been found in the studied sample. Their measurements are as follows (in mm): length = 1.78, 2.05, 2.16; width = 1.12, 1.25, 1.22; height of the ventral umbo = 0.40, 0.49, 0.42.

The shell is minute, scarcely exceeding 2 mm in length, biconvex, elongate oval in outline with a protruding umbo extending up to 24% of the shell length (Fig. 4F, G). Antero-lateral margins are regularly arched, postero-lateral margins are straight to slightly concave. The delthyrium is covered completely by a flat plate without any clear median line of junction (symphytium). The ventral valve umbo is straight to slightly apsacline, pierced apically by a round pedicle foramen. The dorsal valve umbo is swollen medianly but somewhat flattened laterally. Cardinal margins are angular. The shell interior remains unknown.

The studied specimens do not show any traces of punctation although it can be obliterated by silicification. Most probably they represent an unknown group of tiny rhynchonelloids with a possible relationship to the Lambdarinidae. Although the specimens lack the lobation of shell so characteristic for the lambdarinids, they possess a very similarly developed long ventral umbo, which is apically pierced by the pedicle foramen. As in *Lambdarina* and *Hampsia* the delthyrium of the Chinese form is covered by a flat single plate (symphytium). The general view of the ventral and dorsal umbos are strikingly similar to those in the co-occurring *Lambdarina*. Scarcity of the studied material and unknown details of the shell interior preclude the creation of a new taxon.

***Hustedia* sp.** — Two incomplete shells reveal a characteristic radial ornamentation and elongate oval shell outline (Fig. 4A, B). Although silicification obscured the shell punctation, it seems very probable that the specimens represent the cosmopolitan retziidine *Hustedia* Hall & Clarke, 1893. Externally they resemble *H. radialis* (Phillips, 1836) from the Visean of England (Brunton 1984) and *H.* aff. *paula* Roberts, 1971 from the late Visean of Western Australia (Nazer 1977).

***Cleiothyridina* sp.** (Fig. 4E). — Nine small fragments of valves, some of them preserving characteristic spine-like frills, have been found.

***Nucleospira*? sp.** — There are only two fragments of a dorsal valve with preserved cardinalia. The presence of a median septum and characteristic cardinal process (Fig. 4H) suggests that the specimens may be referred to this genus.

***Tylothyris*? sp.** — Eight very small fragments of dorsal and ventral valves reveal strong lateral costae, a prominent sulcus and lamellose growth lines. Strong dental plates and a low median septum are seen inside the ventral valve (Fig. 4C). The specimens are so poorly preserved that they cannot be definitely identified as to genus, or species.

Brachythyridid gen. et sp. indet. — Three fragments of juvenile ventral valves have been found. The valves are strongly convex, with a median sulcus and very weakly marked lateral plication. Internally they are without dental plates. The specimens probably represent a brachythyridid spiriferoid.

Phricodothyridine gen. et sp. indet. — One umbonal fragment of a ventral valve (Fig. 4D) has been found. The interior of the valve is without any dental plates; the delthyrium is open but with pronounced delthyrial flanges. The specimen represents most probably a phricodothyridine, although a martiniid relationship cannot be excluded because the micro-ornamentation is not preserved.

Juvenile brachiopods. — There are about 50 specimens of juvenile brachiopods, which cannot be identified taxonomically, mostly spiriferoids. The smallest shells attain 0.5 mm in length.

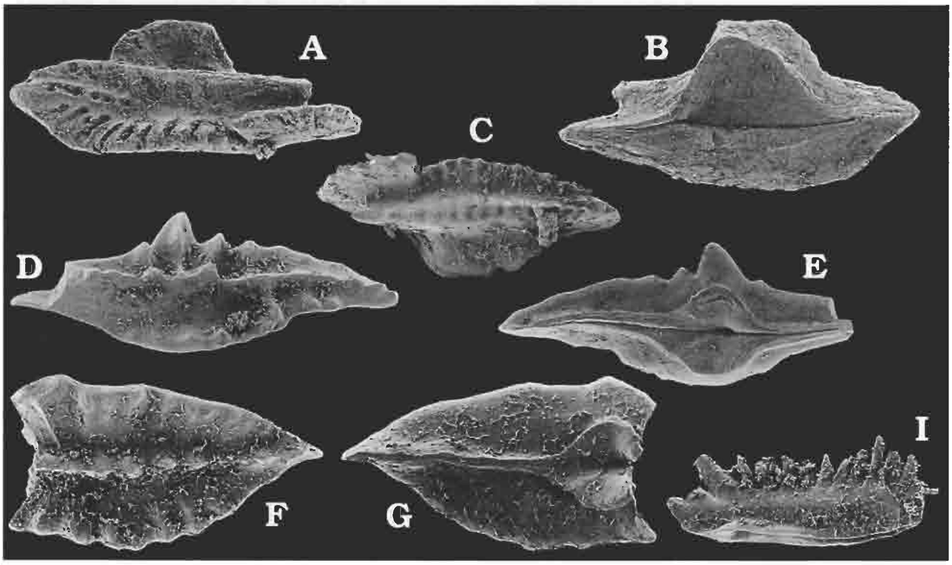


Fig. 5. Conodonts from the Late Tournaisian of the Muhua section (sample Mu-42), Guizhou province, South China. **A–B**. *Mestognathus* sp. ZPAL V.XXVI/54 in upper (**A**) and lower (**B**) views. **C**. *Cavusgnathus* sp. ZPAL V.XXVI/55 in upper view. **D**, **E**. *Pseudopolygnathus primus* (Branson & Mehl, 1934) in upper (**D**) and lower (**E**) views; ZPAL V.XXVI/56. **F**, **G**. *Pseudopolygnathus* sp. ZPAL V.XXVI/57 in upper (**F**) and lower (**G**) views. **I**. *Prioniodina*? sp. ZPAL V.XXVI/58. All are SEM micrographs × 43.

Conodonts

Twenty seven specimens have been found, eight of which are well preserved **sp** platform elements. The most interesting for the assemblage is the occurrence of one specimen of *Mestognathus* sp. (Fig. 5A, B) which is very close morphologically to its cavusgnathid ancestors. It is characterized by a very wide inner part of the basal cavity which caused the development of a thickened flat lobate outgrowth of the inner parapet. The carina is weak and short and developed in the posterior one third of the platform. According to Bełka (1983) a short carina is a primitive feature for the genus. The species from Muhua is evidently new and probably phylogenetically the oldest representative of the genus. Bełka (1983) and von Bitter *et al.* (1986) suggested that the genus *Mestognathus* originated within *Siphonodella isosticha* – Late *S. crenulata* conodont Zone. It can be assumed that the species from Muhua could be coeval to the oldest known species of *Mestognathus*, i.e. *M. harmalai*, or even somewhat stratigraphically older; thus, it indicates the late Tournaisian age for the studied assemblage.

The other characteristic conodont species for the sample are *Cavusgnathus* sp. (Fig. 5C), *Pseudopolygnathus primus* (Fig. 5D, E, H), *Pseudopolygnathus* sp. (Fig. 5F, G), and *Prioniodina*? sp. (Fig. 5I).

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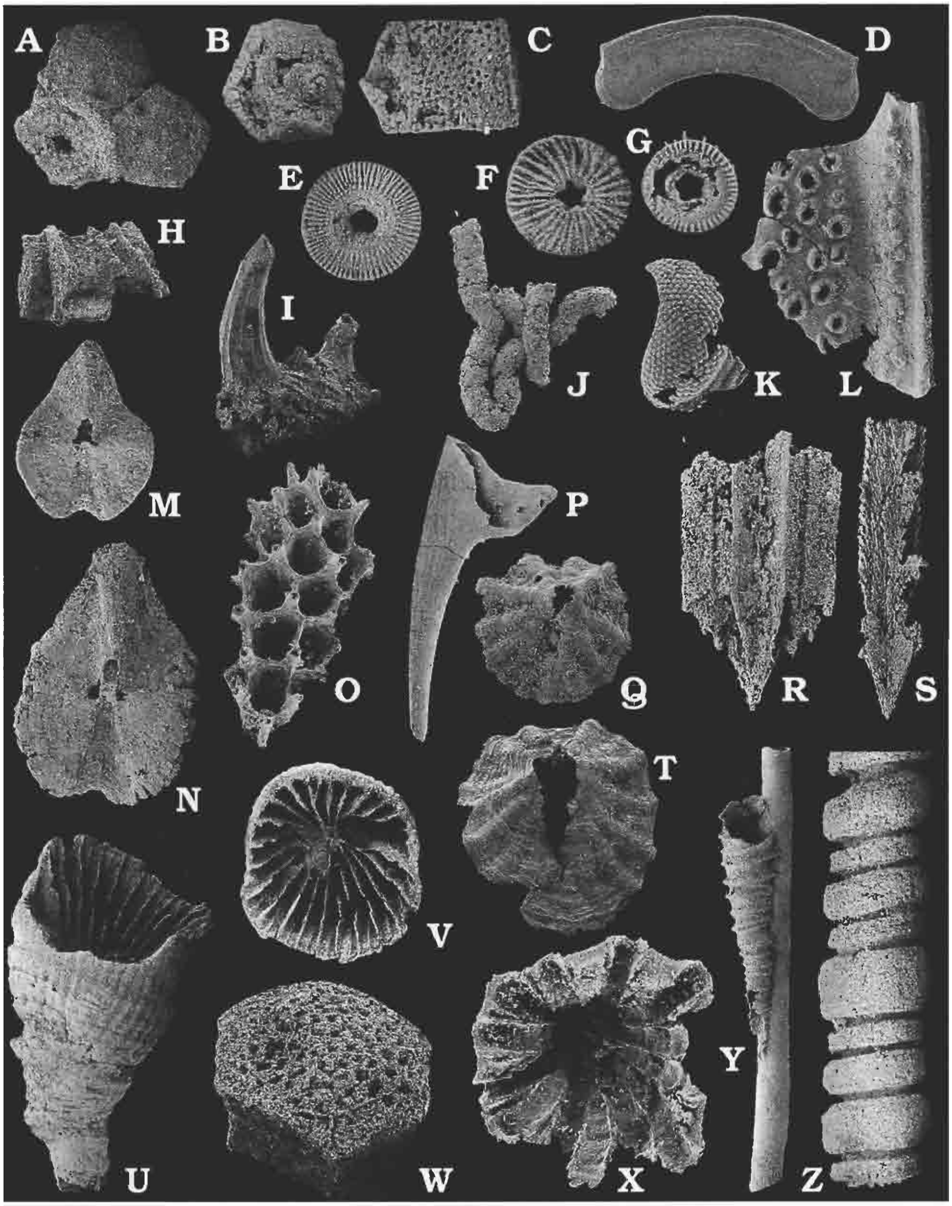
Fig. 6. Silicified fauna from the Late Tournaisian of the Muhua section (sample Mu-42), Guizhou province, South China. **A**, **D**, **H–Z** are SEM micrographs. **A**, **E–G**, **Z**. Crinoid fragments. **A**. Flat basal circlet and radials ZPAL V.XXVI/29, × 10. **E–G**. Columnals ZPAL V.XXVI/30–32, × 3. **Z**. Steam fragment ZPAL V.XXVI/33, × 10. **B**. Echinoid plate, ZPAL V.XXVI/34, × 3. **C**, **W**. Two asterozoan plates, ZPAL V.XXVI/35–36, × 3 (**C**) and × 10 (**W**). **D**, **K**, **L**, **P**. Trilobite fragments. **D**. Anterior part of doublure ZPAL V.XXVI/37, × 12. **K**. Incomplete eye ZPAL V.XXVI/38, × 15. **L**. Incomplete librigena ZPAL V.XXVI/39,



× 12. **P**. Genal spine ZPAL V.XXVI/40 in ventral view, × 10. **H**. Ophiuroid (stenuroid) plate ZPAL V.XXVI/41, × 10. **I**. Shark tooth ZPAL V.XXVI/42, × 30. **J**. Unidentified encrusting organism, ZPAL V.XXVI/43, × 12. **M**, **N**. Two plates ZPAL V.XXVI/44–45 of unknown affinity, × 25. **O**. Fragment of trepostome bryozoan colony ZPAL V.XXVI/46, × 25. **Q**, **T**, **X**. Three valves of unknown affinity (a single-walled bryozoan?) ZPAL V.XXVI/47–49 from exterior (**Q**, **T**), × 15, and interior (**X**), × 30. **R**, **S**. Elements of echinoid Aristotle's lantern, oral parts of two teeth ZPAL V.XXVI/50–51, × 25. **U**, **V**. Lateral and distal views of hapsiphyllid rugose coral ZPAL V.XXVI/52, × 5. **Y**. *Cornulites* sp. ZPAL V.XXVI/53 attached to productoid spine, × 12.

Associated fauna

Residue of the sample Mu-42 which yields brachiopods described above also contains large quantities of debris representing various groups of fossils which are commented shortly below. Thus, the present review characterizes more or less completely the fossil assemblage from the studied sample.

Hapsiphyllid rugose corals. — Three well preserved specimens were found; they probably represent the genus *Allotropiophyllum* (identification by J. Stolarski) (Fig. 6U, V).

***Cornulites* sp.** — Seven specimens (Fig. 6Y).

Trilobites. — Thirty two very small fragments of various parts of proetid exoskeletons, most often fragments of the cephalon (Fig. 6D, K, L, P).

Bryozoans. — One specimen (Fig. 6O).

Gastropods. — Only one fragment of *Platyceras* sp. has been found.

Crinoid, echinoid, asterozoid and ophiuroid debris. — Echinodermatid debris are one of the most frequent remnants in the residue. The most common are crinoid columnals (64%; Fig. 6E–G, Z), echinoid and asterozoid fragments (28%; Fig. 6B, W, Z) including elements of Aristotle's lantern (Fig. 6R, S).

Fish oscicles. — Twelve specimens (Fig. 6I).

Various problematic debris. — There are 16 minute plates of problematic affinity which attain 0.6 to 2.3 mm in length. They are elongate-heart-shaped with convex smooth dorsal(?) surfaces. The other surface (ventral?) possesses a complicated morphology modified by elongately triangular grooves and folds (see Fig. 6M, N); here delicate concentric growth lines are barely noticeable. This plates remotely resemble receptaculitid merome heads (see Dzik & Pisera 1994: fig. 15).

Five conical thin-shelled valves measuring no more than 2 mm in diameter have also been found in the residue. The valves are ornamented by 13 to 16 radial rounded ribs and by weak concentric growth lines (Fig. 6Q, T). Internal surface of the valves is radially divided by sharp and high ridges which bound wide rounded furrows (Fig. 6X). The ridges are simple or tend to bifurcate. Apical parts of all these specimens are destroyed. There is some probability that the specimens represent partially preserved single walled bryozoans.

Ostracodes, which are the commonest, are the subject of separate study by Olempska (1999).

Discussion

The sample Mu-42, which was taken from one of the proposed stratotype candidates of the Devonian–Carboniferous boundary, yielded a fossil assemblage of phosphatic remnants of fish, conodonts, and lingulids, as well as silicified skeletal remnants of various invertebrates which were originally calcitic (eg., ostracodes, articulate brachiopods, echinoderms, tetracorals, trilobites, and bryozoans). A characteristic feature of the assemblage is the absence of skeletons thought to have been originally aragonitic among the silicified remnants. Strikingly absent are bivalves, whereas gastropods are represented by a single calcitic shell of the archeogastropod *Platyceras*. It is commonly believed that the increased importance of aragonite skeletons, following the end-Permian extinctions, caused a substantial drop in the records of silicified fossils in the post-Paleozoic deposits (e.g., Schubert *et al.* 1997). However, the relationship between skeletal mineralogy and silicification seems not to be as straightforward because the less stable aragonite polymorph should be more prone to silicification than is calcite (Schubert *et al.* 1997). This contradiction may be explained by the earlier elimination of aragonitic skeletons from the sediment, before a silicifying fluid became available. Original skeletal microstructure may play a role in a selective silicification process, as was recently shown in the case of brachiopods (Brunton 1984; Daley & Boyd 1996). Generally, many fossils from the studied sample preserve in great detail such skeletal features as growth lines, delicate hollow spines (productides) or surface ornamentation (ostracodes). This type of silicification seems to correspond to pattern V of Schmitt & Boyd (1981) who analyzed silicification in the Permian pelecypods and brachiopods from Wyoming, USA. A similar example is provided by the Early Carboniferous silicified fossils from Fermanagh, Ireland (see Brunton 1984: pp. 31–32), however, echinoderm plates, which form large calcite crystals, are seldom fully silicified there.

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Ramienionogi i konodonty z wczesnego karbonu południowych Chin

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Streszczenie

W osadzie próby Mu-42 rozpuszczonej w kwasie mrówkowym, a pobranej z soczewki wapienia detrytycznego z Formacji Muhua (wczesny karbon) odsłaniającej się w pobliżu wsi Muhua (Południowe Chiny), stwierdzono występowanie licznych, przeważnie skrzemionkowanych skamieniałości. Skamieniałości te nie były dotąd badane, choć odsłonięcie było swego czasu kandydatem na profil stratotypowy granicy dewon–karbon (Ziegler & Sandberg 1984; Zigler *et al.* 1988). W całej kolekcji, liczącej około 5 tysięcy okazów, najliczniej reprezentowane są małżoraczki (88,5% zespołu; patrz Olempska 1999). W niniejszym opracowaniu udokumentowano i zilustrowano pozostałe elementy zespołu skamieniałości, wśród których najliczniejsze są ramienionogi (6,24%) i szkarłupnie (3,05%). Resztę zespołu (2,21%) stanowią trylobity, konodonty, łuski i zęby ryb, kornulity, rugozy, mszywioły, ślimaki oraz zagadkowe mikroskamieniałości o nieznanym pochodzeniu. Wśród ramienionogów i konodontów występują tu z pewnością nowe gatunki i rodzaje, które jednak ze względu na niedostateczną liczbę okazów są opisane w otwartej nomenklaturze. Wiek zespołu można określić na podstawie małżoraczków i konodontów na późny turnej. Cechą charakterystyczną zespołu z Muhua jest jego stan zachowania polegający na dezintegracji złożonych szkieletów i ich fragmentacji. Jednak okazy małe, poniżej 2 mm długości, są na ogół kompletne i zaskakują bardzo dobrze zachowanymi szczegółami urzeźbienia powierzchni. Analiza zespołu z próby Mu-42 wskazuje, że żył on w płytkim przybrzeżnym morzu o normalnym zasoleniu. Jednak, na skutek osunięcia się osadu wzdłuż stoku, szczątki organiczne zostały przetransportowane i ostatecznie osadzone w niezbyt oddalonej strefie głębszego morza.