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Waptia-like Euarthropods from Burgess - Shale - type Biotas in the Early Cambrian of Eastern Yunnan, China

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ABSTRACT

Waptia-like euarthropods existed for rather a long time in the Early Cambrian of eastern Yunnan; well preserved representatives come mainly from three Burgess Shale-type biotas: Chengjiang, Xiaoshiba and Guanshan. Here, we introduce a newly-discovered bivalved euarthropod from the Guanshan biota, the specific identity of which cannot be confirmed due to the absence of soft parts and poor preservation of the specimen, but its general morphology allows it be attributed to *Waptia*. Two representatives from the Chengjiang and Xiaoshiba biotas are also reconsidered: the preservation mode and length of specimens of *Clypecaris pterioidea* are variable; *Clypecaris serrate* has limbs beneath the carapace, which can number up to at least 4 pairs. The fossil sections bearing *Waptia*-like euarthropods occur over a wide area around Dianchi Lake.

1. Introduction

More than 100 years have passed since the first *Waptia*-like euarthropod was discovered. Hitherto, in addition to the type species, *Waptia fieldensis* Walcott, 1912^[1] from the Burgess Shale, Canada, representatives from Early or Middle Cambrian deposits in other areas have also been reported, e.g. in Utah, U.S.A.^[2] and Sirius Passet in Greenland^[3]. In recent years, based on new specimens and new technology, the neuroanatomy, reproductive strategies, feeding mode

and affinity of *Waptia fieldensis* have also been described and discussed^[4-9]. All these works have helped to reveal the original appearance of this bivalved euarthropod. There are also occurrences of *Waptia*-like euarthropods in Early Cambrian localities in eastern Yunnan, especially in the three classic Burgess Shale-type biotas: Chengjiang, Xiaoshiba and Guanshan. Here, we report a species of *Waptia* from the Guanshan biota, reconsider two representatives from Chengjiang and Xiaoshiba, and briefly discuss the temporal and spatial distribution of *Waptia*-like euarthropods in the Early Cambrian of eastern Yunnan.

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2. Materials and Methods

2.1 Materials and Methods

The total of three specimens discussed here come from three different biotas: the Chengjiang biota (YN-JS-500), the Xiaoshiba biota (YN-GS-001) and the Guanshan biota (YN-GLF-831). The last two specimens were prepared using a fine needle under a binocular microscope, revealing parts covered by the matrix. Digital photographs were taken using a Canon EOS 5D MkIII camera and 50 mm macro lens, dry under cross-polarized light and processed in Adobe Photoshop CS 4. Line drawings of all specimens were made using Adobe Illustrator CS 3. Terminology follows Vannier et al. ^[9], Straufeld ^[7] and Yang et al. ^[10].

2.2 Repository and Institutional Abbreviation

The specimens are housed at the School of Earth Sciences and Resources, China University of Geosciences (Beijing) (CUGB). The abbreviations in the specimen number refer to the location of the fossil section (YN, the province of Yunnan; JS, GS, and GLF correspond to the quarry of Jianshan, Guanshan reservoir and Gaoloufang respectively).

3. Systematic Palaeontology

Phylum Arthropoda ^[11]
 Phylum Euarthropoda ^[12]
 Subphylum Mandibulata ^[13]
 Order Hymenocarina ^[14]
 Waptiidae ^[1]
Waptia ^[1]
Waptia sp. indet
 Figure 1.A-C

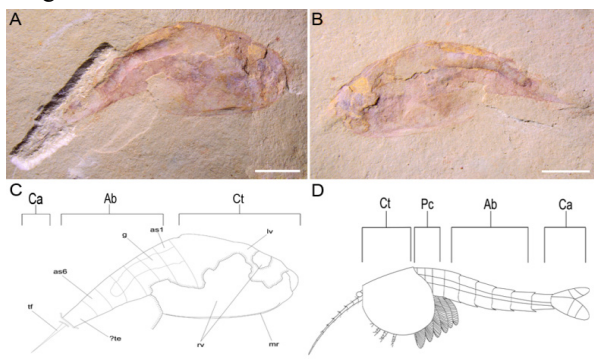


Figure 1. The specimen of YN-GLF-831 and the reconstruction of *Waptia fieldensis*

Note:

(A) counterpart of the specimen of YN-GLF-831; (B) part of the specimen of YN-GLF-831; (C) line drawing of (A); (D) reconstruction of *Waptia fieldensis*, revised from Vannier et al., 2018; Abbreviations are as follows: Ab, abdomen; as, abdominal segment; Ca, cauda; Ct, cephalo-

thorax; g, gut; lv, left valve; mr, marginal rim; Pc, post-cephalothoracic segments; rv, right valve; ?te, the possible telson; tf, tail fluke; Scale bar = 3 mm.

3.1 Material

One specimen (YN-GLF-831), from the Wulongqing Formation (Cambrian Series 2, Stage 4), Gaoloufang section (24.95916°N, 102.80539°E).

3.2 Description

Small specimen, ~ 18 mm (from anterior margin of carapace to distal tip of tail fluke), laterally compressed. General profile of carapace valves suboval; length/height ratio of valves ~ 1.15. Narrow line running along ventral margin of right valve represents marginal rim, as seen in *Clypecaris* ^[10].

Trunk of seven segments, emerging from posterior margin of the carapace. All segments taper evenly in width and increase in length posteriorly, the last being narrowest and longest, possibly representing the telson, as observed in *Waptia fieldensis* Walcott, 1912 ^[7] and *Clypecaris pterodea* Hou, 1999 ^[15]. All segments are lacking appendages. Overall morphology of trunk corresponds to abdomen of *Waptia* (e.g. Caron and Vannier ^[8], Figure 1. a-c; Straufeld ^[7], Figure 1. A). An isolated structure, preserved just behind possible telson, is spine-like and longer than any abdominal segment; its general profile and location suggest it is a tail fluke in lateral view.

First to fifth abdominal segment preserve a three-dimensional gut, 5 mm long and 1mm wide; boundaries of some abdominal segments are impressed on surface of gut fill.

3.3 Discussion

3.3.1 Preservation

The abdomen of this specimen curves downwards from the axis of the carapace, and a similar preservation mode was also observed in *Waptia fieldensis* (e.g. Vannier et al. ^[9], Figure 1.c-d). But different from this, the curve seen in our specimen is possibly due to post-mortem decay, as evidenced by the slight disarticulation of the two valves and the separately preserved tail fluke. This specimen possibly experienced a period of decay before being buried by the fine sediment.

3.3.2 Identity

The species-level identity of the euarthropod described here cannot be confirmed, based only on one incomplete specimen and the fact that no soft parts (e.g. eyes, limbs,

antennae) are preserved. But, judging from the general morphology, this animal probably has close relationship with *Waptia* (Figure 1.D). Therefore, we tentatively define it as a species of *Waptia*.

Another indeterminate species of *Waptia* from the Guanshan biota was reported by Hu et al. [16], which has a pair of stalked eyes and antennae, seven limbless abdominal segments and a tail composed of three flukes. Most of these features cannot be discerned in the species described here and, therefore, we cannot confirm whether the two are the same.

3.3.3 *Waptia*-like euarthropods

To date, six small bivalved euarthropods have been discovered in the Burgess Shale-type biotas in the Early Cambrian of eastern Yunnan, among which four are from Chengjiang Biota: *Chuanodianella ovate* Lee, 1975 [17], *Clypecaris pterioidea* Hou, 1999 [15], *Synophalos xynos* Hou et al., 2009 [18], *Erjiecaris minuscula* Fu et al., 2014 [19], one is from Xiaoshiba Biota: *Clypecaris serrata* Yang et al., 2016 [10]; two indeterminate ones are from Guanshan Biota: *Waptia* sp. Hu et al., 2013 [16] and *Waptia* sp. here. In view of the lack of soft tissues, especially those beneath the carapace, the phylogenetic positions of these euarthropods remain unclear. In addition, *Clypecaris serrate* has a raptorial appendage and the visual organs of *Erjiecaris minuscula* are situated on the carapace, all of which differ from the characteristics of a classic waptiid. But all waptiids have a fixed body design: a large carapace composed of two valves covering the anterior part of the trunk, a limbless abdomen stretching out of the posterior margin of the carapace and a telson with two flukes being situated distally (Figure 1.D). All the bivalved euarthropods mentioned above firmly accord with these fundamental characteristics, and therefore it is reasonable to define them as *Waptia*-like euarthropods.

Class and order uncertain

Family Clypecarididae [15]

Genus *Clypecaris* [15]

Clypecaris pterioidea Hou, 1999 [15]

Figure 2.A-D

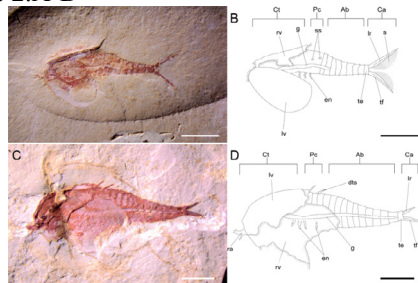


Figure 2. The specimen of YN-JS-500 and the specimen of YN-GS-001.

Note:

(A) the specimen of YN-JS-500, *Clypecaris pterioidea* from Chengjiang biota; (B) line drawing of (A); (C) the specimen of YN-GS-001, *Clypecaris serrata* from Xiaoshiba biota; (D) line drawing of (C); Abbreviations are as follows: Ab, abdomen; Ca, cauda; Ct, cephalothorax; dts, dorsal trunk spine; en, endopod; g, gut; lr, longitudinal ridge; lv, left valve; Pc, post-cephalothoracic segments; ra, raptorial appendage; rv, right valve; s, setae; ss, spine sockets; te, telson; tf, tail fluke; Scale bar = 3 mm.

3.4 Material

One specimen (YN-JS-500), from the Maotianshan Shale Member of the Yu'anshan Formation (Cambrian Series 2, Stage 3), Jianshan section (24.77036°N, 102.57877°E).

3.5 Remarks

The specimen is an almost complete individual preserved in oblique left-side view, different from that of the holotype [15]. The left valve is preserved in almost complete profile, whereas the right valve is barely preserved, with most parts missing. The valves are broken along the hinge articulation, exposing the tissues beneath. Due to the poor preservation, only the convex gut and three endopods, each of which is composed of two or three podomeres, can be discerned. Two subcircular structures, with an average diameter of 0.2 mm, are situated on the segment just behind the right valve. Based on the morphology and relevant position, these two structures should represent the spine sockets observed in *Clypecaris serrata*. The paired stalked eyes, antennae and the appendages of the segments, protruding beyond the posterior margin of the carapace on the holotype [15], cannot be discerned in the specimen herein, possibly due to the post-mortem decay. The length of the specimen, ~ 10 mm, is slightly shorter than the holotype (12mm, excluding eyes and antennae), which possibly indicates it a juvenile of this species.

Clypecaris serrata Yang et al., 2016 [10]

3.6 Material

One specimen (YN-GS-001), from the Hongjingshao Formation (Cambrian Series 2, Stage 3), Guanshan reservoir (24.82766°N, 102.84242°E).

3.7 Remarks

The specimen, with 15 observable trunk tergites, is compressed laterally, the total length (excluding the raptorial appendage) of which is ~ 14 mm. Both valves are poorly preserved, with most parts missing. Compared to the specimens in literature [10], this one preserves some limb impressions on the inner surface of the right valve.

The limbs (at least 4 pairs) are situated under the impression of gut, each of which has one or two observable podomeres. This is the first specimen showing the structures covered by the carapace but, due to the poor preservation, other organs and the related tissues beneath the carapace cannot be clearly discerned.

4. The Temporal and Spatial Distribution of Waptia-like Euarthropods in Early Cambrian, Eastern Yunnan

Chengjiang, Xiaoshiba and Guanshan are the leading examples of Burgess-Shale type biotas in the Early Cambrian of eastern Yunnan, and the time span between the first and the last could be as much as 7 million years (Figure 3). Well preserved *Waptia*-like euarthropods first appeared in the Chengjiang biota and then were discovered in the other two, without any apparent time break, which indicates that this taxon is not confined to any specific biota, but has had existed for a rather long time. The relevant sedimentological analyses show that these three biotas are deposited in different palaeoenvironments with different water depths (e.g. Hu et al. [16]; Hou et al. [20]) and this may suggest that this kind of small bivalved euarthropod has a relatively strong viability and can survive different water environments, which can be further confirmed by the presences of this taxon in the Middle Cambrian biotas (e.g. Burgess Shale Fauna in Canada and Kaili Biota in China).

Series	Stage	Ma.	Stage	Biozone	Formation	Burgess Shale-type Biota	Fossil occurrence
			Longwangmiaoan	<i>Hoffetella-Redlichia murakamii</i>	Shanyicun Fr.		
Series 2	Stage 4	514	Canglangpunan	<i>Megapalaolenus</i>	Wulongqing Fr.	Guanshan Biota	<i>Waptia</i> sp.
				<i>Palaeocidius</i>			<i>Waptia</i> sp.
				<i>Drepanuroides</i>	Hongjingshao Fr.	Xiaoshiba Biota	<i>Clypecaris serrate</i>
Series 3	Stage 3	521	Qiongzhusian	<i>Eoredlichia-Wulingaspis</i>	Yu'anshan Fr.	Chengjiang Biota	<i>Clypecaris pterioidea</i> <i>Chuan-dianella ovata</i> <i>Synophalos xynos</i> <i>Erjiecaris minuscula</i>
				<i>Parabodella</i>			
Cambrian	Stage 2	529	Meishucunian	<i>Sinosachites flabelliformis-Tanuolina zhengwertangi</i>	Shiyantou Fr.		
				Poorly fossiliferous zone			
				<i>Watsonella crosbyi</i>			
				<i>Paragloborhis subglobosus-Purella squamulosa</i>	Zhujiaping Fr.		
Terreneuvian	Fortuntian	541		<i>Anabarites trisulcatus-Protohertzina anabarca</i>			

Figure 3. Stratigraphy of the early Cambrian, eastern Yunnan and the associated occurrences of *Waptia*-like euarthropods, revised from Hu et al. [16].

Clypecaris pterioidea was first discovered in the Xiaolantian section [15] and the specimen described herein

was excavated in the Haikou area. Specimens of *Chuan-dianella ovate* from the Chengjiang biota were discovered at the Maotianshan section and in the Haikou area. Hitherto, *Synophalos xynos* was only known in the Haikou area and *Erjiecaris minuscula* is confined to the Jinning area. The holotype of *Clypecaris serrate* was discovered in the Xiaoshiba area, while the specimen described herein was excavated near the Guanshan reservoir. Both of the two indeterminate species of *Waptia* were discovered at the Gaoloufang section. The geographic map shows that all these fossil sections are situated around Dianchi Lake and cover a rather wide region (Figure 4). This area lay at the southwestern side of the Yangtze Platform in the Early Cambrian which is considered to represent a terrigenous clastic sedimentary basin, in which mud constitutes a considerable part of the sediments [16]. Benefiting from such unique sedimentary conditions, specimens of these small *Waptia*-like euarthropods can be exceptionally preserved.

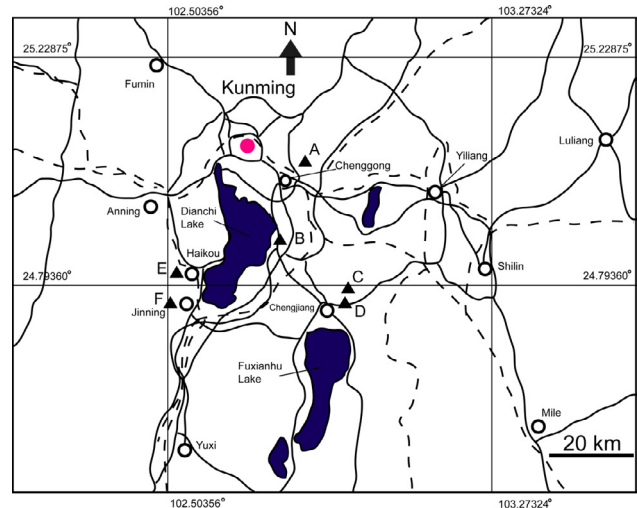


Figure 4. Fossils sections of *Waptia*-like euarthropods around the Dianchi Lake

Note:

- A, Gaoloufang section; B, Guanshan reservoir; C, Xiaolantian section; D, Maotianshan section; E, Haikou area; F, Jinning area

5. Conclusion

Although lacking soft parts, a bivalved animal described from the Guanshan biota is considered to be a euarthropod in the genus *Waptia*.

The mode of preservation and length of the two specimens of *Clypecaris pterioidea* are variable. There are limbs underneath the carapace of *Clypecaris serrate*, which can number up to 4 pairs at least.

Waptia-like euarthropods lived for a rather long time (at least 7 million years) in the Early Cambrian of eastern Yunnan, and the relevant fossil sections cover a wide area

around Dianchi Lake.

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