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Original article

First report of linguloid brachiopods with soft parts from the lower Cambrian (Series 2, Stage 4) of the Three Gorges area, South China

Sur la découverte de brachiopodes linguloïdes avec tissus mous dans le Cambrien inférieur (Série 2, Étage 4) de la région des Trois Gorges, Chine du Sud

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ABSTRACT

Chengjiang-type fossil brachiopods with preservation of non-mineralized tissues are reported for the first time from the Lower Cambrian Shipai Formation of the Three Gorges area, western Hubei Province, China. Recent excavation in the Wangjiaping and Aijiahe sections resulted in the new discovery of some linguloid brachiopods, showing strong similarity in preservation with those occurring in the well-known Chengjiang fauna (Yu'anshan Formation of eastern Yunnan, China). The brachiopods can be referred to *Palaeobolus liantuoensis*, *Lingulellotreta malongensis* and *Eoobolus*. sp. The new material of *Palaeobolus* exhibits a flattened impression of proximal pedicle, which also represents the first report of pedicle known from this cosmopolitan linguloid taxon. The occurrence of *Lingulellotreta* in the Shipai Formation (*Redlichia meitanensis* and *Palaeolenus lantenoisi* zones) represents an important geological extension of this genus to upper Tsanglangpuan Stage (Series 2, Stage 4) in the Yangtze Platform, and signifying that the FAD of *Lingulellotreta* in the regional Lower Cambrian of the Yangtze Platform seems not synchronous.

Mots clés :
Cambrien
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RÉSUMÉ

Des fossiles de brachiopodes de type Chengjiang, avec préservation de tissus non minéralisés, sont décrits pour la première fois dans le Cambrien inférieur de la Formation de Shipai de la région des Trois Gorges, Province de Hubei occidentale, Chine. Des fouilles récentes dans les coupes de Wangjiaping et Aijiahe ont permis la découverte de brachiopodes linguloïdes montrant de très fortes similarités de préservation avec les célèbres faunes de Chengjiang (Formation de Yu'anshan du Yunnan oriental, Chine). Les brachiopodes peuvent être assignés à *Palaeobolus liantuoensis*, *Lingulellotreta malongensis* et *Eoobolus* sp. Le nouveau matériel de *Palaeobolus* montre une impression aplatie du pédicule proximal, ce qui représente également la première description de pédoncule chez ce linguloïde cosmopolite. L'occurrence de *Lingulellotreta* dans la Formation de Shipai (zones à *Redlichia meitanensis* et *Palaeolenus lantenoisi*) constitue une importante extension de la répartition de ce genre jusqu'à l'étage Tsanglangpuan supérieur (Série 2, Étage 4) dans la plate-forme du Yangtze et montre que la FAD de *Lingulellotreta* dans le Cambrien régional de la plate-forme du Yangtze ne semblent pas synchrone.

1. Introduction

Exceptionally preserved Cambrian fossils, such as those from Burgess Shale-Type Fossil-Lagerstätten (Forchielli et al., 2014), have aroused considerable scientific attention because of their

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unique contributions to our knowledge of early animals, such as their organization of body plans and soft tissue character states (Briggs et al., 1994; Hou et al., 2004; Zhang et al., 2004, 2007a, 2009). The articulated nature of skeletal elements (Conway Morris and Peel, 1995; Vannier et al., 2007) has provided clues to the behaviors of extinct organisms (Vannier and Chen, 2005; Zhang et al., 2011c) that are usually unobtainable from shelly and skeletonized fossils alone (Conway Morris and Caron, 2007; Zhang et al., 2010, 2013, 2014a). In the last decades, systematic investigations of the Cambrian sediments around the world led to findings of tens of Konservat-Lagerstätten that yielded a rich abundance of fossils with exceptional preservation (Conway Morris, 1992; Hou et al., 2004; Zhao et al., 2005; Zhang et al., 2008a). In particular, these deposits have an abundance of exceptionally preserved ecdysozoans, such as arthropods and pan-arthropods (Fu and Zhang, 2011; Ma et al., 2012). Until now, not so many taxa of soft-bodied fossils among lophotrochozoans are known from Cambrian Könservat-Lagerstätten (e.g. Peel and Ineson, 2011; Zhang and Holmer, 2013), but include the mollusk-like scleritome-bearing *Wiwaxia* (Smith, 2012, 2014), *Orthrozanclus* (Conway Morris and Caron, 2007) and *Halkieria* (Conway Morris and Peel, 1995; Vinther and Nielsen, 2005), as well as the entirely soft-bodied *Odontogriphus* (Caron et al., 2006) from the classic Burgess Shale Könservat-Lagerstätten. Recent fossil discoveries of Lower Cambrian sipunculans (Huang et al., 2004), polychaetes (Vinther et al., 2011), chaetognaths (Chen and Huang, 2002) and entoprocts (Zhang et al., 2013) have considerably reduced the number of lophotrochozoan animal phyla missing from the Cambrian explosion, albeit there is still a conspicuous phylogenetic gap in the Cambrian explosion for Platyzoa (Edgecombe et al., 2011).

Brachiopods, firmly nested within Lophotrochozoa (Dunn et al., 2008; Paps et al., 2009), are among the most important components of marine communities during the Paleozoic, dominating the benthos of both the Cambrian Evolutionary Fauna and Paleozoic Evolutionary Fauna (Sepkoski, 1984). They provide some of the earliest Phanerozoic evidence for fully skeletonized metazoans. Their skeletal remains are preserved as early as the upper Fortunian Stage (Tommotian equivalent) of the Terreneuvian-Series (= Lowermost Cambrian) well below the first trilobite body fossils (Skovsted et al., 2014). Nevertheless, most fossil brachiopods are known exclusively from their shells; soft parts are preserved only in a few deposits with exceptional preservation (Zhang and Holmer, 2013), most notably the Cambrian Stage 3 Chengjiang Könservat-Lagerstätten (Zhang et al., 2007b, 2009, 2014a; Wang et al., 2012). Such remarkable occurrences offer extraordinary insight into the evolutionary paleobiology, autoecology and community ecology of early brachiopods that are unobtainable from the study of fossil shells alone (Holmer and Caron, 2006; Zhang et al., 2008b, 2010, 2011c). Recently, exceptionally preserved fossil brachiopods with soft parts, including pedicles, are increasing in number, and extending in temporal and paleogeographic ranges from west Gondwana to Laurentia (Sutton et al., 2005; Balthasar and Butterfield, 2009; Bassett et al., 2009; Balinski and Sun, 2013; Zhang et al., 2010; see Fig. 1).

Here, we describe three genera of lingulid brachiopods from the muddy siltstone of the Cambrian Series 2, unnamed Stage 4 Shipai Formation (Zhang and Hua, 2005), showing comparable preservation with those from Chengjiang fauna and Guanshan fauna recovered in eastern Yunnan province of China (Zhang et al., 2008b, 2010). This is the first report of Cambrian brachiopods with preserved pedicle outside of eastern Yunnan in China, and represents the first record on the occurrence of *Lingulellotreta malongensis* Rong, 1974 in the Three Gorges area of South China, thus extending the palaeogeographic range of Family Lingulellotretidae to the centre of the Yangtze platform.

2. Geological setting, locality and stratigraphy

The present-day Yangtze platform is located between the Qinling orogenic belt to the North and the *Cathaysia* suture to the Southeast (Fig. 2). The Yangtze platform rifted from the Cathaysia block around 800 Ma (Li et al., 2008), and developed in a continental margin of the Yangtze block, with Neoproterozoic to Cambrian strata widely distributed in South China (Zhu et al., 2007; Zhang et al., 2008a). These sedimentary rocks were deposited in a basin related to the rifting of the Yangtze and *Cathaysia* Blocks coincident with the breakup of the *Rodinia* supercontinent (Li et al., 2008).

The Yangtze gorges area (Fig. 2.2), geographically located in the north margin of the upper Yangtze platform, is another important and famous auxiliary stratotype section proposed for the Precambrian–Cambrian boundary in China (Wang et al., 2008). In this region, the terminal Neoproterozoic–Cambrian sedimentary successions are well-developed and widely distributed in outcrops around the southeastern limbs of Huangling Anticline (Ishikawa et al., 2014). The Series 3 and Furongian Cambrian is dominated by thick dolostones, ordinarily thought to be unsuitable for exceptional preservation of fossils. By contrast, the depositional succession through the Ediacaran–Cambrian Series 2 interval yielded abundant shale-hosted fossils that aroused broad interests of evolutionary biologists and paleontologist (Guo et al., 2014). The uppermost Neoproterozoic deposits consist of a thick sequence (ca. 300 m) of thick-bedded or thin-bedded carbonate rocks, assigned to the Ediacaran Dengying Formation, disconformably overlain by the traditional "Lower Cambrian" of Terreneuvian-Series 2. The traditional "Lower Cambrian" is divided into five lithostratigraphic units, in ascending order, the Yanjiahe, Shuijingtuo, Shipai, Tianheban and Shilongdong formations. On account of the fossiliferous nature of these rocks, the Ediacaran–Cambrian strata in the Three Gorges area has classically been the focus of studies of bio-, sequence and chemostratigraphy (Wang, 1987; Zhu et al., 2007; Wang et al., 2008; Ishikawa et al., 2014) through the Ediacaran–Cambrian boundary (Figs. 2.2–3). In some recent publications (Wang et al., 2008; Jiang et al., 2012), the Yanjiahe and Shuijingtuo formations are collectively termed as the Niutitang Formation, though the former is limestone-dominated exclusively with rich pre-trilobite Small Shelly Fossils and the latter is black shale-dominated containing abundant trilobites. The overlying ca. 180 m thick Shipai Formation consists of thin-laminated siltstone in its lowest part, and argillaceous siltstone and silty mudstone in the middle and calcareous shale and siltstone with limestone laminations in the upper part (Fig. 2.4). The linguloid fossils dealt with in this paper were collected from the mid-upper mudstone and muddy siltstone of Shipai Formation (Fig. 2.4).

3. Fossil occurrences and regional correlations

The absolute age of the Lower Cambrian from this region is not yet available, but the fossils provide straightforward evidence for correlating the Lower Cambrian Formations of the Three Gorges area.

The Yanjiahe Formation mainly crops out on the south and western limbs of Huangling anticline (Fig. 2.3), and is well-developed in the Three Gorges and Changyang areas (Fig. 2.3). The Yanjiahe Formation near Aijiahe Village about 25 km southwest of Yichang City consists of about 40 m of grayish black carbonate yielding abundant Small Shelly Fossils (Guo et al., 2014). The SSF assemblages can be differentiated into 3 recognizable assemblage zones, in ascending order, the *Anabarites trisulcatus–Protohertzina anabarica* assemblage zone (Bed 2), the *Purella antiqua* assemblage zone (Bed 3), and the *Aldanella yanjiaheensis* assemblage zone (Bed 5). Based on the biozones of SSFs listed above, the Yanjiahe Formation