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The Cambrian brachiopod fauna from the first-trilobite age Shuijingtuo Formation in the Three Gorges area of China

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Abstract

The Yangtze platform of South China offers evidence within its Ediacaran–Cambrian geological record of the Cambrian explosion and diversification events in metazoan history. To understand the explosive radiation of animals and the environments in which it took place, the basal Cambrian fauna succession of the Aijiahe section in the Three Gorges area, western Hubei Province, has been studied, revealing the earliest brachiopod fauna (*Tsunyidiscus* trilobite Zone) in this region, which was dominated numerically by acrotretoids. This is accompanied by abundant skeletal fossils including minute well-preserved phosphatized archaeocyath cups and an assortment of abundant sponge spicules, chancelloriids, mollusks, hyoliths, and bradoriids, retrieved by acid-etching limestone interbeds in the black shale-dominated Shuijingtuo Formation (Series 2). The brachiopods comprise two species of acrotretoids, two types of botsfordiids (Botsfordiidae gen. et sp. indet. A and B), and four species of linguloids. Of the latter, *Spinobolus popovi* n. gen. n. sp. is strikingly distinctive and typified by spine-like ornamentation seen for the first time in the lower Cambrian; the remaining three linguloid genera, *Palaeobolus*, *Eoobolus*, and *Lingulellotreta*, have a trans-paleocontinental distribution. The Three Gorges Shuijingtuo brachiopod assemblage differs from that of the upper Atdabanian Stage (Cambrian Stage 3) in Siberia and South China, but shows great similarities with those discovered in the Tsanglangpuan (equivalent to Botoman or Stage 4) Stage of eastern Yunnan Province, Siberia, and South Australia, suggesting a much more prolonged sedimentary hiatus in basalmost Shuijingtuo Formation of the Three Gorges area than previously expected. The presence of such unconformities provides a caveat to stable isotope-based correlations that involve a number of discussions of global ocean geochemical changes across the time interval that witnessed Cambrian explosion of metazoans.

Keywords: Biostratigraphy; Botoman; Brachiopoda; Lingulids; Archaeocyatha; Small shelly fossils (SSFs)

1. Introduction

The Cambrian explosive radiation of metazoans (Erwin et al., 2011; Z.F. Zhang et al., 2013; Shu et al., 2014) and the international subdivision of Cambrian strata (Babcock et al., 2005; Peng, 2009; Peng et al., 2011) represent two of the most important paleontological topics in the recent decade (Clausen et al., 2015). The continuous improvement in the subdivision of Cambrian strata and its international correlation has significant consequences for our understanding of the tempo, pattern, and magnitude of the "Cambrian explosion" of metazoans (Kouchinsky et al., 2012; X.L. Zhang et al., 2014; Z.F. Zhang et al., 2014a, 2015a). However, the chronostratigraphic subdivision of the second series of the Cambrian is still provisional (Peng and Babcock, 2011; Peng et al., 2012; Clausen et al., 2015) and detailed studies of fossil assemblages and faunal successions on a regional or intercontinental scale are necessary contributions for its continuing improvement (Babcock and Peng, 2007; Clausen et al., 2015).

Trilobites, brachiopods, and hyoliths are among the most common skeletal fossils in the various facies of Cambrian sediments, and constitute three of the most important

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components of the Cambrian Evolutionary Fauna (Sepkoski, 1984; Stanley, 2007). In particular, trilobites are commonly used as index fossils in the subdivision and global correlation of the Cambrian System (Babcock et al., 2005; Babcock and Peng, 2007; Peng, 2009). Nevertheless, it becomes increasingly clear that the definition of Cambrian Series 2 and Stage 3 and its global correlations, which are based merely on the first appearances of different trilobite genera on separate Cambrian continents, are insufficiently precise by themselves. The distribution, in time and space, of different trilobite genera is largely facies-controlled and the earliest recorded genera in regional or intercontinental areas are commonly endemic. Accordingly, the first appearance datum (FAD) of Cambrian epoch 2 trilobite is not perfectly synchronous among the different paleocontinents (see discussions in e.g., Peng et al., 2012). Moreover, trilobites are essentially lacking in some highly fossiliferous lower Series 2 equivalent deposits of some micro-continents (Landing and Westrop, 2004; Steiner et al., 2007). It is therefore currently considered that the base of Stage 3 should approximate the FAD of trilobites. Meanwhile, other fossil assemblages either prior to or coeval with trilobite-bearing Cambrian successions can provide good alternative index fossils in the regional stratigraphic subdivision and intercontinental correlation of the Cambrian (Li et al., 2011; Peng et al., 2012 and references therein).

Owing to the relatively good preservation and wide distribution of outcrops, the Ediacaran–Cambrian (E-C) transition in the Three Gorges area of southern China has become one of the most intensively investigated in China. In this region, the well outcropped E-C transitional sequence encompasses, in ascending order, the Ediacaran Dengying Formation and the traditional "Lower Cambrian" (Terreneuvian–Series 2) Yanjiahe, Shuijingtuo, Shipai, Tianheban formations. It is evident that there are two unconformities in this sequence. One sits at around the E-C boundary between the Dengying and Yanjiahe formations. The other sits just before the FAD of trilobites at the basal Shuijingtuo Formation in this area, which raised a debate regarding the age of these trilobites: can they be correlated with other earliest trilobite occurrence in the world?

A Chinese-Japanese joint research project entitled "Co-evolution of Early life and environments from Snowball to the Early Palaeozoic Earth records in South China" in 2004 has been aimed at understanding the biological and environmental interactive processes at high-resolution scale, based on a series of pristine on-land drillings in South China (Sawaki et al., 2008a, 2008b; Okada et al., 2014). As a result, ocean geochemical analyses, including those of carbon, oxygen and strontium isotopes, and geochronological data are becoming increasingly available (Ishikawa et al., 2013, 2014; Tahata et al., 2013). They provisionally point to the synchronism or causal link between environmental changes and the rapid diversification of various skeletal metazoans (Ishikawa et al., 2013; Okada et al., 2014). However, investigations of the fauna contained in the first trilobite-bearing Shuijingtuo Formation of the Three Gorges area have never been done in detail due to difficulties in collecting macrofossils hosted in the organic-rich black shale and the overlooked micropaleontological potential of the bioclastic limestone interbeds in this formation.

In this paper, we present the first report of brachiopods and some associated skeletal fossils etched from the banded clastic limestone intercalated within the layers of thin-bedded calcareous black shale of the Shuijingtuo Formation in the Three Gorges area. Apart from abundant brachiopods (see Section 5), the fossil assemblage also yielded hyoliths, hyolithellids, lobopodians, mollusks, sponges, chancelloriids, and well-preserved phosphatized moulds of archaeocyathans. The brachiopods are distinctly dominated in number by acrotretoids (Lingulata, Brachiopoda). Recent studies of the Cambrian of eastern Yunnan Province suggest that the acrotretoids occur in association with the Tsanglangpuan (Botoman, Cambrian Series 2, Stage 4 equivalent) trilobite *Malungia* (Paterson and Brock, 2007; Yuan et al., 2011), in Malong and Wuding counties in eastern Yunnan Province. These fossils described here present for the first time the brachiopod diversification during the earliest Cambrian eodiscoid trilobite time interval in the Three Gorges area, and thus facilitate the discussion about the definition and global correlation of the as yet undecided stage 3–4 within Cambrian Series 2.

2. Geological background, stratigraphy, and methods

China is now located between the Siberian platform in the north and Gondwanaland in the south, comprising the tectonically stable Tarim, Qaidam, North China, and Yangtze platforms and the Cathaysia Block (Fig. 1A). Of these, the Yangtze and North China platforms are of especial importance for studying the evolution of early life in that both terranes have well-developed and easily accessible Cambrian sequences (Zhu et al., 2007; X.L. Zhang et al., 2008). In the Yangtze platform, the Terreneuvian and the unnamed Series 2 sedimentary successions finely outcrop in a NE–SW direction (Fig. 1B). In particular, on the western margin of the Yangtze platform (eastern Yunnan Province, Fig. 1B), the lower Cambrian consists of a fairly thick sequence of phosphorite, dolomite limestone or limestone, sandstone, mudstone, and siltstone, generally thought to have been deposited under very shallow-water settings (Luo et al., 1994).

The Ediacaran–Cambrian strata of the Three Gorges area, located on the north margin of the Yangtze platform (Fig. 1B and C), has classically been the focus of studies of the Precambrian–Cambrian transition and Ediacaran–Cambrian bio-, sequence and chemostratigraphy (Wang, 1987; Wang et al., 1998; Zhang, 2003; Zhu et al., 2007). In this region, the terminal Neoproterozoic–Cambrian sedimentary successions are markedly well developed and widely outcropped around the southeastern limbs of the Huangling Anticline (Fig. 1C). There, a thick sequence of Late Neoproterozoic carbonate rocks, assigned to the Ediacaran Dengying Formation (ca. 300 m thick), is disconformably overlain by the lowermost Cambrian Yanjiahe (equivalent to Tianzhushan) and Shuijingtuo formations. In some recent publications (Jiang et al., 2010; X.Q. Wang et al., 2012), the Yanjiahe and Shuijingtuo formations are collectively termed the Niutitang Formation, though the former is limestone-dominated exclusively with rich pre-trilobite SSFs and the latter is black shale-dominated containing the earliest trilobites in this