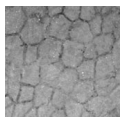


New occurrence of the Cambrian (Stage 4, Series 2) Guanshan Biota in Huize, Yunnan, South China

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Typical elements of the Guanshan Biota are reported from the Cambrian Stage 4 Wulongqing Formation of Huize, Qujing, South China, approximately 100 km north of the Guanshan fossil sites previously reported. Lithostratigraphy and biostratigraphy of the current Zhujiaping section are also discussed herein. Representatives of various phyla recovered therein include not only previously described sponges, palaeoscolecs, arthropods, brachiopods, echinoderms, and vetulicolians, but also some potential new taxa, e.g. a new species of *Vetulicola*. This new occurrence not only expands the palaeogeographic distribution of the Guanshan Biota, but also strengthens the ties between the younger Chengjiang Biota and the older Kaili Biota (and also the coeval Burgess Shale community). • Key words: Guanshan Biota, lower Cambrian, China.

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Trilobites *Palaeolenus lantenoisi* and *Palaeolenus douvillei* from the Cambrian Stage 4 Wulongqing Formation were first reported by Mansuy (1912) and subsequently restudied (Lu 1961, 1962; Luo 1974; Luo *et al.* 1994; Zhang 1966; Zhang *et al.* 1980). The bivalved arthropod *Tuzoia sinensis* Pan was first described by Pan (1957) from the lower part of the Wulongqing Formation (Canglangpu Stage). Brachiopods (Rong 1974) and bradoriids (Zhang 1974, Li 1975) from the same horizon were also described earlier on.

Non-trilobite arthropods and palaeoscolecs worms were first recovered in 1995 from yellow-greenish shale of the lower Wulongqing Formation in Gangtoucun section of Kunming, Yunnan (Luo *et al.* 1999). Excavation (1996) in the Lihuazhuang section of the same level in Yiliang, Yunnan, yielded more abundant arthropods, including the phyllocarid *Yiliangocaris ellipticus* Luo & Hu, the

brachiopod *Branchiocaris* sp., eumalacostracans *Habelia* sp. (?), and trilobites *Redlichia mansuyi* Resser & Endo and *Palaeolenus douvillei* Mansuy, preserved together with abundant brachiopod specimens of *Diandongia pista* Rong (Luo *et al.* 1999). Accordingly, Luo *et al.* (1999) grouped them into the so-called Guanshan Biota, and subsequently investigated the vetulicolian *Vetulicola gangtoucunensis* Luo, Fu & Hu, arthropods *Tuzoia tylodesa* Luo & Hu, and *Isoxys wudingensis* Luo & Hu.

Li *et al.* (2006) reviewed the Guanshan Biota and concluded that it is a Burgess Shale-type Biota consisting mainly of arthropods (accounting for ca 65% in abundance) and other animals (in particular vetulicolians, brachiopods, worms, and sponges, each group accounting for ca 8%). Hu *et al.* (2007) reported eocrinoid echinoderms *Wudingecrinus rarus* Hu & Luo from the Wulongqing Formation in Wuding, Yunnan. This finding

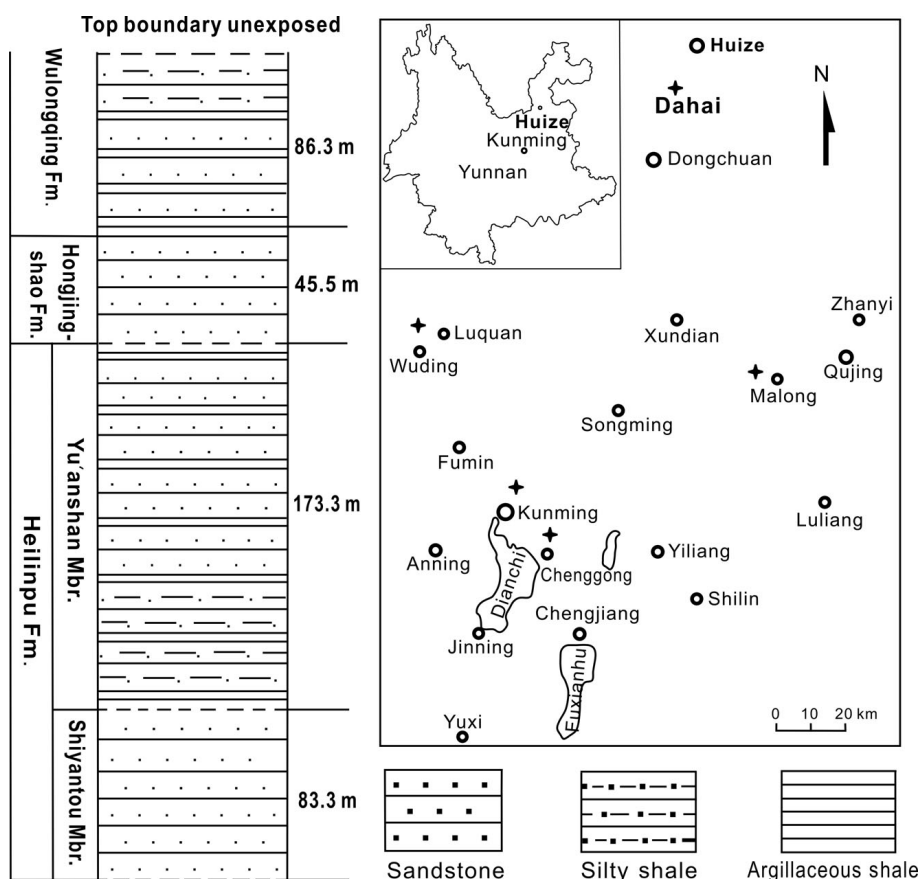


Figure 1. Synthesized stratigraphic column of the Zhujiaying section (Series 2, Stage 4, Cambrian) in Dahai village, Huize, Yunnan and the main occurrences of Guanshan Biota in Yunnan, southwest China.

further enriches the biodiversity of the biota with a phylum-grade group that has significant implications for the origin and ecology of early echinoderms. In addition, more counterparts of the Chengjiang and the Burgess Shale representatives were recently revealed in the Guanshan Biota, including the lobopodian *Hallucigenia* sp., medusoid form *Eldonia* sp., and hyolithid *Linevitus malongensis* with preserved helens, green algae, *Phlogites*, linguliform brachiopod *Acanthotretella* with soft-part (Hu *et al.* 2010a–c), and basal deuterostome *Vetulicola longbaoshanensis* (Yang *et al.* 2010).

New occurrence of Guanshan Biota in Huize

Geological and stratigraphical framework

The Guanshan Biota occurs in the Wulongqing Formation of early Cambrian, which is widely distributed in eastern Yunnan, *e.g.* Kunming–Wuding and Malong–Yiliang area; the best studied sections are Gangtoucun and Gao-loufang of Kunming, Sapushan of Wuding, Lihuazhuang of Yiliang and Wulongqing of Malong (Fig. 1). During a geological survey in 2007, we recovered a specimen of palaeoscolecoid worm, an index of soft-tissue preservation,

from the lower part of the Wulongqing Formation in Zhujiaying section of Dahai village, Huize, Yunnan (Fig. 1). Subsequent systematic excavation revealed that it is a typical Guanshan fossil *Lagerstätte* which demonstrates the extensive distribution of the biota and is promising in further deciphering the evolution and diversification of the biota.

The basal Cambrian succession in the Zhujiaying section in Dahai village, Huize, consists of, in ascending order, the Heilipu Formation (subdivided into the Shiyantou Member and Yu'an Shan Member), Hongjingshao Formation, and Wulongqing Formation (Fig. 1). Generally, as Luo *et al.* (2008) indicated, the Guanshan Biota occurs from the base and continuously to the uppermost Wulongqing Formation, and the fossils are much richer in basal part than upper part. However, the top boundary of Wulongqing Formation is unexposed in this Zhujiaying section. The Wulongqing Formation in Zhujiaying section, with a measured thickness of ~86 meters, is mainly composed of yellow-greenish, thin-bedded argillaceous shale, where Guanshan fossils are prone to preserved, and grey-yellowish, thin-bedded silty shale. The fossiliferous deposits of Zhujiaying section can be subdivided into two zones: the lower part with a biased poor bio-diversification, mainly composed of biomineralized or sclerotized



Figure 2. Some representatives of the Guanshan Biota in Huize, Yunnan. • A – trilobite *Palaeonlenus douvillei* Mansuy, 1912 (ELI-HZ-P-001A). • B, C – trilobite *Redlichia noetlingi* Redlich, 1899 (ELI-HZ-RN-001A). • D – trilobite *Redlichia mansuyi* Resser & Endo, 1937? (ELI-HZ-RM-001A). • E, F – the sponge *Crumillospongia biporosa* Rigby, 1986 (ELI-HZ-C-001). • G – brachiopod *Lingulellotreta malongensis* Rong, 1974 (ELI-HZ-B-001). • H – echinoderm *Wudingeocrinus rarus* Hu & Luo, 2007 (ELI-HZ-W-001). • I, J – an unknown trace fossil (ELI-HZ-TF-001A, B). Scale bars in A, B and G are in mm, others are in cm.

shells of trilobites and brachiopods with rare preservation of soft parts; the upper part with much richer diversification, containing vetulicolians, palaeoscolecid worms, sponges, tentaculate eocrinoids *etc.*, most of which are preserved with soft parts. Compared with the biozones of other Guanshan Biota, the two zones of Zhujiaying section probably both belong to *Palaeolenus* zone (Luo *et al.* 2008), which occurs in the basal part of Wulongqing Formation; in other words, the two zones of Zhujiaying probably is a sub-division of the Guanshan Biota because the top boundary of Wulongqing Formation is unexposed in this Zhujiaying section. Similar to the preservation of other localities of Guanshan Biota, the fossils in Huize are mostly autochthonous or parautochthonous assemblages buried *in situ* or with minimum transportation.

New fossil data

A total of over 500 specimens belonging to various phyla were recovered from the new fossil locality, covering the bulk of reported metazoan taxa from the biota. Arthropods and brachiopods are the most abundant taxa, followed by palaeoscolecid worms, eocrinoid echinoderms, and vetulicolians. Here show some typical representative species: the trilobites *Palaeolenus douvillei* Mansuy (Fig. 2A), *Redlichia cf. noetlingi* (Redlich) (Fig. 2B, C), *Redlichia mansuyi* (Redlich)? (Fig. 2D), possibly the sponge *Crumillospongia biporosa* Rigby (Fig. 2E, F); the brachiopod *Lingulellotreta malongensis* (Fig. 2G); the echinoderm *Wudingecrinus rarus* Hu & Luo (Fig. 2H); some unknown trace fossils (Fig. 2I, J); the non-trilobite arthropod *Tuzoia sinensis* Pan (Fig. 3A–E); the palaeoscolecid *Guanduscolex minor* Hu, Luo & Fu (Fig. 3F–I); the vetulicolian *Vetulicola gangtoucunensis* Luo, Fu & Hu (Fig. 3M, N); and the assemblage of brachiopods (Fig. 3O).

Still noteworthy is the currently discovered vetulicolians of potential deuterostome affinity (Shu *et al.* 2001, 2005, 2010). In addition to *Vetulicola gangtoucunensis* (Luo *et al.* 2005; Fig. 3M, N), a few specimens of vetulicolians with some distinct characters, based on which they could probably be assigned to a new species, are also recovered during this work. Compared to *Vetulicola gangtoucunensis*, they are of smaller size, with the mouth less squared, the lateral groove seemingly undulated (Fig. 3I, K), and the posterior section comparatively slen-

der, with lateral blades of the distal segments being less broad (Fig. 3L), which also differs from the recently reported *Vetulicola longbaoshanensis* (Yang *et al.* 2010) from Kunming, Yunnan.

Another interesting fossil is palaeoscolecid worm, we found four cuticular fragmental specimens of palaeoscolecid worms which are greatly compressed. Our scanning electron microscopy (SEM) analysis revealed that two of them (ELI-HZ-G-001A, B and ELI-HZ-G-002A, B) preserved with detail ornaments of the external cuticles (Fig. 4). The trunk of the first specimen (ELI-HZ-G-001) is cylindrical and straight, *ca* 2 mm in diameter; the gut is represented by dark strand (Fig. 3F, G). The trunk is unevenly and tightly annulated due to strongly and longitudinally contracting of the body. Each annulation bears seemingly one or two transverse rows of circular or sub-circular plates. These plates are rather closely spaced in each row. A single plate, *ca* 30 μ m in diameter, with strongly convex upper surface covered by uniformly 6 nodes surrounded by a lower and wider smooth margin. Apparently, this plate is distinct from *Guanduscolex minor* Hu, Luo & Fu, 2008 but similar to *Palaeoscolex spinosus* Ivantsov & Wrona, 2004, however, the plates of the latter occasionally bears a central nodes (Ivantsov & Wrona 2004) and are more loosely arrayed than the second specimen.

The second specimen (ELI-HZ-G-002) preserved most part of the trunk and the trunk end. The trunk slightly tapers backward and approximately 3–4 mm in diameter. This specimen is sinuously curved and lack any imprint of gut (Fig. 3H, I), seemingly the shedding molts of the animal. The trunk is finely annulated, with about 4 annulations per millimeter. Each annulation bears two transverse rows of circular plates with strongly convex upper surface which reversely appeared as concaved structures (Fig. 4C, D). The plates are *ca* 30 μ m in diameter. The surface ornament of the plates was obscure in most case due to poor preservation; rarely, they were found bearing 4 or 5 nodes (Fig. 4E, F). These plates in the neighboring rows are arranged in a staggering pattern so as to increase the friction against the substrates, and this pattern could also avoid colliding when the trunk is strongly contracted along the anterior-posterior body axial. All these features suggested that this specimen resembles *Guanduscolex minor* Hu, Luo & Fu, 2008, although the latter species bears additional 9 marginal nodes arranged in a circlet around 4–5 central nodes.

Figure 3. Some representatives of the Guanshan Biota in Huize, Yunnan. • A–E – non-trilobite arthropod *Tuzoia sinensis* Pan, 1957 (ELI-HZ-T-001A, B, 002, 003). • F, G – palaeoscolecid *Palaeoscolex spinosus* Ivantsov & Wrona, 2004? (ELI-HZ-G-001A, B). • H, I – palaeoscolecid *Guanduscolex minor* Hu, Luo & Fu, 2008 (ELI-HZ-G-001A, B). • J–L – a new species of vetulicolian (ELI-HZ-V-001A, B, and ELI-HZ-V-002, respectively). • M, N – *Vetulicola gangtoucunensis* Luo, Fu & Hu, 2005 (ELI-HZ-V-003A, B). • O – the assemblage of brachiopods (ELI-HZ-B-002). Scale bars in F, G, J and K are in mm, others are in cm.



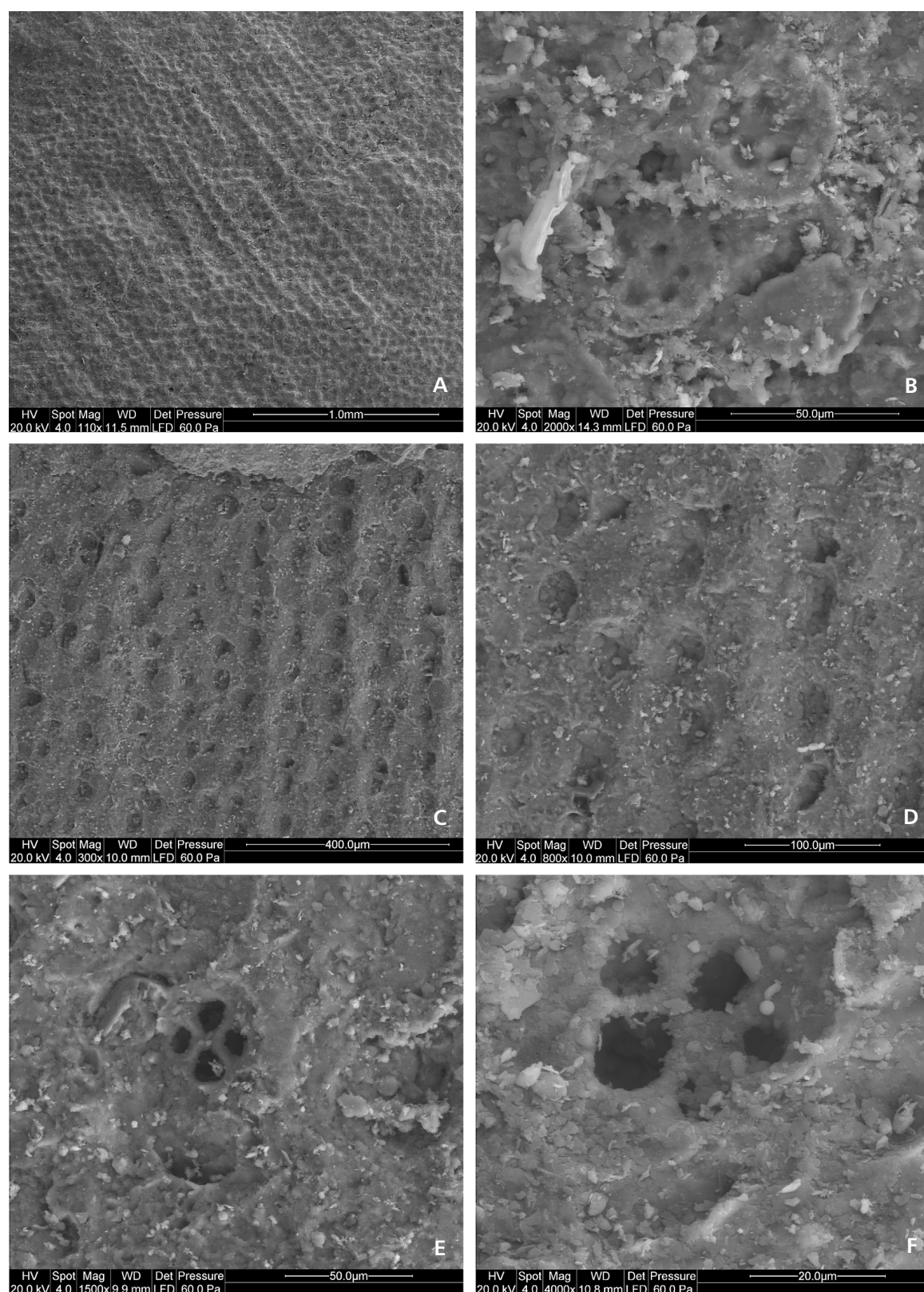


Figure 4. Palaeoscolecoid worms from the lower Cambrian Wulongqing Formation at the Dahai, Huize sections, Yunnan Province, China. • A – SEM pictures showing the trunk annulations of palaeoscolecoid worm ELI-HZ-G-001A. • B – close-up showing of three closely packed plates in a transverse row of ELI-HZ-G-001A. • C, D – SEM pictures showing the trunk annulations of palaeoscolecoid worm ELI-HZ-G-002A. • E, F – enlargement of the plates with nodes of ELI-HZ-G-002A.

Discussion and conclusions

The Guanshan Biota (Cambrian Series 2, Stage 4, *ca* 515–510 Ma) serves as an evolutionary bridge closely linking the older Chengjiang (Cambrian Series 2, Stage 3) and the younger Kaili Biota (Cambrian Series 3, Stage 5 also coeval to Burgess Shale Biota), it has significant implications for our understanding of the chronology of the Cambrian radiation and its aftermath.

Compared with previously reported fossil sites (Kunming-Wuding, Malong-Yiliang; see Hu *et al.* 2010), the new occurrence of the Guanshan Biota in Huize area expands its biogeographic distribution approximately 100 kilometers northwards. This work, thus, provides a new vista not only for research of the Guanshan palaeobiology, but also for investigation of its palaeoecology, palaeo-environment, and palaeobiogeography. Furthermore, the new data presented here emphasize the importance of the Guanshan Biota as a key-element in the chronology of the Cambrian radiation between its early steps exemplified by the Chengjiang Biota and its aftermath.

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