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# Hyolithids and associated trace fossils from the Balang Formation (Cambrian Stage 4), Guizhou, China

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**Abstract**

The Balang Formation (Cambrian Stage 4) of eastern Guizhou, China, yields slender, sinuous, and branching ichnofossils associated with shells of hyolithids. The trace-makers, of speculative identity, are inferred to have been feeding on decaying soft parts of hyolithids and on the microbial halos formed around decaying bodily remains. The comprehensive observation of hyolithid shells and their associated traces suggests that the hyolithid shells may have been moved some distance after scavenging began. This preservational pattern can address some issues relating to hyolith preservation of the Balang Formation.


*Keywords:* Hyolithid; Trace fossil; Taphonomy; Cambrian; China

## 1. Introduction

The Balang Formation (Cambrian Stage 4) of eastern Guizhou, China, is an important Burgess Shale-type deposit that yields a diverse assemblage of biomineralized and non-biomineralized fossils (Peng et al., 2005, 2010, 2012). Most previous work has focused on the systematics and evolutionary history of the Balang Biota. Much remains to be learned of the paleoecology and taphonomy of this bio-assemblage. Trace fossils and hyoliths are abundant in the Balang Formation (Peng, 2009). This paper focuses on some small trace fossils that are associated with the conchs of hyoliths.

## 2. Geological setting

The Balang Formation is exposed in eastern Guizhou Province and western Hunan Province, China. The thickness of the formation ranges from 382 m to 641 m (Peng and Babcock, 2001). The formation overlies black shales of the Bianmachong Formation (Cambrian Stage 3), and underlies interbedded carbonates and shales of the Tsinghsutung (also published as Qingxudong) Formation (Cambrian Stage 4). The lithology varies but is dominated by gray-greenish shale and calcareous shale with intercalations of thin-bedded argillaceous carbonates. Carbonate content increases to the west in the outcrop region. The Balang Formation represents part of the transitional slope belt between the Yangtze Platform and the Jiangnan Basin (Zhou et al., 1979; Fig. 1), and its total thickness is the greatest near the center of the outcrop area (in the slope belt). It comprises a shallowing-upward sequence toward its contact with the overlying Tsinghsutung Formation (Peng et al., 2012).

Zhou et al. (1979) first provided a biostratigraphic framework for the Balang Formation, and that work has been revised several times. Zhou et al. (1979) reported trilobites indicative of the *Arthricocephalus* Zone in the lower Balang Formation, and trilobites indicative of the *Arthricocephalites-Changaspis-Balangia* Assemblage Zone in the upper Balang Formation. Subsequently, Zhou et al. (1980) modified the name of the upper biozone, referring to it as the *Arthricocephalites-Changaspis* Assemblage Zone. Subsequently, the biostratigraphic framework was described from one genus-level assemblage zone (Yin, 1987, 1996), up to four species-level zones or three species-level zones

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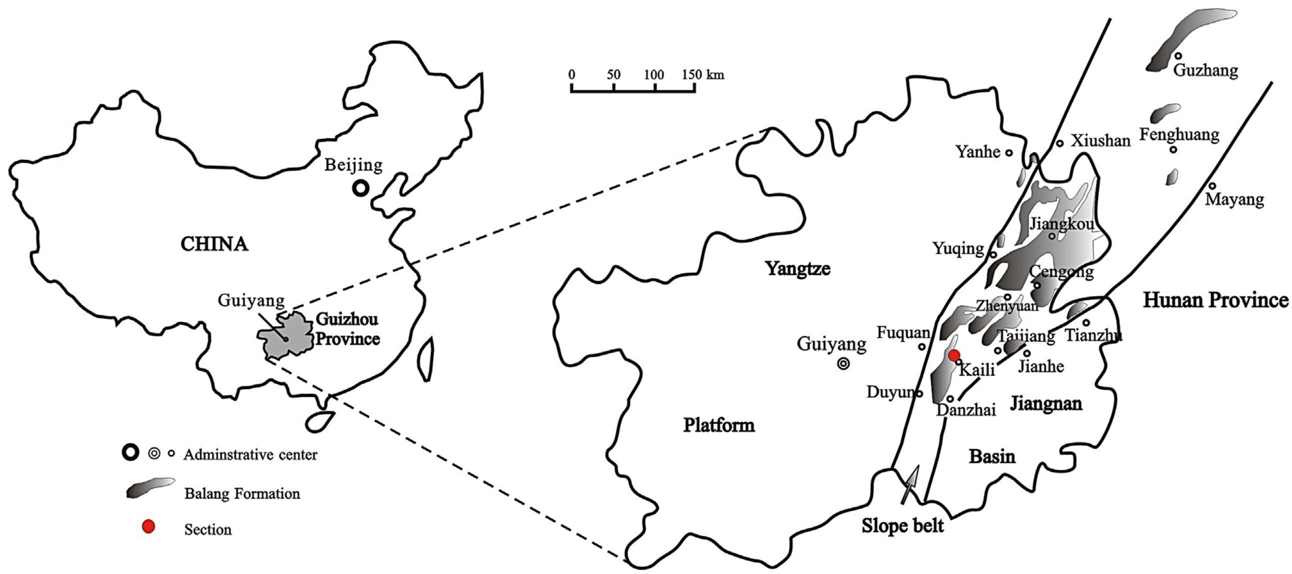


Fig. 1. Map of China (left) showing location of Guizhou Province, and inset (right) showing Guizhou and part of western Hunan with outcrop distribution of the Balang Formation shown in gray. Location of the Wenglingtang Section is indicated in red on the inset. Approximate margins of Yangtze Platform, transitional slope belt, and Jiangnan Basin deposits are also indicated on the inset map.
Map modified from Zhou et al. (1979).

(Yuan et al., 2001, 2002, 2006), and one species-level assemblage zone (Peng, 2009; Qin et al., 2010). Yan et al. (2014) included the entire Balang Formation in the *Arthricocephalus chauveaui* Zone.

## 3. Materials and methods

Six hyolithid specimens with associated trace fossils were collected from the Balang Formation at the Wenglingtang Section, Kaili City, Guizhou Province. All are from greenish-gray shale. Each trace is preserved as a mold on or in a decalcified conch. Specimens are on the ventral side of the hyolithids, and the hyolithid conchs are either parallel or slightly inclined to bedding. The composition of hyolithids and of the matrix is dominated by clay minerals. Barite, iron oxide, and titanium oxide also occur in the matrix, and pyrite is common within hyolithid specimens.

Specimens were examined and imaged using standard light microscopy, digital macrophotography (Canon Rebel Xsi with a 60 mm macro lens), and an FEI Quanta 250 Field Emission Gun Scanning Electron Microscope (SEM) with Electron Dispersive X-ray (EDX). For publication, digital macrophotographs are used. These images were stacked and rendered using Adobe Photoshop and Corel Draw software. Elemental analysis was performed using the EDX capability of the SEM.

Specimens are reposited in the Paleontological Museum of Guizhou University, Guiyang, China.

## 4. Characters of the trace fossils

Sinuous irregular linear ridges or grooves are present on and adjacent to the studied hyolithid shells. The shallow and nearly horizontal traces are small, ranging from 0.1 to 0.4 mm wide, and up to 12 mm long. They are either smooth or branching (Figs. 2A–C, F, and H and 3A and B), and some show serial swellings that are nearly circular in outline, and up to 0.3 mm in diameter (Fig. 2D, E, and G). The traces are sediment-filled, but without obvious spreiten-type backfill. Commonly they are limonite-stained. The hyolithid shells with which they are associated are decalcified. Traces occur preferentially on the venter of hyolithid conchs, both outside and inside, from apex to aperture, and from one lateral edge to the other. The traces have not been observed to extend beyond the margins of the hyolithid shells. Decay halos beyond the shell margins also have not been observed. Traces have been observed on hyolithids referred to *Ambrolinevitus ventricosus* (Fig. 2A and H), *Ambrolinevitus* sp. (Fig. 2E and G), "*Hyolithes*" sp. (Fig. 2B and D), and *Linevitus* sp. (Fig. 2C and F).

Although the materials described herein are not sufficient for confident ichnotaxonomic classification, most resemble *Pilichnus*, which is also small, irregularly wandering, and bifurcating (Uchman, 1999; Mikuláš et al., 2012). They also closely resemble the slightly larger but unbranched *Helminthopsis* (Wetzel and Bromley, 1996). Some of the traces resemble *Gordia*, which has been reported from the Kaili Formation (Wang et al., 2009). *Gordia* comprises smooth, cylindrical or subcylindrical, unbranched, sinuous and irregularly curving burrows that are generally self-crossing. *Gordia* can show swellings (see Wang et al., 2009) resembling those on the traces reported here (Fig. 2D, E, and G). Less similar is *Helminthoidichnites*, which is characterized by its small size and sinuous but unbranched shape (Narbonne and Aitken, 1990; Mángano, 2011). Here we provisionally refer to the illustrated traces as *Pilichnus*-like (Figs. 2A–C, F, and H and 3A and B) or *Gordia*-like (Fig. 2D, E, and G).