**Phosphatized Punctatus with mouthparts and its embryo fossils from the Lower Cambrian of Ningqiang, south Shaanxi, China**

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**Abstract** The appearance of coelenterates marks the real beginning of metazoan evolution. It therefore has a prominent position in the origin and evolutionary history of organisms, and is also a pivotal question of evolutionary biology. Punctatus is an extinct, ancient marine animal from the early stage of the Cambrian explosion, occurring at the lowermost Cambrian of both Kuanchuanpu (Ningqiang, Shaanxi) and Maidiping (Emei, Sichuan) areas. Punctatus has been studied for many years since the discovery of its fragments. Systematic and phylogenetic analysis has long been limited because of the rarity of complete specimens. In order to improve research into Punctatus, more than ten thousand globular fossils were recovered by means of “Chemistry Retting”. On the basis of the study of these globular fossils, a series of Punctatus fossils with cone parts and finely preserved soft-tissue mouthparts and fossilized metazoan embryo were recovered. Through research on characteristics such as shape, modality and structure of these fossils symbiotic with Punctatus emeiensis, the author found many possible embryo fossils including the evidence of gastrula-stage animal fossils. The sequence of fetation might have appeared on the coralliform oral region of Punctatus emeiensis. A study of the soft tissues, functional morphology and the sequence of embryo fossils shows evidence that Punctatus resembles coelenterate polyps in systematic classification. Perhaps it also represents an ancestor of the coelenterate with an original tentacle. A comparison with the real “tentacle animal” found in the Chengjiang Fauna, shows that the original tentacle is very tiny and its function range is limited. This reveals the primitive nature of the animal. Although the original tentacle is so small, it does exist, representing the first big step towards the real flexible tentacle with a strong function from the early evolving tentacle.

**Keywords** Punctatus, mouthparts, Cnidaria, embryo fossils, Meishucun Stage, Kuanchuanpu Member of the Dengying Formation, south Shaanxi

1 **Introduction**

Biomineralization of early metazoans is one of the main proofs of the Cambrian explosion, which took place at the Precambrian–Cambrian transition, and is well below the horizon of the first appearance of trilobites and 10 Ma earlier than the Chengjiang biota. Therefore, the sudden appearance of small shelly fossils at the Meishucunian has been regarded as a prelude to the Cambrian explosion (Qian, 1999). Punctatus is an extinct, ancient marine animal at this stage, occurring at the lowermost Cambrian of both the Kuanchuanpu (Ningqiang, Shaanxi) and Maidiping (Emei, Sichuan) areas.

Punctatus has been studied for 25 years since the discovery of its fragments in 1980. Systematic and phylogenetic analysis has long been limited because of the rareness of complete specimens. Most workers are now apt to assign Punctatus to the Cnidaria (He, 1987; Qian, 1999). Punctatus emeiensis He, 1980 was first described by He et al. (Yin et al., 1980) from the strata of Meishucunian Age, Early Cambrian, in the Maidiping area, Emei, Sichuan, on the basis of the fragments of the conical body showing regularly arranged nodules as the genus name indicated. Subsequently, Yue (Yue and Xing, 1984) discovered relatively complete cone- and tower-like specimens from the Kuanchuanpu Member, and named as Pyrgites mirabilis (Yue, 1983) [syn. Punctatus emeiensis (He et al., 1980)]. He (1987), Conway and Chen (1990, 1992), Bengtson and Yue (1997), Yue and Bengtson (1998), Qian (1999), Hua et al. (2004), and Steiner et al. (2004) studied specimens of...
Punctatus from the strata of Meishucunian in the Yangtze platform.

The research of Steiner et al. (2004), however, did not include the complete study on the mouthpart of Punctatus, owing to the filmy mouthpart of adults, which was not well preserved. The specimens of Punctatus studied and reported were all incomplete, only preserving conical and cylindrical bodies connected with it. And what was the form of the other part connected with the cylindrical body? Was it its mouthpart? What was the form of the mouthpart and were there any tentacles around it? In which stage did the mouthpart form? All these questions have baffled researchers owing to a lack of any specific evidence in the fossils.

Recently, the authors found a series of conical fossils of Punctatus from phosphoric beds on the upper part of the Kuanchuanpu Member of the Dengying Formation in Ningqiang, Shaanxi. Besides the specimens, which were the same as Pyrgites mirabilis (Yue, 1984), we also found specimens of the mouthpart of Punctatus, which were preserved with complete corolliform mouthparts, and likely embryo fossils. Utilizing the data above, we demonstrate the complete form of Punctatus emeiensis and propose a likely sequence of embryo development.

These new data may enhance our knowledge of life at the very onset of the Cambrian explosion, and offer good evidence and material to consider the biological affinities of this organism and a series of issues such as origin, radiation, living habit and systematic assortment of animals at the onset of the Cambrian explosion.

2 Localities and stratigraphy

The fossils were collected from the Kuanchuanpu Member of the Dengying Formation at Shizhonggou Section in Ningqiang, Shaanxi, which is located in the Yangtze platform (Fig. 1). This member conformably overlies the Beiwian Member and contacts unconformably with the overlying Guojiaba and Shuijingtuo Formations. The overlying formations are both characterized by silicious and phosphatic carbonate-bearing trilobites. The Kuanchuanpu Member is correlated to the Tianzhushan, Yanjiahe, Maidiping, Zhongyicun, and Yangjiagou Members in other parts of the Yangtze platform, and is dominated by dark gray and grayish-black bitumen limestone. It produces abundant small shelly fossils, such as Olivooides, Anabrites, Protoherzina, Carinachites, Zhijinites, Siphogonuchites, Lopochites, and Igorella. This stratum belongs to the Meishucun Stage of the Early Cambrian.

3 Description of fossils

The following text is the description on Punctatus emeiensis (He et al., 1980) and the fossils with a corolliform mouthpart and the one with complete mouthparts can be divided into two morphological types: the oval and subcircular mouthparts.

3.1 The oval corolliform mouthpart with ten V-shaped “flower petals” (Fig. 2)

The cylinder connected with the complete elliptical corolliform mouthpart is 3 mm in length (Fig. 2a–b, d–h). There are some thick transverse ridges and some closely spaced parallel vertical lines between the ridges, the width of the ridges being about 80–100 µm and the space between being 500 µm, the width of the longitudinal lines being 8–10 µm. The elliptical corolliform mouthpart is completely preserved, the elongated axis is 1.8 mm, and the shortened axis is 1.25 mm. It is made up of the drape piamater convergent from the inside and outside circles towards the center (Fig. 2d). The piamater has close parallel strialongitudinalis and 10 double-layered folds showing a V-shaped outline and radiating and circumgyrating into two circles (Fig. 2d, f). The hollow circularity enclosed by the outer ring covers the inside track (Fig. 2b, c). The outline of the outer ring is well defined, the majority of the inside tracks are covered by the outer ring and only the center portion is revealed. The inside tracks converge into a dot towards the center, which is the position of the mouth (Fig. 2e).

Another subcircular corolliform mouthpart, which is made up of ten V-shaped “flower petals”, has the same characteristics as the above.

3.2 The subcircular corolliform mouthpart with six V-shaped “flower petals” (Fig. 3a–h)

The subcircular corolliform mouthpart lies at one end of the cylinder that is covered with fine, longitudinal ornaments.