

SEM morphological study of the clam shrimp type specimens of *Eosestheria sihetunensis* from the Lower Cretaceous Yixian Formation in western Liaoning, northeastern China

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Abstract

Morphological reexamination of the type specimens of *Eosestheria sihetunensis* from the Jianshangou beds, the lowest fossil bearing part of the Lower Cretaceous Yixian Formation in Sihetun Village of Beipiao City, western Liaoning Province, northeastern China under a scanning electron microscope (SEM) revealed morphological features on the carapace that had not been recognized previously: growth lines with fine ridges; growth bands near the umbo and in the middle part of the carapace are ornamented with reticulation, within which very fine ridges or cross bars and punta are observed; growth bands in the ventral part of the carapace ornamented with radial lirae, which expand to form triangularly enlarged structure.

Key words: fossil clam shrimps, taxonomy, Lower Cretaceous, Yixian Formation, China.

Introduction

Muroi (1940) established the Yixian Formation in the western part of Yixian County, which is extensively developed in northern Hebei and western Liaoning provinces of China. It is 620–3,695 m thick in western Liaoning (Wang et al., 1989), and consists mainly of volcanic rocks with lacustrine sedimentary intercalations yielding an exceptionally well-preserved Early Cretaceous Jehol Biota (Batten, 1998; Chen and Jin, 1999; Chang et al., 2003; Zhou et al., 2003). The Jehol Biota has become well-known in recent years because its

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beautifully preserved fossils are of evolutionary importance, such as early angiosperms (Sun et al., 1998, 2002), feathered theropod dinosaurs (Chen et al., 1998; Ji et al., 1998), early birds (Hou et al., 1995, 1999; Hou and Chen, 1999) and primitive mammals (Hu et al., 1997; Ji et al., 2002, 2009; Luo et al., 2003, 2007; Li and Luo, 2006).

The Barremian–lower Aptian (Lower Cretaceous) Yixian Formation has been subdivided into four widely recognizable fossil bearing beds within the areas of Yixian County and Beipiao City, western Liaoning Province of northeastern China. The four abundant fossil bearing beds, in ascending order, are called the Jianshangou, Zhuanchengzi, Dakangpu and Jingangshan beds, respectively (Wang et al., 2004; Chen et al., 2005; Wan et al., 2013). Fossil clam shrimps (“Conchostracans”, spinicaudatans) are extremely abundant in the formation. They belong to an *Eosestheria* fauna, and are very common and readily found in the lacustrine mudstone and paper shales of the Yixian Formation. This is the reason why fossil clam shrimps were originally used to nominate the Jehol Biota as *Eosestheria middendorfi* (clam shrimp)-*Ephemeropsis trisetalis* (insect)-*Lycoptera* (fish) fauna (Chen, 1988, 1999a, 2012). The first taxonomic paper on specimens of the *Eosestheria* fauna recovered from the Turga area, Siberia of Russia was that of Jones (1862) who described *Estheria middendorfi* (now *Eosestheria middendorfi* (Jones, 1862) Zhang et al., 1976). This was followed by the publications of Chernyshev (1930), Raymond (1946), Kobayashi and Kusumi (1953), Novojilov (1954), Wang (1976, 1980, 1987), Zhang et al. (1976), Niu (1983), Chen and Shen (1985), Chen (1999b), Niu et al. (2003), Li and Batten (2004a) and Shen (2011). Chen (1988) recognized two clam shrimp zones in the Yixian Formation: i.e. the lower *Eosestheria lingyuanensis* Zone in the Jianshangou beds and the upper *E. middendorfi* Zone in the upper part of the Yixian Formation.

The *Eosestheria* fauna, dominated by *Eosestheria* and *Diastheria*, consists of more than 100 species; the majority are 10–20 mm long (i.e. the carapace length). In consideration of the sexual dimorphism and effects of preservation distortion, maybe only 20 or 30 species will be distinguished satisfactorily (Chen et al., 2007). In this sense the *Eosestheria* fauna needs to undergo taxonomic revision. In this paper a re-examination of the type specimen of *Eosestheria sihetunensis* Chen, 1999b under a scanning electron microscope (SEM) revealed some morphological features not previously seen, as recorded below.

Material and method

The type specimens examined are deposited in the collection of the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (NIGPCAS). They are all natural carapaces, and were originally collected from the Jianshangou beds of the Lower Cretaceous Yixian Formation in Sihetun Village, Beipiao City of western Liaoning Province.

Most of the previous studies on the palaeontology of fossil clam shrimps have used a light

microscope. This means that some potential characters of taxonomic value were difficult to see clearly (Li, 2004; Li and Batten 2004b, 2005; Li et al., 2004, 2006, 2007b, 2009, 2010, 2014; Li and Matsuoka, 2013). Here the authors have relied on examination of specimens using a Leo 1530 VP SEM, and a Zeiss V20 Stereomicroscope.

Systematic palaeontology

The classification of recent spinicaudatans of Martin and Davis (2001) is followed here. Because *Cyclestheria* Sars, 1887 has been removed from the suborder Spinicaudata Linder, 1945 and is now placed in the suborder Cyclestherida Sars, 1899, which is on an equal footing with the remaining Spinicaudata and Cladocera Latreille, 1829, the Conchostraca Sars, 1867 as a taxonomic unit has been abandoned.

Class: Branchiopoda Latreille, 1817

Subclass: Phyllopoda Preuss, 1951

Order: Diplostraca Gerstaecker, 1866

Suborder: Spinicaudata Linder, 1945

Superfamily: Eosestherioidea Zhang and Chen, in Zhang et al., 1976

Family: Eosestheriidae Zhang and Chen, in Zhang et al., 1976

Genus *Eosestheria* Chen, in Zhang et al., 1976

1976 *Eosestheria* Chen gen. nov., Zhang et al., p. 153.

1976 *Liaoningestheria* Chen gen. nov., Zhang et al., p. 161.

1999 *Eosestheria* Chen, p. 114–115.

Type species. *Eosestheria fuxinensis* Chen, in Zhang et al., 1976.

Occurrence. Lower Cretaceous of northern and northeastern China, southern Mongolia and Transbaikial of Russia.

Diagnosis. Carapace rounded, elliptical or oval in outline, carapace size moderate (carapace length 5–15 mm) or large (>15 mm); growth bands, numerous, even and wide; those near the umbo or in the antero-ventral parts of the carapace are ornamented with medium- (mesh diameter 20–70 μm) or large-sized (mesh diameter 70–200 μm) reticulations (Chen and Shen, 1985), which change gradually to radial lirae on the ventral or in the postero-ventral parts, radial lirae less than 40 within a width of 1 mm; reticulation and radial lirae are irregular (Chen, 1999b).

Discussion. Several fossil clam shrimp genera, except for *Eosestheria*, are characterized by bearing two kinds of ornamentation, i.e. reticulation occurring in the dorsal part, and radial lirae in the ventral part of the carapace, such as *Pseudograptia* Novojilov, 1954, *Yanjiestheria* Chen in Zhang et al., 1976, *Carapacestheria* Shen, 1994. In *Pseudograptia*, the growth lines are more pronounced, the reticulation is coarsely polygonal, and the change from reticulation on the dorsal side to radial lirae on the ventral side is abrupt. In *Yanjiestheria*, the carapace is normally moderate in size, the reticulation is smaller and denser (mesh diameter less than 20 μm), the radial lirae are thinner and more closely spaced (more than 40 within a width of 1 mm) (Li et al., 2007a). In *Carapacestheria*, the carapace is of small or moderate size, and the reticulation is medium-sized (mesh diameter 20–36 μm), radial lirae about 40 within a width of 1 mm. The most distinct character in *Carapacestheria* is that puncta occur within the reticulation and between the radial lirae (Shen, 1994). Although Jones (1862, pl. 4, fig. 19) showed punctate reticulation in *E. middendorfi*, until now no researcher has reported any punctum in *Eosestheria*.

Chen (in Zhang et al., 1976) described *Liaoningestheria* based on the occurrence of reticulation on internal surface of the carapace, but later it was found that this character has no taxonomic importance, so that *Liaoningestheria* was considered as a synonym of *Eosestheria* (Chen and Shen, 1985; Chen, 1999b). There are also some other genera (Chen and Shen, 1985; Chen, 1999) that have also been considered as synonyms of *Eosestheria*, such as *Diformograptia*, Wang, 1976, *Amelestheria* Wang, 1976 and *Dongbeiestheria* Wang, 1980. The further morphological re-studies of the type specimens of these taxa are needed in the future.

Eosestheria sihetunensis (Chen, 1999b) emend.

Figs. 1–2

1999b *Eosestheria sihetunensis* Chen sp. nov., p. 118, pl. 4, figs. 4–7.

Material. Holotype NIGPCAS 131917, a right valve, and NIGPCAS 131916, a left valve, Sihetun, Beipiao City, western Liaoning Province, northeastern China.

Emended diagnosis. Carapace oval in outline; growth lines with fine ridges; growth bands in the dorsal part of the carapace ornamented with medium- or large-sized irregular reticulation with cross bars or fine ridges and puncta in the lumina; those on the ventral part of the carapace ornamented with radial lirae, which on the postero-ventral part of the carapace distribute in the lower half or two-thirds of each growth band and leaving its upper part smooth.

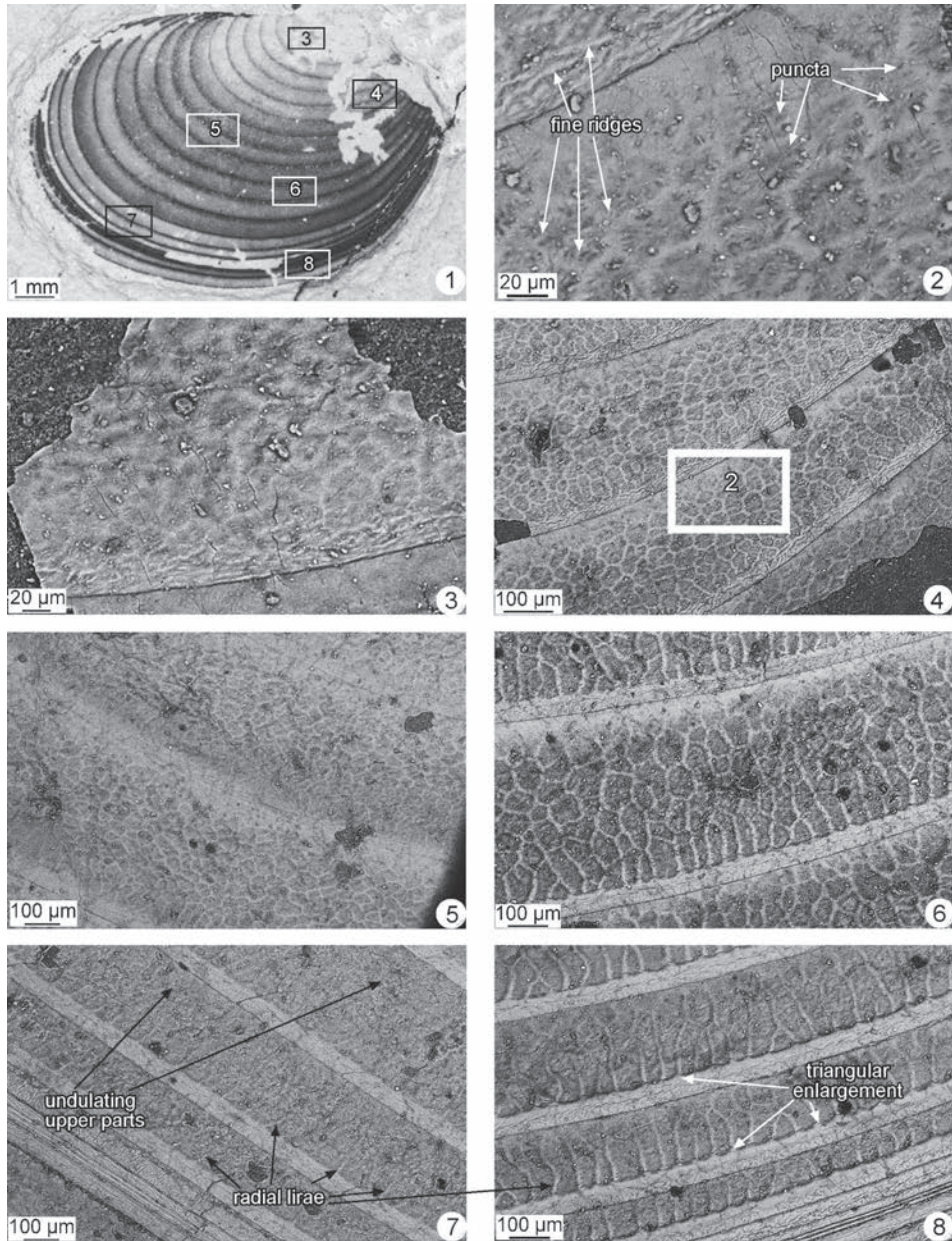


Fig. 1. 1–8, *Eosestheria sihetunensis* (Chen, 1999b) emend., all, except Fig. 1.1 (a light microscopy image), are SEM images of a right valve from the Jianshangou beds of the Lower Cretaceous Yixian Formation, Beipiao City, western Liaoning Province. 1, holotype, NIGPCAS 131917. 2, reticulation on a growth band in the antero-dorsal part of the carapace, showing fine ridges on growth line, fine ridges and puncta within lumina. 3, irregular reticulation on a growth band near the umbo. 4, irregular reticulation on growth bands on the antero-dorsal part of the carapace. 5, irregular reticulation on growth bands in posterior part of the carapace. 6, transition from irregular reticulation to radial lirae on a growth band in the antero-ventral part of the carapace. 7, widely spaced fine radial lirae, occupying the lower half of the growth bands in the postero-ventral part of the carapace. 8, widely spaced radial lirae with triangularly enlarged structure when meeting the growth lines downwards in the antero-ventral part of the carapace.

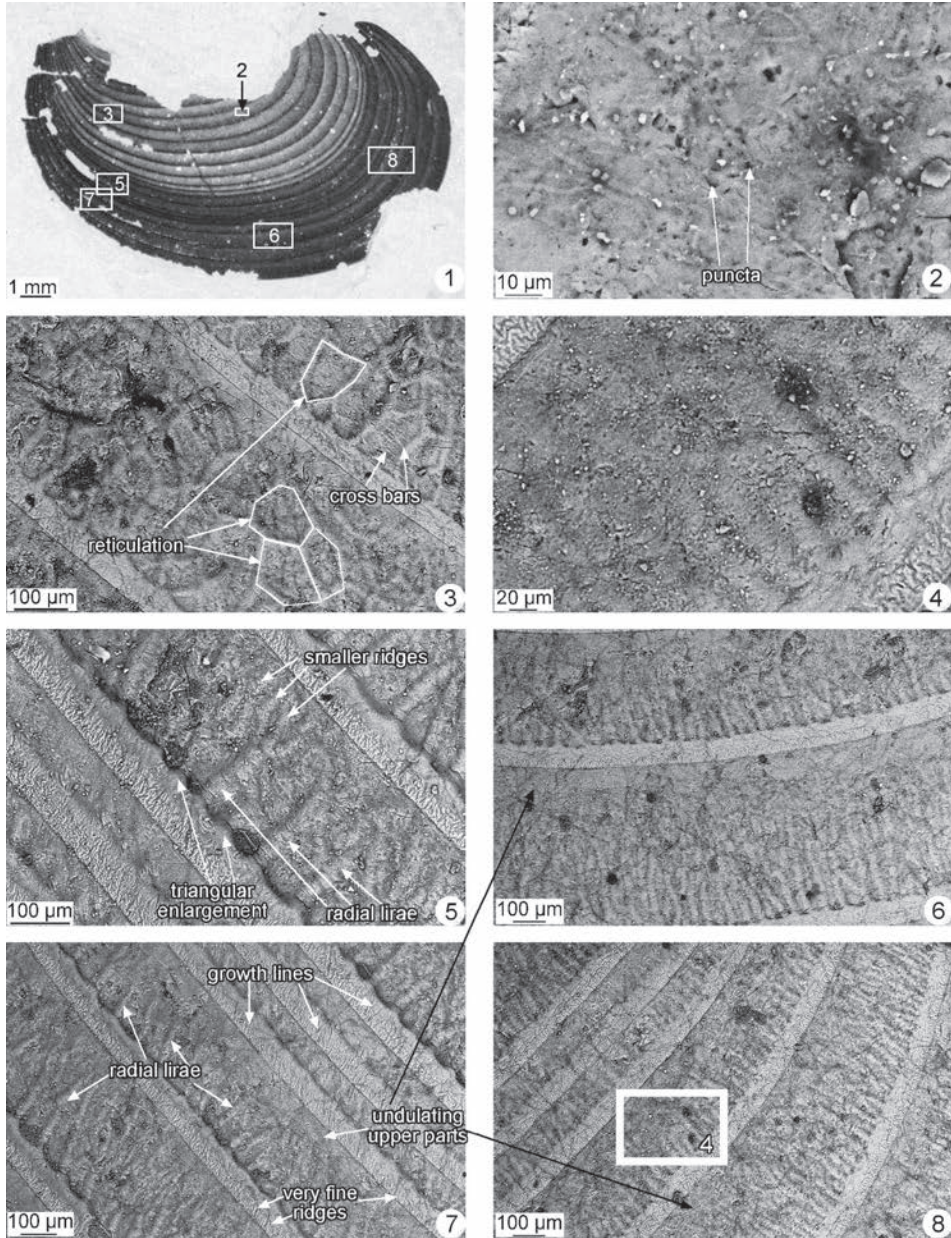


Fig. 2. 1–8, *Eosestheria sihetunensis* (Chen, 1999b) emend., all, except Fig. 2.1 (a light microscopy image), are SEM images of a left valve from the Jianshangou beds of the Lower Cretaceous Yixian Formation in Sihutun Village, Beipiao City, western Liaoning Province. 1, NIGPCAS 131916. 2, punctate ornamentation on a growth band on the dorsal part of the carapace. 3, irregular reticulation on growth bands in anterior part of the carapace. 4, 8, densely spaced radial lirae on growth bands in the postero-ventral part of the carapace. 5, 7, widely spaced radial lirae on growth bands in antero-ventral part of the carapace. 6, densely spaced fine radial lirae on growth bands in the ventral part of the carapace.

Dimensions of the type specimens. In order: specimen no.; number of growth lines; length of carapace (mm); height of carapace (mm): NIGPCAS 131916; >21; 14.6; 9.0; NIGPCAS 131917; >20; 10.6; 7.0.

Description. Carapace is of moderate size (10–15 mm long, 7–9 mm high), which is oval in outline with a higher posterior height; umbo small, located at the anterior one-fourth of the long and straight dorsal margin; growth lines 20–25, even and wide, ornamented with very fine ridges (Fig. 1.2); growth bands in the umbonal area ornamented with irregular polygonal medium-sized reticulation (Fig. 1.3), which become larger in the middle part of the carapace (Fig. 1.4), with fine ridges and puncta (Fig. 1.2) and cross bars (Fig. 2.3); reticulation gradually change into radial lirae in the lower part of the carapace (Figs. 1.6, 1.8, 2.5, 2.8). The transition from reticulation to radial lirae could be seen in one growth band, on which the upper part is ornamented with reticulation, and the lower part with radial lirae (Fig. 1.6). Radial lirae are widely spaced in the antero-ventral part of the carapace (Figs. 1.8, 2.5, 2.7), but become thinner (Fig. 1.7) or densely spaced (Fig. 2.8), and only occupy the lower half or two-thirds of each band in the postero-ventral part (Figs. 1.7, 2.8). Radial lirae change to triangularly enlarged structure when they meet the growth line downwards in the antero-ventral part of the carapace (Figs. 1.8, 2.5), and some radial lirae branch into secondary ridges upwards (Fig. 2.5).

Discussion. Chen (1999b) designated the specimen NIGPCAS 131917 (Fig. 1) as the holotype of *E. sihetunensis* in the explanation of pl. 4, fig. 5, but the image of the specimen of NIGPCAS 131916 (Fig. 2) was showed. Here we still follow the original designation of NIGPCAS 131917 as the holotype. According to the new SEM images of the two specimens, the holotype has well developed reticulation ornamentation, while the specimen labeled as NIGPCAS 131916 has limited reticulation ornamentation, maybe this is caused by the damage of its dorsal part.

E. sihetunensis is similar to *E. ovata* (Chen, in Zhang et al., 1976) in carapace outline, but differs in having smaller carapace dimensions, and the radial lirae occupy the lower part of each growth band in the postero-ventral part of the carapace. In addition, the fine ridges or cross bars and puncta within the reticulation is very special, having not been reported in *Eosestheria* until now. Although Jones (1862) showed punctate reticulation, this ornamentation has not been confirmed before. Although *Carapacestheria* (Shen, 1994) has punctate reticulation, it differs by having smaller mesh diameter (20–36 μm).

In *Eosestheriopsis* Shen and Chen, 1982, a row of tubercles occurs along the lower margin of each growth band in the middle and ventral parts of the carapace. In the present species, the radial lirae expand to form a triangularly enlarged structure when they meet the growth lines downwards, but it differs by not forming tubercles. Further morphological

study on the taxa of *Eosestheria* and *Eosestheriopsis* is needed to confirm the basic difference between the two genera.

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