

SEM morphological study of clam shrimp *Diestheria* (spinicaudatan) of the Jehol Biota of China

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Abstract

Morphological re-examination under a scanning electron microscope (SEM) of the type specimens of *Diestheria longinqua* Chen, in Zhang et al., 1976 from the Lower Cretaceous Yixian Formation of the Jehol Group at Dakangpu of Yixian County, western Liaoning Province, northeastern China revealed morphological features on the carapace that had not been recognized previously: 1) growth lines with fine ridges; 2) radial lirae intercalated with small irregular reticulation on the growth bands in the postero-middle part of the carapace.

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

Introduction

The Upper Mesozoic in China are mainly of continental origin and contain an abundance of fossil clam shrimps, whose rapid evolution and radiation make them biostratigraphically useful in subdividing and classifying non-marine strata (Li et al., 2004, 2010, 2015, 2016a, b; Li and Matsuoka, 2012, 2013, 2015; Boukhalfa et al., 2015; Teng et al., 2016). Muroi (1940) established the Yixian Formation in the western part of Yixian County, which is extensively

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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 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; 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 spinicaudatan *Diestheria* Chen is an important component of the diverse *Eosestheria* fauna of the Early Cretaceous Jehol Biota in northern China (Chen et al., 2007; Li et al., 2007a). In this paper a re-examination under a scanning electron microscope (SEM) of the type specimens of *Diestheria longinqua* Chen, in Zhang et al., 1976 revealed important morphological features not previously seen, as recorded below.

Material and methods

The studied two specimens are deposited in the collection of the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (NIGPCAS). The holotype (NIGPCAS 15462) is an external mould of a left valve and the paratype (NIGPCAS 15463) is a right valve. They were originally collected from the Lower Cretaceous Yixian Formation at Dakangpu of Yixian County, western Liaoning Province, northeastern China.

Most of the previous studies on the palaeontology of fossil clam shrimps have used a light microscope (Zhang et al., 1976). This means that some morphological characters of potential taxonomic value were difficult to see clearly (Li, 2004; Li and Batten, 2004a, b, 2005; Li et al., 2006, 2007a, b, 2009, 2014, 2017). Here the authors have relied on examination of the paratype specimen 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 the genus *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 order Conchostraca Sars, 1867 as a taxonomic unit has been abandoned. Thus, we follow Martin and Davis (2001) to use the order Diplostraca Gerstaecker, 1866 as a taxonomic unit.

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: Diestheriidae Zhang and Chen, in Zhang et al., 1976
Genus: *Diestheria* Chen, in Zhang et al., 1976

1976 *Diestheria* Chen gen. nov., in Zhang et al., p. 175.

1982 *Diestheria* Chen. Shen et al., p. 64.

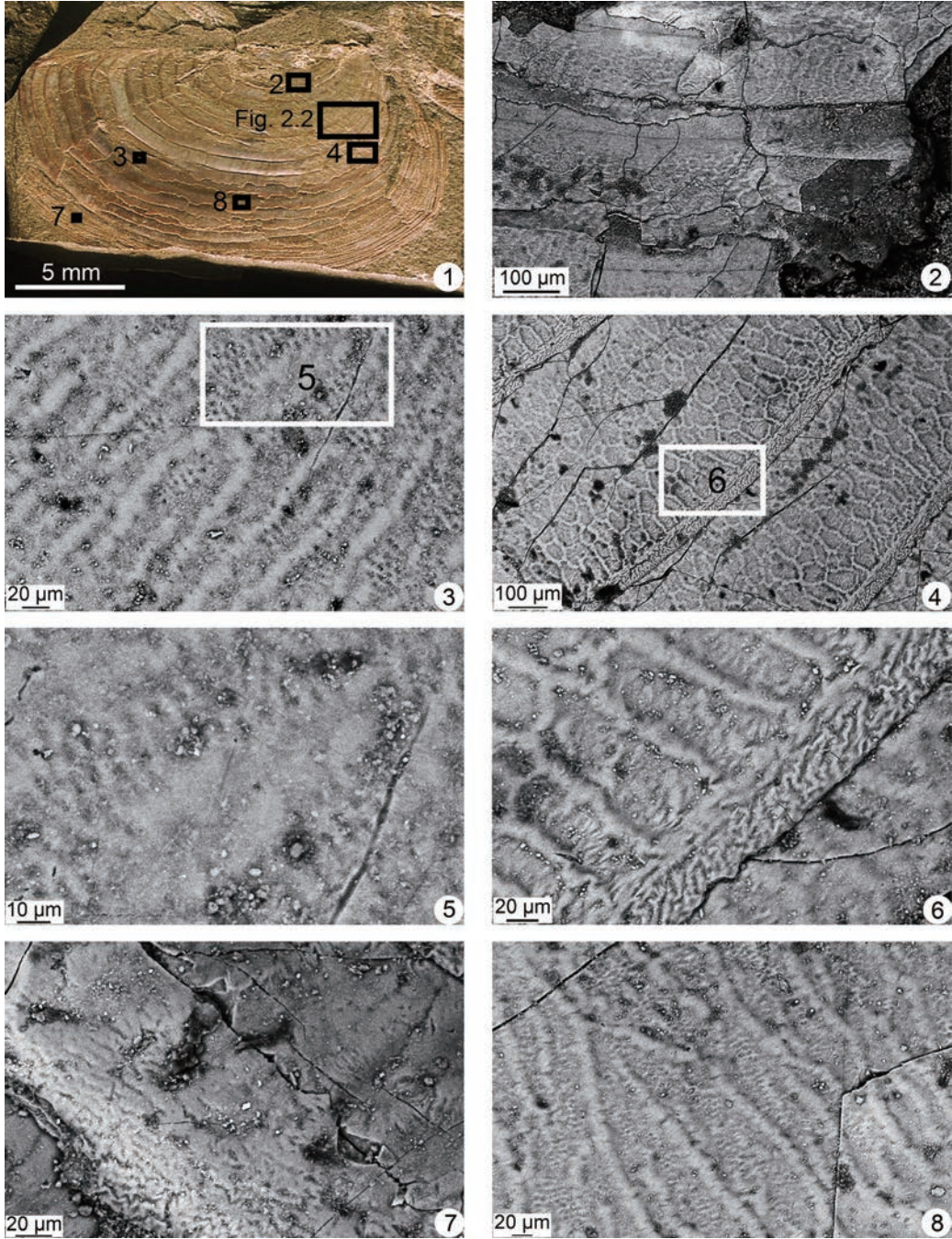
1985 *Diestheria* Chen. Chen and Shen, p. 118.

Type species. *Diestheria yixianensis* Chen, in Zhang et al., 1976

Occurrence. Lower Cretaceous Yixian and Shaihai formations, western Liaoning, northeastern China. Lower Cretaceous Chijinpu Formation, Yumen, Gansu Province; Lower Cretaceous Bayingobi Formation, Inner Mongolia, northwestern China.

Diagnosis. Carapace very large, rounded, elliptical or oval in outline, growth bands in the dorsal or in the antero-ventral parts of the carapace ornamented with medium- or large-sized irregular polygonal reticulations, which change gradually to radial lirae on the ventral or postero-ventral parts, the transition from reticulation to radial lirae could be seen on the growth bands in ventral part of the carapace, on which the upper part is ornamented with reticulation, and the lower part with radial lirae; radial lirae less than 40 within a width of 1 mm, thick and usually curved or forked; growth bands in the posterior or ventral parts of the carapace also ornamented with transversely enlarged reticulation superimposed on the radial lirae.

Discussion. *Diestheria* was erected by Chen (in Zhang et al., 1976) on the basis of a light microscope examination of specimens mostly collected from the Yixian Formation. This genus is widely distributed in the Lower Cretaceous in northern China (Shen et al., 1982; Chen and Shen, 1985; Fu et al., 2007). *Diestheria* is closely related to *Eosestheria*, but differs by having superimposed (overlapping) transversely elongated reticulation on radial lirae in ventral and postero-ventral parts of the carapace. Recent SEM morphological studies on the type specimens of *Eosestheria sihetunensis* Chen, 1999 and *Neodiestheria dalaziensis* Chen, in Zhang et al., 1976 have revealed new features that have not been recognized previously. *Eosestheria sihetunensis* has fine ridges and puncta within the reticulation on the dorsal and middle parts of the carapace (Li et al., 2015). *Neodiestheria dalaziensis* yields



puncta in the carapace, which is either evenly distributed on the growth bands of the dorsal part, or within fine reticulation and between radial lirae in the lower part of the carapace (Li et al., 2016a). The SEM re-examination of the type specimens of *Diestheria longinqua* has also found fine reticulation not recognized previously.

Diestheria longinqua Chen, in Zhang et al., 1976, emend.

Figs. 1–2

1976 *Diestheria longinqua* Chen sp. nov., in Zhang et al., p. 177.

Material. Holotype NIGPCAS 15462, an external mould of a left valve, and paratype NIGPCAS 15463, a right valve, from the Lower Cretaceous Yixian Formation of Yixian County, western Liaoning Province, northeastern China.

Dimensions of the type specimens. In order: specimen no.: number of growth lines, length of carapace (mm), height of carapace (mm): NIGPCAS 15462: >26, 23.0, 12.1; NIGPCA 15463: >20, 20.7, 10.9.

Description. Carapace is very large, which is long elliptical or oblong in outline; umbo small, located between the anterior end and the median point of the long and straight dorsal margin; growth lines more than 20 in number, ornamented with very fine ridges (Fig. 1.4, 1.6, 1.7). Growth bands in the umbonal area ornamented with small-sized irregular polygonal reticulation (Fig. 1.2), which become larger in antero-middle part of the carapace (Figs. 1.4, 2.2); reticulation gradually changes to radial lirae in the ventral part of the carapace (Figs. 1.5, 1.8, 2.4). The transition from reticulation to radial lirae could be seen on the growth bands in the middle part of the carapace, on which the upper part of each band is ornamented with reticulation, and the lower part with radial lirae (Figs. 1.4, 1.6, 2.2). The upper half of each lirae-bearing growth band in the ventral and postero-ventral parts of the carapace is ornamented with overlapping reticulations, which are manifested as large

← **Fig. 1. 1–8.** *Diestheria longinqua* Chen, in Zhang et al., 1976, emend. All figures, except Fig. 1.1 (a light microscopy image), are SEM images of a right valve from the Lower Cretaceous Yixian Formation at Dakangpu of Yixian County, western Liaoning Province, northeastern China. **1**, paratype, NIGPCAS 15463, a right valve. **2**, irregular polygonal small-sized reticulation on growth bands near the umbo of the carapace. **3**, radial lirae intercalated with irregular small-sized reticulation on growth bands in the postero-middle part of the carapace. **4**, transition from irregular reticulation to radial lirae on growth bands in the antero-middle part of the carapace. **5**, small-sized irregular reticulation between radial lirae on a growth band in the postero-middle part of the carapace. **6**, fine ridges on the growth line, fine ridges intercalated between radial lirae. **7**, fine ridges on growth line in the postero-ventral part of the carapace. **8**, thick, forked radial lirae intercalated with fine ridges on growth bands in the ventral part of the carapace.

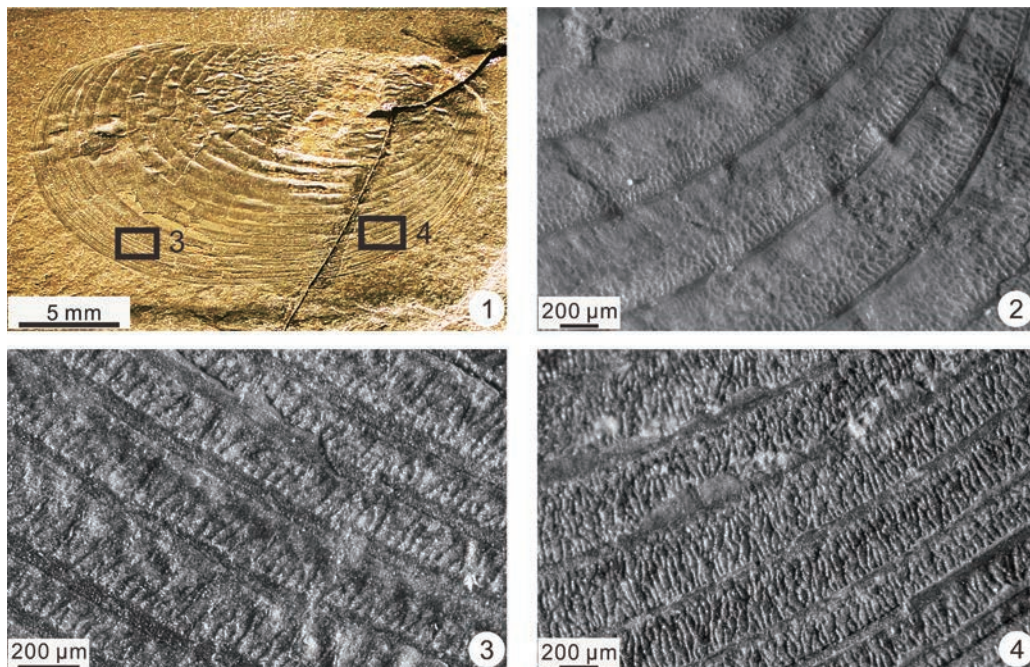


Fig. 2. 1–4, *Diestheria longinqua* Chen, in Zhang et al., 1976, emend. All are light microscopy images of the holotype and paratype specimens from the Lower Cretaceous Yixian Formation at Dakangpu of Yixian County, western Liaoning. **1**, holotype, NIGPCAS 15462, external mould of a left valve. **2**, irregular reticulation and radial lirae on the growth bands in antero-middle part of the carapace of the paratype specimen, NIGPCAS 15463. **3**, large tubercles on the upper half of each lirae-bearing growth band in the postero-ventral part of the carapace of the holotype specimen. **4**, irregular radial lirae on the external mould, the holotype NIGPCAS 15462, on the growth bands in the antero-ventral part of the carapace.

tubercles on external mould (Fig. 2.3). Radial lirae are well developed on the growth bands in the ventral part of the carapace (Figs. 1.5, 1.8, 2.4), which become fine, dense, forked, and intercalated with irregular small-sized reticulation and short ridges in the postero-ventral part of the carapace (Fig. 1.3, 1.5).

Discussion. SEM morphological re-examination of the paratype specimen (NIGPCAS 15463) of *Diestheria longinqua* revealed new features not previously seen: 1) growth lines ornamented with fine ridges; 2) radial lirae intercalated with irregular small reticulation on the growth bands in the postero-middle part of the carapace. The here discovered delicate reticulation between radial lirae is different from the evenly distributed puncta found in *Neodiestheria* (Li et al., 2016a). The specimen of the holotype (NIGPCAS 15462) is too big to be examined under an SEM. The other species of *Diestheria* is needed to be examined under an SEM in the future to recognize if this kind of irregular small reticulation is a common feature within *Diestheria*.

Acknowledgements

This study was supported by National Natural Science Foundation of China (41572006, 91514302, 41688103, 41172010). Many thanks go to Dr. T. Sasaki of the University of Tokyo for his critical review of the manuscript.

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