A proposed evolutionary lineage of *Eurygnathodus* and its role in defining the base of the Olenekian (Lower Triassic)

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Summary

Conodonts have a wide distribution from the Cambrian to Triassic and therefore they play a crucial role in stratigraphic division and correlations. In particular, conodonts are used as an important index fossil in providing a precise Triassic timescale (Orchard, 2016). Although Lower Triassic conodont biostratigraphy has been well studied around the world for more than half a century, the Induan-Olenekian boundary (IOB) remains undefined (Lyu et al., 2018a, b). This study of conodont ontogeny and evolution contributes to the resolution of this boundary.

Jianshi section in China was situated on a carbonate ramp at the northeastern margin of the Upper Yangtze Platform, which was located in the low-latitude eastern Tethys during the Early Triassic. A systematic study of conodont biostratigraphy results in the differentiation of nine conodont zones from the uppermost Permian through Lower Triassic, with the IOB placed at Bed 225 + 40 cm based on the FO of *Nv. waageni eowaageni* (Lyu et al., 2018a, b).

Diverse growth stages of *Eurygnathodus costatus* appear first at Jianshi, followed by a single occurrence of *Eu. hamadai.* The FO of *Eurygnathodus costatus* occurs in Bed 225+10 cm, 30 cm below the FO of *Nv. waageni eowaageni*.

Based on the collections of *Eu. costatus* from Jianshi section, and comprehensive data information from other lower Triassic sections in the world, we propose an ontogenesis for *Eurygnathodus costatus.* Four growth stages (A→B→C→D) are differentiated based on characteristics of the denticles (nodes or ridges), platform, basal cavity, margins profile, and crimp (Fig.1). We believe these stages reflect the following evolutionary lineage for *Eurygnathodus*: *Sweetospathodus kummeli* → *Eurygnathodus costatus*→ *Eurygnathodus hamadai*.

Theory / Method / Workflow

The sampled strata are limestones that belong to the upper part of Daye Formation. A total of 50 samples were collected, ~3 kg in weight, with a sampling interval averaging 30 cm from Bed 224 to Bed 241, and continuously sampled in the IOB interval from the base of Bed 225. Samples were broken into 1 cm^3 size fragments and dissolved with dilute acetic acid (10–12%) (Zhao et al., 2007; Lyu et al., 2018a, b). Following the procedure documented by Zhao et al. (2007), conodonts were handpicked from the sieved (mesh size 0.097 mm) insoluble residues and then studied under a binocular microscope. All photos were taken by an SEM HITACHI SU8000.

Results

A total of 98 well preserved *Eurygnathodus costatus* specimens were recognized from Bed 225 to Bed 241 and also a single occurrence of *Eu. hamadai* have been obtained from Bed 226 in Jianshi. The Length, width, area and circumference of both the platform and the basal cavity have been measured from all *Eu*. *costatus* specimens (Table 1). The basal cavity size is very variable, the largest one (S= 131084 um^2) being 15 times that of the smallest one (S=8667 um^2) in area.

L_b	173 ~ 637 um	mean	336 um；
W_b	62 ~ 417 um	mean	150 um
L_b/W_b	1.53 ~ 4.42 um	mean	2.35 um
L_p	167 ~ 723 um	mean	339 um
W_p	36 ~ 475 um	mean	126 um
L_p/W_p	1.52 ~ 6.14 um	mean	3.19 um

Table 1. Variation of the measured results of length, width, area, and circumference of both the platform and the basal cavity of *Eu*. *costatus* specimens

Observations

The main changes occurring during the "A→B→C→D" growth stages are: 1) Blade-like denticles change to slightly broadened carinal denticles - to transverse ridges - to "V shape" ridges - to discontinuous ridges (or discrete nodose) - to partially smooth. This results from allometric growth of the platform in anterior, posterior and central parts. 2) In general, specimens change from symmetrical to asymmetrical (irregular shape). 3) The platform keeps developing during the entire ontogenesis, from rudimentary to expansive and exceeding the basal area.

These growth stages account for most of the variation exhibited for *Eu. costatus* in the literature, but some other variants may represent new species or geographic subspecies. For example, *Eu*. sp. A from Chaohu has finer and more numerous ridges, whereas *Eu*. sp. B from Japan and South Primorye, Russia is characterized by a row of discrete nodose denticles in the axial region, which the ridge-like denticles are not extended transversely throughout an entire width of the platform.

Conclusions

Based upon previous studies and new conodont data from Jianshi section, we describe four growth stages (A→B→C→D) in the ontogenetic development of Eu. costatus. We believe this development reflects a probable evolutionary lineage starting with a segminate ancestor and ending in an unornamented platform, namely *Sweetospathodus kummeli→Eurygnathodus costatus→Eurygnathodus hamadai*. We propose the FO of *Eurygnathodus costatus* can be a significant auxiliary mark for the Induan-Olenekian boundary defined by the first appearance of *Novispathodus waageni eowaageni*.

Novel/Additive Information

This study is a valuable contribution to the Induan-Olenekian Boundary discussion and work toward definition of its Global Boundary Stratotype Section and Point (GSSP).

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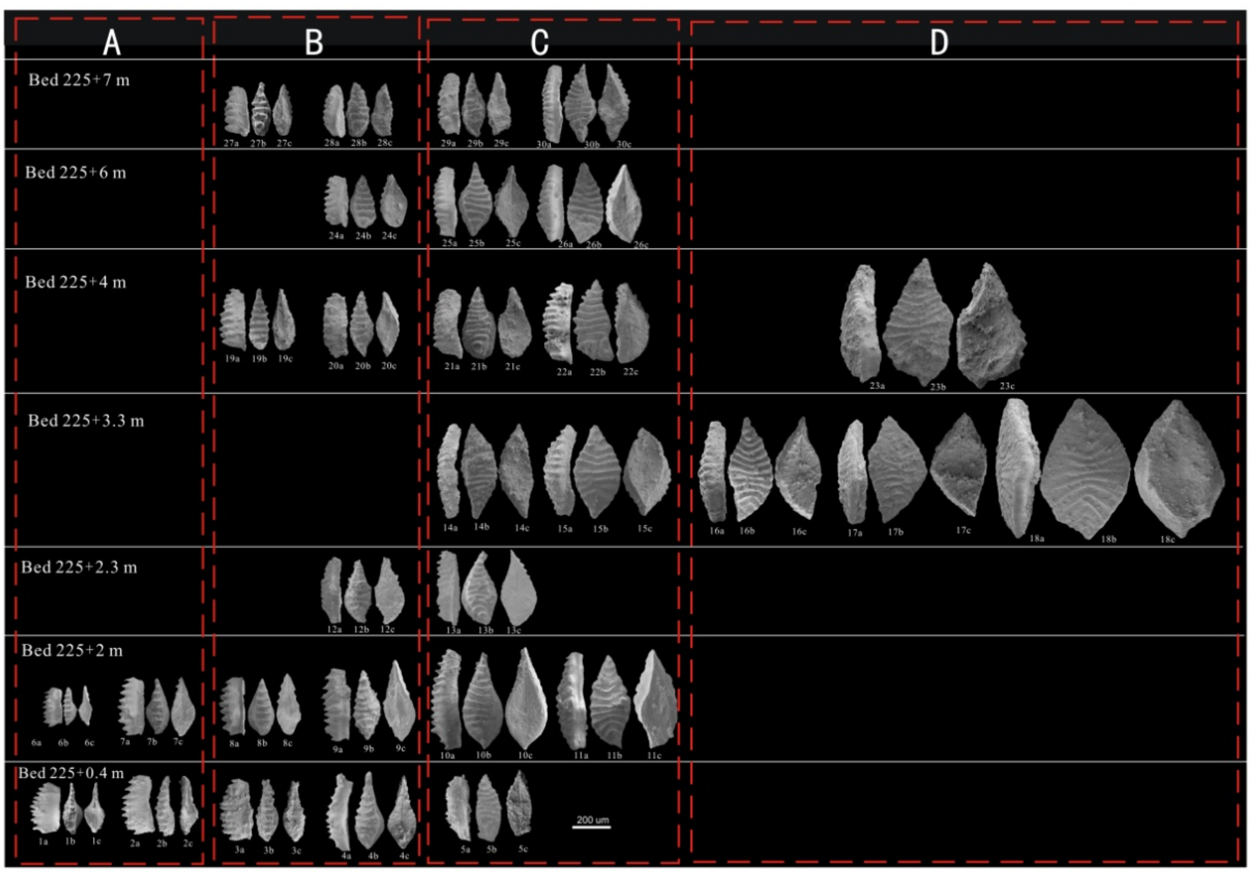

Figure 1. The ontogenesis stages (A→B→C→D) of *Eu. costatus* in Jianshi section

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