

## Belemnites originated in the Triassic—A new look at an old group

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This study sheds new light on the debated existence of Triassic belemnites. Distribution and diversity patterns of belemnites in Middle Jurassic to Cretaceous times have been well recognized. Their evolutionary history in the Early Jurassic is, however, not fully understood. Current hypotheses of the early evolution of belemnites are summarized as follows. *Schwegleria* (Belemnitina), which is characterized by small and short rostra, occur in the Hettangian of northern Europe. This genus is the oldest belemnites so far known, and was considered as a possible stock-group of all belemnites. It has been concluded that the belemnites evolved in Europe in the Hettangian; their distribution was restricted to the European shelf seas until the Pliensbachian (e.g., Doyle, 1994).

Findings of pre-Jurassic “belemnites” (e.g., *Jeletzkyia* from the Carboniferous of North America, Palaeobelemnopsidae from the Permian of China, Sinobelemnitidae from the Triassic of China) challenged this view, but were reclassified later mostly as aulacocerid or phragmoteuthid coleoids (e.g., Doyle et al., 1994). The only exceptions are the Sinobelemnitidae, described by Zhu and Bian (1984) from the lower part of Ma’atang Formation in the Longmen Mountains region, China. We have re-studied the type specimens of these sinobelemnitids, which are stored at the Chengdu University of Technology, Chengdu, China. The Chinese sinobelemnitids have well preserved internal structures such as protoconch and siphuncle. They co-occur with ammonites indicating a Carnian age such as *Protrachyceras*, *Discotropites*, *Tropites*, and *Paratropites* (Gou, 1993). The Sinobelemnitidae can be clearly distinguished from the Aulacocerida by the following diagnostic features of the Belemnitida: (1) a high apical angle of phragmocone (>12°), (2) short distance of each septa, and (3) ventrally inclined protoconch. Previous studies (e.g., Doyle, 1993, 1994; Doyle et al., 1994) also considered the Chinese Sinobelemnitidae as belemnites s.s. (order Belemnitida). At the same time, the Triassic age assignment of these forms has been questioned (Doyle, 1993, 1994; Weis and Delsate, 2006) because the typical belemnite morphology (long rostra with a well-developed alveolar groove), superficially exposed by the Sinobelemnitidae, had not been recorded from pre-Middle Jurassic strata in Europe

(Doyle, 1993, 1994; Doyle et al., 1994). The Sinobelemnitidae have a long belemnite rostrum with, however, one well-developed deep groove on the dorsal side. This dorsal groove, which is only present in the Japanese Hettangian and Sinemurian belemnites (Iba et al., 2012), is a morphological feature that has been overlooked in previous European studies. The presence of Sinobelemnitids from the Triassic of China and earliest Jurassic of Japan therefore (1) extend the origin of the belemnites back by ~33 m.y. into the Triassic, (2) suggest that this group did not necessarily originate in northern Europe, and (3) imply that belemnites survived the Triassic–Jurassic extinction, one of the five big mass extinctions in the Phanerozoic.

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