

Cretaceous Stratigraphy, Paleoenvironment and Terrestrial Biota in Shandong Province

Hongwei Kuang^{1*}, Yongqing Liu¹, Kemin Xu², Zhenguo Ning², Nan Peng¹

¹Institute of Geology, Chinese Academy of Geological Sciences, Beijing, China

²Shandong Institute of Geological Survey, Jinan, China

Email: *kuanghw@126.com

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Abstract

The terrestrial upper Jurassic-Cretaceous (upper and lower)-Cenozoic stratigraphic succession developed continuously in Shandong province. There are intact and continuous terrestrial paleoecosystems dominated by dinosaurs, including five vertebrate fauna (bone fossil assemblages) beds from the bottom to top in the Cretaceous successions of Shandong Province. There are multiple vertebrate footprints (group) bearing beds in the transition period between Jurassic-Cretaceous and Early Cretaceous, and multiple large-scale dinosaur burial bone beds in Late Cretaceous. In recent years, it has also been found that extraterrestrial impact geological event may occur in the K/Pg transition over a hundred meters (siliceous pellet and gamma element anomalies, etc.). Shandong has a well-developed terrestrial Cretaceous succession with perfect information on paleoenvironment and paleoecology, which is an ideal area to explore the co-evolutionary relationship between terrestrial biota and paleoenvironment.

Keywords

Cretaceous, Paleoenvironment, Terrestrial Biota, Shandong Province

1. Shandong Province Developed the Most Systematic and Complete Continental Cretaceous Stratigraphic Succession

In recent 10 years, on the basis of predecessors' researchers, our team not only systematically set and updated the Cretaceous succession of Shandong Province, but also further divided it into the $J_3-K_1^1$ (Mengyin Group between transitional Jurassic-Cretaceous), K_1^2 (Lower Cretaceous Laiyang Group), K_{13} (Lower Cretaceous Qingshan Group/Dasheng Group), K_2^1 (the lower part of Hongtuya

Formation of the Upper Cretaceous Wangshi Group) and K_2^2 (the upper part of Hongtuya Formation of the Upper Cretaceous Wangshi Group). Especially combined with a large number of measured chronological data, we established a comprehensive Cretaceous litho-chronostratigraphic framework with high-precision, and preliminarily summarized the paleogeographic evolution model of Cretaceous sedimentary basin [1] [2] [3] [4].

2. It Contains Cretaceous Paleogeographic Evolution Information

The Cretaceous basin is only developed in western Shandong, which is a fluvial-lacustrine environment with no strong volcanic activities in J/K_1^1 transitional period (~145 - 132 Ma). The basin extends to eastern Shandong during K_{12} (~132 - 125 Ma) [3] [4], which was dominated by extensive lacustrine environment. Magma intrusion and volcanic eruption (Qingshan Group) occurred briefly but strongly, and intermittent alluvial-fluvial-lacustrine facies environment existed in the early K_{13} (~125 - 120 Ma). Rift basin was mainly developed along the Yishu Fault zone, dominated by wide-shallow lake environment in the late K_{13} period (~120 - 100 Ma) [2]. An extremely hot and arid climate prevailed during the K_{21} - K_{22} deposited. Braided rivers dominated in the northern Jiaolai Basin and western Shandong while alluvial fan-fluvial and lacustrine environments co-existed in the central and southern part of Jiaolai Basin [5].

3. It Develops Well-Preserved Terrestrial Ecosystem

Cretaceous in Shandong Province not only outcrops continuously, but also develops 5 sets of vertebrate fossil assemblages dominated by dinosaurs from Early to Late Cretaceous. They are:

- 1) The *Euhelopus zdanskyi*, the largest sauropod ever described in China developed in J/K_{11} in western Shandong Provinces.
- 2) Psittacosaurus of the Linjiazhuang Formation in Jiaolai Basin in K_{13} .
- 3) Ornithopoda duck-billed dinosaur Shantungosaurus assemblage in K_{21} , including *Shantungosaurus*, *Zhuchengosaurus maximus Zhao et al.* and *Giant cathaysian*, Accompanying ceratosaurs, such as *Sinoceratops zhuchengensis gen. et sp. nov.*, theropod *Zhuchengtyrannosaurus rex*, *Zhuchengtyrannus magnus*, as well as a few ankylosaur, coelurosauria scattered bones.
- 4) Taniussinensis assemblage, accompanied by a number of other dinosaur bone fossils, and a large number of dinosaur egg fossils in K_{22} in Jiaolai basin.
- 5) The ornithopoda assemblage represented by *Tsin-taosaurus spinorhinus* is also symbiosis with fossil dinosaur eggs in K_{22} in Jiaolai Basin [5].

The assemblage and buried situation of dinosaur fauna not only reveal the differences of living and buried environment among different dinosaur faunas, but also directly relate to the evolution of Cretaceous paleogeography and paleoclimate. At the same time, the Lower Cretaceous in Shandong Province also has abundant and diverse vertebrate relics dominated by dinosaurs and birds

with a very high distribution density, which reflects the habitats of diverse vertebrate fauna and their systematic evolution characteristics [2]. The dinosaur footprints of theropods, sauropods, ornithopods and other different species [2], pterosaur footprints were developed in the Early Cretaceous and J/K transition period.

4. K/Pg Boundary Recorded Extraterrestrial Impact Event

Several vitreous spherulite layers more than 100 meters thick found on top of K2 [6] and abnormal combination of Ir and Pt elements at K/Pg transition site [7] may indicate the occurrence of extraterrestrial impact events.

Therefore, successions in Shandong Province not only developed complete terrestrial cretaceous stratigraphic sequence, but also bore abundant and diverse information of paleoenvironment (sedimentary basin, paleogeography, paleoclimate and geological events, etc.), evolution and replacement. Especially, it also preserved continuous and perfect ecological system information (flora and fauna and fossil assemblage), and together constituted a complete Cretaceous record of environment evolution, different biome initiation, radiation, replacement or dying or even extinction.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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