New ootype prismatoolithids from the Late Cretaceous, Laiyang Basin and its significance (Postprint)

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Abstract

Here we describe a new ootaxon of prismatoolithids from the Late Cretaceous Jiangjunding Formation in the Laiyang Basin, Shandong Province. Based on characteristics such as an elongate ovoid shape, smooth eggshell surface, relatively thin eggshell thickness, prismatic eggshell units, slender pores in the radial section of the eggshell, and small pores with round or irregular shapes in the tangential section of the eggshell, we erect a new oogenus and oospecies: *Laiyangoolithus lixiangensis* oogen. et oosp. nov. The discovery of *L. lixiangensis* not only enriches the diversity and composition of the Laiyang Dinosaur Egg Fauna, but also expands the paleogeographic distribution of prismatoolithids. In addition, it provides additional paleontological material for the study of the diversity and paleogeographic distribution of troodontids in China.

Full Text

Preamble

New Ootype Prismatoolithids from the Late Cretaceous, Laiyang Basin and Its Significance

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Abstract

We describe half of an egg fossil recovered from the Upper Cretaceous Jiangjunding Formation in the Laiyang Basin, Shandong Province. Based on features such as the relatively pointed preserved end, smooth and unornamented outer eggshell surface, relatively thin eggshell, tightly arranged prismatic shell units, shell unit edges composed of dense calcite, and sparse pores that are round or elliptical in shape, we assign it to the Prismatoolithidae and establish a new oogenus and oospecies: *Laiyangoolithus lixiangensis* oogen. et oosp. nov. The discovery of *L. lixiangensis* not only enriches the composition of the Laiyang Dinosaur Egg Fauna, but also expands the paleogeographic distribution of prismatoolithids, and provides new evidence for studying the diversity and paleogeographic distribution of troodontids in China.

Key words: Laiyang, Shandong; Late Cretaceous; Jiangjunding Formation; dinosaur eggs; Prismatoolithidae

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1 Introduction

Laiyang represents an important locality in China that is exceptionally rich in both dinosaur bones and eggs (Wang et al., 2010). The well-developed terrestrial strata around Laiyang comprise the Lower Cretaceous Laiyang and Qingshan groups, and the Upper Cretaceous Wangshi Group. The Wangshi Group is subdivided from bottom to top into the Xingezhuang, Jiangjunding, Jingangkou, and Changwangpu formations (Hu et al., 2001). The Jiangjunding and Jingangkou formations contain abundant hadrosauroid remains, coexisting with numerous other vertebrate fossils and dinosaur eggs. The dinosaurs and eggs from the Wangshi Group collectively form the Laiyang Hadrosauroid Fauna and Dinosaur Egg Fauna (Wang et al., 2010; Zhang et al., 2017).

The Laiyang Dinosaur Egg Fauna was first discovered in 1950, when teachers and students from Shandong University collected dinosaur remains and eggs from Upper Cretaceous strata near Laiyang, which Chow (1951) subsequently reported. The following year, Young C.C. led a field expedition to Laiyang (Wang et al., 2010; Zhang et al., 2017), conducting extensive excavations at Jingangkou (Wangshi Group) and Doushan (Qingshan Group) that yielded abundant dinosaur and egg specimens. Young (1954) studied these eggs and divided them into two categories—short eggs (*Oolithes spheroides*) and long eggs (*Oolithes elongates*)—thereby establishing a preliminary classification system. Chow (1954) described the microstructure of the eggshells, and these

early studies laid the methodological and nomenclatural foundations for future dinosaur egg research (Zhang et al., 2017).

In the 1970s, Zhao Zikui conducted further microscopic studies on Laiyang Basin dinosaur eggshells, erecting the oofamilies Elongatoolithidae and Spheroolithidae (Zhao and Jiang, 1974; Zhao, 1979). Based on macroscopic egg morphology and eggshell microstructural characteristics, he established a classification and nomenclature system that remains widely used today (Zhao and Jiang, 1974; Zhao, 1979). Liu and Zhao (2004) erected *Dictyoolithus jiangi* for eggs from Laiyang, later revised by Wang et al. (2013a) as *Prodictyoolithus jiangi*. Zhao et al. (2015) verified Chinese dinosaur egg types and reclassified *Spheroolithus jiangjundingensis* from Laiyang into *S. spheroids* and *S. jiangjundingensis*. To date, the Laiyang Dinosaur Egg Fauna comprises four oofamilies, five oogenera, and eleven oospecies (Zhao et al., 2013).

Since 2008, the IVPP-Laiyang expedition team has conducted systematic field investigations in Laiyang, revealing multiple valley systems and over ten dinosaur bone and egg localities (Zhang et al., 2017). Among these fossils, a single elongated egg proved particularly noteworthy, identified as a new turtle egg species and named *Emydoolithus laiyangensis* (Wang et al., 2013b). Other specimens, especially those collected in recent years, include previously undescribed dinosaur egg types that preliminary observations suggest may belong to Elongatoolithidae, Ovaloolithidae, or Prismatoolithidae (Zhao et al., 2013). Here we provide a detailed report on the prismatoolithid dinosaur eggs discovered in 2012.

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2 Systematic Paleontology

Prismatoolithidae Hirsch, 1994
Laiyangoolithus lixiangensis oogen. et oosp. nov.

Etymology: The oogeneric name derives from "Laiyang," the Chinese phonetic alphabet for the type locality; the oospecific name "lixiang" comes from the Chinese phonetic alphabet for the "Laiyang pear" hometown.

Locality and Horizon: Jiangjunding village, Laiyang; Upper Cretaceous, Jiangjunding Formation.

Holotype: An incomplete egg fossil (IVPP V 25232) [Figure 1: see original paper]; dinosaur eggshell sections (120517-09, 120517-10, 120517-11).

Diagnosis: Elongate-ovoid egg with smooth, unornamented outer eggshell surface. Eggshell relatively thin, averaging 0.43 mm in thickness. Eggshell units are prismatic and tightly arranged. Boundary between cone layer and columnar layer indistinct. Cone layer thickness is 0.14 mm, approximately one-third of total eggshell thickness. Cones are sturdy with clear apertures between them. Growth lines are evident in the cone layer. Eggshell unit edges consist of dense calcite. Pores are very sparse, appearing as round or irregular shapes in tangential eggshell section.

3 Description and Comparisons

The specimen is an incomplete elongated ovoid egg [Figure 1: see original paper] with a preserved polar axis of approximately 5.04 cm and an equatorial diameter of 5.20 cm. The outer eggshell surface is smooth and lacks ornamentation [Figure 1B: see original paper].

In radial section, the eggshell units are prismatic and tightly arranged [Figure 2: see original paper]. The eggshell is comparatively thin, averaging about 0.43 mm in thickness. Although no clear boundary exists between the cone layer and columnar layer, they remain distinguishable [Figure 2A: see original paper]. The cone layer measures 0.14 mm thick, representing approximately one-third of the total eggshell thickness. Growth lines are present in the cone layer, gradually becoming less distinct toward the columnar layer [Figure 2A: see original paper]. The cones are sturdy with clear inter-cone apertures [Figure 2A: see original paper]. In tangential section through the cone layer and near the cone-columnar layer boundary, distinct spaces are visible between eggshell units [FIGURE:3A, B]. In tangential section through the middle columnar layer and near the outer eggshell surface, the eggshell units remain well-defined with edges composed of dense calcite [FIGURE:3C, D]. The pores appear slender in radial section [Figure 2A: see original paper] and are unevenly distributed with round or irregular shapes in tangential section [Figure 3: see original paper].

Based on its elongated ovoid shape, smooth eggshell surface, and prismatic eggshell units, this egg is classified within Prismatoolithidae. Currently, three oogenera and eleven oospecies of Prismatoolithidae are recognized globally. Only *Preprismatoolithus coloradensis* is known from the Late Jurassic of North America (Hirsch, 1994; Zelenitsky and Hills, 1996); all other occurrences are from the Late Cretaceous. In China, *Prismatoolithus gebiensis* occurs at Bayan Mandahu (Zhao and Li, 1993), *Pri. hukouensis* in the Nanxiong Basin (Zhao, 2000), *Pri. tiantaiensis* in the Tiantai Basin (Wang et al., 2011), and *Pri. heyuanensis?* in the Heyuan Basin (Lü et al., 2006). Mongolia has three oospecies of *Protoceratopsidovum*: *Pro. sincerum*, *Pro. minimum*, and *Pro. fluxuosum* (Mikhailov, 1994). France yields *Pri. tenuous* and *Pri. matellensis* (Vianey-Liaud and Crochet, 1993), while *Pri. levis* is known from the Two Medicine Formation in North America (Hirsch and Quinn, 1990) and the Oldman Formation in Canada (Zelenitsky and Hills, 1996; Zelenitsky et al., 2002).

The eggshell units are sturdy, contrasting with the slender units of other prismatoolithid eggs. The dense calcite composition of the eggshell unit edges and the obvious spaces between units are distinctive. The relatively thin eggshell, with the cone layer comprising about one-third of total thickness, clearly distinguishes this ootype from other prismatoolithid eggs. Based on these characteristic differences, we erect the new oogenus and oospecies *Laiyangoolithus lixiangensis* oogen. et oosp. nov.

Prismatoolithids represent one of the few dinosaur egg types that can be definitively linked to specific dinosaurs. Embryonic remains from North America have connected prismatoolithid eggs to troodontids (Horner and Weishampel, 1988, 1996). As noted above, described prismatoolithid eggs in China are primarily from Late Cretaceous strata [FIGURE:4; TABLE:1], with additional reports from Xixia, Henan Province (Wang et al., 2008). Troodontids are widely distributed across China, ranging from the Middle-Late Jurassic to the Late Cretaceous, and include 17 genera and 17 species [FIGURE:4; TABLE:1].

Therefore, the discovery of *Laiyangoolithus lixiangensis* not only enriches the diversity of the Laiyang Dinosaur Egg Fauna but also expands the paleogeographic distribution of prismatoolithids. Furthermore, it provides additional paleontological material for studying troodontid diversity and paleogeographic distribution in China.

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