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浙江天台盆地上白垩统赤城山组长形蛋科一新蛋属[1)]

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摘要:浙江天台盆地上白垩统赤城山组发现一新的恐龙蛋类型。依据蛋化石形态、大小和蛋壳柱状层生长纹呈波浪形等特征,将其归入长形蛋科(Elongatoolithidae)。这枚恐龙蛋的蛋壳外表面具网状纹饰,蛋壳锥体层与柱状层界线明显,二者厚度之比近1∶2,气孔道细而直,这些特征区别于其他长形蛋科的成员,因此,建立一新的蛋属、蛋种:网纹副长形蛋(*Paraelongatoolithus reticulatus* oogen. et oosp. nov.),代表晚白垩世早期长形蛋科的新成员。

关键词:浙江天台盆地,上白垩统,赤城山组,长形蛋科
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浙江天台盆地晚白垩世陆相红层富含恐龙蛋化石,最早于20世纪50年代由本文作者之一的蒋严根首先发现。近10多年来,随着基础建设的进行,有大量恐龙蛋和恐龙化石被陆续发现。天台盆地的恐龙蛋化石不但数量大,而且种类也很多(方晓思等,2000, 2003b; Jin et al., 2007; 钱迈平等,2008)。方晓思等(2000, 2003b)曾报道了天台盆地发现的多件归入长形蛋科的化石,并命名为天台长形蛋(*Elongatoolithus tiantaiensis*)、赤城山长形蛋(*E. chichengshanensis*)和赖家长形蛋(*E. laijiaensis*)等,但是,根据作者提供的形态特征和蛋壳显微结构分析,它们有的很难归入长形蛋科,更无法归入长形蛋属(*Elongatoolithus*)了。这里,我们记述一件产自天台盆地的长形蛋科化石,并对前人报道的归入长形蛋类的化石进行初步的对比分析和厘定。

1 地质背景

天台盆地含恐龙蛋化石的陆相红层由下到上分为赖家组和赤城山组(方晓思等,2003a)。下伏地层为塘上组,主要为一套中酸性的凝灰岩,其中产有浙江翼龙(*Zhejiangopterus*)(蔡正全、魏丰,1994)和可能为驰龙类的雁荡鸟(*Yandangornis*)(蔡正全、赵丽君,1999)等脊椎动物化石。红层上部常常为新近系嵊县组玄武岩覆盖。

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赖家组主要为一套红色粉砂质泥岩夹砂岩和细砾岩,我们发现和确认至少有 6 层凝灰岩。赤城山组大致可分为两段,第一段底部为红色砾岩夹砂岩,上部为红色粉砂岩、粉砂质泥岩与灰白色砂岩、含砾砂岩互层,夹 2-3 层凝灰岩;第二段主要为厚层状红色砾岩夹砂岩。在赖家组和赤城山组一段赋存大量的恐龙蛋和恐龙化石。本文研究的长形蛋化石产于赤城山组一段的红色含砾粉砂质泥岩中。我们对赤城山组凝灰岩的初步测年结果显示,其地质时代为晚白垩世早期(Cenomanian-Turonian)(详细测年结果将另文发表)。

2 系统描述

长形蛋科 Elongatoolithidae Zhao, 1975

副长形蛋属(新蛋属) *Paraelongatoolithus* oogen. nov.

词源 “para”,希腊语,意为“近、并行”;“*elongatoolithus*”引自长形蛋属名,合意为“与长形蛋属相近”。

属征 见种征。

网纹副长形蛋(新蛋属、新蛋种) *Paraelongatoolithus reticulatus* oogen. et oosp. nov.

(图 1,2)

词源 “reticulatus”,拉丁语,意为“网状的”,表示蛋壳外表面具网状纹饰。

正型标本 半枚蛋化石(中国科学院古脊椎动物与古人类研究所标本编号 IVPP V 16514)(图 1A)。

产地与层位 浙江天台城关镇酒厂工地,上白垩统赤城山组一段。

特征 蛋化石长形,长径约为 17 cm, 最大横径为 7.2 cm, 形态指数约为 42; 蛋壳外表面具网状纹饰;蛋壳较薄,厚度为 0.50 ~ 0.60 mm; 蛋壳锥体层与柱状层界线清晰,二者厚度之比为 1 : 2; 气孔道细而直,孔径为 0.08 ~ 0.39 mm。

描述 半枚蛋化石,两端缺失,保存部分最大的长径约为 12.2 cm, 最大横径为 7.2 cm。根据蛋化石保存情况复原其形状,推测其实际长径约为 17 cm, 形态指数约为 42(图 1A)。

蛋壳外表面具网状纹饰,网纹呈圆形或椭圆形,径切面呈 U 形凹坑,被次生方解石充填(图 1B, 2A,B)。

蛋壳厚度(不含纹饰)为 0.50 ~ 0.60 mm, 纹饰突起高度为 0.20 ~ 0.25 mm。蛋壳由锥体层与柱状层组成,锥体层与柱状层界线明显(图 2B)。锥体层厚度为 0.15 ~ 0.18 mm, 约占蛋壳厚度(不含纹饰)的 1/3。锥体圆锥形,基部宽度为 0.08 ~ 0.10 mm, 近柱状层锥体宽 0.15 ~ 0.20 mm。锥体间隙明显,锥体中的弧形生长纹发育,楔体呈放射状,乳突发育(图 2B)。锥体层中部弦切面观察,锥体呈圆形或椭圆形,直径约为 0.15 ~ 0.20 mm, 单位面积内锥体数量为 44 ~ 50 个/mm^2(图 2C)。柱状层厚度为 0.30 ~ 0.35 mm。柱状层中生长纹发育,呈波浪形。正交偏光下观察,壳单元界线清楚,壳单元呈扇形或不规则形,柱状消光。柱状层中部弦切面观察,棱柱体排列紧密,正交偏光下,棱柱体呈不规则形,界线清晰。

气孔少,径切面气孔道细而直,弦切面气孔呈圆形或椭圆形(图 2D), 分布不均匀,孔径为 0.08 ~ 0.39 mm。

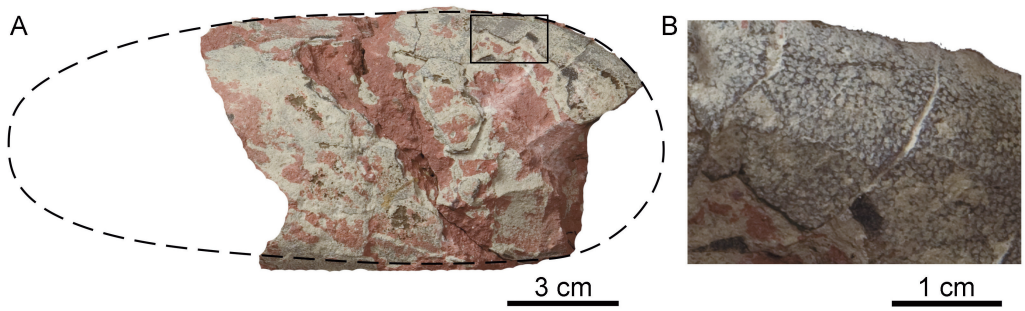

图 1　网纹副长形蛋(新蛋属、新蛋种)正型标本(IVPP V 16514)

Fig. 1　Holotype of *Paraelongatoolithus reticulatus* oogen. et oosp. nov. (IVPP V 16514)

A. 保存的半枚蛋化石及形态复原(黑色虚线) fossil egg showing restored complete egg shape; B. 网状的蛋壳外表面纹饰(A 中框选区放大) reticulate ornamentation of eggshell (enlargement of black box in A)

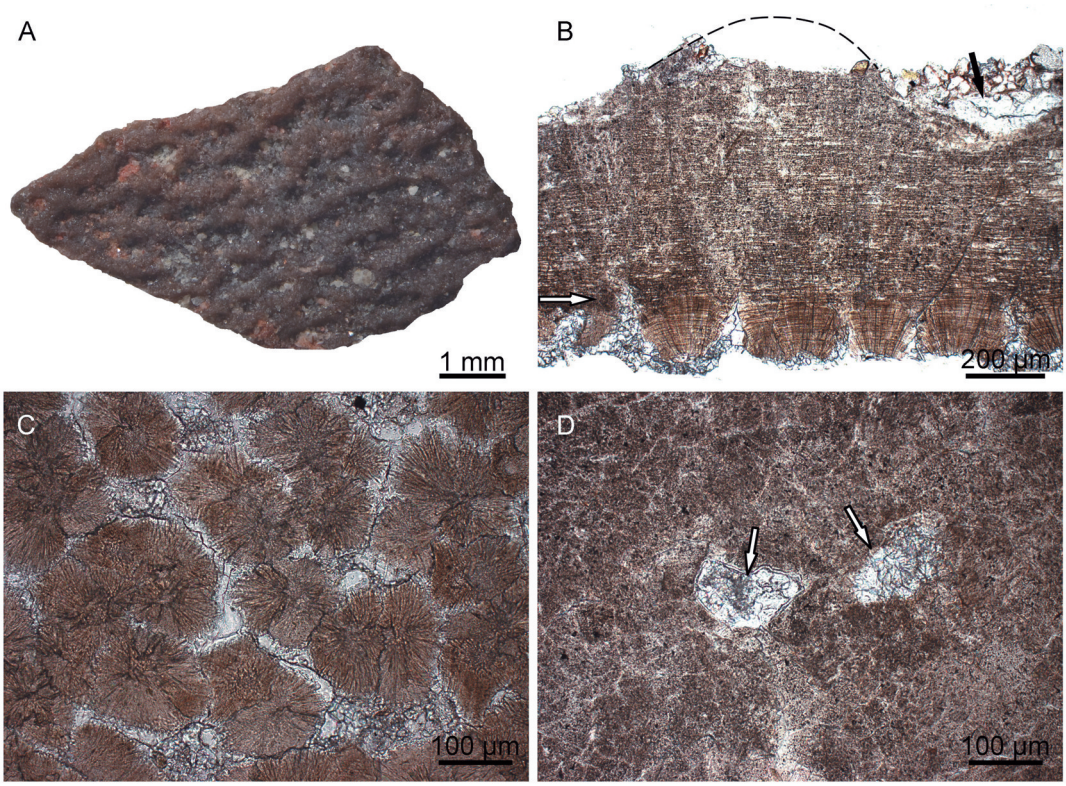

图 2　网纹副长形蛋(新蛋属、新蛋种)正型标本的蛋壳结构(IVPP V 16514)

Fig. 2　Eggshell structure of the holotype of *Paraelongatoolithus reticulatus* oogen. et oosp. nov. (IVPP V 16514)

A. 蛋壳外表面,示网状纹饰 outer surface of eggshell showing reticulate ornamentation; B. 蛋壳径切面,网状纹饰径切面呈 U 形凹坑,被次生方解石充填(黑色箭头所指),虚线所示为被侵蚀的纹饰;锥体层与柱状层之间界线明显(白色箭头所指);锥体圆锥形 radial section of eggshell showing U-shaped pits filled with secondary calcite (black arrows), eroded ornamentation (dotted line), obvious boundary between cone layer and columnar layer (white arrow) and conical cones; C. 蛋壳锥体层弦切面,示圆形或椭圆形锥体及明显的锥体间隙 tangential section through cone layer of eggshell showing cones and intervening spaces; D. 柱状层中部弦切面,示圆形和椭圆形的气孔(箭头所指) tangential section through middle part of columnar layer, showing round and elliptical pores (arrows)

3 比较与讨论

本文记述的标本根据蛋化石长形,蛋壳外表面网状纹饰,蛋壳由锥体层与柱状层组成,柱状层呈波浪形等特征,将其归入到长形蛋科。

到目前为止,比较可靠的归入长形蛋科的化石有 8 属,它们是:发现于我国晚白垩世的长形蛋属(*Elongatoolithus* Zhao, 1975)、巨形蛋属(*Macroolithus* Zhao, 1975)、南雄蛋属(*Nanhsiungoolithus* Zhao, 1975)和早白垩世的黑山蛋属(*Heishanoolithus* Zhao & Zhao, 1999),以及发现于蒙古早白垩世的 *Trachoolithus* Mikhailov, 1994 和印度晚白垩世的 *Ellipsoolithus* Mohabey, 1998;此外,发现于加拿大南部上白垩统 Oldman 组的 *Continuoolithus* 和 *Porituberoolithus* (Zelenitsky et al., 1996)具有类似于长形蛋科的蛋壳显微结构特征,我们认为也应归入长形蛋科(表 1)。

表 1 长形蛋科各类型蛋壳特征

Table 1 Characteristics of different elongatoolithid eggshells (mm)

Taxa	Ornamentation of outer eggshell surface	Thickness of eggshell excluding ornamentation)	Cone layer/ Columnar layer of thickness	Locality and horizon
Macroolithus	dispersituberculate	1.39 ~ 1.93	1 : 3	Pingling Formation
Elongatoolithus	linearituberculate	0.67 ~ 1.12	1 : 5	Upper Cretaceous
Nanhsiungoolithus	smooth surface	0.60 ~ 1.30	—	Nanxiong, Guangdong
Heishanoolithus	slender-nodes	1.20 ~ 1.30	1 : 7	Fuxin Formation Lower Cretaceous Heishan, Liaoning
Trachoolithus	dispersituberculate	0.30 ~ 0.50	1 : 4 ~ 1 : 3	Dushi Ula Formation Lower Cretaceous Ubur-Khangay, Mongolia
Ellipsoolithus	linearituberculate	1.20 ~ 1.64	1 : 4	LametaFormation Upper Cretaceous Gujarat, India
Continuoolithus	dispersituberculate	0.94 ~ 1.24	1 : 5 ~ 1 : 4	Oldman Formation
Porituberoolithus	dispersituberculate	0.50 ~ 0.65	1 : 2	Upper Cretaceous southern Alberta, Canada
Paraelongatoolithus oogen. nov.	reticulate	0.50 ~ 0.60	1 : 2	Chichengshan Formation Upper Cretaceous Tiantai, Zhejiang

以上各长形蛋类蛋化石的主要区别在于蛋壳外表面纹饰、蛋壳的厚度,以及锥体层与柱状层的厚度之比等(表 1)。相比较而言,*Porituberoolithus* 与本文记述的标本较为相近,但是 *Porituberoolithus* 蛋壳外表面具孤立的瘤点状纹饰,气孔在蛋壳外表面的开口位于瘤点状突起之上,而不是分布在突起之间,与本文标本所具网状纹饰有着较为显著的区别。

发现于美国蒙大拿州上白垩统 Two Medicine 组(Hirsch and Quinn, 1990)和新墨西哥州上侏罗统 Morrison 组(Bray and Lucas, 1997)具有似鸟蛋型蛋壳结构的恐龙蛋化石也属于长形蛋科,但都不属于长形蛋属的分子(赵宏、赵资奎,1999)。二者与本文研究的标本主要区别在于它们的蛋壳外表面纹饰呈小瘤状,蛋壳较厚,分别为 1.20 ~ 1.28 mm (Hir-

sch and Quinn, 1990)和0.9~1.0 mm (Bray and Lucas, 1997)。

方晓思等(2000, 2003b)记述的发现于天台盆地的天台长形蛋、赤城山长形蛋和赖家长形蛋,根据其描述和文中所附蛋壳显微结构的图版显示,都不具有长形蛋属的特征。长形蛋属的主要鉴别特征是蛋壳外表面具棱脊状纹饰,柱状层具波浪形生长纹,锥体层与柱状层界线不明显等(赵资奎,1975)。通过对原文描述和文中图版观察,天台长形蛋的蛋壳外表面近光滑,壳单元棱柱状,排列紧密(见方晓思等,2000, 图版7-8; 2003b, 图版I-10),是棱柱形蛋类的典型蛋壳结构特征,应归入棱柱形蛋科(Prismatoolithidae)。赤城山长形蛋具有不规则形的气孔道(见方晓思等,2003b, 图版I-6-7),明显区别于长形蛋类,可能代表一新的蛋化石类群。赖家长形蛋的蛋壳外表面光滑,蛋壳厚度仅为0.3 mm (见方晓思等,2003b, 图版I-4-5),由于文中描述简单,图版不清,无法做进一步的对比,是否属于长形蛋科的新类型尚不能肯定,需要进一步研究。

通过以上初步对比分析,本文研究的标本区别于长形蛋科各已知属种,代表了长形蛋科一新的类型。

最近,Grellet-Tinner 和 Makovicky (2006)报道了发现于美国蒙大拿南部下白垩统 Cloverly 组的恐龙蛋壳化石,这些蛋壳的显微结构特征与本文记述的标本非常相似,但这些蛋壳化石仅为碎片,我们并不清楚其蛋的形态,从蛋壳显微结构分析,它们归入本文记述的网纹副长形蛋应无疑问。由于这些蛋壳化石与恐爪龙(*Deinonychus*)骨骼化石保存在一起,他们据此推测这种类型的蛋壳很可能为驰龙类的恐爪龙或相近属种的恐龙所产(Grellet-Tinner and Makovicky, 2006)。

长形蛋类在我国分布广泛,此前报道的这类蛋化石主要发现于早白垩世晚期(赵宏、赵资奎,1999)和晚白垩世中晚期(赵资奎,1975; 赵资奎、蒋元凯,1974; 曾德敏、张金鉴,1979; 赵宏、赵资奎,1998)。网纹副长形蛋为我国晚白垩世早期长形蛋科的新类型,它的发现为探讨长形蛋类蛋壳的演化及其与恐龙的关系等提供了新的材料。

4　结论

1) 描述和命名了浙江天台盆地晚白垩世长形蛋科一新的蛋属蛋种:网纹副长形蛋(*Paraelongatoolithus reticulatus* oogen. et oosp. nov.)。

2) 天台盆地已经记述的天台长形蛋(*E. tiantaiensis*)、赤城山长形蛋(*E. chichengshanensis*)和赖家长形蛋(*E. laijiaensis*)都不属于长形蛋属的分子。其中,天台长形蛋可以归入棱柱形蛋科,赤城山长形蛋可能代表一新的蛋化石类群,而赖家长形蛋是否属于长形蛋科尚不能确定。

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A NEW OOGENUS OF ELONGATOOLITHIDAE FROM THE UPPER CRETACEOUS CHICHENGSHAN FORMATION OF TIANTAI BASIN, ZHEJIANG PROVINCE

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Key words Tiantai Basin, Zhejiang Province; Upper Cretaceous; Chichengshan Formation; Elongatoolithidae

Summary

Dinosaur eggs are abundant in Tiantai, Zhejiang Province, southeastern China. Some egg taxa have been reported, but most of them were not properly erected. Here, we describe a new egg specimen from the Upper Cretaceous Chichengshan Formation of the Tiantai Basin.

1 Geological setting

The Upper Cretaceous strata of the Tiantai Basin consist of the Laijia Formation and the overlying Chichengshan Formation. The Chichengshan Formation may be subdivided into two members. The lower member, yielding a large number of dinosaur eggs and bones, is composed of red conglomerates, sandstones, and silty mudstones with interbedded tuffs; the upper member is composed of red conglomerates and sandstones interbedded with muddy siltstones. The specimen described in this paper (IVPP V 16514) was collected from the lower member of the Chichengshan Formation (Cenomanian-Turonian).

2 Systematic paleontology

Elongatoolithidae Zhao, 1975

***Paraelongatoolithus* oogen. nov.**

Etymology The prefix *para-*, Greek, is used to indicate similarity in eggshell microstructure to the existing oogenus *Elongatoolithus*.

Diagnosis See oospecific diagnosis below.

***Paraelongatoolithus reticulatus* oogen. et oosp. nov.**

Etymology From Latin *reticulatus*, reticulated, in reference to the texture of the outer surface of the eggshell.

Holotype A partial egg (IVPP V 16514) (Fig. 1A).

Locality and horizon Chengguan, Tiantai, Zhejiang Province; Chichengshan Formation, Upper Cretaceous.

Diagnosis Elongated egg with length about 17 cm, width 7.2 cm and shape index 42; outer surface of eggshell sculptured with reticular ornamentation; eggshell thickness 0.50 ~ 0.60 mm; obvious boundary between cone layer and columnar layer; and thickness ratio 1 : 2; pore canals fine and straight, with diameters ranging from 0.08 to 0.39 mm.

Description The holotype is an elongated crushed egg with both ends missing. The preserved egg is 12.2 cm long and 7.2 cm wide, suggesting that the complete egg's length may be

17 cm (Fig. 1A). The egg shape index is about 42.

The outer surface of the eggshell is sculptured with reticular ornamentation (Fig. 1B, 2A).

The thickness of the eggshell (excluding ornamentation) is 0.50 ~ 0.60 mm, and the height of the ornamentation is 0.20 ~ 0.25 mm. The eggshell is composed of a cone layer and a columnar layer, which are separated by a clear boundary (Fig. 2B).

The cone layer is 0.15 ~ 0.18 mm thick, representing about 1/3 of the thickness of the eggshell. In radial section, the width of each cone is 0.08 ~ 0.10 mm at the base, and 0.15 ~ 0.20 mm near the columnar layer. Clear spaces exist between the cones. The curved growth lines in the cone layer are clear, and the cunei of each cone seem to radiate from a central point (Fig. 2B). In a tangential section which is taken close to the columnar layer through the cone layer, each cone's diameter is 0.15 ~ 0.20 mm. There are 44 ~ 50 cones per mm^2 (Fig. 2C).

The thickness of the columnar layer is 0.30 ~ 0.35 mm. The growth lines in columnar layer are very clear. Under polarized light, the eggshell unit has a fan-like or irregular form with column extinction. A tangential section through the middle part of the columnar layer shows irregular prisms, closely packed and separated by clear boundaries (Fig. 2D).

The round and elliptical pore canals are sparse, with diameters ranging from 0.08 to 0.39 mm. Pore distribution is uneven, with some pores in close proximity (Fig. 2D).

3　Comparison and discussion

Based on its characteristics of elongation, reticular ornamentation and thickness of the eggshell, and presence of a clear boundary between the cone layer and columnar layer, the specimen described in this paper belongs to the Elongatoolithidae, but differs from other known elongatoolithid taxa. The characteristics of the specimen are similar to those of *Porituberoolithus* from the Upper Cretaceous Oldman Formation of Canada. However, *Porituberoolithus* exhibits dispersituberculate ornamentation, and pore openings that are situated on the nodes. Therefore, the present specimen is considered to be a new oogenus and oospecies of the Elongatoolithidae.

None of the previously described species *Elongatoolithus tiantaiensis*, *E. chichengshanensis* and *E. laijiaensis* from the Tiantai Basin can be legitimately referred to *Elongatoolithus* (Elongatoolithidae). Among them, *E. tiantaiensis* can be referred to the Prismatoolithidae, whereas *E. chichengshanensis* should be referred to a new taxa and *E. laijiaensis* requires further study to determine its taxonomic position.

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