A new type of dinosaur eggs from Early Cretaceous of Gansu Province, China

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Abstract The Early Cretaceous outcrops in Gansu Province, northern China, have yielded numerous dinosaur skeleton remains and tracks; however, fossil eggs have not been reported in literatures. Here, we describe a new type of dinosaur eggs from the Lower Cretaceous Hekou Group in the Lanzhou-Minhe Basin, representing a new oogenus and a new oospecies, attributed to a new oofamily. The new specimen can be distinguished from other known dinosaur eggs by the combination of the following eggshell micro-features: branched eggshell units lacking a compact layer near the outer surface; interlocking or isolated multi-angular eggshell units, as viewed in tangential sections; and irregular pore canals. Dinosaur eggs from China largely come from the Late Cretaceous deposits, with occasional reports from the Early Cretaceous in Liaoning Province, northeastern China. The new discovery expands the geological and geographical distribution of the fossil record of dinosaur eggs in China and may reveal the origin of eggshell microstructures of spheroolithid eggs.

Key words Lanzhou-Minhe Basin, Gansu; Early Cretaceous; Polyclonoolithidae; dinosaur egg

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1 Introduction

Compared to those from Upper Cretaceous deposits, fossil eggs from the Lower Cretaceous worldwide are relatively rare. They have been recovered from China, Mongolia, Thailand, Korea, Japan, Spain, and North and South America, including elongatoolithids, macroelongatoolithids, prismatoolithids, spheroolithids, faveoloolithids, dendroolithids,

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reptilian eggs belonging to turtle and crocodile, as well as eggs whose parataxonomic positions are still unknown (Nessov and Kaznachkin, 1986; Kurzanov and Mikhailov, 1989; Kohring, 1990; Bray, 1998; Zelenitsky et al., 2000; Azuma, 2003; Buffetaut et al., 2005; Buscalioni et al., 2008; Kim et al., 2009; Canudo et al., 2010; Grellet-Tinner et al., 2012; Moreno-Azanza et al., 2009, 2014a, b). In China, fossil eggs from the Lower Cretaceous were only reported in Liaoning Province, assigned to the oofamily Elongatoolithidae (Zhao and Zhao, 1999). Most of the ootaxa mentioned above were also recovered from Upper Cretaceous deposits.

The Lower Cretaceous Hekou Group in the Lanzhou-Minhe Basin of Gansu Province is very rich in dinosaur bones and tracks (Qi and Yu, 1999; Zhang et al., 2006; You et al., 2005, 2006, 2008), whereas discoveries of dinosaur eggs are rare. In 2009, the Chinese Academy of Geological Sciences discovered some fossil eggshell fragments in Zhongpu, a town in Lanzhou Basin. However, this discovery remains unpublished, possibly because of uncertainty about the locality and formation that yields the fossil material. In November of 2012, fossil eggshells were again discovered in the Lanzhou-Minhe Basin. Here, we provide a detailed description of the new discovery of dinosaur egg and associated eggshell fragments from Gansu Province. Based on the unique microstructure of the eggshell, we established a new oogenus and oospecies, within a new oofamily. The new discovery has important implications for understanding the diversity and the geological and geographical distribution of Early Cretaceous dinosaur eggs in China, as well as the evolution of dinosaur eggshell structure.

2 Material and methods

The incomplete egg (ZMNH M1849) was collected from the Lanzhou-Minhe Basin, by a work team from Gansu Geological Museum (GGM), Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences (IVPP) and Institute of Geology, Chinese Academy of Geological Sciences (IGCAGS) during the field investigation. Laboratory preparation included removal of sediment from the eggshell with small hand tools. The poorly preserved egg exhibits varying degrees of weathering. Therefore, the least weathered fragments were selected for examination, using a Nikon SMZ1000 stereomicroscope to view the outer surfaces. The eggshell fragments were prepared as standard radial and tangential petrographic thin sections (0.03 mm thick) and studied under a Nikon Eclipse polarized light microscopy (Nikon eclipse LV100POL, PLM). Additional eggshells were coated in gold (10 nm), mounted on aluminum stubs, and imaged by a Hitachi S-3700N Scanning Electron Microscopy (SEM) at 20 kV. Structural attributes (eggshell thickness, eggshell unit width) were measured and analyzed with Java image processing software and a digital caliper. The eggshell fragments and the eggshell thin sections are catalogued at the Zhejiang Museum of Natural History (ZMNH).

3 Locality and geological setting

The specimen occurred in outcrops near the border of Yongjing and Lintao counties (Yang et al., 2013: fig. 1), in the central region of the Lower Cretaceous Lanzhou-Minhe Basin. The Lanzhou-Minhe Basin is located on the border of Gansu and Qinghai provinces, and represents a typical Mesozoic-Cenozoic intracontinental rift basin in western China. Within the basin, the Lower Cretaceous Hekou Group is well exposed (Ye, 1980; Song, 1993; Meng, 1994; Ji, 1995; Cai et al., 2001). It unconformably overlies Ordovician beds or contacts with the Middle and Upper Jurassic by faults. The Hekou Group has a thickness of 4000 m and is composed of sandstone, mudstone, and conglomerate (Editorial Committee of Chinese Stratigraphic Standard, 2000). The Hekou Group is formally divided into Lower and Upper formations and eight informal lithostratigraphic units (Li et al., 2002). The rich dinosaur fauna of the Lanzhou-Minhe Basin includes diverse assemblages of dinosaurs, pterosaurs, and bird tracks (Zhang et al., 2006), three basal titanosauriform sauropod dinosaurs (You et al., 2005, 2006; Li et al., 2014), advanced iguanodontid *Lanzhousaurus magnidens* (You et al., 2005) and Polacanthinae (Yang et al., 2013). The fossil egg comes from the first layer of siltstone from the top of the section measured by Yang et al. (2013) of the Hekou Group (Yang et al., 2013: fig. 2), which indicates a late Early Cretaceous age. This unit records offshore-shallow lacustrine deposits comprised of red brown mudstone with interbedded sage green silty mudstone. The fossil egg was discovered in the same locality with the nodosaurid dinosaur, *Taohelong jinchengensis* (Yang et al., 2013).

4 Systematic paleontology

Polyclonoolithidae oofam. nov.

Etymology From the type oogenus *Polyclonoolithus*.

Type oogenus *Polyclonoolithus* oogen. nov.

Included oogenera The type and only oogenus *Polyclonoolithus*.

Distribution and age As for the type and only oogenus.

Diagnosis As for the type and only oogenus.

***Polyclonoolithus* oogen. nov.**

Etymology *Polyclon-*, in Greek, means “numerous small branches”, in reference to the branched eggshell units; *oo*, in Greek, from the combining form for ova, meaning egg; *lithos*, in Greek, means stone.

Type oospecies *Polyclonoolithus yangjiagouensis* oosp. nov.

Diagnosis As for the type and only oospecies.

***Polyclonoolithus yangjiagouensis* oosp. nov.**

(Figs. 1, 2)

Etymology Yangjiagou, locality of the fossil egg in Gansu Province.

Holotype An incomplete and highly fragmented egg (ZMNH M1849), housed in ZMNH.

Locality and horizon Yangjiagou Town, border region of Lintao and Yongjing counties, Gansu Province, China; Lower Cretaceous Hekou Group.

Diagnosis 1.9 mm thick on average, branched eggshell units and obvious horizontal accretion lines. Eggshell units typically fused towards the outer surface, but lacking a compact layer. Multi-angular eggshell units are interlocked or isolated in tangential sections. Pore canals irregular in shape with large cavities near the inner surface of the eggshell.

Description The eggshell fragments are surrounded by calcareous sandstone and partly cemented to the matrix, whereas in other areas the eggshells separated easily from sandstone (Fig. 1A). The poor condition provides little information about the egg shape other than it may be less than 10 cm in diameter. Because of extensive weathering, the outer surface of ZMNH M1849 is strongly sculptured, which facilitates identification of eggshell units and the pore openings in hand sample (Fig. 1B).

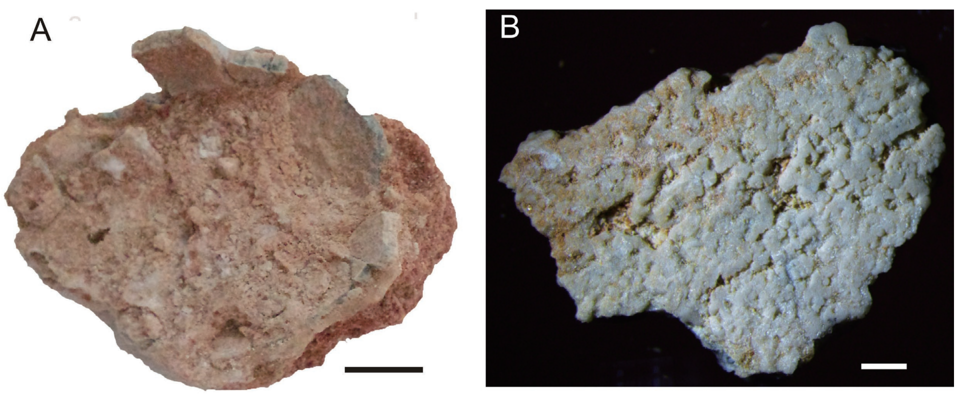

Fig. 1 Photograph of the eggshells, ZMNH M1849
A. The largest eggshell fragment, an incomplete egg, scale bar equals 1 cm;
B. Eggshell fragment showing highly weathered surface, scale bar equals 1 mm

The eggshell thickness ranges between 1.84 and 2.05 mm, with an average of 1.9 mm (Fig. 2A). The closely arranged cones at the inner surface of the eggshell show radiating structure under PLM and SEM (Fig. 2A-B). The height of the cones is about 1/7 of the eggshell thickness. The highly recrystallized portion of the eggshell above the cones represents about 1/4 of the eggshell thickness. The margins of the eggshell units are rather vague in this area. However, the upper 3/5 of the eggshell is well preserved. Eggshell units branch 2-4 times, displaying a sweeping extinction under cross-polarized light. Each eggshell unit typically has more than five branches. The parallel horizontal accretion lines

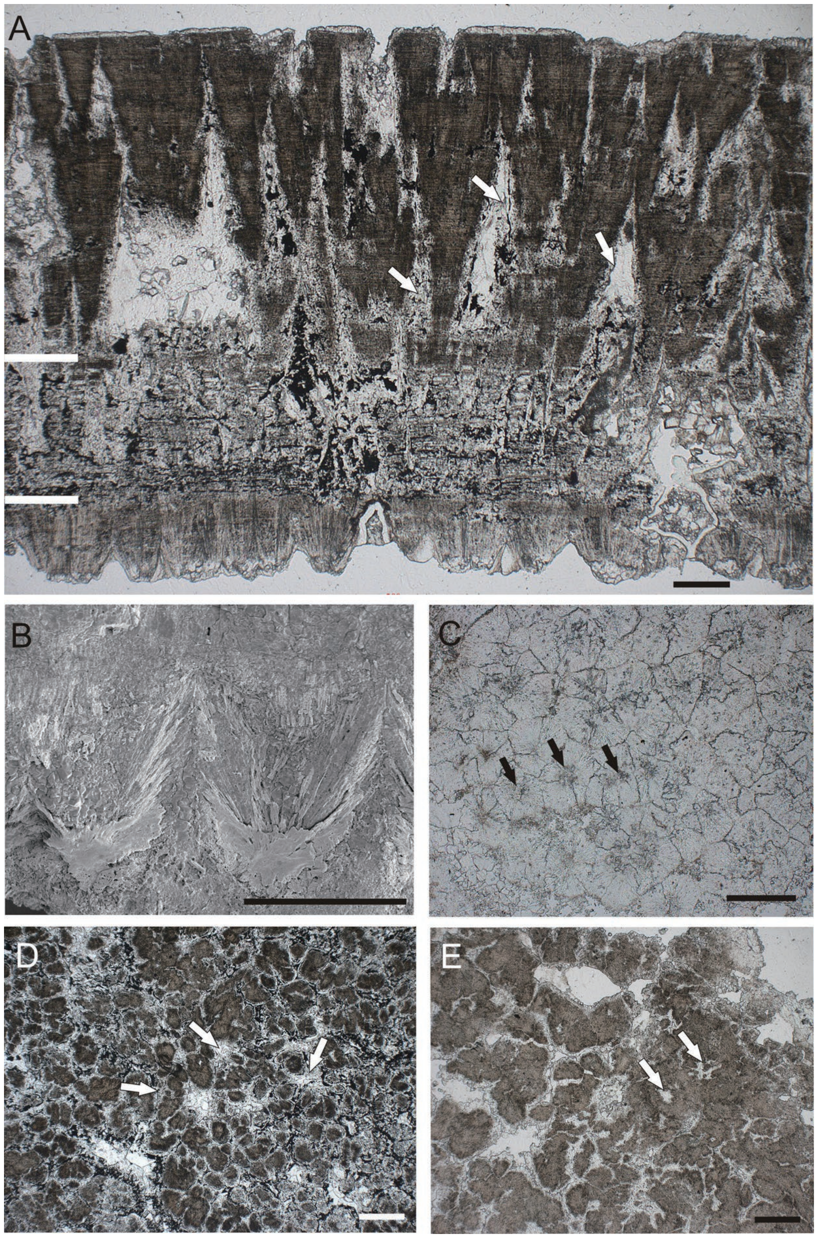

Fig. 2 *Polyclonoolithus yangjiagouensis* eggshell, ZMNH M1849

A. Radial section of eggshell under PLM, showing branched eggshell units and irregular pore canals; the lower white bar marks the boundary between the cones and the upper portion of the eggshell; the upper white bar marks upper 3/5 well preserved eggshell; white arrows point to pore canals; B. Enlargement of cones under SEM; C. Tangential section near the inner surface of eggshell, showing tightly arranged cones; black arrows point to growing centers of cones; D. Tangential section through the middle part of eggshell, showing the isolated eggshell units; white arrows point to pore canals; E. Tangential section through the upper part of eggshell, showing the eggshell units that have fused together; white arrows point to pore canals; scale bars equal 200 μm for A, B, C, and 300 μm for D, E are distributed evenly throughout the eggshell units. Pore canals between eggshell units or the branches of eggshell units are irregular in shape, gradually narrowing towards the outer eggshell surface. The branches of eggshell units are smaller and more closely spaced near the outer surface of the eggshell (Fig. 2A). Tangential sections of the inner surface show multi-angular eggshell units that are tightly packed together (Fig. 2C). There are about 45 cones per square millimeter. In the middle portion of the eggshell, multi-angular eggshell units are separated by large rimiform pore canals, whereas most branches of eggshell units are fused near the outer surface of the eggshell (Fig. 2D-E).

Comparison With the exception of the oofamilies Dendroolithidae Zhao & Li, 1988, Dictyoolithidae Zhao, 1994 and Similifaveoloolithidae Wang et al., 2011, ZMNH M1849 can be easily distinguished from all other oofamilies by the presence of branched eggshell units.

Compared with eggs of the Dendroolithidae, the eggshell units of ZMNH M1849 are not totally fused together near the outer surface of the eggshell; however, we cannot exclude the possibility that this is a result of weathering. A significant difference between ZMNH M1849 and dendroolithid eggs is that the branches of the eggshell units of *Polyclonoolithus yangjiagouensis* are gradually narrowing towards the inner surface of eggshell, probably indicating that these branches are independent eggshell units. Perhaps because of recrystallization, radially arranged calcite crystals are absent in the upper portion of the eggshell under SEM. In contrast to ZMNH M1849, the diameters of branches of the eggshell units are relatively constant in radial sections of dendroolithid eggs. On the other hand, dendroolithid eggs' eggshell units are round or worm-like in tangential sections (Zhao and Li, 1988; Zhao and Zhao, 1998), differing from the multi-angular eggshell units of ZMNH M1849.

Eggs of the Dictyoolithidae are remarkable for their superimposed branched eggshell units (Zhao, 1994; Wang et al., 2013). But the arrangement of the eggshell units is very irregular, forming a reticulate structure, which is not seen in ZMNH M1849. In tangential sections, the shapes of eggshell units of dictyoolithid eggs are similar to those of dendroolithid eggs, which can be easily distinguished from those of ZMNH M1849.

Eggshell microstructure of similifaveoloolithid eggs in radial sections resembles that of dendroolithid eggs. The diameters of branches of eggshell units are also constant in radial sections. Tangential sections show numerous, evenly distributed pores with irregular shapes. Adjacent eggshell units fuse together to form the walls of pore canals (Wang et al., 2011). Both radial and tangential eggshell microstructures differ from those of ZMNH M1849. According to these comparisons, we erect a new oofamily Polyclonoolithidae based on the features of ZMNH M1849.

5 Discussion

In China, abundant dinosaur eggs from the Upper Cretaceous have been divided into several dinosaur egg faunas, showing a general process of evolution of dinosaur eggs. The dinosaur egg fauna from the Tiantai Basin, Zhejiang Province, mainly consists of faveoloolithid, dictyoolithid and macroelongatoolithid eggs, which represents a group that retains primitive structural attributes. The age of this dinosaur egg fauna is 98-91 Ma, corresponding to the early Late Cretaceous (Cenomanian-Turonian) (Wang et al., 2012). Another primitive dinosaur egg fauna is reported from the Xixia Basin, Henan Province, which primarily includes dendroolithid and macroelongatoolithid eggs. Although the absolute age of these dinosaur eggs is unknown, they are believed to come from Late Cretaceous strata based on the studies of other fossils (Wang et al., 2012).

According to the comparison above, ZMNH M1849 likely shares a close relationship to the oofamilies Dendroolithidae, Dictyoolithidae and Similifaveoloolithidae. Considering the horizon of ZMNH M1849 (Lower Cretaceous), it may represents a more basic type of dinosaur egg than aforementioned oofamilies, which had been extinct in Late Cretaceous. The discovery of this new oofamily possibly indicates there is an unknown dinosaur egg fauna preserved in the Early Cretaceous strata of China.

According to the branched eggshell units and irregular pore canals, ZMNH M1849 should have the same eggshell formation mechanism as dendroolithid, dictyoolithid and faveoloolithid eggs (Zhao, 1993). Interestingly, the multi-angular eggshell units are somewhat similar to the eggshell units in the tangential sections near the inner surface of eggshells of spheroolithid eggs (*Spheroolithus spheroides*, *S. chiangchiungtingensis* and *S. megadermus*) (Zhao and Jiang, 1974; Liu et al., 2013), possibly suggesting that this new type of dinosaur egg has some relationships with spheroolithid eggs. If the hypothesis is true, the eggshell formation mechanism of spheroolithid eggs may be the same as that of ZMNH M1849. The "columnar layer" of spheroolithid eggs which is composed of superimposed eggshell units probably was evolved from the branches of eggshell units of the new oofamily Polyclonoolithidae, otherwise may indicates that the branches of eggshell units are actually superimposed eggshell units.

6 Conclusions

The fossil egg ZMNH M1849 from Gansu, China is referable to a new oofamily Polyclonoolithidae based on following diagnosis: branched eggshell units without a compact layer near the outer surface, interlocked or isolated multi-angular eggshell units in tangential sections and irregular pore canals. The discovery of the new material expands the diversity and distribution of Early Cretaceous dinosaur eggs in China. The new oofamily Polyclonoolithidae should represents a very basic ootaxon among known oofamilies. Furthermore, ZMNH M1849 has the same eggshell formation mechanism as that of dendroolithid, dictyoolithid and faveoloolithid eggs, and shows some relationships with spheroolithid eggs. It may reveal the origin of eggshell microstructures of spheroolithid eggs.

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甘肃早白垩世恐龙蛋化石新类型

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摘要：甘肃省早白垩世地层中，出土了大量恐龙骨骼以及恐龙足迹化石，但是至今未有蛋化石的报道。根据发现于兰州—民和盆地下白垩统河口组的蛋壳化石，建立一恐龙蛋新蛋属、蛋种，并将其归于一新蛋科：Polyclonoolithidae (多小枝蛋科)。新发现的蛋化石标本不同于所有已知的恐龙蛋类型，具有独特的显微特征组合：分叉的蛋壳单元向外延伸至蛋壳外表面，并未在靠近蛋壳外表面处融合成层；弦切面上具相互链接或独立的多角形的蛋壳单元；以及不规则的气孔道。中国的恐龙蛋化石大多出自晚白垩世地层，仅在辽宁有早白垩世恐龙蛋的报道。新发现扩展了中国恐龙蛋化石的地质和地理分布，也有可能为圆形蛋科蛋壳结构的起源提供新的认识。

关键词：甘肃兰州-民和盆地，早白垩世，多小枝蛋科，恐龙蛋

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References

Azuma Y, 2003. Early Cretaceous vertebrate remains from Katsuyama City, Fukui Prefecture, Japan. Mem Fukui Pref Dinosaur Mus, 2: 17−21

Bray S, 1998. Dinosaur eggshell *Boletuoolithus carlylensis*, oogenus nov. from the Lower Cretaceous Cedar Mountain Formation of Utah. In: Lucas S G, Kirkland J I, Estep J W eds. Lower and Middle Cretaceous Terrestrial Ecosystems. New Mexico Mus Nat Hist Sci Bull, 14: 221−228

Buffetaut E, Grellet-Tinner G, Suteethorn V et al., 2005. Minute theropod eggs and embryo from the Lower Cretaceous of Thailand and the dinosaur-bird transition. Naturwissenschaften, 92: 477−482

Buscalioni A D, Fregenal M A, Bravo A et al., 2008. The vertebrate assemblage of Buenache de la Sierra (Upper Barremian of Serrania de Cuenca, Spain) with insights into its taphonomy and palaeoecology. Cretaceous Res, 29: 687−710

Cai X F, Li C A, Zhan C S, 2001. Characteristics of dinosaur footprint fossils in the Lanzhou-Minhe Basin and their relation to the environment and tectonism. Region Geol China, 20: 62−66

Canudo J I, Gasca J M, Aurell M et al., 2010. La Cantalera: an exceptional window onto the vertebrate biodiversity of the Hauterivian-Barremian transition in the Iberian Peninsula. J Iber Geol, 36: 205−224

Chinese Academy of Geological Sciences, 2009. The Annual Report of Chinese Academy of Geological Sciences. Beijing: Geological Publishing House. 1−144

Editorial Committee of Chinese Stratigraphic Standard: Cretaceous, 2000. Chinese Stratigraphic Standard: Cretaceous. Beijing: Geological Publishing House. 1−124

Grellet-Tinner G, Fiorelli L E, Salvador R B, 2012. Water vapor conductance of the Lower Cretaceous dinosaurian eggs from Sanagasta, La Rioja, Argentina: paleobiological and paleoecological implications for South American faveoloolithid and megaloolithid eggs. Palaios, 27: 35−47

Ji L M, 1995. Sporo-pollen assemblages from late phase of Early Cretaceous in Minhe Basin. Acta Bot Sin, 37: 566−573

Kim S B, Kim Y G, Jo H R et al., 2009. Depositional facies, architecture and environments of the Sihwa Formation (Lower Cretaceous), mid-west Korea with special reference to dinosaur eggs. Cretaceous Res, 30: 100−126

Kohring R, 1990. Fossil reptile egg shells (Chelonia, Crocodilia, Dinosauria) from the Lower Barremian of Galve (Province of Teruel, SE Spain). Palaeont Z, 64: 329−344

Kurzanov S M, Mikhailov K E, 1989. Dinosaur eggshells from the Lower Cretaceous of Mongolia In: Gillette D D, Lockley M G eds. Dinosaurs Tracks and Traces. New York: Cambridge University Press. 109−113

Li L G, Li D Q, You H L et al., 2014. A new titanosaurian sauropod from the Hekou Group (Lower Cretaceous) of the Lanzhou-Minhe Basin, Gansu Province, China. PLoS ONE, 9: e85979

Li Q L, Xie G Q, Zhou L Q et al., 2002. Sequence stratigraphic framework of the Hekou Group and evolution of the Lanzhou-Minhe Basin. Sediment Geol Tethyan Geol, 22: 73−78

Liu J Y, Wang Q, Zhao Z K et al., 2013. A parataxonomic revision of spheroolithid eggs from the Upper Cretaceous Quantou Formation in Changtu, Liaoning. Vert PalAsiat, 51: 278−288

Meng Z F, 1994. Magnetostratigraphy of Lower Cretaceous (Hekou Group) near Lanzhou. Acta Geophys Sin, 37 (Supp 2): 342−347

Moreno-Azanza M, Canudo J I, Gasca J M, 2009. Megaloolithidae eggshell fragments from the Lower Cretaceous of Zaragoza Province (Villanueva de Huerva Formation, Zaragoza, Spain). In: Huerta Hurtado P, Torcida Fernández-Baldor F eds. Actas de las IV Jornadas Internacionales sobre Paleontología de Dinosaurios y su Entorno, Salas de los Infantes, Burgos. 253−262

Moreno-Azanza M, Canudo J I, Gasca J M, 2014a. Unusual theropod eggshells from the Early Cretaceous Blesa Formation of the Iberian Range, Spain. Acta Palaeont Pol, 59: 843–854

Moreno-Azanza M, Canudo J I, Gasca J M, 2014b. Spheroolithid eggshells in the Lower Cretaceous of Europe: implications for eggshell evolution in ornithischian dinosaurs. Cretaceous Res, 51: 75−87

Nessov L A, Kaznachkin M N, 1986. Discovery of a site in the USSR with remains of eggs of Early and Late Cretaceous dinosaurs. Biol Sci, Zool, 9: 35−49

Qi H R G, Yu Q W, 1999. The first Cretaceous dinosaur footprints from Minhe Basin, Lanzhou. Region Geol China, 18: 223

Song J J, 1993. Cretaceous System in Gansu. Acta Geol Gansu, 2: 1−48

Wang Q, Zhao Z K, Wang X L et al., 2011. New ootypes of dinosaur eggs from the Late Cretaceous in Tiantai Basin, Zhejiang Province, China. Vert PalAsiat, 49: 446−449

Wang Q, Zhao Z K, Wang X L et al., 2013. New forms of dictyoolithids from the Tiantai Basin, Zhejiang Province of China and a parataxonomic revision of the dictyoolithids. Vert PalAsiat, 51: 43−54

Wang X L, Wang Q, Jiang S X et al., 2012. Dinosaur egg faunas of the Upper Cretaceous terrestrial red beds of China and their stratigraphical significance. J Stratigr, 36: 400−416

Yang J T, You H L, Li D Q et al., 2013. First discovery of polacanthine ankylosaur dinosaur in Asia. Vert PalAsiat, 51: 265−277

Ye L S, 1980. Hekou Group in the Minhe Basin across the Gansu and Qinghai provinces. J Stratigr, 4: 96−105

You H L, Ji Q, Li D Q, 2005. *Lanzhousaurus magnidens* gen. et sp. nov. from Gansu Province, China: the largest-toothed herbivorous dinosaur in the world. Geol Bull China, 24: 785−794

You H L, Li D Q, Zhou L Q et al., 2006. *Huanghetitan liujiaxiaensis*, a new sauropod dinosaur from the Lower Cretaceous Hekou Group of Lanzhou Basin, Gansu Province, China. Geol Rev, 52: 668−674

You H L, Li D Q, Zhou L Q et al., 2008. *Daxiatitan binglingi*: a giant sauropod dinosaur from the Early Cretaceous of China. Gansu Geol, 17: 1−10

Zelenitsky D K, Carpenter K, Currie P J, 2000. First record of elongatoolithid theropod eggshell from North America: the Asian oogenus *Macroelongatoolithus* from the Lower Cretaceous of Utah. J Vert Paleont, 20: 130–138

Zhang J P, Li D Q, Li M L et al., 2006. Diverse dinosaur-, pterosaur-, and bird-track assemblages from the Hekou Formation, Lower Cretaceous of Gansu Province, Northwest China. Cretaceous Res, 27: 44−55

Zhao H, Zhao Z K, 1998. Dinosaur eggs from Xichuan Basin, Henan Province. Vert PalAsiat, 36: 282−296

Zhao H, Zhao Z K, 1999. A new form of elongatoolithid dinosaur eggs from the Lower Cretaceous Shahai Formation of Heishan, Liaoning Province. Vert PalAsiat, 37: 278−284

Zhao Z K, 1993. Structure, formation and evolutionary trends of dinosaur eggshells. In: Kobayashi I, Mutvei H, Sahni A eds. Structure, Formation and Evolution of Fossil Hard Tissues. Tokyo: Tokai University Press. 195−212

Zhao Z K, 1994. The dinosaur eggs in China: on the structure and evolution of eggshells. In: Carpenter K., Hirsch K F, Horner J R eds. Dinosaur Eggs and Babies. Cambridge: Cambridge University Press. 184−203

Zhao Z K, Jiang Y K, 1974. Microscopic studies on the dinosaurian eggshells from Laiyang, Shantung Province. Sci Sin, 17: 73−83

Zhao Z K, Li Z C, 1988. A new structural type of the dinosaur eggs from Anlu County, Hubei Province. Vert PalAsiat, 26: 107−115