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Fossilized yolk preserved in a dinosaur egg

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Summary

A spectacular fossil specimen considered to be a fossilized yolk was found preserved in an egg from Upper Cretaceous rocks in the Maoming Basin, Guangdong Province, South China. The carbon, phosphorus and sulfur are found in the studied specimen, suggesting that they must have come from organic matter originally present in the specimen. This is the first well-documented association of dinosaur egg containing an unincubated content from the fossil record.

Introduction

Dinosaur eggs and eggshell fragments are abundant in Upper Cretaceous beds in the world, but the contents of egg are not represented due to their poor fossilization potential. In 1994-1996, four fossil egg localities have been discovered in the Maoming Basin of Guangdong Province, South China for the first time (Qiu *et al.* 1995) by a joint team consisting of the Maoming Museum, the Guangdong Provincial Institute of Cultural Relics and Archaeology, and the Institute of Vertebrate Paleontology and Paleoanthropology, CAS. The locality, south of Xin-Tang-Zai Village, is at a large construction-site in the southeastern Maoming City, where three nests containing eggs with an identical eggshell morphology were dug out from the purplish red beds, about 9-11 meters below the land surface. The three nests of eggs (94MNZH 15, 94MNZH 43 and 95MNZH 73) are separated one from another by 10-30 m. 94MNZH 15 represents a clutch of about 6 eggs. These eggs were naturally intact from the deposit in which they had been preserved. Unfortunately, most of them were broken in varying degrees by the building workers when they were driving in piles to make a firm foundation. One broken egg (94MNZH 15:4) from the clutch contains a specimen of black glassy mass considered to be a fossilized yolk (Fig. 1). In addition, the workers also reported that in the same clutch there were two other broken-up eggs, each of which contained a smaller piece of black glassy mass. But it's a pity they were thrown away. The discovery of this specimen could be potentially important in reconstructing the chemical composition in the dinosaur egg contents, or in understanding the evolution of the organized physicochemical system in vertebrate eggs. The object of this paper is to provide some additional information to further document the preservation of egg contents in the fossil record.

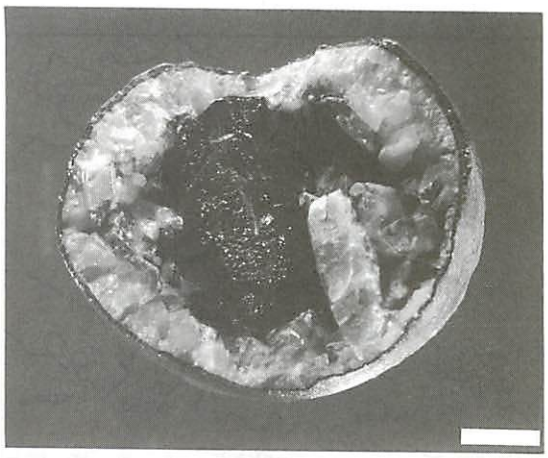

Fig 1. Specimen photograph of 94MNZH 15:4 (The fossilized yolk inside the intact half of a shell). Scale bar 2 cm..

Description of the specimen and discussion

The Maoming Basin is situated in the southwestern part of Guangdong Province (Fig. 2), where the Upper Cretaceous and Tertiary deposits are well-developed (Chow, 1956 iLi, 1995). The stratigraphical sequence exposed in this basin is given as follows (Fig. 3A):

Ⅰ. Upper Cretaceous Tong-Gu-Ling Formation: this unit consists dominantly of purplish red beds of argillaceous siltstones, intercalated with coarse grained sandstones and conglomerates.

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Ⅱ. You-Gan-Wo Formation: it may be subdivided into two parts, namely the Eocene shales yielding fossil turtles, *Anosteira maomingensis*, in the upper, and marl sandstones and conglomerates in the lower;

Ⅲ. Huang-Niu-Ling beds: consisting mainly of granitoid sandstones intercalated with conglomerates;

Ⅳ. Pliocene marl shale beds: containing abundant *Viviparus;*

Ⅴ. Quaternary alluvial soil;

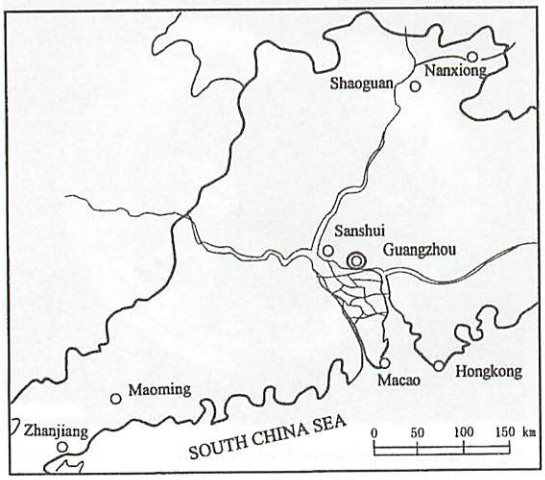

Fig 2. Geographic position of the Maoming Basin, Guangdong Province.

The Upper Cretaceous Tong-Gu-Ling Formation at the locality of south Xin-Tang-Zai Village consists mainly of perplish red, argillaceous siltstones. The nest of eggs (94MNZH 15) is located in this unit, about 10.30 m below the land surface (Fig. 3B). The unit is capped by the Quaternary alluvial soil.

The broken egg (94MNZH 15:4) remains to have the larger half of it, and looks ovoid in shape. It measures 11 x 9.4 cm. It can be seen that the eggshell and the zone of secondary crystalline calcite aggregates (approximately 2 to 4 cm thick on the inner shell surface) enclosed the internal egg-cavity, which is filled up with the black glassy mass (Fig. 1). The outer surface of eggshell is fairly smooth, but grainy in appearance. The microstructure of the eggshell in radial section is a dinosauroid-spherulitic type (Fig. 4). The eggshell is about 2.7-2.8 mm thick. The cone layer is about one-fourth of the eggshell in thickness. The crystallites of adjacent shell units are interlocking, with some fusion. The subvertical structural margins are slightly divergent and faintly developed. The herring-bone pattern of the columnar layer is usually well developed. The pore canals are narrow. Obviously the specimen is quite similar to the eggs classified as Shixingoolithus erbeni (Zhao 1994 ; Zhao *et al.* 1991).

Preliminary studies on the specimens from the four localities indicate the presence of taxa typical of the late Late Cretaceous (that is, *Macroolithus yaotunensis*, *Elongatoolithus andrewsi*, *Elongatoolithus elongatus*, and *Shixingoolithus erbeni*) (Zhao 1975 ; Zhao 1994 ; Zhao *et al.* 1991), suggesting that the egg-bearing beds in this basin may correlate with the Pingling Formation and the upper part of Yuanpu Formation of the Nanxiong Basin.

The black glassy mass specimen preserved in the egg (Fig. 5) is 6.6 cm in length, 2.9 cm in breadth, and 45 g in weight. Its surface is covered with small irregular hollows and furrows which coincide with the projecting secondary calcite crystals. We assume that it was a jelly-like substance before being fossilized. These impressions on the surface were caused by the secondary block calcite crystal layer growing toward the inside of the egg during fossilization. All of these various types of data show that the identity of the specimen as an unincubated content of the dinosaur egg is established beyond any reasonable doubt. Further data will be sought in a study of chemical composition of the specimen and sedimentary environment of the egg-bearing beds in the Maoming Basin. Because of the unique nature of the specimen we did not wish to destroy any major portion of it before finding possible paths for studying it in details. Instead, micron-sized samples were taken from three different spots on the specimen to analyze the elemental composition at the laboratory of the Shanghai Institute of Organic Chemistry, CAS. The relative amounts of these chemical elements are listed in Table Ⅰ.

Table 1. The elemental composition of the fossilized yolk

Relative Amount (per cent)			
	Sample 1	Sample 2	Sample 3
Carbon	0.65	0.90	0.84
Phosphorus	0.84	0.74	0.58
Sulfur	0.62	0.86	0.75

The presence of carbon, phosphorus and sulfur in the studied specimen indicates its organic origin, and strongly suggests that it may be the mixtures of fragments of original yolk and albumen decomposition. During fossilization the yolk and albumen mingle with each other because of dehydration, and a certain degree of chemical decomposition may also occur. It is interesting that the percentage content of phosphorus and sulfur in the

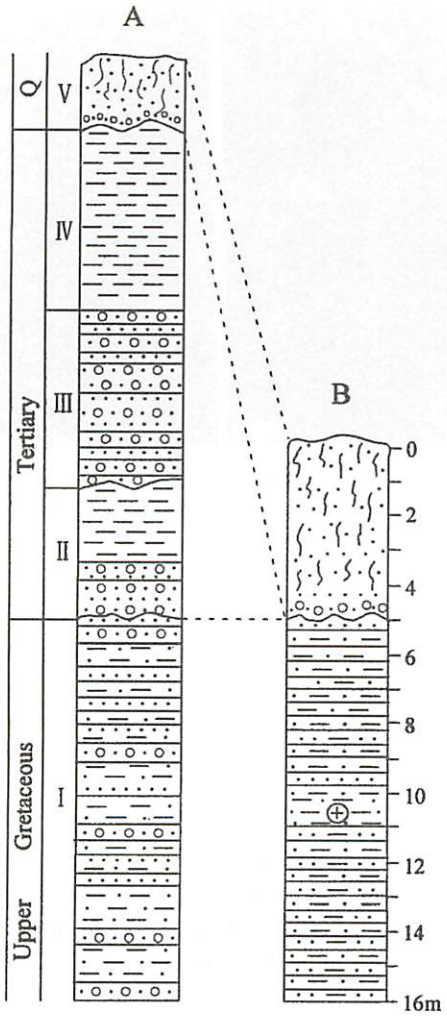

Fig 3. Stratigraphic sequence deposited in the Maoming Basin. A. Composite section of late Mesozoic and Cenozoic strata in the Maoming Basin (after Chow, 1956). B. Section from south of Xin-Tang-Zai Village in the southeastern of Maoming City.

specimen studied seems to be comparable with that of chicken egg's contents (Romanoff and Romanoff, 1949). However, more than 99 per cent of the egg's total phosphorus is in the yolk, and the egg albumen consists chiefly of water. In view of the comparably organized physicochemical system of egg in birds and reptiles (Bellairs, 1970 ; Packard and Pachard, 1989 ; Packard *et al.*, 1997), especially in crocodiles, it is reasonable to assume, therefore, that the components of yolk predominate in the studied specimen (94MNZH 15:4).

Like avian egg, fresh dinosaur egg contains a large yolk that furnishes nourishment for the developing embryo, and watery albumen surrounding the yolk. However, the egg is an unstable physicochemical system. If the new-laid eggs from dinosaurs did not go on with incubation, the chemical decomposition of the egg contents might quickly occur by the activities of microorganisms. It is obvious that there was very little chance for its becoming a fossil. The nature of fossil preservation in the Maoming Basin suggests strongly that it went on under a special condition, probably high salinity and short of oxygen, by which both albumen and yolk could be coagulated. As mentioned above, the egg (94MNZH 15:4) has intact eggshell. During fossilization the zone of secondary calcite grown on the inner eggshell surface had sealed the pore canals of eggshell, and formed a hypoxic microenvironment for the preservation of coagulated contents of egg.

On the basis of circumstantial evidence, two biostratigraphic studies of the Nanxiong Basin (Fig. 2), situated in the northern part of Guangdong Province, suggested that this basin was partly inundated by sea water during the deposition of the upper part of the Yuanpu Formation (Zhang 1989 a ; b). Fossil foraminifers, represented by *Nonion subrusticum*, *Nonion sichuanensis* and *Nonion* sp., coexisted with an abundance of euryhaline non-marine ostracodes in the above-mentioned beds, indicating brackish condition. Besides, abundant marine planktonic microphytes, i.e. dinoflagellates and other acritarchs have been discovered in the Upper Cretaceous Dalangshan Formation of Sanshui Basin (Fig. 2), situated at the Zhujiang (Pearl River) Delta of Guangdong Province (Yu *et al* 1981 ; Zhang, 1989). It seems logical to infer, therefore, that the vast area of Guangdong Province during the deposition of that time, corresponding to the upper part of the Yuanpu Formation or Dalangshan Formation, might serve as a potential condition for the preservation of egg contents. We presume that the Maoming Basin could have been flooded by sea water when the eggs were laid. Immersion in sea water is a favorable environmental condition for the successful preservation of eggs. This process solidifies the egg contents. It is somewhat similar to the Chinese method of preserving eggs used as foodstuff. The avian eggs coated individually with a mixture of salt and wet clay or lime, salt and wood ashes can be kept for many years (Romanoff and Romanoff, 1949) .

If the inference is correct, further searching for similar new fossil eggs containing residue of unincubated content of egg is potential in both the southwestern part and Zhujiang Delta, Guangdong Province.

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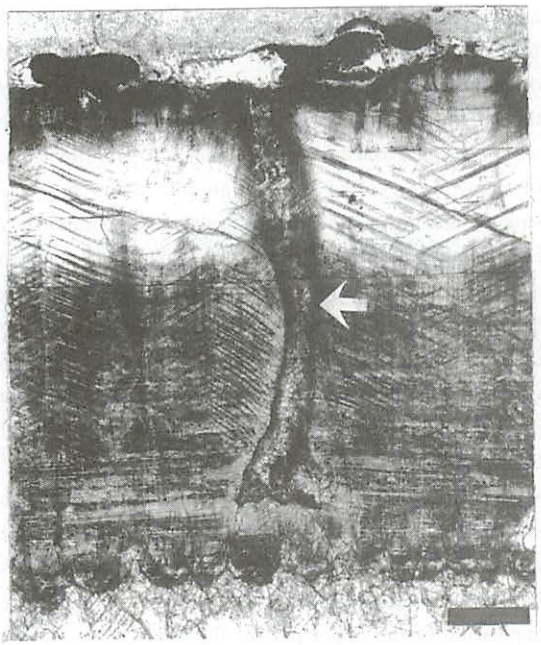

Fig 4. Radial thin section of the eggshell (94MNZH 15:4), not polarized. Note shell units with columns; herringbone pattern and pore canal (arrow). Scale bar 0.5 mm.

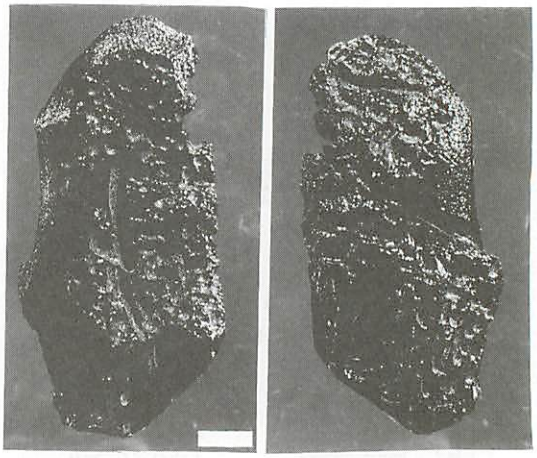

Figure 5. Detail of the fossilized yolk taken from the egg (94MNZH 15:4), a (left side) and b (right side), two different views of the specimen. Scale bar 1 cm.

References

Bellairs, A. d'A. (1970) The Life of Reptiles. Vol. II Universe Books, New York.

Chow, M. M. (1956) Supplementary notes on Anosteira maomingensis. Acta Palaeont. Sinica, 4, 237-238.

Li, H. M. (1995) Lithostratigraphic division of the Cretaceous in Guangdong. Guangdong Geology, 10, 61-68.

Packard, M. J. and Packard, G. C. (1989) Mobilization of calcium, phosphorus, and magnesium by embryonic alligators (*Alligator mississippiensis*). Am. J. Physiol. 257 (Regulatory Integrative Comp. Physiol. 26), R1541-R1547.

Packard, G. C., Tracy, C. R. and Roth, J. J. (1977) The physiological ecology of reptilian eggs and embryos, and the evolution of viviparity within the Class Reptilia. Biol. Rev., 52, 71-105.

Qiu, L. C., Zhang, S. and Chen, G. Y. (1995) Dinosaur eggs from Maoming Basin, Guangdong Province. Vert. PalAsia., 33, 248.

Romanoff, A. L. and Romanoff, A. J. (1949) The Avian Egg, chaps. 6 and 10, (John Wiley and Sons, Inc., New York).

Yu, J. X., Sun, M. R., Sun, S. Y. and Mao, S. Z. (1981) Dinoflagellates and acritarchs from Dalanshan Formation and their significance in explain the depositional environment.Oil and Gas Geology, 2, 254-264.

Zhang, W. (1989) Preliminary study on the Cretaceous stratigraphy in Guangdong. "In Selected Papers for Symposium on Cretaceous of South China". (Chen, P. J., Xu, K. D. and Chen, J. H., eds.) , pp. 215-222, Nanjing Univ. Press.

Zhang, X. Q. (1989a) Discovery of Cretaceous brackish-water Foraminifera and Ostracoda in Nanxiong Basin and its significance. Guangdong Geology, 4, 67-86.

Zhang, X. Q. (1989b) Upper Cretaceous ostracod assemblages of the Nanxiong Formation in Guangdong and their stratigraphic significance. In "Selected Papers for Symposium on Cretaceous of South China". (Chen, P. J., Xu, K. D. and Chen, J. H., eds.), pp. 223-243, Nanjing Univ. Press.

Zhao, Z. K. (1975) The microstructures of the dinosaurian eggshells of Nanxiong Basin, Guangdong Province (I): on the classification of dinosaur eggs. Vert. PalAsia, 13, 105-117.

Zhao, Z. K. (1994) The dinosaur eggs in China: on the structure and evolution of eggshells. In "Dinosaur Eggs and Babies". (Carpenter, K., Hirsch, K. F. and Horner, J., eds.), pp. 184-203, Cambridge Univ. Press.

Zhao, Z. K., Ye, J., Li, H. M., Zhao, Z. H. and Yan, Z. (1991) Extinction of the dinosaurs across the Cretaceous-Tertiary boundary in Nanxiong Basin, Guangdong Province. Vert. PalAsia.,29, 1-20.