FIRST RECORD OF DINOSAUR EGGSHELLS AND TEETH FROM THE NORTH-WEST AFRICAN MAASTRICHTIAN (MOROCCO)

by

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SUMMARY

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Mots-clés: coquilles d'oeufs, dents de théropodes, Maastrichtien, Maroc, Afrique.

Key-words: amniotic eggshells, theropod teeth, Maastrichtian, Morocco, Africa.

(Reçu le 15 Octobre 2003, accepté le 15 Novembre 2003, publié le 15 Décembre 2003)

ABSTRACT

We report the discovery of amniotic eggshells and theropod teeth from the Late Cretaceous period in Morocco. The megaloolithid family represents the only known dinosaur egg remains in the north part of Africa and attests indirectly to the occurrence of sauropod dinosaurs (titanosaurids) in the Maastrichtian of Africa.

RESUME

La découverte de coquilles d'oeufs et de dents de théropodes est signalée dans le Crétacé terminal du Maroc. La famille des Megaoolithidae represente les seuls restes d'oeufs de dinosaures du Nord de l'Afrique et atteste indirectement de la présence de dinosaures sauropodes (titanosauridés) dans le Maastrichtien d'Afrique.

INTRODUCTION

Dinosaur eggs and eggshells are now reported in numerous Mesozoic gondwanan localities (Hirsch, 1989; Sahni *et al.*, 1994; Vianey-Liaud *et al.*, 1994; Vianey-Liaud *et al.*, 1997; Calvo *et al.*, 1997), but a few are known from Africa: in fact, the discoveries from this continent are very limited and located especially in the southern part and more particularly in the Lower Jurassic sediments of South Africa's Elliot Formation (Zelenitsky & Modesto, 2002). It is noticeably different for dinosaur bones which have been reported with a large distribution in different stratigraphic levels (Upper Triassic to Maastrichtian) in Africa: for example, from South Africa (Kennedy *et al.*, 1987; Durand, 2001), from Lesotho (Knoll, 2002), from Malawi (Jacobs *et al.*, 1990), from Niger (Greigert *et al.*, 1954; Sereno *et al.*, 1996; Sereno *et al.*, 1999), from Egypt (Rauhut & Werner, 1997)...

Moreover, from the Upper Cretaceous of Morocco, the youngest dinosaurian bones are Cenomanian (Lavocat, 1951; about 93 m.y.) and the Maastrichtian dinosaur history was not yet known, until our discoveries. Field researches in Central Morocco (Middle Atlas), initiated in 1999 by one of us (R. Tabuce) have resulted in the discovery of numerous micro-remains in several outcrops, that straddle the Maastrichtian/Paleocene transition. Among others, the dinosaur specimens include more than twenty well preserved megaloolithid eggshells and two theropod teeth. So, we relate the first notable record of the megaloolithid family in North Africa, which attests indirectly of the occurrence of sauropod dinosaurs (titanosaurids) in the Upper Cretaceous of Africa.

The eggshells occur in the Irbzer Formation exposed in the Oukdiksou syncline (Fig. 1). The lower part of this formation is a yellowish, cross-bedded, calcareous sandstone with indeterminate shark teeth. It is overlain by phosphatic marls with vertebrate bone-beds. The elasmobranch fauna is typically Maastrichtian based on *Cretolamna maroccana*, *Serratolamna serrata*, *Squalicorax pristodontus*, *Squalicorax bassanii*, *Ganopristis leptodon* and *Dalpiazia stromeri*. The occurrence of *S. bassanii*, present mainly in the lower to middle Maastrichtian deposits in the Ouled Abdoun and Ganntour Phosphate basins of the Moroccan Meseta indicates an age older than the Upper Maastrichtian. Continental fauna and flora occur in light grey mudstones and marls conformably overlaying these strict marine deposits. Charophytes, associated with the eggshells, indicate a Maastrichtian or Early Paleocene age (Schudack & Herbib, 1995), but ostracodes (Colin com. pers.) and an indeterminate ammonite discovered near the Oudiksou syncline (Andreu & Tronchetti, 1996) provide a Maastrichtian age for the upper part of the Irbzer Formation.

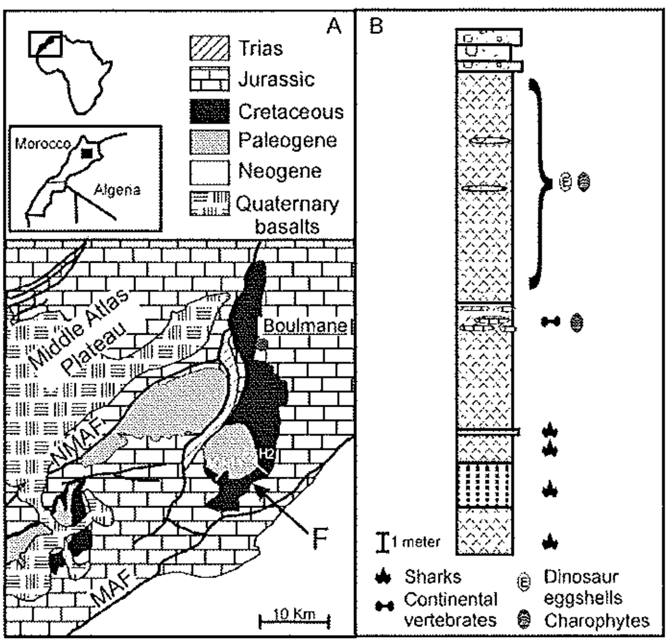

Figure 1.— a: Map showing Morocco and the location of the fossiliferous sites (ACH1a and ACH2)-indicated by the black F- in the Middle Atlas Mountains; b: Section ACH2 of the South Oudiksou syncline with locations of the eggshells-bearing beds in the Irbzer Formation. In the Oudiksou syncline, the lithofacies and thickness of Cretaceous series vary strongly in time and space, even on short distances; it is clearly the case for ACH1a and ACH2.

Eggshells were either collected on exposures and/or by screen-washing of sediment samples. They have been prepared by ultrasonic cleaning, and some (as they are strongly encrusted) by acetic acid (5%) processing. Scanning electron microscopy was used to show the ultrastructure and characteristic features of the outer and inner surfaces of eggshell fragments. Microstructures were studied from thin petrographic sections. Measurements were taken on thin sections with a micrometer, and on fragments with calipers. The structural and parataxonomic terminology follows that of Mikhailov *et al.* (1996) and Mikhailov (1997). Studied specimens are catalogued as ACH- in the collection of the laboratory of Paleontology, University of Montpellier II. The structure of the eggshell described was directly compared with other eggshell material from southern France, Spain and India.

Oofamily **MEGALOOLITHIDAE** ZHAO, 1975 (emend. 1979)
Oogenus ***MEGALOOLITHUS*** VIANEY-LIAUD *et al.*, 1994

Megaloolithus maghrebiensis oosp. nov.

Material: 25 eggshell fragments.

Holotype: ACH2-05, single eggshell fragment (thin section and fragment) (Fig. 2d and e)

Type locality: Achlouj 2, Irbzer Formation, Middle Atlas, Morocco (Fig. 1)

Etymology: In reference to the location - the Maghreb (the French-speaking North Africa) - where the eggshells were found.

Diagnosis: *Megaloolithus* irregularly compactituberculate. Eggshell thickness from 1.7 to 2.5 mm. Elongation ratio (H/W) of the units from 2.5 to 3.7. Fan-shaped units with arched growth lines in the mammillae throughout the shell units. Units are well separated (node diameters 0.5 to 1.3 mm). In the areas where the nodes are fused in short chains and flat, the units are not clearly defined and the horizontal growth lines continue from one to the other. Pore canals are straight or linked by oblique bridges, as in *Megaloolithus siruguei*. Pore canal diameters between 75 to 130 m. Large eisospherite (0.15 to 0.3 mm) per node. Size and shape of the egg unknown.

Description and comparison

This oospecies has been found throughout the sampled Achlouj sections, at the same stratigraphical level in the upper five meters of the Irbzer Formation. They are found scattered in grey, sometimes reddish marls, generally associated with thin detritic intercalations.

The morphological characteristics (multicanaliculate system pore, thickness range and compactituberculate pattern of the outer surface) are very similar to the European *Megaloolithus* species: *M. siruguei* (Garcia & Vianey-Liaud, 2001a). However it differs by the generally larger node diameters, the wider pore canals and more pronounced fan-shaped units.

Defined narrower units, more important shell thickness and wider node diameter differentiate the new material from megaloolithid eggshell previously described from India [*Megaloolithus mohabeyi* (Vianey-Liaud *et al.*, 2003):1.8 to 1.9 mm, H/W <3] and from Argentina (Chiappe *et al.*, 1998: 1 to 1.78 mm, H/W < 2).

A very small fragment from Achlouj 1a (Fig. 1) [thin section ACH1a-01] displaying a discretispherulitic microstructure, is referred to an undetermined species of *Megaloolithus*; It is thin (0.7 mm) with nodes separated by flat areas.

? Oofamily LAEVISOOLITHIDAE MIKHAILOV, 1991
Genus *SUBTILOILITHUS* MIKHAILOV, 1991

Tipoolithus achloujensis oogen. nov., oosp. nov.

Material: 12 eggshell fragments.

Holotype: single eggshell fragment ACH2-06 (thin section and fragment) (Fig. 2a-c)

Type locality: Achlouj 2, Irbzer Formation, Middle Atlas, Morocco (Fig. 1)

Etymology: Tip in reference to the shape of nodes and after the name of the type locality: Achlouj.

Diagnosis: Eggshell thickness 0.40-0.65 mm, excluding the ornamentation; continuous layer: mammillary layer ratio = 2/1 to 1/1; ornamentation dispersituberculate, with high nodes (ratio node height / eggshell thickness = 0.37-0.45); node diameters 0.15-0.40 mm; pore openings situated from top of the nodes to their base, or between them; wide pore openings (90-160 m); angusticanaliculate pore system.

Description and comparison

This oospecies resembles *Porituberoolithus warnerensis* (Zelenitsky *et al.*, 1996) from the Upper Cretaceous of Oldman Formation (Canada), in its general microstructure and thickness (0.5 to 0.65 mm), but the location of the pores is different, exclusively on the nodes. The nodes of *Tipoolithus* are sharp forming tips, generally isolated and rarely twinned or grouped by three, dispersed over the outer surface. On one fragment, the nodes seem to be aligned but the fragments are very small (less than 9 mm2). The pore system is angusticanaliculate with probably very wide and nonbranching canals. *Tipoolithus* is very similar to *Subtiliolithus kachchhensis* (Khosla & Sahni, 1995) of the ornithoid-ratite eggshells from the Late Cretaceous of Anjar (Gujarat, India). This oospecies also exhibits dispersituberculate ornamentation, but is slightly thinner (0.34-0.45 mm) than *Tipoolithus* (0.4 to 0.65 mm) and its nodes are rounded and low.

? Oofamily **PRISMATOOLITHIDAE** HIRSCH, 1994 emend.
? *PRISMATOOLITHUS* ZHAO & LI, 1993

Description

Two very small fragments, less than 1 mm2, from Achlouj 1A (ACH1a-02) studied in thin section, show a prismatic structure with units consisting of slender, interlocking prisms. They exhibit small circular nodes (0.15-0.17 mm in diameter) and an eggshell thickness varying from 0.29 to 0.35 mm. They could correspond to a theropod egglayer (Zelenitsky & Hills, 1996; Mateus *et al.*, 1997).

Oofamily **KROKOLITHIDAE** KOHRING & HIRSCH, 1996.

Description

One single fragment (about 2 mm2) from also Achlouj 1A (ACH1a-03) shows a typical crocodiloid microstructure. The wide shell units display irregular wedges and the characteristic horizontal layering. On the outer surface, the top of the units are flat and separated by wide and shallow valleys.

THEROPODA indet.

Material: two teeth ACH2-07 and ACH2-08 (Fig. 2 f-h)

Description

Only two fragmentary teeth have been found in the Achlouj 2 section (Fig. 1). The first is a fragment of an asymmetrical and laterally compressed tooth without serrations and slightly flattened on one side. The tooth tip is missing, as well as is base. It is 2.7 mm high, 1.6 mm long and 0.8 mm wide. The enamel is very thin (0.01 mm thick) and damaged by thin vertical cracks. The pulp cavity is small, less than 10% of the tooth. The second tooth shows the same shape, low ridges and thin vertical cracks. It differs only by the occurrence of denticles on its posterior edge.

These teeth closely resemble the morphotype "*Paronychodon*" (Carpenter, 1982; Sanz & Frances, 1992) by their morphology, their proportions and their measurements. The lateral profile is strongly asymmetrical, curving posteriorly. They are covered by coarse longitudinal ridges on the two sides of the crown. Three long and low ridges are observed on the flattest side of the crown which becomes faint to the base. On the most rounded side, only one smooth and shallow groove is hardly distinct. One specimen lacks serrations entirely but the other has some denticles on its posterior edge, as it can occur on *Paronychodon* teeth.

The teeth were found in a transitional level within the lowest eggshell bearing level, close to Early Maastrichtian dated strata. They represent the first Late Cretaceous Theropoda remains found in continental African levels. They cannot be precisely referred to any theropod family. *Paronychodon* is assigned either to the Dromaeosauridae or to the Troodontidae (Currie *et al.*, 1990), but even the generic attribution is not quite certain. Nevertheless, both families are Laurasian and the occurrence of this taxon confirms communication during the Upper Cretaceous period between Africa and Laurasia. It was already suspected by the mixed character of the European reptile fauna with both Laurasian and Gondwanian origins (Vasse, 1995; Le Loeuff, 1993).

Records of African Mesozoic eggs are very limited, and before this report, no detailed accounts of North African Cretaceous eggshell have been published. We establish from our Moroccan locality the presence of at least 4 egg morphotypes, two of which may have been laid by theropods: the prismatoolithid shell is similar to that of eggshell referred to *Troodon* (Horner & Weishampel, 1996) and the new genus *Tipoolithus* which shows a "ratite" morphotype could belong to the Laevisoolithid family probably laid either by enantiornithine birds and/or small theropods (Mikhailov, 1997). Thus, indirectly one or two small carnivorous dinosaurs (Theropoda) or birds can be listed in the Late Cretaceous dinosaur fauna of Achlouj.

The megaloolithid family is well diversified and common in the Campano-Maastrichtian continental deposits of Gondwana: Indian, South Europe (Zhao, 1975; Sahni *et al.*, 1994; Vianey-Liaud *et al.*, 1994; Vianey-Liaud & Lopez-Martinez, 1997) and South American localities [Peru (Vianey-Liaud *et al.*, 1997), Argentina (Chiappe *et al.*, 1998; 2000) and Brasil (Price, 1951; Magalhaes Ribeiro, 2000)]. *Megaloolithus maghrebiensis* nov. sp. from Morroco shows close affinities, but also differences especially in some quantitative criteria (node diameter, thickness...) with the South-American, Indian and European Cretaceous megaloolithid oospecies, well studied and described in detail (see for example Garcia, 1998; Chiappe *et al.*, 1998; Garcia & Vianey-Liaud, 2001a; Vianey-Liaud *et al.*, 2003; Garcia *et al.*, submitted). The similarities in egg taxa suggest close phyletic relationships. The discovery in Argentina of embryo remains related to titanosaurs (sauropod) inside typical discritispherulitic eggs (Chiappe *et al.*, 1998) is strongly significant, suggesting that all megaloolithids are associated to titanosaur-like egglayers. Thus, our Moroccan megaloolithid material, which can be tentatively attributed to titanosaurid dinosaur, fills a geographical gap in Gondwanan Late Cretaceous sauropod distributions. Because these eggshells were found in levels overlying Lower Maastrichtian marine strata, it is possible to confirm the presence of titanosaurids in the North African Maastrichtian. This was long known in India, and subject to discussion in Europe, where the Maastrichtian bone localities are scarce (Le Loeuff, 1991), and where the megaloolithid species diversity drastically decreases at the beginning of this stage (Garcia & Vianey-Liaud, 2001b). This discovery is important in the knowledge of the evolution of dinosaur diversity just before their extinction. As several successive levels have yielded bone and eggshell fragments, we can expect to increase rapidly this new fossil record in this crucial time span, near the

Cretaceous-Tertiary boundary.

ACKNOWLEDGEMENTS

The members of the mission would thank Mr M. Sadiqui, the head of the geology department and Mr L. Tabit, manager of the "division SIG et patrimoine géologique" for their helpful collaboration. This work was funded by the UMR 5554, "Institut des Sciences de l'Evolution and by the ECLIPSE CNRS program. Contribution ISEM n 2002-109.

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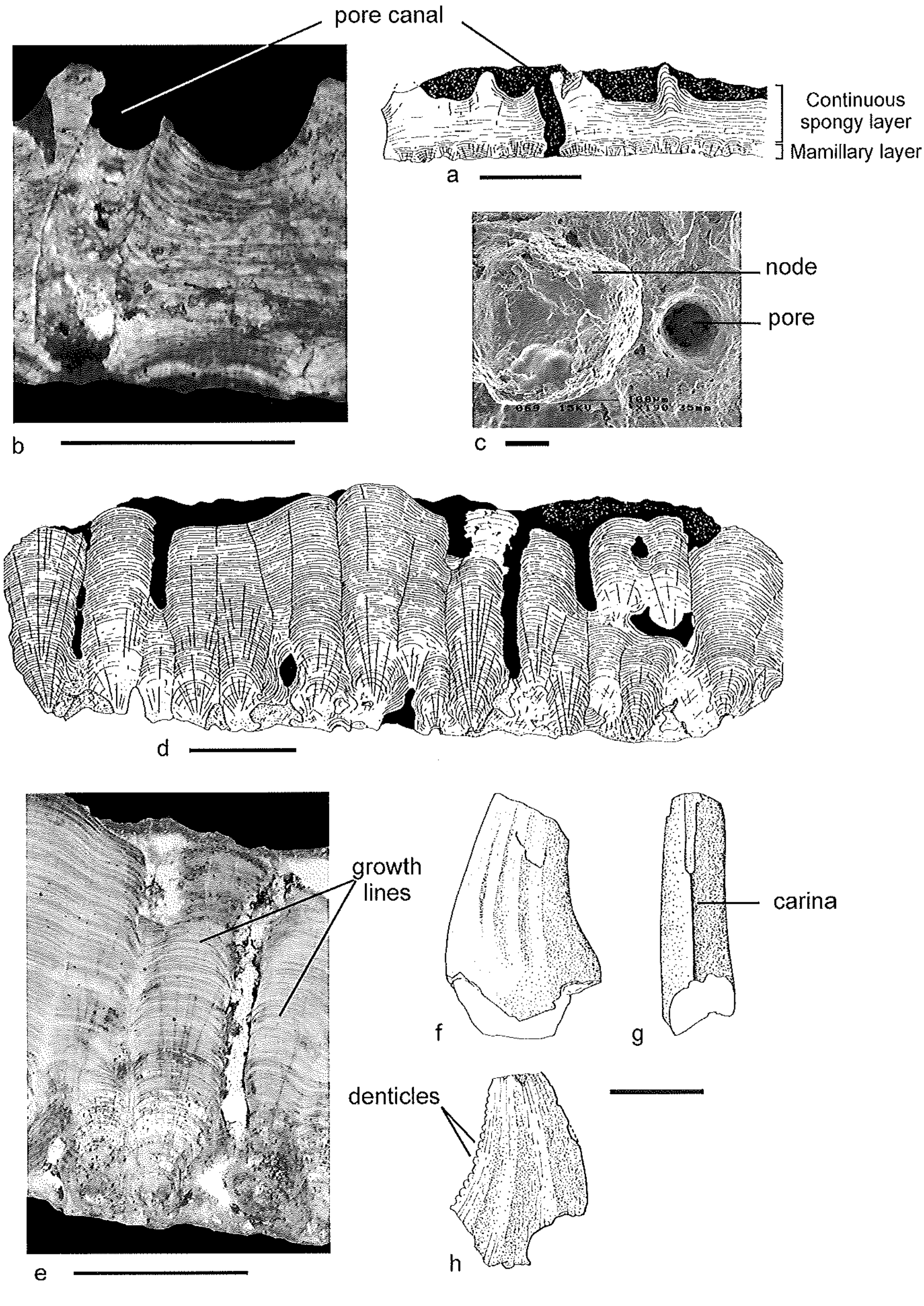
PLATE 1

Tipoolithus achloujensis nov. oogen. nov. oosp. a. Drawing of thin section, showing the two layers (mammillary layer, with spherulites, and the continuous spongy layer) Scale = 1 mm. b. detail of a, PLM, natural light, showing the growth lines continuous in the "spongy" layer, the mammillary layer, and the wide pore canal; Scale = 0.5 mm. c: SEM of outer surface, a pit and a pore in a flat area between the nodes; Scale = 0.1mm.

Megaloolithus maghrebiensis nov. oogen. nov. oosp. d: Drawing of the holotype (thin section). e: Detail of a thin section of *M. maghrebiensis*, PLM, natural light, showing the regular arched growth lines, dipping at the pore canal level, the large eisospherites and circular growth lines around them and the pore canal. Scale 1 mm.

Teeth of Theropoda. f: first tooth, most flat side, with three faint ridges; g: anterior side, showing the faint edge, worn at the top; h: second tooth, convex side with denticles on the posterior edge. Scale = 1 mm.


pore canal
Continuous
spongy layer
Mamillary layer
a
b
node
pore
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