

NOTA PALEONTOLOGICA

Multiple dinosaur egg-shell occurrence in an Upper Cretaceous nesting site from Patagonia

Rodolfo A. CORIA^{1,2}, Leonardo SALGADO^{1,3} and Luis M. CHIAPPE⁴**Introduction**

The discovery of hundreds of megaloolithid-type egg-clutches (some including embryos of an indeterminate species of titanosaur sauropods) in several stratigraphical levels of the Late Cretaceous nesting site of Auca Mahuevo (Chiappe *et al.*, 2005) unveiled important aspects of the reproductive behavior of sauropod dinosaurs and stimulated further work at other Patagonian dinosaur egg sites. In November of 2003, a joint expedition of the National University of Comahue (Neuquén), the Museo Carmen Funes (Plaza Huincul) and the Museo de Lamarque (Lamarque) conducted fieldwork in several Late Cretaceous localities of Bajo Santa Rosa (center-north Río Negro Province, Argentina) bearing the remains of dinosaur eggs and other terrestrial vertebrates (figure 1).

The main focus of this expedition was to assess the diversity of dinosaur eggs, to fine-tune the stratigraphy of the egg-bearing layers, and to document the spatial distribution of the egg-clutches. The overall results of this research were reported elsewhere (Salgado *et al.*, 2007). In this contribution, we make focus in one of the fossil localities worked, Berthe IV, where the association of egg clutches likely belonging to different dinosaur species was detected (figure 1.2).

Collected eggshells were observed with a binocular loupe "Stemi SV6 Zeiss", at magnifications of x1.0 and x3.2 (for macrocharacters). Microcharacters were observed in transverse thin section using a polarizing microscope ("Zeiss Axioplan") at magnifica-

tions of x0.4 and x10. The eggshells were photographed using this polarizing microscope equipped with a digital camera. Prior to analysis, the eggshells were submitted to a process of cleaning using ultrasound (see Salgado *et al.*, 2007 for further methodological details).

Institutional abbreviations. MML-Pv, Museo Municipal de Lamarque, Vertebrate Paleontology, Río Negro, Argentina.

Geological setting

The central region of the Río Negro province is characterized by a series of shallow continental basins originated by both structural and eolian processes (González Díaz and Malagnino, 1984). The Allen Formation (middle Campanian-lower Maastriichtian) outcrops along the edges of these shallow basins and it contains the province's main egg-bearing deposits. The Allen Formation consists of a thick succession of sandstones and mudstones, which upper section is intercalated by carbonate and evaporitic deposits. Leanza and Hugo (2001) proposed the Allen Formation as a continental lithostratigraphic unit with a lower member characterized by fluvial deposits of moderate energy, a middle member of lacustrine and low-energy fluvial sediments, and an upper member containing shallow lacustrine deposits with evaporitic facies (Andreis *et al.*, 1974). The egg-bearing layers described here are located within a lower subunit of the middle member, which comprises fine-grained sandy deposits with subordinate muddy layers and two thin evaporitic levels (figure 1.3). On the basis of sedimentological and lithofacies characters, this lower subunit, which yields vertebrate fossils, is interpreted as reflecting brackish lagoonal and supratidal environments, associated with aeolian sands (dunes) and deposits of ephemeral rivers. Abundant rhizoturbation, termite structures, and caliches in the egg-bearing deposits indicate the presence of palaeosols, which presumably developed in a supratidal environment in close proximity to the coast (Salgado *et al.*, 2007).

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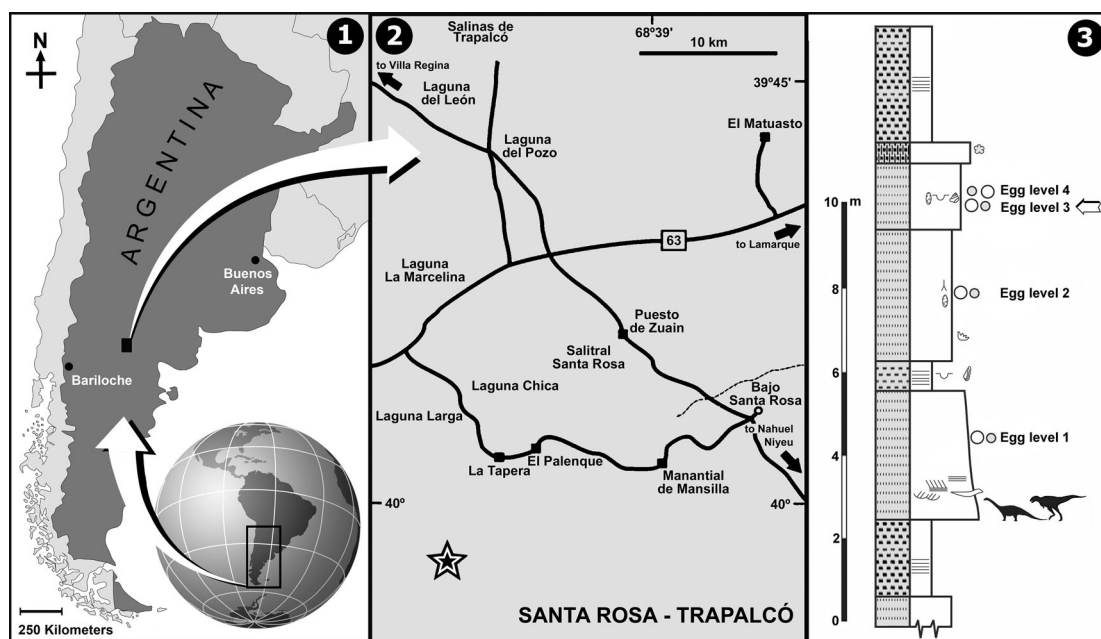


Figure 1. 1, General location map of the fossil site Berthe IV. 2, location of the fossil site Berthe IV within the area of the Bajo Santa Rosa (the spot is marked by the star). 3, simplified geologic section of the site showing the stratigraphical position of the egg-bearing layer 4 (modified from Salgado *et al.*, 2007) / 1, Mapa de localización general del sitio fosilífero Berthe IV. 2, localización del sitio fosilífero Berthe IV dentro del área del Bajo Santa Rosa (sitio indicado por la estrella). 3, perfil geológico simplificado del sitio indicando la posición estratigráfica de la capa portadora de huevos 4 (modificado de Salgado *et al.*, 2007).

Description of the egg-clutches and eggshells

We report the discovery of two different types of egg-clutches found next to one another in the same stratigraphic horizon (figure 2). The specifics of each of these egg-clutches and the morphology of the eggshell are described below.

Type I—Faveloolithid. This clutch is formed by three collapsed eggs, which are possibly the remnants of a larger clutch (the egg-clutch is located at the edge of a hill) (figure 2.2). The eggs are spherical and 18–21 cm in diameter. The three preserved eggs are aligned, although given the fact that these eggs are possibly remnants of a larger clutch, it is impossible to determine if the egg-clutch had any particular spatial arrangement. As in the case of the adjacent megaloolithid egg-clutch, the eggs of the faveloolithid clutch show no indication of being hatched and no evidence of embryos.

The outer surface is sculptured by nodular, sub-polygonal to rounded, non-coalescent structures. The diameter of the nodules varies between 0.32 and 0.80 mm, but more frequently within 0.48 and 0.80 mm (figure 3.1). The thickness of the eggshell varies from 4 to 6 mm (figure 3.2). The pore apertures are sub-circular with an average diameter of 0.16 mm; the pore system is multicanalicate. On the inner surface, the mammillary structures are irregular, with diameters

varying between 0.32 and 0.80 mm, and coalescent in groups of two, three or more. Typically, the shell units are forked with an inner mean diameter of 0.32 mm and outer mean diameter of 0.80 mm. The height of the shell units varies from 4.0 to 4.8 mm. The accretionary lines are arched.

Type II—Megaloolithid. This clutch is roughly 1 meter in diameter and contains 14 sub-spherical eggs, averaging 12–14 cm in diameter (MML-Pv 41, figure 2.1). The eggs do not exhibit any distinguishable spatial arrangement. Given that they are stacked one on top of the other (2–3 layers), the eggs were probably laid in a depression, although unlike some nests from Auca Mahuevo (Chiappe *et al.*, 2004), there is no direct evidence of the nest architecture. The eggs do not appear hatched but examination of a few eggs by mechanical removal of eggshell has failed to reveal any embryonic remains.

The ornamentation of the outer surface is composed of rounded nodules (ranging in diameter from 0.32 to 0.80 mm), a design characteristic of the compactituberculate surface morphology (figure 3.3). The eggshells are thin, with a mean thickness of 1.23 mm (figure 3.4). Pore openings are sub-circular, with diameters averaging 0.16 mm (the pore system is tubocanalicate). The microstructure of the shell units have a fan-like outline, with a outer section ranging in width between 0.64 to 0.8 mm and a inner

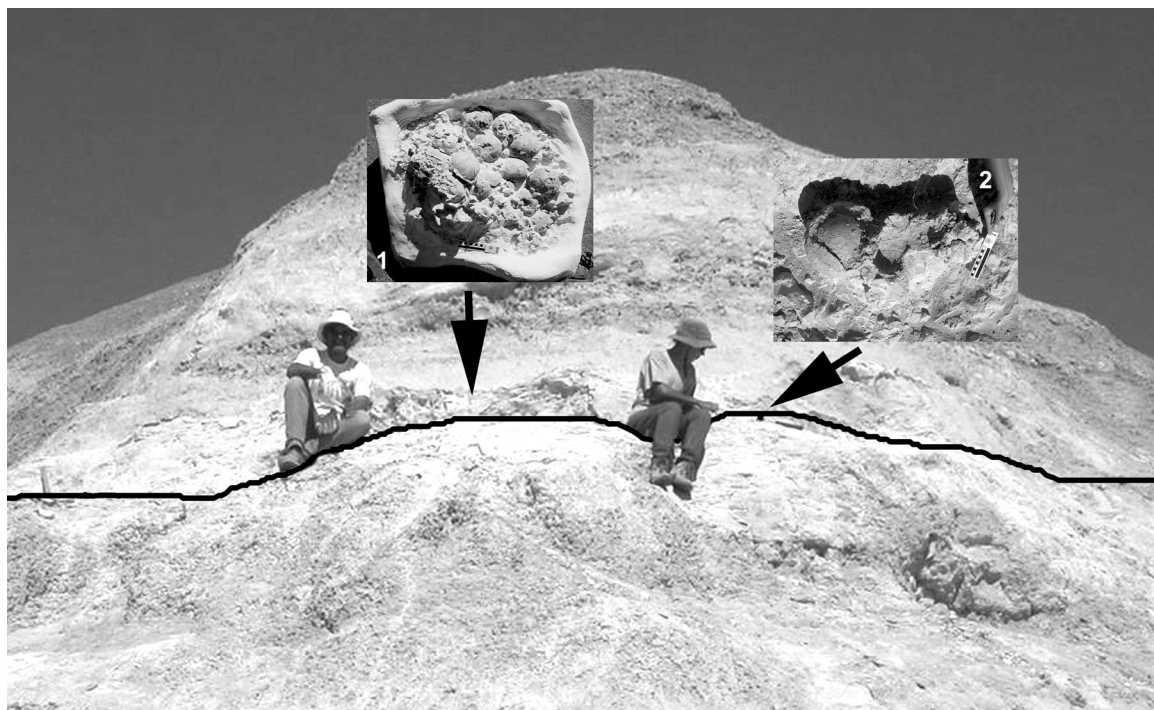


Figure 2. Picture depicting the relative position of the clutches described here. The black line shows the egg-bearing horizon. **1**, Megaloolithidae type egg-clutch MML-Pv 41. **2**, Faveoololithidae type egg-clutch / imagen indicando la posición relativa de las acumulaciones de huevos aquí descritas. La línea negra muestra el horizonte portador de los huevos. **1**, acumulación de huevos tipo Megaloolithidae MML-Pv 41. **2**, acumulación de huevos tipo Faveoololithidae.

width of 0.32 mm. The height of the eggshell unit varies from 0.8 to 1.12 mm. The accretionary lines are arched.

Discussion

The dinosaur nesting sites of the Allen Formation are widely distributed in the Río Negro Province. Although less spectacular than Auca Mahuevo, the Río Negro nesting sites preserve a greater diversity of eggshell types (Salgado *et al.*, 2007): (1) *Megaloolithus patagonicus*, the same type of eggs found at Auca Mahuevo (Chiappe *et al.*, 2005), (2) a second variety of megaloolithid-type egg, (3) faveoololithid eggs, and (4) elongatoolithid eggs (Salgado *et al.*, 2007).

A review of the literature shows that associations of clutches composed of different types of eggs in the same nesting horizon are extremely rare—multispecific associations of dinosaur eggs appear to be largely based on weathered eggshells (*e.g.*, Vianey-Liaud and Crochet, 1993). At Bajo Santa Rosa, not only megaloolithid eggshells are found in association with faveoololithid eggshells but two clutches of different types of eggs have been discovered along side. Although time-averaging—the fact that these two egg-clutches could have been laid in a time span undetectable within the rock record—cannot be entire-

ly ruled out, this evidence suggests that two different dinosaur species nested in proximity to one another. Egg discoveries at Bajo Santa Rosa also provide evidence in support of site fidelity, although this behavior is only evidenced by the multiple occurrences of the same types of eggshells (megaloolithid and faveoololithid) (Salgado *et al.*, 2007).

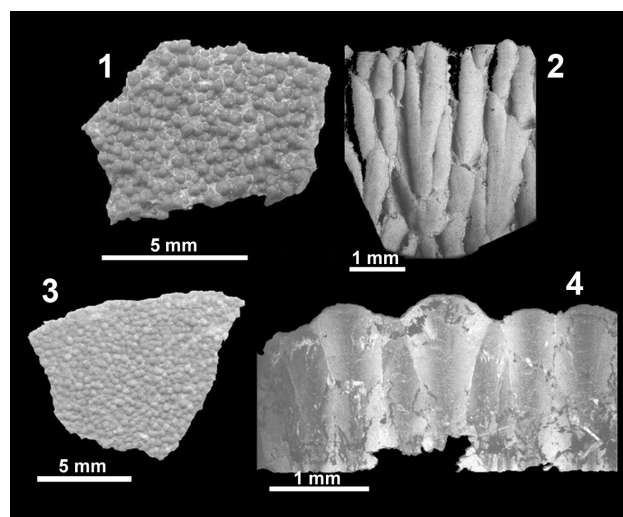


Figure 3. Outer surface and radial thin sections of eggshells of Faveoololithidae type (1, 2) and Megaloolithidae type (3, 4) / superficies externas y cortes delgados radiales de las cáscaras de los huevos tipo Faveoololithidae (1, 2) y Megaloolithidae (3, 4).

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