Zootaxa 3872 (2): 187–194
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

http://dx.doi.org/10.11646/zootaxa.3872.2.5
http://zoobank.org/urn:lsid:zoobank.org:pub:8D1CBBF0-C67E-496B-9757-EEC6CDB66EFD

The first Pan-Podocnemididae turtle egg from the Presidente Prudente Formation (Late Cretaceous, Bauru Group), Brazil

JÚLIO C. DE A. MARSOLA[1,4], GERALD GRELLET-TINNER[2],
FELIPE C. MONTEFELTRO[3] & MAX C. LANGER[1]

[1]*Laboratório de Paleontologia de Ribeirão Preto, FFCLRP, Universidade de São Paulo, Avenida Bandeirantes 3900, Ribeirão Preto, São Paulo, 14040-901, Brazil. E-mail: juliomarsola@gmail.com, mclanger@ffclrp.usp.br*
[2]*Orcas Island Museum, PO Box 134, 181 North Beach Road, Eastsound, WA 98245; Investigador Correspondiente at Departamento de Geociencias, CRILAR, CONICET, Argentina. E-mail: locarnolugano@gmail.com*
[3]*Departamento de Zoologia, Universidade Estadual Paulista, Avenida 24A 1515, Rio Claro, Brazil, felipecmontefeltro@gmail.com*
[4]*Corresponding author. E-mail: juliomarsola@gmail.com. Tel.: +55 16 36023844*

Abstract

Pan-Podocnemididae turtles are ubiquitous in Late Cretaceous rocks of the Bauru Group in southeastern Brazil. This group of side-necked turtles is particularly abundant in a turtle-bearing site of the Presidente Prudente Formation known as Tartaruguito. Here, we describe the first turtle egg (LPRP-USP 0052) from the Tartaruguito site. LPRP-USP 0052 is nearly complete but misses a pole and measures 5,1 and 2,9–2,2 centimeters due to its flattened minor axis. The egg morphology and microstructure were analyzed by observations performed with CT, Optic Microscopy, Scanning Electronic Microscopy and Wave Dispersion Energy analyses. The eggshell ranges from 145 to160 micrometers thick. Considering the matching morphology of the new specimen and its provenance from the stratigraphic horizon that yielded only the podocnemidids *Bauruemys* and *Roxochelys*, it is most likely that LPRP-USP 0052 was produced by a podocnemidid turtle.

Key words: Turtle fossil eggs, *Bauruemys*, *Roxochelys*, Presidente Prudente Formation, Bauru Group

Introduction

The Bauru Group (Late Cretaceous, southeastern Brazil) has a rich record of Pan-Podocnemididae turtles (= Pan-Podocnemidae Joyce *et al*., 2004; Pleurodira, Pelomedusoides, França & Langer, 2006, Candeiro *et al*. 2006; Gaffney *et al*. 2011). The deposits of the Presidente Prudente Formation at the turtle-bearing site called "Tartaruguito" (colloquial fusion of the word tartaruaga, the Portuguese for turtle and the Greek suffix *líthos*), in southwestern São Paulo, Brazil, yielded the most diagnostic remains, which have been assigned to two species: *Roxochelys wanderleyi* and *Bauruemys elegans* (Suárez 2002; Bertini *et al*. 2006; Oliveira & Romano 2007). Previously, the turtle oological record of the Bauru Group was restricted to a single egg from the Adamantina Formation, at Álvares Machado, São Paulo, described by Azevedo *et al*. (2000) and attributed to *Podocnemis* (Pleurodira, Pelomedusoides, Podocnemididae). Here, we describe a fairly complete egg, the first known from the Tartaruguito site, which we refer to a podocnemidid turtle.

Institutional abreviation

LPRP-USP: Laboratório de Paleontologia, Universidade de São Paulo, Ribeirão Preto, Brazil.

Context

Locality. The material was collected in the site informally known as "Tartaruguito" (Bertini *et al*. 2006), located at

Accepted by T.H. Worthy: 19 Sept. 2014; published: 8 Oct. 2014

more abundant pores and a rigid and thicker eggshell, and lack of "caverns". Interestingly, *Bairdemys* is the only podocnemidid known to have nested in marine coastal areas (Winkler & Sánchez-Villagra 2006), contrary to LPRP-USP 0052, which is from a freshwater environment. These ecological preferences probably affected the nesting adaptations of extinct podocnemidids, and could in part explain the variance of their eggshell structures.

Acknowledgments

The authors would like to acknowledge Juliana M. Sayão, João A. Souza Neto and Edvaldo J.P. Santos for their help with SEM and WDS analyses at CTG—UFPE, and also Henrique Trad and Thiago Giacometti for the CT imaging at Central de Diagnósticos Ribeirão Preto. The authors also are grateful to Cláudia Inês da Silva for the help with acquiring images from MO at Laboratório de Palinoecologia (FFCLRP-USP) and Mírian L.A.F. Pacheco and the Laboratório Nacional de Luz Síncronton—LNNano/CNPEM (Project SEM-1667 to FCM) for complementary SEM and EDS analyses. Trevor Worthy, Juliana Sterli and an anonymous reviewer are deeply thanked for their useful suggestions to improve the manuscript. This research is a contribution of the Laboratório de Paleontologia (FFCLRP-USP). JCAM is grateful to Programa de Pós-Graduação em Biologia Comparada, FFCLRP-USP. JCAM and FCM thank Fundação de Amparo Pesquisa do Estado de São Paulo (FAPESP) for the grants provided, respectively in 2010/14797-0 and 2013/11358-3.

References

Azevedo, S.A., Gallo, V. & Ferigolo, J. (2000) A possible chelonian egg from the Brazilian Late Cretaceous. *Anais da Academia Brasileira de Ciências*, 72, 187–193.
http://dx.doi.org/10.1590/s0001-37652000000200007

Batsch, A.J.G.C. (1788) *Versuch einer Anleitung, zur KenntniB und Geschichte der Thiere und Mineralien*. Akademische Buchhandlung, Jena, 528 pp.
http://dx.doi.org/10.5962/bhl.title.79854

Bertini, R.J. Santucci, RM., Toledo, CEV. & Menegazzo, M.C. (2006) Taphonomy and depositional history of an Upper Cretaceous turtle-bearing outcrop from the Adamantina Formatina, Southwestern São Paulo State. *Revista Brasileira de Paleontologia*, 9, 181–186.
http://dx.doi.org/10.4072/rbp.2006.2.01

Board, R.G. (1981) The microstructure of avian eggshells, adaptive significance and practical implications in aviculture. *Wildfowl*, 32, 132–136.

Board, R.G., Perrott, H.R., Love, G. & Seymour, R.S. (1982) A novel pore system in the eggshells of the Mallee fowl, *Leipoa ocellata*. *Journal of Experimental Zoology*, 220, 131–134.

Board, R.G. & Sparks, N.H.C. (1991) Shell structure and formation in avian eggs, *In*: Deeming, D.C. & Ferguson, M.W.J. (Eds.), *Egg incubation: its effects on embryonic development in birds and reptiles*. Cambridge University Press, Cambridge, pp. 53–70.

Booth, D.T. & Thompson, M.B. (1991) A comparison of reptilian eggs with those of megapode birds, *In*: Deeming, D.C. & Ferguson, M.W.J. (Eds.), *Egg incubation: its effects on embryonic development in birds and reptiles*. Cambridge University Press, Cambridge, pp. 325–344.

Bray, E.S. & Hirsch, K.F. (1998) Eggshells from the Upper Jurassic Morrison Formation. *Modern Geology*, 23, 219–240.

Broin, F. de (1988) Les tortues et le Gondwana. Examen des rapports entre le fractionnement du Gondwana et la dispersion gographique des tortues pleurodires partir du Crtac. *Studia Palaeocheloniologica*, 2, 103–142.

Campos, D.A., Oliveira, G.R., Figueiredo, R.G., Riff, D., Azevedo, S.A., Carvalho, L.B. & Kellner, A.W.A. (2011) On a new peirosaurid crocodyliform from the Upper Cretaceous, Bauru Group, southeastern Brazil. *Anais da Academia Brasileira de Ciências*, 83, 317–327.
http://dx.doi.org/10.1590/s0001-37652011000100020

Candeiro, C.R.A., Martinelli, A.G., Avilla, L.S. & Rich, T.H. (2006) Tetrapods from the Upper Cretaceous (Turonian-Maastrichtian) Bauru Group of Brazil: a reappraisal. *Cretaceous Research*, 27, 923–946.
http://dx.doi.org/10.1016/j.cretres.2006.05.002

Cope, E.D. (1865) Third contribution to the herpetology of tropical America. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 1865, 185–198.

de la Fuente, M.S., Sterli, J. & Maniel, I. (2014) South Gondwana pleurodiran turtles, *In*: de la Fuente, M.S., Sterli, J., Maniel, I. (Eds.), *Origin, evolution and biogeographic history of South American turtles*. Springer International Publishing, Switzerland, pp. 53–94.

Dias-Brito, D., Musacchio, E.A., Castro, J.C., Maranhão, M.S.A., Suárez, J.M. & Rodrigues, R. (2001) Grupo Bauru: uma

unidade continental do Cretáceo do Brasil –concepções baseadas em dados micropaleontológicos, isotópicos e estratigráficos. *Revue Paléobiologique*, 20, 245–304.
Fernandes, L.A. (2004) Mapa litoestratigráfico da parte oriental da Bacia Bauru (PR, SP, MG), escala 1:1.000.000. *Boletim Paranaense de Geociências*, 55, 53–66.
Fernandes, L.A. & Coimbra, A.M. (1996) A Bacia Bauru (Cretáceo Superior, Brasil). *Anais da Academia Brasileira de Ciências*, 68, 105–195.
Foote, R.W. (1978) Nesting of *Podocnemis unifilis* (Testudines: Pelomedusidae) in the Colombian Amazon. *Herpetologica*, 34, 333–339.
França, M.A.G. & Langer, M.C. (2006) Phylogenetics relationships of the Bauru Group turtles (Late Cretaceous of the South-central Brazil). *Revista Brasileira de Paleontologia*, 9, 1–9.
Gaffney, E.S., Meylan, P.A., Wood, R.C., Simons, E. & Campos, D.A. (2011) Evolution of the side-necked turtles: the family Podocnemididae. *Bulletin of the American Museum of Natural History*, 350, 1–237.
http://dx.doi.org/10.1206/350.1
Gobbo-Rodrigues, S.R., Coimbra, J.C., Petri, S. & Bertini, R.J. (2003) Kwango Series (Congo), Bauru Group (Brasil) and Neuquén Basin (Argentina) ages, based on ostracodes and vertebrates. *In*: do Carmo, D. (Ed.), *XVIII Congresso Brasileiro de Paleontologia*. Sociedade Brasileira de Paleontologia, Brasília, pp. 152–153.
Grellet-Tinner, G., Chiappe, L.M., Norell, M.A. & Bottjer, D. (2006) Dinosaur eggs and nesting behaviors: A paleobiological investigation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 232, 294–321.
http://dx.doi.org/10.1016/j.palaeo.2005.10.029
Grellet-Tinner, G., Sim, C.M., Kim, D.H., Trimby, P., Higa, A., An, S.L., Oh, H.S., Kim, T. & Kardjilov, N. (2011) Description of the first lithostrotian titanosaur embryo in ovo with Neutron characterization and implications for lithostrotian Aptian migration and dispersion. *Gondwana Research*, 20, 621–629.
http://dx.doi.org/10.1016/j.gr.2011.02.007
Hirsch, K.F. (1983) Contemporary and fossil chelonian eggshells. *Copeia*, 1983, 382–397.
http://dx.doi.org/10.2307/1444381
Hirsch, K.F. (1996) Parataxonomic classification of fossil chelonian and gecko eggs. *Journal of Vertebrate Paleontology*, 16, 752–762.
http://dx.doi.org/10.1080/02724634.1996.10011363
Jackson, F., Jin, X., Varricchio, D.J., Azuma, Y. & Jiang, Y. (2008) The first in situ turtle clutch from the Cretaceous Tiantai Basin, Zhejiang Province, China. *Journal of Vertebrate Paleontology*, 28, 319–323.
http://dx.doi.org/10.1671/0272-4634(2008)28[319:tfistc]2.0.co;2
Joyce, W.G., Parham, J.F. & Gauthier, J.A. (2004) Developing a protocol for the conversion of rank-based taxon namesto phylogenetically defined clade names, as exemplified by turtles. *Journal of Vertebrate Paleontology*, 78 (5), 989–1013.
http://dx.doi.org/10.1666/0022-3360(2004)078<0989:dapftc>2.0.co;2
Ketcham, R.A. & Carlson, W.D. (2001) Acquisition, optimization and interpretation of X-ray computed tomographic imagery: applications to the geosciences. *Computers & Geosciences*, 27, 381–400.
http://dx.doi.org/10.1016/s0098-3004(00)00116-3
Knell, M.J., Jackson, F., Titus, A.L. & Albright III, L.B. (2011) A gravid fossil turtle from the Upper Cretaceous (Campanian) Kaiparowits Formation, southern Utah. *Historical Biology*, 23, 57–62.
http://dx.doi.org/10.1080/08912963.2010.499167
Kohring, R. (1999) Structure, biostratinomy and systematic and phylogenetic relevance of egg shells of vertebrate amniotes. *Courier Forschungsinstitut Senckenberg*, 210, 1–307, A1–A6.
Marsola, J.C.A., Grellet-Tinner, G., Montefeltro, F.C., Sayão, J.M., Hsiou, A.S. & Langer, M.C. (2014) The first fossil avian egg from Brazil. *Alcheringa*, 38. [published online]
http://dx.doi.org/10.1080/03115518.2014.926449
Oliveira, G.R. & Romano, P.S.R. (2007) Histórico dos achados de tartarugas fósseis do Brasil. *Arquivos do Museu Nacional*, 65, 113–133.
Packard, G.C. & Packard, M.J. (1988) The physiological ecology of reptilian eggs and embryos. *In*: Gans, C. & Huey, R.B. (Eds), *Biology of the Reptilia: Ecology (B) - Defense and life history. Vol. 16*. Branta Books, New York, pp. 387–438.
Quinn, B. (1994) Laboratory preparation. Fossilized eggshell preparation. *In*: Leiggi, P. & May, P. (Eds.), *Vertebrate paleontological techniques*. Cambridge University Press, Cambridge, pp. 146–154.
Romano, P.S.R., Oliveira, G.R., Azevedo, S.A., Kellner, A.W.A. & Campos, D.A. (2013) New Information about Pelomedusoides (Testudines: Pleurodira) from the Cretaceous of Brazil. *In*: Brinkman, D.B., Holroyd, P.A., Gardner, J. D. (Eds.), *Morphology and Evolution of Turtles* - Vertebrate Paleobiology and Paleoanthropology Book Series. Springer, Dordrecht, pp. 261–275.
Santucci, R.M. & Bertini, R.J. (2001) Distribuição paleogeográfica e biocronológica dos titanossauros (Saurischia, Sauropoda) do Grupo Bauru, Cretáceo Superior do sudeste brasileiro. *Revista Brasileira de Geociências*, 31, 307–314.
Schleich, H.H. & Kästle, W. (1988) *Reptile egg-shells SEM atlas*. Gustav-Fischer Verlag, Stuttgart, 128 pp.
Schleich, H.H., Kästle, M. & Groessens-van Dyck, M. (1988) Paläogene Eischalenreste von Hainin (Belgien). *Palaontologie Zeitschrift*, 62,133–146.
http://dx.doi.org/10.1007/bf02989839

Soares, P.C., Landim, P.M. B., Fulfaro, V.J. & Sobreiro Neto, A.F. (1980) Ensaio de caracterização do Cretáceo no Estado de São Paulo: Grupo Bauru. *Revista Brasileira de Geociências*, 10, 177–185.

Suárez, J.M. (1969) Um quelônio da Formação Bauru. *Anais do XXIII Congresso Brasileiro de Geologia*. 167–176.

Suárez, J.M. (2002) Sítio Fossilífero de Pirapozinho, SP. Extraordinário depósito de quelônios do Cretáceo. *In*: Schobbenhaus, C.C., Queiroz, E.T., Winge, M., Berbert-Born, M.L.C. (Eds), *Sítios Geológicos e Paleontológicos do Brasil, Comissão Brasileira de Sítios Geológicos e Paleobiológicos (SIGEP)*. DNPM/CPRM, Brasília, 49–54.

Wang, Q., Wang, X., Zhao, Z., Zhang, J. & Jiang, S. (2013) New turtle egg fossil from the Upper Cretaceous of the Laiyang Baisn, Shandong Province, China. *Anais da Academia Brasileira de Ciências*, 85 (1), 103–111.

Williams, E.E. (1956) *Podocnemis bassleri*, a new species of Pelomedusid turtle from the Late Tertiary of Peru. *American Museum Novitates*, 1782, 1–10.

Winkler, J.D. (2006) Testing phylogenetic implications of eggshell characters in side-necked turtles (Testudines: Pleurodira). *Zoology*, 109, 127–136.
http://dx.doi.org/10.1016/j.zool.2005.12.003

Winkler, J.D. & Sánchez-Villagra, M.R. (2006) A nesting site and egg morphology of a Miocene turtle from Urumaco, Venezuela: Evidence of marine adaptations in Pelomedusoides. *Palaeontology*, 49, 641–646.
http://dx.doi.org/10.1111/j.1475-4983.2006.00557.x

Young, J.D. (1950) The structure and physical properties of the testudinian eggshell. *Proceedings of the Zoological Society of London*, 120, 455–469.
http://dx.doi.org/10.1111/j.1096-3642.1950.tb00656.x

Zaher, H., Pol, D., Carvalho, A.B., Riccomini, C., Campos, D.A. & Nava, W.R. (2006) Redescription of the cranial morphology of *Mariliasuchus amarali*, and its phylogenetic affinities (Crocodyliformes, Notosuchia). *American Museum Novitates*, 3512, 1–40.
http://dx.doi.org/10.1206/0003-0082(2006)3512[1:ROTCMO]2.0.CO;2