A COMPLETE CROCODYLIAN EGG FROM THE UPPER MIOCENE (CHINJI BEDS) OF PAKISTAN AND ITS PALAEOBIOGRAPHICAL IMPLICATIONS

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Panadès I Blas, X. & R. Patnaik. 2009. A Complete Crocodylian Egg from the Upper Miocene (Chinji Beds) of Pakistan and its Palaeobiographical Implications. – Palarch's Journal of Vertebrate Palaeontology 6(1) (2009), 1-8. ISSN 1567-2158. 8 pages + 7 figures, 1 table.

Keywords: crocodylians – eggshells – egg – Pakistan – Palaeooölogy – palaeooöspecies

ABSTRACT

The first fossil crocodylian egg from the Upper Miocene the Chinji Formation of the Siwalik Group of Pakistan is reported here. It represents a new locality, and the first record of the order in the area. The specimen was uncovered in a fluvial environment, and cannot be defined more accurately, because of the poor preservation of its structural levels, and lack of direct association to osseous remains.

Introduction

The first fossil crocodile egg from the Upper Miocene of Pakistan is reported here. It was recently discovered in the collections at the Museum of the Department of Earth Sciences at the University of Bristol, England (EC). The specimen was likely acquired by Prof. B. Savage when he was carrying out field work in that area in the 1980s.

Crocodile eggshells have already been found in the area: in the Upper Siwalik of Saketi and Moginand along the Markanda River in Himachal Pradesh (India) (Patnaik & Schleich (1993), and the Malabar Hill and the Worli Hill beds (intertrappean) near Bombay (India) (Singh *et al.*, 1998). Intertrappean beds are freshwater as well as marine fine grained sediments deposited in the peninsular part of India between Deccan basalt trapps of Late Cretaceous age (Bajpai & Prasad, 2000). Our specimen apparently came from the Siwalik molasse of Himalayan foothills, which were deposited between the Middle Miocene (˜ 18 Ma) to Middle Pleistocene (˜.2 Ma) time. This is based on the fact that the rocks exposed around Uchhri (the locality mentioned on the specimen) belong to the Siwalik group and no other rock formation such as Intertrappeans are known from this region. Furthermore, the fine clayey silt attached to the egg also indicates that the egg came from the Siwalik deposits. However, we are not absolutely certain about its original provenance, as we do not have any other supporting evidence.

This paper aims to appraise the parataxonomic position of the egg, and its palaeobiographical and palaeoenvironmental implications.

Institutional abbreviations

BRSUG, The University of Bristol's Geology Museum, Bristol, England (EC).

Geographical and Geological setting

The egg has written on its eggshell layer "Dhok Yakoob (Uchhri)" (figure 1). This is probably a hamlet too small to be depicted on a map (John C. Barry, Ashok Sahni, Michael A. Cremo, Bursz, personal communications). Uchhri is located in the Salt Range on the Potwar Plateau of northern Pakistan (Latitude 33° 22' 0N, Longitude, 71° 55' 0N) close to the Indus River, and is the southern-most part of a triangle with Islamabab and Peshawar (figure 2).

Available museum information states that the egg was recovered from the Upper Miocene of the Chinji Formation of the Siwalik Group, which is exposed near Uchhri in the Potwar Plateau of northern Pakistan (figure 2, see Badgley *et al.*, 1998). Siwalik molasse deposits were formed in a sinking foreland basin all along the southern margin of the rising Himalayas from Pakistan in the west to Myanmar in the east (Willis & Behrensmeyer, 1995). Shah (1977) and Willis (1993) documented the lateral and vertical variation in sedimentary facies of the Siwalik sediments of the Potwar Plateau. These sedimentary rocks, deposited in a variety of fluvial regimes, provide a continuous record of detritus, shed from the Himalaya uplift from early Miocene time onward (Gill, 1952; Johnson *et al.*, 1982, 1985; Opdyke *et al.*, 1979). Sedimentary units comprising the Siwalik Group, in ascending order, include the Kamlial, Chinji, Nagri, Dhok Pathan and Upper Siwalik Formations (Hussain *et al.*, 1979; Johnson *et al.*, 1982, 1985).

Figure 1. Lateral view of the fossil crocodilian egg BRSUG 26834, from the Upper Miocene of the Chinji Formation of the Siwalik group of Dhok Yakoob (Uchhri, Pakistan). Note the heavy compaction producing lateral compression, and name of the locality where the egg was uncovered written on the eggshell's surface. Scale bar in mm. Photograph by X. Panadès I Blas.

Figure 2. Map of Pakistan showing Uchhri, the locality of the Upper Miocene, Chinji Beds on the Pot war Plateau (NW Pot war, Punjab, Pakistan) where the egg was uncovered. Figure by R. Patnaik.

Early studies relied heavily on faunal correlation for dating the Siwalik Group (Pilgrim, 1913; Colbert, 1935). However, magnetic polarity stratigraphy analyses (Keller *et al*., 1977; Opdyke *et al*., 1979) and radiometric dates (Johnson *et al*., 1982) have substantially improved these age estimates. Cheema *et al*. (1977) established the age of the Chinji Formation based on lithostratigraphy, as from the Miocene age, ranging from 14.2 to 11.2 Ma, although, Johnson *et al*. (1982, 1985), dated the formation as middle to lower Upper Miocene, from 14.5 to 10.5 Ma.

The Chinji Formation represents multi-storeyed grey sandstones interpreted as the major trunk channel of a braided fluvial system similar to that of the present day Indus River (Willis, 1993b). These sandstones are separated by thick maroon and red-brown mudstones, often showing signs of pedogenesis, such as presence of bright red paleosols with scattered calcareous nodules and root traces (Retallack, 1991; Behrensmeyer *et al*., 1995).

Methods

Two eggshell fragments were studied and sectioned, one from the egg's equator and one from one of the poles, and were used to test the variation of eggshell thickness among the egg. Standard palaeooölogical methods suggested by Carpenter (1999) to analyse the material parataxonomically, and digital measuring from transverse/tangential or horizontal and radial or vertical pictures of petrographic thin sections were applied (Panadès I Blas, 2005). No chemical cleansing was applied, to avoid damaging the meagre eggshell material. Unfortunately, neither CAT-scan nor x-ray sessions to visualise any possible embryonic remains inside the egg could be arranged, nor could a sample from its sediment to extract further palaeobiostratigraphic information be taken.

SYSTEMATIC PALAEONTOLOGY

Order Archosauria Cope, 1869
Eusuchia Huxley, 1875
Crocodylia Laurenti, 1768

Family indeterminate

Locality – Dhok Yakoob near Uchhri, the Salt Range on the Potwar Plateau (NW Potwar, Punjab, Pakistan) (figure 2).

Stratigraphic Range – Chinji Beds, Upper Miocene.

Material – BRSUG 26834 is a partial large, black, elliptical egg (˜45-55% complete), which preserves both poles. It is embedded in very fine clayey silt (which easily crumbles), and exhibits lateral compaction producing long pronounced cracks. This compaction resulted in deformation, and therefore two different lateral widths, 84 x 64 x 54 mm (figure 1 and 3).

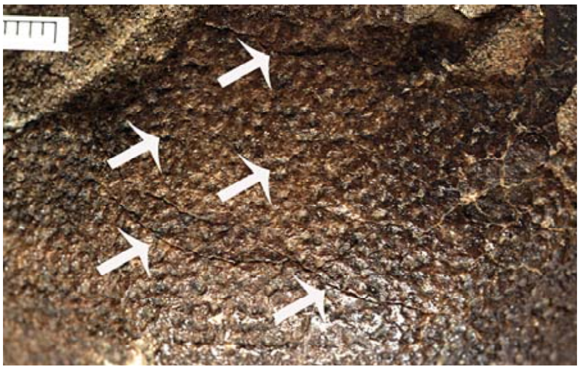

Figure 3. Enlarged view of the surface of BRSUG 26834 displaying cracks, smooth and patchy surfaces, and craters containing pores (arrows). Scale bar in mm. Photograph by X. Panadès I Blas.

Inner and outer surfaces - Both surfaces are heavily eroded, displaying small patches that are irregular and smooth in places, as well as twisted deep interstices, undulations without apparent bulging, and crater-like dimples. These crater-like dimples are very similar to those produced by extrinsic degradation observed by Ferguson in alligator eggs (1981). In fact, the three basal plate groups and radiating wedges of the three basal knobs in the inner surface are absent, apparently dissolved (figure 4 and 5).

Radial View – The eggshell thickness ranges 0.18-0.76 mm. It is built by a single spherulitic crystal layer of chunky units with irregular rounded bulky ends, which are appressed against each other. These units are constructed by large irregular wedge-like crystals growing to the sides towards the top of the eggshell from a basal plate group (figure 6). Prominent accretion lines (tabular structure) extend from the top of the basal knob up to the outer eggshell. This differs in the basal portion of the eggshell, where they exhibit a wavy or fluted appearance and become increasingly horizontal in the upper 2/3 of the eggshell, unlike *Krokolithus wilsoni* and *Krokolithus helleri* (Hirsch, 1985). Polarised light micrographs of thin sections in radial view, captures abrupt rather than sweeping extinction pattern (figure 6).

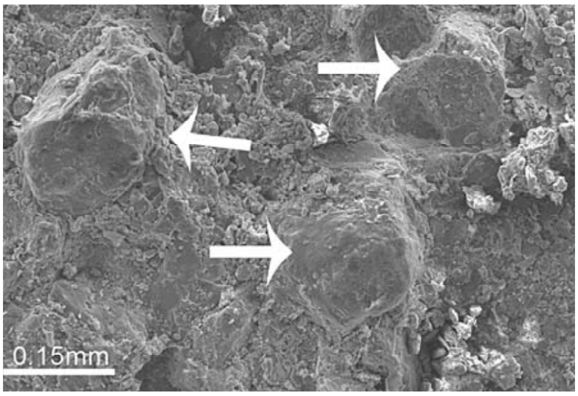

Figure 4. Scanning electron micrograph in inner surface view of BRSUG 26834, illustrating three bared basal knobs (arrows) for which their basal plate groups and radiating wedges of have completely been eroded. Photograph by X. Panadès I Blas.

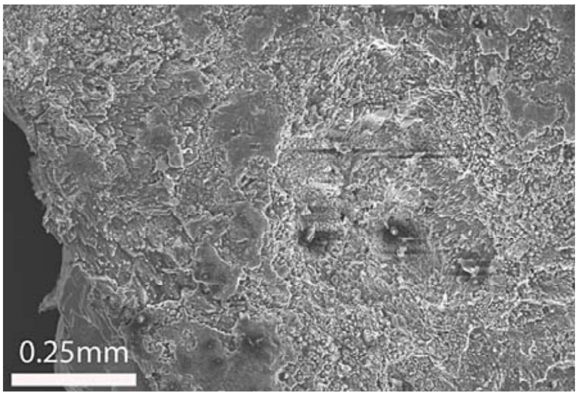

Figure 5. Scanning electron micrograph in outer surface view of BRSUG 26834, showing small patches, twisted deep interstices, and undulations. Photograph by X. Panadès I Blas.

Transverse view – Even though pore canals were not observed in the radial view, ellipsoid openings appearing in the transverse sections, indicate that pore canals were likely to be vertically sub-rounded and straight. Otherwise, longer and narrower openings would have indicated horizontal, oblique, or branching canal shapes (figure 7).

Diagnoses – BRSUG 26834 was laid by a crocodylian because it shares the same structural levels of palaeooölogical and modern crocodylian oospecies. The egg conclusively exhibits the crocodiloid morphotype: discrete, large, adpressed units, built up by rough crystal wedges, with rounded ends, forming a single spherulitic crystal layer. However, lack of direct osseous association with the specimen prevents to affiliate it to a specific crocodylian species.

BRSUG 26834's elliptical shape corresponds with that of modern and fossil palaeooölogical crocodylian oospecies. Its dimensions, 84 x 64 x

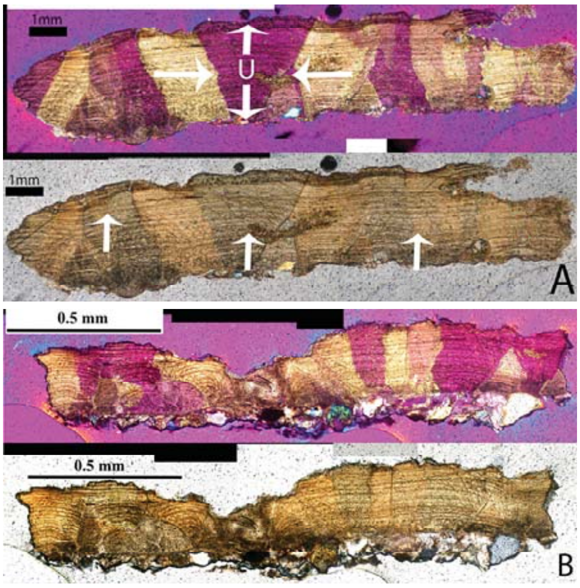

Figure 6. Polarised and light micrographs of a thin section in radial view of BRSUG 26834. Note the chunky units built of large irregular wedge-like crystals, appressing against each other and the accretion lines scattered from the top of the basal knobs to the outer shell (arrows). A and B. Polarised and light micrographs of thin sections in radial view of eggshells from the egg's equator A and a pole B. Units in the equator are much wider units and higher than in the pole. U, unit. Photograph by X. Panadès I Blas.

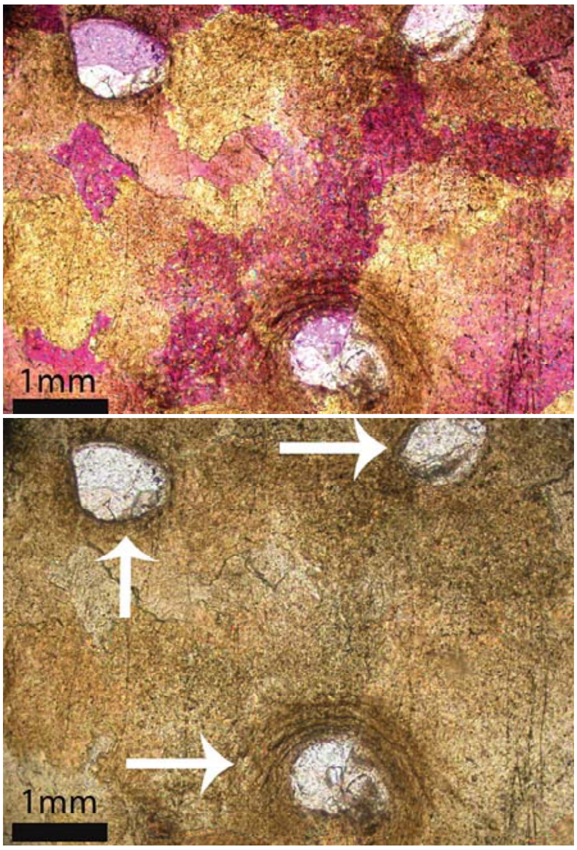

Figure 7. Polarised and light micrographs of a thin section in transverse-view of BRSUG 26834, displaying the circular piercing (arrows) suggesting vertical and surrounded pore canals. Photograph by X. Panadès I Blas.

Egg source	Size (mm)	Thickness (mm)	References
Modern Crocodiles:			
Crocodylus porosus	77 × 52	0.53	(Deeming and Ferguson,1990)
Crocodylus novaeguinae	76 × 43	?	(Deeming and Ferguson,1990)
Crocodylus palustris	75 × 46	?	(Deeming and Ferguson,1990)
Alligator sinensis	68 × 34	?	(Deeming and Ferguson,1990)
Caiman crocodylus crocodylus	65 × 40	?	(Deeming and Ferguson,1990)
Caiman crocodylus yacare	68 × 42	?	(Deeming and Ferguson,1990)
Paleosuchus palpebrosus	66 × 42	?	(Deeming and Ferguson,1990)
Osteolemus tratraspis tretaspis	63 × 37	?	(Deeming and Ferguson,1990)
Caiman latirostris	66 × 46	?	Deeming and Ferguson, 1990)
Crocodylus niloticus	74 × 43	0.58	Deeming and Ferguson, 1990)
Crocodylus johnstoni	66 × 42	0.40	Deeming and Ferguson, 1990)
Alligator mississippiensis	74 × 43	0.51-0.53	Deeming and Ferguson, 1990)
Crocodylus acutus	77 × 48	0.45-0.52	Hirsch &Kohring (1992)
Gavialis gangeticus	82 × 56	0.3-0.59	Ferguson, (1985) and Schleich *et al.* (1994)
Fossil Crocodylian:			
Upper Jurasic-Pai Pai Mogo	eggs	0.3	Antunes *et al.*, (1998)
U. Cret.-France	fragments	0.64	Kerourio (1987)
U. Cret. of Argentina	?	?	Frenguelli (1951)
U. Cret. Montana (USA)	fragments	?	Hirsch and Quinn (1990)
L. Cret. of Morocco	30 × 45	0.45	Garcia et al. (2003)
L. Cret. of Brazil-Araçatuba Fm	fragments	0.15-0.4	Magalhães *et al.*,(2003)
L. Cret. Purbeck Limestone Group-England	fragments	?	Ensom, (1997 and 2002)
L. Cret.-Iberian Peni.	fragments	0.5-0.7	Kohring (1990)
L. Cret.-Malabar Hill section-India	fragments	0.35	Singh *et al.* (1998)
L. Cret. Glen Rose Formation-USA	49 × 28	0.6-0.7	Rogers, (2000)
L. Miocene of Ulm-Germany	fragments	?	Khoring (1992)
Eocene Soft Cold beds Geiseltal-Germany	eggshells	?	Khoring and Hirsch (1996)
Eocene-DeBeque Fm-USA	eggshells	?	Leggitt *et al.*, (2000)
Eocene-DeBeque Fm.-USA	50 × 30	0.25-0.45	Hirsch (1985)
Eocene-Bridger Fm.-USA	fragments	0.76	Hirsch &Kohring (1992)
Eocene DeBeque Formation colorado-USA	68 × 44	?	Hirsch (1985)
Eocene-Murgon Fm.-Australia	fragments	?	Panadès and Godthelp (in prep.)
Miocene- Chinji Beds-Pakistan	fragments	0.15-0.75	Panadès (in press)
Pliocene Silwalik Sequs.-India	64 x 54 x 84	1.9-6.6	Patnaik & Schleich (1993)

Table 1. Egg dimensions and eggshell thickness of fossil and modern eggs.

54 mm, are closer to the eggs of *G. gangeticus* (Singh, 1978: 60, fig. 22) which measure 82.2 x 56.5 mm (Ferguson, 1985), and 86.6 x 56.7 mm (Singh, 1978). It is slightly bigger than eggs from other extant oospecies. Its dimensions are also greater than the Eocene fossil eggs *Krokolithus wilsoni* from the DeBeque Formation (USA) (68 x 40 mm) (Hirsch, 1985), and *Krokolithus helleri* (63 x 35 mm) from the Geiseltal Quarry (Germany) (table 1) (Kohring & Hirsch, 1996).

The eggshell thickness range (0.10-0.75 mm) is similar to modern and fossil palaeooöspecies (0.3-0.59 mm), *G.* cf. *gangeticus* (0.19-0.66mm), and the Krokodiliae oofamily (0.25-0.76 mm) and extant oospecies (0.40-0.65 mm) (Hirsch & Khoring, 1992; Patnaik & Schleich, 1993; Schleich *et al.*, 1994). It also exhibits the same morphometric variability of *G. gangeticus,* thicker in the equator (0.67-0.76 mm) than in the poles (0.18-0.31 mm) (figures 6A and B) (Schleich *et al.*, 1994) (see table 1).

Consequently, units in the equators are also wider, nearly exceeding the height (0.60-0.75 mm). In the poles the units are more tapered (figures 6A and B). It is unclear if these morphometric similarities can be used as a character in phylogenetic analysis. It would be necessary to run further biostatistical comparative analyses among eggs from clutches of fossil and modern crocodylian oospecies to test whether the rest of crocodylian oospecies share the same morphometric variability of *G. gangeticus.*

Palaeobiographical Conclusions

The very fine clayey silt suggests that the egg was deposited on a sandy overbank on a fluvial environment like a river or lake. Such a palaeoenvironment has already been described in other localities of the same area, and belongs to the Upper Miocene of the Chinji Formation of the Siwalik Group (Badgley *et al.*, 1998). Dhok Yakoob represents a new Upper Miocene locality of the Chinji formation of the Siwalik group, and though a crocodilian body fossil has not been found, this egg adds a new faunistic element to the palaeoecosytem of the region at this time.

Acknowledgements

We thank Brian Beatty for his help and the four anonymous referees provided for by the PalArch Foundation for their useful comments on the paper. Special thanks to Liz Loeffler, Mike Benton, Simon Powell and Stuart Kearns from the University of Bristol, England (EC), for granting us access to the fossil crocodile egg, use the local laboratories at the Department of Earth Sciences at the University of Bristol, helping us to use the Scanning Electron Microscope, and taking the pictures of the egg; and Saad Khan (Swiss Pakistan Society, Switzerland), John C. Barry (Harvard University, USA), Jason Head (University of Toronto at Mississauga), Ashok Sahni, Michael A. Cremo (Bhaktivedanta Institute, USA), and Kleo Pullin (USA), for providing us with vital geological and cultural knowledge about the area and the locality. Chris Brochu (University of Iowa, USA) for helping us to understand the palaeobiography of Siwaliks crocodylians. Rajeev Patnaik would like to thank DST, New Delhi for the ongoing project on the Siwaliks (SR/S4/ES-171/2005).

Cited literature

Antunes, M.T., P.V. Taquet & V. Ribeiro. 1998. Upper Jurassic dinosaur and crocodile eggs from Pai Mogo nesting site (Lourinhã -Portugal.). – Memórias da Academia das Ciências de Lisboa, Classe Ciências 37: 83-99.

Badgley, C., W. Downs & L.J. Flynn. 1998. Taphonomy of small mammal fossil assemblages from the middle Miocene Chinji Formation, Siwalik Group, Pakistan. In: **Tomida, Y., L.J. Flynn & L.L. Jacobs. Eds. 1998.** Advances in vertebrate paleontology and geochronology in honor of Everett H. Lindsay. – Tokyo, National Science Museum (National Science Museum Monograph 14): 145-166.

Bajpai, S. & G.V.R. Prasad. 2000. Cretaceous age for Ir-rich Deccan intertrappean deposits: palaeontological evidence from Anjar, western India. – Journal of the Geological Society 157, 2: 257-260.

Behrensmeyer, A.K., B.J. Willis & J. Quade. 1995. Floodplains and paleosols of Pakistan Neogene and Wyoming Paleogene deposits. A comparative study. – Palaeogeography, Palaeoecology, Palaeoclimatology 115: 37-60.

Carpenter, K. 1999. How to study a fossil egg. In: **Carpenter, K. Ed. 1999.** Eggs, nests, and baby dinosaurs. A look at dinosaur reproduction (life of the past). – Indiana, Indiana University Express: 123-144.

Cheema, M.R., S.M. Raza & H. Ahmed. 1977. Cainozoic. In: **Shah, S.M.I. Ed. 1977.** Stratigraphy of Pakistan. – Quetta, Geological Survey of Pakistan (Memoirs 12): 56-98.

Colbert, E.H. 1935. Siwalik mammals in the American Museum of Natural History. – Philadelphia, American Philosophical Society (Transactions 26).

Deeming, D.C. & M.J.W. Ferguson. 1990. Methods for the determination of the physical characteristics of eggs of *Alligator mississippiensis*. A comparison with other crocodylian and avian eggs. – Herpetologica 1: 458-462.

Ensom, P.C. 1997. Reptile eggshell from the Purbeck Limestone Group of Dorset, southern England. – Proceedings of Dorset Natural History and Archaeological Society, for 1996, 118: 79-83.

Ensom, P.C. 2002. Reptile eggshell, tiny vertebrate remains and globular calcified cartilage from the Purbeck Limestone Group of Southern England. – Special Papers in Palaeontology 68: 221-239.

Ferguson, M.W.J. 1981. Extrinsic microbial degradation of the alligator eggshell. – Science 214: 1135-1137.

Ferguson, M.W.J. 1985. The reproductive biology and embryology of crocodylians. In: **Gans, C., F. Billet & P.F.A. Maderson. Eds. 1985.** Biology of the Reptilia. – New York, John Wiley: 329-491.

Frenguelli, J. 1951. Un huevo fosil del Rocanense. – Revista de la Asociación Geológica Argentina 6, 2: 108-112.

Garcia, G., R. Tabuce, H. Cappetta, B. Marandat, I. Bentaleb, A. Benabdallah & M. Vianey-Liaud. 2003. First record of dinosaur eggshells and teeth from the North-West African Maastrichtian (Morocco). – Palaeovertebrata 32: 59-69.

Gill, W.D. 1952. The stratigraphy of the Siwalik Series in the northern Potwar Plateau, Punjab, Pakistan. – Quarterly Journal of the Geological Society of London 107: 375-394.

Hirsch, K.F. 1985. Fossil crocodylian eggs from the Eocene of Colorado. – Journal of Palaeontology 59: 531-542.

Hirsch, K.F. & B. Quinn. 1990. Eggs and eggshell fragments from the Upper Cretaceous Two Medicine Formation of Montana. – Journal of Palaeontology 10: 405-419.

Hirsch, K.F. & R. Kohring. 1992. Crocodylian eggs from the Middle Eocene Bridger Formation, Wyoming. – Journal of Palaeontology 12: 59-65.

Hussain, S.T., J. Munthe, S.M.I. Shah, R.M.I. West & J.R. Lukas. 1979. Neogene stratigraphy and fossil vertebrates of the Daud Khel area, Mianwali district, Pakistan. – Quetta, Geological Survey of Pakistan (Memoirs 13): 1-27.

Johnson, N.M., N.D. Opdyke, G.D. Johnson, E.H. Lindsay & R.A.K. Tahirkheli. 1982. Magnetic polarity stratigraphy and ages of Siwalik Group rocks of the Potwar Plateau, Pakistan. – Palaeogeography, Palaeoecology, Palaeoclimatology 37: 17-42.

Johnson, N.M., J. Stix, L. Tauxe, P.F. Cerveny, R.A.K. Tahirkheli. 1985. Paleomagnetic chronology, fluvial processes, and tectonic implications of the Siwalik deposits near Chinji village, Pakistan. – Journal of Geology 93: 27-40.

Keller, H.M., R.A.K. Tahirkheli, M.A. Mirza, N.D. Opdyke. 1977. Magnetic polarity stratigraphy of the Upper Siwalik deposits, Pabbi Hills, Pakistan. – Earth and Planetary Science Letters 36: 187 -201.

Kerourio, P. 1987. Presence d'oeufs de crocodylians dans le Rognacien inferieur (Maastrichtie superieur) du basin d'Aix-en-Provence (Bouches-du-Rhone, France). Note preliminaire. – Geobios 20: 275-281.

Kohring, R. 1990. Fossil reptile eggshells (Cheloni, Crocodilia, Dinosauria) from Lower Barremian of Galve (Provinz of Teruel SE of Spain). – Palaontologische Zeitschrift 64: 392-324.

Kohring, R. 1992. Fossile Krokodil-eischalen aus der Unteren Susswasser-Molasse (Untermiozan) von Ulm (Ulm-Westtangente, Baden-Wuttemberg). – Stuttgarter Beitrage zur Naturkunde, Series B, 187: 1-10.

Kohring, R. & K.F. Hirsch. 1996. Crocodylian and avian eggshells from the Middle Eocene of the Geiseltal, Eastern Germany. – Journal of Vertebrate Paleontology 16, 1: 67-80.

Leggitt, V.L. & M.A. Loewen. 2000. A dense concentration of crocodylian eggshell fragments. Eocene DeBeque Formation, northwestern Colorado. – Journal of Vertebrate Paleontology 20, 3: 53-54A.

Magalhães Ribeiro, C.M., I.S. Carvalho & W.R. Nava. 2003. Crocodilomorph eggs from the Araçatuba Formation (Bauru Basin, Upper Cretaceous), Brazil. In: **Gallo, V., P.M. Brito, H.M.A. Silva & F.J. Figueiredo. Eds. 2003.** Simpósio Brasileiro de Paleontologia de Vertebrados, 3, UERJ, Rio de Janeiro, 2003. Livro de Resumos. – Rio de Janeiro, UERJ: 48.

Mikhailov, K.E. 1991. Classification of fossil eggshells of Amniotic vertebrates. – Acta Palaeontologica Polonica 36, 2: 193-238.

Opdyke, N.D., E. Lindsay, G.D. Johnson, N. Johnson, R.A.K. Tahirkheli & M.A. Mirza. 1979. Magnetic polarity stratigraphy and vertebrate paleontology of the Upper Siwalik Subgroup of northern Pakistan. – Palaeogeography, Palaeoclimatology, Palaeoecology 27: 1-34.

Panadès I Blas, X. 2005. Diversity versus variability in Megaloolithid dinosaur eggshells. – PalArch's Journal of Vertebrate Palaeontology 2, 1: 1-15 [online at www.PalArch.nl].

Patnaik, R. & H.H. Schleich. 1993. Fossil crocodile from the Upper Siwaliks of India. – Mitteilungen der Bayerischen Staatssammlung fur Palaeontology und Historische Geologie 33: 91-117.

Pilgrim, G.E. 1913. Correlation of the Siwalik with mammal horizons of Europe. – Records of the Geological Survey of India 43: 4.

Retallack, G.J. 1991. Miocene paleosols and ape habitat of Pakistan and Kenya. – Oxford, Oxford University Press (Oxford Monographs on Geology and Geophysics 19).

Rogers, J.V. 2000. A complete crocodiloid egg from the Lower Cretaceous (Albian) Glen Rose Formation, central Texas. – Journal of Vertebrate Paleontology 20, 4: 780-783.

Schleich, H.H., P. Gassner & T.M. Maskey. 1994. Ultrastrukturen und Variabilität der Eischalen von *Gavialis gangeticus* (Gmelin 1789). (Crocodylia, Gavialidae). – Courier Forschungsinstitut Senckenberg 173: 299-313.

Shah, S.M.I. 1977. Stratigraphy of Pakistan. – Quetta, Geological Survey of Pakistan (Memoirs 12).

Singh, L.A.K. 1978. Ecological Studies on the Indian Gharial *Gavialis gangeticus* (Gmelin) (Reptilia, Crocodilia). – PhD Thesis, Utkal University, Bhubaneswar, Orissa, India.

Singh, S.D., A. Sahni, E.S. Gaffney & H.H. Schleich. 1998. Reptilia from the Intertrappean Beds of Bombay (India). – Veroffentlichungen aus dem Fuhlrott-Museum 4: 307-320.

Willis, B.J. 1993. Ancient river systems in the Himalayan Foredeep, Chinji Village area, northern Pakistan. – Sedimentary Geology 88: 1-76.

Willis, B.J. & A.K. Behrensmeyer. 1995. Architecture of Miocene overbank deposits in northern Pakistan. – Journal of Sedimentary Research 65, 3b: 401-407.

Submitted: 17 October 2008
Published: 5 May 2009