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EARTH SCIENCES
RESEARCH JOURNAL

Earth Sci. Res. J. Vol. 13, No.1 (June 2009): 6-15

VERTEBRATES OF THE MARÍLIA FORMATION (LATE MAASTRICHTIAN) FROM THE PEIRÓPOLIS PALEONTOLOGICAL SITE: TOWARD A BETTER UNDERSTANDING

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ABSTRACT

The Peirópolis paleontological site (Late Cretaceous, Maastrichtian) in Minas Gerais State, Brazil yielded an important assemblage of fossil vertebrates. The typical occurrence of South American widespread taxa in Peirópolis is important for correlation between the Brazilian Bauru Basin and Argentinean Late Cretaceous basins. The fishes, turtles, anuran, crocodilians and dinosaurs known from Peirópolis (Marília Formation) resemble the Patagonian latest Late Cretaceous vertebrate faunas but lacks ornithischian dinosaurs.

Key words: Vertebrates, Late Cretaceous, Marília Formation, Minas Gerais State, Brazil.

RESUMEN

En el Sítio Paleontológico de Peirópolis (cretácico superior, Maastrichtiano) ubicado en la província de Minas Gerais, Brasil, hay un contenido muy importante de vertebrados fósiles. La ocurrencia en Peirópolis de taxa típicos y de amplia distribución en la América del Sur es importante para la correlación entre la Cuenca Bauru y cuencas argentinas del cretácico superior. Los pesces, tortugas, anuros, cocodrilianos y dinosaurios de Peirópolis (Formación Marília), se equivalen a las faunas de vertebrados del Neocretácico de Patagonia, sin embargo, sin la presencia de dinosaurios ornitísquios.

Palabras claves: Vertebrados, Neocretácico, Formación Marília, Província de Minas Gerais, Brasil.

Manuscript received: January 10th, 2009.
Accepted for publication: April 30th, 2009.

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Introduction

The Upper Cretaceous beds at the Peirópolis paleontological site of (Uberaba municipality, Minas Gerais State; Fig. 1) consist on an entirely continental sedimentary succession. The Upper Cretaceous Bauru Group units at Peirópolis are divided into the Uberaba Formation (Coniacian-Santonian) and Marília Formation (late Maastrichtian) in ascending order. The Uberaba Formation occurs as small patches mainly in the Peirópolis village. Although extensive paleontological studies have been carried out in Peirópolis area (*e.g*., Price, 1955; Estes and Price, 1973; Báez and Peri, 1989; Gayet and Brito, 1989; Carvalho *et al*., 2004; França and Langer, 2005; Kellner and Campos, 2005; Kellner *et al*., 2005; Campos *et al*., 2005; Novas *et al*., 2005; Santucci and Bertini, 2006; Novas *et al*., 2008; Salgado and Carvalho, 2008; Candeiro *et al*., 2008), fossil vertebrates are unknown so far from Uberaba Formation, except for unstudied dinosaur eggs found near Peirópolis.

On the other hand, abundant vertebrate remains have been reported from the late Maastrichtian Marília Formation (specimens and localities are listed in the Tab. 1 and 2). The first discovery of vertebrate fossils was vertebrate fragments from the "Ponto 1 do Price" from the Serra da Galga Member (Marília Formation) in the 1940´s (Price, 1951; Candeiro and Bergqvist, 2004). Since then, scattered dinosaur bones and other vertebrate fossils including fishes, turtles, and crocodilians have been found in quarries, roads cuts, and stream beds as a result of a Centro de Pesquisas Paleontológicas Llewelyn Ivor Price (Peirópolis) team survey. Abundant plants (palynomorphs) and mollusks have been located from the Peirópolis quarries. They clearly indicate that diversity of vertebrate communities existed during the time of Marília Formation deposition in the Peirópolis area. Except for some the crocodilians, however, the vertebrate faunas remain inadequately published. Therefore, the purpose of this paper is to review the vertebrate fossils from the Marília Formation at this locality and report their occurrence to the paleontological community. Comments and correlations with other vertebrate-bearing formations of Late Cretaceous age from Argentina are discussed. The potential significance of Marília Formation vertebrates from Peirópolis may be seen especially in the

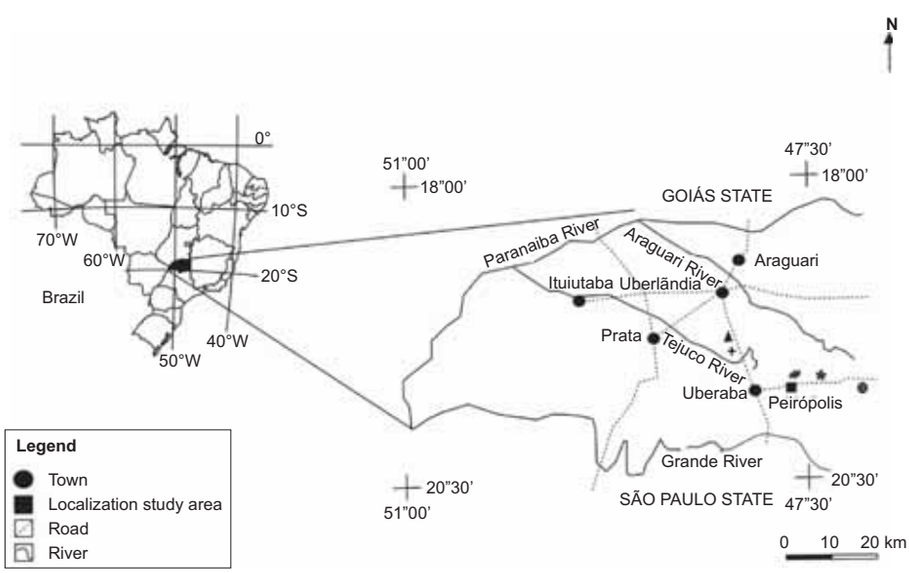

Figure 1. Geographic distribution of the Upper Cretaceous "Marília-Points" of Peirópolis paleontological site. # Point 1 (5 quarries); ✱ Point 2 (1 quarry); ⊕ Point 3 (1 quarry); + Point 4 (2 quarries); ▲ Point 5 (1 quarry).

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context of roughly contemporaneous areas from southern South America (Candeiro and Bergqvist, 2004).

Methodology

The data on vertebrates from Peirópolis paleontological site for the present work are mostly based in literature sources as well as in the direct observation of the specimens deposited at Museu dos Dinossauros (Peirópolis District, Uberaba Town, Minas Gerais State, Brazil). For the stratigraphic units in the Bauru Group I follow the arrangement proposed by Dias Brito et al. (2001).

Results

Geological setting

The Peirópolis paleontological site is northeast of Bauru Basin (Upper Cretaceous) (Fernandes and Coimbra, 1996). The Bauru Group in Triângulo Mineiro region is represented by sediments belonging to the Adamantina, Marília and Uberaba formations (Fig. 2). These layers overlie basalts belonging to Serra Geral Formation (São Bento Group, Paraná Basin), sandstone belonging to Botucatu Formation (São Bento Group), metamorphic and Proterozoic outcrops belonging to Araxá and Canastra groups (Sanfransiscana Basin) and Mesozoic intrusion of the

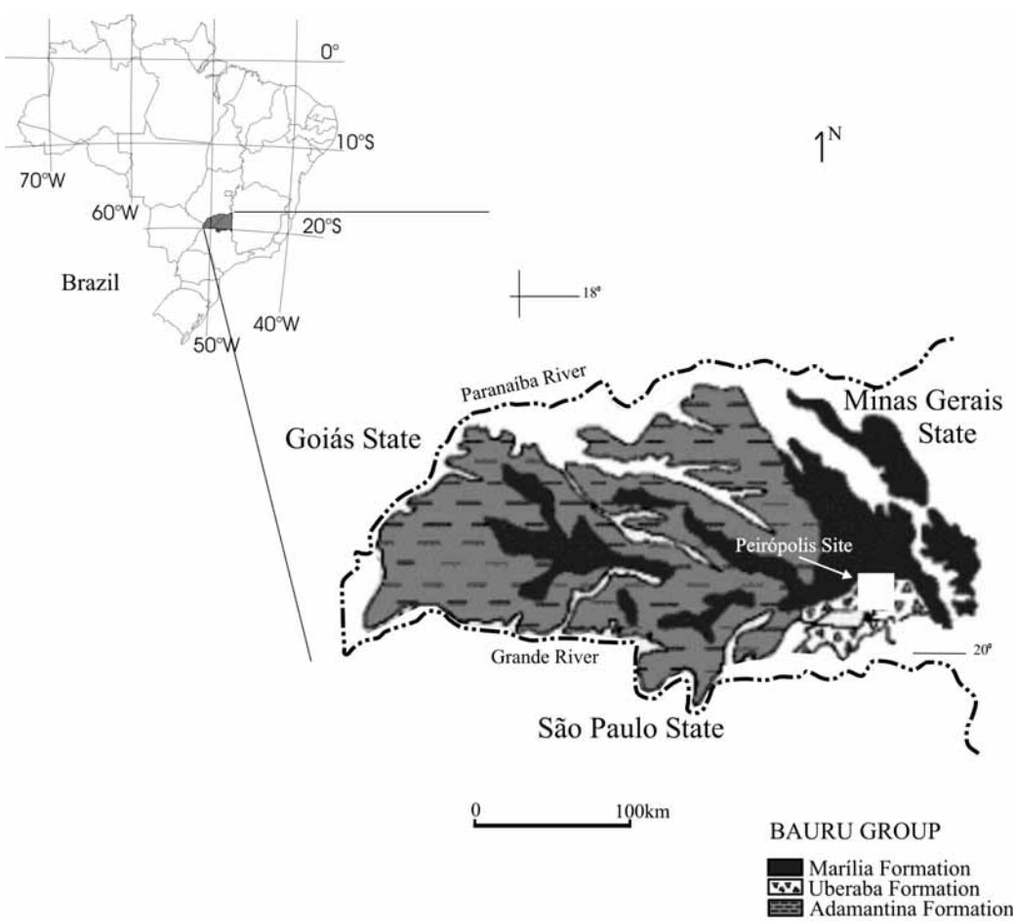

Figure 2. Geological map of Bauru Group in Triângulo Mineiro region (modified Fernandes and Coimbra, 1996).

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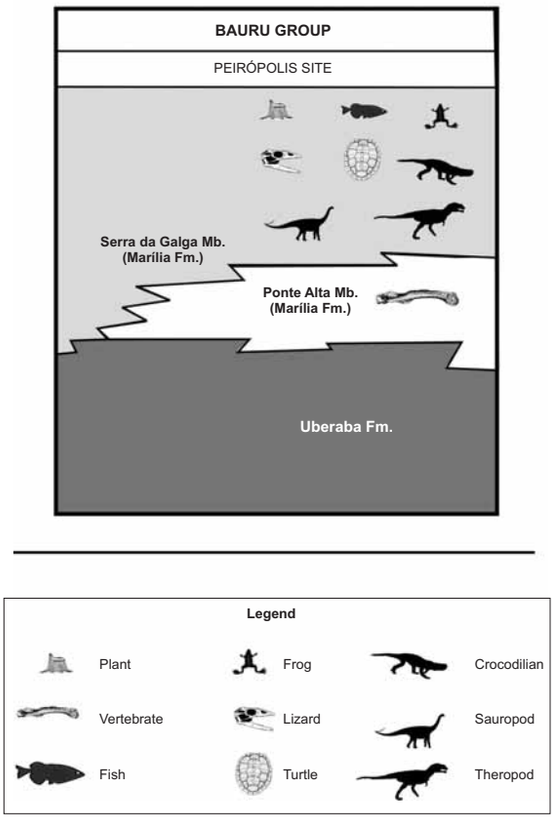

Figure 3. Upper Cretaceous Bauru Group generalized geological section in Peirópolis showing occurrence of the biota.

Soerguimento of Alto Paranaíba (Suguio et al., 1979).

Outcrops of the Marília Formation are unevenly distributed throughout the Peirópolis paleontological site. According to Barcelos and Suguio (1987), that unit was deposited by coalescing alluvial fans, and later reworked by a braided system in association with calcretes and lacustrine calcareous sediments. Barcelos (1984) subdivided the Marília Formation into the Echaporã, Ponte Alta, and Serra da Galga members, although only the latter two members are exposed in the Peirópolis area. Ponte Alta and Serra da Galga members show the following characteristics (Garrido et al., 1992): *Ponte Alta member*– a basal "calcareous white member", characterized by thin and medium calcareous beds with pebbles and calcareous nodules which were deposited in lakes; *Serra da Galga member*– "member of white sandstone and conglomerate", composed of bleached conglomerate and sandstone with feldspar matrix deposited by alluvial fans, braided rivers and lakes. Those two members, according to Suguio (1973, 1980), were formed in a partially dry climate, which would have favored the fossil preservation found in these layers.

Dias-Brito et al. (2001) assigned a late Maastrichtian age to the Marília Formation. This lithostratigraphic unit yielded invertebrates and plants, and abundant vertebrates (Fig. 3). Vertebrates from the Marília Formation are represented by anurans (*Baurubatrachus pricei*), lizards (*Pristiguana brasiliensis*), crocodilians (*Itasuchus jesuinoi, Peirosaurus tormini, Uberabasuchus terrificus*), chelonians (*Cambaremys langertoni*), dinosaurs (Abelisauridae, Carcharodontosauridae, Maniraptora, and eutitanosaurian *Baurutitan britoi*, *Trigonosaurus pricei, Uberabatitan ribeiroi*, *Aeolosaurus*).

Vertebrate paleontology

The vertebrate fossils of the Triângulo Mineiro region have been known since 1920, however only with the pioneer studies of paleontologist Llewellyn Ivor Price, which started in 1947, the fossils found in the Peirópolis paleontological site became not only more known, but at the same time better classified. Just a small part of collected material in this paleontological site was described to the level of species due to fragmentary nature of most the specimens which made a more refined description impossible (*e.g.*, Fig. 4).

Abundant fish fossils have recently been found in the Peirópolis. To date four localities have yielded isolated scales and teeth. They produced Characiformes, Perciformes and Siluriformes. The species which were described formally are represented by amphibian *Baurubatrachus pricei* Báez and Peri, 1989; lepidosaurian *Pristiguana brasiliensis* Estes and Price, 1973 and crocodilians *Itasuchus jesuinoi*, *Peirosaurus tormini* Price, 1955

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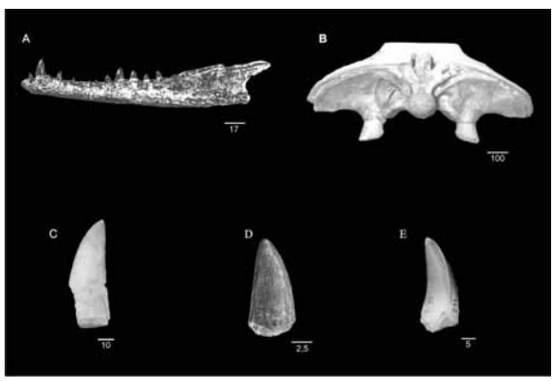

Figure 4. Reptilian fossils from the Peirópolis paleontological site. A, lower jaw Itasuchus jesuinoi (modified from Price, 1955); B, pelvis of the "Titanosauridae" (modified from Campos and Kellner, 1999); C, Abelisauridae teeth; D, Carcharodontosauridae tooth; E, Theropoda indet. tooth. Scale bar in mm.

and *Uberabasuchus terrificus* Carvalho, Ribeiro and Avilla, 2004. The dinosaurs represent the most abundant remains and they are represented by theropods which were attributed by Candeiro (2002) and Candeiro et al. (2004) to Abelisauridae and Carcharodontosauridae, first Abelisauridade bone remains by (Novas et *al*., 2008) and Maniraptoran claw recently described by Novas *et al*. (2005). The sauropods are represented by the titanosaurians *Baurutitan britoi* Campos and Kellner, 2005 and *Trigonosaurus pricei* Campos, Kellner, Bertini and Santucci, 2005; *Uberabatitan ribeiroi* Salgado and Carvalho, 2008 and others different elements *e.g*., teeth, vertebrae, ribs, hemal arches, phalanges and osteoderms. These specimens were studied by Campos and Kellner (1999),

Table 1. Vertebrate fauna of the Marília Formation from Peirópolis paleontological site.

	Area 1	Area 2	Area 3	Area 4	Area 5
Ponte Alta Member	x		x		x
Serra da Galga Member	x	x			
VERTEBRATA					
Vertebrata indet	x	x	x	x	x
PISCES					
Characiform	x		x		
Perciform	x		x		
Siluriform	x		x		
ANURA *Baurubatrachus pricei*	x				
REPTILIA					
Squamata					
Pristiguana brasiliensis	x				
Chelonia					
Chelonia indet.	x				
Podcnemidae	x				
Crocodylomorpha					
Itasuchus jesuinoi		x			
Peirosaurus tormini		x			
Uberabasuchus terrificus		x			
Dinosauria					
Sauropoda					
Titanosauria					

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	Area 1	Area 2	Area 3	Area 4	Area 5
"Titanosauridae" A				x	
"Titanosauridae" B				x	
"Titanosauridae" C				x	
"Titanosaurinae"	x	x			
"*Titanosaurus*"	x				
Aeolosaurus sp.					
Baurutitan britoi	x				
Trigonosaurus pricei	x				
Theropoda					
Theropoda indet.	x				
Abelisauridae indet.	x	x			
Carcharadontosauridae indet.	x				
Maniraptora	x				

Table 2. Fossiliferous areas (quarries), in the Peirópolis paleontological site, Minas Gerais State.

Areas	Generalities	Reference selected
Area 1 (quarry 1)	This outcrop has been known as "Caieira"	Campos and Kellner (1999)
Area 1 (quarry 2)	This outcrop is inside of "Caieira"	Kellner (1996)
Area 1 (quarry 3)	This quarry has been known as "Point 2"	Price (1955)
Area 1 (quarry 4)	This outcrop has been known as "Point 3"	Campos and Kellner (1999), Trotta et al. (2002)
Área 1 (quarry 5)	This outcrop is known as "Mumbuca"	Powell (1987, 2003)
Area 2	The outcrop is situated on the BR-262 throughway about 3,5 km east of Peirópolis	Campos and Kellner (1999)
Area 3	The outcrop is situated on the Ponte Alta district throughway about 18 km east from Peirópolis	Magalhães-Ribeiro (2002)
Area 4 (quarry 1)	Quarry 1 is known as the " Rio Tejuco 1"	Albuquerque and Candeiro (2003)
Area 4 (quarry 2)	Quarry 2 is known as the "Rio Tejuco 2"	Albuquerque and Candeiro (2003)
Area 5	This area has been known as "Partezan Quarry"	Bertini et al. (1993)

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Santucci (2002), Powell (2003) and Santucci and Bertino (2006) who attributed part of these remains to Titanosauria (see detailed assignments in Tab. 1). Dinosaur eggs found in sediments of the Serra da Galga Member are related to "Megaloolithidae" oofamily, according to Magalhães-Ribeiro (2002). Furthermore there are numerous cranial and post cranial remains belonging to crocodilians and turtles. Numerous fragments of disarticulated bones and coprolites are found in Marília Formation sediments in the Peirópolis paleontological site, however they have not been attributed to taxonomic level below Vertebrata; they are housed in the Centro de Pesquisas Paleontológicas Llewellyn Ivor Price and Museu de Ciências da Terra (Rio de Janeiro).

Fossil sites from Marília Formation in the Peirópolis paleontological site of: The first fossil site was studied by Price in the 1940´s. Since then, new fossil localities of the Marília Formation have been found in the Uberaba municipality with five mentioned in literature so far (Fig. 1; Tab. 2).

The best known fossil vertebrates of Marília Formation found in the Peirópolis paleontological site of are listed below.

Discussion

The present study and those of the previous works in the Marília Formation Peirópolis paleontological site), it is attempted here to point a comprehensive point of view of this area. The Peirópolis paleontological site contains a moderately diverse Late Cretaceous (Maastrichtian) vertebrate assemblage, from which some of the taxa are reported also in Argentina (*e.g.*, Chubut, Neuquén and Malargüe groups; Candeiro and Martinelli, 2003; Lamanna *et al*., 2003; Martinelli and Forasiepi, 2004; Leanza *et al*., 2004).

Some of the vertebrate taxa reported at Peirópolis occur with other vertebrates known from other areas of Argentina, and are important for correlation with Argentinean units. Supporting this correlation are the mesoeucrocodylian *Peirosaurus tormini* and the titanosaur *Aeolosaurus*, which are found in Bajo de la Carpa, Allen, Angostura Colorada, Los Alamitos, and Bajo Barreal formations in Patagonia. Abelisaurid and carcharodontosaurid remains are known to occur in the Bauru Group. In addition to the titanosaurian material from Peirópolis area, remains of those sauropods are widely known in Upper Cretaceous units of Argentina. Additional support for correlation is given by the presence in Peirópolis of the Gondwanan "Megaloolithidae" eggshells.

Other support of the correlation between Peirópolis area and Argentinean areas may be given by other vertebrate groups, but more detailed studies are needed before this can be done. For example, characiform, siluriform and perciform fishes and podocnemid turtles are known in most of the Neuquén and Malargüe groups, but they cannot be used as correlation tools since their remains are not well known from the Marília Formation.

Ornithischian records are remarkable in Argentina (Late Cretaceous), however, not a single ornithischian remain has been identified so far in the Marília Formation or the Bauru Group. Considering that ornithischians occurred in Argentina, this bias may be from lack of extensive or least systematic prospecting in the Marília Formation rather than from depositional or preservational events.

Conclusions

So far, four fossil sites have been recorded at the Peirópolis paleontological site of, the Marília Formation with a diverse vertebrate fauna of Upper Maastrichtian age. These fossils are represented mainly by fishes, frogs, turtles, crocodilians, and dinosaurs. The diverse fossiliferous, but poorly known Marília Formation accumulated in the northwestern Bauru Basin during the latest Cretaceous. Deposition occurred on a fluvio-lacustrine environment. The Maastrichtian age of the Marília Formation suggested by previous authors has several important biogeographical and paleontological correlations. First, it indicates that the Marília Formation assemblage is approximately contemporaneous in age with

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the vertebrate assemblage recovered from the Patagonia (*e.g*., Chubut, Malargüe, and Neuquén groups). This finding is certainly consistent with striking similarities between faunas from these two southern South America areas. Second, this Maastrichtian Marília Formation fauna, when considered in the light of the Late Cretaceous discoveries, was different by the lack of ornithischian records in Brazil, but which are found in Argentina.

Acknowledgments

This paper forms part of the undergraduate project of the R. Candeiro who gratefully acknowledges financial assistance in the form of an Undergraduate Fellowship (1998-1999) received from the Council of Scientific from Brazil (CNPq/166/98) under Dr. Ignácio Brito advisor (financial supported by FAPEMIG/UFU/801/98 fellow). The manuscript was substantially improved after the revision work of Dr. Yaneth Muñoz-Saba (Universidad Nacional de Colombia). I would like to thank Prof. Luiz Carlos Borges Ribeiro and the Centro de Pesquisas Paleontológicas Llewellyn Ivor Price crew, Dr. Adriano Rodrigues dos Santos (Universidade Federal de Uberlândia, UFU), Dr. Lílian Paglarelli Bergqvist (Universidade Federal do Rio de Janeiro, UFRJ) and Thiago da Silva Marinho (UFRJ) for reviewing the earlier drafts of the manuscript. The manuscript was substantially improved by of Dr. Simone Magnuco (Museo Civico di Storia Naturale di Milano, Italy), Dr. Walter Hartwig (Touro University, United States) and Dr. David Gillette (Museum of Northern Arizona, United States). The author also would like to thank the friends, Lisete, Ana and Fernando Brito, that in some ways helped us to start our Paleontological studies, since they are wife, daughter and son of Professor Ignácio Machado Brito, who opened the doors of his house and ignited my life into Paleontology.

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