

# Cretaceous chelonians from Marília Formation, Peirópolis, Minas Gerais, Bauru Basin, Brazil

*Quelônios do cretáceo da Formação Marília, Peirópolis, Minas Gerais, Bacia Bauru, Brasil*

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**ABSTRACT:** In the Upper Cretaceous deposits of Bauru Basin, the complete specimens of chelonians are rare. However, a large amount of bone fragments of *Pleurodyra* suborder is found. In the paleontological sites located at Peirópolis (Uberaba, Minas Gerais), which belong to Marília Formation (Maastrichtian – Campanian), there is one of the best fossil registers for this group in Brazil. The 315 skeletal remains collected in these outcrops and housed in the *Complexo Cultural e Científico de Peirópolis* of *Universidade Federal do Triângulo Mineiro* allow an assessment of the diversity and abundance of Testudines during the Upper Cretaceous. A comparative analysis of these fossils with specimens from other localities from Bauru Basin enabled a better understanding of the chelonians of the region in the Cretaceous period.

**KEYWORDS:** Bauru Basin; chelonians; Cretaceous.

**RESUMO:** Nos depósitos do Cretáceo Superior da Bacia Bauru, são raros os espécimes completos de quelônios. No entanto, encontra-se uma grande quantidade de fragmentos ósseos da subordem *Pleurodyra*. Em afloramentos situados em Peirópolis (Uberaba, Minas Gerais), pertencentes à Formação Marília (Maastrichtiano – Campaniano), há um dos melhores registros fossilíferos para este grupo. As 315 peças desarticuladas, coletadas nestes afloramentos, pertencentes à coleção do *Complexo Cultural e Científico de Peirópolis* da *Universidade Federal do Triângulo Mineiro*, possibilitam uma avaliação da diversidade e da abundância destes animais durante o Neocretáceo. A análise comparativa destes fósseis com exemplares de outras localidades da Bacia Bauru possibilitou o melhor entendimento dos quelônios da região durante o Cretáceo.

**PALAVRAS-CHAVE:** Bacia Bauru; quelônios; Cretáceo.

## INTRODUCTION

In the Brazilian Upper Cretaceous, the fossiliferous record of chelonian is concentrated in Adamantina and Marília Formations, both in the Bauru Basin. Seven species are formally described in this basin (*sensu* Gaffney *et al.* 2011). In Triângulo Mineiro's region, in the Marília Formation sediments, many fossil fragments that belong to chelonian are found. These fossils are usually fragmented and complete skeletons are rare, like the specimen MCT-1499-R (Fig. 1) housed in *Departamento Nacional de Produção Mineral* (DNPM) collection. There are few studies about these fossils, which make the analysis of this material important for understanding the chelonian diversity from Marília Formation.

Bauru Basin was originated in the Upper Cretaceous and extended through the Brazilian states of Mato Grosso do Sul, Goiás, Minas Gerais, São Paulo and Paraná occupies an area of approximately 350,000 km<sup>2</sup> (Fig. 2). Its origin is related to the basaltic magmatism and tectonism during the rupture of the gondwanic continent and opening of the South Atlantic Ocean (Fernandes & Coimbra 2000). This basin has Santonian-Maastrichtian age, and elliptical shape with an elongated shaft in the NE direction (Dal Bó *et al.* 2009).

According to Dias-Brito *et al.* (2001), Bauru Basin rocks comprise a set dominated by sandstones, siltstones, and mudstones/shales, which were accumulated in several depositional systems ranging from alluvial, aeolian, fluvial, and lacustrine. It is divided into two major units:

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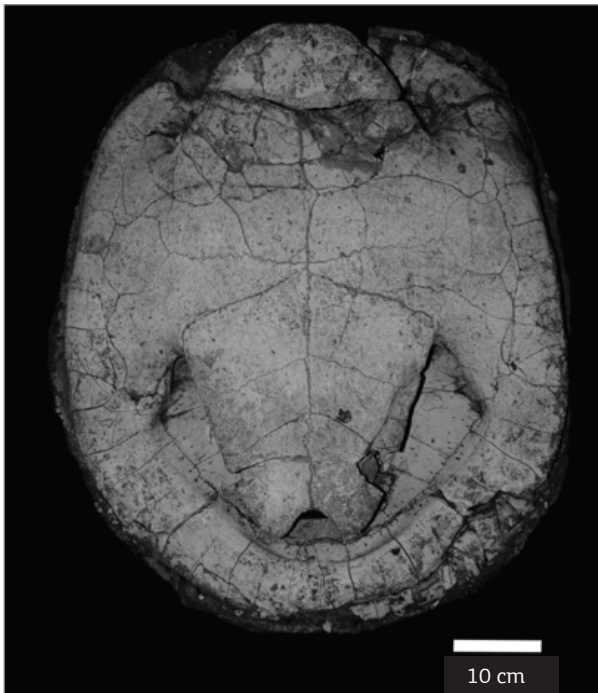


Figure 1. Chelonian carapace (MCT 1499-R) from Peirópolis and housed at Departamento Nacional de Produção Mineral (DNPM) collection.

the Caiuá and Bauru Groups. The Caiuá Group happens in Paraná, São Paulo, and Mato Grosso do Sul, and also appearing in Northeastern Paraguay. This group is subdivided in three formations: Rio Paraná, Goio Êre, and Santo Anastácio. There are fine to very fine sandstones interpreted as sand sheets, *wadis*, and dunes. The Bauru Group occurs mainly in Triângulo Mineiro region, in São Paulo State and in the North of Paraná State. It is divided into Adamantina, Uberaba, and Marília formations. It is observed in this group the presence of conglomerates, mudstones, and siltstones interpreted as alluvial fan systems, fluvial and swamps (Fernandes & Coimbra 2000).

Reptile fossils (crocodylomorpha, chelonian, and dinosaurs), fish, anuran, mollusks, crustaceans and plants, as well as vertebrate and invertebrate ichnofossils (Dias-Brito *et al.* 2001, Carvalho 2000) are found in Bauru Basin. In Marília Formation, at Triângulo Mineiro region, are found the chelonian fossils analyzed here. Dias-Brito *et al.* (2001) suggested Neo-Maastrichtian age to the sediments in Marília Formation. This formation is extended through Goiás and São Paulo states and Triângulo Mineiro Region in Minas Gerais State. Its sediments consist of fine to medium sandstones intercalated with conglomeratic levels (Fúlfaro & Barcelos 1991). The depositional system would be a combination of alluvial fans reworked by a braided fluvial system, with lacustrine limestones (Barcelos

& Suguio 1987). This unit was divided in three members: Ponte Alta, Serra da Galga, and Echaporã.

The Ponte Alta Member is found predominantly at Triângulo Mineiro region and it is the basal portion of Marília Formation (Ribeiro 2001). The Echaporã Member occurs at the top edge of the basin, being more significant in the region of Marília, Echaporã, and Monte Alto, in São Paulo State. The Serra da Galga Member occurs only at Triângulo Mineiro region, and concentrates the most important fossiliferous sites of large vertebrates in the Bauru Basin.

## FOSSIL CHELONIANS OF BAURU BASIN

The Bauru Basin presents a very diversified fauna of fossil reptile (Bertini 1994, Carvalho 2000). Many chelonian fossils are found in its sediments and so far seven species closely related and included in the family *Podocnemididae* were described, as seen in Fig. 2 (Oliveira & Romano 2007, Gaffney *et al.* 2011).

The first formal description of a chelonian from the Bauru Basin was "*Podocnemis*" *harrisi* Pacheco, 1913, from a location next to the municipality of Colina, São Paulo State. Later, based on five photographs, a new species was described in the São Paulo State, "*Podocnemis*" *brasiliensis* Staesch, 1937 (Price 1953).

Price (1953) examined the material described by Staesch (1937) and observed that the photographed material and the one described as "*Podocnemis*" *brasiliensis* were actually two distinct species. Thus, based on the holotype of "*Podocnemis*" *brasiliensis*, a new species was described, *Roxochelys wandeleyi* Price, 1953. Furthermore, Broin (1988) and Kischlat (1994) noticed a similarity grouping "*Podocnemis*" *harrisi* and *Roxochelys wandeleyi* in a single genus, *Roxochelys*. The fact that the holotype of "*Podocnemis*" *harrisi* was lost precludes any confirmation. Then, "*Podocnemis*" *harrisi* should be considered as *nomen dubium* (Kischlat *et al.* 1994, Oliveira & Romano 2007).

A fourth species found among the cities of Presidente Prudente and Pirapózinho, in São Paulo State, was described by Suárez (1969), *Podocnemis elegans*. This species was first assigned to the genus *Roxochelys* (Broin 1971); but later Kischlat and Azevedo (1991) concluded that it could not be assigned to this genus. Kischlat (1994) proposed a new genus: *Bauruemys*, in which *Podocnemis elegans* and *Podocnemis brasiliensis* were included. Kischlat (1994) and Kischlat *et al.* (1994) indicated that there are no morphological features to add "*Podocnemis*" *harrisi* and "*Podocnemis*" *brasiliensis* in the genus *Podocnemis*. Therefore, these

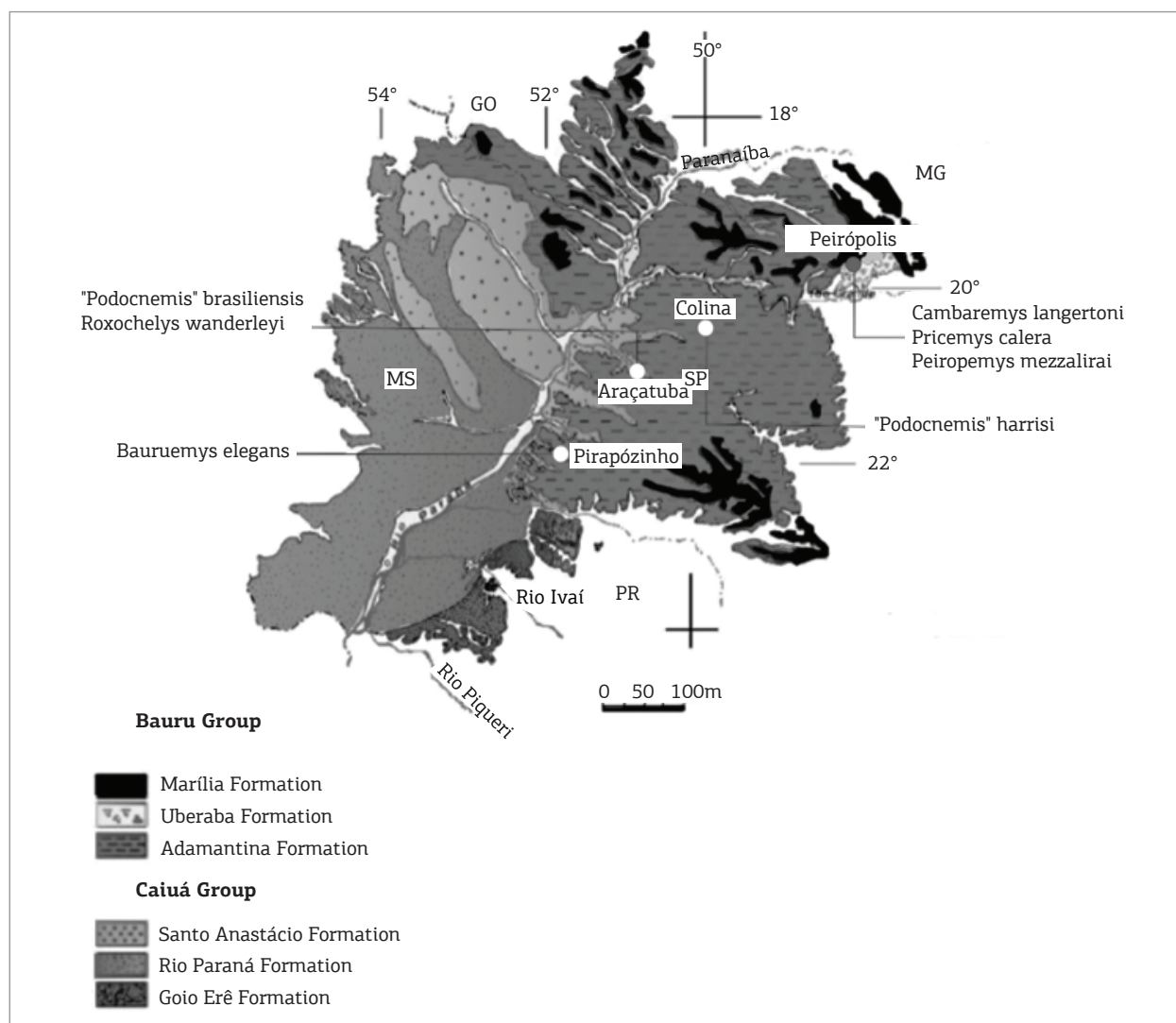


Figure 2. Map indicating the location of Bauru Basin, where the formation of Bauru Group and Caiuá Groups emerge, emphasizing the place of the chelonian species described to the basin (based on Fernandes 2004).

species correspond respectively to *Roxochelys harrisi* and *Bauruemys brasiliensis*.

França and Langer (2005) designated a new species from Peirópolis locality, at Uberaba city in Minas Gerais, which was named *Cambaremys langertoni*. However, they stated that this could represent a juvenile individual of *Bauruemys brasiliensis*. Recently, Gaffney *et al.* (2011) described two new species to Bauru Basin. Both of them, *Peiopemys mezzalirai* and *Pricemys caiera*, were characterized with samples from Peirópolis (Tab. 1).

## MATERIAL AND METHODS

The studied material consists of 315 fossils that belong to Upper Cretaceous chelonian from Bauru

Basin. These fossils are housed at Complexo Cultural e Científico de Peirópolis of Universidade Federal do Triângulo Mineiro (CCCP/UFTM) collection. All specimens have already been prepared and are well-preserved, although most of them are not articulated. There are stratigraphic controls of all materials deposited in the collection.

The fossils were identified and analyzed in the Universidade Federal do Rio de Janeiro *Geology Department* and CCCP/UFTM laboratories. At the beginning, all material was selected based on the sites where they were collected: “Ponto 1” de Price (Fig. 3), “Ponto 2” de Price (Fig. 4) and “BR-050” (Fig. 5). After this process, each specimen was measured and a description was made. All the material was then photographed with a Canon EOS Digital Rebel semiprofessional camera.

Posteriorly, the fragments were compared with the specialized literature, with the description of chelonian from Cretaceous papers, and also with chelonian osteology in general. The fossils were with others from Bauru Basin.

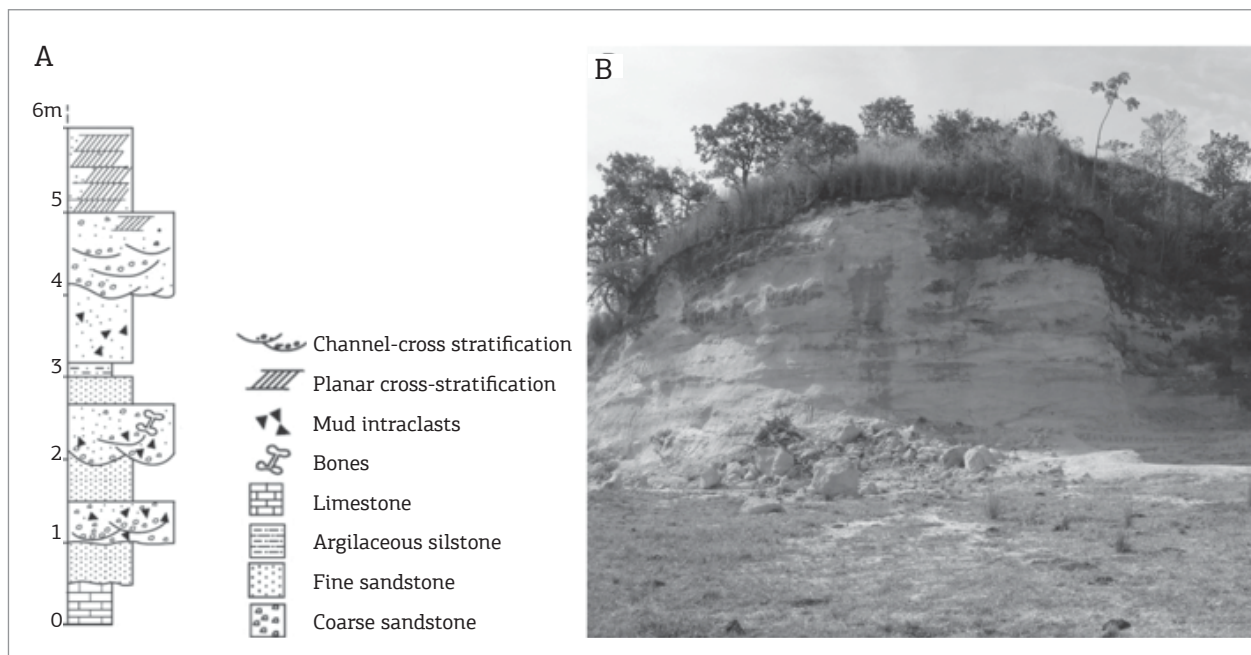
The specimens here analysed was cataloged with the inicial CPP (Centro de Pesquisas Paleontológicas “Llewellyn Ivor Price” Peirópolis, Uberaba, Minas Gerais) and MCT (Divisão de Geologia e Mineralogia, Departamento Nacional de Produção Mineral).

## DISCUSSION

In the quantitative analysis, it was found that most of the fragments belong to the dorsal shell, being 63 costal plates, 67 peripheral plates, 8 neural plates, 5 nuchal plates and 2 pygal plates. The total plastron elements are 64 fragments being epiplastra, entoplastron hyoplastra, hypoplastra, and xiphiplastra. There are also 18 of appendicular skeleton, 7 vertebrae, and 1 cranial fragment, besides other unidentified fragments (Fig. 6).

**Table 1. Temporal, stratigraphic, and geographic distributions of the chelonian species described in Bauru Basin**

Species	Stratigraphic distribution	Age	Locality	References
“Podocnemis” <i>brasiliensis</i>	Adamantina Formation	Turonian - Santonian	Near Araçatuba city, São Paulo State	Staesche 1937, Price 1953, Kischlat 1994, Oliveira & Romano 2007, Gaffney et al. 2011
“Podocnemis” <i>harrisi</i>	Adamantina Formation	Turonian - Santonian	Colina city, São Paulo State	Pacheco 1913, Broin 1971, Oliveira & Romano 2007, Gaffney et al. 2011
<i>Roxochelys wanderleyi</i>	Adamantina Formation	Turonian - Santonian	Between Araçatuba and Jupiá Cities, São Paulo State	Price 1953, Oliveira & Romano 2007, Gaffney et al. 2011
<i>Bauruemys elegans</i>	Adamantina Formation	Turonian - Santonian	Pirapózinho city, São Paulo State	Oliveira & Romano 2007, Suárez 1969, Kischlat 1994, Gaffney et al. 2011
<i>Cambaremys langertoni</i>	Marília Formation, Serra da Galga Member	Neomaastrichtian	Peirópolis locality, Minas Gerais State	França & Langer 2005, Oliveira & Romano 2007, Gaffney et al. 2011
<i>Peiropemys mezzalirai</i>	Marília Formation, Serra da Galga Member	Neomaastrichtian	Peirópolis locality, Minas Gerais State	Gaffney et al. 2011
<i>Pricemys caiera</i>	Marília Formation, Serra da Galga Member	Neomaastrichtian	Peirópolis locality, Minas Gerais State	Gaffney et al. 2011



**Figure 3. (A) Sedimentographic profile of “Ponto 1” de Price (adapted from Carvalho et al. 2004); (B) Photograph of “Ponto 1” site, where most parts of the studied fossils were collected.**



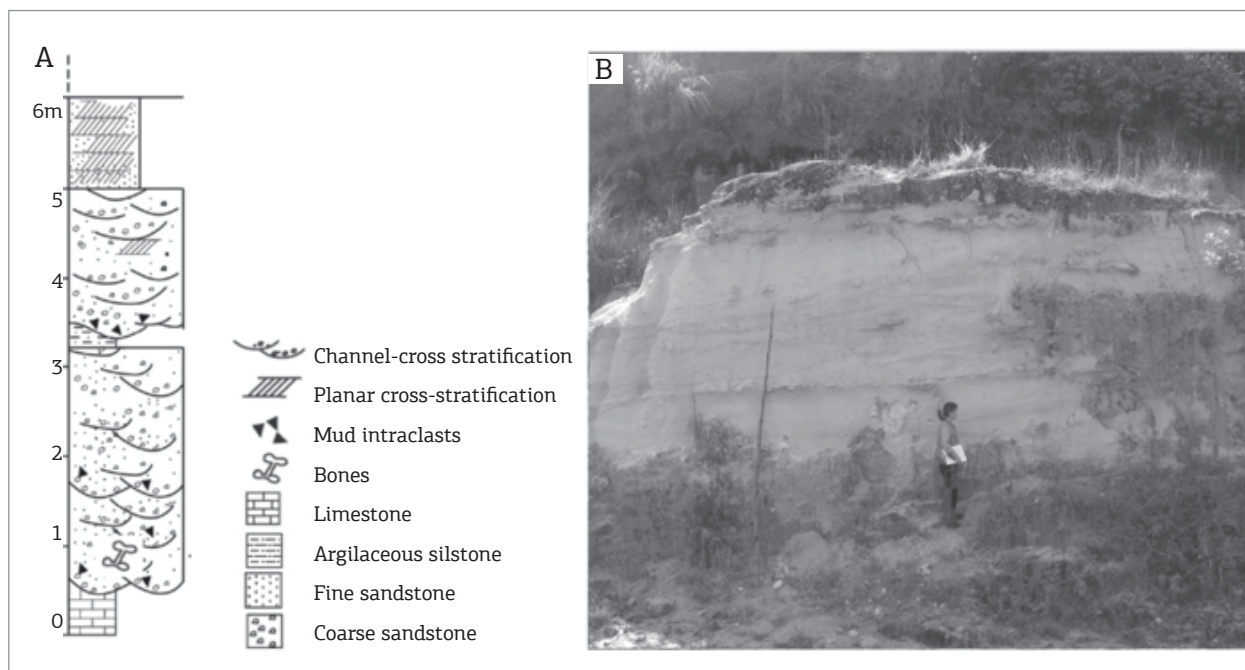


Figure 4. (A) Sedimentographic profile of “Ponto 2” de Price (adapted from Salgado & Carvalho 2008); (B) Photograph of “Ponto 2” site, where the material used for describing *Cambaremys langertoni* was collected.

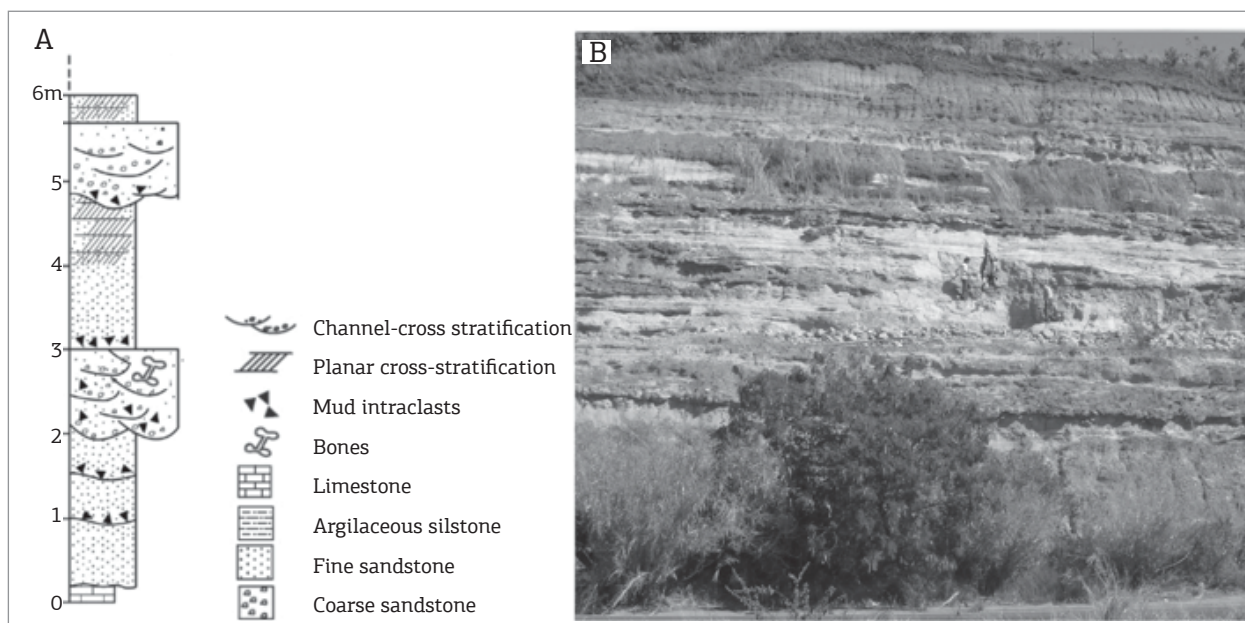


Figure 5. (A) Sedimentographic profile of “BR-050” (adapted from Salgado & Carvalho 2008); (B) Photograph of “BR-050” site, where the epiplastra was found.

At “Ponto 1” we have a significantly higher number of specimens, there are 291 fossil fragments (Fig. 7). At “Ponto 2”, only 23 fragments (Fig. 8) were found, and at “BR050” only one epiplastra fragment.

The differences in the amount of fossils from each site can be related to the few fieldworks in “Ponto 2” and in “BR-050”, in contrast with the systematic collect

work performed by the CCCP-UFTM team at “Ponto 1” (Tab. 2).

According to Gaffney *et al.* (2011), there are three distinct types of postcranial elements to the Peirópolis chelonian, “Peirópolis A” and “Peirópolis B” – informally names given by such authors – and *Cambaremys langertoni*, a species described by França and Langer (2005).

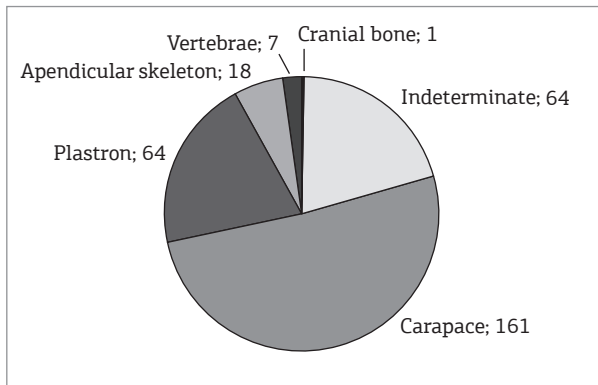


Figure 6. Amount of each bone fragment in the Complexo Cultural e Científico de Peirópolis of Universidade Federal do Triângulo Mineiro collection.

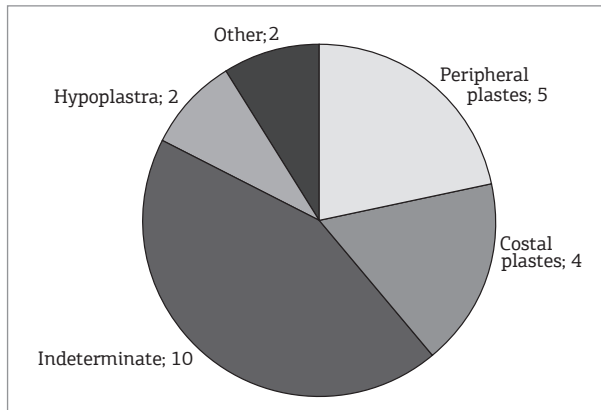


Figure 8. Number of bone elements of "Ponto 2" in a total of 23 fragments.

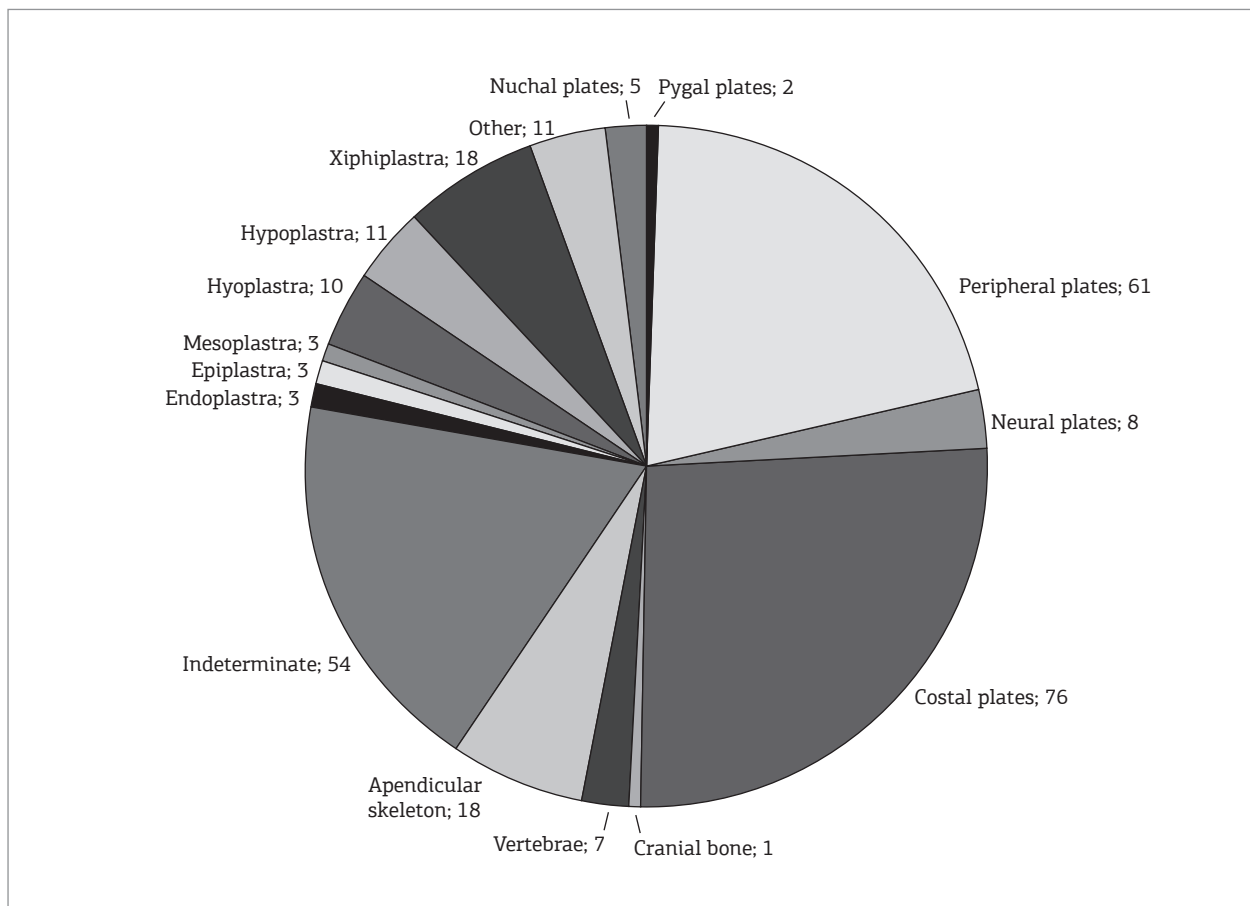


Figure 7. Number of bone elements of "Ponto 1" in a total of 291 fossils.

The specimen CPP 1165, a first costal plate, is relatively bigger than the other ones. According to the measures, it is estimated that the shell of this individual could reach 60 cm width. The morphology of the suture of the axillary process of the bigger plates is different from the smaller ones. In CPP 1165, the axillary suture has uniform width from its outer to the inner region, unlike the smaller

material, in which it has a tapering near the external region (Figs. 9 and 10). Based on Gaffney *et al.* (2011) data, we believe that the bigger individuals belong to "Peirópolis A" and the smaller ones belong to "Peirópolis B".

The material cataloged as CPP 764 consists in a second costal plate articulated with the second neural. It is estimated that the shell of this chelonian could reach about 60 cm.

Table 2 – Table indicating the quantity of elements at “Ponto 1”, “Ponto 2” and “BR-050”

	“Ponto 1”	“Ponto 2”	“BR-050”
Element	Number of specimens		
Costal plates	76	4	0
Peripheral plates	61	5	0
Neural plates	8	0	0
Nuchal plates	5	0	0
Pygal plates	2	0	0
Plastron	59	4	1
Apendicular skeleton	18	0	0
Vertebrae	7	0	0
Cranial fragment	1	0	0
Indetermined	54	10	0
TOTAL	291	23	1

Figure 9. (A) Morphology suggested by Gaffney *et al.* (2011) to the first costal plate of “Peirópolis A”; (B) First costal of “Peirópolis B”.

The exemplar CPP 782 is very similar to CPP 764, but its medial and lateral regions are broken. This specimen is 1.5 cm in length longer than CPP 764, which would probably be an adult individual of the same species. We still have costal plates with two distinct sizes, a medium and a slightly smaller one. The second costal plate CPP 764 has a different character from the other ones. The smaller costal plates (CPP 549, CPP 551, CPP 768, CPP 773, CPP 775) present a thickness in the medial and anterior parts, which would have the purpose of supporting the axillary process present in the first costal plate. The specimen CPP 764 does not show it. According to Gaffney *et al.* (2011), “Peirópolis A” (bigger individual) does not present this thickness in the medial and anterior parts of the costal plates, but in “Peirópolis B” we can see it (Fig. 11).

The costal plates present morphological differences at the local of the inguinal process suture. In “Peirópolis A” we can see this scar uniform, having almost the same width in its medial and lateral areas. In the studied material, there are samples related to this first morphotype, but we have found in greater number the second morphotype, which would be wider in the medial region, tapers and widens again. In the larger studied specimens, we observed the uniform scar (“Peirópolis A”), and in the smaller ones, the second morphology was seen (Fig. 12).

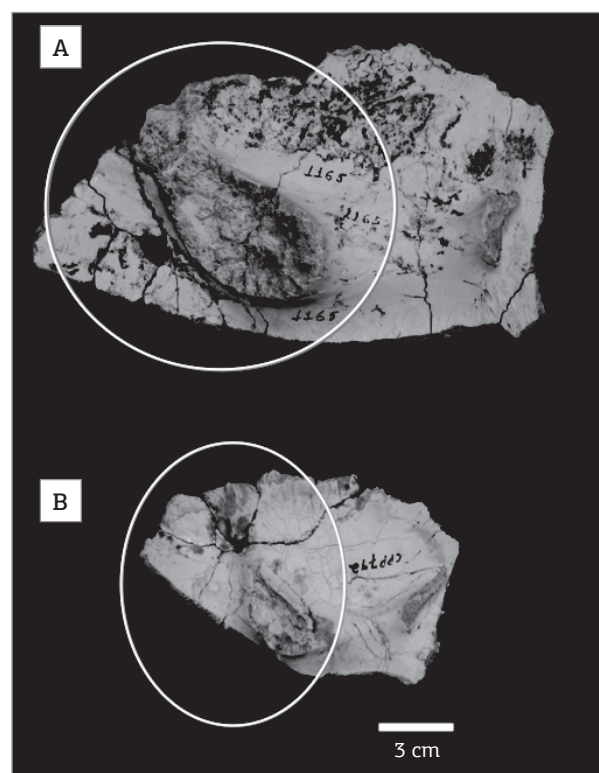


Figure 10. (A) Morphology of the axillary suture of CPP 1165, highlighted by a circle, indicating that the material belongs to “Peirópolis A”; (B) Morphology of the axillary suture of CPP 742, highlighted by a circle, therefore this specimen belongs to “Peirópolis B”.

The peripheral plates are those that provide the greatest difference in thickness and other characters. In the posterior peripheral plates, we can observe the presence of a gutter (CPP 415) in the anterior region characterized as an autapomorphy of “Peirópolis A” (Gaffney *et al.* 2011). In other specimens, this gutter is not present, which would be characteristic of “Peirópolis B” (CPP 419). Also, based on peripheral plates, we can observe plates with at least three different sizes. At the median posterior peripheral plates, we can see a difference in thickness, with specimens two times bigger and more thickened than others (Fig. 13).

According to Gaffney *et al.* (2011) the nuchal plates can be differentiated by the presence or absence of a notch V-shaped in the anterior region. “Peirópolis A” has such notch, while “Peirópolis B” does not (Fig. 14).

The studied nuchal plates present three distinct sizes. The smaller one, CPP 746, belong to “Peirópolis B”, because it does not have the notch in its anterior region. The other two present it quite evidently, which makes us believe that those two specimens belong to “Peirópolis A”. The bigger one was compared with an actual individual, being estimated that the shell of this chelonian could reach 75 cm length (Fig. 15).



Figure 11. (A) CPP 775 and 768 indicating thickness at second costal, showed by a circle, features belonging to “Peirópolis B”; (B) CPP 539 and 775 specimens do not show thickness, this feature indicates that they belong to “Peirópolis A”.

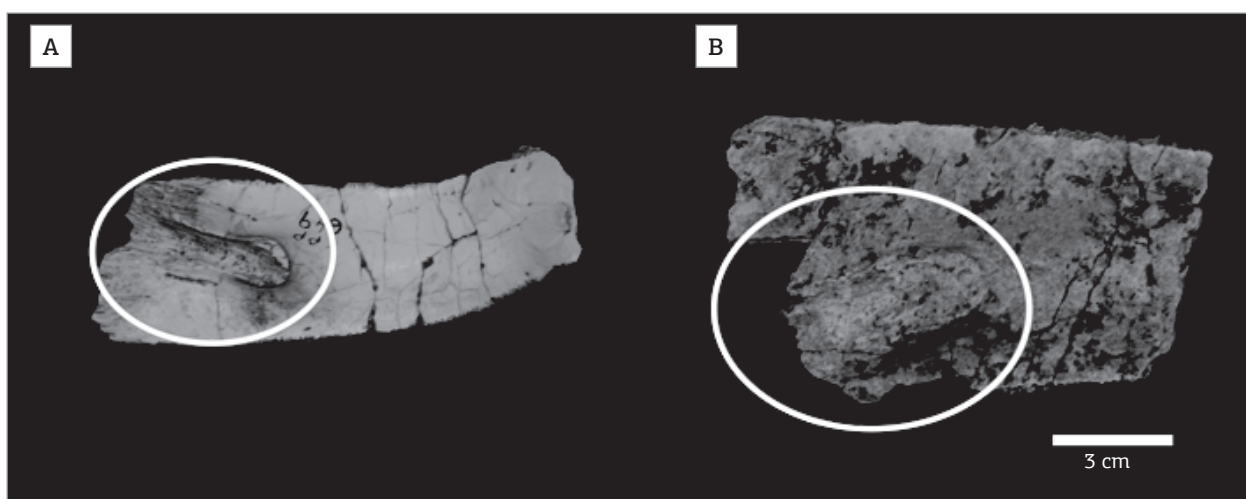


Figure 12. (A) Morphology of the inguinal scar belonging to “Peirópolis B” in CPP 647 highlighted by a circle; (B) Inguinal scar morphology of “Peirópolis A” in CPP 427 highlighted by a circle.

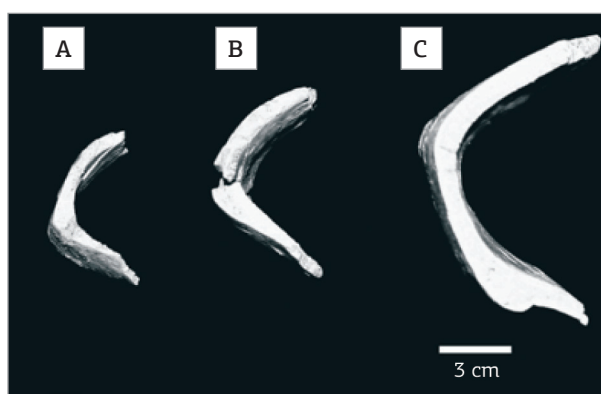


Figure 13. Comparison between the costal plates CPP 802 (A), 802 (B) and not cataloged plate (C).

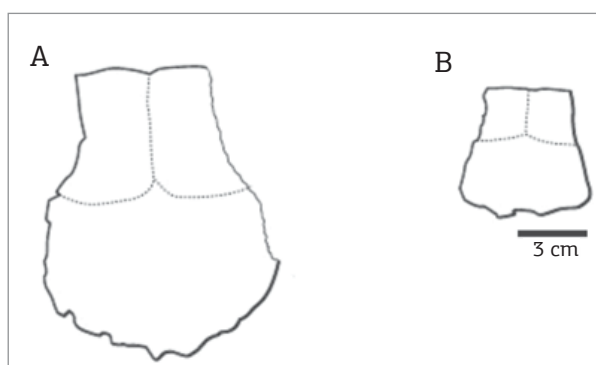


Figure 14. (A) V-shaped notch in “Peirópolis A”; (B) Absence of this notch in “Peirópolis B” (adapted from Gaffney et al. 2011).



At the plastron elements, the same differences happen in individual sizes. The specimen CPP 417, a fragment of hypoplastra or hyoplastra, is about twice the thickness of the other elements, indicating that these animals were more robust than the other ones. The epiplastra fragments present distinct sizes, but we observed the presence of a lip in its anterior region. This feature is pointed by Gaffney *et al.* (2011) as an autapomorphy of “Peirópolis A”. All epiplastra studied present such lip (Fig. 16).

Almost all xiphiplastra presents pubic and ischiatic scars with the same morphology. The ischiatic scar is triangular with twice of the width in the lateral region compared to the medial region. The pubic scar has oval shape and is bent at about 30°. The specimen CPP 720, a xiphiplastra partially complete, does not present this morphology. We observed that the ischiatic of CPP 720 (Fig. 17) has a slight curvature from its medial to the lateral region. The medial area would have a little more than a half the width of the lateral region. This scar ends almost at the end of the plastron at lateral posterior region. Its pubic scar is in vertical position without curvature, its anal notch is deep and rounded, and these characters are shared with CPP 761 and CPP 762.

The xiphiplastra CPP 770 presents differentiated morphology. Its ischiatic scar is almost horizontal and the pubic one has a slight curvature, about 30°, but its anal notch appears to be V-shaped instead of U-shaped, as we observed in the other specimens (Fig. 18).

According to França and Langer (2005), *Cambaremys langertoni* has a L-shaped ischiatic scar, characterizing

three different morphologies to the xiphiplastra. The pubic scar has the same oval shape, however it does not have the 30° curvature being practically vertically (Fig. 19). Moreover, the anal notch seems to be deeper than the other observed material.

The only cranial fragment studied consists in a fragment of the quadrate bone, CPP 433. This bone compared with other cranial materials, described by Gaffney *et al.* (2011), belongs to the species *Pricemys caiera* (Fig. 20).

The specimens CPP 1325, CPP 1327, and CPP 1326 are very different from the further studied material. These three specimens have a distinct ornamentation, with rectangular shape and they are very prominent. This pattern of ornamentation was not observed in any other specimen, therefore this is an indication that this material could be a fourth species from Peirópolis (Fig. 21).

At “Ponto 2” we have a peripheral plated CPP 292. This specimen consists in the 11<sup>th</sup> peripheral plate of a medium sized chelonian, probably bigger than CPP 333. This plate appears to belong to “Peirópolis A” because of a concavity present in its anterior region. The specimen CPP 286, which is the eighth peripheral plate, is fairly thick because this plate should be linked to the costal plate that supports the inguinal process.

Furthermore, it was seen this size and thickness variation in the plastron fragments found at this site. The material CPP 249 is visibly thinner than CPP 251 and CPP 250. The specimen CPP 249 has 0.9 cm of thickness, while CPP 251 and CPP 250 have only 0.6 cm. We could not know

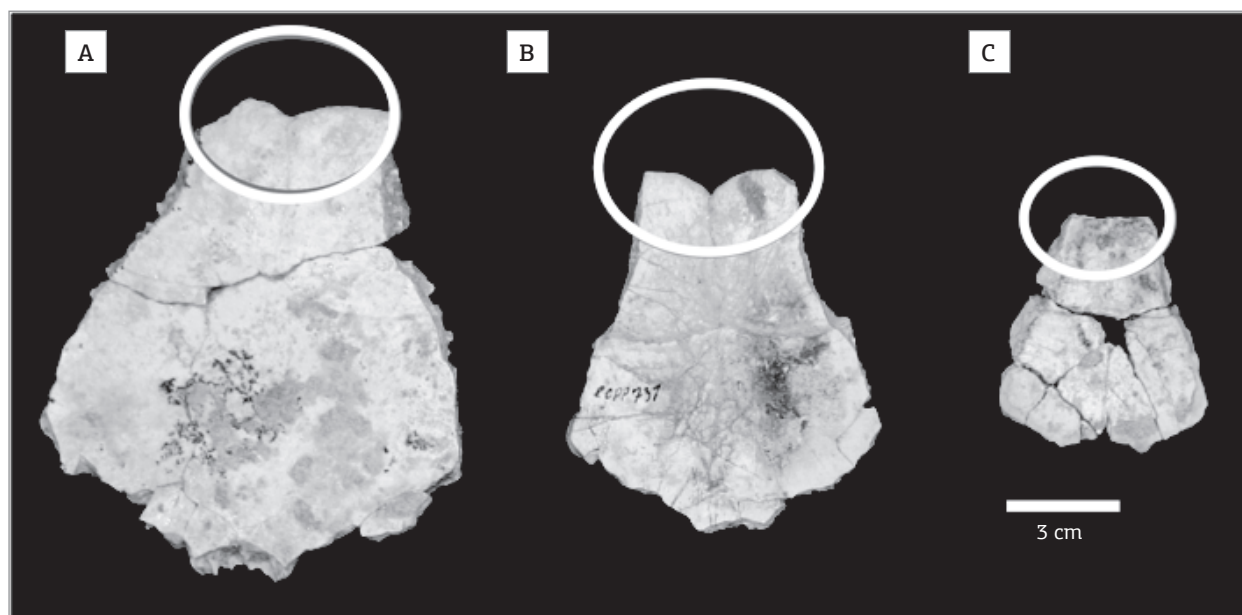


Figure 15. Presence of a V-shaped notch in A and B (CPP 348 and 731), highlighted by a circle. Note that in C, the notch is absent (CPP 746).



Figure 16. Figure comparing the epiplastra CPP 714 (A), 646 (B), and 734 (C).

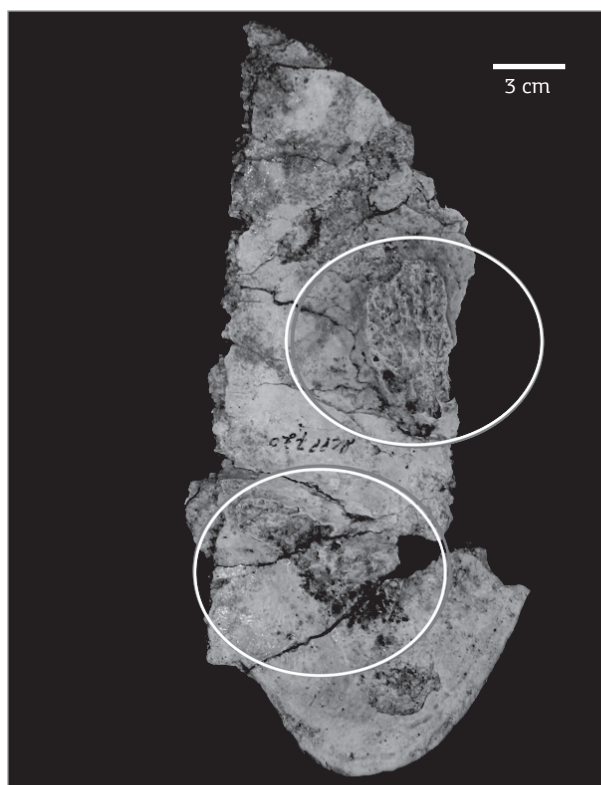


Figure 17. Preserved xiphiplastron CPP 720. Circles indicate the pubic and ischiatic scars respectively.

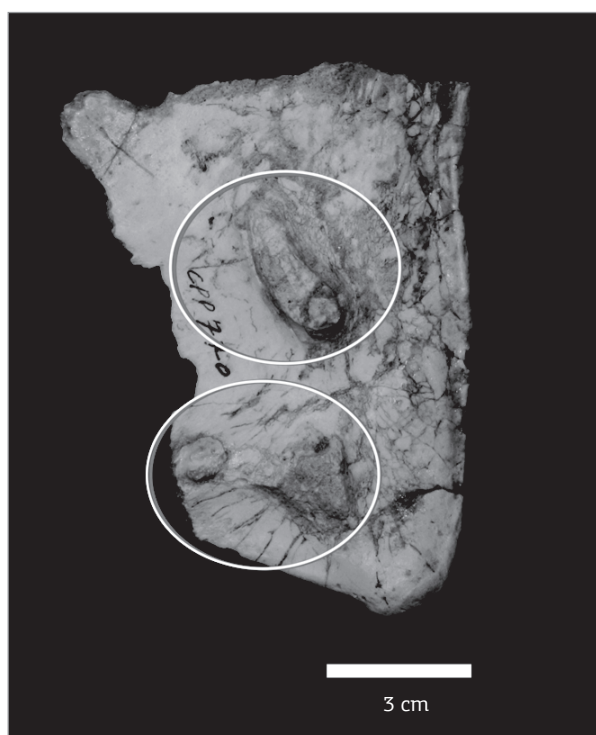


Figure 18. Preserved xiphiplastron CPP 770. Circles indicate pubic and ischiatic scars respectively.

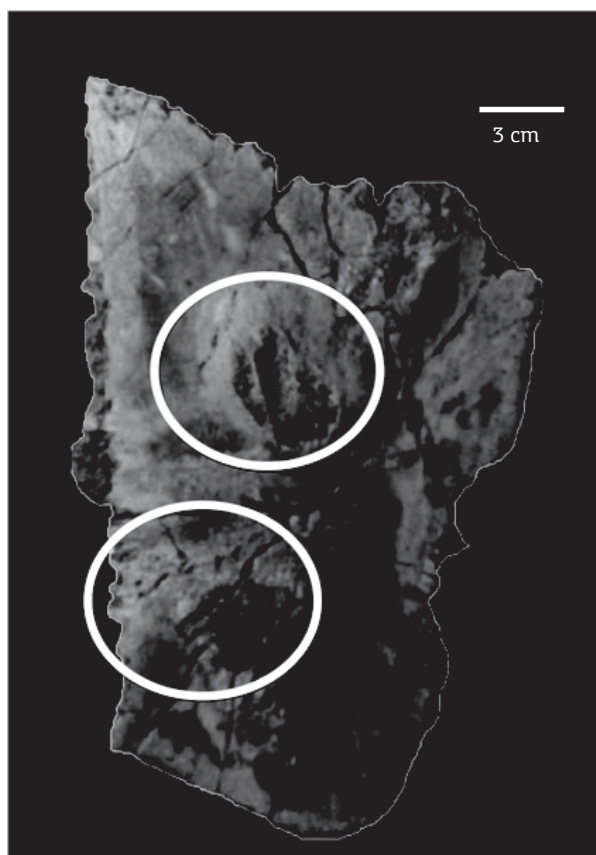


Figure 19. *Cambaremys langertoni* xiphiplastron (extracted from França & Langer 2005). Circles indicate the pubic and ischiatic scars respectively.

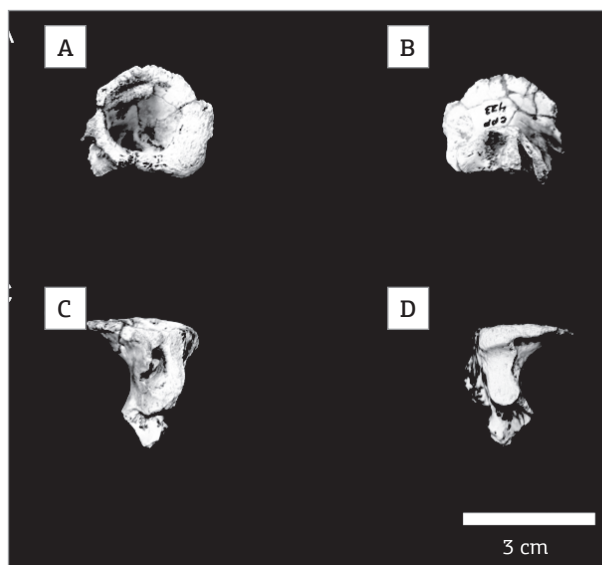


Figure 20. Cranial fragment that belongs to *Pricemys caiera* found at “Ponto 1”.

their exact size, because the material was broken. Since all of them are hypoplastra, this thickness difference indicates that CPP 251 belongs to a robust animal. At “Ponto 2”, we also have the articulated specimen used to describe *Cambaremys langertoni*. This chelonian would be a small individual, smaller than the rest of the specimens from Peirópolis.

## CONCLUSIONS

The fossils housed in CCCP-UFTM collection consists in 315 fossil fragments, mostly postcranial elements, which are generally disarticulated. The high disarticulation degree of these elements represents the major difficulty in using it for taxonomic purposes, not being possible to reach the level of species.

There are cases of more complete and articulated fossils, as CPP 252 specimen that is used to describe *Cambaremys langertoni* and the complete shell housed at DNPM collection with the number MCT 1499-R. We believe that the fossils from Peirópolis and those housed at CCCP-UFTM collection belong to *Podonemididae* family, as described by Gaffney *et al.* (2011).

At “Ponto 1” we found a significantly greater number of fossils than in “Ponto 2” and “BR-050”. The large quantitative difference could be related with the often fieldwork performed at “Ponto 1”. In this site, there are systematic collects, where technicians work daily. At “Ponto 2” and “BR-050” the fieldwork is more extemporaneous.

There are considerable differences in the individual sizes. We have specimens in which the animal could reach 60 cm

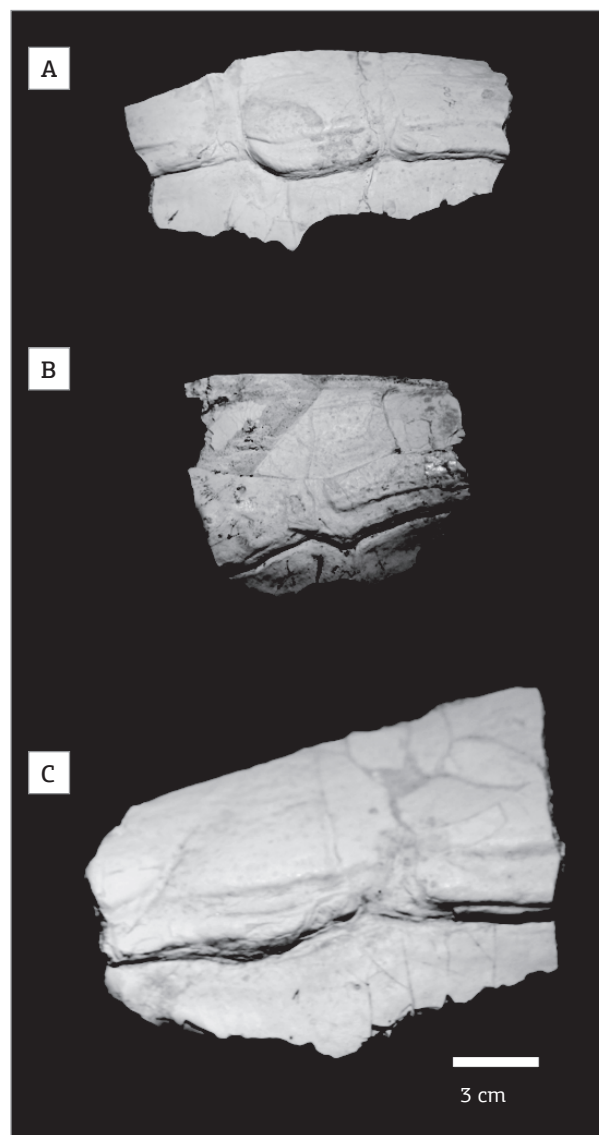


Figure 21. Ornamented plates CPP 1325 (A), 1327 (B), and 1326 (C).

width and other one with half of this width. The distinct sizes could indicate the presence of three different species or we can assign it to animals with different ages, adults and juveniles. In this case, we have nonselective death, if we considered that they were young, adults and old individuals.

Part of the material housed at the CCCP-UFTM collection, 120 samples, unlike the other chelonians of this site, was found in a clayey-sandy greenish sediment, probably in related mudflow deposits. Among this material, several carapace elements, as costal, peripheral and nuchal plates, plastron elements and apendicular skeleton were identified. Due to the high disarticulation degree, we believe that this chelonian died at a time of prolonged drought and subsequently its bone elements were carried and remobilized in a moment of

more humidity. The major quantity of fragments indicates that these animals are possibly grouped at dry times in the few water bodies existing.

The only cranial fragment founded among the material house in the collection consists in a quadrate bone that belongs to *Pricemys caiera* species. Combining the data obtained by the postcranial elements with those concerning species described to the region, we can say that there were four distinct species inhabiting the region of Peirópolis at Neo-Maastrichtian: *Cambaremys langertoni*, *Pricemys caiera*, *Peiropemys mezzalirai*, and a nameless one.

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