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ON A TITANOSAURID (DINOSAURIA, SAUROPODA) VERTEBRAL COLUMN FROM THE BAURU GROUP, LATE CRETACEOUS OF BRAZIL [1]

(With 39 figures)

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ABSTRACT: A new titanosaurid dinosaur from the Late Cretaceous continental deposits of the Bauru Group is described. *Trigonosaurus pricei* n.gen., n.sp., is based on two specimens, both collected at the Caieira Quarry near Peirópolis, Minas Gerais. The holotype consists of the five most posterior cervical vertebrae, 10 dorsals, six sacrals and the left ilium (MCT 1488-R). The second specimen (paratype) consists of 10 caudal vertebrae that according to a quarry map, were found isolated but show a similar morphology and compatible size suggesting that they belonged to one individual (MCT 1719-R). *Trigonosaurus pricei* is diagnosed by a combination of characters such as elongated cervicals and middorsals, dorsal vertebrae 9 and 10 with incipient postzygodiapophyseal lamina and transverse processes well developed throughout the sequence formed by anterior and medial caudals. The occurrence of this new taxon indicates a higher diversity of titanosaurids in the Brazil during the Cretaceous period.

Key words: Dinosauria, Sauropoda, Titanosauria, Titanosauridae, Cretaceous, Brazil.

RESUMO: Sobre uma coluna vertebral de um titanossaurídeo (Dinosauria, Sauropoda) do grupo Bauru, Neocretáceo do Brasil.

Um novo titanossaurídeo procedente dos depósitos continentais do grupo Bauru (Neocretáceo) é descrito. *Trigonosaurus pricei* n.gen., n.sp. é baseado em dois exemplares coletados na localidade Caieira na região de Peirópolis, Minas Gerais. O holótipo é composto das últimas cinco vértebras cervicais, 10 vértebras dorsais, seis sacrais e o ílio esquerdo (MCT 1488-R). O segundo exemplar (parátipo) é formado por 10 vértebras caudais que, de acordo com um mapa da escavação, foram encontradas isoladas, mas apresentam o mesmo padrão morfológico e um tamanho compatível, sendo, deste modo, consideradas como pertencentes a um mesmo indivíduo (MCT 1719-R). *Trigonosaurus pricei* é diagnosticado por uma combinação de caracteres tais como vértebras cervicais e dorsais médias alongadas, vértebras dorsais 9 e 10 com uma incipiente lâmina diapopós-zigapofisiária e processos transversos bem desenvolvidos por toda seqüência anterior e média da série caudal. A ocorrência deste novo táxon demonstra a existência de uma maior diversidade de titanosaurídeos no Brasil durante o período Cretáceo.

Palavras-chave: Dinosauria, Sauropoda, Titanosauria, Titanosauridae, Cretáceo, Brasil.

INTRODUCTION

The most abundant dinosaur group in Brazil is the Sauropoda, particularly those belonging to the clade Titanosauria from the Bauru Group (BERTINI *et al.*, 1993; KELLNER, 1998). Remains of those sauropods have been found in several localities, particularly in the states of Minas Gerais and São Paulo (BERTINI, 1993; KELLNER & CAMPOS, 2000). Despite being numerous, most records of titanosaurids from Brazil consist of undescribed isolated elements. Up to date, the most complete specimens are the holotype of *Gondwanatitan faustoi* Kellner & Azevedo, 1999 and the so called "Series B" (POWELL, 1987, 2003). The latter was collected at the quarry

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known as "Caieira" in Peirópolis by Llewellyn Ivor Price, where strata of the Bauru group have yielded several titanosaurid bones (e.g., CAMPOS & KELLNER, 1999; Fig.1). This vertebral sequence is housed at the Museu de Ciências da Terra of the Departamento Nacional de Produção Mineral (MCT/DNPM) in Rio de Janeiro, under the numbers MCT 1488-R and MCT 1719-R (see comments below). Although recognized as perhaps the best specimen recovered from the Peirópolis region (PRICE in LAMEGO, 1959) and representing a new taxon (e.g. POWELL, 1987; BERTINI, 1993; CAMPOS & KELLNER, 1999), this dinosaur still remained unnamed and undiagnosed. The main purpose of this paper is to diagnose this new titanosaurid taxon, here named *Trigonosaurus pricei* n.gen., n.sp., and compare it with members of the Titanosauria. Since several details of this new taxon were already published (POWELL, 1987; 2003; CAMPOS & KELLNER, 1999), we opted to provide a general morphological review and repeat only the main features that make *Trigonosaurus pricei* distinct from other titanosaurids. We also provided illustrations and detailed descriptions of the caudal vertebrae (MCT 1719-R) which were neither described nor illustrated before. We also illustrate the cervical series of this species that except for cervicals 12 and 13 were also not figured before.

Abbreviations as follows: (ac) acetabulum, (dia) diapophysis, (il) ilium, (isped) ischiatic peduncle, (nc) neural canal, (ns) neural spine, (podl) postzygodiapophyseal lamina, (posl) postspinal lamina, (poz) postzygapophysis, (pped) pubic peduncle, (prsl) prespinal lamina, (prz) prezygapophysis, (s) sacral vertebra, (sri) sacral rib, (tp) transverse process, (l) left, (r) right.

Comments on the "Series B"

The "Series B" is composed of a partial vertebral column with cervicals, dorsals, sacrals, caudals, and the left ilium, all previously treated as belonging to the same individual (e.g, POWELL, 1987). As CAMPOS & KELLNER (1999) pointed out, the main problem of this association is the fact that the 10 caudals referred to this series were not found articulated or in close contact with the remaining parts of the specimen. Actually, several caudal elements have been found isolated at the Caieira quarry and the association of those 10 caudals among themselves and with the remaining part of the "Series B" was probably done by Price, likely based on the similar morphology and

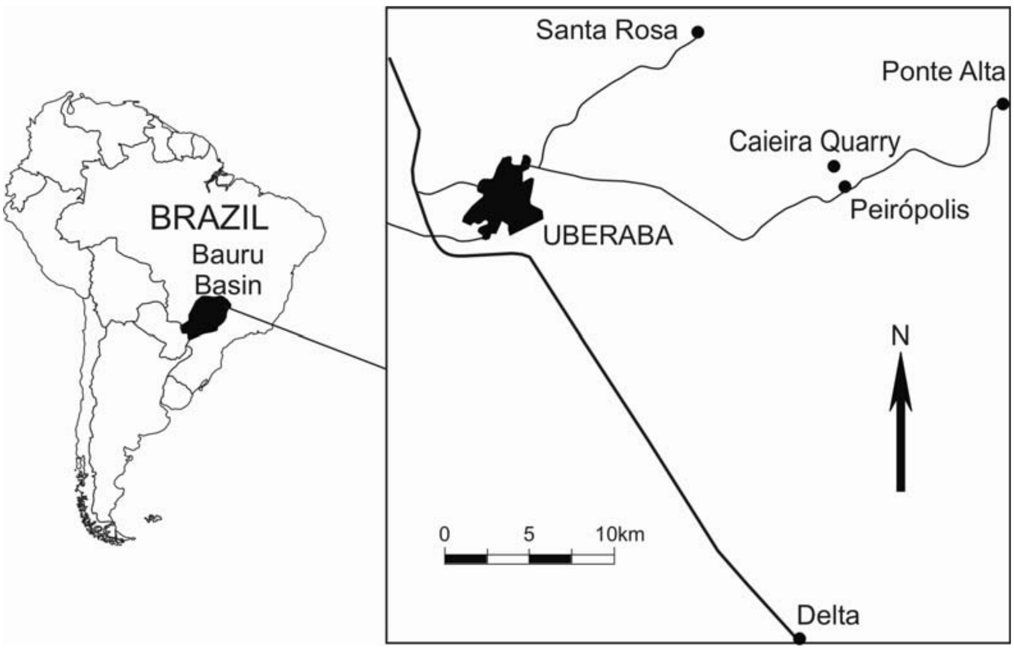

Fig.1- The map of South America showing the distribution of the Bauru Basin. In detail the location of the Caieira Quarry, near Peirópolis, where *Trigonosaurus pricei* n.gen., n.sp. was collected.

compatible size. According to his 1958 report, PRICE (in LAMEGO, 1959) mentioned that he previously believed that all titanosaurid specimens recovered from this quarry belonged to three individuals of different sizes of the same genus, but with the discovery of an articulated series of caudal vertebrae in 1957, he understood that there was more taxonomic diversity in this collection than he had assumed (see also KELLNER, CAMPOS & TROTTA, 2005, this volume).

Examining the material it is clear to us that those caudal vertebrae show a similar morphology and differ in size, which is consistent with their probable different position in the tail. Compared to the articulated caudal series represented by MCT 1490-R, some elements appear to articulate, but most belong to different parts of the tail. Their size is compatible with the sacral elements and therefore we cannot preclude the possibility that they belong to the same individual represented by MCT 1488-R, as has been apparently assumed by Price (and followed by POWELL, 1987; 2003). Nevertheless, since they were found neither articulated nor in close contact with the remaining part of the "Series B", we opted to regard them as belonging to a different individual but representing the same species as MCT 1488-R. Therefore the caudals received a distinct number (MCT 1719-R).

Observing Price's quarry map in detail (CAMPOS & KELLNER, 1999; KELLNER, CAMPOS & TROTTA, 2005, this volume), the number of vertebrae individualized on the map differs from the elements that are present in MCT 1488-R. On the map there are five sacral vertebrae and 13 presacral elements instead of the six sacrals and 15 presacral vertebrae. We believe that those discrepancies indicate that this map was made when the specimen was still in the field and before all elements had been fully prepared, with sediment possible obscuring the limits of some bones.

SYSTEMATIC PALAEONTOLOGY

Saurischia Seeley, 1888
Sauropodomorpha Huene, 1932
Sauropoda Marsh, 1878
Titanosauriformes Salgado, Coria & Calvo, 1997
Titanosauria Bonaparte & Coria, 1993
Titanosauridae Lydekker, 1893

Trigonosaurus n.gen.

Type- species – *Trigonosaurus pricei* n.sp.

Etymology – from the Greek language *trigónos* (triângulo) in allusion to the region known as "Triângulo Mineiro" from the Minas Gerais State, where the specimen was collected, and *saurus* meaning reptile.

Diagnosis – the same as for the species.

Trigonosaurus pricei n.sp.

Holotype – incomplete vertebral column formed by five cervical vertebrae, ten dorsals (last cervical and all dorsals articulated), sacrum and ilium (MCT 1488-R) housed at the Museu de Ciências da Terra (Departamento Nacional de Produção Mineral).

Paratype – ten caudals (MCT 1719-R) housed at the Museu de Ciências da Terra (Departamento Nacional de Produção Mineral).

Etymology – the specific name is given in honor of Llewellyn Ivor Price, a very important vertebrate paleontologist, whose birth day centenary is celebrated in 2005. L.I. Price collected this and several other specimens and inspired the authors of this paper, some of which had the pleasure to work with him (DAC and RJB).

Type-locality – MCT 1488-R and MCT 1719-R were collected at the quarry known as "Caieira" (locality 120 of BERTINI, 1993), an abandoned quarry from the São Luís Farm, Veadinho Hill, situated about 2km north of Peirópolis, Municipality of Uberaba, State of Minas Gerais, Southeastern Brazil (BERTINI, 1993; CAMPOS & KELLNER, 1999).

Geological setting – the specimen was found in fine to medium grained white and yellow sandstones, with conspicuous siltic-argillaceous matrix, and some disseminated small argilitic pellets from the Bauru Group, Marília Formation, Serra da Galga Member, height 835m. The age of this stratigraphic unit is regarded as Maastrichtian (GOBBO-RODRIGUES, PETRI & BERTINI, 1999).

Diagnosis – titanosaurid dinosaur characterized by the following combination of characters: elongated midcervical vertebrae, with low neural spine and concave ventral margin; elongated middorsal vertebrae with strongly posteriorly inclined neural spine; dorsal vertebrae 9 and 10 with incipient postzygodiapophyseal lamina; anterior caudal vertebrae with thin base broadening towards the top; anteriormost caudals (2-5), with two and middle caudals with one pronounced dorsal depression on the transverse process; prezygapophyses on the caudal vertebrae extended forward (but not to the same degree as *Aeolosaurus rionegrinus* and *Gondwanatitan faustoi*), with wide articular faces; articulation surfaces for haemal arches strongly developed starting on caudal 3 until the last preserved element (caudal 20); transverse processes well developed throughout the sequence formed by anterior and medial caudals (until at least caudal 20).

DESCRIPTION AND COMPARISONS

The preserved part of the vertebral column of *Trigonosaurus pricei* is formed by five cervical vertebrae, 10 dorsals, six sacrals and the right ilium (MCT 1488-R), and 10 caudals (MCT 1719-R). The last cervical vertebra, the dorsals and the pelvis were found articulated, as was also indicated on the quarry map made by Price (CAMPOS & KELLNER, 1999; KELLNER, CAMPOS & TROTTA, 2005, this volume). The bones of *Trigonosaurus pricei* have a whitish colour and are well preserved, a common feature of the fossils found in the Peirópolis region. Except for the neural spine of the sixth dorsal vertebra, no sign of strong distortion is observed. Parts of some vertebrae were broken, particularly the cervicals and some of the neural spines of the caudals. The nomenclature regarding different lamina is based on WILSON (1999).

CERVICAL VERTEBRAE

Five cervical vertebrae of *Trigonosaurus pricei* are known. Based on Price's quarry map (CAMPOS & KELLNER, 1999), those elements were not articulated but closely associated, although not all could be recognized or distinguished from the dorsal vertebrae in the map. Their sizes are compatible and as far as comparisons are possible they articulate suggesting that they formed a continuous sequence (Figs.2-14). The last cervical was found articulated with the first dorsal and both were not separated (Figs.2, 5). Based on an almost complete cervical series from another point of Peirópolis (Mombuca quarry, according to CAMPOS & KELLNER, 1999), POWELL (1987) established that the titanosaur neck was formed by 13 elements (including atlas and axis). Therefore the five cervicals of *Trigonosaurus pricei* are here regarded to represent cervicals 9 to 13.

Overall none of the cervical vertebrae of *Trigonosaurus pricei* is complete. Except for cervical 9, all lack to most dorsal part of the neural spine. Cervicals 9 and 10 have part of the right lateral side broken particularly the region of the cervical rib. Cervicals 12 and 13 also have the cervical ribs broken on the right side. All posterior ends of the remaining cervical ribs were broken possible prior to fossilization or during the collecting of the specimen.

In general, the anterior cervical tend to be more elongated (cervicals 9 and 10) while the posterior ones tend to be shorter and laterally expanded giving them a more robust appearance (Tab.1). All are opisthocoelous, with the lateral margin of the centrum concave, and lack pleurocoels. Ventrally the anterior surface of the centrum shows a deep depression between the parapophyses and turns to a convex surface close to the posterior articulation surface. Pre- and postzygapophyses are short and project anteriorly and posteriorly, showing well developed articular facets. The neural spine in cervical 9 is low, has the dorsal portion laterally expanded and tends to be more elongated compared to the more posterior elements (e.g., cervicals 12 and 13). The spinoprezygapophyseal lamina is very thick and is more developed in the more anteriorly positioned cervicals. There is a shallow depression on the medial surface of the prezygapophyses (medial to the spinoprezygapophyseal lamina) that is displaced medially in cervical 9 but gets gradually more horizontal in the posterior cervicals. The spinopostzygapophyseal lamina tends to be more developed running on the medial surfaces of the neural spine and the postzygapophyses. Deep pre- and postspinal fossae are present. The last cervical vertebra has a relatively thick vertebral centrum, wider than tall, with a wide and laterally expanded neural arch. The diapophyses of this cervical are strong and they have downward and backward orientated articulation surfaces.

The cervical ribs are not complete in any of the elements, lacking the posterior projection. They are double-headed and are fused with the diapophysis and the parapophysis, and are placed parallel to the axis of the vertebral column. The anterior projection is well developed, surpassing the centrum and (in lateral view) level with the prezygaphophysis.

TABLE 1. Measurements of the cervical vertebrae of *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R)

Cervical vertebrae	Total length of centrum (mm)
cervical 9	280
cervical 10	282
cervical 11	277
cervical 12	258
cervical 13	202

The comparisons of the cervical vertebrae of *Trigonosaurus pricei* are restricted since the neck is known in only a few titanosaur species. Only one cervical of *Malawisaurus dixeyi* (Haughton, 1928) is figured (JACOBS *et al.*, 1993) and possible comes from the middle-posterior part of the neck. It is also an elongated element and differs from *Trigonosaurus pricei* mainly by having a higher neural spine and the ventral margin of the centrum straighter. The cervicals of *Isisaurus colberti* (JAIN & BANDYOPADHYAY, 1997; WILSON & UPCHURCH, 2003) are quite different from *Trigonosaurus pricei* (and other titanosaurids) by being much shorter, showing a higher neural spine and showing pleurocoels. *Trigonosaurus pricei* further differs from this species by having the anterior and posterior projection of the cervical ribs more developed. *Gondwanatitan faustoi* has only an incomplete centrum of a possible posterior cervical that is remarkably different from *Trigonosaurus pricei* by showing the anterior condyle smaller and by having two ventral depressions separated by a bony ridge (KELLNER & AZEVEDO, 1999). According to CALVO & GONZÁLEZ RIGA (2003), *Rinconsaurus caudamirus* has a long anterioposterior depression with small pleurocoels on the lateral surface of the cervical centrum, which is absent in *Trigonosaurus pricei*.

The cervicals of *Saltasaurus loricatus* are also quite distinct from *Trigonosaurus pricei* by being comparatively shorter, presenting deep pleurocoels and a very low neural spine. Furthermore, *Saltasaurus loricatus* has a straighter ventral margin and peculiar long and posteriorly projected postzygapophyses (POWELL, 2003: 114). The lateral tuberosity of the neural spine observed in some cervicals of *Saltasaurus loricatus* is absent in *Trigonosaurus pricei*. Furthermore, *Trigonosaurus pricei* does not show the short prezygapophyses with the articular facets positioned near the level of the diapophysis, which is regarded a diagnostic feature of the Saltasaurinae (SALGADO, CORIA & CALVO, 1997).

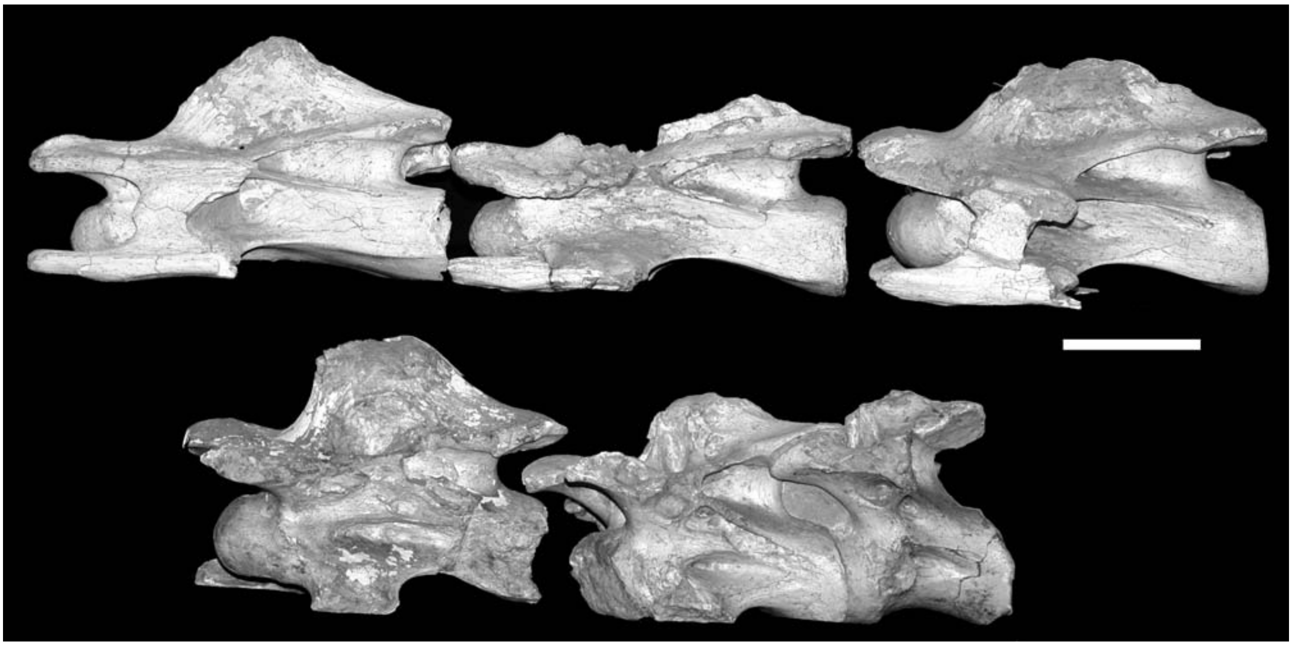

Fig.2- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical vertebrae (9-13) and first dorsal in left lateral view. Scale bar = 100mm.

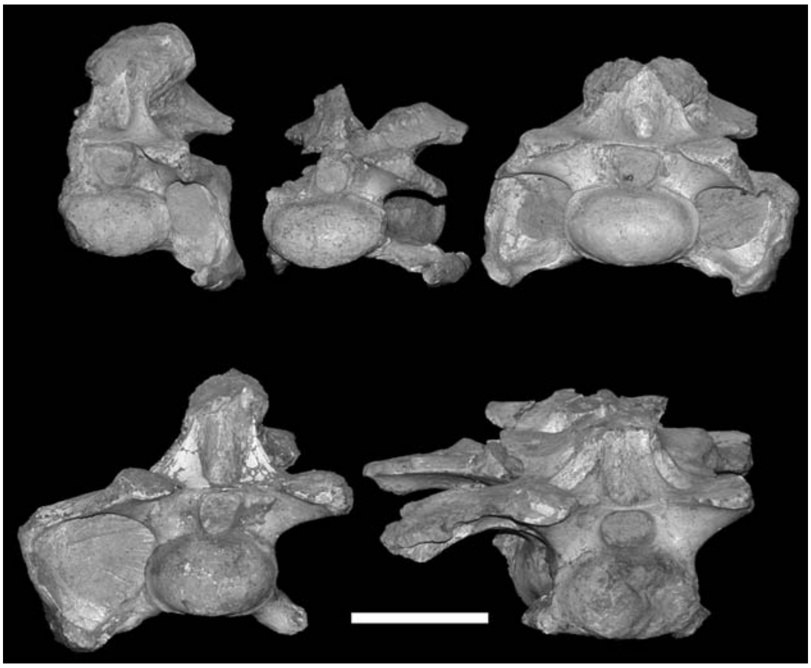

Fig.3- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical vertebrae (9-13) in anterior view. Scale bar = 100mm.

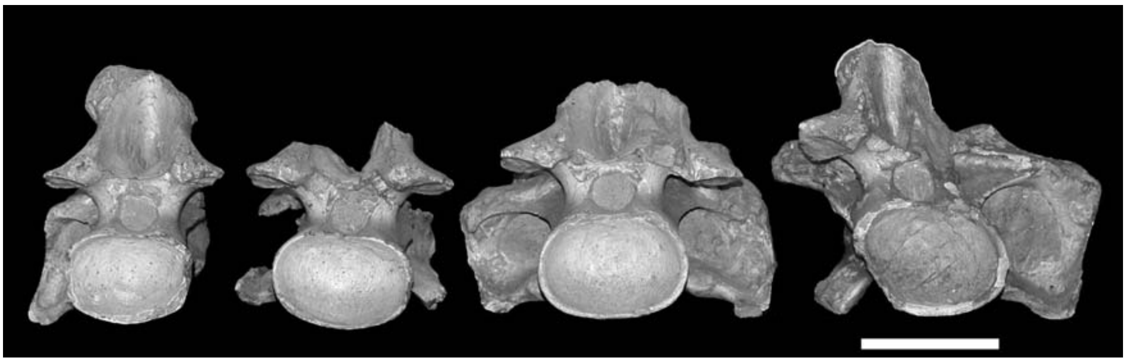

Fig.4- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical vertebrae (9-12) in posterior view. Scale bar = 100mm.

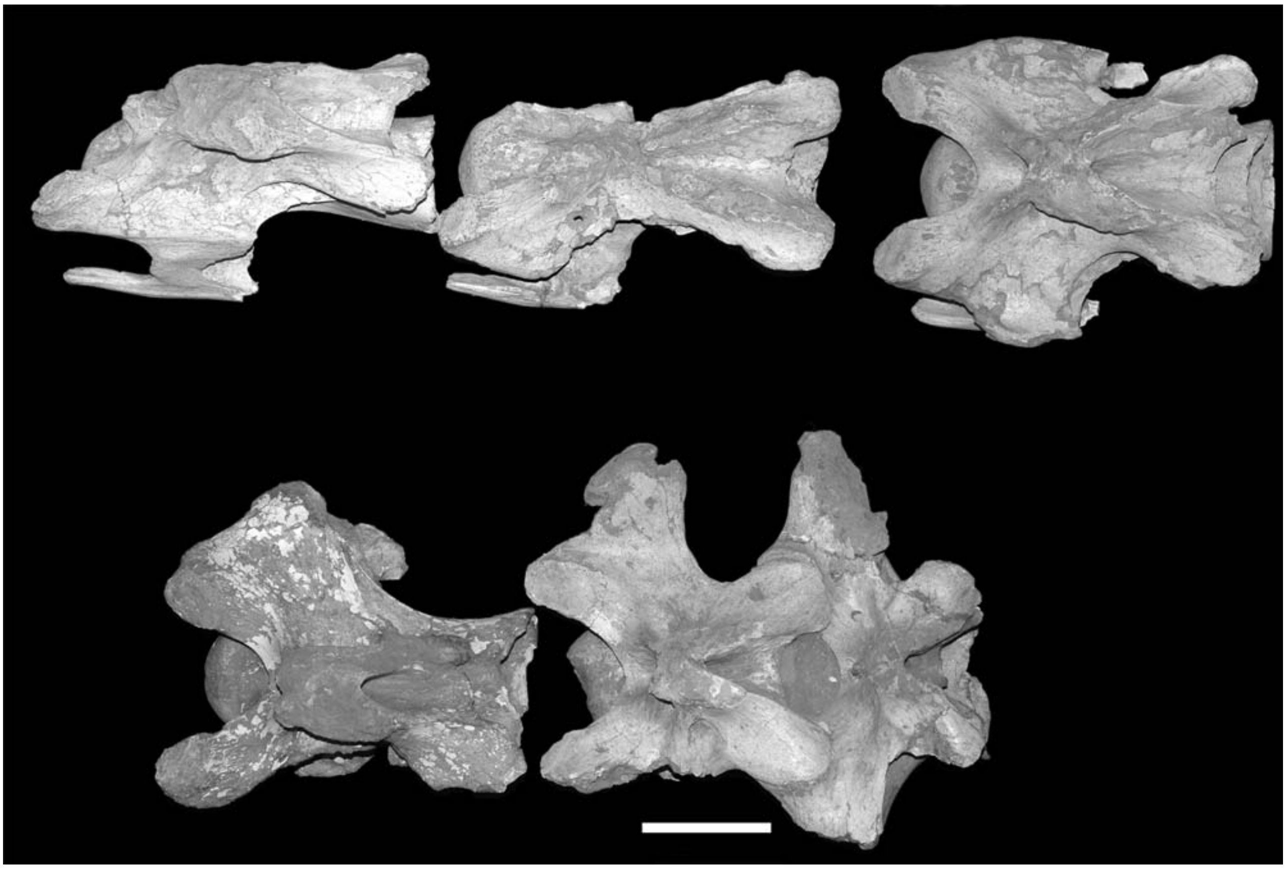

Fig.5- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical vertebrae and first dorsal in dorsal view. Scale bar = 100mm.

Fig.6- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical 9 in left lateral view. Scale bar = 100mm.

Fig.7- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical 9 in anterior view. Scale bar = 100mm.

Fig.8- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical 9 in posterior view. Scale bar = 100mm.

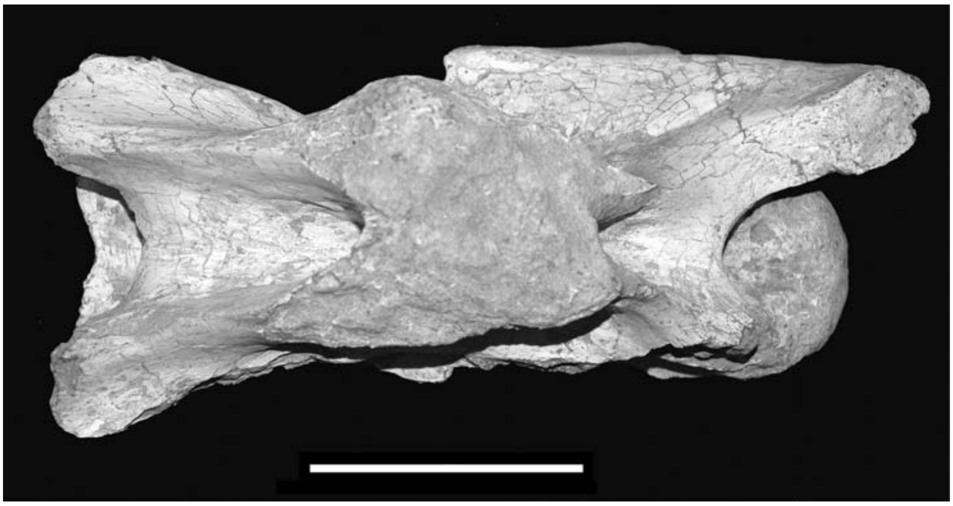

Fig.9- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical 9 in dorsal view. Scale bar = 100mm.

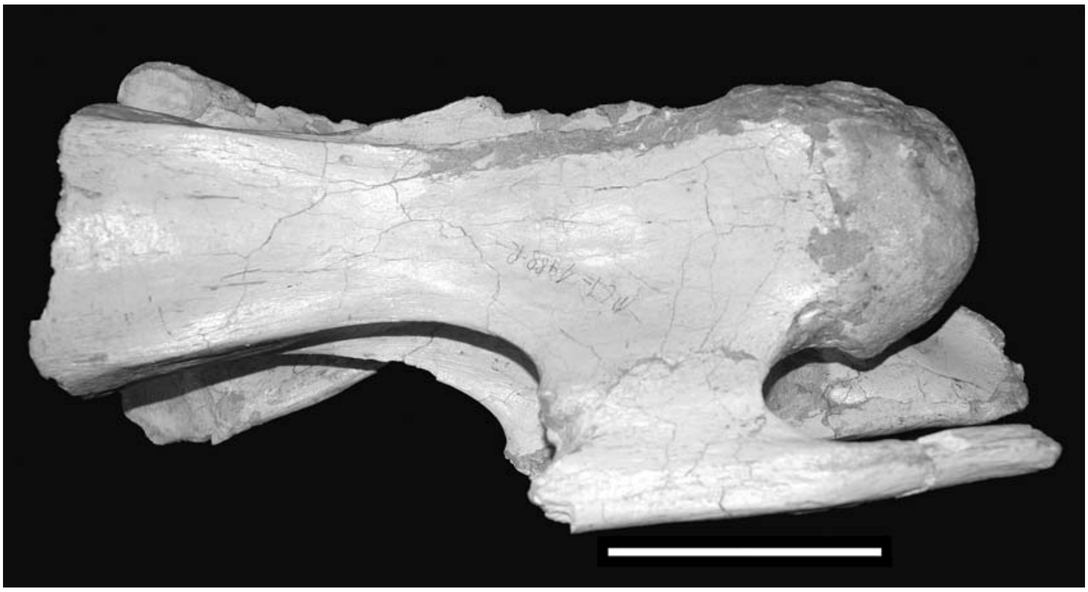

Fig.10- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical 9 in ventral view. Scale bar = 100mm.

Fig.11- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical 11 in anterior view. Scale bar = 100mm.

Fig.12- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical 11 in posterior view. Scale bar = 100mm.

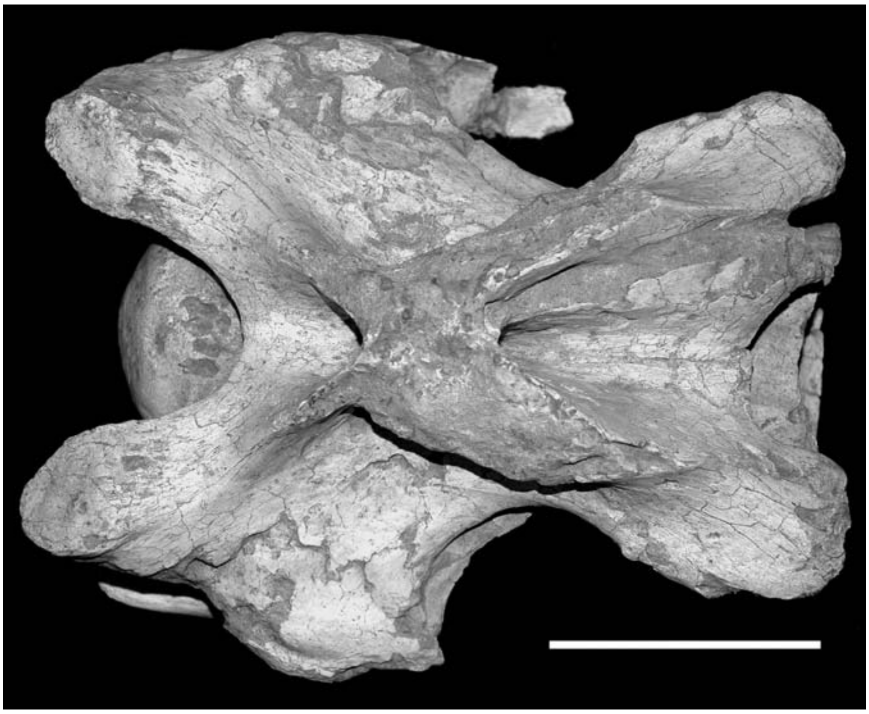

Fig.13- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical 11 in dorsal view. Scale bar = 100mm.

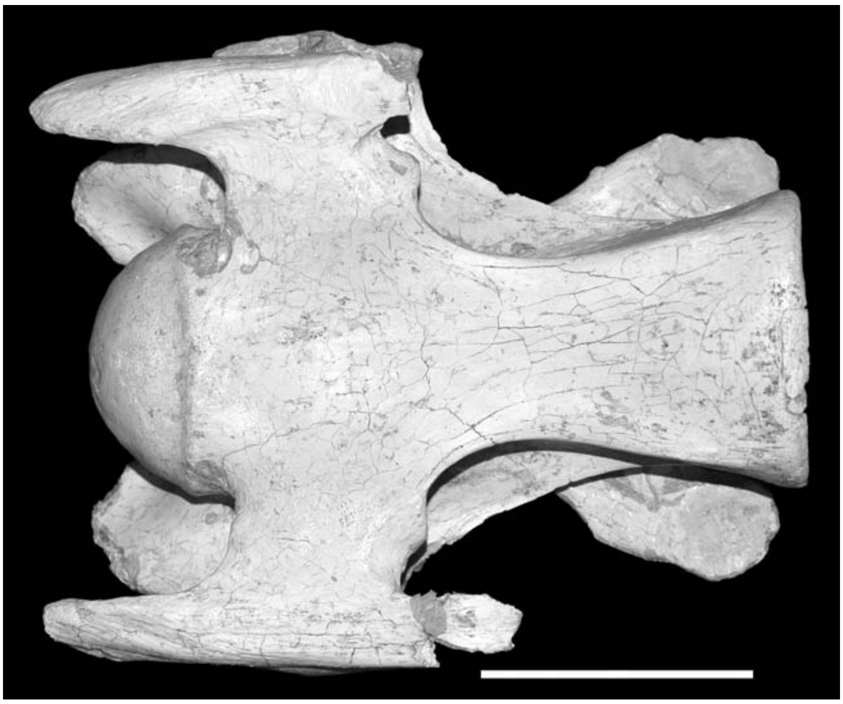

Fig.14- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), cervical 11 in ventral view. Scale bar = 100mm.

Dorsal vertebrae

The dorsal vertebral sequence of *Trigonosaurus pricei* is complete and was already described in some detail by POWELL (1987, 2003) and a summary with the main features is presented below (Figs.15-20; Tab.2). All elements are strongly opisthocoelous, a common feature among titanosaurids. The anterior surfaces are hemispherical and convex, while the posterior surfaces are larger and concave. All dorsals bear a deep pleurocoel marked by sharp borders positioned on the lateral surface of the centrum, below the neural arches. This pleurocoel is smallest in the dorsal 2, getting gradually more elongated ("eye shaped") in the remaining elements. The size of the centrum varies, being relatively longer in the middle part of the series. No hyposphene-hypantrum is present. The neural arches have a broad lateral base that occupies over 50% of the centrum length. The neural spine of the first dorsal is incomplete but the preserved portion indicates it was low and undivided. Starting at dorsal 3, the neural spine gets elongated and gradually more inclined posteriorly extending above the anterior part of the subsequent vertebra. In the last dorsal (the 10th) the neural spine changes abruptly to a vertical position. Dorsal 5 shows a pair of accessory

TABLE 2. Measurements of the dorsal vertebrae (MCT 1488-R) of *Trigonosaurus pricei* n.gen., n.sp.

Dorsal vertebrae	Total length of centrum (mm)
dorsal 1	~148
dorsal 2	~ 128
dorsal 3	~ 110
dorsal 4	~155
dorsal 5	~150
dorsal 6	~ 170
dorsal 7	~ 155
dorsal 8	~ 150
dorsal 9	~ 148
dorsal 10	~ 140

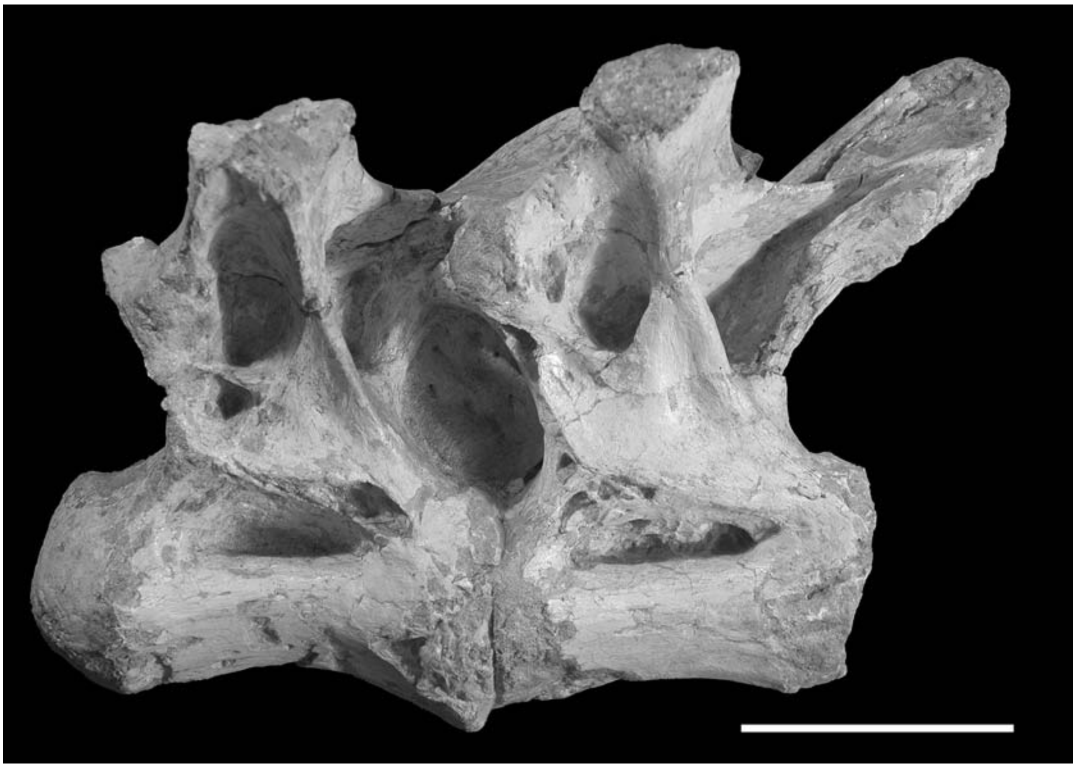

Fig.15- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), dorsals 4 and 5 in left lateral view. Scale bar = 100mm.

diapophyseal laminae (Fig.18) which are also well developed in dorsal 7. At dorsal 1, the parapophysis are located on the lateral part of the anterior half of the centrum, but gradually migrates to a more dorsal position in the subsequent elements, reaching almost the same height of the diapophysis at dorsal 6. On dorsals 9 and 10 the parapophysis migrates again to a more ventral position relative to the diapophysis. The prezygapophysis does not project very much anteriorly. The postzygapophysis is always located very close to the neural spine. A prespinal lamina is present in all dorsals and gets gradually more developed and thicker in the more posteriorly elements until dorsal 9.

Overall the dorsal vertebrae of *Trigonosaurus pricei* differ from most other titanosaurid taxa by being proportionally longer (similar to *Gondwanatitan faustoi* and *Saltasaurus loricatus*), with large pleurocoels (smaller than in *Gondwanatitan faustoi* and *Epachthosaurus sciuttoi*). The neural spines of the middorsals are inclined, apparently more than in any other titanosaurid. *Trigonosaurus pricei* lacks hyposphene-hypantrum, which is observed in the more basal titanosaurid *Andesaurus delgadoi* and in *Epachthosaurus*. A postzygodiapophyseal lamina linking the diapophysis and the postzygapophysis is incipiently developed in dorsals 9 and 10 of *Trigonosaurus pricei* (Fig.20). Such a lamina is absent in *Opisthocoelicaudia skarzynskii*. The difference in size of the anterior and posterior articulation surface is more strongly developed in *Gondwanatitan faustoi* (KELLNER & AZEVEDO, 1999) compared with *Trigonosaurus pricei*. *Opisthocoelicaudia skarzynskii* bears a neural spine bifurcated into two "low metapophyses" (BORSUK-BIALYNICKA, 1977), absent in *Trigonosaurus pricei*. The dorsal vertebrae of *Opisthocoelicaudia skarzynskii*, and the few incomplete remains of *Pellegrinisaurus powelli*, have the centra twice as wide than high (BORSUK-BIALYNICKA, 1977; SALGADO, 1996), also differing from *Trigonosaurus pricei*. The few dorsal vertebrae known from *Malawisaurus dixeyi* bear wide and more robust transverse processes (JACOBS *et al.*, 1993),

Fig.16- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), dorsal 4 in anterior view. Scale bar = 100mm.

differing from *Trigonosaurus pricei*. Based on the illustrations presented by CORIA *et al.* (1998: Fig.61) of the dorsals of *Argentinosaurus huinculensis*, *Trigonosaurus pricei* shows a larger size variation within the dorsal vertebral elements.

SACRUM

The sacrum of *Trigonosaurus pricei* is composed of six vertebrae (total length 583mm), which are well preserved, except for the right transverse process of the third sacral vertebra (Figs.21-24). Except for the last sacral, all centra are fused. The first sacral vertebra was incorporated from the dorsal vertebral series and the last from the caudal series (CAMPOS & KELLNER, 1999). As far as observations are possible, sacrals 1 to 5 are opisthocoelous, while the last sacral is either procoelous or biconvex, with a convex posterior articulation for the first caudal (not preserved). Pre- and postspinal laminae, forming a sagittal bony surface, uniting the neural spines of adjacent sacrals, are present. The spinodiapophyseal, postzygodiapophyseal and prezygodiapophyseal laminae are observed, which tend to be more reduced in the last three sacrals.

Sacral ribs tend to be robust and directed laterally. The first sacral rib is very long and contacts the anterior margin of the ilium blade. The left ilium is connected to the sacrum and has the preacetabular lobe elongated and laterally projected. More details of sacrum and pelvis, including comparisons, were provided by CAMPOS & KELLNER (1999).

CAUDAL VERTEBRAE

There are 10 caudal vertebrae known of *Trigonosaurus pricei* (Figs.25-39). Compared to the articulated caudal series MCT 1490-R (see

Fig.17- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), dorsal 5 in posterior view. Scale bar = 100mm.

KELLNER, CAMPOS & TROTTA, 2005, this volume), they are tentatively interpreted as being the 2nd, 3rd, 5th, 6th, 9th, 12th, 14th, 16th, 18th, and 20th (Table 3). Overall they show a very similar morphology. All are procoelous, with the posterior condyle slightly displaced dorsally and a strongly concave cotyle. The condyle is separated from the centrum by a bony ridge that is developed in all preserved elements. The lateral surface is concave. The anterior surface of the centrum is always wider than high, with an oval outline that gets more subrectangular in the more posterior elements. The posterior part of the centrum changes from elliptical (e.g., wider than high) in caudals 2 and 3, to a more rectangular shape condition (e.g., higher than wide) from caudals 5, 6 and 9 and to a more oval shape in remaining elements. A shallow groove or depression is observed in the posterior condyle of some elements (caudals 2, 9, 12 and 14). The articulation for the haemal arches are strongly developed starting on caudal 3 and are present until the last preserved element.

As in several titanosaurid dinosaurs, the neural arch is placed over the anterior half of the centrum, near the rim of the anterior margin. The neural spine is inclined anteriorly until caudal 18 and gets more vertical in caudal 20. From anterior and posterior views it is possible to observe that the base of the neural spine is laterally compressed and the dorsal part slightly expanded laterally, what is more visible in the anterior elements but is

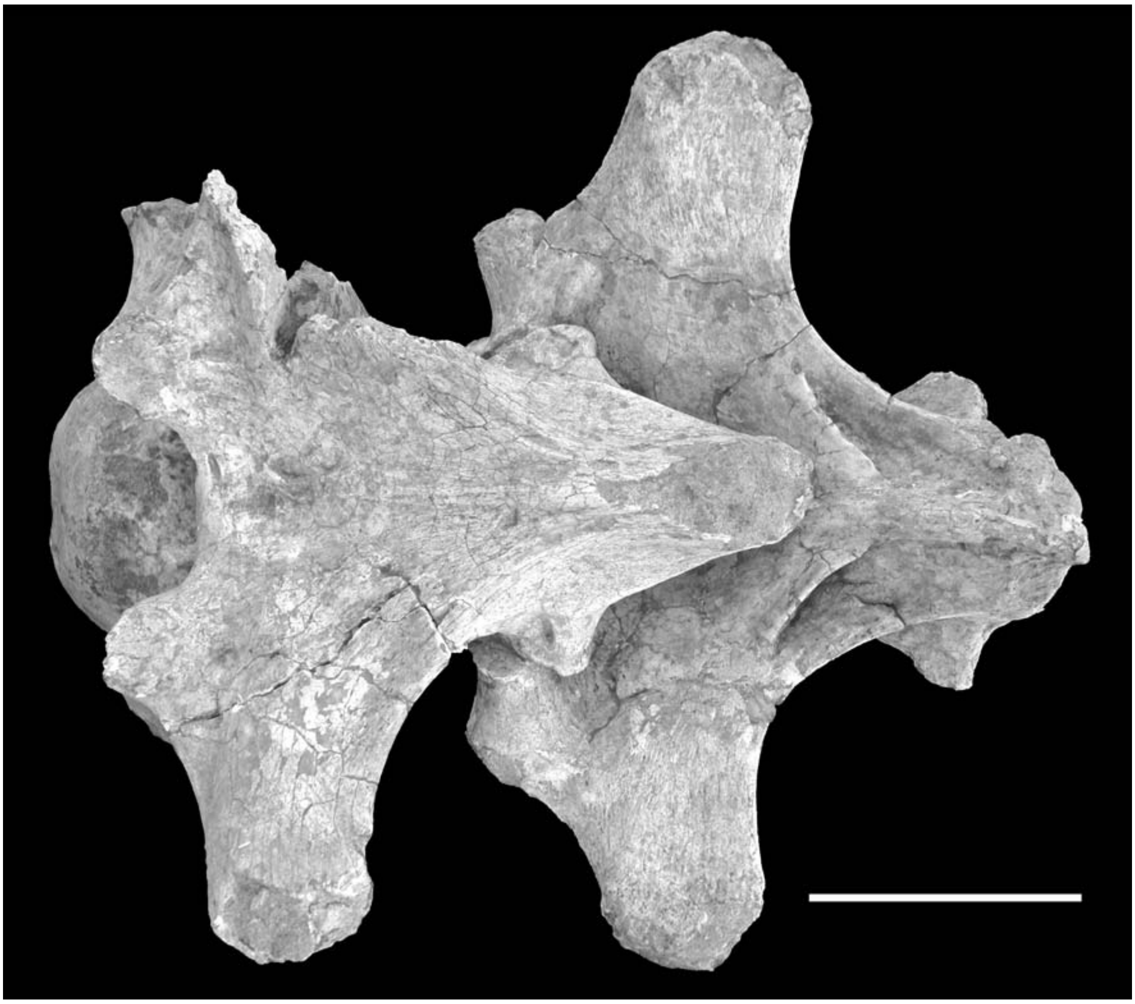

Fig.18- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), dorsals 4 and 5 in dorsal view. Scale bar = 100mm.

still perceptible in caudal 14. Pre- and postspinal laminae are present, with the prespinal lamina more developed. Spinoprezygapophyseal laminae are present and well developed particularly in caudal 2, running from the anterolateral margin of the neural spine until the prezygapophysis. In caudal 3, the spinoprezygapophyseal lamina is reduced, migrates posteriorly, and bifurcates, sending one additional lamina (accessory spinoprezygapophyseal lamina) to the anterolateral portion of the neural spine. The decrease of the spinoprezygapophyseal laminae continues until it is no more perceptible in caudal 6. The accessory lamina, however, is well developed in caudal 5 contacting the prespinal lamina, merging with the lateral margin of the neural spine in the posterior elements.

The prezygapophyses of caudal 2 are short and projected dorsoanteriorly. In the remaining caudals, prezygapophyses get longer and gradually get less inclined, assuming a subhorizontal position starting at caudal 9. A tuberosity is observed in the dorsolateral margin of the articulation surface of the prezygapophyses. It is very well developed in caudals 3 to 6 and smoothens out in the more posteriorly positioned elements. The articular faces of the prezygapophysis are strongly inclined, forming a very acute angle in respect to the sagittal plane in the anterior caudals, getting gradually less inclined in the posterior elements.

The postzygapophyses are placed very closely to the neural spine and are well developed in all preserved elements, having large articulation surfaces (caudal 20). In the more anteriorly positioned elements (caudals 2-5), the postzygapophyseal articular surface forms a

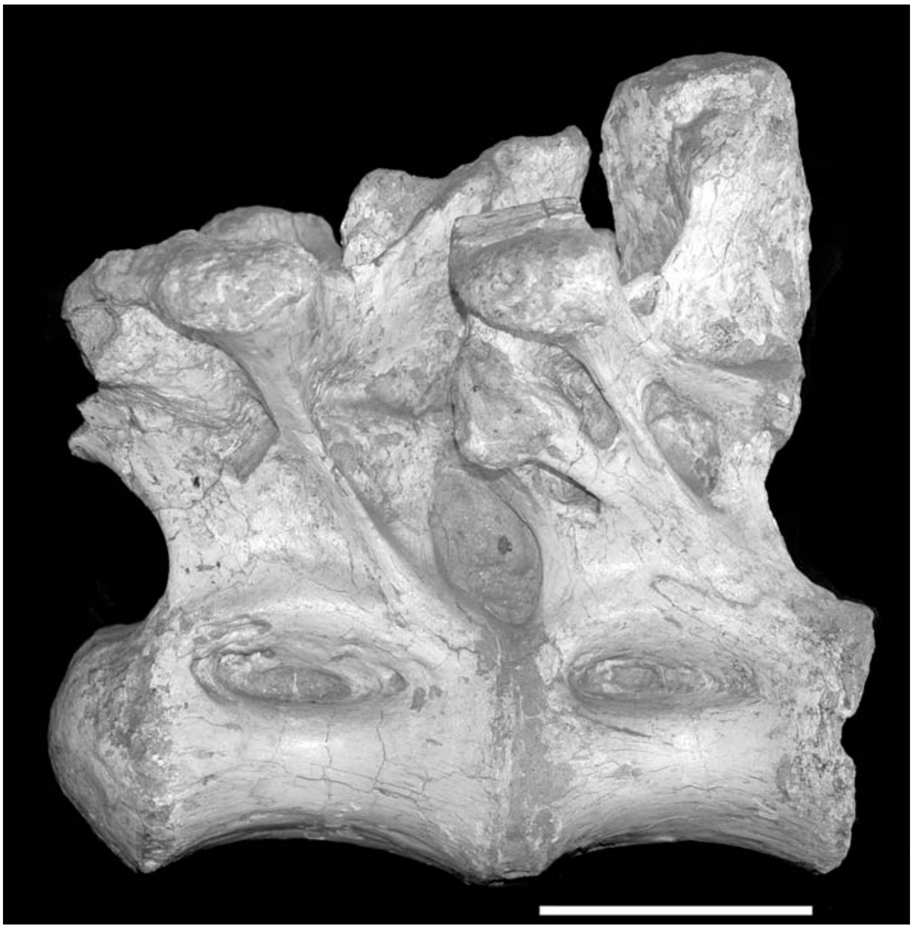

Fig.19- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), dorsals 9 and 10 in left lateral view. Scale bar = 100mm.

flattened and inclined surface, but starting in caudal 6, this surface gets gradually more concave with the dorsal margin becoming directed laterally. All preserved caudals show well developed lateroposteriorly oriented transverse processes that get reduced only in the more posteriorly situated elements (caudal 14) and are still present as clearly distinct processes in caudal 20 (the last preserved one attributed to *Trigonosaurus pricei*). Among the most interesting features of those elements is the presence of two dorsal depressions on the transverse processes of caudals 2-5, with the most laterally placed one smoothing out in caudal 6. The second depression, however, is perceptible until caudal 12. At the contact surface between the transverse process and the neural arch, the bone is rugose but no dorsal tuberosity as in MCT 1490-R is observed in the anterior elements. Caudals 16 and 18, however, have the bone surface in this part thickened, forming a ridge displaced to the anterolateral surface of the transverse process.

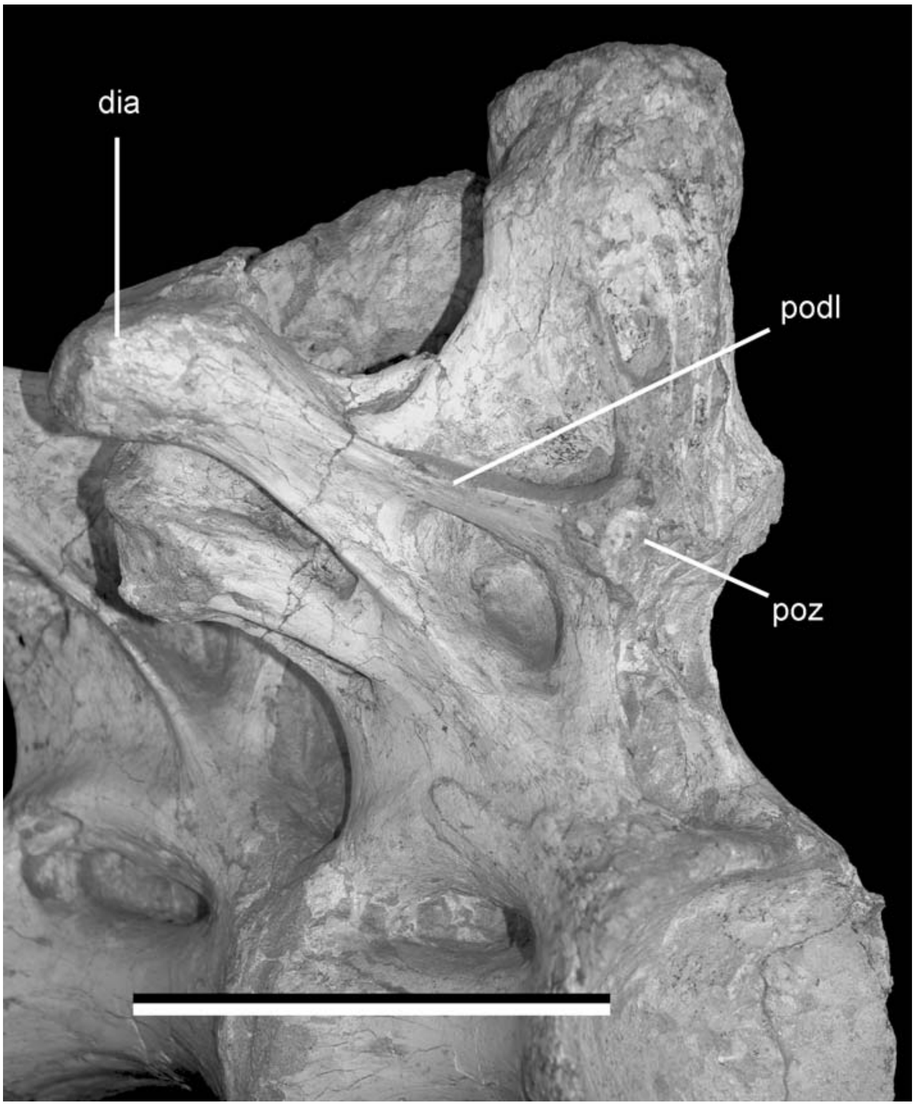

Fig.20- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), detail of dorsal 10 in lateroposterior view. Scale bar = 100mm. See text for abbreviations.

From all known titanosaurid dinosaurs, the caudal vertebrae of *Trigonosaurus pricei* are more similar to the ones reported for *Aeolosaurus rionegrinus* and *Gondwanatitan faustoi*, sharing with those taxa the anterodorsally directed neural spine and prezygapophyses. Differing from *Aeolosaurus rionegrinus*, the prezygapophyses of *Trigonosaurus pricei* are comparatively shorter. Furthermore, *Trigonosaurus pricei* does not show the "heart-shaped" condition found in *Gondwanatitan faustoi* (KELLNER & AZEVEDO, 1999), *Aeolosaurus rionegrinus* (Kellner, pers. obs.) and in caudals 4-8 of MCT 1490-R (KELLNER, CAMPOS & TROTTA, 2005, this volume). *Trigonosaurus pricei* also differs from MCT 1490-R by having the prespinal lamina more developed than the postspinal lamina and by having the transverse process more developed.

Furthermore, *Trigonosaurus pricei* shows depressions on the dorsal surface of the transverse process, which, as far as we know, were not recorded in any other titanosaurid dinosaur of which large parts of the tail are known such as *Epachthosaurus sciuttoi* (MARTÍNEZ *et al.*, 2004), *Alamosaurus sanjuanensis* (GILMORE, 1946), *Titanosaurus araukanicus* (POWELL, 2003), *Gondwanatitan faustoi* (KELLNER & AZEVEDO, 1999), MCT 1490-R (KELLNER, CAMPOS & TROTTA, 2005, this volume), *Pellegrinisaurus powelli* (SALGADO, 1996), and *Rinconsaurus caudamirus* (CALVO & GONZÁLEZ RIGA, 2003).

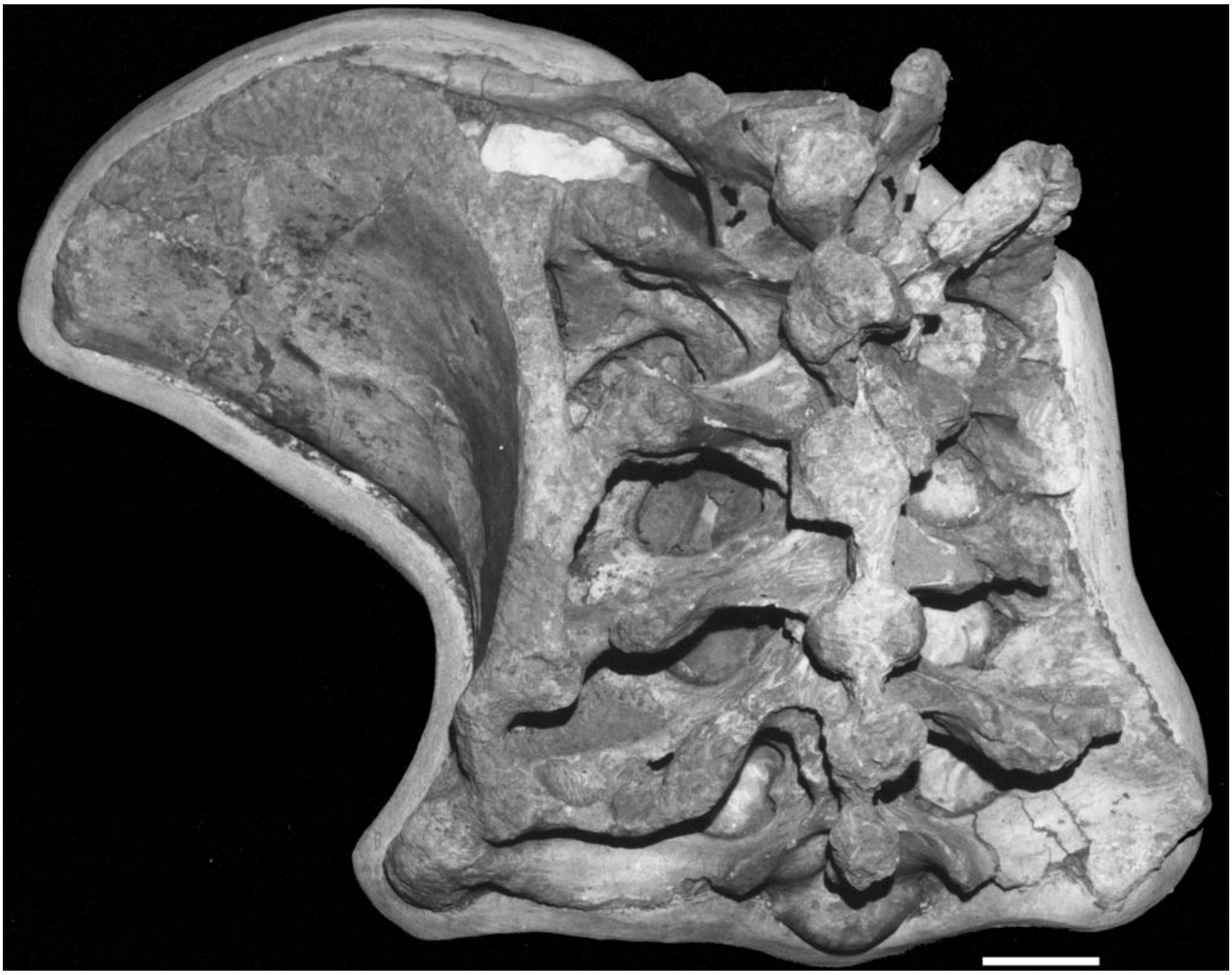

Fig.21- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), sacrum and left ilium in dorsal view. Scale bar = 100mm.

TABLE 3. Measurements of the caudal vertebrae of *Trigonosaurus pricei* n.gen., n.sp. - paratype (MCT 1719-R)

Caudal vertebrae*	Total length of centrum	Maximum length of centrum (left side) without condyle	Maximum height of centrum - anterior face	Maximum width of centrum - anterior face
caudal 2	94.5	77.8	~87.0	105.0
caudal 3	96.0	72.8	86.2	99.8
caudal 5	90.5	75.2	76.7	93.6
caudal 6	96.0	78.4	71.9	82.1
caudal 9	89.5	77.0	~64.5	72.1
caudal 12	85.7	71.0	61.0	68.3
caudal 14	79.5	68.5	58.5	71.6
caudal 16	72.5	~62.0	51.6	64.6
caudal 18	76.0	63.8	54.7	67.0
caudal 20	75.1	65.0	48.0	~59.0

* Note that the number of the caudals regarding their position in the tail is tentative.

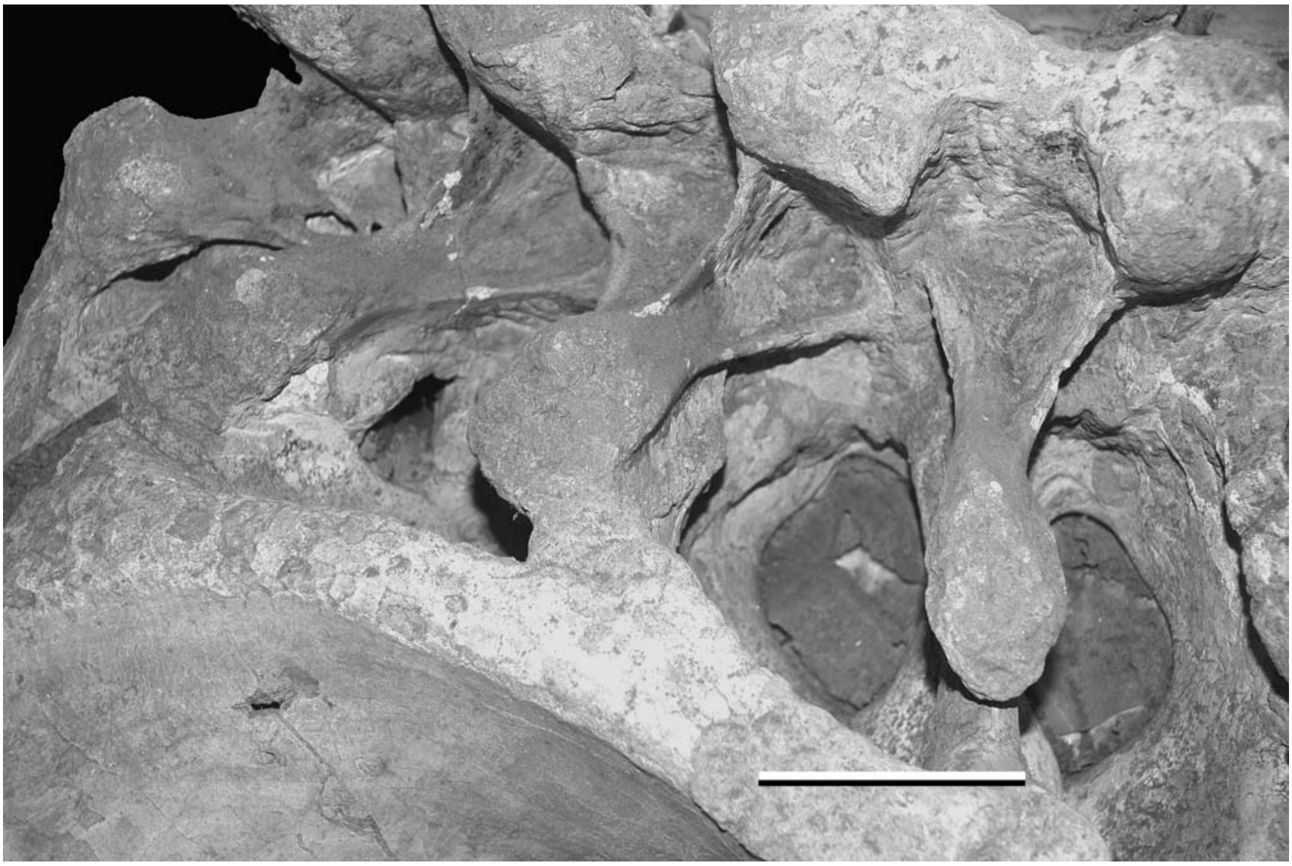

Fig.22- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), detail of the sacrum and left ilium. Scale bar = 100mm.

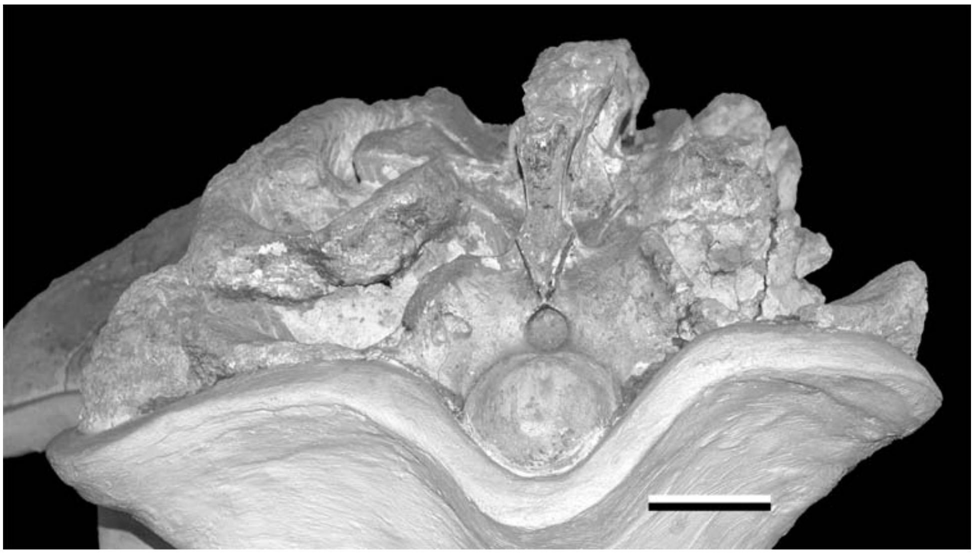

Fig.23- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), pelvis in posterior view. Scale bar = 100mm.

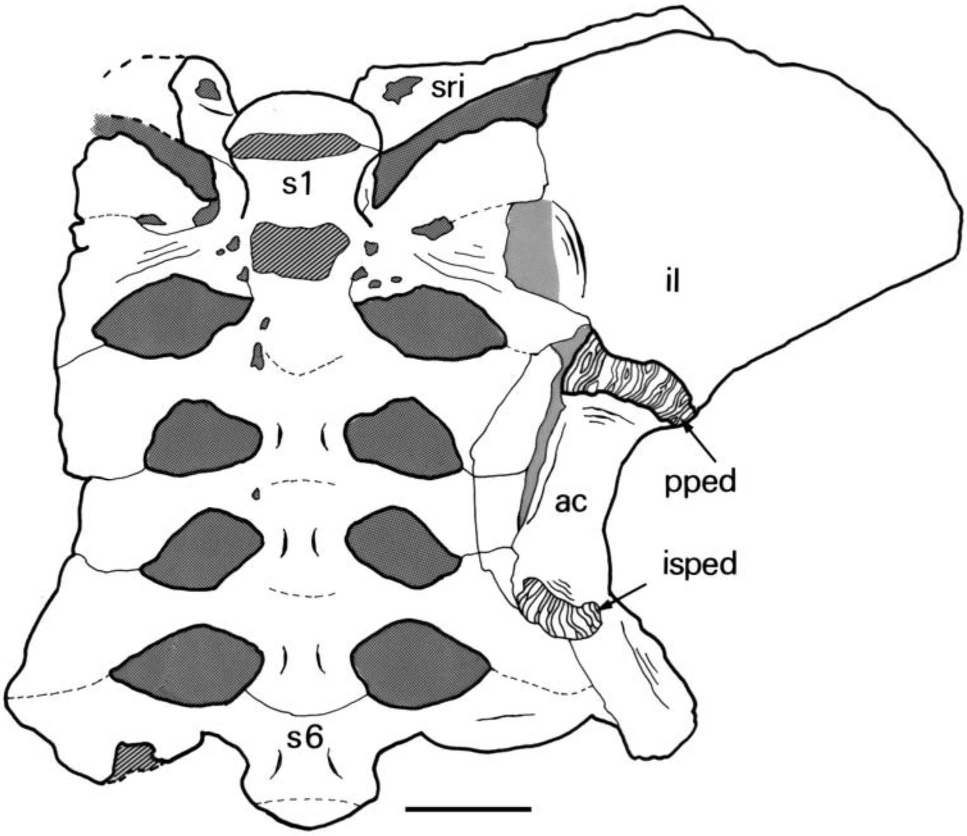

Fig.24- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1488-R), drawing of pelvis in ventral view (from CAMPOS & KELLNER, 1999). Scale bar = 100mm. See text for abbreviations.

Fig.25- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), anterior caudal vertebrae in right lateral view. Scale bar = 100mm.

Fig.26- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), middle caudal vertebrae in right lateral view. Scale bar = 100mm.

Fig.27- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), anterior caudal vertebrae in anterior view. Scale bar = 100mm.

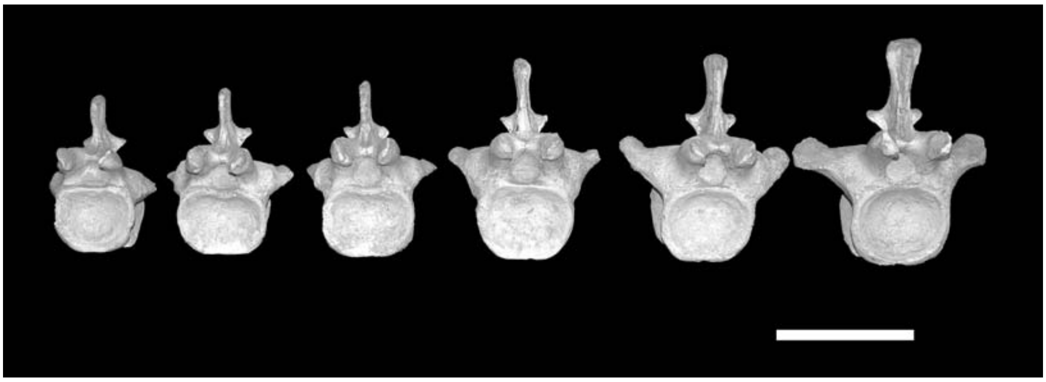

Fig.28- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), middle caudal vertebrae anterior view. Scale bar = 100mm.

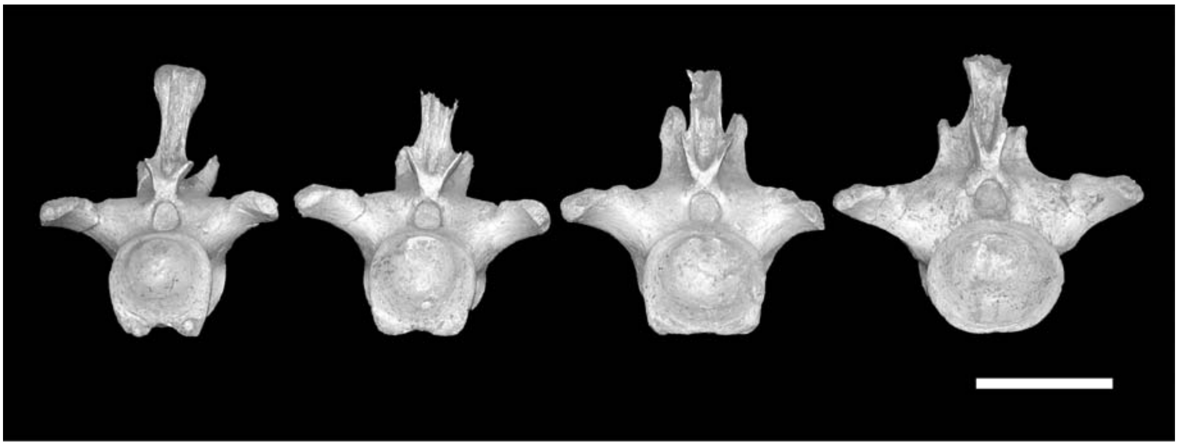

Fig.29- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), anterior caudal vertebrae in posterior view. Scale bar = 100mm.

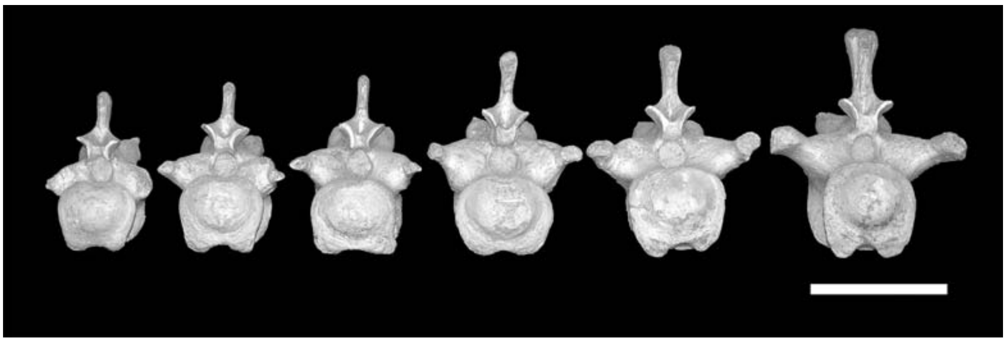

Fig.30- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), middle caudal vertebrae in posterior view. Scale bar = 100mm.

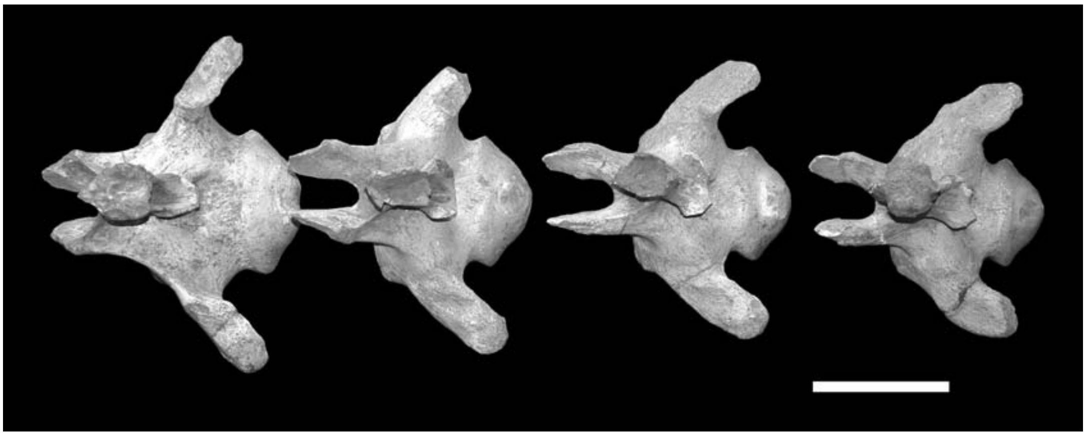

Fig.31- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), anterior caudal vertebrae in dorsal view. Scale bar = 100mm.

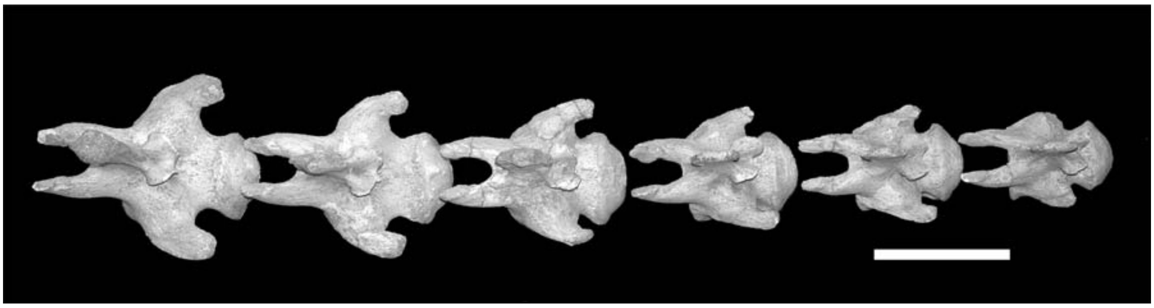

Fig.32- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), middle caudal vertebrae in dorsal view. Scale bar = 100mm.

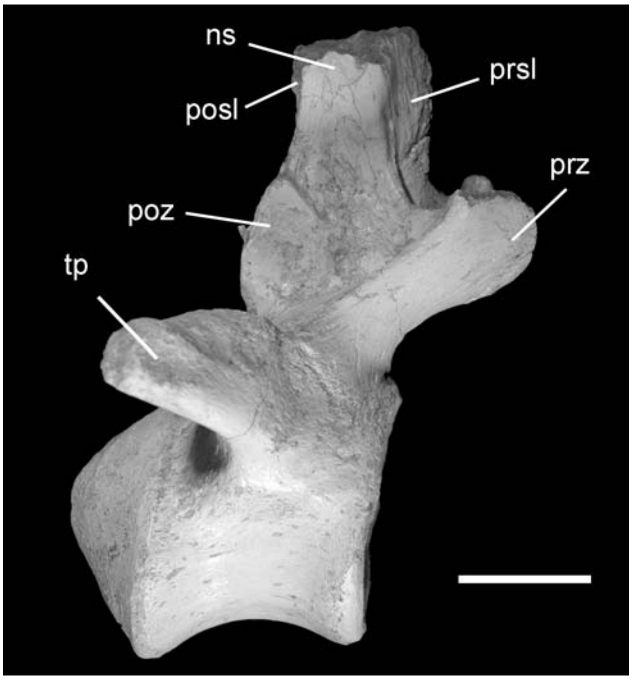

Fig.33- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), possible caudal vertebrae 2 in right lateral view. Scale bar = 50mm. See text for abbreviations.

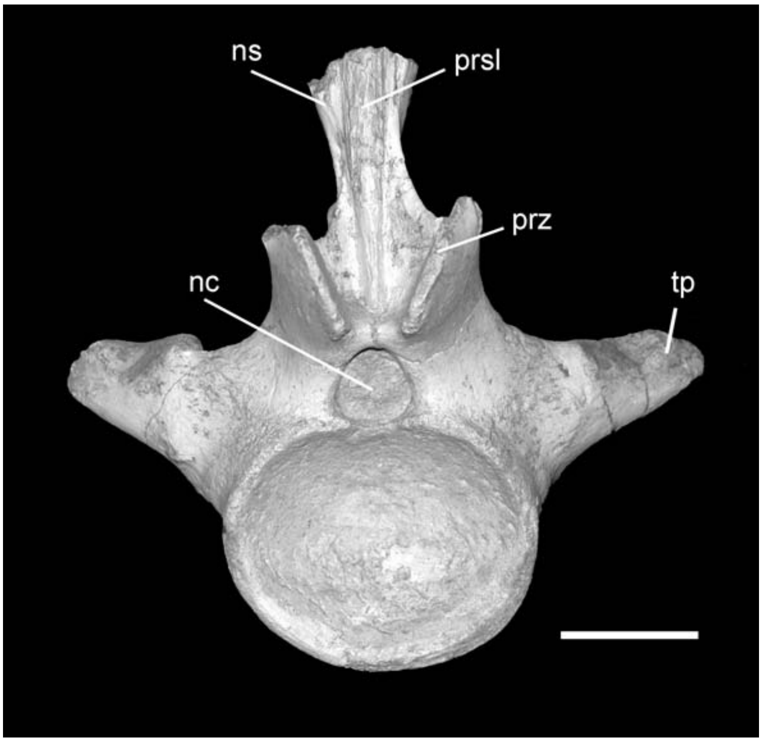

Fig.34- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), possible caudal vertebrae 2 in anterior view. Scale bar = 50mm. See text for abbreviations.

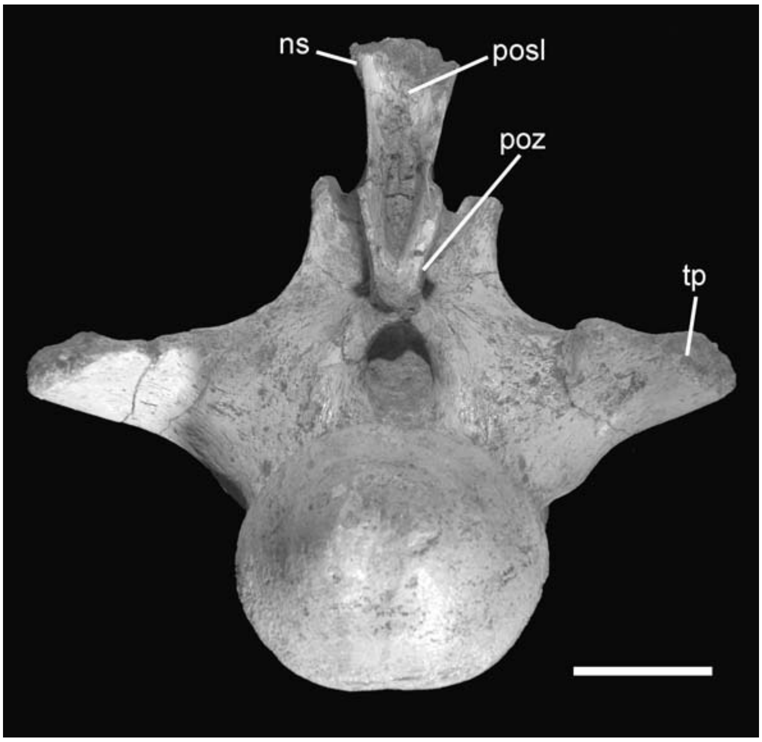

Fig.35- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), possible caudal vertebrae 2 in posterior view. Scale bar = 50mm. See text for abbreviations.

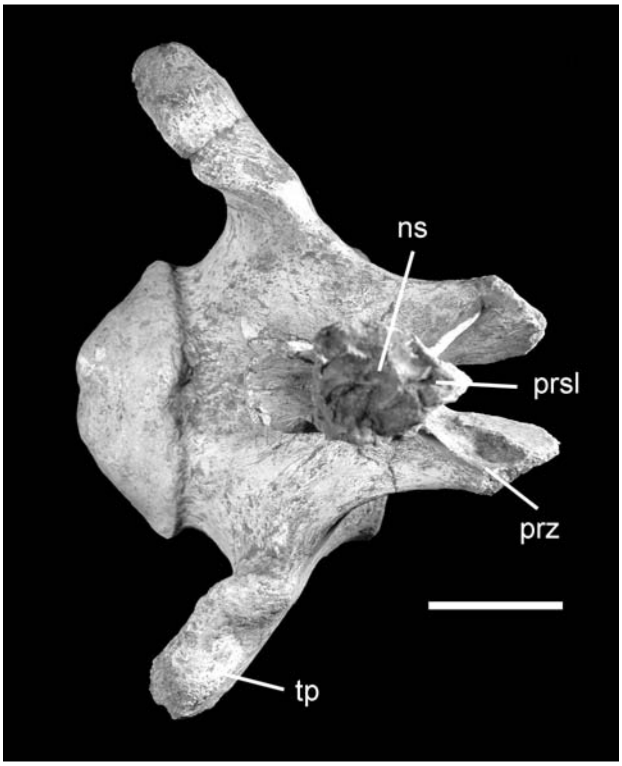

Fig.36- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), possible caudal vertebrae 2 in dorsal view. Scale bar = 50mm. See text for abbreviations.

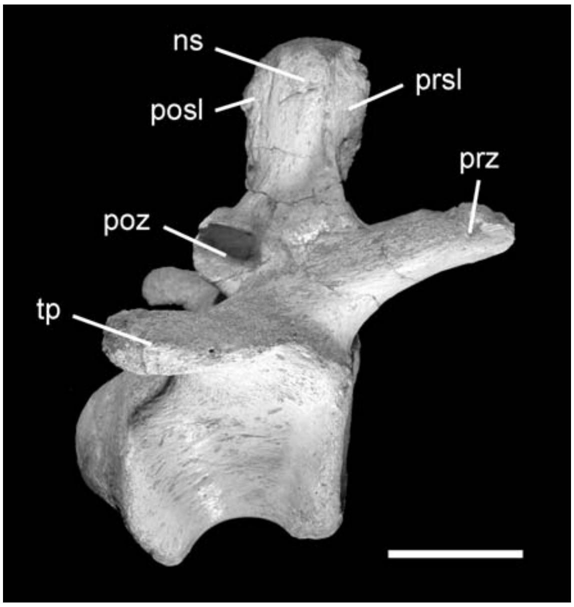

Fig.37- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), possible caudal vertebrae 9 in right lateral view. Scale bar = 50mm. See text for abbreviations.

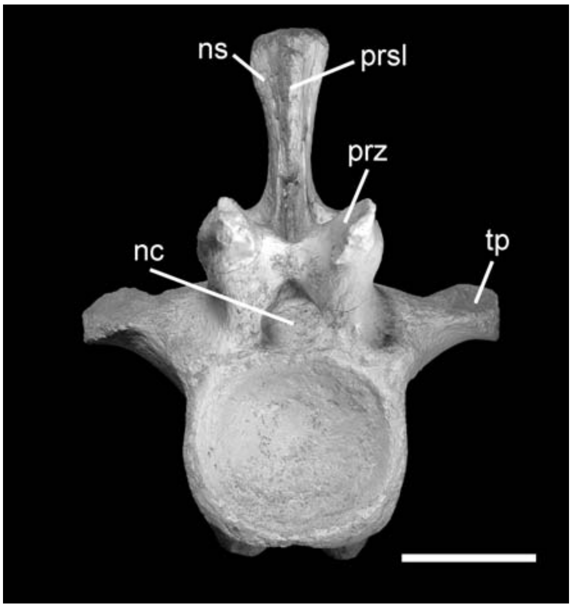

Fig.38- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), possible caudal vertebrae 9 in anterior view. Scale bar = 50mm. See text for abbreviations.

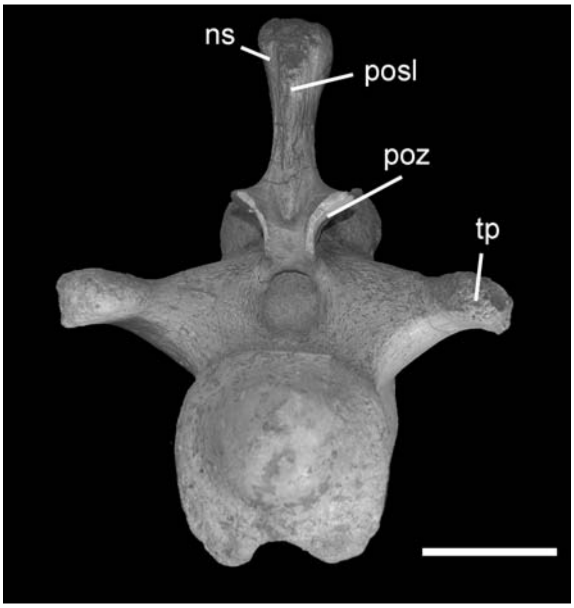

Fig.39- *Trigonosaurus pricei* n.gen., n.sp. (MCT 1719-R), possible caudal vertebrae 9 in posterior view. Scale bar = 50mm. See text for abbreviations.

DISCUSSION AND CONCLUSION

From the hundreds of sauropod bones found in the Peirópolis region, all attributed to the Titanosauridae (PRICE, 1955; BERTINI, 1993; CAMPOS & KELLNER, 1999), the most important specimens are the informally known "A, B and C Series" (POWELL, 1987; 2003). They consist of an almost complete series of cervical vertebrae and three dorsals (Series A), the last five cervicals, complete dorsal series, sacrum and caudal vertebrae (Series B), and the last sacral and a sequence of 18 articulated caudal vertebrae (Series C, see KELLNER, CAMPOS & TROTTA, 2005, this volume). As pointed out, the "Series B" (here described as *Trigonosaurus pricei* n.gen., n.sp.) was already mentioned several times in the literature, even used in phylogenetic studies (e.g., SALGADO, CORIA & CALVO, 1997). Its importance was recognized by Price (in LAMEGO, 1959), who always regarded this specimen representing a new titanosaurid taxon, here named *Trigonosaurus pricei* n.gen., n.sp. Based on comparisons with the cervical sequence also collected in the Peirópolis region (MCT 1487-R) the holotype of this species had an estimated length of about 9.5 meters

While the dorsal vertebrae and the sacrum (with the ilium articulated) were described in some detail (POWELL, 1987; CAMPOS & KELLNER, 1999), the cervical and caudal vertebrae have not received the same attention. POWELL (2003) provided more information on this material, but some are probably mistaken. For example, POWELL (2003:62) presented measurements for 15 caudals of the "Series B", but there are only 10 preserved elements (POWELL, 1987; CAMPOS & KELLNER, 1999). Furthermore, cervical 12 of *Trigonosaurus pricei* was illustrated as belonging to the Series A (POWELL, 2003: pl. 13, fig.12), what is incorrect.

SALGADO, CORIA & CALVO (1997) regarded *Trigonosaurus pricei* as a member of the Titanosauridae, closely related to the Asian *Opisthocoelicaudia skarzynskii*. The sole character shared by those taxa is the absence of a postzygodiapophyseal lamina in the posterior dorsals. However, a close examination indicates that an incipient lamina uniting the postzygapophysis and the diapophysis is observed in dorsals 9 and 10, corresponding to the horizontal lamina of POWELL (2003). In any case, this phylogenetic relationship is somewhat unexpected and has to be further evaluated.

Still regarding the phylogenetic position of *Trigonosaurus pricei*, it is not a member of the more derived titanosaurs (Saltasaurinae) lacking features such as a strongly dorsoventrally flattened centrum of the anterior caudals with centrum significantly wider than high, and the position of the neural spine, with the anterodorsal edge positioned posteriorly relative the anterior border of the postzygapophyses. This new species does not occupy a more basal position within Titanosauria, showing strongly procoelous caudal vertebra in all preserved elements, different from *Andesaurus delgadoi* and *Malawisaurus dixeyi* (CALVO & BONAPARTE, 1991; JACOBS *et al.*, 1993). It also lacks the hyposphene-hypantrum articulation observed in more basal titanosaurids and in *Epachthosaurus sciuttoi* (MARTÍNEZ *et al.*, 2004). The anteriorly displaced neural arch and the anterodorsally projected neural spine of *Trigonosaurus pricei* suggest some affinities with *Aeolosaurus rionegrinus* and *Gondwanatitan faustoi*. However, none of the preserved elements of the new taxon shows the ventral part of the centrum constricted, giving the posterior surface of the centrum a "heart-shaped" appearance.

To conclude, *Trigonosaurus pricei* confirms the supposition that more than one taxon was present in the Caieira Quarry, as pointed out by Price (in LAMEGO, 1959), indicating a higher diversity of titanosaurids in Brazil during the Cretaceous, presently represented by only two taxa - *Gondwanatitan faustoi* and MCT 1490-R (KELLNER, CAMPOS & TROTTA, 2005, this volume).

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