



## Short communication

## Multiple neoplasms in a single sauropod dinosaur from the Upper Cretaceous of Brazil



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## ARTICLE INFO

## Article history:

Received 17 November 2015

Received in revised form

15 January 2016

Accepted in revised form 25 January 2016

Available online 11 February 2016

## Keywords:

Neoplasia

Ostema

Hemangioma

Titanosauria

Cretaceous

## ABSTRACT

Tumors are thought rare in dinosaurs, previously limited in distribution to a single family – hadrosaurs. Here we recognized two different neoplastic lesions, osteoma and hemangioma, in a single caudal vertebra of a titanosaur dinosaur from the Upper Cretaceous of Brazil, diagnosed on the basis of macroscopic, radiological and histological analysis. This is the first occurrence of neoplasia in a non-hadrosaur dinosaur. Therefore, neoplasia is not restricted to hadrosaur dinosaurs, as previously suggested.

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## 1. Introduction

Diagnosis of neoplasia, either malignant or benign, is extremely rare in vertebrate fossil record (Rothschild et al., 2003). Among dinosaurs, recognition of neoplasia has been previously restricted to hadrosaurids (duck-billed dinosaur), mainly *Edmontosaurus* (Rothschild et al., 2003). There are, however, two case reports in bones of indeterminate dinosaurs from the Upper Jurassic of North America (Rothschild et al., 1998; Rothschild et al., 1999). This phylogenetic distribution is quite different when compared to other diseases, such as infection (Hanna, 2002; Foth et al., 2015; Redelstorff et al., 2015) and traumatic lesions (Hanna, 2002; Farke and O'Connor, 2007; Peterson and Vittore, 2012; Bell and Coria, 2013; McCrea et al., 2014; Foth et al., 2015; Redelstorff et al., 2015) where there are a large number of cases across dinosaur phylogeny.

Although South America presents a large dinosaur fossil record, the pathological condition – regardless of whether or not neoplastic – still remains underexplored. Up to now, only three

works are specifically related to paleopathology: Candeiro and Tanke (2007) recorded a dentary anomaly in a tooth of a *Carcharodontosauridae* from the Upper Cretaceous of Brazil; Bell and Coria (2013) performed a paleoepidemiological study in a population of *Mapusaurus* (*Carcharodontosauridae*) from the Upper Cretaceous of Argentina and Martinelle et al. (2015) described two fused vertebrae and a hemal arch with healing fracture callus in *Uberabatitan riberoi* (Titanosauria) from the Upper Cretaceous of Brazil. This shows the need for performing new paleopathological studies as paleopathology can be a useful tool in paleobiological studies of fossil organisms, besides providing a better understanding of the lesions that affected ancient animals (Frigolo, 2007).

Here we present two different types of neoplasia in a single vertebra of a titanosaur dinosaur, from the Upper Cretaceous of Brazil, representing the first case of documented neoplasia in a non-hadrosaur dinosaur.

## 2. Material and methods

UFRJ-DG 508-R was recovered from rocks of Late Cretaceous age (Turonian-Santonian) of the Adamantina Formation, Bauru Basin (Dias-Brito et al., 2001; Batezelli et al., 2003; Paula-e-Silva et al.,

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2003), in the Alfredo Marcondes municipality, State of São Paulo, southeastern Brazil (Fig. 1). It is curated in the fossil reptile collection of Departamento de Geologia of Universidade Federal do Rio de Janeiro, Brazil. It comprises an isolated caudal vertebral centrum (17 cm long, 8.9 cm large and 10.5 cm deep), lacking both transverses and spinal processes. The vertebra is procoelous, with a deeply concave anterior face and a strongly convex posterior face. Although it is not possible to identify the specimen at species level, this feature is diagnostic of the family Titanosauridae, the most abundant Cretaceous dinosaur family of South America (Salgado et al., 1997).

The pathological analysis of UFRJ-DG 508-R consisted of three steps, macroscopical examination, computed tomography (CT) scan and histologic examination. The scan was performed in the Philips MX 8000 QuadCT scanner (120 Kv peak voltage, 300 mAs, 344 mA and 873 ms exposure time). 2.0 mm thick slices were obtained, analyzed and processed with Mimics 8.13 and in open source software InVesalius 3.0. The area of the anterior articular surface and neoplasm was obtained with open source software ImageJ 1.48v. For histological analysis, we manually removed the button-shaped lesions of the vertebra, embedded it in a polyester resin and sectioned it using Model 650 Low Speed Diamond Wheel Saw (SBT – South Bay Technology, INC.). The sample was then affixed to glass slide and ground on a lap wheel. Thin section was photographed under ordinary light using Zeiss Axioplan petrographic microscope.

### 3. Results

The UFRJ-DG 508-R is a caudal vertebra centrum with an isolated small bony button-shaped protuberance at the anterior articular surface (Fig. 2). The protuberance measures 8.6 mm dorsoventrally and 7.5 mm mediolaterally, occupying an area of 50.03 mm<sup>2</sup>, corresponding to 5.45% of the articular surface.

CT scan images of the protuberance demonstrated a dense, ivory-like sclerotic mass on the anterior articular surface (Fig. 3A). The radiologic appearance and macroscopic morphology have

limited diagnostic considerations: an osteoma – a benign, slow-growing bone-forming tumor neoplasm (Greenspan, 1993) or a hamartoma – abnormal proliferation of normal bone (Eshed et al., 2002). Histological examination of the osseous protuberance revealed a micro-trabecular pattern, contrasted with that of normal trabecule. The component bone was well-vascularized with copious osteocyte lacunae (Fig. 3F-G).

Tomographic images analysis allowed recognition of additional radiological features unrelated to bony protuberance. The cancellous bone has a sclerotic zone extending from medial to posterior (Fig. 3B-E). In the coronal view, this sclerotic zone visualized as several small punctuate areas of high density, a “polka-dot appearance” (Eshed et al., 2001; Rudnick and Stern, 2004) (Fig. 3D). In sagittal view, a detached sclerotic area is noted in the medial region (Fig. 3E). The “polka-dot appearance” is not well defined in correspondent coronal and axial views (Fig. 3C-D).

### 4. Discussion

The histological pattern of the button-shaped lesion of the dinosaur vertebra is characteristic of an osteoma and clearly distinguishable from a hamartoma. The latter is poorly vascularized with very few osteocyte lacunae (Eshed et al., 2001; Eshed et al., 2002). In humans, common cranial button-shaped lesions, often referred to as osteomas, are actually composed of normal cortical bone, rather than the fine trabecular pattern of osteomas (Eshed et al., 2001). The neoplasia recognized in the titanosaurid is an osteoma.

Osteoma is a benign neoplasm with “clinical” manifestations related to its location and size (Greenspan, 1993). The bone likely represents an asymptomatic finding, given its small size.

Sagittal view of the vertebral centrum reveals an abnormal trabecular pattern in the cranial region of vertebral body (Fig. 3E). This abnormal trabecule pattern is aligned with the longer axis, thickened and associated with relatively lucent area (an area absorbing less X-ray energy) (Saab et al., 2008) (Fig. 3E). This set of characteristics, specially its “polka-dot appearance,” is considered



Fig. 1. Location map of the fossil locality (Alfredo Macordes City, São Paulo State, Brazil).

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