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Theropod (Dinosauria) diversity from the Potiguar Basin (Early-Late Cretaceous Albian-Cenomanian), northeast Brazil

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Cretaceous Research

THEROPOD (DINOSAURIA) DIVERSITY FROM THE POTIGUAR BASIN (EARLY - LATE CRETACEOUS), NORTHEAST BRAZIL

--Manuscript Draft--

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Abstract:	<p>The theropod record from the Cretaceous of northeastern Brazil are rare and consist mostly of isolated and incomplete remains, with only four species described. Here we describe, identify and evaluate the diversity of theropod materials from the Albian-Cenomanian Açu Formation, Potiguar Basin. The material consists of nine isolated vertebrae and a tooth. The vertebrae have been identified as belonging to four theropod groups: Abelisauria, Carcharodontosauria, Spinosauridae, Megaraptora, and Maniraptora. The isolated tooth was classified as belonging to a spinosaurid. One of the significant results so far is the occurrence of Megaraptora in the Potiguar Basin, based on the general morphology, the bones are very similar to Aerosteon and Megaraptor. Another unexpected result is the identification and presence of a maniraptoran caudal vertebrae, very rare in Brazil, with few fossils described. Besides this, other groups already found on isochronous basins of the Northeast region of Brazil and Africa as Carcharodontosauria and Spinosauridae. The presence of these theropod groups in the Açu Formation reveals a dinosaur richness in in the Potiguar Basin similar to isochronous basins in Northern Africa and increases the knowledge about the diversity of South American dinosaurs.</p>
Suggested Reviewers:	<p>Manuel Alfredo Medeiros manuel.alfredo@ufma.br Extensive knowledge and experience with brazilian dinosaurs fauna</p> <p>Juan Canale juanignaciocanale@hotmail.com Interest and great knowledge of theropoda fauna in south america</p> <p>Rafael Matos Lindoso rafael.lindoso@ifma.edu.br Has experience with Theropoda materials from Brazil</p>
Opposed Reviewers:	

The suggestions were taken into consideration during the reviewing process and were a valuable contribution for the improvement of the paper.

Almost all the specific revisions and suggestions from reviewer 02 and 03 were made with no exception and are highlighted in red color in the text (in the “with highlights” version). Bellow we answer some of the edito/reviewers question and suggestions.

Editor: Place your Figure captions at the end of the manuscript file, after References.

A: Done

Editor: As the reviewers have commented below, the English of the manuscript needs to be improved (grammar, syntax, structure of sentences, odd phrasing, etc.). It is the authors' responsibility to proof their manuscript for English problems. The revised version should be carefully proofed before you resubmit it. You should seek help from your co-author, Prof. Steve Busatte, to carefully go through the manuscript before submission. This would help to remove the linguistic problems and in dealing with all the key issues mentioned by the reviewers.

A: Done. The English was improved. Prof. Steve Busatte read carefully the manuscript.

Editor: Order of Figures: All figures must to be presented in the same sequence that have their first citations in the manuscript text. Please check and correct carefully the order of figures in the manuscript and their corresponding first citations. Delete out-of order citations and/or rearrange them if necessary. Check also for missing citations

A: Done.

Reviewer 01: All revision in the abstract.

A: All the revisions were accepted.

Reviewer 01: I recommend to change the title for a more realistic one, for example: "Theropod dinosaur remains from..."

A: We understood the statement of Revisor 01, but we preferred to keep the original title, as it summarizes the results seen in the manuscript.

Reviewer 03: Five theropod species only in the northeast, or in all Brazil?

A: The four specimens are only from northeastern Brazil. This detail is better explained in the second paragraph of the Introduction.

Reviewer 03: Spinosauridae was recognized by a tooth, not a vertebra

A: done

Reviewer 03: I suggest to end this sentence with something more "... about the diversity of dinosaursxxx..."

A: Done

Reviewer 01: Please, restrict to Cretaceous record, to address the relevance of the materials here reported.

A: We choose to keep this part of the text to preserve the cohesion within of the Introduction, featuring the first works and discoveries on theropod paleontology of Brazil. The next paragraph has a small summary of the Cretaceous northeastern theropod dinosaurs of Brazil.

Reviewer 01: Please, restrict to Cretaceous record

A: Done

Reviewer 01: Confuse

A: We rewrite this paragraph.

Reviewer 03: To this list should be added the recently described *Vespersaurus paranaensis* Langer et al., 2019 and *Gnathovorax cabreirai* Pacheco et al., 2019.

A: We choose to limit this list to the northeastern Brazil's theropod record only to make the text more easy to read/understand

Reviewer 03: The authors do not describe any osteoderm in the text.

A: Done

Reviewer 01: Do you mean the sedimentary infilling is divided into three groups?

A: Yes, we are following the terminology and geological description of the Basin.

Reviewer 03: I suggest to add its collection number

A: Done

Reviewer 03: They were described only five morphotypes in the text.

A: Done

Reviewer 01: This is not necessary to say. Anatomy is based on morphology. Avoid the use of "morphotypes", as if they were discrete biological units. Based on morphology, you identify vertebrae as corresponding to such section of the column, and to which theropod clade it may belong. Identification of "morphotypes" is useless.

A: We agree. We decided to remove the word “morphology” to avoid confusion.

Reviewer 01: Considering that this is not a ms devoted to analyze theropod teeth as a whole, and taking into account that just only one tooth is described, I suggest to remove all these considerations.

A: Done.

Reviewer 03: I suggest to be consistent with the abbreviations, using their English versions as is usual besides FABL: CBW: crown basal width (rather than EST), CH: crown height (rather than ALT), etc. See Hendrickx et al 2015. The dentition of megalosaurid theropods . Acta Paleontologica Polonica 60 (3): 627-642.

A: We followed the reviewer 01 and removed this part.

Reviewer 03: The values of most of these parameters were not specified in the analysis of the tooth recovered. I suggest to add them.

A: We followed the reviewer 01 and removed this part.

Reviewer 03: This measurement has a big fault, given there covered tooth lacks most of its tip.

A: Done. We didn't use this measurement any more.

Reviewer 03: Other abbreviation was used in Material and methods

A: We followed the reviewer 01 and removed this part.

Reviewer 01: Remove this and replace for "Systematic Paleontology"

A: Done

Reviewer 03: I suggest that, before comparing this material with other spinosaurids, the authors should add a summary of characters that allow to assign it to Spinosauridae.

A: Done. We summarize the characteristics of spinosaurids in the Discussion.

Reviewer 03: Given there are two morphotype assigned to Megaraptora, both showing similar characteristics, the authors should explain why there are not included in a single morphotype.

A: Done. We reorganized the material in the groups and removed the division “Morphotypes”

Reviewer 03: The word “expressive” seems wrong in this context.

A: Done.

Reviewer 01: Which is the systematic relevance of all these ratios?

A: We strongly suggest that the reviewer read the articles about the use of quantitative analysis in the identification of theropod teeth:

-HENDRICKX, C. & MATEUS, O. 2014. Abelisauridae (Dinosauria: Theropoda) from the Late Jurassic of Portugal and dentition-based phylogeny as a contribution for the identification of isolated theropod teeth. *Zootaxa*, 3751, 1–74.

-HENDRICKX, C., MATEUS, O., ARAÚJO, R. 2015. A proposed terminology of theropod teeth (Dinosauria, Saurischia). *Journal of Vertebrate Paleontology* 35 (5), e982797. <http://dx.doi.org/10.1080/02724634.2015.982797>. HENDRICKX, C. & MATEUS, O. 2014. Abelisauridae (Dinosauria: Theropoda) from the Late Jurassic of Portugal and dentition-based phylogeny as a contribution for the identification of isolated theropod teeth. *Zootaxa*, 3751, 1–74.

-HENDRICKX, C., MATEUS, O., ARAÚJO, R., AND CHOINIÈRE, J. 2019. The distribution of dental features in non-avian theropod dinosaurs: Taxonomic potential, degree of homoplasy, and major evolutionary trends. *Palaeontologia Electronica* 22.3.74 1– 110. <https://doi.org/10.26879/820palaeo-electronica.org/content/2019/2806-dental-features-in-theropods>.

-SMITH, J.B., VANN, D.R., DODSON, P. 2005. Dental morphology and variation in theropod dinosaurs: implications for the taxonomic identification of isolated teeth. *The Anatomical Record Part A* 285: 699-736.

-SANKEY, J.T., BRINKMAN, D.B., GUENTHER M., CURRIE, P.J. 2002. Small theropod and bird teeth from the Late Cretaceous (Late Campanian) Judith River Group, Alberta. *Journal of Paleontology*, 76, 751–763.

Reviewer 01: “Which are the anatomical bases to refer these elements as to Neovenatoridae/Megaraptora? The present manuscript suffers of the lack of anatomical descriptions and comparissons allowing the reader to understand why present authors conclusions.”;

“Please, provide morphological bases to support this referral.”;

“Please, give reasons for referring these elements as to Abelisauroida”

“Please, explain why this element is referred as to Maniraptora”

“Please, explain why this element is referred as to Carcharodontosauria”

“Please, explain why this element is referred as to Megaraptora”;

A: These parts have been rewrite to increase cohesion and make it clearer to understand. The first paragraph of the "comparisons" part has the characteristics used to allocate the fossil in the specific theropod group and the corresponding bibliography.

Reviewer 01: Please, obviate this detail. It is not morphological!

A: We removed the measurements.

Reviewer 01: Please, clarify

A: Done

Reviewer 01: Before description of any dinosaur bone, it must be glued.

A: Done. Material have been found associated, but there is no clear point of junction between both pieces, with most of the middle portion being lost.

Reviewer 03: Sem-spherical or semicircular?

A: Done. Semicircular

Reviewer 03: The authors should describe (and figure) the materials as a single vertebra, not as two different fragments. It is confusing and does not help with interpretation of the materials.

A: Ok. Done

Reviewer 03: At the beginning of this morphotype description the authors suggest that they are possibly caudal vertebrae.

A: Ok. Done

Reviewer 03: Why anterior? It could not be posterior?

A: We removed this fragment because it is not significant or relevant for this manuscript.

Reviewer 03: Why the authors assign this material to morphotype 1? They only suggest that it belongs to a theropod.

A: We removed this fragment because it is not significant or relevant for this manuscript.

Reviewer 01: I am surprised with this statement: Ceratosauria as members of Tetanurae. This is not a serious manuscript.

A: It was just a confusion when we were arranging the morphotypes. We know that Ceratosauria is not inside Tetanurae. Thanks for the revision...

Reviewer 03: This character used for differentiate this morphotype is clearly related to the position of the vertebra inside the vertebral series; This character is used for differentiate this morphotype is also present in morphotype 1; I suggest to look for other more specific characters to differentiate this morphotype.

A: We revised the attribution of this morphotype in Abelisauria and not found any solid characteristic to sustain this classification. We decided to follow the reviewers and be conservative and put these material at Theropoda indet.

Reviewer 03: I think both are synonyms

A: Done.

Reviewer 03: This sentence is confusing.

A: Done.

Reviewer 03: Think the authors should specify which transition point are referring here (I suppose that proposed by Russel (1972), but this is my guess)

A: Done

Reviewer 03: The shape of the articular face of caudal vertebrae is so variable, it show differences inside the same taxonomic group. For example inside Abelisauridae, Carnotaurus shows semicircular articular surface, and Majungasaurus show oval articular surface, as the authors clearly show in the figure 8. This makes this character not useful for separating morphotypes.

A: We don't use anymore this ratio type of character on the description.

Reviewer 03: The articular surfaces shown in the figure 4 has ovoidal articular faces.

A: Done.

Reviewer 03: hourglass-shaped

A: Done.

Reviewer 03: The lateral surfaces are slightly concave in these taxa, not very.

A: Done

Reviewer 03: Please see Aranciaga-Rolando et al (2018) A supposed Gondwanan oviraptorosaur from the Albian of Brazil represents the oldest South American megaraptoran. Cretaceous Research 84: 107-119.

A: Done

All the reviewers: All the revisions in the discussion.

A: We followed the suggestion of the reviewer 01 and reorganized the discussion. We replaced the most part to results in the comparative morphology and rewrite the discussion based on the importance of the Potiguar's fossils.

FIGURES

We done all the revisions requested by the reviewers and improved the figures.

Highlights – article: THEROPOD (DINOSAURIA) DIVERSITY FROM THE POTIGUAR BASIN (EARLY - LATE CRETACEOUS), NORTHEAST BRAZIL

- These are the first described theropod materials from the Potiguar Basin, Brazil.
- Four morphotypes were described based on morphological and/or diagnostic characters.
- Carcharodontosauria and Spinosauridae were groups identified.
- Rare Megaraptora, and Maniraptora materials were also identified.

28 groups: Spinosauroidea, Carcharodontosauria, Megaraptora, and Maniraptora. One of the
29 significant results is the occurrence of Megaraptora in the Potiguar Basin; based on the
30 general morphology, some of the bones we describe are very similar to those of *Aerosteon*
31 and *Megaraptor*. Another unexpected result is the identification and presence of a
32 maniraptoran caudal vertebrae; these dinosaurs are very rare in Brazil, with few fossils
33 previously described. Furthermore, we identify other groups that have already been found
34 in isochronous basins of the Northeast region of Brazil and Africa, including
35 Carcharodontosauria and Spinosauroidea. The presence of these theropod groups in the
36 Açu Formation reveals a dinosaur richness in in the Potiguar Basin similar to isochronous
37 basins in Northern Africa and increases knowledge about the diversity of South American
38 dinosaurs.

39

40 Keywords: Dinosauria, Potiguar Basin, Theropoda, faunistic richness,
41 Carcharodontosauria, Megaraptora, Spinosauridae, Maniraptora.

42

43 Introduction

44 The first studies in Brazil that attributed vertebrate fossil remains to dinosaurs
45 were published in the nineteenth and mid-twentieth centuries (Marsh, 1869; Derby, 1890;
46 Mawson and Woodward, 1907; Price, 1960, 1961). Since that time, dinosaur fossils have
47 been recorded from three principal localities and ages in Brazil: the Triassic of the Santa
48 Maria and Caturrita formations (Langer et al., 2007a), the mid-Cretaceous of the Araripe,
49 Triunfo and São Luís-Grajaú basins (Frey and Martill 1995; Kellner 1996a, b, 1999;
50 Medeiros *et al.*, 2007; Carvalho *et al.*, 2017), and the Late Cretaceous of the Bauru and
51 Parecis groups (Franco-Rosas *et al.*, 2004; Kellner *et al.*, 2004; Brusatte *et al.* 2017).

52 There are eight theropod dinosaur species formally described from Brazil so far,
53 four from the northeastern region: *Santanaraptor placidus* Kellner, 1999, *Irritator*
54 *challengeri* Martill, Cruikshank, Frey, Small and Clarke, 2002 and *Mirischia*
55 *asymmetrica* Naish, Martill and Frey 2004 from the Araripe Basin; and *Oxalaia*
56 *quilombensis* Kellner, Azevedo, Machado, Carvalho and Henriques, 2011 from the São
57 Luís-Grajaú Basin.

58 A promising area for new dinosaur discoveries is the rocks of the Açu Formation,
59 in the Potiguar Basin. Until now, the macrofossils of the Açu Formation consisted of
60 bivalve molluscs, small crustaceans, fish scales, and plant remains (Duarte and Santos,
61 1961). However this changed in the 2000s, when researchers from the Group of Analogs
62 to Oil Reservoirs of the Department of Geology of the Federal University of Rio Grande
63 do Norte, in geological mapping of the Açu 4 operational unit, found large vertebrate
64 fossils.

65 In the decade after the discovery of these first continental vertebrate fossils in the
66 formation (Santos *et al.*, 2005), no other fieldwork was conducted. However, in 2015 and
67 2016, this area was again prospected by Laboratório de Macrofósseis of the Universidade
68 Federal do Rio Janeiro and dozens of fossils were found. The aim of the present work is
69 to describe and identify the collected materials attributed to theropod dinosaurs, showing
70 that the Potiguar Basin preserves a large diversity of species and has great potential for
71 future discoveries and studies about the mid-Cretaceous paleoenvironments of the
72 Atlantic margin of Brazil.

73 Geological Setting and Lithostratigraphy

74 The Potiguar Basin is located at the eastern continental margin of northeastern
75 Brazil, cropping out in the states of Rio Grande do Norte and Ceará (Fig. 01), with a total

76 estimated area of 60,000 km², of which 22,000 km² is interpreted as continental (Cassab,
77 2003). The Potiguar Basin is bounded to the east by Alto de Touros, which separates it
78 from the Pernambuco-Paraíba Basin, to the northwest by the Alto de Fortaleza, which
79 separates it from the Ceará Basin, and to the south and west by crystalline basement rocks
80 (Pessoa-Neto *et al.*, 2007).

81 The sedimentary units of the Potiguar Basin are divided into three groups: Areia
82 Branca (Pendência and Alagamar formations), Apodi (Açu, Quebradas and Jandaíra
83 formations) and Agulha (Ubarana, Guamaré and Tibau formations) (Araripe and Feijó,
84 1994). The Açu formation is divided into four subunits according to electric logs,
85 identified from bottom to top as Açu 1, Açu 2, Açu 3 and, Açu 4 (Vasconcelos *et al.*,
86 1990). The material described here comes from the Açu 4 subunit, which corresponds to
87 a transgressive, coastal-estuarine system.

88 The Açu-4 Unit consists of sixteen facies, fourteen being siliciclastic and two
89 being hybrid. The siliciclastic facies are grouped into nine associations, namely: (1) lag
90 residual deposits, (2) channel fill deposits, (3) crevasse-splay deposits, (4) floodplain
91 deposits, (5) abandoned channel deposits, (6) upper-flow regime sandflat deposits, (7)
92 lower-flow regime sandflats, (8) sandflat/mudflat deposits of restricted environment, and
93 (9) mudflat deposits. The first five facies associations represent a meandering fluvial
94 system with tidal influence, and the remaining integrate the intermediate and distal sectors
95 of an estuarine complex dominated by tides. The hybrid facies were deposited in a shallow
96 platform adjacent to an estuary (Costa *et al.*, 2014).

97 The Açu Formation has been suggested to be Albian-Cenomanian in age (Early–
98 Late Cretaceous), based on palynological data (Araripe and Feijó, 1994).

99

100 **Material and Methods**

101 The fossils were collected from outcrops of the Açu Formation, Potiguar Basin
102 (Ceará state, northeastern Brazil) and are deposited at the Fossil Reptile Collection of the
103 Departamento de Geologia (DG), Universidade Federal do Rio de Janeiro (UFRJ). The
104 material consists of seven isolated theropod vertebrae (UFRJ-DG 521-R, 523-R, 524-R,
105 528-R, 558-R, 575-R, and 634-R) and a tooth (619-Rd)

106 The following tooth characteristics were assessed, following the nomenclature
107 proposed by Hendrickx *et al.* (2015): general morphological traits of the dental crown
108 (its overall shape, curvature, ornamentations in the enamel), denticles (presence, size and
109 shape) cross section (compression and shape), orientation of the tooth (lingual, labial,
110 mesial and distal) and measurements.

111

112 **Systematic paleontology**

113 **SAURISCHIA** Seeley, 1888

114 **THEROPODA** Marsh, 1881

115

116 Referred material: UFRJ-DG 532-R and 575-R.

117 *Description:*

118 **UFRJ-DG 528-R**

119 Specimen 528-R is a theropod vertebral centrum (Fig. 02, C-E). It is
120 amphicoelous, and slightly higher than long. Its lateral surface is smooth and slightly
121 concave, without marks or other remarkable characteristics, giving the vertebra a straight
122 and somewhat featureless appearance. The ventral surface smooth with no groove or keel
123 and it is slightly concave in lateral view.

124 The dorsal surface possesses a distinct longitudinal groove extending from one
125 articular facet to the other that can be identified as the neural canal. The articular faces

126 have nearly straight margins. The anterior facet is somewhat concave, and the posterior
127 is slightly convex and slightly oval in shape; both articular facets have the same general
128 proportions (height longer than length). The anterior articular face presents a deeper
129 concavity, and is slightly larger in size, than the posterior face, which is very flat and
130 without deep depressions.

131 **UFRJ-DG 575-R**

132 Specimen 575-R (Fig. 02, A-B) is a theropod vertebral centrum broken in two: a
133 smaller anterior piece and a larger posterior section. Although the material was found
134 associated there is no clear point of junction between both pieces, as most of the middle
135 portion has been lost. The anterior fragment exhibits a very concave articular face of semi-
136 circular shape and slightly forward-protruding margins.

137 On the lateral surface of the anterior fragment there is a deep perforation close to
138 the dorsal region that reaches the other lateral surface, which can be described as a
139 pleurocoel. The ventral surface of the anterior fragment is smooth and concave in anterior
140 view. The dorsal surface of the anterior fragment is broken, missing most of the surface
141 above the pleurocoel.

142 The posterior fragment has a slightly smaller articular surface, which is broken on
143 the anterior portion; it is also concave and of semi-circular shape, with slightly
144 backwards-protruding margins. Its dorsal surface and the dorsal half of the left lateral
145 surface are broken, while the right lateral surface is broken in a slightly more dorsal region
146 in comparison to the left one. The ventral surface of the fragment is smooth and concave
147 in lateral view. Due to the highly fragmentary state of UFRJ-DG 575-R, it is possible to
148 see multiple small pervasive pneumatic chambers, the camellae, in the internal bone.

149 *Comparisons:*

150 The highly pneumatized camellate bone seen in UFRJ-DG 575-R is a
151 characteristic seen in many groups of theropods, from the basal *Ceratosaurus* to tetanuran
152 groups such as carcharodontosaurids and coelurosaurs mainly in its presacral vertebrae
153 (Carrano and Sampson, 2008). This feature, together with the poor preservation of this
154 specimen, which prevents the identification of other more diagnostic characteristics,
155 hinders the classification of this specimen beyond Theropoda.

156

157 **THEROPODA** Marsh, 1881158 **TETANURAE** Gauthier, 1986159 **? SPINOSAUROIDEA** Stromer, 1915

160

161 **Referred material:** UFRJ-DG 619-Rd.162 *Description:*

163 UFRJ-DG 619-Rd (Fig. 03) is a fragment of a large isolated tooth crown, probably
164 belonging to the middle to almost apical portion of the tooth. The specimen lacks any
165 form of enamel, as it has dentine exposed, what prevents description of external
166 ornamentation such as transversal undulations, flutes and denticulation. The crown is
167 almost completely straight with only a subtle curvature in its lingual surface, while the
168 labial surface remains slightly convex.

169 The crown fragment has an overall cone-like shape with an almost ovoid cross
170 section. In basal view, it is possible to see concentrically deposited rings of dentine
171 surrounding a small depression, which probably represents the apical-most portion of the
172 dental pulp cavity.

173 *Comparisons:*

174 UFRJ-DG 619-Rd have some characteristics that it shares with the highly
175 specialized teeth of spinosauroid theropods. The most salient of these is the almost
176 straight conical shaped crown, with an ovoid cross section, a feature often seen in
177 piscivorous animals (Mateus, 2011; Hendrickx and Mateus, 2014).

178

179 **THEROPODA** Marsh, 1881

180 **TETANURAE** Gauthier, 1986

181 **MANIRAPTORA** Gauthier, 1986

182

183 Referred material: UFRJ-DG 521-R

184 *Description:*

185 **UFRJ-DG 521-R**

186 Specimen UFRJ-DG 521-R (Fig. 04) is an almost complete distal caudal vertebrae
187 of a maniraptoran theropod. It is amphicoelous with a length to height ratio of almost 2.5,
188 making it a least twice longer than tall. The dorsal surface of the centrum is almost
189 complete with half of a dorsal midline ridge reminiscent of reduced neural spine, a well
190 preserved and more dorsally positioned prezygapophysis, and a lost postzygapophysis.
191 The prezygapophysis articular surface is ellipsoid and is reclined 45° laterally. The neural
192 canal is almost completely preserved, having lost only its posterior half .

193 The lateral surfaces of the centrum are mostly smooth, marked only with a midline
194 ridge reminiscent of a reduced transverse processes. The ventral surface of the centrum
195 has a shallow groove that extends from one articular facet to the other. In the lateral view
196 the ventral surface is slightly concave.

197 The articular facets of the centrum are both concave, with the anterior facet being
198 more excavated than the posterior facet, and have a semi-circular shape. The articular

199 margins are almost straight, with the anterior margin being larger than the posterior
 200 margin.

201 *Comparisons:*

202 UFRJ-DG 521-R has characteristics of a maniraptoran centrum positioned after
 203 the transition point in the tail (Russell, 1972, Gauthier, 1986; Tykoski, 2005), as it is longer
 204 than high and possesses a large reduction in both its neural spine and transverse processes,
 205 with those structures becoming midline ridges (Senter *et al.*, 2011; Motta *et al.*, 2018).
 206 Thus, it is possible to deduce that it is positioned after vertebra 11 of the caudal series as
 207 seen in *Buitreraptor*, *Rahonavis*, Dromaeosauridae and Troodontidae (Ostrom, 1969;
 208 Forster *et al.*, 1998; Senter *et al.*, 2012; Xu *et al.*, 2017).

209 The presence of a reduced transverse process forming a midline ridge after the
 210 transition point is seen in the distal caudal vertebrae of *Rahonavis* and *Buitreraptor*
 211 (Forster *et al.*, 1998; Novas *et al.*, 2017), a characteristic also seen in UFRJ-DG 521-R,
 212 which differentiates it from most other paravians as dromaeosaurids, *Archaeopteryx*,
 213 *Jeholornis* and *Anchiornis*.

214 In addition, the 521-R specimen also has dorsally positioned pre-zygapophyses in
 215 the same way as in *Buitreraptor*, *Rahonavis* and *Anchiornis* (fig. 05) (Motta *et al.*, 2018).
 216 The vertebral centrum has a length-to-height ratio between close to 2.5, a ratio usually
 217 seen in dromaeosaurids with exception to *Buitreraptor* but not seen in other
 218 maniraptorans as troodontids and microraptorians whose ratio can reach up to 5.0 to 6.0.

219

220 **THEROPODA** Marsh, 1881

221 **TETANURAE** Gauthier, 1986

222 **ALLOSAUROIDEA** Marsh, 1878

223 **CARCHARODONTOSAURIA** Benson, Brusatte and Carrano, 2010

224

225 Referred material: UFRJ-DG 523-R and 524-R.

226 *Description:*

227 **UFRJ-DG523-R**

228 Specimen 523-R (Fig. 06, D-F) is a theropod vertebral centrum, with the following
229 characteristics: it is amphicoelous, and slightly longer than high. Its lateral surface is very
230 concave and smooth on both sides, with the shape of an hourglass in dorsal view. The
231 ventral surface is mostly smooth on the anterior part, with marks that possibly indicate
232 the articulation with the hemal arch on the posterior part.

233 The dorsal surface is marked by a long and deep longitudinal canal from one
234 articular face to the other, which widens on the extremities and tapers in the middle. This
235 canal was possibly the space of the neural canal of the vertebra, given the marks of fusion
236 with the neural arch that meet on its borders.

237 The articular faces are ovoid in shape and have slightly forward-protruding
238 margins, the anterior facet being higher in comparison to the posterior facet. The anterior
239 articular face has a concavity deeper than the posterior one, being also slightly larger in
240 its proportions.

241

242 **UFRJ-DG524-R**

243 Specimen 524-R (Fig. 06, A-C) is a centrum of a theropod caudal vertebra. It is
244 amphicoelous and is slightly longer than high, which indicates a more proximal position
245 in the caudal series. The lateral surface is smooth and marked by two deep concavities on
246 both lateral faces, giving it an hourglass-like shape.. Additionally, on the most dorsal
247 region of the lateral surface there is a small and shallow longitudinal depression on each
248 side.

274

275 Referred material: UFRJ-DG 558-R e 634-R

276 *Description:*277 **UFRJ-DG 558-R**

278 Specimen 558-R is a centrum of a theropod caudal vertebra, damaged by various
279 cracks (Fig. 08, D-F). It is amphicoelous, and slightly longer than high, indicating a
280 somewhat proximal position within the caudal series. Its ventral surface is very smooth
281 and convex in lateral view, but is very damaged in the region where the base of the
282 posterior articular face would be.

283 The dorsal surface is marked by a great depression extending longitudinally from
284 one articular face to the other, wider in the extremities, denoting the neural canal. The
285 lateral surfaces are marked by a longitudinal elliptic depression on their medial parts,
286 where there is a pleurocoel on each side. The left lateral pleurocoel is deeper and better
287 defined than the right lateral one.

288 Its articular faces are semi-circular and have very straight margins. The anterior
289 articular face possesses a more distinctive depression of a slightly greater size than the
290 posterior face and is also in a better state of preservation. The posterior articular face
291 possesses a very slight concavity, making it almost straight, and is in a much more
292 damaged state, presenting cracks and breaches on the ventral base of the face.

293 **UFRJ-DG 634-R**

294 This material is in a worse state of preservation than UFRJ-DG 558-R(Fig. 08, A-C). The
295 ventral centrum portion and anterior articular face are fragmented. On its lateral surface,
296 there is what appears to be the border of the pleurocoel in the same position seen in
297 specimen 558-R.

298 Different from the other vertebra of this group, part of the neural arch and the
299 transverse process are preserved on the right side of the specimen. The transverse process
300 is positioned upwards at an angle of approximately 45° degrees.

301 *Comparisons*

302 The presence of pleurocoels in the caudal vertebrae is characteristic of
303 megaraptoran neovenatids (Benson *et al.*, 2010). Pneumaticity in the caudal vertebrae is
304 rare in Theropoda, present only in some groups: Megaraptora, Oviraptorosauria,
305 Therizinosauria, and Carcharodontosauridae (Benson *et al.*, 2012). As far as is known, no
306 fossils of therizinosaurs have been found in South America and South American fossils
307 attributed to oviraptorosaurs have been reassigned to other taxa, including to Maniraptora
308 (*e.g.* Agnolín and Martinelli, 2007, Aranciaga-Rolando *et al.*, 2018). In addition, the
309 caudal vertebrae of Oviraptorosauria have, on the ventral surface, a medial groove
310 delimited by two longitudinal elevations (*e.g.*, Sues, 1997; Xu *et al.*, 2007). Specimen
311 UFRJ-DG 558-R does not have this feature (Fig. 09).

312 South American carcharodontosaurids (*e.g.*, *Giganotosaurus*, *Mapusaurus*,
313 *Tyrannotitan*) show slightly concave lateral sides in the caudal vertebrae, but do not bear
314 actual pneumatic foramina. Stromer (1931) described an anterior caudal vertebra from
315 northern Africa, which he identified as *Carcharodontosaurus*, which had pneumatic
316 characteristics, including a pleurocoel. However, that vertebra has a different general
317 morphology and proportions when compared with the megaraptorid vertebrae from the
318 Potiguar Basin (length-height ratio is 1 in *Carcharodontosaurus* and approximately 1.48
319 in UFRJ DG 558-R) and other members of Megaraptora.

320 Among the Megaraptora group, only *Aerosteon*, *Aoniraptor*, *Orkoraptor* and
321 *Megaraptor* have preserved caudal vertebrae (Fig. 10) (Serenó *et al.*, 2008; Benson *et al.*,
322 2010; Motta *et al.*, 2016). The height/length ratio of UFRJ DG 558-R is 1.4, consistent

323 with a median tail position, compared to the ratios of 1.2 and 1.3, respectively, of the
324 medial caudal vertebrae of *Aerosteon* and *Orkoraptor* (Novas *et al.*, 2008). The Potiguar
325 Basin specimens resemble those of *Aoniraptor* (Fig. 07, F) due to the absence of a keel
326 in the ventral region, but are distinguished by the presence of a pair of pneumatic troughs
327 in the lateral region, separated by a septum. Only the first caudal vertebra of *Aoniraptor*
328 presents such fossae, a characteristic present in the other megaraptorans (e.g., Novas *et*
329 *al.*, 2008; Sereno *et al.*, 2008).

330 Comparing the morphology of pneumatic foramina, UFRJ DG 558-R (Figure 10,
331 A) is very similar to *Aerosteon* (Figure 10, C), *Megaraptor* (Figure 10, H) and *Orkoraptor*
332 (Figure 10, G) in the presence of a large elliptic foramen and a second smaller circular
333 shaped foramen. In addition, UFRJ-DG 558-R and 634-R has its cavities located on the
334 lateral surface of the vertebral centrum near the base of the neural arch, which does not
335 occur in the other species observed.

336 UFRJ-DG 558-R and 634-R also presents extensive pneumatization in the
337 vertebral centrum, composed of a camerate internal microstructure (Britt, 1993), with
338 several small chambers, similar to other megaraptorans (e.g., *Aerosteon*, *Megaraptor*;
339 Martinelli *et al.*, 2013).

340

341 **Discussion**

342 **The Açu Formation material and its importance**

343 The fossil potential of Açu Formation was poorly known, with only a few
344 fossils recovered (Duarte and Santos, 1962; Silva-Santos, 1963; Mussa *et al.*, 1984), until
345 the discovery of vertebrae and teeth identified as belonging to Theropoda indet. and
346 Titanosauria (Santos *et al.*, 2005).

347 No further work was conducted until 2018, when the materials described here
348 were studied in more detail. Thus far, the dinosaur fauna of the Potiguar Basin includes
349 two groups of Sauropoda (Diplodocoidea: Rebbachisauridae, Pereira et al., in press;
350 Titanosauriformes, Barbosa et al., 2018; Titanosauria, Pereira et al., 2018) and four
351 groups of Theropoda (Spinosauroidea, Carcharodontosauridae, Megaraptora and
352 Maniraptora, present work).

353 The occurrence of these groups (except Megaraptora) in the Potiguar Basin is yet
354 another similarity between the faunas of northeastern Brazil and multiple North Africa
355 Cretaceous units (e.g. Medeiros and Schultz, 2001a, 2002; Sereno and Brusatte, 2008;
356 Contessi, 2009; Candeiro et al., 2011; Candeiro, 2015). Except for the Elrhaz (Niger);
357 Douiret and Ain El Guettar (both in Tunisia) and Chicla (Libya) formations, which were
358 dated to the Early Cretaceous, all other Cretaceous formations from Northern Africa are
359 Albian-Cenomanian in age, roughly equivalent to the Açu Formation (Werner, 1994;
360 Rossetti, 1997; Rossetti and Truckenbrodt, 1997; Smith et al., 2001; Anderson et al.,
361 2007; Sereno and Brusatte, 2008; Cavin et al., 2010). Among the formations, the
362 Alcântara Formation (Brazil), Bahariya Formation (Egypt), Echkar Formation (Niger)
363 and the Waldi Milk Formation (Sudan) have similarities with the Açu Formation's
364 dinosaur fauna.

365 According to paleobiogeographic models, South America and Africa started
366 separating from each other in the Valanginian (Early Cretaceous), leading to the
367 formation of the South Atlantic Ocean (Viramonte et al., 1999; Jokat et al. 2003;
368 Macdonald et al., 2003). Although the ocean turned into one of the most important
369 continental barriers of the southern hemisphere, faunal interchange among the terrestrial
370 landmasses of western of Gondwana definitely occurred up to the Albian, and possibly

371 until the Cenomanian (e.g. Petri, 1987; Reyment and Dingle, 1987; Pletsch et al., 2001,
372 Tello Saenz et al., 2003, Guedes et al., 2005, Bodin et al., 2010).

373 Based on the proposed age and geographic position, the fossil vertebrates of the
374 Açu Formation may have lived during some of the last intervals of continental connection
375 between South America and Western Africa, before the complete formation of the South
376 Atlantic Ocean (Arai, 2009; Castro et al., 2012). This makes them exceedingly important
377 for understanding biogeography and faunal evolution.

378 More extensive comparisons are still limited by the lack of completeness of the
379 Açu material and the absence of formally described taxa. The continuation of studies on
380 previously collected material (like that described in this paper) and prospecting for new
381 fossils is important in this basin which, while still the subject of only recent research,
382 already exhibits among the greatest diversity of dinosaur groups in Brazil.

383

384 **Conclusion**

385 In the present work we assigned the material from Açu Formation, Potiguar Basin,
386 to four groups: Spinosauroida, Carcharodontosauria, Maniraptora and Megaraptora (Fig.
387 11), the two last groups being relatively rare in Brazil. All these groups have already been
388 found in isochronous formations in both Northeastern Brazil and Northern Africa, leading
389 further support for faunal similarities in the “mid”-Cretaceous western Gondwana. These
390 fossils provide the first theropod record from Potiguar Basin and an important opportunity
391 to increase the knowledge on the diversity of this still poorly known basin.

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406

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677

678 **Figure captions**

679

680 Figure 01: Geological map of the continental part of the Potiguar Basin with the region
681 near the Limoeiro do Norte municipality (Ceará state) where the material were discovered
682 (dark star). CE, Ceará state; RN, Rio Grande do Norte state and its capital, Natal.
683 Modified from Cassab (2003).

684

685 Figure 02: The theropod vertebrae UFRJ-DG 528-R (A-C) and UFRJ-DG 575-R (D-E).
686 UFRJ-DG 575-R: A, lateral view; B, the anterior articular facet. UFRJ-DG 528-R: C, the
687 lateral view; D, the ventral view; E, anterior articular facet. Note the large pneumatic

688 foramen on the side of the anterior fragment of UFRJ-DG 575-R. pfr = pneumatic
689 foramen. Scale bar: 2 cm.

690

691 Figure 03: Spinosauroid tooth (UFRJ-DG 619-R): A, the labial view; B, the lingual view;
692 and C, the cross section. Scale: 1 cm

693

694 Figure 04: Maniraptoran caudal vertebrae (UFRJ-DG 521-R): A, Lateral view; B,
695 ventral view; C, anterior articular facet. Prz, prezygophysis; Nc, neural canal. Scale:

696 1cm.

697

698 Figure 05: Comparison of UFRJ-DG 521-R and other maniraptorans. A, Potiguar's
699 material; B, *Rahonavis*; C, *Buitreraptor*; D, *Anchiornis*. Pr, prezygapophysis; lg,
700 Longitudinal groove. Modified from Motta et al., (2018).

701

702 Figure 06: Carcharodontosaurid caudal vertebrae UFRJ-DG 523(A-C) and UFRJ-DG
703 524-R (D-F). UFRJ-DG 524-R: A, ventral view; B, lateral view; C, anterior articular
704 facet. UFRJ-DG 523-R: D, ventral view; E, lateral view; F, anterior articular facet. Nc,
705 neural canal. Scale: 1cm.

706

707 Figure 07: Comparison of UFRJ-DG 523-R and 524-R and other carcharodontosaurids.
708 A and B, UFRJ DG 523-R; C and D, UFRJ DG 524-R; E and F, Kem Kem beds material
709 (from Rauhut, 1999); G, *Tyrannotitan chubutensis* MPEF-PV 1156 (Modified from
710 Canale et al., 2015); H, *Mapusaurus roseae* MCF-PVPH-108.81 (Modified from Coria
711 and Currie, 2006) ; I, *Acrocanthosaurus atokensis* NCSM 14345 (Modified from Currie
712 and Carpenter, 2000). Scale bar = 5 cm.

713

714 Figure 08: Caudal vertebrae UFRJ-DG. UFRJ-DG 558-R: A, posterior articular facet; B,
715 lateral view; C, ventral view. UFRJ-DG 634-R: D, anterior articular facet; E, lateral view;
716 F, ventral view. Pfr, Pneumatic foramen. Scale bar: 1cm.

717

718 Figure 09: Brazilian megaraptoran vertebrae findings. A and B, UFRJ DG 558-R; C and
719 D, MPMA 08-003-94 (Méndez et al., 2012); E and F, CPPLIP 1324 (Martinelli et al.,
720 2013). A, C e E, lateral view; B, D e F, ventral view. Pfr, Pneumatic foramen. Scale bar =
721 1cm.

722

723 Figure 10: Megaraptoran caudals vertebrae. A and B, UFRJ DG 558-R; C and D,
724 *Aerosteon*; E and F, *Aoniraptor*; G, *Orkoraptor*. H, *Megaraptor*. A, C, E, G e H, lateral
725 view; B, D e F, ventral view. Pfr, pneumatic foramen. Scale bar = 5cm.

726

727 Figure 11: Reconstruction of the theropods groups from Açú Formation, Potiguar Basin.
728 In the center, a group of megaraptorans slaughtering a titanosaur; on the right a
729 carcharodontosaurid awakens from its sleep; in the top center, a maniraptoran just
730 watches. Art by Luciano da Silva Vidal.

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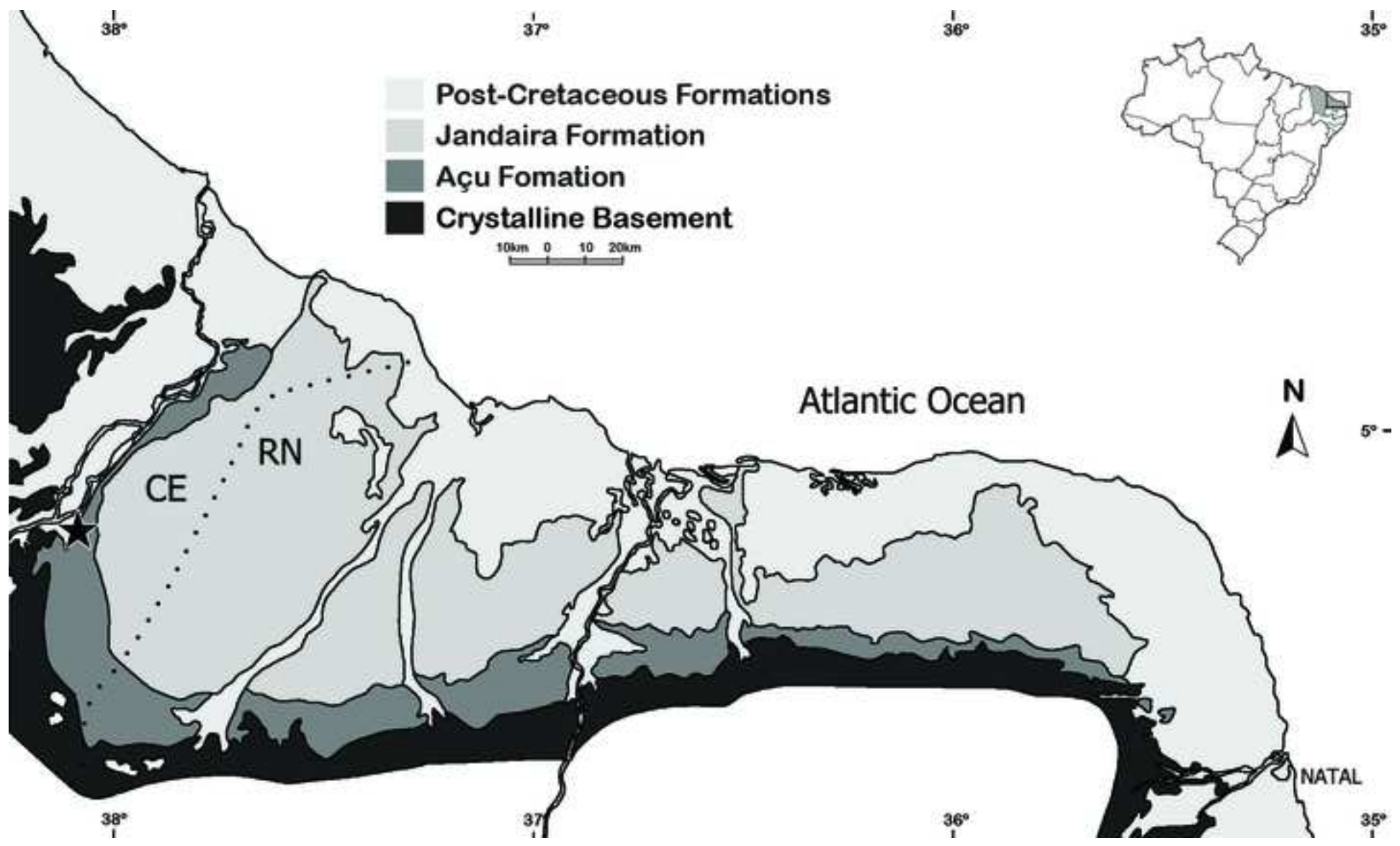
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A



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B



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E



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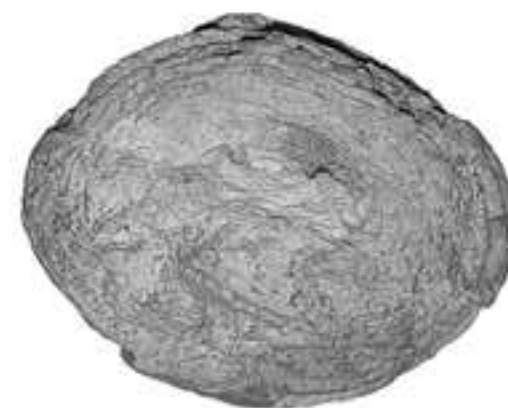
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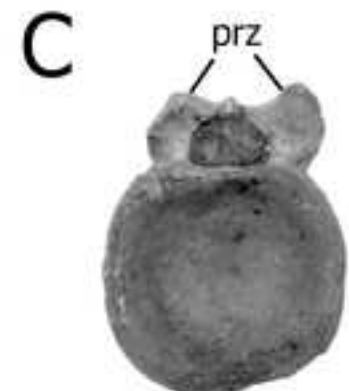


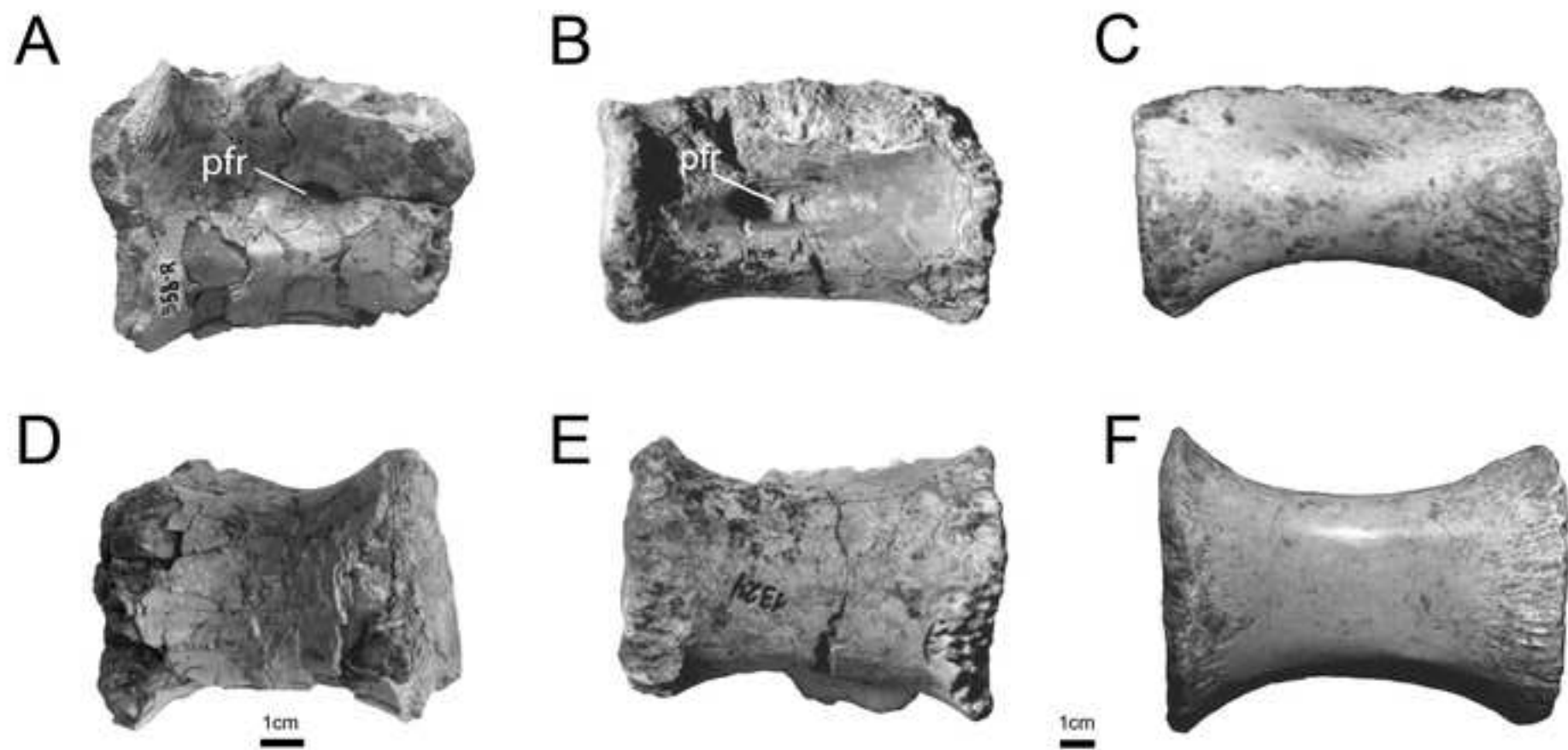
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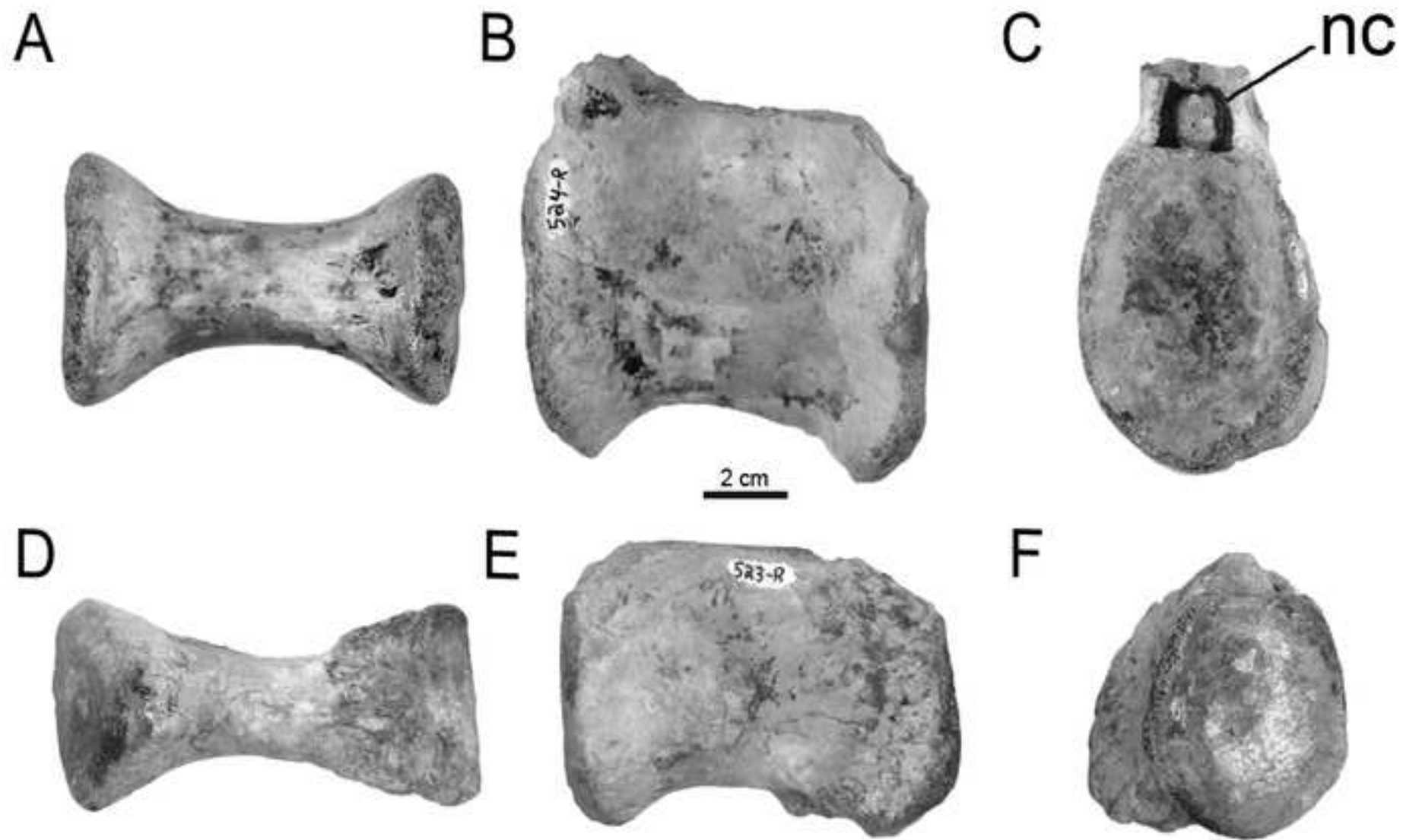


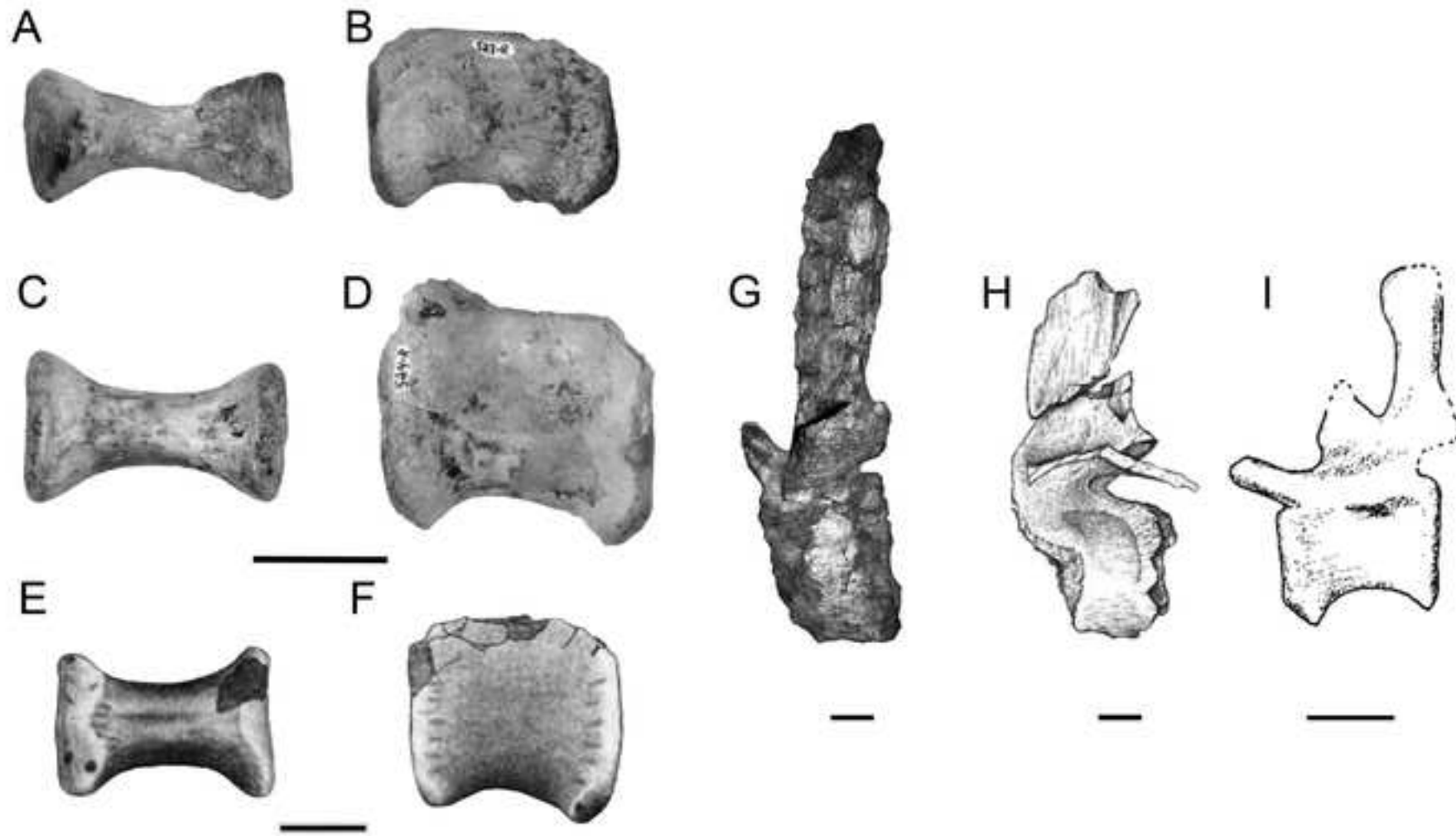
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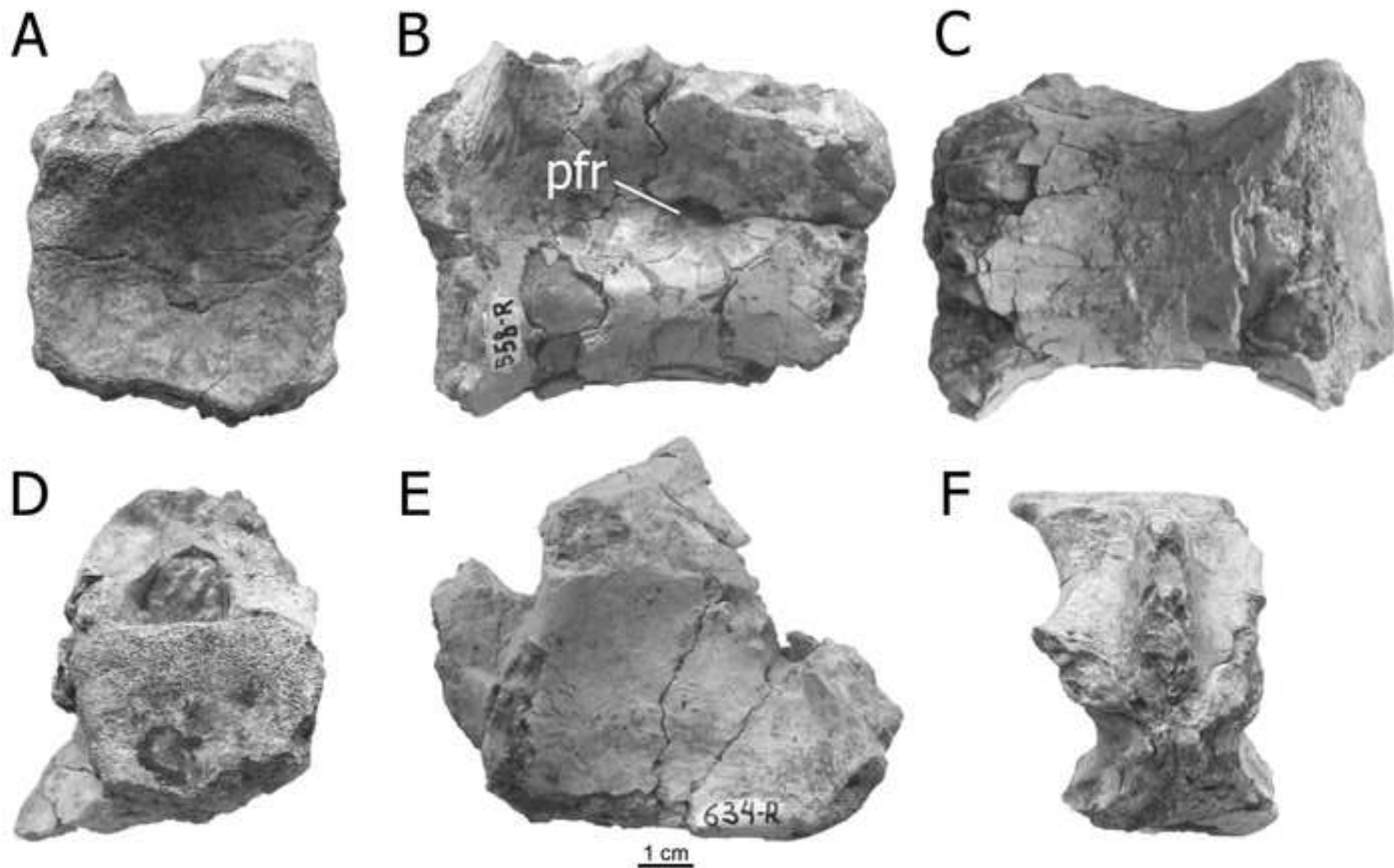


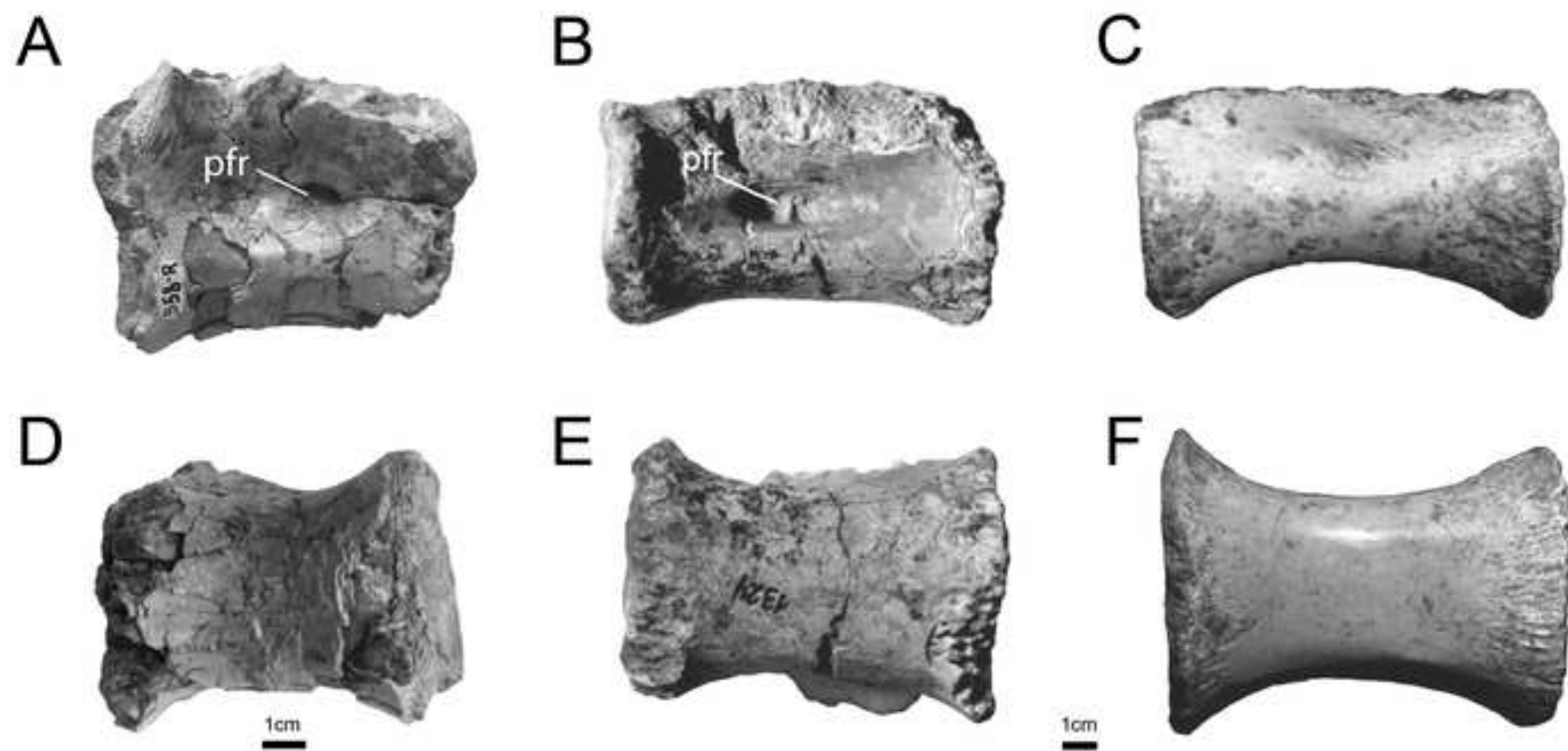


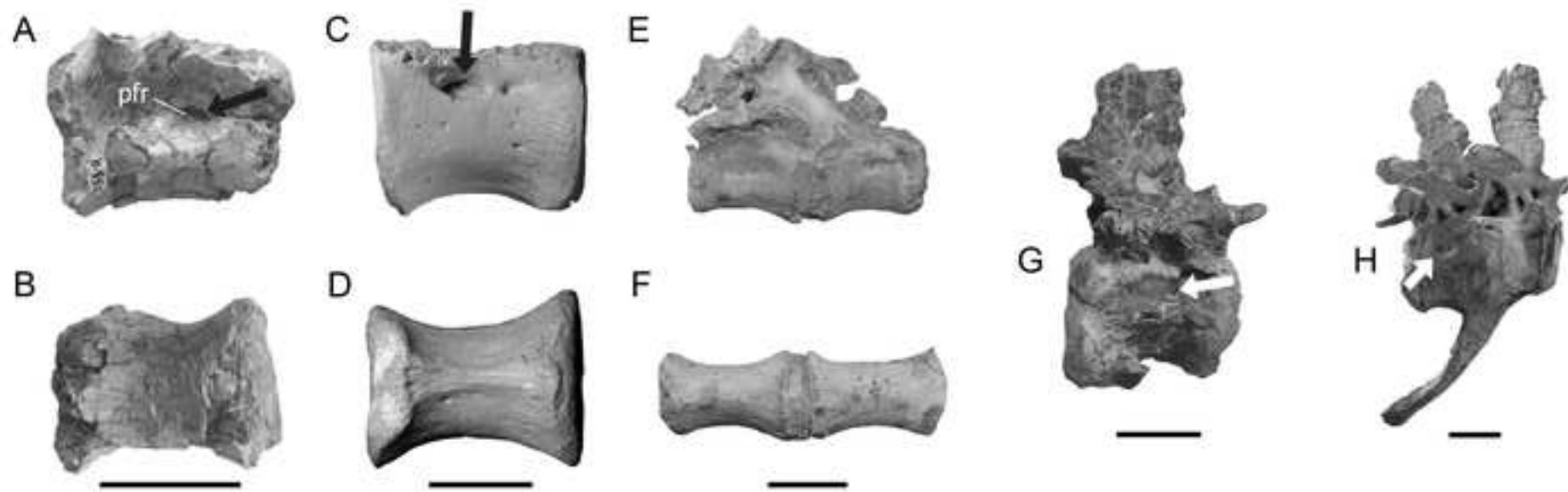








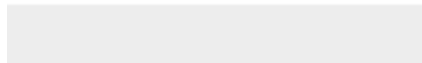








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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Author Statement

Paulo Victor Luiz Gomes da Costa Pereira: Conceptualization, Investigation, Writing - Original Draft, Writing - Review & Editing, Supervision, Funding acquisition.

Theo Baptista Ribeiro: Investigation, Writing - Original Draft, Writing - Review & Editing, Visualization.

Stephen Louis Brusatte: Validation, Writing - Review & Editing, Supervision

Carlos Roberto dos Anjos Candeiro: Writing - Original Draft, Writing - Review & Editing, Supervision.

Thiago da Silva Marinho: Investigation, Writing - Review & Editing

Lilian Paglarelli Bergqvist: Resources, Writing - Review & Editing, Supervision, Project administration, Funding acquisition.

Dear Editor

I, Dr. Paulo Victor Luiz Gomes da Costa Pereira, the first author of this manuscript, send this letter in order to request the change of the reviewer 01. I know that such a change can cause a delay in publication, but I believe that is important. We consider all the changes requested by you and the other reviewers and I am absolutely sure that the manuscript improved a lot with the changes proposed by you all. But I have to point out that the criticisms made by the reviewer 01 were often disrespectful and arrogant, a role that does not compete with the duties of a reviewer in a major international magazine.

His comments, did not contribute much to our work, since the reviewer limited himself to not agreeing with our classifications, always without presenting actual arguments or presenting bibliography that disagreed with our results, a totally different behavior when compared to the other two reviewers.

Our work is based on morphological description and comparison between materials, based on several similar articles with African and European fossils that have already been published, including by Cretaceous Research.

The role of our manuscript (and science in general) is to contribute as much as possible with the fossils collected. Nothing prevents better preserved fossils from disagreeing with our considerations in the future.

I'm really upset that I had to wait more than 8 months for a review that did not seek to improve the manuscript at all.

I thank you very much for the attention given by you and the other reviewers to our manuscript. Be sure that our work has improved a lot with your contributions!

Yours sincerely,

Dr. Paulo Victor Luiz Gomes da Costa Pereira

1 **THEROPOD (DINOSAURIA) DIVERSITY FROM THE POTIGUAR BASIN**
 2 **(EARLY-LATE CRETACEOUS ALBIAN–CENOMANIAN), NORTHEAST**
 3 **BRAZIL**

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21 **Abstract**

23 The theropod records from the Cretaceous of northeastern Northeast of Brazil are rare
 24 and consist mostly of isolated and incomplete remains, with only ~~four~~ ^{five} species
 25 described. Here we describe, identify and evaluate the diversity of theropod materials
 26 from the Albian-Cenomanian Açú Formation, Potiguar Basin. The material consists of
 27 ~~seven~~ ^{nineteen} isolated theropod vertebrae (UFRJ-DG-521-R, 523-R, 524-R, 528-R, 532-

Commented [PP1]:

Revisor 01: I recommend to change the title for a more realistic one, for example: "Theropod dinosaur remains from..."

A: We understood the statement of Revisor 01, but we preferred to keep the original title, as it summarizes the results seen in the manuscript.

Commented [BS2R1]: I actually agree with the reviewer. Because we are describing a series of new fossils, 'Theropod dinosaur remains' sounds better. But this is your choice.

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Commented [3]: Five theropod species only in the northeast, or in all Brazil?

Commented [LM4]: A: The four specimens are only from northeastern Brazil. This detail is better explained in the second paragraph of the Introduction.

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28 R, 547 R, 558 R, 575 R, 587 R and 589 R) and a tooth (UFRJ-DG-653 R). ~~We identify~~
 29 ~~the material, have been identified~~ as belonging to ~~four~~ theropod groups: ~~Abelisauria,~~
 30 ~~Carcharodontosauria,~~ Spinosauoidea, ~~Carcharodontosauriidae,~~ Megaraptora, and
 31 ~~Maniraptora.~~ The vertebrae were classified into five ~~four~~ morphotypes based on
 32 ~~morphological form and/or diagnostic characters and comprised represented at this~~
 33 ~~moment by five four groups: Abelisauria, Carcharodontosauria,~~
 34 ~~Spinosauridae, Megaraptora, and Maniraptora.~~ ~~We classify the~~ The isolated tooth was
 35 ~~classified as belonging to a spinosaurid.~~ One of the ~~significant~~ ~~great~~ results ~~so far~~ is the
 36 occurrence of Megaraptora in the Potiguar Basin, ~~;~~ based on the general morphology,
 37 ~~some of the bone elements described we describe~~ are very similar to ~~those of Aerosteon~~
 38 and ~~Megaraptor.~~ Another ~~unexpected~~ ~~remarkable~~ result is the ~~description~~ ~~identification~~
 39 and presence of ~~a maniraptoran~~ ~~a~~ caudal vertebrae ~~of a maniraptoran~~ ~~;~~ ~~these dinosaurs are~~
 40 very rare in Brazil, with few ~~fossils~~ ~~remnants~~ ~~previously~~ described. ~~Besides~~
 41 ~~this~~ ~~Furthermore, we identify~~ other groups ~~that have~~ already ~~been~~ found ~~on~~ ~~in~~ isochronous
 42 basins of the Northeast region of Brazil and Africa, ~~including as~~ Carcharodontosauria and
 43 Spinosauridae. The presence of these theropod groups ~~in the~~ ~~at~~ Açu Formation reveals
 44 ~~an unexpected~~ dinosaur richness ~~fauna~~ ~~in the~~ ~~in the~~ Potiguar Basin ~~similar to~~
 45 ~~isochronous basins in Northern Africa and opens up an important opportunity to increase~~
 46 ~~the~~ knowledge about ~~the~~ ~~the~~ diversity ~~of South American dinosaurs.~~

Commented [B5]: Five groups are listed

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Commented [6]: Spinosauridae was recognized by a tooth, not a vertebra

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Commented [7]: I suggest to end this sentence with something more "... about the diversity of dinosaurs xxx..."

Commented [PP8]: A: Done

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48 ~~Keywords: Dinosauria, Potiguar Basin, Theropoda, faunistic richness, Abelisauria,~~
 49 ~~Carcharodontosauria, Megaraptora, Spinosauridae, and Maniraptora.~~

51 Introduction

52 ~~The first works studies~~ in Brazil that attributed vertebrate fossil remains to

53 dinosaurs were ~~conducted~~ ~~published into~~ the nineteenth and mid-twentieth centuries
 54 (Marsh, 1869; Derby, 1890; Mawson ~~&~~ Woodward, 1907; Price, 1960, 1961). Since
 55 that time, dinosaur fossils have been recorded ~~in~~ ~~from~~ three principal localities/ and ages
 56 in Brazil: the Triassic of the Santa Maria and Caturrita formations (Langer et al., 2007a),
 57 the mid-Cretaceous of the Araripe, Triunfo and São Luís-Grajaú basins (Frey ~~&~~ Martill
 58 1995; Kellner 1996a, b, 1999; Medeiros *et al.*, 2007; Carvalho *et al.*, 2017), and the Late
 59 Cretaceous of the Bauru and Parecis groups (Franco-Rosas *et al.*, 2004; Kellner *et al.*,
 60 2004; Brusatte *et al.* 2017).

61 ~~As of now, there have been five theropod dinosaur species formally described~~
 62 ~~from Brazil: *Staurikosaurus pricei* Colbert, 1970 and *Guaibasaurus candelariensis*~~
 63 ~~Bonaparte, Ferigolo & Ribeiro, 1999 from the Caturrita Formation; *Angaturama limai*~~
 64 ~~Kellner & Campos, 1996, *Santanaraptor placidus* Kellner, 1999, *Irritator challengeri*~~
 65 ~~Martill, Cruikshank, Frey, Small and Clarke, 2002 and *Mirischia asymmetrica* Naish,~~
 66 ~~Martill & Frey 2004 from the Araripe Basin; *Oxalaia quilombensis* Kellner, Azevedo,~~
 67 ~~Machado, Carvalho & Henriques, 2011 from the São Luís Grajaú Basin, and~~
 68 ~~*Pycnonemosaurus nevesi* Kellner & Campos, 2002 from the Bauru Group.~~ There are eight
 69 theropod dinosaur species formally described ~~from~~ ~~for~~ Brazil so far, four ~~of those~~
 70 ~~described for its~~ ~~from the~~ northeastern region: *Santanaraptor placidus* Kellner, 1999,
 71 *Irritator challengeri* Martill, Cruikshank, Frey, Small and Clarke, 2002 and *Mirischia*
 72 *asymmetrica* Naish, Martill and Frey 2004 from the Araripe Basin; and *Oxalaia*
 73 *quilombensis* Kellner, Azevedo, Machado, Carvalho and Henriques, 2011 from the São
 74 Luís-Grajaú Basin.

75 A promising area for new dinosaur discoveries is the rocks of the Açu Formation,
 76 in the Portiguar Basin. ~~Recently~~ Until now, the macrofossils of the Açu Formation ~~(in this~~

Commented [PP9]: Revisor 01: Please, restrict to Cretaceous record, to address the relevance of the materials here reported.

A: We choose to keep this part of the text to preserve the cohesion within of the Introduction, featuring the first works and discoveries on theropod paleontology of Brazil. The next paragraph has a small summary of the Cretaceous northeastern theropod dinosaurs of Brazil.

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Commented [10]: To this list should be added the recently described *Vespersaurus paranaensis* Langer et al., 2019 and *Gnathovorax cabreirai* Pacheco et al., 2019

Commented [LM11]: We choose to limit this list to the northeastern Brazil's theropod record only to make the text more easy to read/understand

77 ~~area were restricted to a few occurrences from outcrops on the western border of the basin~~
78 ~~(Russas and Tabuleiro do Norte municipalities, Ceará state), consisting~~ of bivalve
79 molluscs, small crustaceans, fish scales, and plant remains (Duarte ~~& Santos, 1961~~).
80 ~~This situation lasted until~~ However this changed in the 2000s, when researchers from the
81 Group of Analogs to Oil Reservoirs of the Department of Geology of the Federal
82 University of Rio Grande do Norte, in geological mapping of the Açú 4 operational unit,
83 found large vertebrate fossils. ~~These fossils were attributed to Titanosauria and~~
84 ~~Theropoda indet., but were not described in detail (Santos et al., 2005).~~

85 In the decade after the discovery of these first continental vertebrate fossils in the
86 formation (Santos *et al.*, 2005), no other fieldwork was conducted. However, in ~~the years~~
87 2015 and 2016, this area was again prospected by Laboratório de Macrofósseis of the
88 Universidade Federal do Rio Janeiro and dozens of fossils were ~~collected~~ found. The aim
89 of the present work is to describe and identify the collected materials attributed to
90 theropod dinosaurs, showing that the Potiguar Basin preserves a ~~great large~~ diversity of
91 species and has great potential for future discoveries and studies about the mid-
92 Cretaceous paleoenvironments of the Atlantic margin of Brazil.

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94 Geological Setting and Lithostratigraphy

95 The Potiguar Basin is located at the eastern continental margin of northeastern
96 Brazil, cropping out in the states of Rio Grande do Norte and Ceará (Fig. 01), with a total
97 estimated area of 60,000 km², of which 22,000 km² is interpreted as continental (Cassab,
98 2003). The Potiguar Basin is bounded to the east by Alto de Touros, ~~which~~ ~~which~~
99 separates it from the Pernambuco-Paraíba Basin, to the northwest by the Alto de

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Fortaleza, which ~~bordering-separates~~ it from the Ceará Basin, and to the south and west by crystalline basement rocks (Pessoa-Neto *et al.*, 2007).

~~Figure 01: Geological map of the continental part of the Potiguar Basin with the region near the Limoeiro do Norte municipality (Ceará state) where the osteoderm were was discovered (dark star). CE, Ceará state; RN, Rio Grande do Norte state (Capital is Natal). Modified from Cassab (2003).~~

The ~~sedimentary units of the~~ Potiguar Basin ~~is~~are divided into three groups: Areia Branca (Pendência and Alagamar formations), Apodi (Açu, Quebradas and Jandaíra formations) and Agulha (Ubarana, Guamaré and Tibau formations) (Araripe ~~&and~~ Feijó, 1994). The Açu formation is divided into four subunits according to electric logs, identified from bottom to top as Açu 1, Açu 2, Açu 3 and, Açu 4 (Vasconcelos *et al.*, 1990). The material described here comes from the Açu 4 subunit, which corresponds to a transgressive, coastal-estuarine system.

The Açu-4 Unit consists of sixteen facies, fourteen being siliciclastic and two being hybrid. The siliciclastic facies ~~were~~are grouped into nine associations, namely: (1) lag residual deposits, (2) channel fill deposits, (3) crevasse-splay deposits, (4) floodplain deposits, (5) abandoned channel deposits, (6) upper-flow regime sandflat deposits, (7) lower-flow regime sandflats, (8) sandflat/mudflat deposits of restricted environment, and (9) mudflat deposits. The first five facies associations represent a meandering fluvial system with tidal influence, and the remaining integrate the intermediate and distal sectors of an estuarine complex dominated by tides. The hybrid facies were deposited in a shallow platform adjacent to an estuary (Costa *et al.*, 2014).

Commented [13]: The authors do not describe any osteoderm in the text.

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Commented [PP15]: Revisor 01: Do you mean the sedimentary infilling is divided into three groups?
A: Yes, we are following the terminology and geological description of the Basin.

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125 The Açu Formation has been suggested to be Albian-Cenomanian in age (Early-
126 Late Cretaceous), based on palynological data (Araripe ~~and~~ Feijó, 1994).

127

128 Material and Methods

129 The fossils were collected from outcrops of the Açu Formation, Potiguar Basin
130 (Ceará state, northeastern Brazil) and are deposited at the Fossil Reptile Collection of the
131 Departamento de Geologia (DG), Universidade Federal do Rio de Janeiro (UFRJ). The
132 material consists of ~~40-seven~~ isolated theropod vertebrae (UFRJ-DG 521-R, 523-R, 524-
133 R, 528-R, ~~532-R~~, ~~547-R~~, 558-R, 575-R, ~~587-R~~ and ~~589634-R~~) and a tooth (~~619-Rd~~)

134 tooth. The vertebrae were classified into ~~five~~six morphotypes based on morphological
135 form and/or diagnostic characters.

136 The following tooth characteristics were ~~analyzed~~assessed, according following to
137 the nomenclature proposed by Hendrickx *et al.* (2015): ~~—describing:~~ general
138 morphological ~~traits~~ogy of the dental crown (geometric shape, relative curvature and
139 surface ornamentation ~~its overall shape, curvature, ornamentations in the enamel~~),
140 denticles (presence, size and shape) ~~and~~, cross section (compression and shape),
141 orientation of the tooth (lingual, labial, mesial and distal) and measurements ~~and blood~~
142 grooves (presence and visibility) (Currie *et al.*, 1990; Sankey *et al.*, 2002; Smith *et al.*,
143 2005; Candeiro, 2007);

144 AL: Maximum apicobasal extent, of the tooth crown mesial base, measured from the
145 mesial portion at the level of the cervix to the apical most point of the crown (Smith *et*
146 *al.*, 2005);

147 CBL: Maximum mesiodistal extent of the tooth crown at the level of the cervix (Smith
148 *et al.*, 2005). Equivalent to FABL used by some authors (Currie *et al.*, 1990; Farlow *et*
149 *al.*, 1991; Sankey *et al.*, 2002);

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Commented [16]: I suggest to add its collection number

Commented [LM17]: Done.

Commented [18]: They were described only five morphotypes in the text.

Commented [LM19]: Done.

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Commented [PP20]: Revisor 01: Considering that this is not a ms devoted to analyze theropod teeth as a whole, and taking into account that just only one tooth is described, I suggest to remove all these considerations. A: Done.

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150 ~~CBW: Maximum labiolingual extent of the tooth crown base, perpendicular to the CBL~~
 151 ~~and at the level of the cervix. (Smith *et al.*, 2005).~~

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152 ~~CBR: Ratio expressing the narrowness, the lateral compression of the base of the crown,~~
 153 ~~corresponding to the quotient of CBW by CBL ($CBR=CBW/CBL$, Smith *et al.*, 2005). A~~
 154 ~~strongly labiolingually narrow crown has a quotient of less than 0.4; a moderately narrow~~
 155 ~~tooth is around 0.5-0.6; a weakly narrow crown, with an ovoid cross section, has a ratio~~
 156 ~~fluctuating between 0.6-0.7; and a tooth with a subcircular transversal section has a ratio~~
 157 ~~between 0.9 and 1.1 (Smith *et al.*, 2005).~~

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158 ~~CH: Maximum apicobasal extent of the distal margin of the crown (Smith *et al.*, 2005).~~
 159 ~~Equivalent to the TCH proposed by Farlow *et al.* (1991).~~

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160 ~~CHR: Ratio expressing elongation, the relative size of the tooth, equivalent to the~~
 161 ~~quotient of CH by CBL ($CHR=CH/CBL$, Smith *et al.*, 2005). A short crown tooth has a~~
 162 ~~quotient less than 1.5; a medium crown tooth has a quotient varying from 1.5-2.5 and a~~
 163 ~~strongly elongated crown has a ratio above 2.5.~~

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164 ~~DC: Number of denticles on the distal carina at mid crown per 5mm (Smith *et*~~
 165 ~~*al.*, 2005). Equivalent to five times the posterior medial carina denticles per millimeter~~
 166 ~~(Buckley *et al.*, 2010). In this study, teeth with less than 20mm had their denticles~~
 167 ~~measured over 1mm, with this value then multiplied by five.~~

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168 ~~MC: Number of denticles on the medial part of the mesial carina per 5mm (Smith~~
 169 ~~*et al.*, 2005). Corresponds to five times the number of denticles of the medial part of the~~
 170 ~~mesial carina per millimeter (Buckley *et al.*, 2010). In this study, teeth smaller than 20mm~~
 171 ~~had their denticles measured over 1mm, and this value was then multiplied by five.~~

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172 ~~Anteroposterior basal length—commonly referred to as FABL (fore aft basal~~
 173 ~~length)—a measure taken between the most extreme points of the tooth at its base. It is~~
 174 ~~conceptually represented by a straight line.~~

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175 ~~Total crown height — ALT — the distance between the apex and the base of the~~
176 ~~crown.~~

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177 ~~Relative crown height — IAR — division of the total crown height by~~
178 ~~baselineanteroposterior length (ALT/FABL).~~

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179 ~~Transverse section thickness — EST — measure of the labial-lingual thickness of~~
180 ~~the basal cross section of the tooth.~~

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181 ~~Density of denticles — DDA (anterior carina, also known as mesial carina) — DDP~~
182 ~~(posterior carina, also known as distal carina). Measurement of the number of denticles~~
183 ~~per 1 mm on the medial part of the crown, in both carinae.~~

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Commented [21]: I suggest to be consistent with the abbreviations, using their English versions as is usual besides FABL: CBW: crown basal width (rather than EST), CH: crown height (rather than ALT), etc. See Hendrickx et al 2015. The dentition of megalosaurid theropods. Acta Paleontologica Polonica 60 (3): 627-642.

184 ~~Terminology~~

185 ~~In the present work, the terminologies proposed by Smith et al., (2005) were used~~
186 ~~to refer to both the dental structures and the positioning of the analyzed teeth. According~~
187 ~~to these authors, the dental crown is divided into three parts: apical (the most distal part~~
188 ~~of the tooth), medial (region between the apical and basal), and basal (lower part of the~~
189 ~~tooth, closer to the root). The authors defined as the labial surface the surface that was in~~
190 ~~contact with the animal's lips, and the lingual surface to that which faced the tongue of~~
191 ~~the animal.~~

Commented [LM22]: Done. We updated the method and nomenclatures according to Hendrickx et al., 2015 **A proposed terminology of theropod teeth (Dinosauria, Saurischia)**. We also cut some redundant parts of the methods, such as the terminology.

Commented [23]: The values of most of these parameters were not specified in the analysis of the tooth recovered. I suggest to add them.

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Commented [LM24]: The values of the measurements are now stated in the description of UFRJ 654-Rd.

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194 ~~Results~~

195 ~~Dental element:~~

196 ~~Sistematie~~ **Systematic paleontology**

197 ~~Teeth~~

198 **THEROPODA** Marsh, 1881

~~TETANURAE~~ Gauthier, 1986

~~SPINOSAURIDAE~~ Stromer, 1915

Referred material: UFRJ DG 653 R, a tooth.

Description and comparisons:

The material consists of an incomplete Spinosauridae crown (Fig. 02, A and B) whose apex has been lost. The crown has a high relative height (HR = 2.4) and is lingually curved. Its cross section is rounded with a Crown Base Ratio (CBR) of 7.8 (Smith et al., 2005).

This crown does not have denticulation in any of its carinae is shared with *Irritator challengeri* and *Spinosaurus aegyptiacus* but differs from the denticulated carinae of *Baryonyx walkeri* (Mateus et al., 2011). On the labial surface, there are no striations, while on the lingual surface there are ca. 9 well defined striations that bifurcate near the base of the crown.

UFRJ DG 653 Rd shares many characteristics seen in other spinosaurines as a conical teeth crown with a ovoid shaped crown base, feature usually seen in piscivorous animals; the non serrated carinae, which differentiates it from the other spinosauroid family, the Baryonychinae, whose teeth features a large number of small sized serrations on both of its carinae; flutes (Must see the material again).²

Axial elements:

Commented [25]: This measurement has a big fault, given the recovered tooth lacks most of its tip.

A: Done. We added to the text that we estimated the total height of the crown based on the works of (CITE)

Commented [26]: Other abbreviation was used in Material and methods

A: Done

Commented [27]: This ratio was not mentioned in Materials and methods

A: Done

Commented [28]: I suggest that, before comparing this material with other spinosaurids, the authors should add a summary of characters that allow to assign it to Spinosauridae.

A: Done. We summarize the characteristics of spinosaurids in the Discussion.

Commented [29]: I suggest to change to "...carinae, a shared condition..."

A: Done.

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Commented [PP30]: A: Review the tooth description and explain why

SAURISCHIA ~~Cite~~ Seeley, 1888 ~~year~~ Morphotype 1:

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THEROPODA Marsh, 1881

AVEROSTRA Paul, 2002

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TETANURAE Gauthier, 1986

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NEOVENATORIDAE Benson, Carrano & Brusatte, 2010

? MEGARAPTORA Benson, Carrano & Brusatte, 2010

Commented [31]: Given there are two morphotypes assigned to Megaraptora, both showing similar characteristics, the authors should explain why there are not included in a single morphotype.
A: Done.

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Referred material: UFRJ-DG 532-R and 575-R, and 587-R

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Description and comparisons:

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Morphotype 1 consists of two specimens (Fig. 02, C-F) based on partial centra and is characterized by semicircular articular surfaces and high pneumaticity. They are possibly caudal vertebrae, but a more conclusive description is difficult because of the poor preservation of the material.

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Figure 02: Tooth and vertebrae attributed to Morphotype 01: Spinosauridae tooth,

Commented [32]: Which view?

A: FAZER

A; tooth cross section, B; Articular view, C(UFRJ DG 587 R); D (UFRJ DG 575 R).

Commented [33]: In the figure there is a black circle, I strongly suggest to add the real basal cross-section picture.

A: FAZER

Lateral view, E and F(UFRJ DG 575 R). Note the large pneumatic foramen on the side of the anterior fragment. pfr = pneumatic foramen. Scale bar: 1cm.

Commented [34]: Those are lateral views of the same fragment, or one of each fragment?

A: FAZERPAULO

UFRJ-DG 528-R

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248 Specimen 528-R is a theropod vertebral centrum (Fig. 023, CA-EBE). It is
 249 amphicoelous, and slightly higher than long. Its lateral surface is smooth and slightly
 250 concave, without marks or other ~~remarcable~~remarkable —characteristics, giving the
 251 vertebra a straight and ~~cleansomewhat~~ featureless appearance. The ventral surface
 252 smooth with no groove or keel and ~~is not very concave~~it is slightly concave in lateral
 253 view., being smooth on the medial region and presenting a groove on the posterior region
 254 close to the articular face margin.

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255 The dorsal surface possesses a distinct longitudinal groove extending from one
 256 articular facet ~~end~~ to the other that, and this groove can be identified as the neural canal.
 257 The anterior part of this groove is covered, but this covering is lost from the medial part
 258 further posteriorly, exposing the neural canal of this region in dorsal view.
 259 The articular faces have ~~almost~~nearly straight margins. The anterior facet is somewhat
 260 concave, and the posterior is slightly convex and slightly oval in shape; both articular
 261 facets have the same general proportions (height longer than length). The anterior
 262 articular face presents a ~~deeper concavity~~, and is slightly larger in size, than ~~the~~ the posterior
 263 face, which is very flat and without deep depressions.

Commented [35]: The word “expressive” seems wrong in this context.
A: Done.

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265 UFRJ-DG 575-R

266 Specimen 575-R (Fig. 02, ~~AC-BED-F~~) is a theropod vertebral centrum broken in
 267 two: a ~~4,5cm long~~ smaller anterior piece and a ~~5,2cm long~~ larger posterior section.
 268 Although the material ~~have been~~was found associated there is no clear point of junction
 269 between both pieces, ~~with~~as most of the middle portion ~~being~~has been lost. The anterior
 270 fragment ~~presents~~ ~~exhibits~~ a very concave articular face of semi-circular shape and
 271 slightly forward-protruding margins.

Commented [PP36]: Revisor 01: Before description of any dinosaur bone, it must be glued.
A: Done.

272 On the lateral surface of the anterior fragment there is a deep perforation close to
 273 the dorsal region that reaches the other lateral surface, which can be described as a
 274 pleurocoel ~~(=pneumatic foramen) (=pneumatic foramen)~~ ~~(as the left lateral surface close~~
 275 ~~to the dorsal surface is missing a piece, exposing the internal part of the bone)~~. The ventral
 276 surface of the anterior fragment is smooth and concave in anterior view. The dorsal
 277 surface of the anterior fragment is broken, missing most of the surface above the
 278 pleurocoel.

279 The posterior fragment has a slightly smaller articular surface, ~~which is~~ broken on
 280 the anterior portion; it is also concave and of ~~semi-spherical~~ circular shape, with slightly
 281 backwards-protruding margins. Its dorsal surface and the dorsal half of the left lateral
 282 surface are broken, while the right lateral surface is broken in a slightly more dorsal region
 283 in comparison to the left one. The ventral surface of the fragment is smooth and concave
 284 in lateral view. Due to the highly fragmentary state of UFRJ-DG 575-R, it is possible
 285 to see multiple small pervasive pneumatic chambers, the camellae, in the internal bone.

286 ~~When both fragments are joined, it is clear that the length of the centrum is even~~
 287 ~~larger than the height on its most complete point, in this case the anterior articular face.~~
 288 ~~This is common in anterior dorsal vertebrae of Allosauroidea (measured next to the~~
 289 ~~pleurocoels, which confirms the more anterior location). Furthermore, the margins of the~~
 290 ~~articular facets have forward protrusions like those found in this group (Gilmore, 1920;~~
 291 ~~Madsen, 1976).~~

292

293 *Comparisons:*

294

295

Commented [37]: Sem-spherical or semicircular?
Done.

Commented [38]: The authors should describe (and figure) the materials as a single vertebra, not as two different fragments. It is confusing and does not help with interpretation of the materials.

Commented [39]: At the beginning of this morphotype description the authors suggest that they are possibly caudal vertebrae.

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296 The highly pneumatized camellate bone seen in UFRJ-DG 575-R is a characteristic seen
 297 in many groups of theropods, from the basal *Ceratosaurus* to tetanuran groups such as
 298 carcharodontosaurids and coelurosaurs mainly in its presacral vertebrae (Carrano &and
 299 Sampson, 2008). This feature, together with the poor preservation of this specimen,
 300 which prevents the identification of other more diagnostic characteristics, hinders the
 301 classification of this specimen beyond *Averostra* Theropoda.

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302

303 **UFRJ-DG587-R**

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304 Specimen 587-R is the anterior articular face of a theropod vertebra (Fig. 02, C).
 305 It has an semicircular shape, is slightly taller (9,5 cm) than wide (8cm), and has a shallow
 306 concavity on its articular surface, possibly indicating it is the anterior face of an
 307 amphicoelous vertebra, characteristic of Theropoda. The dorsal surface is indented with
 308 a concavity representing the beginning of the neural canal.

Commented [40]: Why anterior? It could not be posterior?

Commented [41]: Why the authors assign this material to morphotype 1? They only suggest that it belongs to a theropod.

309

310 Morphotype 2:

311

312 **THEROPODA** Marsh, 1881

313 **TETANURAE** Gauthier, 1986

314 **CERATOSAURIA** Marsh 1884

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315 **NEOCERATOSAURIA** Novas 1989

316 **ABELISAURIA** Novas 1992

317

318 Referred material: UFRJ-DG 528-R and 532-R.

319 *Description and comparisons:*

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320 Morphotype 2 (Fig. 03) includes two vertebrae with a low length/height ratio and
 321 semicircular articular faces with little lateral compression.

322

323 UFRJ-DG528-R

324 Specimen 528-R is a theropod vertebral centrum (Fig. 03, A-C). It is amphicoelous, and
 325 slightly higher than long (8,5 vs. 6cm). Its lateral surface is smooth and slightly concave,
 326 without marks or characteristics of note, giving the vertebra a straight appearance. The
 327 ventral surface is not very concave in lateral view, being smooth on the medial region and
 328 presenting a breach groove on the posterior region close to the articular face margin.

329 The dorsal surface possesses a distinct longitudinal groove extending from one articular
 330 end to the other, and this groove can be identified as the neural canal. The anterior part of
 331 this groove is covered, but this covering is lost from the medial part further posteriorly,
 332 exposing the neural canal of this region in dorsal view.

333 The articular faces have almost straight margins. The anterior face is somewhat concave,
 334 and the posterior is slightly convex and slightly oval in shape; both articular faces have
 335 the same general proportions (height longer than length). The anterior articular face
 336 presents a more expressive concavity, and is slightly larger in size than, the posterior face,
 337 which is very flat and without deep depressions.

338

339

340 UFRJ-DG532-R

341 It is a fragment of a theropod vertebral² articular facet (Figure reference?). Its oval shape
 342 in the dorso-ventral direction, due to its height being longer than its length (8cm vs. 6cm),
 343 indicates a position in the most proximal region of the caudal vertebrae. The articular
 344 surface is slightly concave, presenting only a small depression, which indicates it is the

Commented [42]: This character used for differentiate this morphotype is clearly related to the position of the vertebra inside the vertebral series.

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Commented [43]: This character is used for differentiate this morphotype is also present in morphotype 1

Commented [44]: I suggest to look for other more specific characters to differentiate this morphotype

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Commented [45]: This sentence seems wrong, please rephrase
 A: Done.

Commented [46]: The word "expressive" seems wrong in this context.
 A: Done.

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345 posterior articular face of the centrum (Bonaparte, 1985; Sampson et al. 1998; Coria et al.
 346 2002, Méndez, 2014 year?). The articular surface is slightly damaged on its lower right
 347 part, missing a fragment that goes almost up to the medial part of the articular face.

348

349 THEROPODA Marsh, 1881

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350 TETANURAE Gauthier, 1986

351 ? SPINOSAUROIDEA Stromer, 1915

352

353 Referred material: UFRJ-DG 619-Rd.

354 Description:

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355

356 UFRJ-DG 619-Rd (Fig. 03) is a fragment of a large isolated tooth crown,
 357 probably belonging to the middle to almost apical portion of the tooth. The specimen
 358 lacks any form of enamel, ~~having as it has all its~~ dentine exposed, what prevents ~~the~~
 359 ~~possibility to~~ description of ~~describe any kind of external~~ ornamentation ~~as such as~~
 360 transversal undulations, ~~and~~ flutes and denticulation. The crown is almost completely
 361 straight with only a subtle curvature in its lingual surface, while the labial surface remains
 362 slightly convex.

363 The crown fragment has an overall cone-like shape with an almost ovoid cross
 364 section. ~~In the~~ basal view, ~~it's~~ possible to see concentrically deposited rings of dentine
 365 surrounding a small depression, which probably represents the apical-most portion of the
 366 dental pulp cavity.

367 Comparisons:

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368 UFRJ-DG 619-Rd have some characteristics that it shares with the highly specialized
 369 teeth ~~seen in of~~ spinosauroid theropods. The most salient of these is the almost straight

370 conical shaped crown, with an ovoid cross section ~~shape~~, a feature ~~usually~~ often seen in
371 piscivorous animals (~~CITE~~ Mateus, 2011; Hendrickx & and Mateus, 2014) ~~being the most~~
372 ~~remarkable of those.~~

Commented [BS47]: Which shape? Cross sectional?

374 ~~The lack of denticulation in on any of its carina is a characteristic seen in spinosaurines~~
375 ~~such as Irritator challengeri and Spinosaurus aegyptiacus (cite~~ Stromer, 1915; Martill et
376 ~~al., 1996) while the highly denticulated carina is characteristic of baryonychines as~~
377 ~~Baryonyx walkeri (Charig & Milner, 1986; Mateus et al., 2011). However, due to the lack~~
378 ~~of enamel in this material it is not possible to distinguish between Baryonychinae and~~
379 ~~Spinosaurinae nor its possible.~~

Commented [BS48]: This paragraph is not necessary because you cannot assess the denticulation. So, just delete it.
A: Done

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382 Morphotype 3:

384 **THEROPODA** Marsh, 1881

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385 **TETANURAE** Gauthier, 1986

386 **MANIRAPTORA** Gauthier, 1986

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391 Referred material: UFRJ-DG 521-R

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392 *Description: and comparisons:*

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393 Morphotype 3 (Fig. 03, E? F G) consists of one vertebra whose ratio between height
394 and its length somewhat greater than six and dorsally positioned prezygapophyses.

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395 length is more than twice its height, and which lacks any processes, indicating to be a
396 distal caudal vertebra.

Commented [49]: Again, using characters related to the vertebral position in the caudal series is

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398 UFRJ-DG_521-R

399 Specimen UFRJ-DG 521-R (Fig. 04) is an almost complete distal caudal vertebrae
400 of a paravianmaniraptoran theropod. It is amphicoelous with a length to height ratio of
401 almost 2.5, making it a least twice longer than tall. The dorsal surface of the centrum is
402 almost complete with half of a dorsal midline ridge reminiscent of reduced neural spine,
403 a well preserved and more dorsally positioned pre-zygapophysis, and a lost post-
404 zygapophysis. The pre-zygapophysis articular surface is ellipsoid and is reclined 45°
405 laterally. The neural canal is almost completely preserved, -having lost only its posterior
406 half.

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Commented [BS50]: A paravian? Can you be this specific? If so, this should go in the Systematic Palaeontology section. If not, then just call it a maniraptoran here.

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407 The lateral surfaces of the centrum are mostly smooth, marked only with a midline
408 ridge reminiscent ~~from of the a reduced~~ transverse processes ~~of the vertebrae~~. The ventral
409 surface of the centrum has a shallow groove that ~~goes extends~~ from one articular facet to
410 the other. In the lateral view the ventral surface is slightly concave.

411 The articular facets of the centrum are both concave, with the anterior facet being
412 more excavated than the posterior facet, and have a semi-circular shape. The articular
413 margins are almost straight, with the anterior margin being larger than the posterior
414 margin.

415 Specimen ₅₂₁-R is a distal caudal vertebra of a theropod. It is almost complete, damaged
416 only in the postzygapophysis region. It is ~~a biconcave, amphicoelous~~ vertebrae with a
417 centrum slightly shorter anteroposteriorly than twice the height near the neural spine
418 remnant and diapophysis, which confirms its more distal position within the caudal series
419 (but not so distant from a medial position).

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Commented [51]: I think both are synonyms
A: Done.

420 On the dorsal surface, the neural canal and the prezygapophyses are well preserved on
 421 the anterior part of the vertebra, being damaged ~~only on in medial posterior portion~~. The
 422 prezygapophyses are intact. The lateral surfaces of the centrum? are smooth and present
 423 only a pair of small depressions on the part close to the dorsal surface. The ventral surface
 424 is intact and is very smooth and concave in lateral view.

425 ~~The articular faces are biconcave; i.e. both present very expressive concavities on~~
 426 ~~their surfaces, the anterior being much deeper than the posterior. Their margins are very~~
 427 ~~straight and have a semi-circular shape, the anterior one being slightly larger than the~~
 428 ~~posterior~~

429 ~~-Comparisons:~~

430 UFRJ-DG 521-R has characteristics of a paravian maniraptoran centrum ~~;~~
 431 positioned after the transition point in the tail (Russell, 1972, Gauthier, 1986; Tykoski,
 432 2005), ~~as it is being~~ longer than high and ~~possessing~~ possesses a large reduction in both its
 433 neural spine and transverse processes, with those structures becoming midline ridges
 434 (Senter *et al.*, 2011; Motta *et al.*, 20187). ~~This way it is~~ Thus, it is possible to deduce that
 435 it is ~~positioned at least~~ after ~~the~~ vertebra 11 of the caudal series as seen in *Buitreraptor*,
 436 *Rahonavis*, Dromaeosauridae and Troodontidae (Ostrom, 1969; Forster *et al.*, 1998;
 437 Senter *et al.*, 2012; Xu *et al.*, 2017).

438 The presence of a reduced transverse process forming a midline ridges after the
 439 transition point is seen seen in some paravians, such as *Microraptor*, *Rahonavis*,
 440 *Buitreraptor*, and *Archeopteryx*. but it is seen in specimens of in the distal caudal
 441 vertebrae of *Microraptor*, *Rahonavis* and *Buitreraptor*. *Anchiornis* and *Archeopteryx*
 442 (Hwang *et al.*, 2002; Hu *et al.*, 2009; Han *et al.*, 2014; Forster *et al.*, 1998; Novas *et al.*,
 443 2017), a characteristic also seen in UFRJ-DG 521-R, which differentiates it from most
 444 other paravians as dromaeosaurids, *Archeopteryx*, *Jeholornis* and *Anchiornis*. ~~;~~

Commented [52]: This sentence is confusing.
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Commented [53]: I think the authors should specify which transition point are referring here (I suppose that proposed by Russel (1972), but this is my guess)
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Commented [BS54]: I don't agree with this taxonomy. *Microraptor* and *Buitreraptor* are dromaeosaurids, at least in most phylogenetic analyses. *Rahonavis* probably too. *Anchiornis* may

be a troodontid. The Agnolin and Novas phylogeny has many strange results and is not widely accepted.

So instead, just say that:

'The presence of a transverse process after the transition point is seen in some paravians, such as *Microraptor*, *Rahonavis*, *Buitreraptor*, and *Archeopteryx*.'

Don't use the term *Averaptor*.

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The presence of the transverse processes after the transition point of the tail is not observed in more basal paravian groups of like dromaeosaurids and troodontids that have smooth lateral surfaces in their centra (Ostrom, 1969; Norell & Makovicky, 1999; Currie & Dong, 2001; Xu et al., 2012), but it is seen in specimens of *Microraptor*, *Rahonavis*, *Buitreraptor*, *Anchiornis* and *Archaeopteryx* (Hwang et al., 2002; Hu et al., 2009; Han et al., 2014; Novas et al., 2017), all belonging to the group Averaptora.

In addition, the 521-R specimen also has ~~the dorsally positioned prezygapophyses more dorsally positioned~~ in the same way as in *Buitreraptor*, *Rahonavis* and *Anchiornis* (fig. 059) (Motta *et al.*, 20188). The vertebral centrum has a length-to-height ratio between ~~its height and its length is~~ close to 2.5, a ratio usually seen in dromaeosaurids with exception to *Buitreraptor* but not seen in other maniraptorans as troodontids and microraptorians whose ratio can reach up to 5.0 to 6.0. ~~a ratio seen in more basal paravians such as dromaeosaurids, in contrast to troodontids and more derived averaptorans whose ratio can be as much as 6.0.~~

Figure 03: Caudal vertebrae attributed to Morphotype 02 (A-D) and Morphotype 03 (E-G). UFRJ-DG-528-R: A, ventral view; B, Lateral view; C, anterior articular facet. UFRJ-DG-532-R: D, anterior articular facet. UFRJ-DG-521-R: E, Lateral view; F, ventral view; G, anterior articular facet. Prz, prezygophysis; Ne, neural canalhannel. Scale: 1cm.

Morphotype 4:

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Commented [B555]: I don't agree with this taxonomy. *Microraptor* and *Buitreraptor* are dromaeosaurids, at least in most phylogenetic analyses. *Rahonavis* probably too. *Anchiornis* may be a troodontid. The Agnolin and Novas phylogeny has many strange results and is not widely accepted.

So instead, just say that:

'The presence of a transverse process after the transition point is seen in some paravians, such as *Microraptor*, *Rahonavis*, *Buitreraptor*, and *Archaeopteryx*.'

Don't use the term Averaptor.

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Commented [B556]: Again, don't use averaptorans. Instead, just say that long vertebrae like these are seen in some, but not all, paravians.

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470 **TETANURAE** Gauthier, 1986
 471 **ALLOSAUROIDEA** Marsh, 1878
 472 **CARCHARODONTOSAURIA** Benson, Brusatte and Carrano, 2010

473
 474 Referred material: UFRJ-DG 523-R and 524-R.

475 *Description and comparisons:*

476 Morphotype 4 (Fig. 04) is formed by two vertebrae with low length/height ratio,
 477 close to morphotype 1, and oval articular facet with strongly waisted centra with lateral
 478 depressions in the dorsal half of the lateral surface, a double keel cut by a longitudinal
 479 groove and offset articular facets.

480

481 Figure 04: Caudal vertebrae attributed to Morphotype 4. UFRJ-DG 524-R: A, ventral
 482 view; B, lateral view; C, anterior articular facet. UFRJ-DG 523-R: D, ventral view; E,
 483 lateral view; F, anterior articular facet. Nc, neural canal channel. Scale: 1cm.

484

485 **UFRJ-DG523-R**

486 Specimen 523-R (Fig. 064, D-F) is a theropod vertebral centrum, with the
 487 following characteristics: it is amphicoelous, and slightly longer than high (8,9 cm vs.
 488 6,5cm). Its lateral surface is very concave and smooth on both sides, with the shape of an
 489 hourglass in dorsal view. The ventral surface is mostly smooth on the anterior part, with
 490 breaches and marks that possibly indicate the articulation fusion of with the hemal arch
 491 on the posterior part.

492 The dorsal surface is marked by a long and expressive deep longitudinal canal
 493 from one articular face to the other, which widens on the extremities and tapers in the

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Commented [58]: Again, this character varies with the position inside the caudal series.

Commented [59]: The shape of the articular face of caudal vertebrae is so variable, it show differences inside the same taxonomic group. For example inside Abelisauridae, Carnotaurus shows semicircular articular surface, and Majungasaurus show oval articular surface, as the authors clearly show in the figure 8. This makes this character not useful for separating morphotypes.

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494 middle. This canal was possibly the space of the neural canal of the vertebra, given the
495 marks of fusion with the neural arch that meet on its borders.

496 The articular faces are ~~ovoidal~~ ~~semi-circular~~ in shape and ~~with~~ have slightly
497 forward-protruding margins ~~of the articular faces~~, the anterior facet being higher in
498 comparison to the posterior facet. The anterior articular face has a concavity deeper than
499 the posterior one, being also slightly larger in its proportions.

500

501 UFRJ-DG524-R

502 Specimen 524-R (Fig. 064, A-C) is a centrum of a theropod caudal vertebra. It is
503 amphicoelous and is slightly longer than high (~~7,5 cm vs. 8,5 cm~~), which indicates a more
504 proximal position ~~between them in the~~ caudal ~~vertebrae series~~. The lateral surface is smooth
505 and marked by two ~~deep~~ ~~expressive~~ concavities on both lateral faces, ~~giving to it an~~
506 ~~hourglass-like shape~~ ~~with a shape like an hourglass~~. Additionally, on the most dorsal
507 region of the lateral surface ~~it is possible to notice~~ ~~there is~~ a small and shallow longitudinal
508 depression on each side.

509 The ventral surface is a double keel marked by a very superficial groove extending
510 from the anterior part up to the posterior part. The dorsal surface is marked by the neural
511 canal of the vertebrae. Above the anterior part of this canal the entire ~~cover~~ ~~upper~~
512 ~~portion~~ of the ~~neural~~ tube is preserved, forming a small arch filled by sediment
513 positioned slightly above ~~of~~ the anterior articular face.

514 The articular faces are semi-circular and somewhat oval, with the anterior one
515 being slightly larger than the posterior, and their margins slightly protrude forward. The
516 anterior articular face has a concavity slightly deeper than the posterior, ~~which is more~~
517 ~~superficial~~.

518 *Comparisons:*

Commented [60]: The articular surfaces shown in the figure 4 has ovoidal articular faces.
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Commented [61]: hourglass-shaped
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519 Both vertebrae of morphotype 4 UFRJ-DG 523 and AND-524 present
 520 characteristics commonly found in carcharodontosaurids (Fig. 0740). For instance,
 521 depressions in the most dorsal part of ~~their~~the lateral surface are found in
 522 *Giganotosaurus*, *Mapusaurus* and *Tyrannotitan* and in the mid-caudal vertebrae Vb-870
 523 found in the Wadi Milk Formation (Coria & Salgado, 1995; Coria & Currie, 2006;
 524 Novas *et al.*, 2005a; Canale *et al.*, 2015; Rauhut, 1999), ~~which~~This condition is different
 525 from that in *Carcharodontosaurus*, ~~that~~which has pleurocoels in ~~their~~its anterior caudal
 526 vertebrae (Stromer, 1931). Furthermore, the strongly waisted centrum morphology, a
 527 double keel cut by a longitudinal groove and offset articular facets (although it is a
 528 plesiomorphic feature found in *Allosaurus* Gilmore, 1920; Madsen, 1976) are also found
 529 in specimens such as the carcharodontosaurid material from Sudan (Rauhut, 1999) and
 530 in *Tyrannotitan*, *Mapusaurus* and *Acrocanthosaurus* (Canale *et al.*, 2015; Harris, 1998;
 531 Coria & Currie, 2006; Currie & Carpenter, 2000).

Commented [BS62]: I thought you were not using the morphotype terminology any more?

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535 Morphotype 5:

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537 **THEROPODA** Marsh, 1881

538 **NEOVENATORIDAE** Benson, Carrano & Brusatte, 2010

539 **MEGARAPTORA** Benson, Carrano & Brusatte, 2010

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540

541 Referred material: UFRJ-DG 558-R e 634-R

542 Description and comparisons:

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Morphotype 5 (Fig. 05) includes two amphicoelous caudal vertebrae with pleurocoels and high pneumaticity.

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Figure 05: Caudal vertebrae attributed to Morphotype 05. UFRJ-DG-634 R: A, posterior articular facet; B, lateral view; C, ventral view. UFRJ-DG-558 R: D, anterior articular facet; E, lateral view; F, ventral view. Pfi, Pneumatic foramen. Scale bar: 1cm.

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UFRJ-DG-558-R

Specimen 558-R is a centrum of a theropod caudal vertebra, damaged by various cracks (Fig. 085, D-F). It is amphicoelous, and slightly longer than high (6cm vs. 7cm), indicating a somewhat proximal position within the caudal series. Its ventral surface is very smooth and convex in lateral view, but is very damaged in the region where the base of the posterior articular face would be.

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The dorsal surface is marked by a great depression extending longitudinally from one articular face to the other, wider in the extremities, denoting the neural canal. The lateral surfaces are marked by a longitudinal elliptic depression on their medial parts, where there is a pleurocoel on each side. The left lateral pleurocoel is deeper and better defined than the right lateral one. ~~The presence of pleurocoels in the caudal vertebrae is characteristic of megaraptoran neovenatorids the Megaraptora group of the Neovenatoridae family (Benson *et al.*, 2011).~~

Commented [B563]: This shouldn't be here, but in the comparisons section, below.

Its articular faces are semi-circular and have very straight margins. The anterior articular face possesses a more distinctive depression of a slightly greater size than the posterior face and is also in a better state of preservation. The posterior articular face

568 possesses a very slight concavity, making it almost straight, and is in a much more
569 damaged state, presenting cracks and breaches on the ventral base of the face.

570

571 **UFRJ-DG_634-R**

572

573 — This material is in a worse state of preservation than UFRJ-DG 558-R (Fig. 085,
574 A-C). The ventral centrum portion and anterior articular face are fragmented. On its
575 lateral surface, there is what appears to be the border of the pleurocoel in the same position
576 seen in specimen 558-R, leading to the attribution of this vertebra to this morphotype.

577 Differently from the other vertebrae of this morphotype group, part of the neural
578 arch and the transverse process ~~are~~ preserved on the right side of the specimen. The
579 transverse process is positioned upwards at an angle of approximately 45° degrees.

580 Comparisons

581 The presence of pleurocoels in the caudal vertebrae is characteristic of
582 megaraptoran neovenatids (Benson *et al.*, 2010). Pneumaticity in the caudal vertebrae is
583 rare in Theropoda, present only in some groups: Megaraptora, Oviraptorosauria,
584 Therizinosauria, and Carcharodontosauridae (Benson *et al.*, 2012+). As far as is known,
585 no fossils of therizinosauurs have been found in South America and South American fossils
586 attributed to oviraptorosaurs have been reassigned to other taxa, including to Maniraptora
587 (e.g. see Agnolín & Martinelli, 2007, Aranciaga-Rolando *et al.*, 2018). In addition, the
588 caudal vertebrae of Oviraptorosauria have, on the ventral surface, a medial groove
589 delimited by two longitudinal elevations (e.g., Sues, 1997; Xu *et al.*, 2007). Specimen
590 UFRJ-DG 558-R does not have this feature (Fig. 09),

591 South American carcharodontosaurids (e.g., *Giganotosaurus*, *Mapusaurus*,
592 *Tyrannotitan*) show a slightly concave lateral sides in the caudal vertebrae, while but do

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593 ~~not being bear~~ actual pneumatic foramina. Stromer (1931) described an anterior caudal
 594 vertebra from northern Africa, which he identified as *Carcharodontosaurus*, which had
 595 pneumatic characteristics, including a pleurocoel. However, that vertebra has a different
 596 general morphology and proportions when compared with ~~morphotype~~ the megaraptorid
 597 ~~vertebrae~~ from the Potiguar Basin (length-height ratio is 1 in *Carcharodontosaurus* and
 598 approximately 1.48 in UFRJ DG 558-R) and other members of Megaraptora.

Commented [BS65]: Again, I thought you were not using the morphotype descriptions any more.

599 Among the Megaraptora group, only *Aerosteon*, *Aoniraptor*, *Orkoraptor* and
 600 *Megaraptor* have preserved caudal vertebrae (Figure 1007) (Sereno *et al.*, 2008; Benson
 601 *et al.*, 2010; Motta *et al.*, 2016). The height/length ratio of UFRJ DG 558-R is 1.4,
 602 consistent with a median tail position, compared to the ratios of 1.2 and 1.3, respectively,
 603 of the medial caudal vertebrae of *Aerosteon* and *Orkoraptor* (Novas *et al.*, ~~al.~~, 2008). The
 604 Potiguar Basin specimens resemble those of *Aoniraptor* (Fig. 07, F) due to the absence
 605 of a keel in the ventral region, but ~~is~~are distinguished by the presence of a pair of
 606 pneumatic ~~septal~~ troughs in the lateral region, separated by a septum. Only the first caudal
 607 vertebra of *Aoniraptor* presents such fossae, a characteristic present in the other
 608 megaraptorans (e.g., Novas *et al.*, 2008; Sereno *et al.*, 2008).

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609 Comparing the morphology of pneumatic foramina, UFRJ DG 558-R (Figure
 610 1007, A) is very similar to *Aerosteon* (Figure 1007, C), *Megaraptor* (Figure 0710, H) and
 611 *Orkoraptor* (Figure 1007, G) ~~by~~in the presence of a large elliptic foramen and a second
 612 smaller circular shaped foramen. In addition, ~~morphotype 6~~ UFRJ-DG 558-R and 634-R
 613 has its cavities located on the lateral surface of the vertebral centrum near the base of the
 614 neural arch, which does not occur in the other species ~~analyzed~~observed.

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Commented [BS66]: Same comment as above.

615 UFRJ-DG 558-R and 634-R The ~~morphotype 06~~ vertebrae also presents extensive
 616 pneumatization in the vertebral centrum, composed of a camerate internal microstructure

Commented [BS67]: Same comment

617 (Britt, 1993), with several small chambers, similar to other megaraptorans (e.g.,
 618 *Aerosteon, Megaraptor*; Martinelli *et al.*, 2013).

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619

620 Discussion

621

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622 The Açú Formation material and ~~your~~its importance

623 The fossil potential of Açú Formation was poorly known, with only a few
 624 fossils recovered (Duarte and Santos, 1962; Silva-Santos, 1963; Mussa *et al.*, 1984), until
 625 the discovery of vertebrae and teeth identified as belonging to Theropoda indet. and
 626 Titanosauria (Santos *et al.*, 2005).

627 No further work was conducted until 2018, when the materials described here
 628 were studied in more detail. Thus far, the dinosaur fauna of the Potiguar Basin includes
 629 two groups of Sauropoda (Diplodocoidea: Rebbachisauridae, Pereira *et al.*, in press;
 630 Titanosauriformes, Barbosa *et al.*, 2018; Titanosauria, Pereira *et al.*, 2018) and four
 631 groups of Theropoda (Spinosauroida, Carcharodontosauridae, Megaraptora and
 632 Maniraptora, present work).~~The fossil potential of Açú Formation was poorly known,~~
 633 ~~with only a few fossils recovered (Duarte & Santos, 1962; Silva Santos, 1963; Mussa *et*~~
 634 ~~*al.*, 1984), until the discovery of vertebrae and teeth identified as belonging to Theropoda~~
 635 ~~indet. and Titanosauria (Santos *et al.*, 2005).~~

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636

637 The occurrence of these groups (except Megaraptora) in the Potiguar Basin is yet
 638 another similarity between the faunas of northeastern Brazil and multiple North Africa
 639 Cretaceous units (e.g. Medeiros and Schultz, 2001a, 2002; Sereno and Brusatte, 2008;
 640 Contessi, 2009; Candeiro *et al.*, 2011; Candeiro, 2015). Except for the Elrhaz (Niger);
 641 Douiret and Ain El Guettar (both in Tunisia) and Chicla (Libya) formations, which were

642 dated to the Early Cretaceous, all other Cretaceous formations from Northern Africa are
643 Albian-Cenomanian in age, roughly equivalent to the Açu Formation (Werner, 1994;
644 Rossetti, 1997; Rossetti and Truckenbrodt, 1997; Smith et al., 2001; Anderson et al.,
645 2007; Sereno and Brusatte, 2008; Cavin et al., 2010). Among the formations, the
646 Alcântara Formation (Brazil), Bahariya Formation (Egypt), Echkar Formation (Niger)
647 and the Waldi Milk Formation (Sudan) have similarities with the Açu Formation's
648 dinosaur fauna.

649 According to paleobiogeographic models, South America and Africa started
650 separating from each other in the Valanginian (Early Cretaceous), leading to the
651 formation of the South Atlantic Ocean (Viramonte et al., 1999; Jokat et al. 2003;
652 Macdonald et al., 2003). Although the ocean turned into one of the most important
653 continental barriers of the southern hemisphere, faunal interchange among the terrestrial
654 landmasses of western of Gondwana definitely occurred up to the Albian, and possibly
655 until the Cenomanian (e.g. Petri, 1987; Reymont and Dingle, 1987; Pletsch et al., 2001,
656 Tello Saenz et al., 2003, Guedes et al., 2005, Bodin et al., 2010).

657 Based on the proposed age and geographic position, the fossil vertebrates of the
658 Açu Formation may have lived during some of the last intervals of continental connection
659 between South America and Western Africa, before the complete formation of the South
660 Atlantic Ocean (Arai, 2009; Castro et al., 2012). This makes them exceedingly important
661 for understanding biogeography and faunal evolution.

662 More extensive comparisons are still limited by the lack of completeness of the
663 Açu material and the absence of formally described taxa. The continuation of studies on
664 previously collected material (like that described in this paper) and prospecting for new
665 fossils is important in this basin which, while still the subject of only recent research,
666 already exhibits among the greatest diversity of dinosaur groups in Brazil.

667 No further work was conducted until 2018, wherehen the materials described
 668 here began to be describedwere studied in more detail. For nowThus far, the Dinosaur
 669 fauna of the Potiguar Basin has so far includes two groups of Sauropoda (Diplodocoidea:
 670 Rebbachisauridae, Pereira *et al.* in press; Titanosauriformes, Barbosa *et al.*, 2018;
 671 Titanosauria, Pereira *et al.*, 2018) and four groups of Theropoda (Spinosauroidea,
 672 Careharodontosauridae, Megaraptora and Paraves, present work).

673 The occurrence of these groups (except Megaraptora) in the Potiguar Basin is
 674 oneyet another of the numerous similaritiessimilarity between the faunas of northeastern
 675 Brazil and multiple North Africa Cretaceous units (e.g. Medeiros & Schultz, 2001a, 2002;
 676 Sereno & Brusatte, 2008; Contessi, 2009; Candeiro *et al.*, 2011; Candeiro, 2015). Except
 677 for the Elhaz (Niger) formations: Douiret and Ain El Guettar (both in Tunisia) and Chiela
 678 (Libya) formations, which were dated to belong to the Early Cretaceous, all other
 679 Cretaceous formations from Northern Africa are Albian Cenomanian in age, roughly
 680 equivalent to the Açu Formation (Werner, 1994; Rossetti, 1997; Rossetti & Truckenbrodt,
 681 1997; Smith *et al.*, 2001; Anderson *et al.*, 2007; Sereno & Brusatte, 2008; Cavin *et al.*,
 682 2010). Among the formations,, the Alcântara Formation (Brazil), Bahariya Formation
 683 (Egypt), Echkar Formation (Niger) and the Waldi Milk Formation (Sudan) may have
 684 special attention due thehave similarities with the Açu Formation's dinosaur fauna.

685 According to paleobiogeographic models, South America and Africa started
 686 separating from each other in the Valanginian (Early Cretaceous), leading to the
 687 formation of the South Atlantic Ocean (Viramonte *et al.*, 1999; Jokat *et al.*, 2003;
 688 Maedonald *et al.*, 2003). Although the ocean turned into one of the most important
 689 continental barriers of the southern hemisphere, faunal interchange among the terrestrial
 690 landmasses of western of Gondwana definitely occurred up to the Albian, and possibly

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Commented [BS68]: I am not convinced this is a paravian bone. It might be, but what are the clear diagnostic characters that say it must be a dromaeosaurid/troodontid/bird and not a member of another maniraptoran group?

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Commented [BS69]: The Albian is Early Cretaceous

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691 ~~until the Cenomanian (e.g. Petri, 1987; Reymont & Dingle, 1987; Pletsch *et al.*, 2001;~~
 692 ~~Tello Saenz *et al.*, 2003, Guedes *et al.*, 2005, Bodin *et al.*, 2010).~~

693 ~~Based on the proposed age and geographic position, the fossil vertebrates of the~~
 694 ~~Açu Formation may have lived during some of the last moments/intervals of continental~~
 695 ~~connection between South America and Western Africa, before the complete formation~~
 696 ~~of the South Atlantic Ocean (Arai, 2009; Castro *et al.*, 2012). This makes them~~
 697 ~~exceedingly important for understanding biogeography and faunal evolution.~~

698 ~~More extensive comparisons are still limited by the lack of completeness of the~~
 699 ~~Açu material and the absence of formally described taxa. The continuation of the studies~~
 700 ~~on the already/ previously collected material (like that described in this paper) and the~~
 701 ~~prospecting for new fossils is important in this basin which, while the research still the~~
 702 ~~subject of only recent research, it is already a formation that shows one of exhibits among~~
 703 ~~the greatest diversity of dinosaur groups in Brazil.~~

704
 705 The first described megaraptoran was *Megaraptor namunhuaiquii* from the Turonian of
 706 Patagonia/Argentina (Novas, 1998). Recently, new findings have increased our
 707 knowledge about the anatomy and taxonomic diversity of these animals (Calvo *et al.*,
 708 2004; Novas *et al.*, 2008; Hocknull *et al.*, 2009; Novas, 2009).

709 In 2010, Benson *et al.* created the name Megaraptora for a newly recognized clade of
 710 theropods including taxa found in Argentina (*Acrosteon*, *Megaraptor*, *Aoniraptor* and
 711 *Orkoraptor*), Australia (*Australovenator*) and Japan (*Fukuiraptor*). One of the most
 712 striking features of the group is the presence of pneumatic anterior caudal vertebrae
 713 (Calvo *et al.*, 2004).

714 Pneumaticity in the caudal vertebrae is rare in Theropoda, present only in some groups:
 715 Megaraptora, Oviraptorosauria, Therizinosauria and Carcharodontosauridae (Benson *et*

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716 al., 2011). As far as is known, no fossils of therizinosaurs have been found in South
 717 America and South American fossils attributed to oviraptorosaurs have been reassigned
 718 to other taxa (see Agnolín & Martinelli, 2007). In addition, the caudal vertebrae of
 719 Oviraptorosauria have, on the ventral surface, a medial groove delimited by two
 720 longitudinal elevations (e.g., Sues, 1997; Xu et al., 2007). Specimen UFRJ-DG-558-R
 721 does not have this feature.

722 South American carcharodontosaurids (e.g., *Giganotosaurus*, *Mapusaurus*, *Tyrannotitan*)
 723 show ~~very deeply concave lateral sides in the caudal vertebrae, but not pneumatic~~
 724 ~~foramen. Stromer (1931) described an anterior caudal vertebra from northern Africa,~~
 725 ~~which he identified as *Carcharodontosaurus*, which had pneumatic characteristics,~~
 726 ~~including a pleurocoel. However, that vertebra has a different general morphology and~~
 727 ~~proportions when compared with morphotype 6 from the Portuguese Basin (length-height~~
 728 ~~ratio is 1 in *Carcharodontosaurus* and approximately 1.48 in UFRJ-DG-558-R) and other~~
 729 ~~members of Megaraptora.~~

730 ~~In Brazil, there are only two previous records (Fig. 06) attributed to Megaraptora, both in~~
 731 ~~the Bauru Group. Méndez et al. (2012) described an isolated caudal vertebral centrum~~
 732 ~~(MPMA 08-003-94), found in the municipality of Ibirá, São Paulo (Maastrichtian, Late~~
 733 ~~Cretaceous). The authors compared their specimen with the megaraptorids *Aerosteon* and~~
 734 ~~*Megaraptor*, and found important differences, such as the absence of a median~~
 735 ~~longitudinal keel on the ventral surface and its more elongated proportions. Martinelli et~~
 736 ~~al. (2013) described another isolated caudal vertebra found in Uberaba (Campanian, Late~~
 737 ~~Cretaceous) as belonging to Megaraptora.~~

738 In a recent work, Motta et al. (2016) considered that both specimens are in fact sacral
 739 vertebrae, due to their more elongated proportions, rough articular face and
 740 anteroposteriorly expanded transverse processes. Due to this fact, a comparison with the

Commented [70]: The lateral surfaces are slightly concave in these taxa, not very.
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Commented [71]: Please see Aranciaga-Rolando et al (2018) A supposed Gondwanan oviraptorosaur from the Albian of Brazil represents the oldest South American megaraptoran. *Cretaceous Research* 84: 107-119.

741 material analyzed here becomes difficult, and the Potiguar vertebrae ~~are~~ thus the first
742 caudal vertebrae of megaraptorans from Brazil.

743
744
745 ~~Figure 06: Brazilian Megaraptoran Vertebrae findings. A and B, UFRJ DG 558 R; C and~~
746 ~~D, MPMA 08-003-94 (Méndez et al., 2012); E and F, CPPLIP 1324 (Martinelli et al.,~~
747 ~~2013). A, C e E, lateral view; B, D e F, ventral view. Pfr, Pneumatic foramen. Scale bar~~
748 ~~= 1cm.~~

749
750 ~~Among the Megaraptora group, only *Aerosteon*, *Aoniraptor*, *Orkoraptor* and *Megaraptor*~~
751 ~~have preserved caudal vertebrae (Figure 07) (Sereno et al., 2008; Benson et al., 2010;~~
752 ~~Motta et al., 2016).~~

753 ~~The height/length ratio of UFRJ DG 558 R is 1.4, consistent with a median tail position,~~
754 ~~compared to the ratios of 1.2 and 1.3, respectively, of the medial caudal vertebrae of~~
755 ~~*Aerosteon* and *Orkoraptor* (Novas et al. al., 2008). The Potiguar Basin specimens~~
756 ~~resemble those of *Aoniraptor* (Fig. 07, F) due to the absence of a keel in the ventral region,~~
757 ~~but is distinguished by the presence of a pair of pneumatic septal troughs in the lateral~~
758 ~~region, separated by a septum. Only the first caudal vertebra of *Aoniraptor* presents such~~
759 ~~fossae, a characteristic present in the other megaraptorans (e.g., Novas et al., 2008; Sereno~~
760 ~~et al., 2008).~~

761 ~~Comparing the morphology of pneumatic foramina, UFRJ DG 558 R (Figure 07, A) is~~
762 ~~very similar to *Aerosteon* (Figure 07, C), *Megaraptor* (Figure 07, H) and *Orkoraptor*~~
763 ~~(Figure 07, G) by the presence of a large elliptic foramen and a second smaller circular~~
764 ~~shaped foramen. In addition, morphotype 6 has its cavities located on the lateral surface~~

765 of the vertebral centrum near the base of the neural arch, which does not occur in the other
766 species analyzed.

767

768 Figure 07: Megaraptoran caudals vertebrae. A and B, UFRJ DG 558 R; C and D,
769 *Aerosteon*; E and F, *Aoniraptor*; G, *Orkoraptor*; H, *Megaraptor*. A, C, E, G e H, lateral
770 view; B, D e F, ventral view. Pfr, pneumatic foramen. Scale bar = 5cm.

771

772 The morphotype 06 vertebrae also presents extensive pneumatization in the vertebral
773 centrum, composed of a camerate internal microstructure (Britt, 1993), with several small
774 chambers, similar to other megaraptorans (e.g., *Aerosteon*, *Megaraptor*; Martinelli et al.,
775 2013). Based on the general morphology, the elements described herein possibly belong
776 to a form closer to *Aerosteon* and *Megaraptor* than to *Aoniraptor*.

777 The Potiguar material is also one of the oldest records of the group in South America,
778 together with *Aoniraptor* from the Early Cenomanian mid-Turonian of Argentina (Motta
779 et al., 2016).

780 The abelisauroid fossil record from Brazil is known from fragmentary specimens.
781 Recently, Silva (2013) and Santucci et al. (2018) described incomplete abelisaurid cranial
782 and postcranial Abelisauria remains from Barremian-Aptian age of Quiricó Formation
783 (São Francisco Basin) of northern Minas Gerais state.

784 Brazilian noosaurids were known only by teeth from Albian-Cenomanian of Alcântara
785 Formation, where *Masiakasaurus* like teeth were recorded. However this changed when
786 *Vespersaurus paranaensis*, a desert dwelling monodactyl noosaurid, was described in the

787 Late Cretaceous Rio Paraná Formation (Langer et al., 2019). From Albian-Cenomanian of
788 Alcântara formation bed have produced one tooth reported as *Masiakasaurus* like
789 (Noosauridae) by Lindoso et al. (2012).

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Commented [72]: This is a too risky statement given the scarcity of the recovered materials.

Commented [73]: Please see Aranciaga-Rolando et al (2018) A supposed Gondwanan oviraptorosaur from the Albian of Brazil represents the oldest South American megaraptoran. Cretaceous Research 84: 107-119.

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Commented [74]: You can add *Vespersaurus*. A: After revising the discussion, the comparison to *Masiakasaurus* and other Noosaurids seemed to have no place anymore. In the end we restricted to the abelisaurid record only, not to the abelisauroid.

790 ~~The first abelisaurid species discovered in Brazil was *Peyronemosaurus nevesi* was the~~
 791 ~~first and unique specie of abelisaurid from Brazil (Kellner & Campos, 2002). It was~~
 792 ~~described based on postcranial remains from the Upper Cretaceous of the~~
 793 ~~Ribeirão Boiadeiro Group and represents the most complete collection known to Brazil.~~
 794 ~~Additionally, Bittencourt and Kellner (2002) described nine Abelisauria teeth from the~~
 795 ~~same locality of *Peyronemosaurus*. The second abelisaurid discovered in Brazil was~~
 796 ~~*Thanos simonattoi* (Delecourt & Iori, 2018), whose description was based on an almost~~
 797 ~~complete axis with an axial intercentrum.~~

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798 The first record of Abelisauridae known to Brazil was reported by Bertini (1996) and was
 799 discovered in the Adamantina Formation, western São Paulo State. Later, other authors
 800 reported isolated teeth from the Adamantina Formation from western São Paulo state
 801 (e.g., Candeiro et al., 2004; Azevedo et al., 2007) and from Minas Gerais state (e.g.,
 802 Candeiro et al., 2006; Oliveira et al., 2012). Also, there are some known postcranial
 803 records from the São José do Rio Preto and Marília formations (Méndez et al., 2014) were
 804 recently described by Méndez et al (2014) as well as other abelisaurid materials from the
 805 Adamantina Formation, São Paulo State (a partial femur, Brum et al., 2016).

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806 However, the most abundant materials of abelisaurid are from the Marília Formation that
 807 outcrops in the region of Peirópolis, municipality of Uberaba. Innumerable teeth
 808 (Candeiro et al. 2012) and postcranial materials (Novas et al. 2008, Machado et al. 2013)
 809 from this locality were already described.

810 ~~Even though most of the abelisaurid axial characteristics are mainly in their uniquely~~
 811 ~~shaped transverse processes in the caudal vertebrae (e.g. Méndez, 2014), there are some~~
 812 ~~characteristics that can be seen in their caudal centra.~~

813 The mid-caudal vertebrae of Abelisauria have, as basic characteristics, an amphicoelous
 814 condition with subcircular articular facets, a centrum twice as long as tall, well marked

Commented [75]: As was stated before, this character varies a lot inside Abelisauridae.

815 facets, and a ventral concavity in its lateral view as seen in *Majungasaurus*, *Aucasaurus*,
 816 and *Hokelesia* (Coria & Salgado, 1998), however much these features are also seen in
 817 Abelisauridae and even in basal ceratosaurs (Méndez, 2014). All these characteristics
 818 can be observed in the specimens of morphotype 2, with specimen 547 R standing out
 819 from the others for the presence of two small depressions on its lateral surface, a
 820 characteristic not very common within the group.

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821 The anterior caudal vertebrae of Abelisauria present a set of striking features that can be
 822 observed in specimens of morphotype 3 (Fig. 08). First is its oval, taller than wide, facet
 823 that both the 528 R specimen and the 532 R have. In addition, there are features found in
 824 the centrum of specimen 528 R, such as the slight centrum? central? or constriction
 825 (Méndez, 2014) and a concave anterior margin while the posterior convex margin is seen
 826 in the first four caudal vertebrae of *Aucasaurus*, *Carnotaurus*, *Majungasaurus*,
 827 *Ekrixinatosaurus*, *Rajasaurus* and *Rahiolisaurus* (Bonaparte, 1985; Sampson et al. 1998;
 828 Coria et al. 2002). Unlike *Aucasaurus*, *Carnotaurus* and *Ekrixinatosaurus*, specimen 528
 829 R also does not exhibit any forms of depression or pneumaticity on its lateral surface.
 830 These are the oldest record of Abelisauria at Brazil.

Commented [77]: None of the characters mentioned are exclusive of Ceratosauria, but they are present in other theropods. Moreover, the specimens described and figured for this morphotype are anterior caudals, not middle.

Commented [78]: Which is the specimen 547-R? It was not described or figured!

Commented [79]: Morphotype 3 was assigned to Maniraptora in the text, not Abelisauria.

Commented [80]: Again, this character is so variable. Please compare anterior articular surface of *Carnotaurus* and *Majungasaurus* in the figure 8.
 A: Done.

Commented [81]: It is not clear to which margins the authors refers.
 A: Done.

Commented [82]: I feel that the evidence given by the authors in the text is not enough to assign this material to Abelisauria, so this statement is too risky.

833 ~~Figure 08: Comparison of morphotype 02 and other abelisaurids. A and B,~~
 834 ~~*Majungasaurus*; C and D, *Carnotaurus*; E and F, *Ekrixinatosaurus*; G and H,~~
 835 ~~*Aucasaurus*; I and J, morphotype 02. Scale bar: 5 cm.~~

837 The record of maniraptorans is rare in Brazil (see Delcourt & Grillo, 2014). It is based
 838 mostly on isolated teeth from several localities and postcranial elements, namely, a
 839 manual ungual and scapula from the Serra da Galga Member of Peirópolis, Uberaba,

840 Minas Gerais state (Marília Formation, Maastrichtian), and an unenlagiuid dorsal vertebra
 841 and fragmentary remains of an undetermined maniraptoran from the Adamantina
 842 Formation (Late Cretaceous) of São Paulo state (Novas et al., 2005; Machado et al., 2008;
 843 Candeiro et al., 2012; Delcourt & Grillo, 2014). The material here described is the first
 844 post-cranial remain of a maniraptoran outside Bauru Basin and from the mid-Cretaceous,
 845 shedding new light on the biogeography of this group in South America and western
 846 Gondwana.

847 Specimen 521-R has characteristics of a vertebral centrum positioned after the transition
 848 point, being longer than high possessing a large reduction in both its neural spine and
 849 transverse processes (Senter et al., 2011). This way it is possible to deduce that it is at
 850 least after the vertebra 11 of the caudal series as seen in *Buitreraptor*, *Rahonavis*,
 851 *Dromaeosauridae* and *Troodontidae* (Ostrom, 1969; Forster et al., 1998; Senter et al.,
 852 2012; Xu et al., 2017).

853 The maintenance of the transverse processes is not observed in more basal groups of
 854 Paraves like dromaeosaurids and troodontids that have smooth lateral surfaces in their
 855 centra (Ostrom, 1969; Norell & Malkovicky, 1999; Currie & Dong, 2001; Xu et al., 2012),
 856 but is seen in specimens of *Microraptora*, *Rahonavis*, *Buitreraptor*, *Anchiornis* and
 857 *Archaeopteryx* (Hwang et al., 2002; Hu et al., 2009; Han et al., 2014; Novas et al., 2017),
 858 all belonging to the group Averoportora. In addition, the 521-R specimen also presents the
 859 prezygapophyses more dorsally positioned in the same way as in *Buitreraptor*, *Rahonavis*
 860 and *Anchiornis* (fig. 09) (Motta et al., 2018). The vertebral centrum has a ratio between
 861 its height and its length somewhat greater than six which is seen in almost all the groups
 862 of Paraves except for *Dromaeosauridae* that displays a smaller ratio being the only 3 times
 863 longer than high.

864

Commented [83]: I think the authors should specify which transition point are referring here (I suppose that proposed by Russel (1972), but this is my guess)
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865 Figure 09: Comparison of Morphotype 3 and other paravians. A, Potiguar's material; B,
 866 *Rahonavis*; C, *Buitreraptor*; D, *Anchiornis*. Pr, prezygapophysise; lg, Longitudinal
 867 groove. Modified from Motta et al., (2018).

Commented [84]: In the references the date of the publication is 2017

868
 869 ~~———— Carcharodontosaurid were amongst the largest and some of the most widespread~~
 870 ~~theropods during the Kimmeridgian-Turonian (Candeiro, 2015; Delecourt & Grillo, 2017).~~
 871 ~~In Brazil, carcharodontosaurids were recorded based on isolated teeth and putative~~
 872 ~~remains from São Luís-Grajaú Basin (Cenomanian) and Bauru Group (Late Cretaceous)~~
 873 ~~(Vilas Bôas et al., 1999; Medeiros, 2001; Azevedo et al., 2013). The Potiguar Basin~~
 874 ~~materials lie within the age range of occurrence of carcharodontosaurids and, might be~~
 875 ~~related to the São Luís-Grajaú and western Africa fauna where these are common~~
 876 ~~findings.~~

877 ~~Both vertebrae of morphotype 4 present characteristics commonly found in~~
 878 ~~carcharodontosaurids (Fig. 10). For instance, depressions in the most dorsal part of their~~
 879 ~~lateral surface are is found in *Giganotosaurus*, *Mapusaurus* and *Tyrannotitan* and in the~~
 880 ~~mid-caudal vertebrae Vb 870 found in the Wadi Milk Formation (Coria & Salgado, 1995;~~
 881 ~~Coria & Currie, 2006; Novas et al., 2005; Canale et al., 2015; Rauhut, 1999), which is~~
 882 ~~different from *Carcharodontosaurus*, which has pleurocoels in their anterior-caudal~~
 883 ~~vertebrae (Stromer, 1931). Furthermore, the strongly waisted centrum morphology, a~~
 884 ~~double-keel cut by a longitudinal groove and offset articular facets (although it is a~~
 885 ~~plesiomorphic feature found in *Allosaurus* Gilmore, 1920; Madsen, 1976) are also found~~
 886 ~~in specimens such as the carcharodontosaurid material from Sudan (Vb 870) and in~~
 887 ~~*Tyrannotitan*, *Mapusaurus* and *Acrocanthosaurus* (Canale et al., 2015; Harris, 1998;~~
 888 ~~*Coria & Currie, 2006; Currie & Carpenter, 2000).*~~

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890 Figure 10: Comparison of Morphotype 4 and *Carcharodontosauria* indet. A and B, UFRJ
 891 DG 523 R; C and D, UFRJ DG 524 R; E and F, Kem Kem beds material (from Rauhut,
 892 1999). G? H? I?. Scale bar = 5 cm.

Commented [86]: The item G of the figure has a very poor resolution. Also G, H, I were taken from the literature, and the figure caption lack the proper cite.

893
 894 The record of maniraptorans is rare in Brazil (see Delcourt & Grillo, 2014). It is based
 895 mostly on isolated teeth from several localities and postcranial elements, namely, a
 896 manual ungual and scapula from the Serra da Galga Member of Peirópolis, Uberaba,
 897 Minas Gerais state (Marília Formation, Maastrichtian), and an unenlagiuid dorsal vertebra
 898 and fragmentary remains of an undetermined maniraptoran from the Adamantina
 899 Formation (Late Cretaceous) of São Paulo state (Novas et al., 2005; Machado et al., 2008;
 900 Candeiro et al., 2012; Delcourt & Grillo, 2014). The material here described is the first
 901 post-cranial remain of a maniraptoran outside Bauru Basin and from the mid-Cretaceous,
 902 shedding new light on the biogeography of this group in South America and western
 903 Gondwana.

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904 Specimen 521 R has characteristics of a vertebral centrum positioned after the transition
 905 point, being longer than high possessing a large reduction in both its neural spine and
 906 transverse processes (Senter et al., 2011). This way it is possible to deduce that it is at
 907 least after the vertebra 11 of the caudal series as seen in *Buitreraptor*, *Rahonavis*,
 908 *Dromaeosauridae* and *Troodontidae* (Ostrom, 1969; Forster et al., 1998; Senter et al.,
 909 2012; Xu et al., 2017).

910 The maintenance of the transverse processes is not observed in more basal groups of
 911 Paraves like dromaeosaurids and troodontids that have smooth lateral surfaces in their
 912 centra (Ostrom, 1969; Norell & Malkovicky, 1999; Currie & Dong, 2001; Xu et al., 2012),
 913 but is seen in specimens of *Microraptor*, *Rahonavis*, *Buitreraptor*, *Anchiornis* and
 914 *Archaeopteryx* (Hwang et al., 2002; Hu et al., 2009; Han et al., 2014; Novas et al., 2017),

915 all belonging to the group Averaptora. In addition, the 521-R specimen also presents the
 916 prezygapophyses more dorsally positioned in the same way as in *Buitreraptor*, *Rahonavis*
 917 and *Anchiornis* (fig. 10) (Motta et al., 2018). The vertebral centrum has a ratio between
 918 its height and its length somewhat greater than six which is seen in almost all the groups
 919 of Paraves except for Dromaeosauridae that displays a smaller ratio being the only 3 times
 920 longer than high.

921 The spinosaurid record of Brazil is known by two species: *Oxalaia quilombensis* (CITE)
 922 and *Irritator challengeri* (CITE), both spinosaurines from the "mid"-Cretaceous strata
 923 from the Cenomanian Aleantra Formation and from the Aptian-Albian Santana Formation
 924 respectively. Other than those two species, there are many unidentified isolated
 925 spinosaurid postcranial elements and teeth that range from Berriasian-Valanginian Feliz
 926 Deserto Formation (CITE) to the "mid"-Cretaceous Santana and Aleantra Formations
 927 (CITE).

928
 929 There is no discussion about the recovered tooth, and the traits that allow assigning it to
 930 Spinosauridae.

932 Conclusion **REVISARRRRR**

933 In the present work we assigned the material from Açu Formation, Potiguar Basin,
 934 to four groups: Spinosaurioidea, Carcharodontosauria, Maniraptora and Megaraptora (Fig.
 935 11), the two last groups being relatively rare in Brazil. All this groups have already been
 936 found in isochronous formations in both Northeastern Brazil and Northern Africa, leading
 937 further support for faunal similarities in the "mid"-Cretaceous western Gondwana. These
 938 fossils provide the first theropod record from Potiguar Basin and an important opportunity
 939 to increase the knowledge on the diversity of this still poorly known basin. We describe

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940 ~~several newly discovered dinosaur fossils, which constitute~~ A new dinosaur fauna was
 941 discovered and described from ~~the~~ Açu Formation (Potiguar Basin), Northeast region of
 942 Brazil. The vertebrae were ~~are~~ classified into five morphotypes based on morphological
 943 form and/or diagnostic characters and comprised at this moment ~~by~~ can be assigned to
 944 ~~five~~ four groups: Abelisauria, Carcharodontosauria, Spinosauridae, Megaraptora, and
 945 Maniraptora. ~~While the teeth was recovered as a Spinosaurid~~ Furthermore, a single tooth
 946 is attributed to Spinosauridae. ~~Besides~~ These groups were ~~have already been found on in~~
 947 isochronous basins of the Northeast region of Brazil and Africa, leading further support
 948 for faunal similarities between these regions.

Commented [88]: This group was not recognized by any vertebra, but a tooth.
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949
 950 ~~the presence of these theropod groups at Açu Formation~~ The new fossils reveals an
 951 unexpected dinosaur richness fauna at ~~from the~~ Potiguar Basin (fig. 11) and opens up
 952 an ~~provide an important opportunity to increase the knowledge about~~ on the diversity and
 953 palaeobiogeography of this important vertebrate group ~~these animals during a time of~~
 954 Gondwanan fragmentation.

955
 956 ~~Figure 11: Reconstruction of the theropods groups~~ described in this present study to the
 957 Açu Formation, Potiguar Basin. ~~In~~ the water, a Spinosauridae. On the ground, on the left
 958 an Abelisauridae; in the center, a group of megaraptorans Megaraptora and a slaughtered
 959 atitanosaur Titanosauriasauropod while to the right, a Carcharodontosauridae awakens
 960 from its sleep; in the top center, a Paraves just watches. Drawing of Luciano da Silva
 961 Vidal.

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962
 963

964 Acknowledgements

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 966 site where the material were found, and for the support given to the fieldwork. We thank
 967 the students Luciano Vidal for assistance with the figures. PVLGCP was funded by a
 968 grant from the Jurassic Foundation and pos doctoral grant by Coordenação de
 969 Aperfeiçoamento de Pessoal de Nível Superior (CAPES, number 88882.463232/2019-
 970 01). LPB and CRAC were financially supported by Conselho Nacional de
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 972 Pesquisa. IMMGB and LPB were also supported by Conselho Nacional de
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 974 acknowledge Fundação de Amparo a Pesquisa do Estado do Rio de Janeiro [grants #E-
 975 26/202.829/2018]. This research was funded partially by Fundação de Amparo à Pesquisa
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 978 from the Fundação de Amparo a Pesquisa e Goiás and the Newton Fund, which supported
 979 SLB's visit to Brazil to work with PVLGCP and CRAC in June–July 2016.

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1552 Figure captions

1553

1554 [Figure 01: Geological map of the continental part of the Potiguar Basin with the region](#)
 1555 [near the Limoeiro do Norte municipality \(Ceará state\) where the material were discovered](#)
 1556 [\(dark star\). CE, Ceará state; RN, Rio Grande do Norte state and its capital, Natal.](#)
 1557 [Modified from Cassab \(2003\).](#)

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1558

1559 [Figure 02: The ~~aviostran~~theropod vertebrae UFRJ-DG 52875-R \(A-CB\) and UFRJ-DG](#)
 1560 [57528-R \(DC-E\). UFRJ-DG 575-R: A, lateral view; B, the anterior articular facet. UFRJ-](#)
 1561 [DG 528-R: C, the lateral view; D, the ventral view; E, anterior articular facet. Note the](#)
 1562 [large pneumatic foramen on the side of the anterior fragment of UFRJ-DG 575-R. pfr =](#)
 1563 [pneumatic foramen. Scale bar: 2 cm.](#)

1564

1565 [Figure 03: Spinosauroid tooth \(UFRJ-DG 619-R\): A, the labial view; B, the lingual view;](#)
 1566 [and C, the cross section. Scale: 1 cm](#)

1567

1568 Figure 04: Maniraptoran caudal vertebrae (UFRJ-DG 521-R): A, Lateral view; B,
 1569 ventral view; C, anterior articular facet. Prz, prezygophysis; Nc, neural canal. Scale:
 1570 1cm.

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1571
 1572 Figure 05: Comparison of UFRJ-DG 521-R and other maniraptorans. A, Potiguar's
 1573 material; B, *Rahonavis*; C, *Buitreraptor*; D, *Anchiornis*. Pr, prezygapophysis; lg,
 1574 Longitudinal groove. Modified from Motta et al., (2018).

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1575
 1576 Figure 06: Carcharodontosaurid caudal vertebrae UFRJ-DG 5234(A-C) and UFRJ-DG
 1577 5243-R (D-F). UFRJ-DG 524-R: A, ventral view; B, lateral view; C, anterior articular
 1578 facet. UFRJ-DG 523-R: D, ventral view; E, lateral view; F, anterior articular facet. Nc,
 1579 neural canal. Scale: 1cm.

1580
 1581 Figure 07: Comparison of UFRJ-DG 523-R and 524-R and other carcharodontosaurids.
 1582 A and B, UFRJ DG 523-R; C and D, UFRJ DG 524-R; E and F, Kem Kem beds material
 1583 (from Rauhut, 1999); G, *Tyrannotitan chubutensis* MPEF-PV 1156 (Modified from
 1584 Canale et al., 2015); H, *Mapusaurus roseae* MCF-PVPH-108.81 (Modified from Coria
 1585 & Currie, 2006) ; I, *Acrocanthosaurus atokensis* NCSM 14345 (Modified from Currie
 1586 & Carpenter, 2000). Scale bar = 5 cm.

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1587
 1588 Figure 08: Caudal vertebrae UFRJ-DG. UFRJ-DG 558-R-634-R: A, posterior articular
 1589 facet; B, lateral view; C, ventral view. UFRJ-DG 634-R-558-R: D, anterior articular facet;
 1590 E, lateral view; F, ventral view. Pfr, Pneumatic foramen. Scale bar: 1cm.

1591

1592 Figure 09: Brazilian megaraptoran vertebrae findings. A and B, UFRJ DG 558-R; C and
 1593 D, MPMA 08-003-94 (Méndez et al., 2012); E and F, CPPLIP 1324 (Martinelli et al.,
 1594 2013).A, C e E, lateral view; B, D e F, ventral view. Pfr, Pneumatic foramen. Scale bar =
 1595 1cm.

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 1597 Figure 10: Megaraptoran caudals vertebrae. A and B, UFRJ DG 558-R; C and D,
 1598 *Aerosteon*; E and F, *Aoniraptor*; G, *Orkoraptor*. H, *Megaraptor*. A, C, E, G e H, lateral
 1599 view; B, D e F, ventral view. Pfr, pneumatic foramen. Scale bar = 5cm.

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1600
 1601 Figure 11: Reconstruction of the theropods groups from Açu Formation, Potiguar Basin.
 1602 In the center, a group of megaraptorans slaughtering a titanosaur; on the right a
 1603 carcharodontosaurid awakens from its sleep; in the top center, a maniraptoran just
 1604 watches. [DrawingArt](#) by Luciano da Silva Vidal.

1605 Figure captions

1606
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1611
 1612 Figure 02: The avirostran vertebrae UFRJ DG 575 R (A-B) and UFRJ DG 528 R (C-E).
 1613 UFRJ DG 575 R: A, lateral view; B, the anterior articular facet. UFRJ DG 528 R: C, the
 1614 lateral view; D, the ventral view; E, anterior articular facet. Note the large pneumatic
 1615 foramen on the side of the anterior fragment of UFRJ DG 575 R. pfr = pneumatic
 1616 foramen. Scale bar: 2 cm.

1617
 1618 Figure 03: Spinosauroid tooth (UFRJ DG 619 R): A, the labial view; B, the lingual view;
 1619 and C, the cross section. Scale: 1 cm

1620
 1621 Figure 04: Maniraptoran caudal vertebrae (UFRJ DG 521 R): A, Lateral view; B,
 1622 ventral view; C, anterior articular facet. Prz., prezygophysis; Ne, neural canal. Scale:
 1623 1cm.

1624
 1625 Figure 05: Carcharodontosaurid caudal vertebrae UFRJ DG 524 (A-C) and UFRJ DG
 1626 523 R (D-F). UFRJ DG 524 R: A, ventral view; B, lateral view; C, anterior articular
 1627 facet. UFRJ DG 523 R: D, ventral view; E, lateral view; F, anterior articular facet. Ne,
 1628 neural canal. Scale: 1cm.

1629
 1630 Figure 06: Caudal vertebrae UFRJ DG. UFRJ DG 634 R: A, posterior articular facet; B,
 1631 lateral view; C, ventral view. UFRJ DG 558 R: D, anterior articular facet; E, lateral view;
 1632 F, ventral view. Pfr, Pneumatic foramen. Scale bar: 1cm.

1633
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 1637 1cm.

1638
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 1640 Aerosteon; E and F, Aoniraptor; G, Orkoraptor. H, Megaraptor. A, C, E, G e H, lateral
 1641 view; B, D e F, ventral view. Pfr, pneumatic foramen. Scale bar = 5cm.

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1642

1643 Figure 09: Comparison of Morphotype 3 and other paravians. A, Potiguar's material; B,
 1644 Rahonavis; C, Buitreraptor; D, Anchiornis. Pr, prezygapophysis; Ig, Longitudinal
 1645 groove. Modified from Motta et al., (2018).

1646

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