A turiasaurian sauropod dinosaur from the Early Cretaceous Wealden Supergroup of the United Kingdom

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The Jurassic/Cretaceous (J/K) boundary, 145 million years ago, has long been recognised as an extinction event or faunal turnover for sauropod dinosaurs, with many 'basal' lineages disappearing. However, recently, a number of 'extinct' groups have been recognised in the Early Cretaceous, including diplodocids in Gondwana, and non-titanosauriform macronarians in Laurasia. Turiasauria, a clade of non-neosauropod eusauropods, was originally thought to have been restricted to the Late Jurassic of western Europe. However, its distribution has recently been extended to the Late Jurassic of Tanzania (*Tendaguria tanzaniensis*), as well as to the Early Cretaceous of the USA (*Mierasaurus bobyoungi* and *Moabosaurus utahensis*), demonstrating the survival of another 'basal' clade across the J/K boundary. Teeth from the Middle Jurassic–Early Cretaceous of western Europe and North Africa have also tentatively been attributed to turiasaurs, whilst recent phylogenetic analyses recovered Late Jurassic taxa from Argentina and China as further members of Turiasauria. Here, an anterior dorsal centrum and neural arch (both NHMUK 1871) from the Early Cretaceous Wealden Supergroup of the UK are described for the first time. NHMUK 1871 shares several synapomorphies with Turiasauria, especially the turiasaurs *Moabosaurus* and *Tendaguria*, including: (1) a strongly dorsoventrally compressed centrum; (2) the retention of prominent epipophyses; and (3) an extremely low, non-bifid neural spine. NHMUK 1871 therefore represents the first postcranial evidence for Turiasauria from European deposits of unequivocal Early Cretaceous age. Although turiasaurs show clear heterodont dentition, only broad, characteristically 'heart'-shaped teeth can currently be attributed to Turiasauria with confidence. As such, several putative turiasaur occurrences based on isolated teeth from Europe, as well as the Middle Jurassic and Early Cretaceous of Africa, cannot be confidently referred to Turiasauria. Unequivocal evidence for turiasaurs is therefore restricted to the late Middle Jurassic–Early Cretaceous of western Europe, the Late Jurassic of Tanzania, and the late Early Cretaceous of the USA, although remains from elsewhere might ultimately demonstrate that the group had a near-global distribution.

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2   **United Kingdom**

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9   RRH: EARLY CRETACEOUS UK TURIASAUR
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11
12   **ABSTRACT**

14   The Jurassic/Cretaceous (J/K) boundary, 145 million years ago, has long been recognised as an
15   extinction event or faunal turnover for sauropod dinosaurs, with many 'basal' lineages
16   disappearing. However, recently, a number of 'extinct' groups have been recognised in the
17   Early Cretaceous, including diplodocids in Gondwana, and non-titanosauriform macronarians in
18   Laurasia. Turiasauria, a clade of non-neosauropod eusauropods, was originally thought to have
19   been restricted to the Late Jurassic of western Europe. However, its distribution has recently
20   been extended to the Late Jurassic of Tanzania (*Tendaguria tanzaniensis*), as well as to the Early
21   Cretaceous of the USA (*Mierasaurus bobyoungi* and *Moabosaurus utahensis*), demonstrating
22   the survival of another 'basal' clade across the J/K boundary. Teeth from the Middle Jurassic–
23   Early Cretaceous of western Europe and North Africa have also tentatively been attributed to
24   turiasaurs, whilst recent phylogenetic analyses recovered Late Jurassic taxa from Argentina and
25   China as further members of Turiasauria. Here, an anterior dorsal centrum and neural arch
26   (both NHMUK 1871) from the Early Cretaceous Wealden Supergroup of the UK are described
27   for the first time. NHMUK 1871 shares several synapomorphies with Turiasauria, especially the
28   turiasaurs *Moabosaurus* and *Tendaguria*, including: (1) a strongly dorsoventrally compressed
29   centrum; (2) the retention of prominent epipophyses; and (3) an extremely low, non-bifid
30   neural spine. NHMUK 1871 therefore represents the first postcranial evidence for Turiasauria
31   from European deposits of unequivocal Early Cretaceous age. Although turiasaurs show clear
32   heterodont dentition, only broad, characteristically 'heart'-shaped teeth can currently be
33   attributed to Turiasauria with confidence. As such, several putative turiasaur occurrences based
34   on isolated teeth from Europe, as well as the Middle Jurassic and Early Cretaceous of Africa,
35   cannot be confidently referred to Turiasauria. Unequivocal evidence for turiasaurs is therefore
36   restricted to the late Middle Jurassic–Early Cretaceous of western Europe, the Late Jurassic of
37   Tanzania, and the late Early Cretaceous of the USA, although remains from elsewhere might
38   ultimately demonstrate that the group had a near-global distribution.

39
40   **INTRODUCTION**
41
42   The Late Jurassic is often regarded as a period of heightened sauropod dinosaur diversity,
43   prior to a precipitous decline across the Jurassic/Cretaceous (J/K) boundary (145 million years
44   ago), at which point many 'basal' sauropod lineages went extinct (Bakker, 1977; Hunt *et al*.,

45 1994; Wilson & Sereno, 1998; Upchurch & Barrett, 2005; Barrett, McGowan & Page, 2009;
46 Mannion *et al*., 2011). Increasingly, however, it is becoming apparent that any J/K extinction
47 was not instantaneous (Tennant *et al*., 2017), at least for sauropods, with representatives of
48 several 'extinct' sauropod groups now recognised from Early Cretaceous deposits (Gallina *et al*.,
49 2014; Royo-Torres *et al*., 2014, 2017a,b; Upchurch, Mannion & Taylor, 2015; D'Emic & Foster,
50 2016; McPhee *et al*., 2016).
51   The non-neosauropod eusauropod clade Turiasauria was first recognised by Royo-Torres,
52 Cobos & Alcalá (2006) for three genera (*Turiasaurus riodevensis*, *Losillasaurus giganteus*,
53 *Galveosaurus herreroi*) from the Late Jurassic of Spain (see Campos-Soto et al. [2017] regarding
54 this revised age). Although *Galveosaurus* has subsequently been demonstrated to more likely
55 represent a macronarian neosauropod (e.g. Barco, Canudo & Cuenca-Bescós, 2006; Carballido
56 *et al*., 2011; D'Emic, 2012; Mannion *et al*., 2013), the western European record of named
57 turiasaurs has since been expanded to include the Late Jurassic Portuguese taxon *Zby atlanticus*
58 (Mateus, Mannion & Upchurch, 2014). In addition to postcranial remains, both *Turiasaurus* and
59 *Zby* preserve teeth. These tooth crowns are mesiodistally broad relative to their apicobasal
60 length, and have a distinctive 'heart'-shaped outline (Royo-Torres, Cobos & Alcalá, 2006),
61 narrowing mesiodistally along their apical halves (Mateus, Mannion & Upchurch, 2014).
62 Primarily consisting of isolated teeth, additional remains have been referred to Turiasauria from
63 contemporaneous Iberian deposits (Royo-Torres, Cobos & Alcalá, 2006; Royo-Torres *et al*.,
64 2009; Mocho *et al*., 2016). Several authors have suggested that 'heart'-shaped teeth from the
65 Middle Jurassic–Early Cretaceous of the UK and France might also be attributable to turiasaurs,
66 including the type specimens of '*Cardiodon rugulosus*', '*Neosodon*', and '*Oplosaurus armatus*'
67 (Royo-Torres, Cobos & Alcalá, 2006; Néraudeau *et al*., 2012; Royo-Torres & Upchurch, 2012;
68 Mocho *et al*., 2016).
69   The distribution of turiasaurs was recently expanded to include the Early Cretaceous of the
70 western USA (Royo-Torres *et al*., 2017a), based on relatively complete skeletons of two taxa,
71 *Mierasaurus bobyoungi* (Royo-Torres *et al*., 2017a) and *Moabosaurus utahensis* (Britt *et al*.,
72 2017), and thus confirming the group's survival across the J/K boundary (Royo-Torres *et al*.,
73 2017a). Finally, several remains from Africa have been suggested to represent turiasaurs.
74 Mocho *et al*. (2016) commented upon similarities of two fragmentary Middle Jurassic teeth
75 from Madagascar and Morocco, as well as a partial tooth from the Early Cretaceous of Libya,
76 with European turiasaurs. Xing *et al*. (2015) also recovered the Middle Jurassic Moroccan
77 sauropod *Atlasaurus imelakei* in a polytomy with *Losillasaurus* and *Turiasaurus*. Royo-Torres &
78 Cobos (2009) suggested that several postcranial remains from the Late Jurassic Tendaguru
79 Formation of Tanzania might also belong to Turiasauria. Most recently, Mannion *et al*. (in press)
80 presented new anatomical data (see also Britt et al., 2017: p. 236) and phylogenetic analyses
81 linking the enigmatic Tendaguru sauropod *Tendaguria tanzaniensis* with the turiasaur
82 *Moabosaurus*. These authors recovered additional Late Jurassic taxa as possible turiasaurs: in
83 some of their analyses, the Tendaguru sauropod *Janenschia robusta* and the Argentinean taxon
84 *Tehuelchesaurus benitezii* were also placed in Turiasauria, whilst the Chinese sauropod
85 *Bellusaurus sui* was consistently positioned as a turiasaur too.
86   Here, a previously undescribed anterior dorsal vertebra (NHMUK 1871) of a turiasaur from
87 the Early Cretaceous Wealden Supergroup of the UK is presented. The putative turiasaurian

88   affinities of several African and European occurrences are also discussed, including the utility of
89   tooth morphology for identifying turiasaurs.
90
91   **HISTORY AND PROVENANCE OF NHMUK 1871**
92
93   NHMUK 1871 is a relatively complete, but poorly preserved, anterior dorsal centrum and
94   neural arch from an unknown Early Cretaceous 'Wealden' locality of the UK. Purchased by the
95   NHMUK in 1891 as part of the Samuel H. Beckles collection, this specimen does not seem to
96   have ever been mentioned in the published literature. Correspondence between Beckles and
97   the NHMUK also does not provide any information on the provenance of NHMUK 1871. Most of
98   the dinosaur specimens collected by Beckles (e.g. the sauropod *Haestasaurus* ['*Pelorosaurus*']
99   *becklesii* [Upchurch, Mannion & Taylor, 2015]) came from the late Berriasian–Valanginian
100 Hastings Group, in Hastings, East Sussex, southeastern England (Woodhams, 1990), and so this
101 is the most likely source of NHMUK 1871. However, Beckles also collected material from
102 elsewhere in the southeast of England, including the Isle of Wight (Woodhams, 1990), and so
103 the specimen could conceivably have come from another Wealden locality. It also remains
104 possible that NHMUK 1871 came from a slightly older stratigraphic unit, given that Beckles also
105 collected fossil remains from the Berriasian section of the Purbeck Group (Owen, 1854),
106 although the reported provenance of 'Wealden' suggests that this was probably not the case.
107 Stratigraphically older and younger units in the areas in which Beckles collected were deposited
108 under marine environments, and thus are also unlikely to have yielded NHMUK 1871. As such,
109 although NHMUK 1871 is most likely to be late Berriasian–Valanginian, this cannot be
110 conclusively demonstrated. Given the above discussion, it seems that the specimen can be
111 attributed to the Wealden Supergroup, but it could conceivably have come from any section.
112 Thus, the stratigraphic age of NHMUK 1871 can only be constrained to late Berriasian–early
113 Aptian (Batten, 2011).
114 NHMUK 1871 comprises a centrum (including neural arch pedicels) and an unfused neural
115 arch (Figs 1, 2). Although the two elements are a close match in size, it is not possible to re-
116 articulate the centrum and neural arch, and this also results in an unusually dorsoventrally
117 elongate neural canal. As such, it seems probable that they do not belong to the same vertebra.
118 Both appear to be from the anterior region of the dorsal vertebral series though, and they
119 probably represent approximately the second and third dorsal vertebrae. One further note of
120 caution pertains to their preservation: whereas the neural arch is primarily black in colour, only
121 a few small areas of the centrum display a similar colour. As such, although the available
122 information indicates that they came from the same locality, and their relative sizes are
123 consistent with being from the same individual, it is possible that the centrum and neural arch
124 come from separate beds.
125
126 **Institutional Abbreviations**
127
128 **NHMUK**, Natural History Museum, London, UK
129
130 **SYSTEMATIC PALAEONTOLOGY**
131

132   Sauropoda Marsh, 1878
133   Eusauropoda Upchurch, 1995
134   Turiasauria Royo-Torres, Cobos & Alcalá, 2006
135   Turiasauria indet.
136
137   **Material:** NHMUK 1871, a relatively complete, but poorly preserved, anterior dorsal centrum
138   (Fig. 1) and separate neural arch (Fig. 2).
139
140   **Locality and stratigraphic position:** Unknown locality, southeastern England, United Kingdom;
141   probably from the Wealden Supergroup; late Berriasian–early Aptian (Early Cretaceous).
142
143   **DESCRIPTION**
144
145   The centrum is poorly preserved and incomplete, especially around the ventrolateral
146   margins of its posterior cotyle (Fig. 1; see Table 1 for measurements). It is strongly
147   opisthocoelous, and much wider mediolaterally than it is dorsoventrally tall (ratio = 1.44). The
148   ventral surface is transversely convex, lacking ridges or excavations. Each lateral surface is too
149   poorly preserved to determine whether the parapophyses were situated on the centrum or on
150   the neural arch pedicels, although they are definitely absent from the preserved neural arch.
151   Based on the right side of the centrum, a lateral pneumatic foramen is present (Fig. 1), but poor
152   preservation and infilling by matrix mean that little of its morphology can be discerned. There is
153   evidence for several poorly preserved laminae, comprising the anterior centrodiapophyseal
154   lamina (ACDL), posterior centrodiapophyseal lamina (PCDL), centroprezygapophyseal lamina
155   (CPRL), and centropostzygapophyseal lamina (CPOL) (Fig. 1). The neural arch pedicels terminate
156   a short distance from the posterior margin of the centrum. The lack of fusion of both the
157   centrum and neural arch with the rest of its respective vertebra indicates that this individual
158   was not fully grown at the time of death.
159   Erosion of the centrum in places reveals that it was pneumatised, with rounded camerae of
160   ~15 mm in diameter. No evidence for pneumaticity is visible in the neural arch. Unfortunately,
161   attempts to CT scan the vertebra, to examine its internal tissue structure, were unsuccessful, as
162   a result of its high density. As such, we cannot be sure whether the centrum was pneumatised
163   by small camerae throughout, or if these were primarily restricted to near the outer bone
164   surface.
165   In general, the neural arch is better preserved than the centrum (Fig. 2; see Table 1 for
166   measurements). The flat articular surfaces of the widely separated prezygapophyses face
167   dorsomedially and slightly anteriorly. They also expand anteroposteriorly towards their lateral
168   tips. There is evidence for a V-shaped interprezygapophyseal lamina (TPRL), but this has been
169   largely worn away (Fig. 2). The postzygapophyses are situated more dorsally than the
170   prezygapophyses, and their articular surfaces face ventrolaterally and posteriorly. Overall, the
171   zygapophyseal table is oriented at approximately 40° to the horizontal. There is no hyposphene,
172   which is consistent with this being an anterior dorsal vertebra, and the postzygapophyses are
173   connected by a horizontal interpostzygapophyseal lamina (TPOL). A prominent epipophysis is
174   present on the dorsal surface of each postzygapophysis (Fig. 2).

175   The diapophyses project laterally and slightly ventrally, and there is evidence for a poorly
176 preserved PCDL. The anterior and posterior surfaces of the diapophyses are unexcavated. A
177 poorly preserved, near-horizontal postzygodiapophyseal lamina (PODL) is present. A shallow,
178 dorsally-facing, elliptical spinodiapophyseal fossa (SDF) is situated anterior to the PODL,
179 bounded anteriorly by the spinoprezygapophyseal lamina (SPRL) (Fig. 2).
180   SPRLs run dorsomedially from the middle of the posterior margin of the prezygapophyses.
181 The anterior surface of the neural spine is transversely concave between the two SPRLs, and
182 becomes rugose towards the midline, although there is no clearly defined prespinal ridge. The
183 posterior surface of the neural spine is transversely concave, but poor preservation obscures
184 whether a postspinal ridge or rugosity was present. Dorsomedially oriented, undivided
185 spinopostzygapophyseal laminae (SPOLs) contribute to the posterolateral margins of the neural
186 spine, but there are no spinodiapophyseal laminae (SPDLs). The dorsoventrally low,
187 unbifurcated neural spine projects only very slightly above the level of the postzygapophyses,
188 and is anteroposteriorly narrow, especially towards the midline (Fig. 2).
189
190 **DISCUSSION**
191
192 **Taxonomic affinities of NHMUK 1871**
193
194   To determine the taxonomic affinities of NHMUK 1871, it is compared with anteriormost
195 dorsal vertebrae from an array of eusauropods (see Fig. 3). A strongly dorsoventrally
196 compressed centrum (mediolateral width to dorsoventral height ratio of > 1.3) characterises
197 the anterior dorsal vertebrae of several somphospondylan titanosauriforms (Mannion *et al.*,
198 2013), the basal macronarian *Lourinhasaurus* (Mocho *et al.*, 2014), *Apatosaurus* (Gilmore,
199 1936), and Turiasauria (Royo-Torres *et al.*, 2017a; Mannion *et al.*, in press). The presence of
200 camerae in the centrum is consistent with the anteriormost dorsal vertebrae of most
201 eusauropods more derived than *Omeisaurus*, whereas the absence of clear camellae suggests
202 that NHMUK 1871 lies outside of Titanosauriformes, and that it is not a mamenchisaurid
203 (Wedel, 2003, 2005).
204   The steeply inclined zygapophyseal table of NHMUK 1871 is most similar to the morphology
205 in the anterior dorsal vertebrate of titanosaurs and rebbachisaurids, contrasting with the more
206 shallowly oriented tables of other sauropods, including turiasaurs (Carballido *et al.*, 2012;
207 Poropat *et al.*, 2016). Whereas the cervical vertebrae of most sauropods are characterised by
208 the presence of epipophyses (Yates, 2007; Wilson & Upchurch, 2009; Mannion *et al.*, 2013),
209 their retention in anterior dorsal vertebrae is much less common, where they tend to be
210 reduced structures (Mannion *et al.*, in press). However, NHMUK 1871 shares the presence of
211 prominent epipophyses with the turiasaurs *Moabosaurus* and *Tendaguria*, as well as *Jobaria*
212 (Mannion *et al.*, in press). Epipophyses are absent in other turiasaurs in which anteriormost
213 dorsal vertebrae are preserved, i.e. *Mierasaurus* and *Turiasaurus* (Royo-Torres *et al.*, 2006,
214 2017a; Mannion *et al.*, in press). Only a small number of sauropod taxa are characterised by
215 such a low neural spine in their anterior dorsal vertebrae, in which the spine is approximately
216 level with the SPOLs. *Euhelopus* and *Mamenchisaurus* both share this feature, but the anterior
217 dorsal neural spines of those taxa are bifid (Ouyang & Ye, 2002; Wilson & Upchurch, 2009). In
218 contrast, the non-bifid anterior dorsal neural spines of the turiasaurs *Moabosaurus* (Britt *et al.*,

219   2017), *Tendaguria* (Bonaparte, Heinrich & Wild, 2000) and, to a lesser extent, *Mierasaurus*
220   (Royo-Torres *et al.*, 2017a), strongly resemble that of NHMUK 1871. In contrast, the
221   anteriormost dorsal vertebrae of *Turiasaurus* have dorsoventrally taller neural spines (Royo-
222   Torres *et al.*, 2006, 2017a).
223   In summary, the combination of: (1) a dorsoventrally compressed centrum; (2) the retention
224   of prominent epipophyses; (3) the low, non-bifid neural spine; and (4) the overall morphology
225   of NHMUK 1871, more closely resembles the anteriormost dorsal vertebrae of turiasaurs than
226   any other sauropods (Fig. 3). In particular, NHMUK 1871 appears to be most similar to
227   *Moabosaurus* and *Tendaguria*. The anterior and posterior surfaces of the diapophyses of
228   NHMUK 1871 are unexcavated though, contrasting with those two taxa (Mannion *et al.*, in
229   press). Despite the incomplete and fragmentary nature of NHMUK 1871, it appears to be
230   readily referable to Turiasauria, more closely related to *Moabosaurus* + *Tendaguria* than to
231   other turiasaurs.
232
233   **Possible implications for turiasaurs from the Late Jurassic Tendaguru Formation of Tanzania**
234
235   Upchurch, Mannion & Taylor (2015) recovered a sister taxon relationship between
236   *Janenschia* and *Haestasaurus* (see also Mannion *et al.*, in press), which are sympatric with
237   *Tendaguria* and (probably) NHMUK 1871, respectively. Such close affinities might indicate a
238   close faunal relationship between the latest Jurassic Tendaguru Formation and the Early
239   Cretaceous Wealden Supergroup. Furthermore, this could conceivably be regarded as
240   circumstantial evidence that *Tendaguria* is a junior synonym of *Janenschia* if NHMUK 1871 was
241   recovered from the same area and stratigraphic bed as *Haestasaurus*. Given that both
242   *Janenschia* and *Tendaguria* are recovered as turiasaurs in some of the phylogenetic analyses of
243   Mannion *et al.* (in press), synonymy remains a possibility. However, until we find limb material
244   associated with anterior dorsal vertebrae that can be referred to any of these taxa, such
245   synonymisation cannot be justified.
246
247   **Turiasaurian sauropod biogeography and evolutionary history**
248
249   In addition to the named taxa *Turiasaurus*, *Losillasaurus*, *Zby*, *Mierasaurus*, *Moabosaurus*,
250   and *Tendaguria*, several remains have been referred to Turiasauria (see Introduction). Most of
251   these referrals are based on isolated teeth. Although the 'heart'-shape is quite distinctive in
252   most of the referred western European teeth, this is not the case in all instances (e.g. the type
253   specimen of *Oplosaurus armatus*, from the Early Cretaceous of the UK), and especially not for
254   the African specimens (two of which preserve only half of the crown). Mocho *et al.* (2016)
255   identified three morphotypes of putative turiasaur teeth, which they suggested could be
256   explained in two ways: either they represent different taxa, potentially including non-
257   turiasaurs, or they are indicative of variation along the tooth row. The North American
258   turiasaurs *Mierasaurus* and *Moabosaurus* show a clear heterodont dentition (Britt *et al.*, 2017;
259   Royo-Torres *et al.*, 2017a), with subtle heterdonty present in *Turiasaurus* too (Royo-Torres &
260   Upchurch, 2012). As such, the second hypothesis of Mocho *et al.* (2016) might well be correct.
261   However, two of their morphotypes overlap with the teeth of other non-neosauropods (e.g.
262   *Jobaria*; see also Mocho *et al.*, 2016: fig. 7), and thus only broad, 'heart'-shaped teeth can

263 currently be attributed to Turiasauria with confidence. As such, the isolated teeth from the
264 Middle Jurassic and Early Cretaceous of Africa cannot unambiguously be referred to
265 Turiasauria, and are herein regarded as indeterminate eusauropods.
266   Xing *et al.* (2015) recovered the Middle Jurassic Moroccan sauropod *Atlasaurus* as a
267 turiasaur in their phylogenetic analysis, but this result was not supported in recent studies that
268 scored turiasaurian taxa based on firsthand observations (Mannion, Allain & Moine, 2017;
269 Royo-Torres *et al.* 2017a; Mannion *et al.*, in press). Very little published information is currently
270 available for *Atlasaurus*, and it is in need of revision. As such, its phylogenetic affinities are
271 uncertain (see Mannion *et al.*, in press), but there is currently no evidence to support a
272 turiasaurian placement. Finally, Mannion *et al.* (in press) recovered two Late Jurassic taxa
273 within Turiasauria that would greatly extend the group's distribution: the Argentinean
274 sauropod *Tehuelchesaurus*, and the Chinese taxon *Bellusaurus*. However, those placements
275 should be treated with caution: *Tehuelchesaurus* was placed outside of Turiasauria when
276 extended implied weighting was applied, and *Bellusaurus* is known only from juvenile remains,
277 which might affect its phylogenetic position (Moore *et al.*, 2018). Furthermore, these positions
278 have not been recovered in independent analyses (e.g. D'Emic, 2012; Royo-Torres & Upchurch,
279 2012; Carballido *et al.*, 2017).
280   In summary, there is currently only unequivocal evidence for Turiasauria in the late Middle
281 Jurassic–Early Cretaceous of western Europe (UK, France, Spain and Portugal), the Late Jurassic
282 of Tanzania, and the late Early Cretaceous of the USA, but other remains suggest the possibility
283 that the clade was more widespread, at least in the Late Jurassic.
284
285 **CONCLUSIONS**
286
287   A previously undescribed anterior dorsal centrum and neural arch (NHMUK 1871) from the
288 Early Cretaceous Wealden Supergroup of the UK is recognised as a turiasaurian eusauropod
289 dinosaur. This material shares several synapomorphies with Turiasauria, especially the Late
290 Jurassic Tanzanian sauropod *Tendaguria*, and *Moabosaurus*, from the Early Cretaceous of the
291 USA. NHMUK 1871 represents the first postcranial evidence for Turiasauria from European
292 deposits of unequivocal Early Cretaceous age. Unambiguous evidence for the non-neosauropod
293 eusauropod clade Turiasauria is restricted to the late Middle Jurassic–Early Cretaceous of
294 western Europe, the Late Jurassic of Tanzania, and the late Early Cretaceous of the USA,
295 although remains from the Late Jurassic of Argentina and China might mean that the group had
296 a near-global distribution.
297
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301 for providing access to NHMUK 1871, as well as to all those who have facilitated the study of
302 sauropod remains in their care. Comments from Rafael Royo-Torres also improved this
303 manuscript.
304
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444

445 **Figure 1.** Photographs of the anterior dorsal centum NHMUK 1871 in (A) anterior, (B) posterior,
446 (C) left lateral, (D) right lateral, (E) dorsal, and (F) ventral views. Abbreviations: ACDL, anterior
447 centrodiapophyseal lamina; CPOL, centropostzygapophyseal lamina; CPRL,
448 centroprezygapophyseal lamina; lpf, lateral pneumatic foramen; nc, neural canal; PCDL,
449 posterior centrodiapophyseal lamina. Scale bar equals 100 mm. Photographs taken by the
450 author.

451

452 **Figure 2.** Photographs of the anterior dorsal neural arch NHMUK 1871 in (A) anterior, (B)
453 posterior, (C) right lateral, and (D) dorsal views. Abbreviations: dia, diapophysis; epi,
454 epipophysis; PCDL, posterior centrodiapophyseal lamina; PODL, postzygapophysis; poz,
455 postzygapophysis; prz, prezygapophysis; SDF, spinodiapophyseal fossa; SPOL,
456 spinopostzygapophyseal lamina; SPRL, spinoprezygapophyseal lamina; TPOL,
457 interpostzygapophyseal lamina; TPRL, interprezygapophyseal lamina. Scale bar equals 200 mm.
458 Photographs taken by the author.

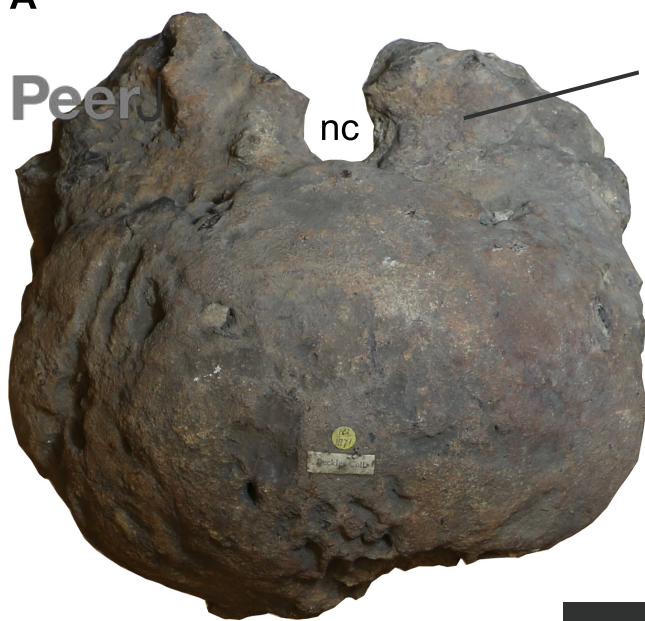
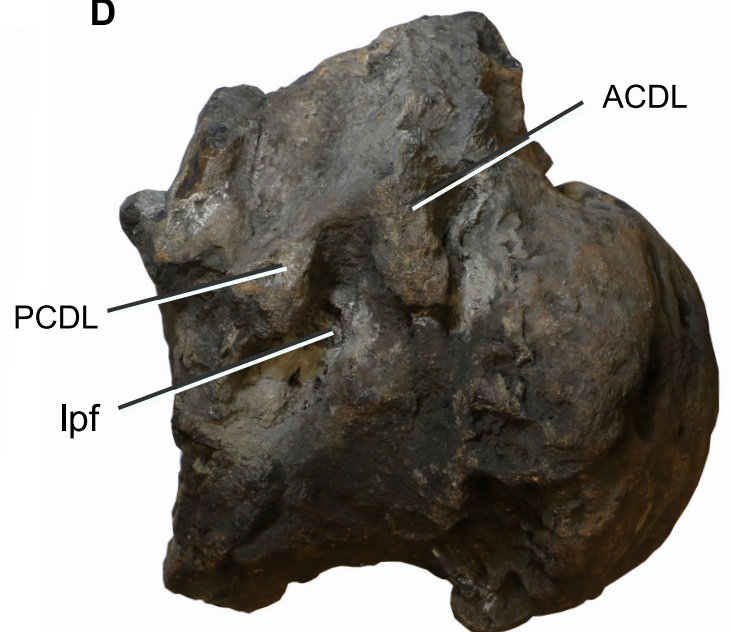
459

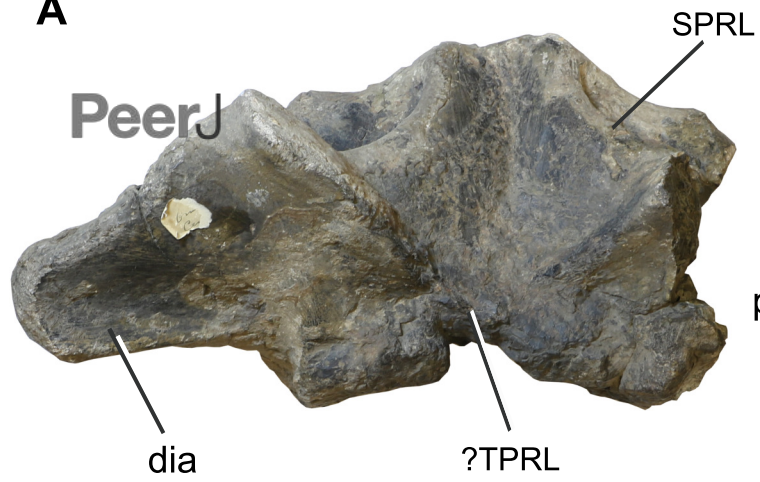
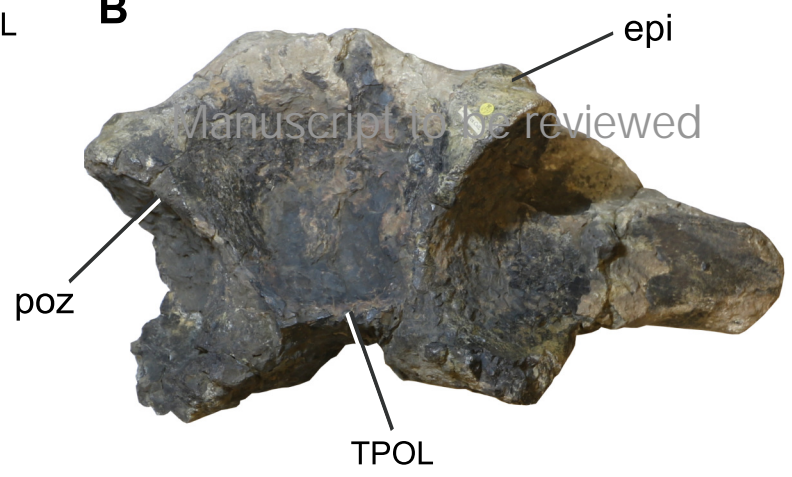
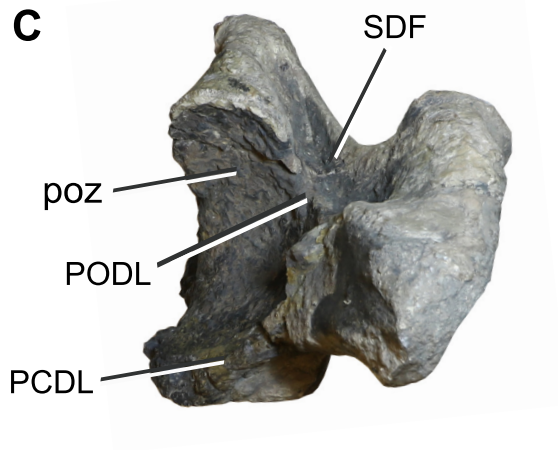
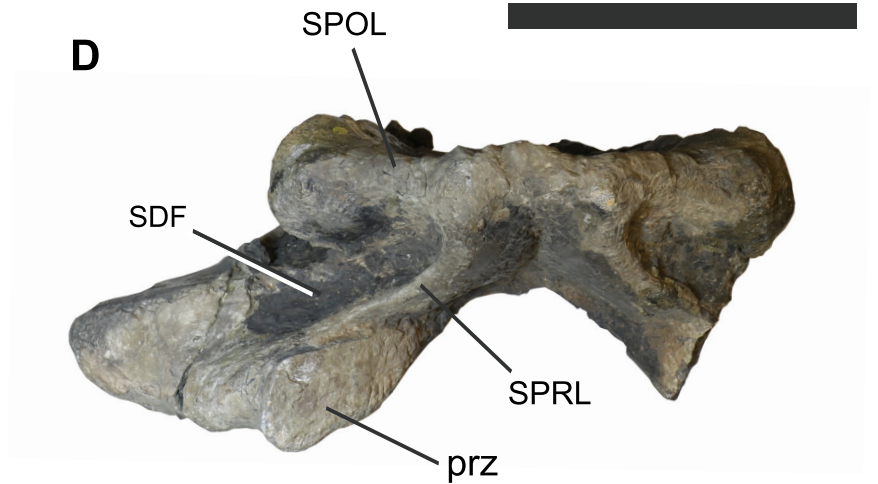
460 **Figure 3.** Comparative line drawings showing dorsal vertebra 2–3 in anterior view for an array
461 of eusauropods: (A) NHMUK 1871 (centrum + arch); (B) the turiasaur *Tendaguria tanzaniensis*
462 (after Mannion *et al*., in press); (C) the turiasaur *Moabosaurus utahensis* (after Britt *et al*.,
463 2017); (D) the mamenchisaurid *Mamenchisaurus youngi* (after Ouyang & Ye, 2002); (E) the
464 diplodocid *Apatosaurus louisae* (after Gilmore, 1936); (F) the basal macronarian *Camarasaurus*
465 *supremus* (after Osborn & Mook, 1921; (G) the brachiosaurid *Europasaurus holgeri* (after
466 Carballido & Sander, 2014); and (H) the basal somphospondylan specimen known as the
467 Cloverly titanosauriform (after D'Emic & Foreman, 2012). Vertebrae partially reconstructed
468 where incomplete and not drawn to scale relative to one another.

469

470 **Table 1.** Measurements of the anterior dorsal vertebra NHMUK 1871. All measurements in
471 millimetres.

Photographs of the anterior dorsal centum NHMUK 1871.

(A) anterior, (B) posterior, (C) left lateral, (D) right lateral, (E) dorsal, and (F) ventral views. Abbreviations: ACDL, anterior centrodiapophyseal lamina; CPOL, centropostzygapophyseal lamina; CPRL, centroprezygapophyseal lamina; lpf, lateral pneumatic foramen; nc, neural canal; PCDL, posterior centrodiapophyseal lamina. Scale bar equals 100 mm. Photographs taken by the author.

Photographs of the anterior dorsal neural arch NHMUK 1871.

(A) anterior, (B) posterior, (C) right lateral, and (D) dorsal views. Abbreviations: dia, diapophysis; epi, epipophysis; PCDL, posterior centrodiapophyseal lamina; PODL, postzygapophysis; poz, postzygapophysis; prz, prezygapophysis; SDF, spinodiapophyseal fossa; SPOL, spinopostzygapophyseal lamina; SPRL, spinoprezygapophyseal lamina; TPOL, interpostzygapophyseal lamina; TPRL, interprezygapophyseal lamina. Scale bar equals 200 mm. Photographs taken by the author.

Comparative line drawings of anterior dorsal vertebrae of eusauropods

Comparative line drawings showing dorsal vertebra 2–3 in anterior view for an array of eusauropods: (A) NHMUK 1871 (centrum + arch); (B) the turiasaur *Tendaguria tanzaniensis* (after Mannion *et al*., in press); (C) the turiasaur *Moabosaurus utahensis* (after Britt *et al*., 2017); (D) the mamenchisaurid *Mamenchisaurus youngi* (after Ouyang & Ye, 2002); (E) the diplodocid *Apatosaurus louisae* (after Gilmore, 1936); (F) the basal macronarian *Camarasaurus supremus* (after Osborn & Mook, 1921; (G) the brachiosaurid *Europasaurus holgeri* (after Carballido & Sander, 2014); and (H) the basal somphospondylan specimen known as the Cloverly titanosauriform (after D'Emic & Foreman, 2012). Vertebrae partially reconstructed where incomplete and not drawn to scale relative to one another.

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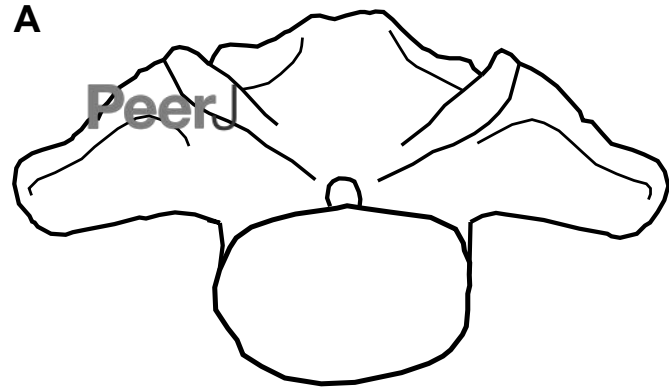
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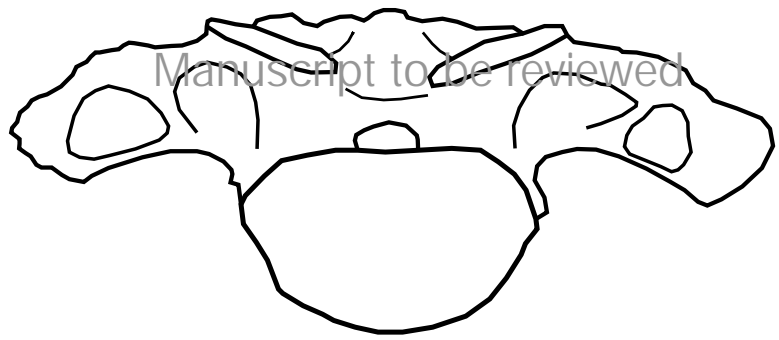
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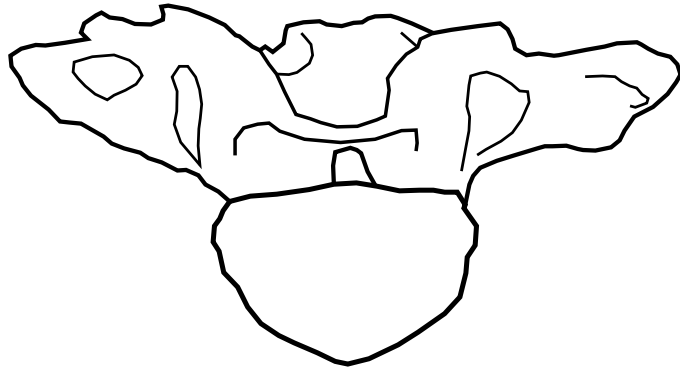
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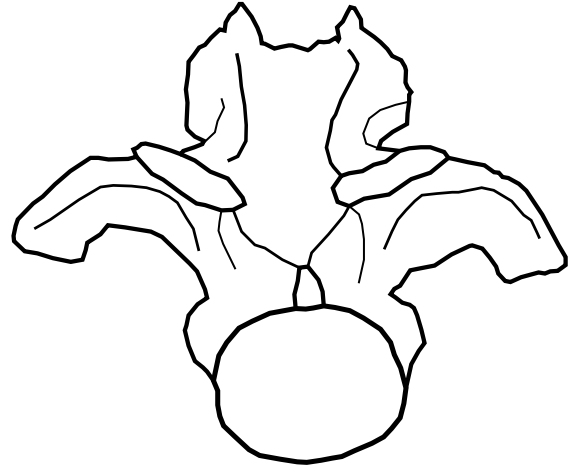
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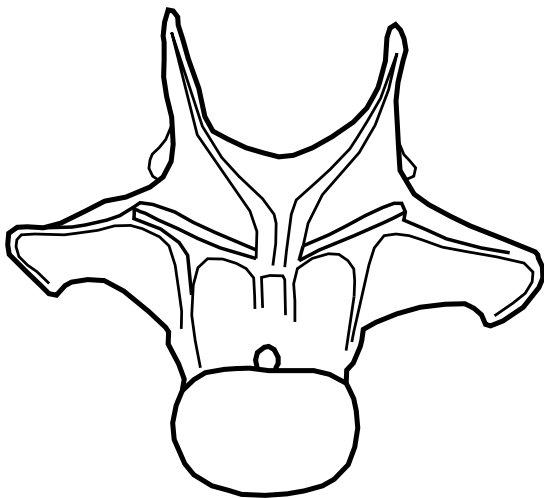
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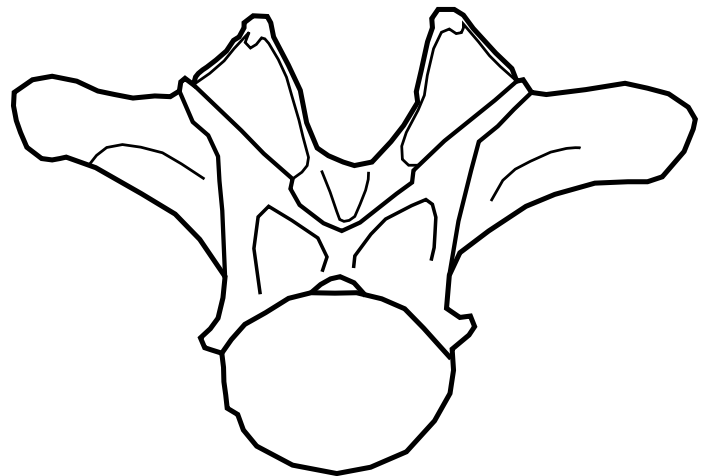
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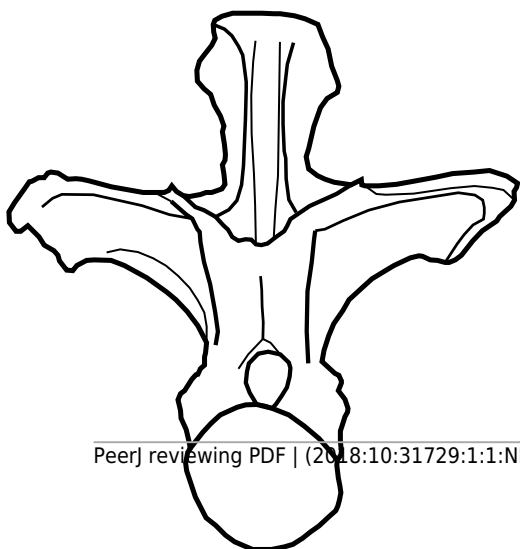
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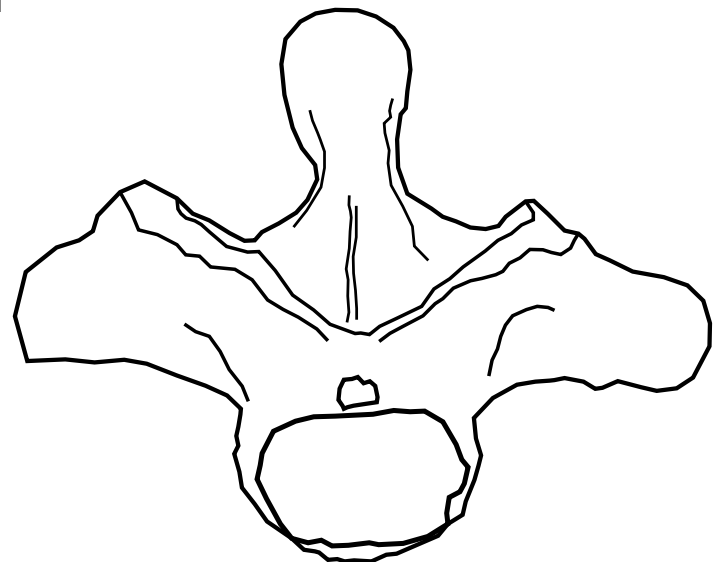
Measurements of the anterior dorsal vertebra NHMUK 1871.

All measurements in millimetres.

1   **Table 1.** Measurements of the anterior dorsal vertebra NHMUK 1871. All measurements in
2   millimetres.

Dimension	Measurement
Centrum length (including condyle)	229
Centrum length (excluding condyle)	170
Anterior centrum dorsoventral height	158
Anterior centrum mediolateral width	228
Total preserved dorsoventral height of neural arch and spine	205
Neural arch height	167
Transverse width from midline to distal tip of right diapophysis	248