



A new specimen of the theropod dinosaur *Baryonyx* from the early Cretaceous of Portugal and taxonomic validity of *Suchosaurus*

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Abstract

Although the Late Jurassic of Portugal has provided abundant dinosaur fossils, material from the Early Cretaceous is scarce. This paper reports new cranial and postcranial material of the theropod dinosaur *Baryonyx walkeri* found in the Barremian (Papo Seco Formation) of Portugal. This specimen, found at Praia das Aguncheiras, Cabo Espichel, consists of a partial dentary, isolated teeth, pedal ungual, two calcanea, presacral and caudal vertebrae, fragmentary pubis, scapula, and rib fragments. It represents the most complete spinosaurid yet discovered in the Iberian Peninsula and the most complete dinosaur from the Early Cretaceous of Portugal. This specimen is confidently identified as a member of Baryonychinae due to the presence of conical teeth with flutes and denticles in a dentary rosette. The specimen ML1190 shares the following characteristics with *Baryonyx walkeri*: enamel surface with small (nearly vertical) wrinkles, variable denticle size along the carinae, 6–7 denticles per mm, wrinkles forming a 45 degree angle near the carinae, and tooth root longer than crown. In addition, dubious taxa based on teeth morphology such as *Suchosaurus cultridens* (Owen, 1840–1845), and *Suchosaurus girardi* (Sauvage 1897–98; Antunes & Mateus 2003) are discussed, based on comparisons with well-known material such as *Baryonyx walkeri* Charig & Milner, 1986. *Suchosaurus cultridens* and *S. girardi* are considered as *nomen dubium* due to the lack of diagnostic apomorphies, but both specimens are referred to Baryonychinae incertae sedis.

Key words: Theropod dinosaurs, Spinosauridae, *Baryonyx*, early Cretaceous, Portugal

Introduction

Spinosauridae is a group of theropod dinosaurs with snout and tooth morphology convergent with that of crocodiles (Serenó *et al.* 1998; Rayfield *et al.* 2007). The group is placed as part of spinosauroid (Serenó *et al.* 1998, Rauhut 2003), or megalosauroid (Benson 2010), tetanurans, and divided into Baryonychinae (with *Baryonyx walkeri* Charig & Milner, 1986 and *Suchomimus tenerensis* Serenó *et al.*, 1998, and possibly also *Cristatusaurus lapparenti* Taquet & Russell, 1998 pending verification of its synonymy with *S. tenerensis*) and Spinosaurinae (with *Spinosaurus aegyptiacus* Stromer, 1915 and *Irritator challengeri* Martill *et al.*, 1996) (Charig & Milner 1986, 1997; Serenó *et al.* 1998; Sues *et al.* 2002). The Thai form *Siamosaurus suteethorni* Buffetaut & Ingavat, 1986 also seems to belong to Spinosauridae (Buffetaut *et al.* 2008).

Although dinosaur bones and tracks from the Late Jurassic of Portugal are well known (Mateus & Antunes 2000, 2003; Ricqlès *et al.* 2001; Antunes & Mateus 2003; Mateus 2006; Mateus & Milàn 2008), Lower Cretaceous fossils are rare, and are restricted to isolated teeth and bone remains (Sauvage 1897–98; Antunes & Mateus 2003) and tracks (Mateus & Antunes 2003, and references therein). The only genera reported are *Iguanodon* and a possible basal macronarian sauropod attributed to the dubious taxa ‘*Astrodon*’ or ‘*Pleurocoelous*’ (Sauvage 1897–98), and ‘*Megalosaurus*’. Sauvage (1897–1898) erected the new species *Suchosaurus girardi* based on two dentary fragments with teeth (specimen MG324, reported by Sauvage 1897–98 as specimens 29A, 29B; a third dentary

fragment, 29C, was described by Buffetaut 2007; Fig. 1) and an isolated tooth (Sauvage 1897–98: pl. V, fig. 6). This material was collected from what was thought to be the “couches que l’on rapporte au terrain Aptien ou au terrain Albien” (Sauvage 1897–98: 27) of Boca do Chapim, Cabo Espichel, in central west Portugal (Fig. 2). The transgressive sequence at Boca do Chapim and Papo Seco was later dated as early Barremian by Rey (1972: 174; 1992), Rey *et al.* (2003: 29; 2006), and Dinis *et al.* (2008: 774). This formation was also referred to as “Grès marneux à grands sauriens” (Choffat 1904–1907: 13), “Grès aux Dinosauriens” (Rey 1972: 174), and “Camadas com *Iguanodon mantelli*” (Ferreira 1961: 255). Recently, Buffetaut (2007) recognized Sauvage’s specimens as *Baryonyx* sp. based exclusively on tooth morphology. Prior identification of this specimen as a crocodile by Sauvage (1897–1898) is understandable because spinosaur morphology was unknown at that time, and *Suchosaurus* had already been identified as a crocodile by Owen (1840–1845).

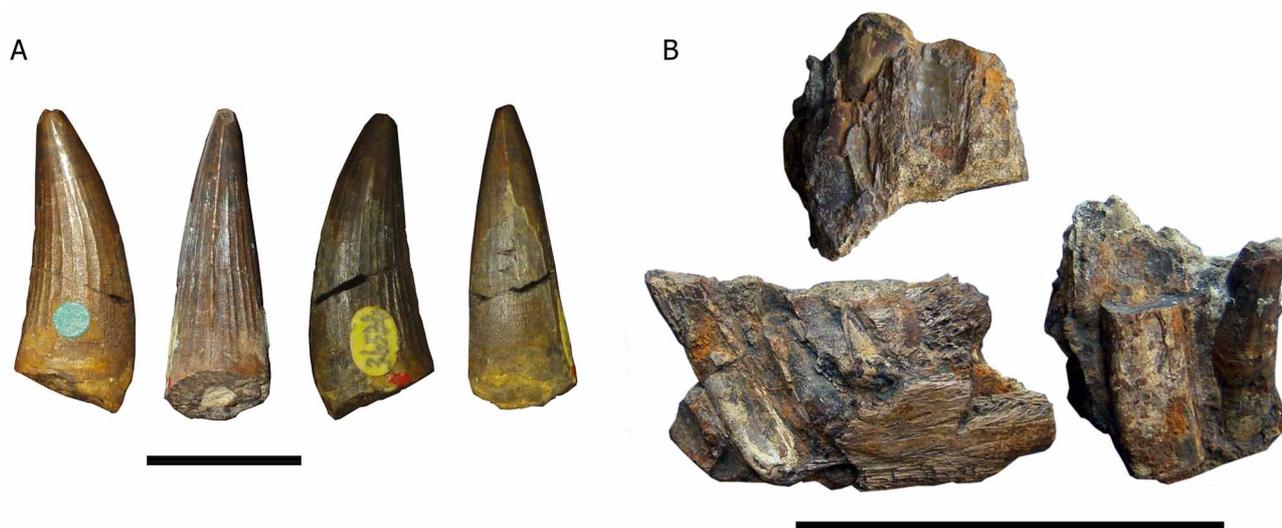


FIGURE 1. **A**, Tooth of possible Baryonychinae indet. (NHM R36536), holotype of the nomen dubium *Suchosaurus cultridens* (Owen, 1840–45). Scale bar: 2 cm; **B**, Jaw and teeth of Baryonychinae indet., possibly referable to *Baryonyx walkeri* (MG324), holotype specimen of the nomen dubium *Suchosaurus girardi* Sauvage, 1897–1898. Scale bar: 10 cm.

Two spinosaurid specimens are currently known from Portugal: the teeth and bone fragments described by Sauvage under the name *Suchosaurus girardi* (MG324) and a new specimen described herein (ML1190). Both specimens come from the Papo Seco Formation of the Lusitanian Basin (see Kullberg *et al.* in press), which yielded the small collection of dinosaur remains described by Sauvage (1897–1898). The new specimen reported here was discovered by one of us (CN) in 1999, from the Papo Seco Formation (Rey 1992), early Barremian, of Cabo Espichel, in layers 36–38 of Choffat (1904–1907: 15). The first fragments were collected in 1999 and field excavations followed from 2004 to 2008.

The Papo Seco Formation (underlain by the Areia do Mastro Formation and overlain by the Boca do Chapim Formation) is comprised of two carbonate-rich units and was deposited during the regression seen in the Lusitanian Basin, although with a localized transgression demonstrated by intertidal clastics during the early Barremian (Rey *et al.* 2003: 29–30; Dinis *et al.* 2008: 774–775). The Papo Seco Formation is predominantly composed of a series of marls representative of a saline lagoonal environment, with intermittent layers of coarse sediment (Rey 1972: 174). The stratigraphic age and geological context of the new Portuguese specimen is somewhat similar to other *Baryonyx* remains that have been recovered, either from transitional or strictly terrestrial environments (Owen 1878; Stromer 1915; Charig & Milner 1997; Ruiz-Omeñaca *et al.* 1998, 2005; Sereno *et al.* 1998; Buffetaut & Ouaja 2002).

Institutional abbreviations: **MG**, Museu Geológico, Lisbon, Portugal; **ML**, Museu da Lourinhã, Lourinhã, Portugal; **MNN**, Musée National du Niger, Niamey, Niger; **NHM**, Natural History Museum, London, UK.

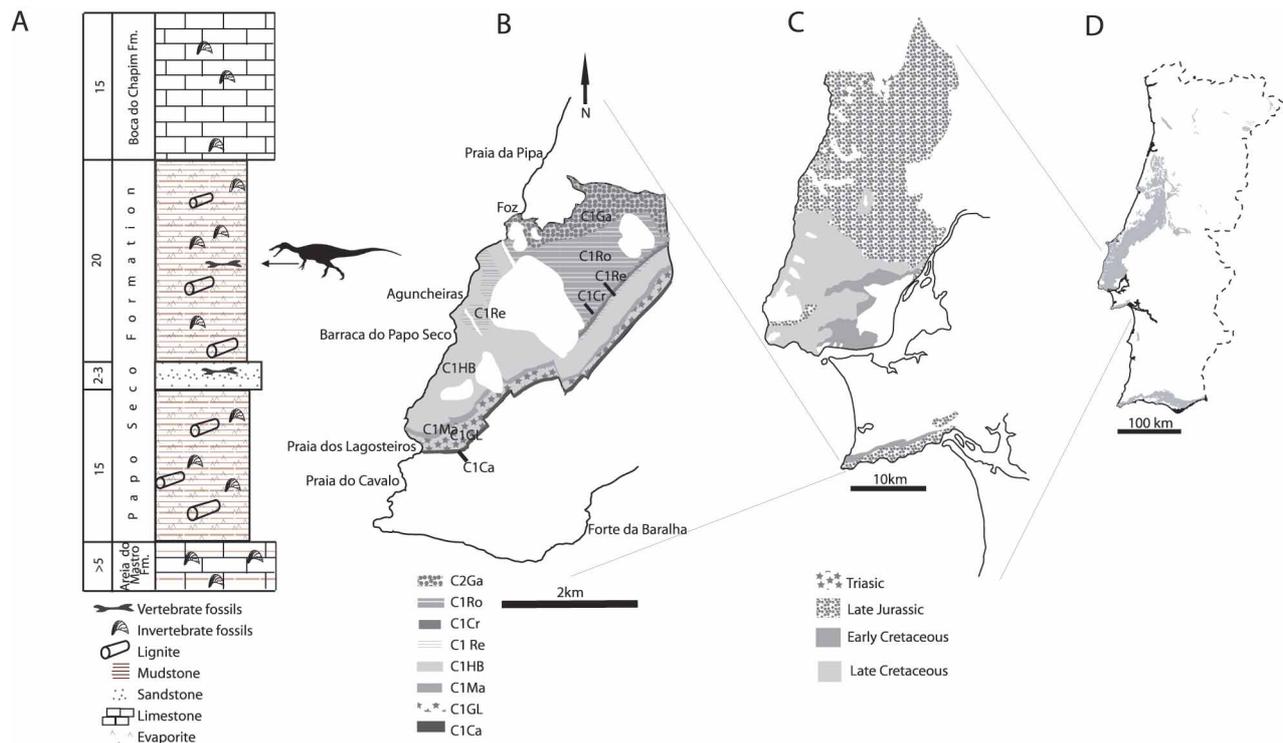


FIGURE 2. Geology and stratigraphy context. **A**, Stratigraphic log at Praia das Aguncheiras; **B**, Cretaceous geological formations at Espichel Cape (based on Manuppella 1994); **C**, Lisbon and Tagus Valley Mesozoic sedimentary rocks based on Liñán, 2001; **D**, Portuguese Mesozoic sedimentary rocks based on Liñán, 2001. Abbreviations: C2Ga, Galé Formation; C1Ro, Rodízio Formation; C1Cr, Cresmina Formation; C1Re, Regatão Formation; C1HB, Ladeiras, Rochadouro, Areia do Mastro, Papo-Seco and Boca do Chapim Formations; C1Ma, Maceira marls and reefal limestones; C1GL, Vale de Lobos and Guia grés, mudstones and limestones; C1Ca - Mudstones and sandstones of Porto da Calada Fm.

The validity of *Baryonyx* and *Suchosaurus*

The holotype species of *Suchosaurus*, *Suchosaurus cultridens* (Owen, 1840–45), was based on a tooth (NHM R36536) from the Early Cretaceous of England believed to belong to a crocodile and initially named *Crocodylus cultridens* (Owen 1840–45: 287), and later referred to the new genus *Suchosaurus* (Owen 1842: 67; see figures in Owen 1878). Buffetaut (2007) and Fowler (2007) have shown this taxon to have affinities with *Baryonyx walkeri*. This specimen was part of the collection of Gideon Mantell that was later incorporated into the collections of the NHM (Owen 1878). The vertebra NHM R46785, also described as *Suchosaurus cultridens*, by Owen (1842), was later referred to *Iguanodon* (Lydekker 1888; Norman & Barrett 2002). Indeed, it does not seem to be spinosaurid, because the caudal vertebrae of *Baryonyx walkeri* possess a ventral depression extending anteroposteriorly, whereas there is a keel in NHM 46785.

The holotype tooth of *Suchosaurus cultridens* (NHM R36536) is similar (in the gentle curvature, round cross section, presence and size of flutes) to those of *Baryonyx walkeri* (NHM R9951), except that the tooth of *Suchosaurus cultridens* has more pronounced fluting (i.e. prominence on the lingual side) and lacks serrations, but these features are not distinctive enough to be considered autapomorphic. Although the holotype of *Suchosaurus cultridens* probably belongs to the same taxon as NHM R9951 (i.e., *Baryonyx walkeri*), we regard *Suchosaurus cultridens* as a nomen dubium due to the lack of diagnostic features, because the carina is worn down and it is therefore difficult to determine if the tooth genuinely lacked serrations or if they are missing solely because of wear. We were not able to assign any autapomorphy or unique combination of characters to *Suchosaurus cultridens*, which agrees in part with the conclusions of Buffetaut (2007).

Sauvage (1896–97) erected the species *Suchosaurus girardi* from Portugal as having the following features that are currently regarded as characteristic of Baryonychinae: ziphodont teeth with about 7 denticles per millimetre, long tooth roots (at least 1.5 times the length of the crown), micro-wrinkled enamel, eight flutes on the lingual

side (four faint flutes on the labial side), sub-circular cross-section, and variation in denticle sizes. The baryonychine specimens NHM R9951 (type of *Baryonyx walkeri*), MG324 (type of *Suchosaurus girardi*), ML1190 (described herein), and various specimens of *Suchomimus tenerensis* (Serenó *et al.* 1998) share the following characters: enamel surface with small, nearly vertical ridges (not to be confused with “enamel wrinkles”, which are transverse corrugations on the labial and lingual sides of the tooth, as described in Brusatte *et al.* 2007), variable denticle size along the carinae, between 4 and 7 flutes in the crown, 6–7 denticles per millimetre, wrinkles forming a 45 degree angle near the carinae, and a tooth root that is longer than the crown. Most theropods have a gradual variation in denticle size along the carinae, but only baryonychines appear to have random size variation in which a larger denticle could be followed by a smaller one, or vice versa. Because this combination of features is only known in Baryonychinae (*Baryonyx walkeri*, *Suchosaurus girardi*, and *Suchomimus tenerensis*; see Table 1), this confirms that *Suchosaurus girardi* is a member of this clade (as stated by Buffetaut 2007). However, there is currently no clear evidence that *Suchosaurus girardi* represents the same taxon as *Baryonyx walkeri*, because *Baryonyx walkeri* does not have any tooth or dentary autapomorphies that distinguish it from other baryonychines such as *Suchomimus tenerensis* (Serenó *et al.* 1998) and *Cristatusaurus lapparenti* (Taquet & Russell 1998). Nevertheless, the teeth of NHM R36536, MG324 and ML1190 are all essentially identical in morphology and thus are very likely to pertain to the same species. If this is true, it may be more likely that this species would be *Baryonyx walkeri*, and not *Suchomimus tenerensis*, due to the stratigraphic and geographical context. *Suchosaurus girardi* is here regarded as a nomen dubium that is probably referable to *Baryonyx walkeri*.

Spinosaurid teeth are unique among theropods (e.g. Smith *et al.* 2005), but their phylogenetic importance is not well understood. Charig & Milner (1997) considered the following dental characteristics as diagnostic of Spinosauridae: 1) tooth crowns flattened only slightly labio-lingually and lightly fluted on lingual side; 2) anterior and posterior carinae finely serrated (about seven denticles per millimetre); 3) exceptionally long and slender tooth roots. Nevertheless, there are other tooth characters that must be assessed throughout all Spinosauridae, such as smooth or wrinkled enamel surface, enamel bearing apicobasally oriented striations at the base of the crown, irregular denticle size, presence and number of flutes, 45 degree orientation between more distal or mesial wrinkles and carina, and denticles with fluted apices (see Table 1, and Martill & Hutt 2006, for discussion of some of the characters).

TABLE 1. Tooth characters in *Torvosaurus tanneri* (as outgroup) and spinosaurid dinosaurs.

	<i>Torvosaurus tanneri</i>	Baryonychinae “ <i>Suchosaurus girardi</i> ”	<i>Baryonyx walkeri</i>	<i>Suchomimus tenerensis</i>	<i>Irritator challengeri</i>	<i>Spinosaurus aegyptiacus</i>
Tooth crown suboval to subcircular in cross-section	no	yes	yes	yes	yes	yes
Presence of flutes	no	yes	yes	yes	yes	yes
Carinae bearing 6 or more denticles per mm	no	yes	yes	yes	N/A	N/A
Exceptionally long and slender tooth roots	no	yes	yes	yes	yes	yes
Enamel surface of the crown	smooth	sculptured (vertical striations)	sculptured (vertical striations)	sculptured (vertical striations)	smooth	smooth
Base of the crown enamel surface	smooth	sculptured (vertical striations)	sculptured (vertical striation)	smooth or poorly sculptured	smooth	smooth
Irregular denticle size	no	yes	yes	yes	N/A	N/A
Number of flutes	n/a	12	6-8	0-10	7	5
45 degree orientation of enamel sculpture near interdentine sulci	no	yes	yes	yes	no	no
Well-pronounced carinae	yes	no	no	no	yes	yes
Curvature of the crown	yes	yes	yes	yes	no	no

Systematic Palaeontology

Dinosauria Owen, 1841

Theropoda Marsh, 1881

Tetanurae Gauthier, 1986

Spinosauridae Stromer, 1915

Baryonychinae (Charig & Milner, 1986)

Baryonyx walkeri Charig & Milner, 1986

Holotype. NHM R9951, partial skull and associated postcranial skeleton.

Locality and horizon. The holotype is from the Upper Weald Clay (base of the Barremian, Lower Cretaceous) of Walliswood, England. The Portuguese specimen, ML1190, is from the Praia das Aguncheiras, Sesimbra Municipality (Papo Seco Formation; early Barremian; 38.44N 9.20W).

Synonyms. Possibly the nomina dubia *Suchosaurus cultridens* (Owen, 1840–45) and *Suchosaurus girardi* Sauvage, 1897–1898.

Referred specimen described here. One individual (ML1190) comprising a partial left dentary, two teeth, four dorsal neural arches, five caudal centra, fragments of chevrons, dorsal rib fragments, right scapula, right pubic shaft, possible pubic peduncle of left ilium, two calcanea, and one pedal ungual phalanx (Figs 3–10).

Addition to the diagnosis: Besides the diagnostic features provided by Charig & Milner (1986, 1997), Sereno et al. (1998), and Martill & Hutt (1996), *Baryonyx* has an unique combination of characters of the teeth: carinae with high denticles density (6–7 denticles per millimetre), variable and non-gradual denticle size along the carinae, enamel surface with small and nearly vertical wrinkles (including at the base of the crown), and wrinkles forming a 45 degree angle near the carinae.

Description. Except for the mid-caudal vertebrae, all skeletal elements of *Baryonyx walkeri* ML1190 are also represented in NHM R9951, the holotype specimen of *Baryonyx walkeri*, thus enabling comparison. The bone dimensions are similar to those of NHM R9951; thus, the Portuguese specimen would have had a similar body size. Most of the bones of the Portuguese specimen ML1190 have damaged articular ends filled with sediment, and some have scratches on their surfaces, which may be marks of small scavengers. The disarticulation of ML1190 is indicative of transport, possibly from more terrestrial environments, due to the following factors: 1) the skeleton is incomplete; 2) the specimen is disarticulated but closely associated; 3) there was a significant loss of bone, indicative of disarticulation stage M (taphonomical terms from Heinrich 1999: 31).

The left dentary (Fig. 4), 162 mm long as preserved, comprises the symphysis with the 12 anterior-most alveoli. Most teeth are still present but with the crown broken off. The erupting replacement teeth are visible on the medial side of the dentary at the first, second, sixth and eighth alveoli. As in all spinosaurids, the anterior end of the dentary exhibits the tooth rosette, i.e., a dorsoventral expansion near the symphysis that results in a sigmoidal dorsal margin. As a result, the ninth and tenth teeth positions are in a more ventral position than the more anterior teeth. The dentary is laterally compressed and straight. The Meckelian groove is narrow (up to 3 mm deep dorsoventrally) and shallow. The preserved lateral view of the dentary bears 28 well defined and deep foramina for nutrient supply. The paradental groove is not visible, and it is unclear if it was present. The paradental plates are triangular and low, and nearly absent.

The specimen includes one complete isolated tooth with its root (but with damaged serrations; Fig. 3) and several teeth within the left dentary. The cross section is eye-shaped or round (rather than D-shaped as in most theropods), resulting in a conical appearance, with only weak linguolabial compression. The tooth crowns in the dentary exhibit fluting on the lingual surface only. It has been shown that the presence of fluting in baryonychine teeth is highly variable (Ruiz-Omeñaca *et al.* 1998: 206). Carinae are present on the mesial and distal margins of the teeth. The denticle density of the erupting teeth is about 6–7 denticles per millimetre, and the enamel is densely wrinkled (apicobasally extending micro-ridges). There is a small, posterior dentary fragment that bears four alveoli (7 mm in diameter anteroposteriorly and 6 mm lateromedially).



FIGURE 3. Tooth (ML1190) of *Baryonyx walkeri* Charig & Milner, 1986. Isolated tooth (A) with detailed inset of the vertical flutes (B), wrinkled enamel (C), denticles (D), and carina (E, F) Scale bars: 1 cm (A) and 0.5 cm (C–E).

Three presacral neural arches, possibly of dorsal vertebrae, are preserved (Fig. 5). We describe here the most complete arch, which is identified as a posterior dorsal. It is fragmentary, missing the neural spine and diapophyses. Four laminae diverge from the diapophysis: the prezygadiapophyseal, the anterior and posterior centrodiapophyseal, and postzygadiapophyseal laminae. Vertical, small, auxiliary laminae support the posterior centrodiapophyseal lamina from beneath (synapomorphy of Spinosauridae: Sereno *et al.* 1998). The postzygapophyses do not bear epipophyses. The base of the neural spine is well compressed transversely and is supported posteriorly by spinopostzygapophyseal laminae.

Five caudal vertebrae with complete centra, and a sixth with a half centrum, are present (Fig. 6; Table 2). Taking into consideration the fact that few caudal vertebrae are preserved in the holotype of *Baryonyx walkeri* (NHM R9951), the exact position of these specimens within the tail is difficult to establish. However, we estimate their positions as one anterior, two mid-anterior, one mid-posterior, and one posterior caudal vertebra. All caudal vertebrae of Portuguese *Baryonyx* ML1190 are amphicoelous, although the posterior facet tends to be more shallowly concave. The anterior caudal centrum is hourglass-shaped in ventral view (but less so than in NHM R9951), while in posterior view, the centrum is sub-circular. The chevron facets are well visible, mainly on the ventroposterior margin of the centrum, giving a more squared shape to the outline in anterior and posterior views.

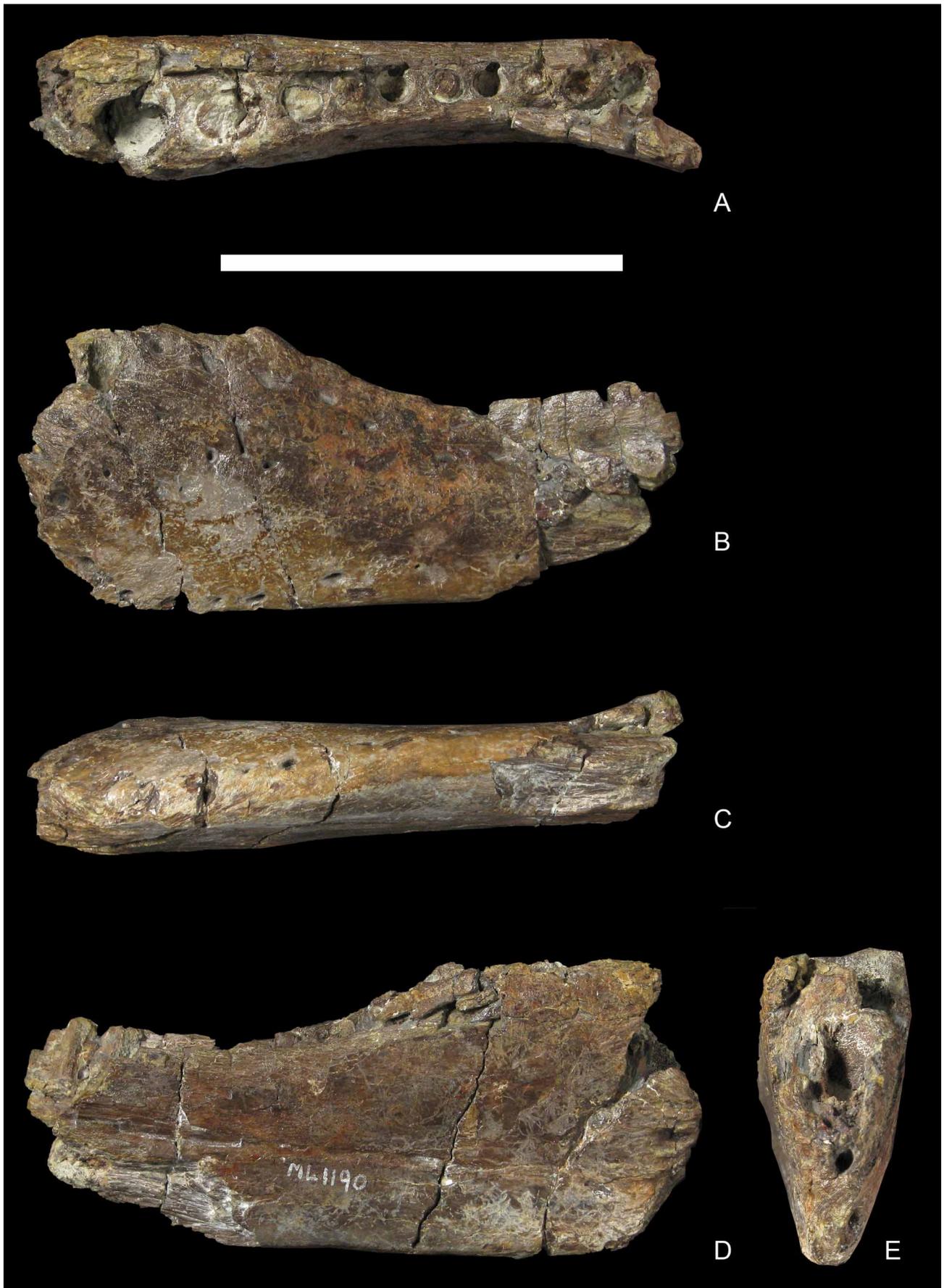


FIGURE 4. Left dentary (ML1190) of *Baryonyx walkeri* in dorsal (A), lateral (B), ventral (C), medial (D), and anterior (E) views. Scale bar: 10 cm.

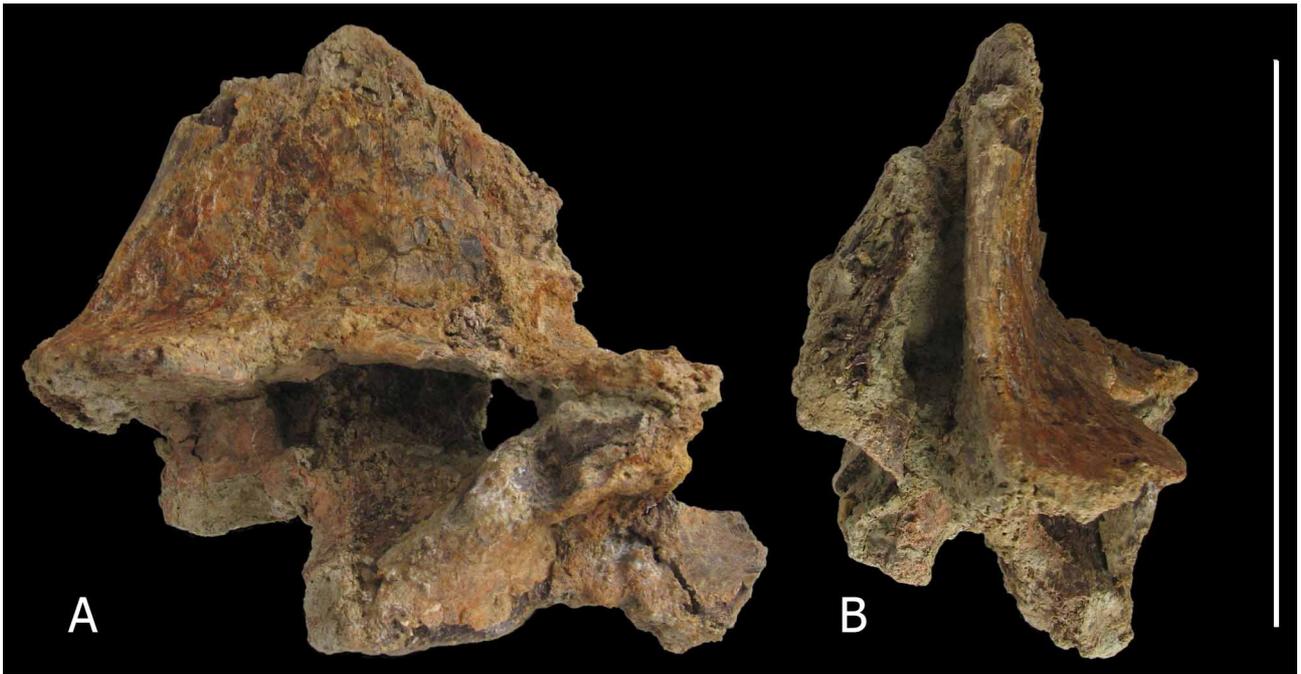


FIGURE 5. Posterior dorsal vertebral neural arch (ML1190) of *Baryonyx walkeri* Charig & Milner, 1986 in lateral (A) and posterior views (B). Scale bar: 10 cm.

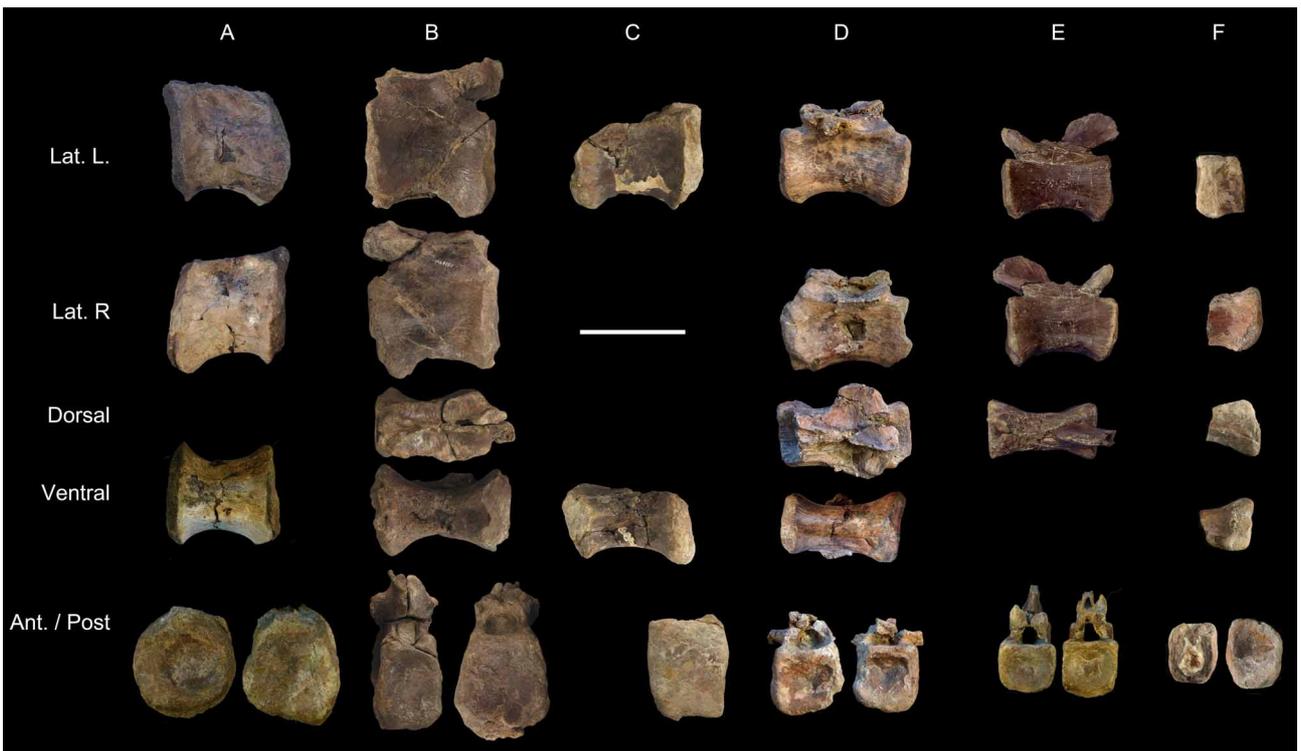


FIGURE 6. Caudal vertebrae (ML1190) of *Baryonyx walkeri* Charig & Milner, 1986. A–F, most anterior caudal vertebra (A) to more posterior vertebrae. Abbreviations: Ant./Post., anterior and posterior views; Lat.L., left lateral view; Lat. R., right lateral view. Note perforation in the lateral side of centrum D, probably due to tooth mark from a large predator or scavenger. Scale bar: 10 cm.

In all the caudal vertebrae, the ventral face of the centrum has two parallel ridges between which a deep and wide longitudinal groove extends along the midline. The groove is deepest posteriorly, where the ridges are confluent with the chevron facets.

TABLE 2. Caudal vertebral centra measurements for ML1190 (in mm).

Position in caudal series	Length	Anterior Height	Anterior Width
Anterior	95	107	101
Mid-anterior	105	81	71
Mid-anterior	104	79*	63
Mid-posterior	96	55	56
Posterior	82	48	49
Posterior	-	52*	43*

* measured for the posterior facet due to the lack of preservation anteriorly.

The anterior caudal has an unfused centrum and neural arch. The neurocentral suture is unfused in the most anterior vertebrae but is fused and visible in middle caudal vertebrae and is fused and invisible in the most posterior vertebra. This suggests a posterior-to-anterior sequence of fusion. The unfused neurocentral suture is considered a young ontogenetic feature (Brochu 1996) but is common in very large (and thus most likely adult) spinosaurids. The sutural area of the unfused centrum is much wider than the area for the neural canal itself, which is deep, narrow, and constricted in the middle. The anterior dorsal rim is prominent at the midline. The mid-posterior caudal vertebrae is the only tail vertebra to be preserved with a partial transverse process, which is placed on the posterior half of the vertebra, just above the neurocentral suture. The transverse process is a horizontal, platform-like projection supported by a centrodiaephyseal lamina.

The left side of the mid-posterior centrum has a 21 mm long elliptical pit (apparently produced post-mortem) that may correspond to an orthogonal tooth mark from a large predator or scavenger. More posterior centra have a more rectangular posterior outline, and are higher than wide. Part of the neural arch is preserved in the most posterior vertebrae. The prezygapophyses project anteroposteriorly at a 45 degree angle to the horizontal, with the small vertical prezygapophyseal facets positioned close to one another, while the postzygapophyses are partly confluent with the neural spine, which projects posterodorsally. In one posterior caudal vertebra only the posterior half of the centrum is preserved, showing the cross section of the vertebra with a hollow interior (now infilled with a calcite geode).



FIGURE 7. Dorsal ribs (ML1190) of *Baryonyx walkeri* Charig & Milner, 1986 in proximal (A), anterior (B, E), posterior (C, G), medial (D), lateral (F), and cross sectional (H) views. Scale bar: 10 cm.



FIGURE 8. *Baryonyx walkeri* Charig & Milner, 1986 (ML1190). A–C, right scapula in lateral (A), posterior (B), and medial (C) views. D–G, right pubis in anterior (D), lateral (E), posterior (F), and medial (G) views. Scale bar: 5 cm.

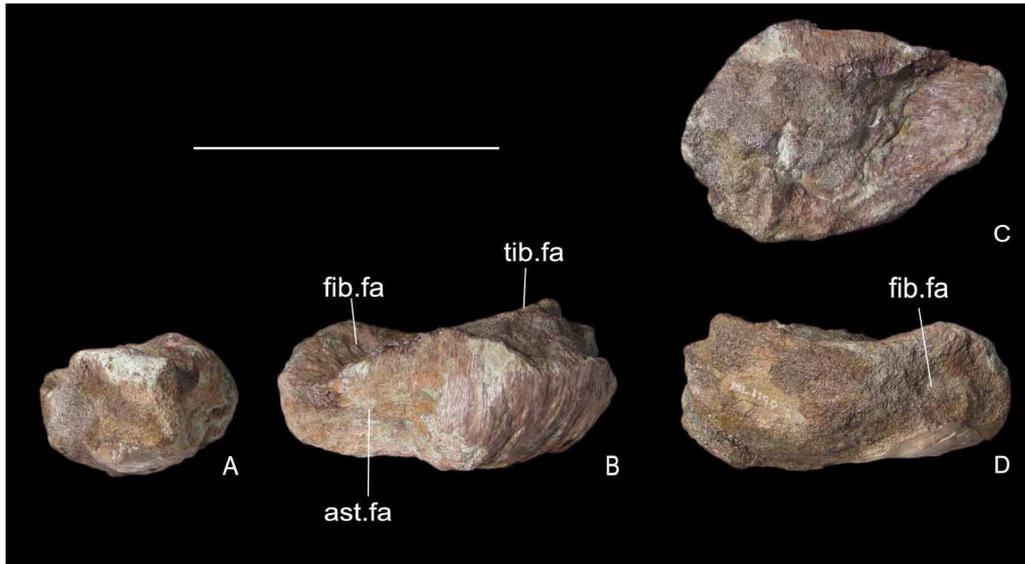


FIGURE 9. Right calcaneum of *Baryonyx walkeri* Charig & Milner, 1986 (ML1190) in anterior (A), medial (B), proximal (C), and lateral (D) views. Abbreviations: ast.fa, astragalar facet; fib.fa, fibular facet; tib.fa, tibial facet. Scale bar: 10 cm.

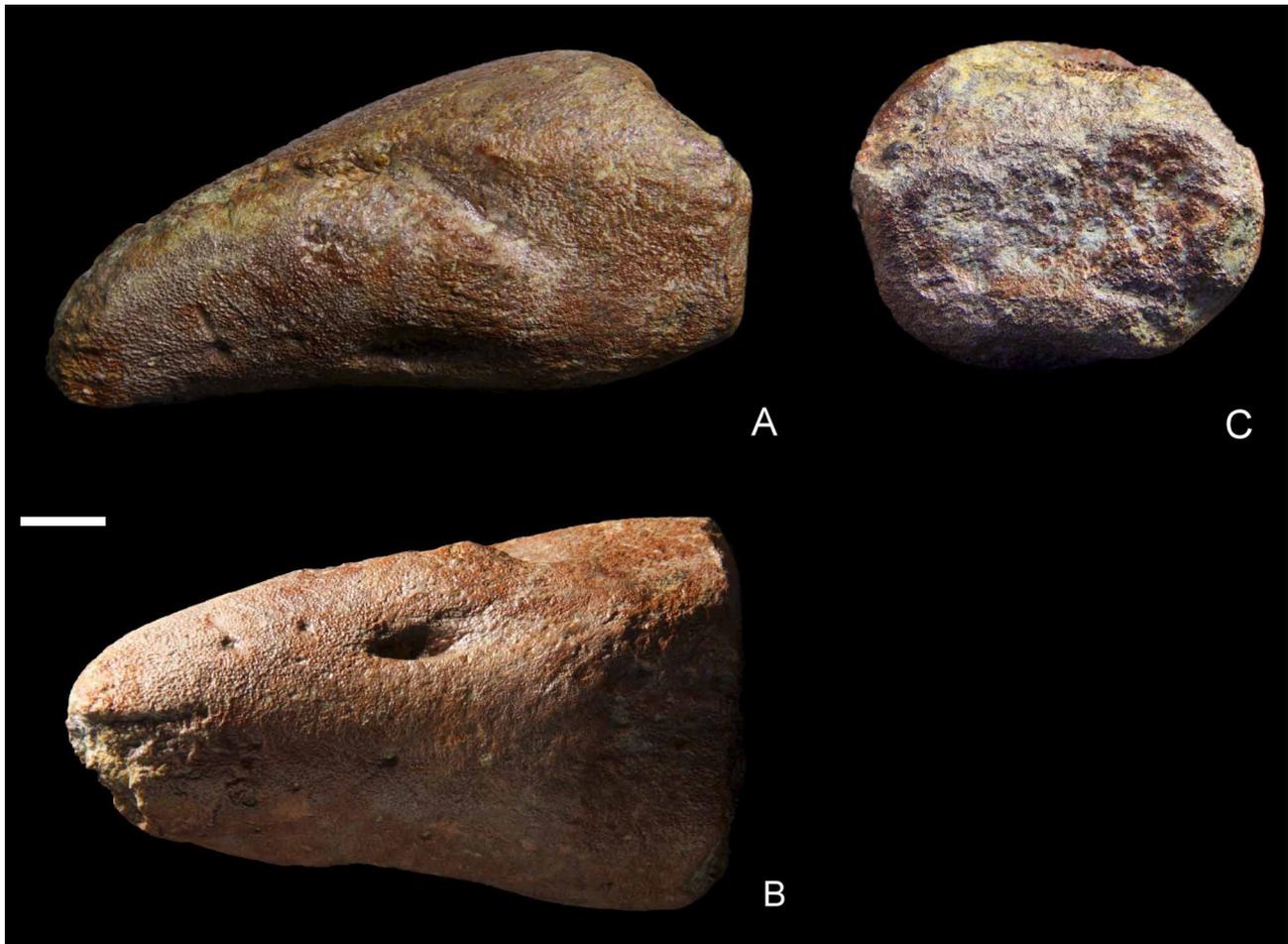


FIGURE 10. Pedal ungual phalanx of *Baryonyx walkeri* Charig & Milner, 1986 (ML1190) in lateral (A) and ventral (palmar) (B), and proximal views (C). Scale bar: 1 cm.

Several incomplete dorsal ribs are preserved (Fig. 7). The tuberculum is confluent with the shaft and the capitulum in ML 1190, whereas in NHM R9951 the tuberculum is more pronounced. The curve at the tuberculum area

is pronounced, and the inner rim bears a sharp edge or keel, rather than the typical round margin present along the rest of the rib. Proximally, the shaft is broad, being convex anteriorly and concave posteriorly, but more distally, the shaft becomes rounder in cross section. The rib head is long and at its base there are two anterior shallow grooves running along its length that produce a distinctive crest near the tuberculum. Such features are not visible in *Suchomimus tenerensis*, *Allosaurus fragilis*, *Lourinhanosaurus antunesi*, and *Ceratosaurus nasicornis*, and less evident in NHM R9951 (Gilmore 1920; Madsen 1976; Mateus 1998; Sereno *et al.* 1998).

The preserved portions of the right scapula (Fig. 8) are the proximal end and about one third of the blade, 327 mm long as preserved and 184 mm at the proximal expansion. Although only partially preserved, the scapula bears the typical curvature along its length, demonstrating that this bone would fit against the ribcage. The anterior and posterior margins of the blade are subparallel. The anterior margin is slightly thicker than the posterior margin. Proximally, the scapula is expanded relative to the blade, bearing the acromion process posteriorly and the glenoid fossa anteriorly. There is a prominent posteroventral lip that is widely distributed among theropods including *Majungasaurus crenatissimus* and *Allosaurus fragilis* as well as NHM R9951 (Madsen 1976; Charig & Milner 1997; Carrano 2007). The mediolateral thickness of the blade tends to decrease distally. The acromion process is not complete, and thus it cannot be determined whether it is of the typical subretangular shape present in *Suchomimus tenerensis* (Sereno *et al.* 1998). ML1190 shares with *Baryonyx walkeri* the well-formed peg-and-notch scapular attachment with the coracoid on its proximal surface (Charig & Milner 1997: fig. 31; autapomorphy of *Baryonyx walkeri* according to Sereno *et al.* 1998: 1302).

Only the proximal middle part of the right pubis (Fig. 8) shaft is preserved; the acetabular and distal portions are missing entirely. The preserved element measures 295 mm in length. The pubic apron is not preserved, but its medial sinuous outline, to which the main shaft of the pubis was connected, is preserved. As in NHM R9951, the middle part of the pubis is straight and compressed lateromedially at its proximal end (Charig & Milner 1997: 49) and at its distal fracture has a teardrop shaped cross section. The lateral surface of the bone is slightly concave and anteriorly there is a small mound-like process with longitudinal striations. The dorsal surface bears longitudinal striations on the distal part and forms a well-defined, rounded edge towards the proximal end. The rounded edge of the ventral surface tapers proximally.

Two calcanea are present in ML1190, each measuring 110 mm in maximum expansion (Fig. 9). The right calcaneum of NHM R9951 was figured by Charig & Milner (1997) and was used for comparison. The calcanea of ML1190 are unfused to the astragali or tibiae. Both articulation surfaces for the tibia and fibula are preserved, concave, and equivalent in area to one another. The distal and anterior surfaces are rugose with longitudinal striations. The tibial articular facet is damaged.

A single pedal ungual phalanx is preserved (Fig. 10), measuring 44 mm transversely and 78 mm in length. The shape of its proximal articular contour is roughly ellipsoidal (but slightly depressed forming a sigmoid). Thus, its overall shape might be triangular if complete. The proximoventral flexor tubercle is very reduced: it is only a smooth eminence visible in lateral view. The collateral grooves extend from the very tip of the phalanx until the distal third of the bone. Due to the relative orientation of the collateral grooves, it is presumed that this element comes from the left side of the specimen, because the lateral groove is placed more dorsally than the medial groove.

Discussion

The new specimen, ML1190, from the Early Cretaceous of Portugal is securely identified as a member of Spinosauridae because of the presence of a dentary rosette, and as a member of Baryonychinae because of the presence of conical teeth with flutes and denticles. The teeth of ML1190 share the following characters with *Baryonyx walkeri*: enamel surface with small (and nearly vertical) wrinkles, variable denticle size along the carinae, 6–7 denticles per millimetre, wrinkles forming a 45 degree angle near the carinae, and tooth root longer than crown. We therefore refer ML1190 to *Baryonyx walkeri* despite the presence of some morphological differences such as the mound-like eminence on the lateral surface of the proximal pubis, because these differences are likely within the range of regular intraspecific variation.

In the pubis of the Portuguese specimen, as in the holotype of *Baryonyx walkeri* (NHM R9951), the ventral edge tapers medially into the pubic apron (medial symphysis) (Charig & Milner 1997: 49). The sinuous outline of

the pubic apron is very similar to that of *Suchomimus tenerensis* (MNN GDF500). The flange approximates an "S"-shaped curve located proximally on the ventral side and distally on the dorsal side, that can also be seen in NHM R9951 (Charig & Milner 1997: 50). ML 1190 differs from *Suchomimus tenerensis* (MNN GDF500) because, in ventral view, the lateral margin of the pubic shaft of ML1190 is straight, as is also the case in NHM R9951 (Charig & Milner 1997: 49, fig. 39A).

Baryonyx has been previously discovered in roughly contemporaneous deposits in England, Spain and Portugal (Charig & Milner 1997; Ruiz-Omeñaca *et al.* 2005); therefore, this new specimen is within the chronological and geographical range of the genus. The occurrence of the species *Baryonyx walkeri* in the Iberian Peninsula confirms the expansion of the species into southern Europe, which was an archipelago by the Early Cretaceous (Ziegler 1988).

However, the palaeobiogeography of the Spinosauridae remains unclear, having been the subject of long debate and speculation. Sereno *et al.* (1998) suggested that spinosaurids had a worldwide distribution that subsequently, with the opening of the Tethys Sea, allowed baryonychines to evolve in Laurasia and spinosaurines in Gondwana. Buffetaut & Ouaja (2002), by contrast, have advocated a more traditional hypothesis in which Laurasian baryonychines dispersed to Gondwana, with spinosaurines subsequently evolving in the latter landmass. Ruiz-Omeñaca *et al.* (2005) suggested that baryonychines originated in Europe and migrated to Gondwana in the Barremian–Aptian. Machado & Kellner (2005) have posited that a form related to *Baryonyx* originated in Europe and then subsequently dispersed to Africa, from where Spinosaurinae spread to South America. Canudo (2006) proposed a theory of vicariant evolution for spinosaurids. The strong similarities between European and African Baryonychinae suggest that dispersal is a more likely explanation for the mechanism of distribution of this particular subfamily. Consequently, the Portuguese specimen described herein confirms the presence of Baryonychinae in the Iberian Peninsula, a crucial landmass for the dispersion of Spinosauridae from higher latitudes to lower latitudes (Milner 2003). Recent discoveries in the Early Cretaceous of China (Buffetaut *et al.* 2008) and Australia (Barrett *et al.* 2010) show that the origin and dispersal of spinosaurids is probably more complex than previously thought.

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