

New vertebral remains of the stegosaurian dinosaur *Dacentrurus* from Riodeva (Teruel, Spain)

Nuevos restos vertebrales del estegosaurio Dacentrurus en Riodeva (Teruel, España)

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ABSTRACT

The discovery of new stegosaurian remains from a site in Riodeva (Teruel, Spain) included in the Villar del Arzobispo Formation evidences the strong presence of these plated dinosaurs in the Jurassic-Cretaceous transition of the Iberian Range -specifically in the tidal and supratidal systems which gave birth to this lithostratigraphic unit. These fossils, which consist of four vertebral centra, are attributed to *Dacentrurus armatus*. Their abundance can prove that the slight variations which can be seen among different individuals -sometimes between specimens really close geographically and temporally- actually correspond to intraspecific variation of this taxon.

Key-words: Teruel, Villar del Arzobispo Formation, Stegosauria, *Dacentrurus armatus*.

RESUMEN

El hallazgo de nuevos restos de estegosaurios procedentes de un yacimiento de Riodeva (Teruel, España), incluido en la Formación Villar del Arzobispo, evidencia la notable presencia de estos dinosaurios con placas en el tránsito Jurásico-Cretácico de la Cordillera Ibérica (concretamente en los sistemas mareales y supramareales que dieron lugar a esta unidad litoestratigráfica). Los fósiles, que consisten en cuatro centros vertebrales, son atribuidos a *Dacentrurus armatus*. Esta abundancia permite demostrar que las ligeras variaciones presentes entre individuos localizados incluso en yacimientos próximos geográfica y temporalmente corresponden en realidad a variaciones intraespecíficas de este taxón.

Palabras clave: Teruel, Formación Villar del Arzobispo, estegosaurio, *Dacentrurus armatus*.

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Introduction

One of the most abundant stegosaurian dinosaurs in Europe is the genus *Dacentrurus*, present in outcrops of England, France, Portugal and Spain. In the Teruel province, located in the centre-southeast of Spain, stegosaurian bones mainly come from the Jurassic-Cretaceous transition of the Villar del Arzobispo Formation.

Several postcranial remains from the axial, pelvic girdle and appendicular skeleton of different-sized individuals assigned to aff. *Dacentrurus* come from many sites in Riodeva, such as El Romeral (RD-3), Barrihonda-El Húmero (RD-10), Prado de las Arenas (RD-16) and La Quineta 2 (RD-44) (Cobos *et al.*, 2010) and also from the site called San Cristobal (CT-28) in El Castellar, assigned to *Dacentrurus* by Cobos *et al.* (2009). Other stegosaurian remains have been discovered in the site called Están de

Colón (RD-34) (Cobos *et al.*, 2008), but this material is still undescribed.

In addition, Royo-Torres *et al.* (2008) referred partial remains from a sacrum from the locality of Jabaloyas to an undetermined thyreophoran. Probably this element belongs to a stegosaur.

Finally, the La Canaleta site from the locality of Galve yielded some undetermined stegosaurian remains. This site was considered as belonging to El Castellar Formation (Hauterivian in age) by Pereda-Suberbiola *et al.* (2005), while other authors (Royo-Torres *et al.*, 2009) locate it in the underlying Villar del Arzobispo Formation, probably being basal Berriasian in age.

In this paper we describe some stegosaurian vertebral remains, which were found grouped together *ex situ* in a new site called Barranco Conejero (RD-46), also located in the Villar del Arzobispo Formation in Riodeva (Teruel). This new site was cata-

logged in the context of the palaeontological activities carried out by the Fundación Conjunto Paleontológico de Teruel-Dinópolis in 2008 (Exp. 226/2008).

Geographical and geological setting

The fossils discussed here come from a site found in the locality of Riodeva (Teruel), administratively located in the Comarca called 'Comunidad de Teruel'.

This site is located in the South Iberian Basin, in facies from 'Sandstones, Limestones and Clays from Villar del Arzobispo' Formation (Fig. 1). This lithostratigraphic unit was defined by Mas *et al.* (1984) in the Levantine Sector of the Iberian Range, specifically in the town of Villar del Arzobispo, where it reaches a thickness up to 550 meters. In the Riodeva area, this formation features more than 200 meters in

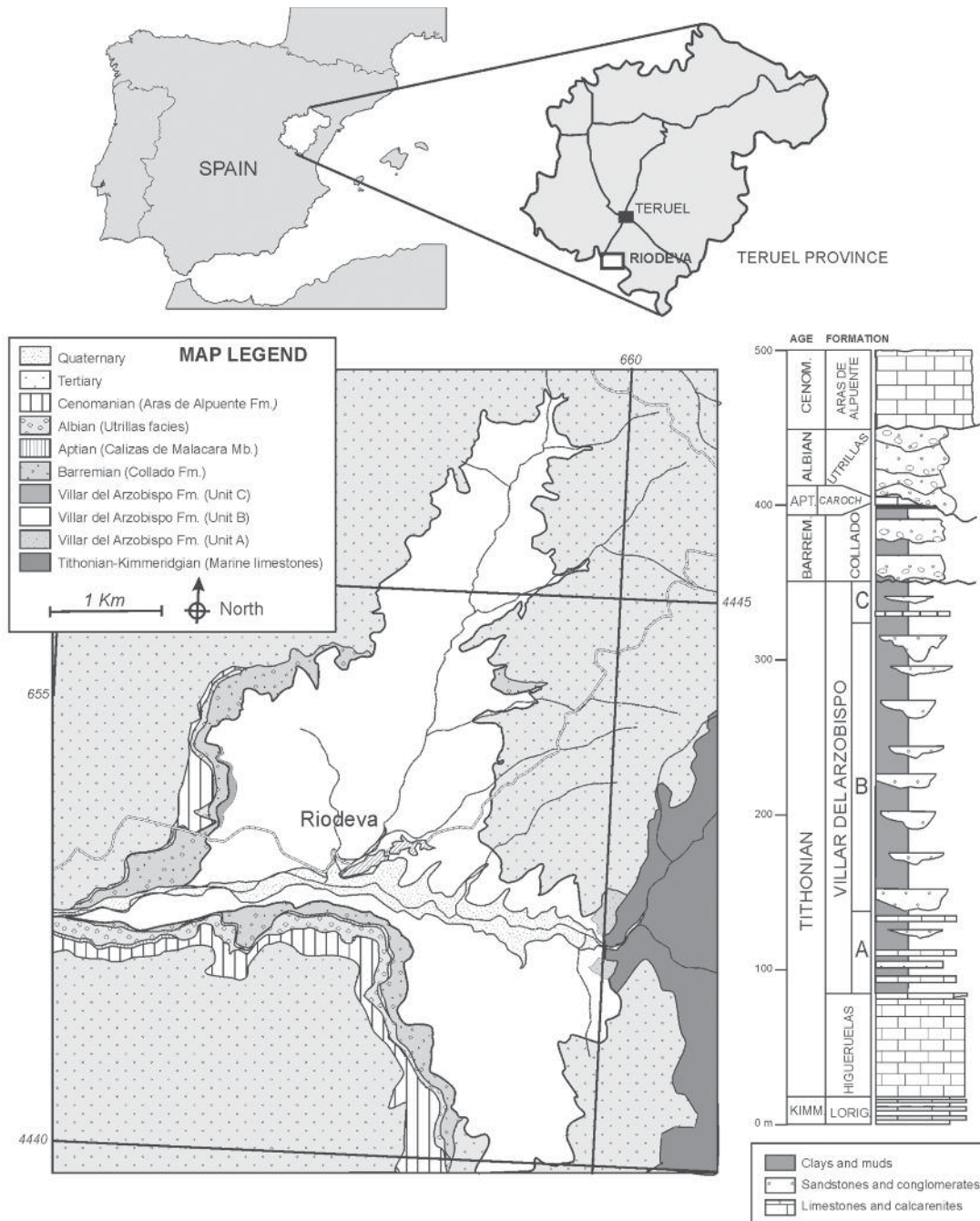


Fig. 1.- Geographical and geological setting of Riodeva. Modified from Luque *et al.* (2005).

Fig. 1.- Situación geológica y geográfica de Riodeva. Modificado de Luque *et al.* (2005).

width and it is found in relation with the underlying formation, 'Oncolithic Limestones from Higuieruelas' (Luque *et al.*, 2005). The change to the latest formation is quite gradual, representing a clear sequence of shallowing with an increase in the thicker siliciclastic material towards the top of it. The site RD-46 is located in areas of supratidal origin, in a sector dominated by sandy channelled facies and fluvial-influence lutites.

In this sector of the Iberian Range, the upper part of the Higuieruelas Formation has

been dated as basal Tithonian based on the presence of the foraminifer *Anchispirocyclus lusitanica* (Fezer, 1988). Although the lower boundary of the Villar del Arzobispo Formation is not isochronous, its age in the area of Riodeva has been dated according to stratigraphic correlations as middle-upper Tithonian although this formation can reach the basal Berriasian in other sectors of the Iberian Range according to some authors (Bádenas *et al.*, 2008-2009; Badenas and Aurell, 2010).

Systematic Palaeontology

- Dinosauria** Owen, 1842
- Ornithischia** Seeley, 1887
- Thyreophora** Nopcsa, 1915
- Stegosauria** Marsh, 1877
- Stegosauridae** Marsh, 1880
- Dacentrurus*** Lucas, 1902
- Dacentrurus armatus* (Owen, 1875)

Material

Four vertebral centra (MAP-4488, MAP-4489, MAP-4490 y MAP-4491: Fig. 2; Table I).

Locality and horizon

This material comes from a site called Barranco Conejero (RD-46) in Riodeva (Teruel, Spain). These remains were found grouped together but *ex situ*, probably fallen from a overlying sandstone level-as shown by the rock matrix present in some of the elements-. This similar preservation and their relative size suggest they belonged to the same individual. The site is located in the Villar del Arzobispo Formation. The coordinates are available at Dirección General de Patrimonio Cultural, Gobierno de Aragón.

Description

The vertebral centra MAP-4488 (Fig. 2A-B) and MAP-4489 (Fig. 2C-D) belong to two cervical vertebrae. They are slightly amphicoelous and they show a heart-shaped outline in posterior view. The anterior and posterior mediolateral widths of MAP-4489 are similar. Both centra show a concavity with a depression on the centre of their caudal face. Their general appearance is compact, with shallow depressions on their lateroventral surface. Their neural canal is wide (especially in MAP-4489) and circular in shape. In MAP-4488 the ribs were fused to the centrum -in both lateral sides part of the capitulum is preserved-. MAP-4488 shows a slightly bigger anteroposterior length than the maximum lateromedial width, which corresponds to a middle-cervical vertebrae. It is also very similar to CPT-1007 from the site El Romeral (RD-3) also in Riodeva -see Cobos *et al.* (2010)-. MAP-4489 has a lower anteroposterior length than MAP-4488 and its lateromedial width is similar,

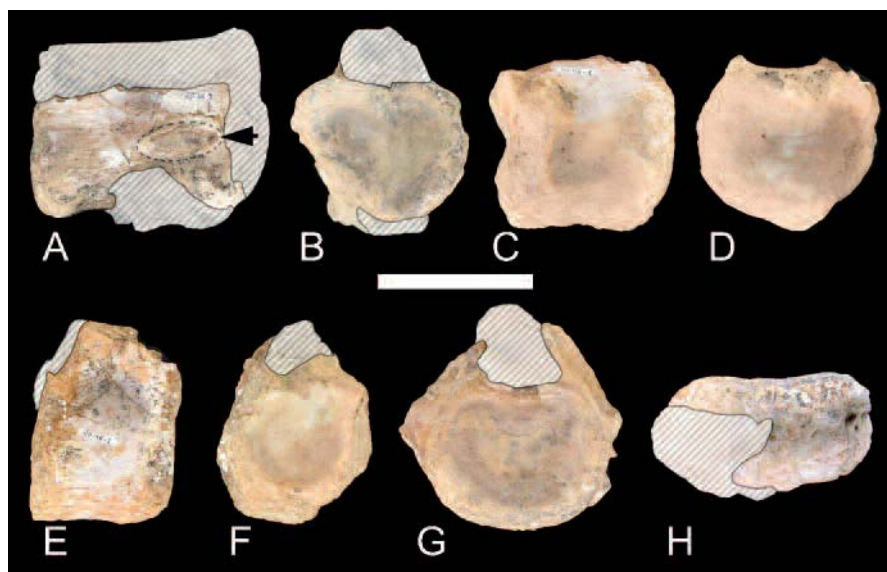


Fig. 2.- *Dacentrurus armatus* from the Barranco Conejero site (RD-46): cervical centrum (MAP-4488) in right lateral (A) and posterior (B) views; cervical centrum (MAP-4489) in right lateral (C) and posterior (D) views. The arrow points to the part of the capitulum fused to the cervical centrum; dorsal centrum (MAP-4490) in lateral (E) and anterior (F) views and caudal centrum (MAP-4491) in anterior (G) and ventral (H) views (notice MAP-4490 and 4491 preserve the base of the neural arch). The hatched area corresponds to the rock matrix. Scale bar: 10 cm.

Fig. 2.- *Dacentrurus armatus* del yacimiento Barranco Conejero (RD-46): centro cervical (MAP-4488) en vistas lateral derecha (A) y posterior (B); centro cervical (MAP-4489) en vistas lateral derecha (C) y posterior (D). La flecha indica la posición en la que parte del capitulum de la costilla cervical está fusionado al centro; centro dorsal (MAP-4490) en vistas lateral (E) y anterior (F) y centro caudal (MAP-4491) en vistas anterior (G) y ventral (H) (nótese que se conserva en ellas la base del arco neural). El área rayada corresponde a roca matriz. Escala: 10 cm.

so it is interpreted as belonging to a more posterior cervical vertebrae.

Another centrum, MAP-4490 (Fig. 2E-F) belongs to a dorsal vertebra. Its anterior face is almost flat, and the posterior face is slightly concave. As the *Dacentrurus armatus* holotype (Galton, 1985), it has a depression adjacent to the neural arch, showing a concave lateral face (the other lateral face being eroded). Although it is not complete, it can be stated that its lateromedial width is similar (although slightly bigger) to its anteroposterior length. This identifies this

centrum as belonging to a posterior dorsal vertebra.

MAP-4491 (Fig. 2G-H) shows a somewhat heart-shaped centrum and both articular faces are slightly concave. It is antero-posteriorly compressed and its maximum width is the lateromedial. It does not show articular facets for the chevrons. It is very similar to the anterior caudal centra from the site Barrionda-El Húmero (RD-10), so it is considered, to be an anterior caudal centrum (probably the third or fourth caudal vertebrae in the series).

Collection number	Element	ACH	ACW	CL	PCH	PCW
MAP-4488	Cervical centrum	85*	?	120	80	100*
MAP-4489	Cervical centrum	95	105	100	95	110
MAP-4490	Dorsal centrum	85	85*	75	85*	80*
MAP-4491	Caudal centrum	85	110	60	75*	115

Table I.- Measurements (in mm) of *Dacentrurus armatus* remains from Barranco Conejero (RD-46). ACH, anterior centrum height; ACW, anterior centrum width; CL, centrum length; PCH, posterior centrum height; PCW, posterior centrum width. Measurements marked with asterisk (*) are estimated.

Tabla I.- Medidas (en mm) de los huesos de *Dacentrurus armatus* de Barranco Conejero (RD-46). Abreviaturas: ACH, altura anterior del centro; ACW, anchura anterior del centro; CL, longitud del centro (máxima); PCH, altura posterior del centro; PCW, anchura posterior del centro. Las medidas marcadas con asterisco (*) son estimadas.

Discussion

Until 2009, when Mateus *et al.* defined *Miragaia longicollum* (characterised by its long neck and six autapomorphies mainly related to the cervical series and skull), practically all the material from the Late Jurassic and Jurassic-Cretaceous transition from the Iberian Peninsula was assigned to *Dacentrurus*. The only exception was the material assigned to *Stegosaurus* by Escaso *et al.* (2007). Mateus *et al.* (2009) also established a new clade named Dacentrurinae. This

clade would include at least two taxa: *D. armatus* and *M. longicollum*. However, Cobos *et al.* (2010) discuss that all the diagnostic characters of *M. longicollum* are based on elements not present in the *Dacentrurus* holotype, while the common characters are considered to be shared within the clade Dacentrurinae. This fact -it is impossible to differentiate the two taxa through their holotypes- and the descriptive contributions on the abundant material from Teruel and Valencia, made it possible for Cobos *et al.* (2010) to propose *Miragaia* as a synonym of *Dacentrurus*. Thus, the first taxon, *Dacentrurus*, prevails assuming all the diagnostic characters proposed by Mateus *et al.* (2009) for *Miragaia*.

With this background, the sum of all characters proposed by Galton and Upchurch (2004) and Maidment *et al.* (2008) for *Dacentrurus* and also by Mateus *et al.* (2009) for *Miragaia* is used for the systematic identification in this paper. According to Galton and Upchurch (2004) one of the diagnostic features is the fusion of cervical ribs to the centra. This characteristic is present in MAP-4488 (although, in our opinion, the most posterior cervical vertebrae do not have the ribs fused to the centra, as in the specimen ML433 from Portugal and, probably, the *Dacentrurus* holotype). Other autapomorphy from these authors and also from Maidment *et al.* (2008) is that the dorsal vertebral centra are wider transversely than longer anteroposteriorly. This feature can be seen in MAP-4490.

In addition, the anterior caudal centrum MAP-4491 is identical to those described from the site Barihonda-El Humero (RD-10) in Riodeva and attributed by Cobos *et al.* (2010) to aff. *Dacentrurus* sp. It also resembles several undescribed anterior caudal vertebrae from San Cristobal (RD-28) from El Castellar (Teruel), which belong to an individual assigned to *Dacentrurus* by Cobos *et al.* (2009). In these two last sites, both individuals show another diagnostic character for *Dacentrurus* according to Maidment *et al.* (2008): the ischium dorsal surface of the distal diaphysis is straight (the ischium of *Miragaia* is not preserved).

Therefore, the increasing abundance of stegosaurian remains in these ages from

the Teruel province leads to the conclusion that the differences and similarities between different individuals represent a case of intraspecific variability. This variability could also be due to ontogeny, sexual dimorphism or individual pathologies, as in *Kentrosaurus aethiopicus* (Barden and Maidment, 2011), or in other ornithischians such as *Hypsilophodon foxii* (Galton, 1974). For all these reasons, all the stegosaurian remains from Teruel described in Cobos *et al.* (2010) and in this paper are assigned to the stegosaurian *Dacentrurus armatus*.

Conclusions

This site has yielded four vertebral centra, which were found *ex situ* but quite close to each other. Their relative sizes and preservation indicate they could belong to the same individual. MAP-4488 and MAP-4489 belong to cervical vertebrae, MAP-4490 to a dorsal vertebrae, and MAP-4491 to a caudal vertebra. All four vertebrae are assigned to the stegosaur *Dacentrurus armatus* (here regarded as a senior synonym of *Miragaia*; see Cobos *et al.*, 2010)

These fossils, as well as other previously known in several sites from Teruel reflect the intraspecific variability of this taxon. Moreover, it shows the strong presence of this dinosaur during the Jurassic-Cretaceous transition in the Iberian Range. This is quite remarkable, since the fossil records of these plated dinosaurs was scarce until the beginning of the XXI century.

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