

First evidence of stegosaurs (Dinosauria: Thyreophora) in the Vega Formation, Kimmeridgian, Asturias, N Spain

Primera evidencia de estegosaurios (Dinosauria: Thyreophora) en la Formación Vega, Kimmeridgiense, Asturias

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ABSTRACT

We describe a dinosaur caudal centrum from an outcrop of the Vega Formation (Kimmeridgian) in Colunga (Asturias Principality, Northern Spain). It is very similar to the centra of mid-caudal vertebrae of some stegosaurs, like *Dacentrurus* and *Stegosaurus*, which are characterized by the presence of well developed haemal processes on the posteroventral corner. Because this character is not diagnostic to the generic level, the vertebral centrum is assigned to *Stegosauria* indet. This is the first evidence of stegosaurs in this geological formation.

Key-words: Iberian Peninsula, Late Jurassic, caudal vertebra, *Dacentrurus*, *Stegosaurus*.

RESUMEN

Se describe un centro vertebral caudal de dinosaurio procedente de un afloramiento de la Formación Vega (Kimmeridgiense) en Colunga (Asturias). Es muy similar a los centros de vértebras caudales medias de algunos estegosaurios, como *Dacentrurus* y *Stegosaurus*, que se caracterizan por la presencia de procesos hemales posteroventrales, pero no es diagnóstica a nivel de género, por lo que se asigna a *Stegosauria* indet. Constituye la primera evidencia de estegosaurios en esta formación geológica.

Palabras clave: Península Ibérica, Jurásico Superior, vértebra caudal, *Dacentrurus*, *Stegosaurus*.

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Introduction

Stegosaurian fossils are relatively frequent in the Late Jurassic of the Iberian Peninsula. Three genera have been cited up to now: *Dacentrurus* Lucas 1902, *Stegosaurus* Marsh 1877 and *Miragaia* Mateus, Maidment *et* Christiansen 2009.

Dacentrurus has been described in both Portugal and Spain. Portuguese remains have been recovered since the 1940's in the districts of Leiria and Lisboa (Galton, 1991; see also Escaso *et al.*, 2007b, Maidment *et al.*, 2008 and references).

Spanish remains, discovered since 1995 to now, come from Valencia, Teruel and, with reservations, Burgos provinces (Company *et al.*, 2010, and references therein). Maidment *et al.* (2008; p. 372) have re-

garded all the Iberian material previously assigned to *Dacentrurus armatus* (Owen 1875) as *Dacentrurus* sp.

Stegosaurus and *Miragaia* are exclusive of Portugal:

Stegosaurus cf. *ungulatus* has been described in the Kimmeridgian-lower Tithonian (Alcobaça Formation) of Leiria district, Portugal (Escaso *et al.*, 2007a; later assigned to *Stegosaurus armatus* Marsh 1877 by Maidment *et al.*, 2008), and *Stegosaurus* sp. has been described in the upper Kimmeridgian-lower Tithonian (Lourinhã Group) of Leiria and Lisbon districts (Escaso *et al.*, 2008a, 2008b).

Miragaia longicollum Mateus, Maidment *et* Christiansen 2009, the type and only known species of the genus, comes from the upper Kimmeridgian-lower Titho-

nian (Sobral Formation) of Lisbon district (Mateus *et al.*, 2009).

In Asturias, stegosaur evidences have been found in Tereñes and Lastres formations (Kimmeridgian), which have provided prints and trackways assigned to the ichnogenus *Deltapodus* (García-Ramos *et al.*, 2008; Lockley *et al.*, 2008). A locality in the Lastres Formation (La Escalera, Villaviciosa) contains the only body fossils described up to now, assigned to *Dacentrurinae* indet. (see Company *et al.*, 2010: Table 1).

In this paper we describe an isolated vertebral centrum from the Vega Formation. This is the first evidence of stegosaurs in that formation, where, hitherto, only theropod and sauropod remains have been described.

Geographical and geological location

The vertebral centrum described here was found in 2003 by one of us (L.P.) in the removed materials of the Vega Formation that crop out 1.7 km north of the town of Colunga (Asturias Principality, Northern Spain), when the access road that leads to the *Museo del Jurásico de Asturias* (Jurassic Museum of Asturias), opened April 2004, was in construction.

The Vega Formation is a fluvial unit in the base of the Ribadesella Group, an Upper Jurassic succession made up by four formations (Vega, La Ñora, Tereñes and Lastres) that crops out in the Gijón-Villaviciosa Basin, in the northern sector of Asturias.

The Vega Formation has been dated as Kimmeridgian according to ostracods and charophytes found in the sections of Playa de Vega and Ribadesella (see Schudack and Schudack, 2002, and references therein), east of Colunga.

Systematic palaeontology

Dinosauria Owen 1842

Ornithischia Seeley 1888

Stegosauria Marsh 1877

Stegosauria indet. (Fig. 1)

Material and provenance

One isolated caudal centrum from Colunga (Asturias Principality, Spain), housed in the Museo del Jurásico de Asturias (MUJA-1271). Vega Formation, Upper Jurassic, Kimmeridgian.

Description

MUJA-1271 is a partial centrum that preserves the right lateral and ventral sides, and the half of the proximal and distal ends. The missing parts of the vertebra (left half of the centrum and, probably, the neural arch) were destroyed by the construction vehicles that excavated the access road to the MUJA.

The matrix that surrounded the centrum had a small crocodylomorph crown tooth (8 mm high) that was removed during the preparation.

The centrum measures 87 mm in anteroposterior length (measured ventrally) and 100 mm in dorsoventral height (measured over the posterior end).

The preserved width of the posterior articular face is 87 mm, but the estimated total width of this articular surface would be 104 mm (calculated by duplicating the width of the right half measured from the center of that face). So, the centrum is slightly wider than high, and higher than long.

Both articular surfaces are slightly concave, so the centrum is amphicoelous. The excavation on the posterior surface is deeper than on the anterior one, which is nearly flat (Fig. 1A, 1C).

The form of both articular faces is not fully observable, but it seems to be subhexagonal to circular. Concentric rings are developed in the external edges of both articular faces, and are more marked on the ventral edge.

The lateral side (Fig. 1B) is dorso-ventrally convex and anteroposteriorly concave, and small nutrient foramina are randomly distributed. On the right side there is a transverse process (Fig. 1C: "tp"). It is placed very high on the centrum, possibly near the base of the pedicels of the neural arch, which are not preserved.

The transverse process is inclined, so its anterior edge is above the level of the posterior one; it forms an angle of about 30° with the horizontal.

The transverse process is anteroposteriorly elongated and its anterior edge is broken. It measures, as preserved, 30 mm anteroposteriorly, 20 mm lateromedially, and 15 mm dorsoventrally.

MUJA-1271 shows evidence of a proximodorsal projection on the transverse process (Fig. 1B, 1C; "dorsal process" in Galton and Upchurch, 2004). However, this part of the centrum is not well preserved and the size of this projection can not be established, but it will be small, as is the case in *Dacentrurus* (Galton and Upchurch, 2004; p. 353).

The dorsal side is not preserved, so it is not known if the neural arch was or was not fused to the centrum. In the dorsal most preserved part of the right lateral side there is a shallow elongated depression over the transverse process.

The ventral side (Fig. 1D) is lateromedially flat and anteroposteriorly concave, and presents facets for the chevrons. On both ends, right and left facets are differentiated. The posterior facets are much more marked than the anterior ones and form true protuberances or tubercles on the posteroventral

surface (Fig. 1B: "ch", 1D). These protuberances are called "hemal processes" by Galton (1985; p. 220), and are not developed on the anteroventral surface.

In ventral view, the haemal processes are triangular in shape (Fig. 1D). They measure 25 mm antero-posteriorly, 20 mm lateromedially and 8 mm dorsoventrally.

Discussion

MUJA-1271 has been identified as a mid-caudal centrum by the presence of 1) facets for chevrons, and 2) a reduced transverse process. The anterior most caudals have no chevron facets and the posterior most ones have no transverse processes (Gilmore, 1914; Galton, 1985; Galton and Upchurch, 2004).

Among dinosaurs, the presence of proximodorsal projections in the transverse process is exclusive of stegosaurs. These structures are always developed in the anterior half of the transverse process and so they permit to orientate the centrum.

The most striking feature of this vertebra is the presence of well-developed facets for chevrons (haemal processes) on the posteroventral corner.

According to Galton and Upchurch (2004; p. 353), in stegosaurian caudals "the proximal chevron facet is usually much smaller than the distal chevron facet and well separated from it". This feature and the general morphology (and size) of the caudal vertebra are coherent with its assignment to Stegosauria. In ankylosaurs, the chevron facets of the caudal vertebrae are commonly less marked, and there is no evidence of a proximodorsal projection in the transverse process.

The Late Jurassic record of ankylosaurs in Europe is rather scarce as compared to that of stegosaurs, with only a few discoveries, including the material of *Dracopelta* Galton 1980 from the Tithonian of Portugal (but no caudal vertebrae are known; see Galton, 1983). In Asturias, stegosaurs have been described so far in Late Jurassic sites on the basis of both osteological and ichnological evidences, whereas ankylosaurs are currently unknown.

Haemal processes were already mentioned and figured by Owen (1875) and Marsh (1880) in the first published description of *Omosaurus armatus* Owen 1875 and of *Stegosaurus unguatus* Marsh 1879.

Owen (1875; p. 55) wrote on this re-

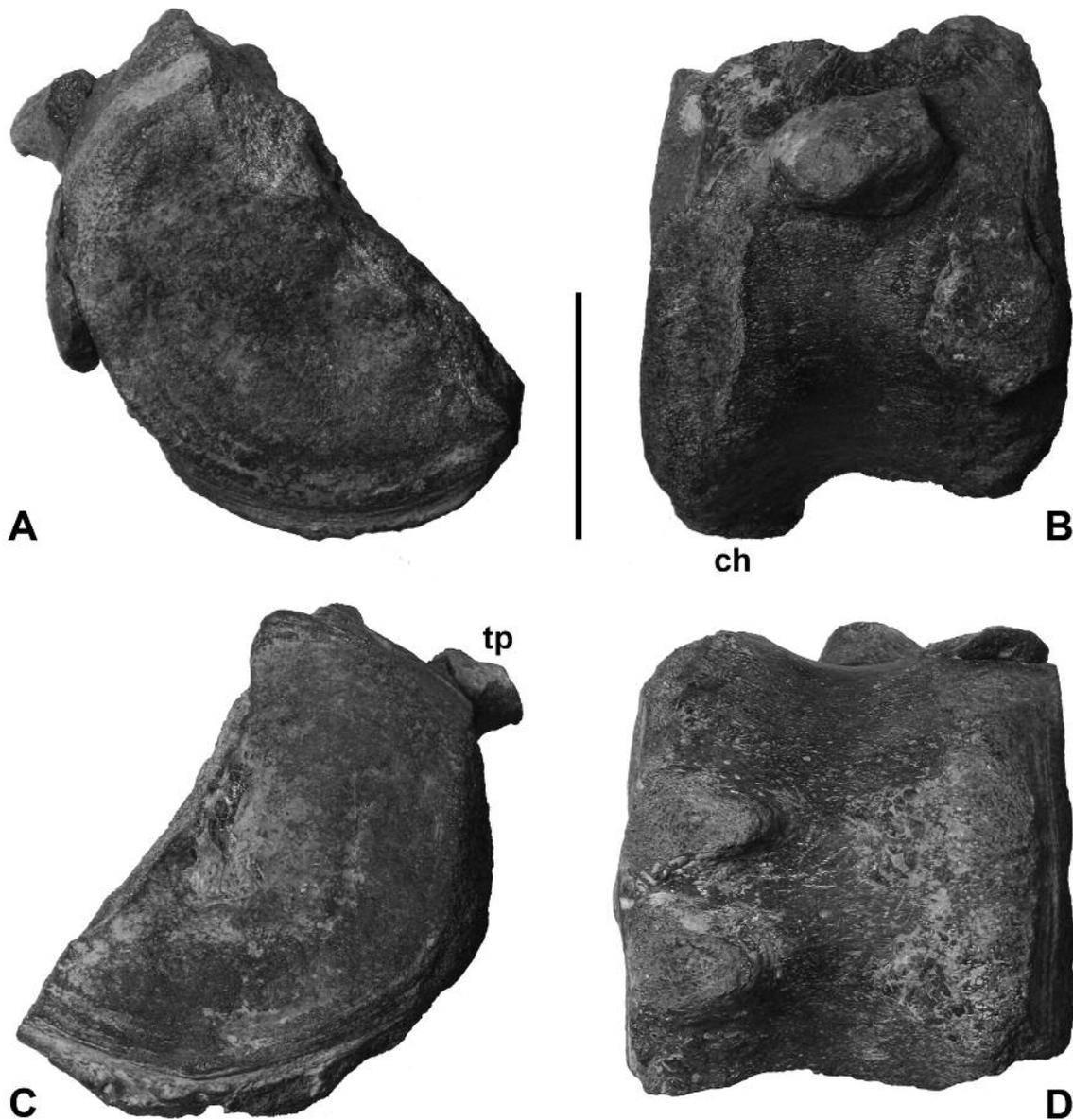


Fig. 1.- MUJA-1271. Mid-caudal centrum of *Stegosauria* indet. from Colunga (Asturias, N Spain), in anterior (A), right lateral (B), posterior (C) and ventral (D) views. Scale bar = 50 mm. Abbreviations: ch, processes for chevron; tp, transverse process.

Fig. 1.- MUJA-1271. Centro caudal medio de *Stegosauria* indet. procedente de Colunga (Asturias, norte de España), en vistas anterior (A), lateral derecha (B), posterior (C) y ventral (D). La escala son 50 mm. Abreviaturas: ch, procesos para el chevron; tp, proceso transversal.

spect that in mid-caudal vertebrae “hypophyses are more distinctly marked. These articular protuberances form a pair at the hind border of the inferior surface of the centrum; the articular tracts at the fore border of that surface are barely defined”.

Marsh (1880; p. 256) noted that “in the median caudals ... the faces for chevrons are placed on prominent tubercles on the postero-inferior surface”.

The record of stegosaurs in the Middle and Late Jurassic of Europe is made of several genera:

- *Dacentrurus* (type species *Omosaurus armatus* from the Kimmeridgian [Lower Kimmeridge Clay] of Wiltshire, U.K.; in-

cluding *Omosaurus lennieri* Nopcsa 1911 from the lower Kimmeridgian [Argiles d’Octeville] of Normandy, France, see Galton 1985, 1991),

- *Loricatosaurus* Maidment, Norman, Barrett *et* Upchurch 2008 (type species *Stegosaurus priscus* Nopcsa 1911, from the Callovian [Oxford Clay] of Cambridgeshire, U.K.; this species was previously referred to *Lexovisaurus durobrivensis* (Hulke 1887) by Galton, 1985, and Galton and Upchurch, 2004, see discussion in Maidment *et al.*, 2008),
- *Stegosaurus* (*Stegosaurus* cf. *ungulatus* and *Stegosaurus* sp. in the Upper Jurassic of Portugal, see above), and

- *Miragaia* (type species *Miragaia longicollum* in the Upper Jurassic of Portugal, see above).

Lexovisaurus Hoffstetter 1957 (type species *Omosaurus durobrivensis* from the Callovian [Oxford Clay] of Cambridgeshire, U.K.) has been recently regarded as a *nomen dubium* (Maidment *et al.*, 2008; but see Buffetaut and Morel, 2009).

Other historical species of the stegosaurian genus *Omosaurus* Owen 1875 (preoccupied by the phytosaur *Omosaurus* Leidy 1856) are now also regarded as *nomen dubia* (see Maidment *et al.*, 2008 for details): *Omosaurus hastiger* Owen 1877, *Omosaurus phillipsi* Seeley 1892-1893,

Omosaurus leedsi Seeley in von Huene 1901, and *Omosaurus vetustus* Huene 1910.

Caudal vertebrae are known in *Dacentrurus*, *Stegosaurus* and *Loricatosaurus* but not in *Miragaia*.

Loricatosaurus has an autapomorphy in their proximal and mid-caudal vertebrae, which have "large proximal chevron facet that unites with the distal one to give a V-shaped centrum" (Galton and Upchurch, 2004; p. 359 as *Lexovisaurus*; see Maidment *et al.*, 2008; p. 83). In MUJA-1271, the proximal chevron facets are poorly developed so the vertebra do not pertain to *Loricatosaurus*.

Whether valid or not, the holotype of *Lexovisaurus durobrivensis* does not preserve caudal vertebrae, so it is not possible to know if they were like those of *Loricatosaurus priscus*.

MUJA-1271 is similar to the figured mid-caudal vertebrae of both *Dacentrus armatus* from the U.K. (Owen, 1875: plate 16, figs. 1-2; Galton, 1985: figs. 20, 7H-J, 8J-O, 12U-X) and *Stegosaurus unguatus* from the USA (Marsh, 1880: plate 7, figs. 7-8; Gilmore, 1914: fig. 28; Ostrom and McIntosh, 1999: plates 28, 29).

Compared to *Dacentrus armatus*, MUJA-1271 is, by its dorsally placed transverse process, more similar to the caudals posterior to 6th-7th (Galton, 1985: fig. 8M-O) than to the 6th-7th caudal itself (Galton, 1985: fig. 8J-L) or even to the more anterior caudals ones that have no chevron facets (Galton, 1985: fig. 8A-I).

In the Iberian Peninsula several caudal vertebrae assigned to *Dacentrurus* have been cited and described (see Galton, 1991, Escaso *et al.*, 2008a for Portugal, and Company *et al.*, 2010: Table 1 and references for Spain) but none of them are mid-caudals, so a comparison is not possible.

A partial skeleton from Casal Novo locality in Batalha (Leiria district, Portugal), described by Escaso *et al.* (2007a) as *Stegosaurus* cf. *unguatus*, preserves a mid-caudal vertebra [Laboratório de História Natural da Batalha, LHN(CN)-1-02]. It represents, up to now, the only stegosaur mid-caudal described in the Iberian Peninsula.

MUJA-1271 is very similar to the above-mentioned vertebra (Escaso *et al.* 2007a:

fig. 2L; more views of the same vertebra in Escaso Santos, 2005: plate 12, figs. A-E), but less complete. Escaso Santos (2005; p. 21) identified this vertebra as possibly the 11th-12th caudal vertebra because of the absence of a "dorsal process" on the transverse process (Galton and Upchurch, 2004; p. 353). MUJA-1271 preserves a small "dorsal process" (see description), so it is possible that it comes from a more anterior position among the mid-caudal series.

Escaso Santos (2005, plate 2, figs. F-J) also figured another centrum that he identifies as a mid-caudal [LHN(CN)-1-08]. However, it has no transverse processes and it is probably a distal caudal.

The observed characters do not permit us to distinguish *Dacentrurus* mid-caudal centra from *Stegosaurus* ones. As both genera are present in the Kimmeridgian of the Iberian Peninsula, MUJA-1271 is assigned to *Stegosauria* indet.

Conclusions

A mid-caudal centrum with peculiar posteroventral processes for the chevron is described. It comes from an outcrop of the Vega Formation (Upper Jurassic, Kimmeridgian) in Colunga (Asturias Principality, North Spain). It has been identified as belonging to a stegosaur, and is the first evidence of this group of dinosaurs in the Vega Formation.

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