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RESEARCH ARTICLE

A distal femur end of a Stegosauria dinosaur from the Upper Jurassic (Tithonian) of the Cameros Basin (Aguilar del Río Alhama, La Rioja province, Spain)

Terminación distal del fémur de un dinosaurio Stegosauria del Jurásico superior (Titoniense) de la Cuenca de Cameros (Aguilar del Río Alhama, La Rioja, España)

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Key points

The distal end of the femur of a dinosaur from the Cameros Basin is described.

The specimen could belong to a stegosaurid dinosaur, probably close to the genera *Stegosaurus* and *Dacentrurus*.

This finding constitutes the first osteological remain of the Stegosauria clade in the eastern sector of the Cameros Basin.

ABSTRACT

This paper describes the distal end of the femur of a dinosaur from the Upper Jurassic of Aguilar del Río Alhama (La Rioja), in the eastern part of the Cameros Basin. Discovered in 2001, it has unfortunately been delocalized for many years, so that it has not been possible to provide an adequate description and interpretation of it before. Although the material is very fragmentary, the morphology of both condyles (tibial and fibular) is well observed. The shallow intercondylar groove, the clearly bilobulated and very wide morphology in distal view, as well as the morphometric indices analyzed, indicate that this specimen could belong to a stegosaurid dinosaur, probably close to the genera *Stegosaurus* and *Dacentrurus*. The area of the tibial condyle (mostly on its anterior face) presents a fracture of tectonic origin that is filled with quartz and calcite crystals. This finding constitutes the first osteological remain of the Stegosauria clade in the eastern sector of the Cameros Basin which, together with some ichnites of thyreophorans already known in this area, represents a significant complement on the presence of stegosaurian dinosaurs in the vertebrate communities of the last phase of the Jurassic in the Cameros Basin.

Keywords: Dinosauria, Stegosaurs, Jurassic, Tithonian, Cameros Basin, Spain.

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Puntos clave

Se describe la terminación distal del fémur de un dinosaurio encontrado en la Cuenca de Cameros.

El ejemplar podría pertenecer a un dinosaurio estegosaurio, probablemente cercano a los géneros *Stegosaurus* y *Dacentrurus.*

El hallazgo constituye el primer resto osteológico del clado Stegosauria en el sector oriental de la Cuenca de Cameros.

RESUMEN

Se describe en este trabajo un fragmento distal del fémur de un dinosaurio procedente del Jurásico superior de Aguilar del Río Alhama (La Rioja), en la zona oriental de la Cuenca de Cameros. Descubierto en el año 2001, desafortunadamente ha estado deslocalizado durante muchos años, de modo que no ha sido posible antes proporcionar una adecuada descripción e interpretación del mismo. Aunque el material es muy fragmentario, se observa bien la morfología de ambos cóndilos (tibial y fibular). El surco intercondilar poco profundo, la morfología claramente bilobulada y muy ancha en vista distal, así como los índices morfométricos analizados, sugieren que este ejemplar podría pertenecer a un dinosaurio estegosáurido, probablemente cercano a los géneros *Stegosaurus* y *Dacentrurus*. La zona del cóndilo tibial (mayoritariamente en su cara anterior) presenta una fractura de origen tectónico que está rellena por cristales de cuarzo y de calcita. Este hallazgo constituye el primer resto osteológico del clado Stegosauria en el sector oriental de la Cuenca de Cameros lo que, unido a algunas icnitas de tireóforos ya conocidas en esta área, supone un complemento significativo sobre la presencia de dinosaurios estegosaurios en las comunidades de vertebrados de la última fase del Jurásico en la Cuenca de Cameros.

Palabras clave: Dinosauria; Estegosaurios; Jurásico; Titoniense; Cuenca de Cameros, España.

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1. Introduction

The Cameros Basin represents one of the most interesting regions to study the paleobiological and paleogeographical circumstances of the European vertebrate communities during most of the Lower Cretaceous and it is well-known for its more than a hundred of dinosaur tracksites (Moratalla, 1993; Pérez-Lorente, 2015; Hernán, 2018). This region is divided into two large sub-basins: the Western and the Eastern presenting rather different tectonic, sedimentological and stratigraphic conditions (Mas *et al.*, 2004; Moratalla and Hernán, 2010; Hernán, 2018). Thus, while in the western sector there are much more osteological localities (Pereda-Suberbiola *et al.*, 2003b; Torcida *et al.*, 2011; Torcida *et al.*, 2017), in the eastern sector the opposite seems to be true, with numerous dinosaur tracksites in the provinces of Soria and La Rioja. Thus, the scarcity of bone remains in the eastern sector of Cameros makes each finding of special importance, no matter how modest and fragmentary the material is, as is the case of the present study.

However, this does not mean that the records are exclusive in both sub-basins. In fact, there are very interesting track localities in the western sector (Burgos province) (Platt and Meyer, 1991; Moratalla *et al.*, 1994; Torcida *et al.*, 2006; Huerta *et al.*, 2012; Torcida *et al.*, 2015) and, for example, also some osteological remains of fish and diverse archosaurs in the eastern sector (Viera and Torres, 1995; Bermúdez-Rochas *et al.*, 2006; Fuentes Vidarte and Meijide Calvo, 2010; Pereda-Suberbiola *et al.*, 2012).

Although there has been a significant increase in the number of findings of stegosaur remains in the European record (Escaso *et al.*, 2007; Ruiz-Omeñaca *et al.*, 2009; Mampel *et al.*, 2011; Alcalá *et al.*, 2012; Cobos *et al.*, 2012; Cobos and Gascó, 2013; Costa and Mateus, 2019; Sánchez-Fenollosa *et al.*, 2022), the remains of these dinosaurs in the Iberian Peninsula are not as abundant as perhaps those of others and they are rather represented by fragmentary findings of partial skeletons (Pereda-Suberbiola and Galton, 2001). Most of these materials come from deposits mainly from the Upper Jurassic, which is highly expected for this group of thyreophorans. Perhaps the most representive area in the Iberian Peninsula is the Lusitanian Basin, in the Lourinhá area (Portugal) (Lapparent and Zbyszewski, 1957; Galton, 1981; Galton, 1990, 1991). To this we must add also remarkable discoveries, where the genus *Miragaia* stands out (Mateus *et al.*, 2009) or the presence in Iberia of the genus *Stegosaurus*, which leads to interesting paleogeographic implications (Escaso *et al.*, 2007). However, *Miragaia* seems to be a problematic taxon due to some authors consider it as similar to *Dacentrurus* (Maidment *et al.*, 2015). In Spain, stegosaur remains were already known from the region of Los Serranos (Valencia) (Casanovas *et al.*, 1995a, 1995b, 1997 and 1999) assigned to *Dacentrurus*. Posteriorly, fragmentary remains tentatively assigned to stegosaurs from the same area, have also been cited (Company *et al.*, 2009; Suñer and Martín, 2009; Company *et al.*, 2010; Sánchez-Fenollosa *et al.*, 2022). However, the most complete remains come perhaps from the Villar del Arzobispo Formation (Teruel) (Cobos *et al.*, 2010) where the presence of the genus *Dacentrurus* stands out. Stegosaurian remains have also been reported from the Lower Cretaceous of Castellote (Teruel province) (Ruiz-Omeñaca, 2000).

The increasingly evident presence of stegosaur bone remains in the Iberian Peninsula suggests their possible reflection also in the paleoichnological record. And, indeed, it seems clear that stegosaurs left a good ichnological record in the Upper Jurassic of Asturias, with the presence of well-preserved trackways in the Ribadesella area (García-Ramos *et al.*, 2007, 2008; Piñuela, 2015). But, in addition, we must also mention the presence of well-preserved stegosaur trackways in the Jurassic-Cretaceous transition in the Teruel area, specifically in the Villar del Arzobispo Formation of the El Castellar locality (Cobos *et al.*, 2010).

The findings of thyreophoran dinosaur prints have also been extended to the Cameros Basin, where stegosaur tracks were cited for the first time from two localities in the province of Soria: Valloria (Pascual *et al.*, 2012) and San Felices (Pascual-Arribas and Hernández-Medrano, 2015). While the San Felices tracks are included in the Magaña Fm. (Tithonian), the Valloria footprints belong to the Huérteles Fm., considered as Berriasian by Gómez Fernández and Meléndez (1994) and mostly accepted as such (Moratalla and Hernán, 2010; Hernán, 2018). This fact is interesting because it would confirm the presence of stegosaurs well into the Cretaceous of the Cameros area. Beyond these findings, no other stegosaur tracks have been found in other Berriasian sites in Cameros nor in the more modern and abundant localities of the Enciso Group (Upper Barremian-Lower Aptian). This absence of stegosaur tracks from such Cretaceous period -as well as the data from the general fossil record-suggests the decline of this group of thyreophorans during the Cretaceous (Galton 1981, 1997), although some species could be present even during the Late Cretaceous (Yadagiri and Ayyasami, 1979).

The aim of this work is to report the existence of a fragment femoral distal end identified as Stegosauria and to evidence the presence of these thyreophoran dinosaurs in the Upper Jurassic of the Eastern Cameros Basin. The fragment was found in the area of La Llana (Aguilar del Río Alhama) in 2001. Although a brief preliminary review had been carried out as a report (Moratalla *et al.*, 2001), due to location and identification problems related with the specimen, it is not until now that we provide a more detailed description.

2. Geographical and geological framework

The osteological fragment object of this study was found in 2001 by Santiago Jiménez (Iberdrola company), Ramón Martínez (then mayor of Aguilar del Río Alhama) and some volunteers near the LR-284 road that connects the town of Aguilar with San Felices (Figure 1). The specimen was found isolated, that is, not included in any of the stratigraphic levels that constitute intercalations of sandstones and micro-conglomerates that characterize the site. This fact made it impossible to precisely locate the stratigraphic level of origin.

The area where the specimen was located (La Llana) is a small outcrop that belongs to the Tera Group and, specifically, to the Magaña Formation, Tithonian in age (Guiraud and Seguret, 1985). This Formation is predominantly made up of fluvial clastic deposits, represented by shales with intercalations of sandstones and occasionally conglomerates. There are also some palustrine-lacustrine carbonate deposits represented by micritic and oncolitic limestones with frequent nodulized levels (Mas *et al.*, 2004).

The complex is part of the J 10.2 depositional sequence of the Iberian Mesozoic Basin (Salas *et al.*, 2001) which belongs to the second syn-rift phase (Upper Jurassic-Lower Cretaceous) (Figure 2). It also presents a zone with low to very low grade of metamorphism and frequent associated pyrite deposits (Mas *et al.*, 2004).

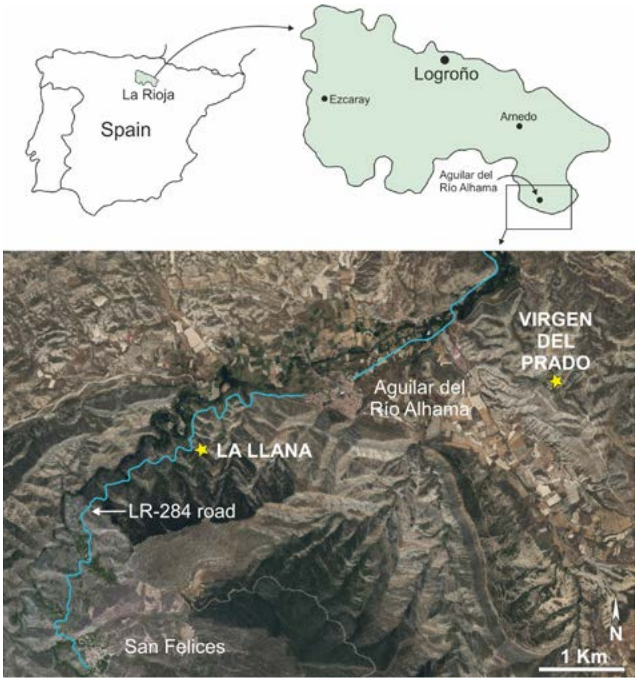

Figure 1. Geographical location of the site, called La Llana, where the dinosaur bone of this work was found in the municipality of Aguilar del Río Alhama (La Rioja, Spain). The site of dinosaur ichnites at Virgen del Prado has also been pointed out.

Figura 1. Situación geográfica del yacimiento, denominado La Llana, donde fue hallado el hueso de dinosaurio de este trabajo, en el término municipal de Aguilar del Río Alhama (La Rioja, España). Se ha señalado también en el mapa el yacimiento de icnitas de dinosaurios de Virgen del Prado.

3. Material and provenance

LLA-1-001 consists of a distal end of a Stegosauria dinosaur right femur. This fossil bone is provisionally holded in the Museo Geominero (Instituto Geológico y Minero de España, IGME-CSIC) in Madrid City, Spain.

The bone material has been restored by the technical staff of the Restoration Laboratory of the Museo Geominero (IGME-CSIC).

4. Statistical analysis

Morphometric comparison was carried out using PAST software (Hammer *et al.*, 2001) by means of 3 computational algorithms:

1) Bivariate linear regression analysis, using the Ordinary LS algorithm.
2) Bivariate nonlinear regression analysis, using two alternative calculations:

   a) Power allometric equation.
   b) Logistic Sigmoidal.

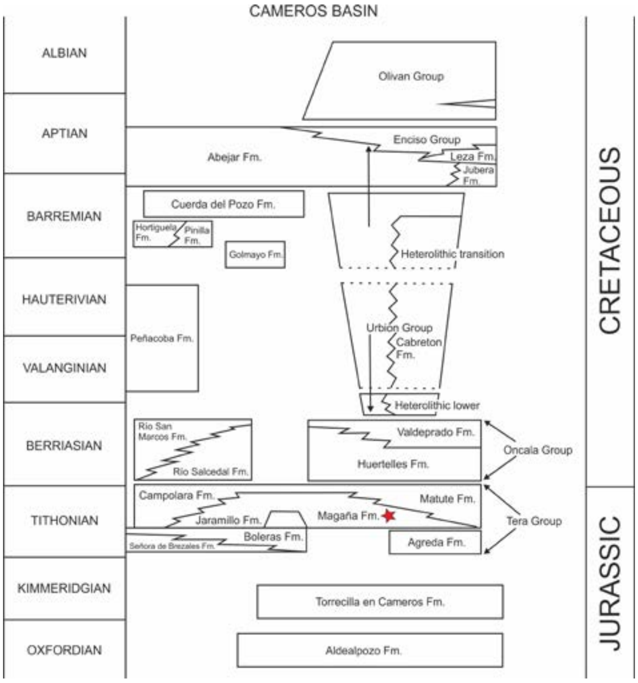

Figure 2. General stratigraphic scheme of the Cameros Basin. The red star indicates the location of the La Llana outcrop, within the Magaña Formation (Tera Group, Upper Jurassic, Tithonian).

Figura 2. Esquema estratigráfico general de la Cuenca de Cameros. La estrella roja indica la localización del afloramiento de La Llana, incluido en la Formación Magaña (Grupo Tera, Jurásico Superior, Tithoniense).

The graphical results can be checked in the Discussion Section.

5. Systematic Paleontology

Dinosauria	Owen	1842
Ornithischia	Seeley	1888
Stegosauria	Marsh	1877
Stegosauria indet		

6. Locality and Horizon

La Llana toponym, municipality of Aguilar del Río Alhama (La Rioja province). Magaña Formation, Upper Jurassic, Tithonian in age.

7. Description

LLA-1-001 consists of the distal zone of a femur including the complete distal end, as well as a very small part of the diaphysis (Figure 3). Although relatively well preserved, very compact and tough, it appears partially broken in the area immediately before the beginning of the diaphysis. The external texture of the specimen is well visible

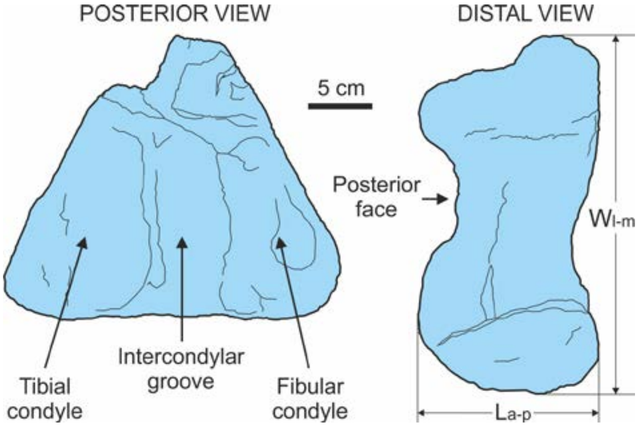

Figure 3. Variables used for the study or the dinosaur bone from La Llana (Aguilar del Río Alhama, La Rioja). $L_{a\text{-}p}$, maximum antero-posterior length. $W_{l\text{-}m}$, maximum latero-medial width.

Figura 3. Variables que se han utilizado en el estudio del hueso de dinosaurio de La Llana (Aguilar del Río Alhama, La Rioja). $L_{a\text{-}p}$, longitud máxima antero-posterior. $W_{l\text{-}m}$, anchura máxima latero-medial.

in certain areas, where it evidences a certain porosity; in others, however, the surface shows slightly weathered areas or even the presence of lichen remains that mask the original texture. The latter suggests that LLA-1-001 may have been exposed to weathering for some time. From the diagenetic point of view, it is worth mentioning the presence of a fracture located in the area of the tibial condyle that can be clearly seen both on the anterior face of this condyle and on the medial edge, where is much thinner and barely noticeable. Although the fossil remain is only a fragment and, therefore, key elements for its correct orientation and identification are perhaps missing, the observable morphology suggests that it is probably the distal end of the right femur of a dinosaur. This hypothesis is based on the morphology of the intercondylar groove, deeper on the posterior face, as well as on the different dimensions and relative development of both condyles.

LLA-1-001 is relatively large, with a maximum width -near its base- of 29.5 cm and an approximate height of 25 cm (Figure 4A). The morphology of the bone, both in anterior and posterior views, is clearly subtriangular (with a fairly flat and straight base) with the upper edge formed by the fracture in the area where the diaphysis begins. Its anterior-posterior dimension (length) -14 cm- is much smaller than its transverse one (width) -29.5 cm-, both values considered as maximum dimensions.

In posterior view (Figure 4B), the tibial condyle is broad, with a well-rounded contour and a not very

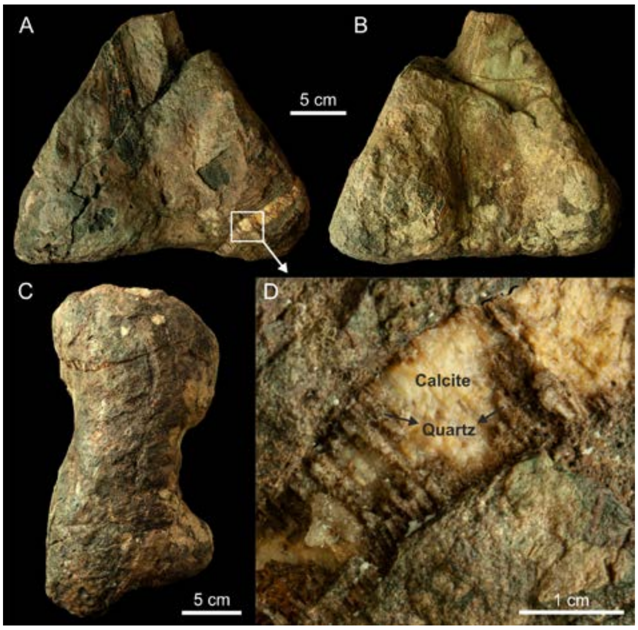

Figure 4. Dinosaur bone from the La Llana site (LLA-1-001). A, anterior view. B, posterior view. C, distal view. D, enlarged view showing the fracture filled with quartz and calcite located in the area of the tibial condyle: note the textural difference between the quartz crystals (more grayish) and the calcite crystals (whitish).

Figura 4. Hueso de dinosaurio del yacimiento de La Llana (LLA-1-001). A, vista anterior. B, vista posterior. C, vista distal. D, vista aumentada mostrando la fractura rellena de cuarzo y calcita situada en la zona del cóndilo tibial: nótese la diferencia de textura entre los cristales de cuarzo (más grises) y los cristales de calcita (más blanquecinos).

prominent surface, presenting a width of about 10 cm. In contrast, the fibular condyle is smaller and narrower (width approximately 4.5 cm) and somewhat more prominent. The intercondylar groove is broad and shallow, showing a gently extensive concavity of a maximum width of about 8 cm.

The anterior face of LLA-1-001 shows worse preservation (Figure 4A), which is most noticeable in the areas of both condyles. The medial condyle shows a very flattened and low surface with slight signs of weathering and wear. On the contrary, the lateral condyle is altered by the aforementioned calcite and quartz filled crack which, in anterior view, is very noticeable. On top of it there are a series of parallel laminae related with the main crack, as well as punctual remains of lichen in several areas. The anterior face shows a large, long and narrow black deposit, forming a thin film of material embedded in the bone with a slightly cracked surface in some areas. The texture and color suggest that it is an unspecific carbonized plant fossil remain. The central area is a very shallow and extensive concavity. In distal view, LLA-0-001 presents a general bilobed shape (Figure 4C), much wider than long (L_{a-p}/W_{l-m} ratio = 0.47), being somewhat asymmetrical due to the different degree of development of both condyles and also much narrower in the central area (about 9.5 cm maximum length).

The fossil presents abundant parallel fractures, which outcrop all over its surface. Although some of these fractures are responsible for the loss of the diaphysis, the rest of the bone has not suffered major deformations. The most notable fracture is located in the tibial condyle, much more visible than the rest due to its larger opening and its grayish-white mineral filling (Figure 4D). The maximum opening of the vein is 15 mm and it wedges laterally to a thickness of about 1 mm.

The vein is filled with quartz and calcite. The quartz is pseudo-fibrous, translucent to transparent and somewhat colored (probably by iron oxide inclusions). It is distributed according to a syntaxial texture (Durney and Ramsay, 1973), formed by elongated crystals perpendicular to the lode walls. These crystals show a slight sigmoidal character (the vein filling is slightly asymmetrical) indicating a small lateral displacement of one part of the bone compared to the other (Figure 4D). The calcite has a milky and opaque appearance (due to the abundance of fluid inclusions). It occupies the available space between the fibrous quartz, so it seems to have formed later than the fibrous quartz. In the lode, the surface of the calcite is very smooth and is in bas-relief with respect to the quartz, indicating that the bone was exposed to weathering so that some of the calcite (much more soluble than the quartz) was dissolved.

The origin of the fracturing of the bone is clearly tectonic. After burial and lithification, the specimen was already incorporated into the rock and fractured with it in response to extensional stresses. Unfortunately, we do not know the original orientation of the bone, so correlation with the main fracturing directions in this sector of the Cameros Basin is impossible.

Veins or seams filled with quartz and calcite are very abundant in the area surrounding the Aguilar del Río Alhama deposit. Within the collecting field, quartz crystals from the Cervera del Río Alhama veins are well known (Calvo, 2018). In addition, some of these veins have been studied petrologically (e.g., Mantilla-Figueroa *et al*., 1998) in relation to fluid circulation, produced during the low-grade hydrothermal metamorphism that affected this sector of the Cameros basin from the Cretaceous to

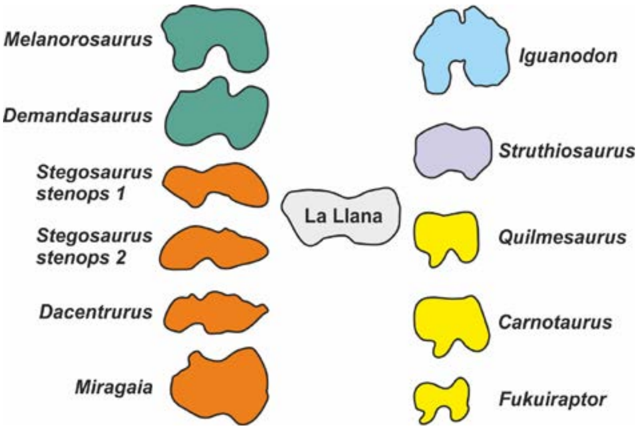

Figure 5. Different contours (distal view) of the femur of some dinosaur groups compared to the specimen under study. Although not to scale, they are all oriented with the posterior edge facing down the figure. *Melanorosaurus,* (Galton *et al.*, 2005). *Demandasaurus,* (Torcida, 2012). *Stegosaurus stenops* 1, (Galton, 2010; Figure 72A). *Stegosaurus stenops* 2, (Galton, 2010; Figure 72B). *Dacentrurus,* (Cobos *et al.*, 2010). *Miragaia,* (Costa and Mateus, 2019). *Iguanodon,* (Verdú *et al.*, 2015). *Struthiosaurus,* (Pereda-Suberbiola and Galton, 2001). *Quilmesaurus,* (Juárez Valieri *et al.*, 2007). *Carnotaurus,* (Juárez Valieri *et al.*, 2007). *Fukuiraptor,* (Azuma and Currie, 2000).

Figura 5. Diferentes contornos (vista distal) del fémur de algunos grupos de dinosaurios comparados con el espécimen estudiado. Aunque no están a escala, todos están orientados con el borde posterior orientado hacia debajo de la figura. *Melanorosaurus,* (Galton *et al.*, 2005). *Demandasaurus,* (Torcida, 2012). *Stegosaurus stenops* 1, (Galton, 2010; Figure 72A). *Stegosaurus stenops* 2, (Galton, 2010; Figure 72B). *Dacentrurus,* (Cobos *et al.*, 2010). *Miragaia,* (Costa and Mateus, 2019). *Iguanodon,* (Verdú *et al.*, 2015). *Struthiosaurus,* (Pereda-Suberbiola and Galton, 2001). *Quilmesaurus,* (Juárez Valieri *et al.*, 2007). *Carnotaurus,* (Juárez Valieri *et al.*, 2007). *Fukuiraptor,* (Azuma and Currie, 2000).

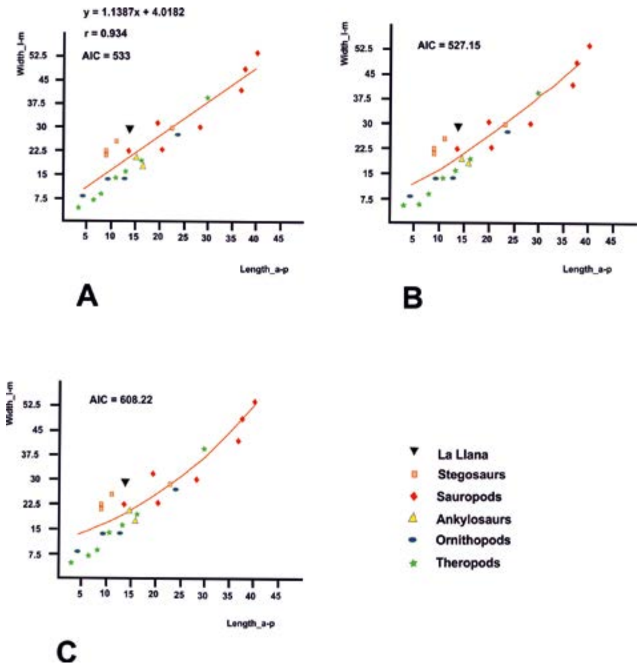

Figure 6. Comparative morphometric analysis of specimen LLA-1-001. A, bivariate linear regression analysis using the Ordinary LS algorithm. B, Bivariate nonlinear regression analysis, using Power Allometric Equation algorithm. C, Bivariate nonlinear regression analysis, using the Logistic Sigmoidal algorithm. AIC, Alkaike Information Criterion Index, which refers to the data fit, the lower the AIC value, the more accurate the data fit. The variables used for these analyses can be seen in Table 1.

Figura 6. Análisis morfométrico comparativo del espécimen LLA-1-001. A, Análisis bivariante de regresión linear utilizando el algoritmo Ordinary LS. B, Análisis bivariante de regresión no linear utilizando el algoritmo Logistic Sigmoidal. AIC, Índice de criterio informativo Alkaike, que se refiere al ajuste de los datos. Cuanto menos sea el valor AIC, mejor será el ajuste de los datos. Las variables utilizadas para estos análisis se pueden ver en la Tabla 1.

the Paleogene, reaching a maximum temperature of 370ºC (Mantilla-Figueroa *et al.*, 2002).

Despite the state of preservation of the bone surface and the presence of the aforementioned crack that crosses the medial area (tibial) of the specimen under study and the fact that only the distal end is available, there are morphological elements that allow us to identify the specimen in broad strokes and justify an attempt to identify it as precisely as possible.

8. Discussion

The characters described in the previous section can be summarized in the following points:

- Relatively large size.
- Relatively large and smooth tibial and fibular condyles.
- Tibial condyle somewhat more developed than the fibular.
- Posterior intercondylar groove shallow and very wide.
- Distal end much wider than long (in the anterior-posterior direction).
- Bilobed and symmetrical morphology in distal view.
- Anterior and posterior intercondylar grooves very symmetrical, shallow and relatively wide.
- Diaphysis probably quite flattened, much with a width much greater than its anterior-posterior length.

Although the femur in general, and that of dinosaurs in particular, shows a rather conservative morphology, it seems clear that in the case of steg-

Nº	Taxa	La-p	Wa-m	La-p/Wl-m	Reference
1	**La Llana**	14	29,5	0,47	This paper
2	*Dacentrurus*	11,1	25,5	0,43	Cobos et al., 2010
3	*Stegosaurus stenops 1*	9	21,5	0,42	Galton, 2010
4	*Stegosaurus stenops 2*	9	22	0,41	Galton, 2010
5	*Miragaia*	22,8	30	0,76	Costa & Mateus, 2019
6	*Sauropelta*	16	20	0,8	Coombs, 1978, 1979
7	*Ankylosaurus*	15,2	20,8	0,73	Coombs, 1978, 1979
8	*Struthiosaurus*	5,5	8,25	0,66	Pereda-Suberbiola & Galton, 2001
9	*Dryosaurus*	4,2	8,1	0,52	Marsh, 1894
10	*Tenontosaurus*	9,4	13,5	0,69	Winkler et al., 1997
11	*Mantellisaurus atherfieldensis*	12,8	13,6	0,94	Hooley, 1925; Paul, 2007
12	*Iguanodon galvensis*	23,5	27,5	0,85	Verdú et al., 2015
13	*Fukuiraptor*	7,5	9	0,83	Azuma & Currie, 2000
14	*Allosaurus fragilis*	16	20	0,8	Madsen, 1976
15	*Tyrannosaurus rex*	30	39	0,77	Osborn, 1917
16	*Ingenia*	6,8	7,7	0,88	Barsbold et al., 1990
17	*Quilmesaurus*	10,8	13,75	0,78	Juárez Valieri et al., 2007
18	*Carnotaurus*	12,9	15,8	0,81	Juárez Valieri et al., 2007
19	*Bambiraptor*	1,7	1,7	1	Burnham, 2004
20	*Tastavinsaurus*	28,3	30	0,94	Canudo et al., 2008
21	*Demandasaurus*	18,9	31	0,61	Torcida, 2012
22	*Diplodocus*	20,3	23,3	0,87	Wilhite, 2005
23	*Brachiosaurus*	40	54	0,74	Janensch, 1961
24	*Dicraeosaurus*	37	42	0,88	Janensch, 1961
25	*Melanorosaurus*	13,7	22,5	0,61	Galton et al., 2005
26	*Camarasaurus*	37,7	48,8	0,77	McIntosh et al., 1996

Table 1. Morphometric variables used to compare the anatomy of the femoral distal ends of different dinosaur groups. $L_{a\text{-}p}$, Maximum antero-posterior length. $W_{l\text{-}m}$, Maximum latero-medial width. Measurements in cm.

Tabla 1. Variables morfométricas utilizadas para comparar la anatomía de las terminaciones femorales en distintos grupos de dinosaurios. $L_{a\text{-}p}$, longitud máxima antero-posterior. $W_{l\text{-}m}$, anchura máxima latero-medial. Medidas en cm.

osaurs this bone is quite wide in anterior view and also quite narrow in lateral or medial view (Figure 5) (Galton, 1997). This refers to the diaphysis and also both ends, proximal and distal. In Table 1 we have constructed a simple length versus width index. Length ($L_{a\text{-}p}$) is represented by the maximum antero-posterior dimension and Width ($W_{l\text{-}m}$) by the maximum medio-lateral dimension.

Thus, in theropod dinosaurs the distal femoral end is quite symmetrical and compact, with indices $L_{a\text{-}p}/W_{l\text{-}m}$ that are close to 0.8. At the same time, the posterior intercondylar groove is deeper and narrower than in the La Llana specimen. The same can be commented in the case of medium-large ornithopods such as *Mantellisaurus (Iguanodon) atherfieldensis*, where this index ($L_{a\text{-}p}/W_{l\text{-}m}$) presents a value of 0.94. Other ornithopods, such as *Dryosaurus* or *Tenontosaurus*, have lower indices, perhaps due to their smaller size that allows a less graviportal bone structure. As for sauropods, Table 1 also shows a high index for *Tastavinsaurus* (0.94) and somewhat less for

Demandasaurus, the rebaquisaurid dinosaur from the Burgos province: 0.61. In addition to the general structure (much more compact and symmetrical), the intercondylar groove is usually narrower and deeper. The same occurs in the femoral structure of the other group of thyreophorans, such as the ankylosaurs (Carpenter, 1997; Vickaryous *et al*., 2004). So, the general design of the body is much heavier and compact, reaching an armored structure with a great development of the dermal armor. This is reflected in the morphology of the femur, which has higher L_{a-p}/W_{l-m} relationship, significantly closer to 1 than in the case of stegosaur dinosaurs (Table 1).

Indeed, the La Llana specimen presents a L_{a-p}/W_{l-m} index of 0.47, much closer to the values presented by *Stegosaurus* (Galton, 2010) and *Dacentrurus* (Cobos *et al*., 2010). The characteristics mentioned above and these numerical values place it in the range represented by dinosaurs belonging to the Stegosauridae clade.

The dimensions of LLA-1-001, expressed as the variables L_{a-p} and W_{l-m}, were subjected to a comparative statistical analysis with similar material as shown in Table 1. For this purpose, PAST 4.05 software (Hammer *et al*., 2001) was used to carry out 3 types of analysis: 1) bivariate linear regression analysis and, 2) bivariate nonlinear regression analysis (Figure 6).

The bivariate linear regression analysis yields a fit to the following line equation: y=1.1387x + 4.0182, with a correlation coefficient R^2 of 0.87235 (Figure 5A). For the bivariate analysis of nonlinear regression, two calculation algorithms have been used: 1) power allometric equation and 2) logistic sigmoidal because both have the lowest Alkaike Information Criterion Index (AIC), which implies a better fit of the data. In both cases, similar results are obtained in the sense that the stegosaur specimens analyzed are located, within a small area, above the fit line and outside the 95% of the confidence (Figure 5B and 5C).

So, the general morphology and the statistical analyses support the hypothesis that the La Llana specimen (LLA-001) belongs to a stegosaurian dinosaur. Three genera of stegosaurs seem typical of the European fossil record: *Dacentrurus* (Galton, 1991; Mateus *et al*., 2008; Company *et al*., 2010; Cobos *et al*., 2010; Costa and Mateus, 2019; Sánchez-Fenollosa *et al*., 2022), *Loricatosaurus* (Nopcsa, 1911) and *Miragaia* –may be a *Dacentrurus* synonym- (Mateus *et al*., 2009). Although we should also add the genus *Stegosaurus* (Escaso *et al*., 2007) as well as other taxa, such as *Lexovisaurus* –may be a *Loricatosaurus* synonym- (Hoffstetter, 1957; Galton, 1985).

The genus *Stegosaurus* (which gives its name to the clade) is perhaps the best known and is very abundant in the Upper Jurassic of North America (Galton, 1982; Galton, 2010) and in the Iberian Peninsula (Portugal) (Escaso *et al*., 2007). In this case, although there are elements of the appendicular skeleton (part of the astragalus, calcaneus, tibia and fibula), the femur has not been preserved. Consequently, it is not possible to carry out a morphological comparison with our material under study. The same occurs with the genus *Miragaia*, proposed on remains mostly from the anterior part of the body and characterized by a remarkable development of the neck region (Mateus *et al*., 2008). Unfortunately, the absence of femur elements does not allow comparison. The same occurs with the remains of thyreophorans from the Upper Jurassic of Asturias (Vega Fm.), consisting only of a fragment of the vertebral centre (Ruiz-Omeñaca *et al*., 2013).

The characteristics of the femur of *Stegosaurus stenops* are very well illustrated in Galton (2010) and have allowed a fairly consistent morphological comparison. Indeed, the distal diaphysis of *S. stenops* is much wider medio-laterally than long (antero-posteriorly). The measures can be seen in Table 1 and the L_{a-p}/W_{l-m} index is estimated at 0.41 and 0.42. Both the tibial and fibular condyles are broad and rounded, with little relief, and between them it is located the intercondylar groove, broad and shallow. The posterior intercondylar groove is slightly deeper than the anterior one.

Other stegosaur remains have also been described in the Lower Cretaceous (Hauterivian-Barremian) of the province of Burgos (Pereda-Suberbiola *et al*., 2003a), in the westernmost part of the Cameros Basin (Piedrahita de Muñó Fm.). This publication was the first record of Stegosauridae from Cameros, although it is referred to the western sub-basin. It is only the fragmentary vertebral remains and a possible very deteriorated dermal plate that the authors identify as Stegosauridae but that presents some character that would bring it closer to the genus *Dacentrurus*, although only as a suggestion (Pereda-Suberbiola *et al*., 2003a).

Cobos *et al*. (2010) described much more complete stegosaurian remains from the Tithonian-Berriasian of the Villar del Arzobispo Fm. (Teruel province, South-Iberian Basin). In addition to abundant vertebral remains, plates and hip elements, there are also appendicular bones (tibia, metatarsals) and a relatively well preserved complete femur from the Barrihonda-El Humero site. The structure in general is quite flattened and also with regard to the morphology of the distal diaphysis, which L_{a-p}/W_{l-m} index is 0.43 (see Table 1). Both condyles present low relief, i.e., they are shallowly protruding and the intercondylar groove is rather shallow. The La Llana material shares these two characteristics, as does the genus *Stegosaurus*. However, the distal contour of the femur of *Dacentrurus* has a rounded profile, i.e., it is slightly convex at the distal edge, clearly visible in anterior view. In contrast, La Llana presents a much straighter contour in that area, which also occurs in the femur of *Stegosaurus*, which is even slightly concave. In addition, the morphology of the intercondylar groove of the bone of La Llana is much more similar to *Stegosaurus* than to *Dacentrurus*, with respect to its relative width and depth. These two characters suggest a strong morphological similarity of La Llana and *Stegosaurus*. However, the lateral edge of La Llana is less rounded, it shows a straighter contour making a more acute angle than in *Stegosaurus*.

Consequently, the characters present in LLA-1-001 could suggest its inclusion in the Stegosauridae clade and, within this group, it seems to be more similar to *Stegosaurus* than to *Dacentrurus* (although the L_{a-p}/W_{l-m} index is somewhat higher: 0.47). Despite this, the very partial state and the preservation conditions of this fossil does not allow for the moment a generic assignment so we consider LLA-1-001 as Stegosauria indet.

9. Conclusions

If this identification is correct, LLA-1-001 constitutes the first osteological remain of a stegosaur in the eastern sub-basin of the Cameros Basin. This specimen represents an interesting complement to the findings of dinosaur tracks also attributed to thyreophorans (Pascual *et al*., 2012; Pascual-Arribas and Hernández-Medrano, 2015) and supports the presence of this taxonomic group in Cameros during the Jurassic, just before the paleoichnological "great explosion" that would begin during the Cretaceous (Berriasian – deposits mainly in the province of Soria) and would culminate in the Upper Barremian-Lower Aptian transition with the abundant dinosaur tracksites of the Enciso Group (mainly through La Rioja province). In addition, it is important to highlight the presence of thyreophorans in the Jurassic of the Cameros Basin, an area well representative of the continental ecosystems of the Iberian Plate, one of the most significant paleogeographic areas of the then fragmented archipelago, germ of the future European continent.

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