Riodeva sites (Teruel, Spain) shedding light to European Sauropod phylogeny

Aportaciones de los yacimientos de Riodeva (Teruel, España) a la filogenia de los saurópodos europeos

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RESUMEN

En el término municipal de Riodeva se han excavado hasta el momento tres yacimientos de dinosaurios situados en sedimentos de la Formación Villar del Arzobispo, de edad Titónico-Berriasiense. En ellos se han recuperado restos de tres individuos de saurópodos pertenecientes al menos a dos taxones diferentes, determinados como Diplodocinae indet. y como Eusauropoda indet. Los restos hallados en Riodeva corroboran las propuestas apuntadas en trabajos anteriores acerca de la presencia del clado Diplodocinae y de eusaurópodos basales en la Península Ibérica. El registro de estos taxones proporciona nuevos datos para documentar la evolución de los saurópodos durante el Jurásico Superior y el Cretácico Inferior en Europa.

Key words: *Diplodocinae, Eusauropoda, Tithonian-Berriasian, Iberian Range.*

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Introduction

In this paper we present some of the results achieved in several campaigns of excavation, preparation and systematic study of dinosaurs carried out by Fundación Conjunto Paleontológico de Teruel-Dinópolis in the area of Riodeva (southern of Teruel province, Spain) since 2002. The sites are placed within the South-Iberian Basin geological context, in Tithonian-Berriasian age deposits of Villar del Arzobispo Formation concordant over Higueruelas Formation, which is dated at the top in Riodeva as the base of Tithonian with *Anchispirocyclina lusitanica* (Fezer, 1988). The deposits consist of shallowing para-sequences which alternate sediments of littoral and fluvial environments, being the siliciclastic facies (sandstones and red clays) dominant (Luque *et al*., 2005).

Besides Riodeva, Villar del Arzobispo Formation has provided, previously, direct and indirect remains of dinosaurs in the province of Teruel (Canudo *et al*., 2005; Cobos *et al*., 2005). In Riodeva more than 40 places with different palaeontological potential have been recorded; they have yielded remains belonging to sauropods, stegosaurids and theropods and also recently isolated material from basal ornithopods. We have also recovered isolated crocodile teeth, partially articulated turtle shells, many fish teeth and scales and vegetable remains. Three sites have been or are being excavated: Barrihonda-El Humero (RD-10), El Carrillejo (RD-11) and Puntal de Santa Cruz (RD-13). The recovered sauropod dinosaur remains belong to three individuals with cranial (teeth) and postcranial remains. In this paper we focus on two of these sites: RD-11 y RD 13 (Fig. 1). The information that emerges from their study confirms the high degree of biodiversity existing within this group at the end of the Upper Jurassic with the presence of diplodocids and basal Eusauropods, not only in Spain (Royo-Torres and Cobos, 2004; 2005; Canudo *et al*., 2006) but also in Portugal (Antunes and Mateus, 2003).

Remains of Diplodocinae from RD-11 (El Carrillejo) site

At Riodeva El Carrillejo (RD-11) site we have recovered several vertebrae and indeterminable bones, which are being excavated and prepared nowadays. One of the anterior caudal vertebra which has been prepared (Fig. 2) has the following characters: the internal bone texture is solid, the anterior face is concave and the posterior convex without the presence of a condyle so it is procoelous. The transverse processes start at the upper part of the centrum and are complex with the presence of laminae. The centrum is characterized by deep pleurocoels and a marked ventral wrinkle with anteroposterior direction. All these are diagnostic characters of the clade Diplodocinae according to Wilson's (2002) analysis. This material has been compared to that of *Losillasaurus* from Valencia (Casanovas *et al*., 2001) and to the anterior caudals found in other sites in Riodeva: RD-13-2 from El Carrillejo site (see below) and RD-27-65R from La Cautiva 2 site (Royo-Torres and Cobos, 2005). The result is that they are clearly different due to the lack of pleurocoelous and ventral wrinkle. This would indicate the presence of at least two different taxa in Riodeva.

The presence of remains included in Diplodocoidea or Diplodocimorpha in the European Upper Jurassic had previously been cited, in an isolated way, with a pencil-shaped tooth in Villar del Arzobispo Formation in Galve (Teruel) with Diplodocidae indet.? (Cuenca-Bescós *et al*., 1997) and in Lastres Formation in Asturias with another tooth assigned to Diplodocidae indet. (Martínez *et al*., 2000). Also two taxa included in Diplodocidae have been described with *Dinheirosaurus lourinhanensis* (Bonaparte and Mateus, 1999; Antunes and Mateus (2003) and with *Losillasaurus giganteus* (Casanovas *et al*., 2001). These teeth from Teruel and Asturias are different from the classical teeth described for Diplodocidae because they have a

Fig. 1.- (a) El Carrillejo site (RD-11), (b) Puntal de Santa Cruz site (RD-13) in Riodeva (Teruel, Spain).

Fig. 1.- (a) Yacimiento El Carrillejo (RD-11), (b) yacimiento Puntal de Santa Cruz (RD-13) en Riodeva (Teruel, España).

spatulate apex in Galve or present an elliptic occlusal end in Asturias so they would be different from the known genera within Diplodocidae. *Dinheirosaurus* considered also Diplodocoidea *incertae sedis* by Upchurch *et al*. (2004) being unlike Diplodocidae, has finally been included within Diplodocinae together with *Barosaurus* and *Diplodocus* from USA and *Torniera* from Africa (Rauhut *et al*., 2005). *Losillasaurus* was proposed as Diplodocoidea (Casanovas *et al*., 2001) although recent cladistic analysis place it out of Neosauropoda (Harris and Dodson, 2004; Harris 2006; Rauhut *et al*., 2005). Other possible Diplodocoidea remains found in Europe are doubtful, such as *Cetiosauriscus stewartii* (see Charig, 1980) of the Callovian in England (Diplodocoidea *incertae sedis*, Upchurch *et al*. 2004), or belong to the Rebbachisaurids described in the Lower Cretaceous of Burgos, Spain (Pereda Suberbiola *et al.*, 2003) and in Istria, Italy (Dalla Vecchia, 1998).

The ilion assigned to Diplodocidae in Riodeva (Royo-Torres and Cobos, 2004) and the cranial elements found in Galve and Asturias (Canudo *et al*., 2006) or at least some of them could also be related to the material found in El Carrillejo site. Thus, Diplodocinae, in the light of recent studies (Rauhut *et al*., 2005) and of the remains found in Riodeva (RD-11), would be well represented in Europe at least around the Upper Jurassic-Lower Cretaceous boundary.

Eusauropod indet. from RD-13 (Puntal de Santa Cruz)

The remains found at Puntal de Santa Cruz (RD-13) include an axis, several cervical and dorsal centra, a caudal centrum, vertebral spines and neural arches (Fig. 3). Axis is characterized by a short neural spine in the anterior half of the vertebra. Presacral vertebrae are opisthocoelous, with simple well-developed pleurocoels. Also, the cervical centra show a ventral surface having a convex and smooth crest with anteroposterior direction. Prezygapophyses have a convex dorsal surface. The presence of triangular lateral processes in spines are similar to those of *Losillasaurus* (Casanovas *et al*., 2001) and *Haplocanthosaurus* (Hatcher, 1903); the main characteristics observed in RD-13 are the absence of prespinal lamina (prsl) and postspinal lamina (posl) and that the spinoprezygapophyseal laminae (sprl) are separated. From the sacrum there is only one neural spine preserved, which is transversally compressed, lacking triangular processes. Caudal series is represented by an anterior caudal vertebra, with concave centrum in anterior view and convex in posterior view without presence of condyle; neural arch is in centered position and is characterized by transversal processes pointing slightly forwards. The internal bone texture is solid in the axial series and in the dorsal ribs.

The cervical and dorsal vertebrae from RD-13 probably belong to the same taxon as a dinosaur of RD-10 (study in progress), because they share opisthocoelous centra, simple well-developed pleurocoels, absence of prespinal and postspinal laminae and presence of lateral triangular processes in neural spines of the dorsal vertebrae. From the comparison between RD-13-2 and RD-27-65R caudals, noticeable differences emerge, such as the presence of a keel in the ventral surface and a great anteroposterior compression of the anterior caudal centrum, absent both in the caudal vertebra of RD-13.

Comparison of RD-13 sauropod with other Iberian sauropods

The sauropod material from RD-13 has been compared to those Iberian sauropods which could bear a resemblance due to their geographical location and similar age in Spain and Portugal.

It is clearly different from the Portugal taxa but presents, without being exactly alike, more similarities with the Villar del Arzobispo Formation taxa in the Iberian Range. RD-13 differs to *Lourinhasaurus alenquerensis* from Portugal (Lapparent and Zbyszewski, 1957; Dantas *et al*., 1998) because the latter has a large postspinal lamina on dorsal vertebrae. *L. alenquerensis* was originally identified as a new species of *Apatosaurus* by Lapparent and Zbyszewski (1957), but McIntosh (1990) transferred this species to *Camarasaurus*. Recently in Upchurch's *et al*. (2004) analysis it has been included within Eusauropoda basal as the closest known relative of Neosauropoda. This classification is not conclusive; a comparison with *Aragosaurus ischiaticus* (Sanz *et al*., 1987) lets us prove similar characters in humerus, vertebrae and pelvic bones. This situation places *L. alenquerensis* within a new group of Macronaria close to Titanosauriformes, identified by Royo-Torres (2005), including also *Cedarosaurus*, *Venenosaurus* and the sauropod from Peñarroya de Tastavins, Teruel (MPZ99/9). The second taxon from

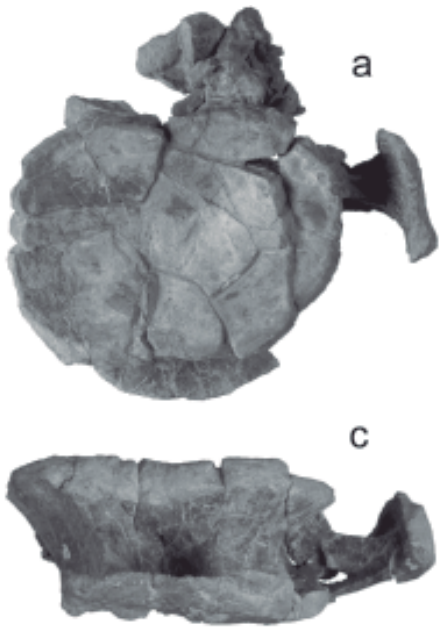

Fig. 2.- Anterior caudal vertebra (RD-11-1) of Diplodocinae indet. from El Carrillejo site (RD-11) in anterior view (a), left lateral view (b) and ventral view (c). Scale 10 cm.

Fig. 2.- Vértebra caudal anterior (RD-11-1) de Diplodocinae indet. procedente del yacimiento El Carrillejo (RD-11) en vista anterior (a), en vista lateral izquierda (b) y en vista ventral (c). Escala 10 cm.

Portugal we compare it with is *Dinheirosaurus lourinhanensis* described by Bonaparte and Mateus (1999) which is different from RD-13 sauropod because *D. lourinhanensis* has prespinal and postspinal laminae on dorsal vertebrae. Other sauropod species from Portugal is *Lusotitan atalaiensis* classified within Brachiosauridae (McIntosh, 1990; Antunes and Mateus, 2003) hence within Titanosauriformes (Upchurch *et al*., 2004). RD-13 lacks the diagnostic characters proposed by different authors for Titanosauriformes, for example: spongy presacral bone texture is absent; mid-cervical centra elongate (length four times posterior centrum height, Wilson, 2002) is absent. It also lacks some diagnostic characters proposed by Salgado *et al*. (1997) such as prespinal lamina divided in the base until the prezygapophysis, absent in Riodeva specimen.

The Villar del Arzobispo Formation Spanish sauropod taxa show similarities between themselves, but also differences. For example RD-13 and *Losillasaurus* develop procoelous anterior caudal vertebrae, and spines in dorsal vertebrae with lateral triangular processes. However, RD-13 is different to *Losillasaurus* because the first has dorsal vertebrae with convex prezygapophyses and the spinoprezygapophysial (sprl) laminae are less developed in the Riodeva taxon. The anterior caudal vertebrae from Riodeva sauropod has the transversal processes pointing forwards, while those of *Losillasaurus* point backwards. In relation to the taxon from Galve proposed as a basal Neosauropoda named *Galvesaurus herreroi* by Barco *et al*. (2005) and as a non-Neosauropod Eusauropoda named *Galveosaurus herreroi* by Sánchez-Hernández (2005), RD-13 presents the following differences: it lacks pneumatic cavities inside the bone of cervical vertebrae, and presents neural spines in dorsal vertebra with a greater lateromedial expansion.

As a conclusion the sauropod of Puntal de Santa Cruz (RD-13) is different from the rest of the taxa described in the Iberian Peninsula of similar age and has more resemblances with *Losillasaurus*. All of the above and the presence of primitive characters in RD-13, such as simple pleurocoels in presacral vertebrae and solid internal bone structure in vertebrae and ribs (Wilson, 2002) leads us to classify it as Eusauropoda indet.

Paleobiogeographical implications of the sauropods from Riodeva

Recent data dealing with the European sauropod record provides new arguments to decipher their groupings in clades and their evolution. Firstly, we need to consider the implications of the presence of basal Eusauropods in Europe during the Upper Jurassic and their probable maintenance there until the Berriasian.

Secondly the presence of the Diplodocinae group in the Iberian Peninsula at the end of the Upper Jurassic would point to a relationship with the North-American sauropods. In this way Diplodocidae would be well represented and with a large number of genera in the Morrison Formation (North-America), where there are up to six known

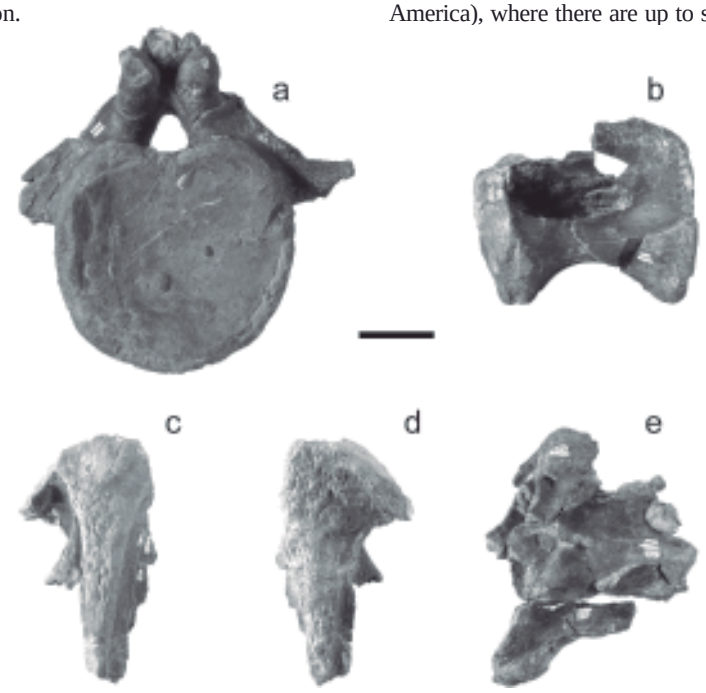

Fig. 3.- Vertebrae from Puntal de Santa Cruz site (RD-13). Anterior caudal vertebra (RD-13-2) in anterior view (a); dorsal centrum (RD-13-7) in left lateral view (b); dorsal spine (RD-13-29) in anterior view (c) and posterior view (d); and axis (RD-13-8) in left lateral view (e). Scale 10 cm.

Fig. 3.- Vértebras del yacimiento Puntal de Santa Cruz (RD-13). Vértebra caudal anterior (RD-13-2) en vista anterior (a), centro dorsal (RD-13-7) en vista lateral izquierda (b), espina dorsal (RD-13-29) en vista anterior (c), en vista posterior (d) y axis (RD-13-8) en vista lateral izquierda (e). Escala 10 cm.

genera of Diplodocidae (Upchurch *et al*., 2004) but with a scarce number in Tendaguru Formation (Africa): just one genus, *Torniera africana* FRAAS 1908 (=*Barosaurus africanus* JANENSCH 1922, in Upchurch *et al*. 2004). The presence of other groups of sauropods such as Titanosauriformes in the three continents points also to the biogeographic relationship between them, although the genera are different and also the proportion, being Diplodocidae more abundant in North-America and Titanosauriformes in Africa (Rees *et al*., 2004). The relationship, diversity and difference of taxa between Laurasia and Gondwana has been explained due to the fragmentation of Pangea in the Middle Jurassic (Sereno, 1997; 1999). In Europe the palaeogeographical history is complex; for much of the Jurassic and Cretaceous periods, it was composed of several major islands: e.g. Britain, Iberia and Eastern Europe (Upchurch *et al.*, 2002). This isolation could lead to the persistence and evolution of a group of basal sauropods different to Neosauropoda. The presence of similar groups such as Diplodocidae could be explained by two possibilities: they could have arrived at the Iberian Peninsula through intercontinental bridges or they could have evolved by vicariance.

Conclusions

In Riodeva, in Villar del Arzobispo Formation, there are at least two different taxa of sauropod dinosaurs. The first one is classified as Diplodocinae indet. from the RD-11 site, being this the first time that this group is cited in Spain (and the second time in Europe following *Dinheirosaurus*). The second taxon, represented by RD-13 site, is included in this work within Eusauropoda indet. The record of the sauropod from RD-11 is coherent with the presence of the Portuguese Diplodocinae *Dinheirosaurus* and the record of RD-13 corroborates the hypothesis suggested in previous studies about the existence of basal eusauropods in the Iberian Peninsula. These taxa provides new data to document the early evolution of sauropods, keeping in mind the importance of their interpretation to support the presence or not of intercontinental bridges during the fragmentation of Laurasia in the Upper Jurassic between North-America and Europe.

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