

# The oldest evidence of a dortokid turtle (stem Pleurodira) from the uppermost Hauterivian-basal Barremian El Castellar Formation (Teruel, Spain)

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## Abstract

**Purpose** Dortokidae is a poorly understood group of pan-pleurodires, exclusive to the European record. Dortokidae is one of the few defined clades of the stem group of Pleurodira, grouping all the forms of this stem described in the post-Jurassic record of Laurasia. Despite this clade has a relatively wide temporal distribution, only three valid forms of Dortokidae are currently known: one from the late Barremian (Early Cretaceous) of Morella (Spain), *Eodortoka morellana*; another from the uppermost Cretaceous of Spain and probably southern France, *Dortoka vasconica*; and the last one from the Paleogene of Romania, *Ronella botanica*. The oldest of these taxa is synchronous with the findings of Dortokidae indet. from the Spanish fossil locality of Vallipón, Vallipón and Morella being the only two localities where Lower Cretaceous material of this clade was so far known. Dortokidae is recognized in this paper for the first time in El Castellar Formation, by a partial xiphiplastron. This finding comes from the El Castellar locality (Teruel, Spain).

**Methods** The plate from El Castellar is compared with the xiphiplastra of all so far valid representatives of Dortokidae,

and with the indeterminate form from Vallipón. A phylogenetic hypothesis on the members of this clade is proposed. **Results** The specimen studied here is identified as the oldest known evidence of Dortokidae, being recognized as Dortokidae indet.

**Conclusions** This new remain of a dortokid expands the known temporal range of distribution for this clade, being recognized from the uppermost Hauterivian-basal Barremian levels.

**Keywords** Freshwater turtle · Dortokidae · Early Cretaceous · Oldest evidence · Iberian record

## Resumen

**Objetivo** Dortokidae es un grupo de tortugas pan-pleurodiras relativamente mal conocido, exclusivo del registro europeo. Dortokidae es uno de los pocos clados que forman parte del stem group Pleurodira. Este clado agrupa a todas las formas del stem conocidas en niveles post-jurásicos de Laurasia. A pesar de su relativa amplia distribución temporal, solo tres representantes de Dortokidae son reconocidos como válidos: *Eodortoka morellana*, procedente del Barremiense superior (Cretácico Inferior) de Morella (España); *Dortoka vasconica*, del Cretácico terminal de España y, probablemente, de Francia; y *Ronella botanica*, del registro Paleógeno de Rumanía. El más antiguo de estos taxones es conocido en niveles sincrónicos a los del yacimiento español de Vallipón, donde se identificaron restos de un dortokido indeterminado. Así, los ejemplares de Morella y de Vallipón correspondían a los únicos restos de Dortokidae hasta ahora conocidos en el registro del Cretácico Inferior. Este clado es aquí identificado en la Formación El Castellar, mediante un xifiplastrón parcial, proveniente de la localidad homónima, ubicada en la provincia española de Teruel.

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**Metodología** La placa de El Castellar es comparada con los xifiplastrones de todos los taxones de Dortokidae considerados como válidos, y con los de la forma indeterminada de Vallipón. Se propone una hipótesis filogenética para los miembros de este clado.

**Resultados** El ejemplar presentado aquí supone la evidencia más antigua de Dortokidae, siendo atribuido a Dortokidae indet.

**Conclusiones** Este nuevo hallazgo permite ampliar el rango de distribución temporal conocido para Dortokidae, su presencia siendo reconocida al menos desde el Hauteriviense terminal-Barremiense basal.

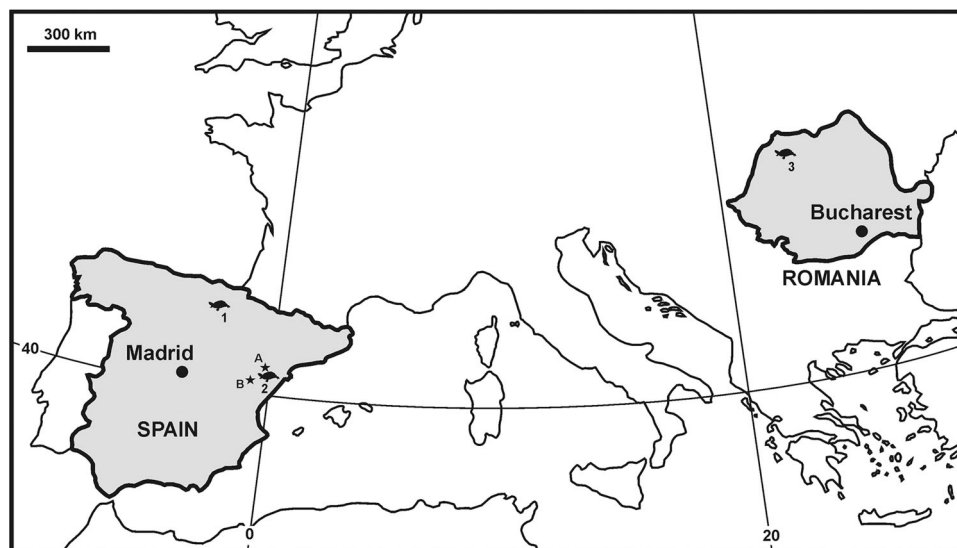
**Palabras clave** Tortuga dulceacuícula · Dortokidae · Cretácico Inferior · primera evidencia · registro ibérico

## 1 Introduction

Dortokidae is a poorly known group of Pan-Pleurodira, exclusive to Europe, where it is known from the Early Cretaceous to the Paleogene (Lapparent de Broin and Murelaga 1999; Lapparent de Broin et al. 2004; Pérez-García et al. 2014). Although its systematic position is imprecise, it is considered as a clade belonging to the stem group of Pleurodira (Pérez-García et al. 2014; Cadena and Joyce 2015). The study of this lineage is very relevant from a systematic perspective, because the pleurodiran stem is known by a small number of specimens and taxa from a

few sites worldwide (Cadena and Joyce 2015). Thus, the dortokids are the only members of the stem group of Pleurodira known in the Laurasian post-Jurassic record. The other representative of the stem group of Pleurodira in Laurasia is the Tithonian *Platychelys oberndorferi* Wagner 1853, a member of Platychelyidae defined in Germany, this genus having subsequently been identified in the Kimmeridgian of Switzerland (Rütimeyer 1867, 1873).

During the Late Cretaceous, Dortokidae coexisted in European freshwater environments with some members of Pleurodira, corresponding to Bothremydidae, a lineage of African origin that reached Europe in the early Late Cretaceous, and show its maximum European diversity in the uppermost Cretaceous record (Gaffney et al. 2006; Pérez-García et al. 2012a; Pérez-García 2016a), surviving in this continent until the Eocene (Pérez-García 2016b). The known diversity of Dortokidae is limited to three representatives (Fig. 1). The first defined member was the Western European *Dortoka vasconica* Lapparent de Broin and Murelaga 1996, 1999, described by abundant shell material from the upper Campanian-lower Maastrichtian Spanish site of Laño, and probably present in other Spanish sites and in Southern France (Lapparent de Broin and Murelaga 1996, 1999; Pérez-García et al. 2012b). The oldest representative so far defined of this lineage has recently been described, *Eodortoka morellana* Pérez-García, Gasulla, and Ortega 2014. It comes from the late Barremian of Morella (Castellón, Spain). Several primitive character states for this Dortokidae, shared with other



**Fig. 1** Type localities of the currently recognized members of Dortokidae (each of them represented on the map by the profile of a turtle and by a number), and location of the sites providing Lower Cretaceous remains of Dortokidae indet. (represented by stars and letters). Type localities: 1 upper Campanian-lower Maastrichtian (Late Cretaceous) site of Laño (Condado de Treviño, Spain), type locality of *Dortoka vasconica*, 2 late Barremian (Early Cretaceous)

area of Morella (Castellón, Spain), type locality of *Eodortoka morellana*, 3 upper Thanetian (Paleocene) site of Jibou (Transylvania, Romania), type locality of *Ronella botanica*. The other two so far identified localities providing Early Cretaceous dortokid remains are the Spanish sites of Vallipón (late Barremian, Castellote, Teruel; A) and El Castellar (uppermost Hauteriviense-basal Barremian, Teruel; B), the finding from this last site being presented in this paper

clades of Pan-Pleurodira, were recognized in this taxon, such as the presence of mesoplastra or the absence of overlap of the second pair of pleural scutes on the first pair of costal plates. In addition to these two forms from Western Europe, a representative of this group is known in Eastern Central Europe. It corresponds to the only representative of the stem group of Pleurodira defined in the Cenozoic record: *Ronella botanica* Lapparent de Broin in Gheerbrant et al. 1999, from the late Paleocene of Transylvania (Romania).

Material corresponding to indeterminate members of Dortokidae has been recorded in other sites of both Western Europe and Eastern Central Europe, some of them probably attributable to new forms (Murelaga Bereikua 1998; Vremir and Codrea 2009; Vremir 2010; Vullo et al. 2010; Vremir and Rabi 2011; Rabi et al. 2013). Only one of these findings of indeterminate dortokids has been found in Lower Cretaceous levels: that from Vallipón (Castellote, Teruel, Spain) (Murelaga Bereikua 1998). This finding is synchronous with that of the late Barremian of Morella (Salas et al. 1995; Bover-Arnal et al. 2016). However, this taxon cannot be attributable to *E. morellana*, showing the presence of at least two taxa at that time (Pérez-García et al. 2014).

The Spanish uppermost Hauterivian-basal Barremian El Castellar Formation (Martín-Closas 1989) had so far provided remains of three clades of turtles: the stem turtles Solemydidae, the paracryptodiran Pleurosternidae and the basal eucryptodiran Xinjiangchelyidae (Pérez-García et al. 2013). A new specimen from this Formation, found in the locality of El Castellar (Teruel) (Fig. 2), is presented here (Fig. 3). It is a partial xiphiplastron. This plate cannot be assigned to any of the clades previously identified in that

formation, being recognized as belonging to Dortokidae. Therefore, it represents the oldest known evidence of Dortokidae, allowing to extend the stratigraphic range of distribution for this clade.

Institutional abbreviations: CPT, Museo Aragonés de Paleontología (Fundación Conjunto Paleontológico de Teruel-Dinópolis), Teruel, Spain; MCNA, Museo de Ciencias Naturales de Álava, Vitoria-Gasteiz, Spain.

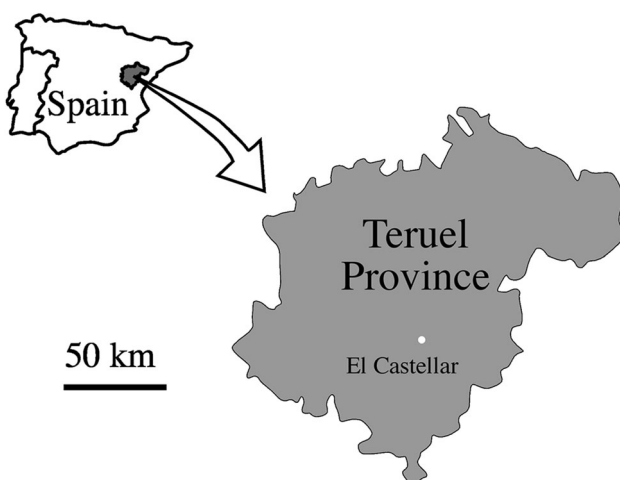
## 2 Geographic and geological situation of the Spanish Lower Cretaceous findings of Dortokidae

As indicated (see Sect. 1) the only worldwide references to Dortokidae in Lower Cretaceous levels are part of the Spanish record: the upper Barremian localities of Vallipón and Morella (Murelaga Bereikua 1998; Pérez-García et al. 2014), and now the uppermost Hauterivian-basal Barremian site of El Castellar.

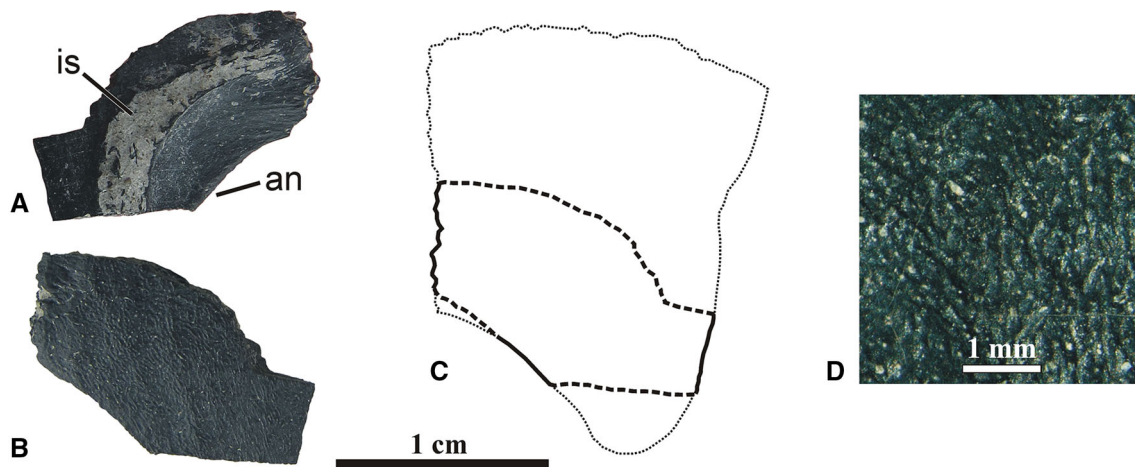
El Castellar is a municipality of the Teruel Province belonging to the Gúdar-Javalambre administrative region. The vertebrate fossil sites of El Castellar are located in the western region of the Peñagolosa Sub-basin, in the southern sector of the Maestrazgo Basin, which forms part of the Iberian Ranges (see Cobos et al. 2010, 2014). El Castellar is the locality where El Castellar Formation was defined (Salas 1987). The Proa site (CT-5), from which the specimen analyzed here comes, is located in El Castellar. The study of the ostracods and charophytes identified in that Formation allowed its dating as deposited during the uppermost Hauterivian-basal Barremian (Martín-Closas 1989).

The site of Vallipón is located in the Teruel Province, in the northwestern part of the Maestrazgo Basin (Salas et al. 1995; Canudo et al. 1996). The remains of dortokids found there come from the Artoles Formation, overlaying the lower Barremian Mirambel Formation (Martín-Closas 1989). The macroforaminifera *Paleorbitolina lenticularis lenticularis* gives a late Barremian-early Aptian age for the upper part of the Artoles Formation, the site of Vallipón having being dated as late Barremian (Salas et al. 1995; Canudo et al. 1996).

*Eodortoka morellana* was also found in younger levels than those of El Castellar. All the so far known specimens of this taxon come from the Mas de la Parreta quarry (Morella, Castellón Province) (Pérez-García et al. 2014). This quarry is located in the Morella Sub-basin of the Maestrazgo Basin. The material of Dortokidae from this locality comes from the Arcillas de Morella Formation, now recognized as an upper Barremian formation (Villanueva-Amadoz et al. 2015; Bover-Arnal et al. 2016).



**Fig. 2** El Castellar (Teruel Province, Spain), locality where the uppermost Hauterivian-basal Barremian Proa site (CT-5), which provides the specimen of Dortokidae presented here (i.e. CPT-691), is located



**Fig. 3** CPT-691, partial xiphiplastron of *Dortokidae* indet., from the uppermost Hauterivian-basal Barremian Proa site (CT-5), in El Castellar (Teruel Province, Spain). **a** Dorsal view. **b**, **c** Ventral view, **b** corresponding to a photo and **c** to a schematic drawing, in which the

broken edges and the preserved margins are differentiated, and a hypothetical reconstruction of the complete plate is provided. **d** Detail of the outer surface showing the well-developed microreticulation present in the dortokids. *an* anal notch, *is* ischiatic scar

### 3 Methodology

The plate from El Castellar studied here (i.e. CPT-691, Fig. 3) is compared with the xiphiplastrs of all so far valid representatives of *Dortokidae* (the Spanish upper Barremian *Eodortoka morellana*, the Spanish Campano-Maastrichtian *Dortoka vasconica*, and the Romanian Paleocene *Ronella botanica*) based on the first-hand study of the type specimens, as well as of other specimens corresponding to these taxa. In addition, it is also compared with the other known reference of a Lower Cretaceous dortokid, from the Spanish upper Barremian site of Vallipón, belonging to an indeterminate representative not attributable to *E. morellana* (Murelaga Bereikua 1998; Pérez-García et al. 2014).

A phylogenetic hypothesis on the members of this clade is proposed here from the characters discussed by Pérez-García et al. (2014), and also considering other characters (see Lapparent de Broin and Murelaga 1999; Lapparent de Broin et al. 2004; Pérez-García et al. 2014 and references therein). Thus, the three so far defined dortokid taxa, and also the European Upper Jurassic *Platycheilus oberndorferi* (a member of *Platycheilidae*, i.e. a clade belonging to the stem lineage of the crown *Pleurodira*), are included. This character-taxon matrix is composed by 30 characters (Appendices 1 and 2). The present character-taxon matrix has been analyzed using TNT 1.0 (Goloboff et al. 2008), in order to find the most parsimonious trees (MPTs). Given the limited number of characters and taxa considered here, an implicit enumeration was performed. The findings of Vallipón and El Castellar are considered in this context.

### 4 Systematic paleontology

Testudines Batsch 1788

Pan-Pleurodira Joyce, Parham and Gauthier 2004

*Dortokidae* Lapparent de Broin and Murelaga 1996

*Dortokidae* indet.

(Figure 3)

*Material*: CPT-691, a partial left xiphiplastron.

*Locality and horizon*: Proa site (CT-5), El Castellar, Gúdar-Javalambre, Teruel Province. Peñagolosa Sub-basin, southern sector of the Maestrazgo Basin, Iberian Ranges. El Castellar Formation, uppermost Hauterivian-basal Barremian (Martín-Closas 1989; Cobos et al. 2010, 2014).

*Description*: CPT-691 is a partial left xiphiplastron, lacking both its anterior half and the postero-lateral areas (Fig. 3a–c). The maximum length of the preserved region is 7.20 mm, its maximum width is 12.23 mm, and its maximum thickness is 3.16 mm. A sutured margin, corresponding to the contact with the right xiphiplastron, is identified. The outer surface of this plate shows a well-developed sculpturing pattern, corresponding to a microreticulated surface (Fig. 3d). This plate is relatively thick considering its the maximum estimated length. The preserved area of the lateral margin is substraight (Fig. 3a–c). This plate shows a well-developed and deep anal notch, having a subrounded margin. The ischiatic scar is long. It does not reach the medial portion of the xiphiplastron. Its relation with the posterior xiphiplastral tip is not known because this region is not preserved. The ischiatic branches form a slightly obtuse angle. The posterior branch is wider than the anterior.



### 5 Discussion

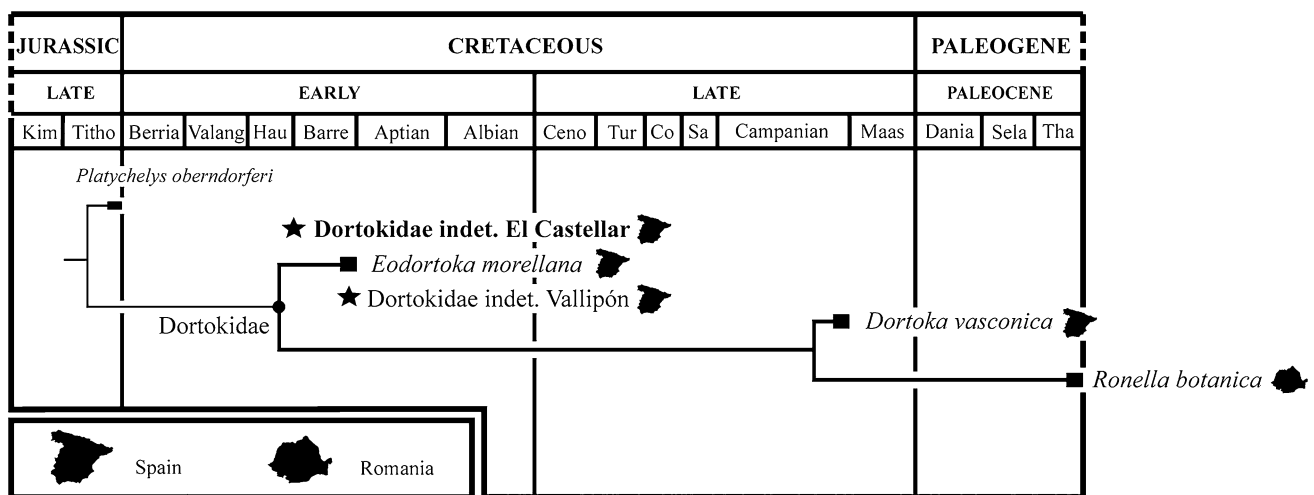
The presence of a well-developed microreticulate decoration in the outer surface of CPT-691, defined as exclusive to Dortokidae (i.e., strong, composed by linear crests not composing a vermiculated or punctuated pattern, sensu Lapparent de Broin et al. 2004), allows its attribution to this clade. Other characters recognized as shared with all the representatives of this clade and, being part of the exclusive character combination for it, are the identification of CPT-691 as a relatively thick plate, and the presence of substraight lateral margin, a well-developed anal notch, and a long ischiatic scar relative to the xiphiplastral length (for the comparison of all these characters with those present in other taxa see Lapparent de Broin and Murelaga 1999; Lapparent de Broin et al. 2004; Pérez-García et al. 2014).

The presence of substraight or subrounded lateral margins of the anal notch is a character subject to intraspecific variability in Dortokidae (see Pérez-García et al. 2012b). The presence or absence of overlap of the ischiatic scar on the medial portion of the xiphiplastron is also subject to intraspecific variability in this clade (see Pérez-García et al. 2012b). A well-developed posterior branch of the ischiatic scar is also shared with the only known xiphiplastron from the upper Barremian site of Vallipón (see figure 2a in Murelaga Bereikua 1998). A well-developed posterior branch of the ischiatic scar was identified as probably present in the only known xiphiplastron of *Eodortoka morellana*, considering the morphology of the preserved region. However, the study of a taxon represented by several individuals, from a single locality (i.e. *Dortoka*

*vasconica*), shows a wide range of variability for this character, with forms such as MCNA 6315 and MCNA 6708, with a strong development of the anterior branch, the posterior being very reduced and narrow, or MCNA 6851 and MCNA 6342, with both branches being well-developed, as in the case of the specimen studied here. The limited availability of characters in CPT-691 only allows its attribution to Dortokidae indet.

The cladistic analysis performed here results in a single tree, with a length of 32 steps (Fig. 4). The clade grouping all dortokids except the oldest representative (i.e. *E. morellana*) is characterized by the overlap of the anterior region of the second pair of pleurals on the first pair of costals (character 19, state 1), the presence of relatively long posterior marginals (character 22, state 1), and the absence of mesoplastra (character 24, state 1). *D. vasconica* is defined by the well development of crests and ridges in the medial area of the carapace, including the medial region of the costals (character 2, state 2); the presence of carapace fontanelles in adult individuals (character 4, state 1); the presence of axillary processes reaching the second pair of costals (character 9, state 2); the overlapping of the postero-lateral region of the second pair of pleurals on the fifth pair of costals (character 20, state 1); and the location of the pubic scars overlapping the posterior region of the hypoplastra (character 29, state 1). *Ronella botanica* is defined by the presence of the pectoral scutes contacting the posterior margin of the entoplastron or overlapping its posterior region (character 26, state 1), and that of more than twice longer than wide pubic scars (character 28, state 1).

The phylogenetic results obtained here allow support the hypotheses on the systematic and paleobiogeographical



**Fig. 4** Temporally calibrated cladogram of Dortokidae, corresponding to the analysis performed here, and also showing the stratigraphic position of the remains of Dortokidae from the Spanish sites of El

Castellar (uppermost Hauterivian-basal Barremian, Teruel Province) and Vallipón (late Barremian, Castellote, Teruel Province)

distribution of the members of Dortokidae previously proposed by Pérez-García et al. (2014). Thus, *E. morellana* is recognized as a primitive dortokid. Not only the Spanish Upper Cretaceous *Dortoka* and the Romanian Paleocene *R. botanica*, but also the indeterminate taxon from the late Barremian of the Spanish site of Vallipón and the indeterminate taxa from the Campanian of Austria and Maastriichtian of Romania are grouped by several derived character states (i.e. those obtained in the cladistic analysis, see Pérez-García et al. 2014). In fact, a pattern of vicariant distribution between the more derived forms that *E. morellana* from Western Europe and those from Eastern Central Europe, whose divergence potentially occurred in the Early Cretaceous, was recognized by Pérez-García et al. (2014). The oldest evidence on the presence of this clade, corresponding to the upper Hauterivian-basal Barremian specimen from El Castellar presented here, allows us to extend the known range of stratigraphic distribution for this group. This study provides new arguments to understand the early diversity and divergence of this lineage from the Early Cretaceous.

## 6 Conclusions

Three clades of turtles were known in the Spanish uppermost Hauterivian-basal Barremian El Castellar Formation (Iberian Ranges): the stem turtles Solemydidae, the paracryptodiran Pleurosternidae and the basal eucryptodiran Xinjiangchelyidae. A new specimen, found in the locality of El Castellar (Teruel Province), corresponds to the first dortokid identified in this Formation. It also represents the oldest evidence of this group until now known, and one of the scarce Lower Cretaceous dortokid findings. The other Lower Cretaceous remains of dortokids so far known were those from the late Barremian of two Spanish sites: Vallipón (Teruel Province) and Morella (Castellón Province). These upper Barremian findings were identified as corresponding to two different forms. Therefore, the specimen from El Castellar allows us extending the known stratigraphic distribution for this group, providing new arguments to understand the early diversity and divergence of this lineage, known from the Early Cretaceous to the Paleogene.

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## Appendix 1

Characters employed in the cladistic analysis performed here, obtained by comparing *Platycheilus oberndorferi* and the members of Dortokidae (see the discussion of these characters in Lapparent de Broin and Murelaga 1999; Lapparent de Broin et al. 2004; Pérez-García et al. 2014):

1. Carapace keels: 0, presence of one medial and two lateral carapace keels; 1, absent.
2. Small crests and ridges on the plates composing the medial area of the carapace: 0, absent; 1, present, poorly developed; 2, present, well developed, not only in the neurals but in the medial region of the costal plates.
3. Thickness of the plastral plates: 0, relatively thin; 1, thick.
4. Carapace fontanelles in adult specimens: 0, absent; 1 present.
5. Plastral fontanelles in adult specimens: 0, present; 1, absent.
6. Anterior carapace margin: 0, straight; 1, subrounded.
7. Dentate carapace margins: 0, present, well developed; 1, absent.
8. Nuchal plate: 0, significantly wider than long; 1, as wide as long.
9. Axillary process: 0, on the first pair of costals (C1), but perpendicular to the C1-C2 suture or slightly antero-medially directed; 1, on C1, but postero-medially directed; 2, reaching C2 and postero-medially directed.
10. Length of the first pair of costals: 0, short, almost twice wider than long; 1, relatively long, the length being equal to 2/3 of the width or higher.
11. First thoracic rib: 0, long; 1, reduced.
12. Anterior tubercle on first thoracic rib: 0, present; 1, absent.
13. Costovertebral tunnel: 0, wide; 1, relatively narrow.
14. Length of the first pair of peripherals: 0, as long as the latero-anterior margin of the nuchal plate, contacting the first costal; 1, reduced, lacking contact with the first costal.
15. Suprapygial: 0, narrower than the pygal plate; 1, wider than the pygal plate.
16. Iliac scar: 0, on the last two pairs of costals, the pygal and the last pair of peripherals; 1, restricted to the last two pairs of costals.
17. Vertebrae scutes: 0, significantly wider than long; 1, relatively narrow.

18. First pair of pleural scutes: 0, the full posterior margin on the second pair of costals; 1, postero-medial region on the second pair of costals; 2, lacking overlapping on the second pair of costals.
19. Anterior region of the second pair of pleurals: 0, lacking contact with the first pair of costals; 1, overlapping the first pair of costals.
20. Postero-lateral region of the second pair of pleurals: 0, on the fourth pair of costals; 1, on the fifth pair of costals.
21. Supramarginals: 0, present; 1, absent.
22. Length of the last pair of marginal scutes: 0, short marginals, with a length less than half of the length of the last pair of peripherals; 1, relatively long marginals, equal or greater than half of the length of the last pair of peripherals.
23. Supracaudal scute: 0, present; 1, absent.
24. Mesoplastra: 0, present; 1, absent.
25. Gulars: 0, relatively long, length of the gulars approximately as long as half of the length of the intergular; 1, reduced gulars, at least three times shorter than the intergular.
26. Pectoral scutes: 0, far behind the entoplastron; 1, contacting the posterior margin of the entoplastron or overlapping its posterior region.
27. Femoro-anal sulcus: 0, on the xiphiplastral; 1, on the postero-medial region of the hypoplastra.
28. Length of the pubic scars: 0, less than twice longer than wide; 1, more than twice longer than wide.
29. Location of the pubic scars: 0, exclusively located on the xiphiplastra, not contacting the hypoplastra; 1, overlapping the posterior region of the hypoplastra.
30. Ischiatic scars: 0, lacking two well developed branches, and with the posterior margin parallel and close to the anal notch; 1, showing two clearly separate branches, and not close to the anal notch.

## Appendix 2

Character-taxon matrix for the phylogenetic analysis performed here:

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Platychelys oberndorferi 00000 00000 00000 00000
00000 00000
Eodortoka morellana 11101 11111 11111 1100? 10?01
00001
Dortoka vasconica 12111 11121 11111 11111 11111
0[01]011
Ronella botanica 11101 11111 11111 11210 11111
10101
    
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