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A new species of *Bathynomus* A. Milne-Edwards, 1879 (Malacostraca: Peracarida: Isopoda: Cirolanidae) from the upper Miocene of the Guadalquivir Basin (Spain)

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Abstract

Today representatives of the giant cirolanid isopods of the genus *Bathynomus* inhabit tropical to warm-temperate waters of the West Atlantic and the Indo-West Pacific. In not so distant geological past, however, the genus was present also in the Mediterranean, as documented by numerous fossils from the Plio–Pleistocene of Italy. Herein, a somewhat older occurrence of the genus is reported, from the North-East Atlantic. Based on a single posterior moult from the upper Miocene (Tortonian) of southwestern Spain, a new species is described. *Bathynomus civisi* **sp. nov.** differs from its congeners by both uropod rami having the obtuse distolateral corner produced as a distinct tip and a wider gap between the second and third side distal spines than between others. The new species is so far known only from the type locality in close vicinity of Arroyo Trujillo, in the municipality of Cantillana (Seville, Spain), where the marls of the Écija Formation are exposed. At the time of deposition of these marls, the area represented a part of the Norbetic Strait, a corridor connecting the North-East Atlantic with the Mediterranean. The new occurrence reported herein further supports the environmental preferences of the genus throughout its geological past for deep-marine settings.

Key words: Cirolanidae, Écija Formation, Seville, fossil crustaceans, Tortonian

Introduction

The cirolanid isopod genus *Bathynomus* A. Milne-Edwards, 1879 (Malacostraca: Peracarida: Isopoda: Cymothoida) is well-known for its large size, with up to 50 cm in length being the largest peracaridan (Wetzer 1986; Lowry & Dempsey 2006). Due to its size, and hence increased fossilization potential, the fossil record of *Bathynomus* is not sparse (Imaizumi 1953; Wieder & Feldmann 1989; Karasawa *et al.* 1995; Kato *et al.* 2016; Hyžný *et al.* 2019), although somewhat obscured due to a confusion made when adopting a rather broadly defined genus *Palaega* Woodward, 1870 for virtually any cirolanid fossil with uncertain affinities (Feldmann & Rust 2006; Polz *et al.* 2006; Pasini & Garassino 2012a, b; Hyžný *et al.* 2013; Jones *et al.* 2014). The material from the upper Miocene of Spain presented below can be unequivocally assigned to *Bathynomus*. Its preservation allows erection of a new species and its direct comparison with extant taxa.

Material and methods

The holotype was collected from the marls of the local unit V of the studied section B as indicated in Fig. 3. Due to extreme fragility of the fossil, Paraloid B-72 preservative was applied to it. Despite that and due desiccation of the sample, one pleotelsonic spine was damaged and its outline is present only in photographs taken before full taxonomic treatment was possible (Fig. 4). Uropods were exposed during preparation in the laboratory. The specimen forming a basis of this study is deposited at Museo Geominero in Madrid, Spain (MGM).

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Geological settings

he studied material originated from an old marl quarry located in the close vicinity of Arroyo Trujillo, in the municipality of Cantillana, Seville (Spain). It is a part of the central area of the Guadalquivir Basin (Fig. 1), a long depression located in the South of the Iberian Peninsula through which the waters of the Atlantic Ocean and the Mediterranean were connected during much of the Miocene (Sanz de Galdeano & Vera 1991; Martín *et al.* 2001) (Fig. 2). This basin is bordered by Palaeozoic rocks to the North, the Bética Mountain Range to the South and East, and to the South-West it is open to the Atlantic Ocean through the Gulf of Cádiz. The studied deposits correspond to the Transgressive System Tract (TST) that filled the Guadalquivir Basin from the Tortonian to the Pliocene (González Delgado & Civis 2000).

In the studied area, two sections (A and B; Fig. 3) were examined, separated from each other by a distance of approximately 1,000 m. The lower part of the composite section consists of sands and conglomerates of the Tortonian age, overlying discordantly the Carboniferous strata (Civis *et al.* 1987, Cárdenas *et al.* 2017, 2019). The upper part of the composite section consists of beige and gray marls of the late Tortonian-Messinian age (Civis *et al.* 1987).

Strata of the Section A consists of three different lithostratigraphic local units. In the Unit I a 0.5 m-thick sequence of redeposited conglomerates are followed by an approximately 6 m-thick sequence of brown sands with gravel. Rounded clasts have a diameter of 2 to 10 mm. Unit II begins with a 5 m-thick sequence of sands with gravels, intercalated with three levels of conglomerates: the first one consisting of loose clasts is rather narrow, the second with a thickness of 0.5 m is cemented and containing abundant shells *Crassostrea gryphoides* (Schlotheim, 1820), and the third one, also cemented, contains only occasional fragments of unidentifiable ostreids. Unit III consists of 20–30 m-thick sequence of silty, beige sands with intercalations of sandstone blocks of variable shape and size. In this section the macrofossils such as *Aequipecten scabrella* (Lamarck, 1819) are very scarce.

Section B is located more towards the interior of the basin. The section begins with the strata of the Unit II, consisting of 1.5 m-thick sequence of brown, strongly cemented sands, with a high concentration of *Heterostegina gomezangulensis* Perconig, 1972. The abundance of *Heterostegina* decreases toward the upper part of the section, accompanied with scattered remains of *Crassostrea gryphoides* or, more scarcely, of other bivalves. Following strata of the Unit III consist of 13–15 m of brown silty sands, containing dispersed tests of *Heterostegina*. Frequent levels of concentration of macrofossils are accompanied by somewhat thicker sands. These levels are of variable thickness between 15 to 30 cm. Sometimes, by processes of postdiagenetic cementation, they give rise to nodules of very irregular shapes, interspersed within the sediment. In the central part of this section there are palaeocanals of concave erosive base filled with sand and conglomerates of reddish colour from the erosion of the Carboniferous substrata. Unit IV begins with 8–10 m-thick sequence of fine, loamy sands of beige colour, intensely bioturbated at their base and with dispersed fossils. Close to the uppermost part of the section, there is a level of sands with abundant glauconite. Above these sands, there is another level of conglomerates with clasts of medium size. The loamy sands gradually pass into greenish gray marls of the Unit V, attaining a thickness of 10 to 13 m. The studied isopod fossil originated from the middle part of the Unit V exposed in the Section B.

The marls exposed in the section studied correspond to the lower part of the Écija Formation (Verdenius 1970; Civis *et al.* 1987), attaining locally up to 1000 meters of thickness and constituting the largest volume of the upper Neogene strata of the Guadalquivir Basin (Ríos 1958; Perconig & Martínez Díaz 1977). In the middle part of the Unit V, where the *Bathynomus* specimen has been found, *Globorotalia menardii* (Parker, Jones & Brady, 1865) dextrose is abundant, but *Globorotalia miotumida* Jenkins, 1960 is scarce, with no specimen of *Globorotalia margaritae* Bolli & Bermúdez, 1965 appearing, so it would correspond to Chron C3Br.1N, just before Tortonian-Messinian boundary (7.24 Ma), where the *Miotumida* group is abundant (Sierro in Civis *et al.* 1990; Hilgen *et al.* 2000a, b; Ledesma 2000; Sierro *et al.* 2000, 2014).

The fossil fauna of the middle part of the Unit V is relatively scarce. Most fossil remains are disarticulated, and only rarely preserved in the life position. Mollusc association is represented by *Nucula placentina* Lamarck, 1819, *Malletia transversa* Ponzi, 1872, *Korobkovia oblonga* (Philippi, 1844), *Propeamussium duodecimlamellatum* Bronn, 1832, *Delectopecten vitreus* (Gmelin, 1791), *Limea strigilata* (Brocchi, 1814), *Abra alba* (Wood, 1802), *Abra longicallus* (Scachia, 1835), *Parilimya loveni* (Jeffreys, 1882), *Corbula gibba* (Olivi, 1792), *Cuspidaria* aff. *lamellosa* (G.O. Sars, 1872), *Cuspidaria rostrata* (Spergler, 1793), *Clio pyramidata* Linnaeus 1767, *Cavolinia* sp., *Genota* cf. *ramosa*, and *Aturia aturi* (Basterot, 1825). The association includes also echinoids (*Brissopsis* sp., *Spatangus* sp.), solitary corals, bryozoans and sponges.

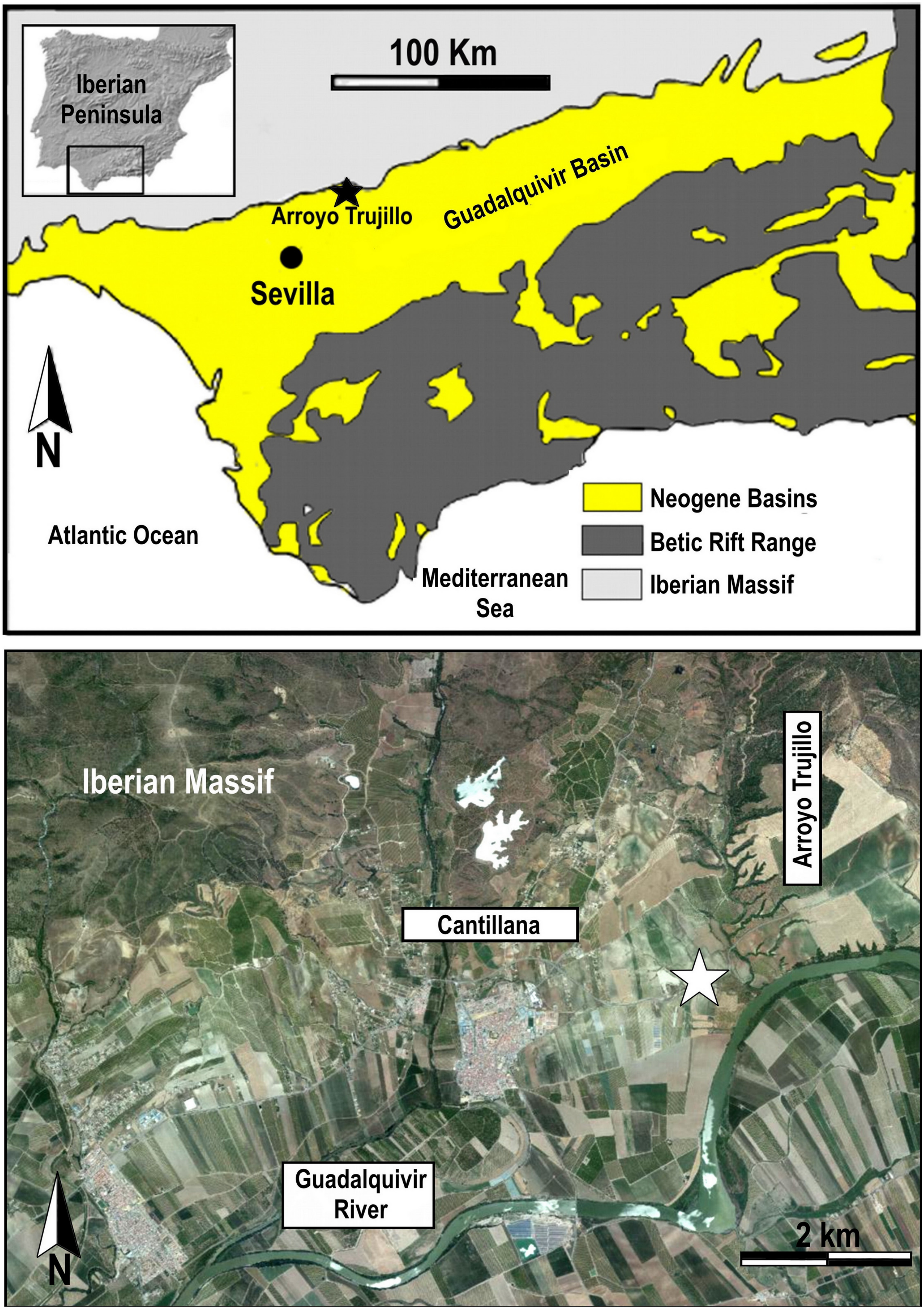

FIGURE 1. Studied area of Arroyo Trujillo is a part of the Guadalquivir Basin (top). The locality (white asterisk) is situated within the close surrounding of Cantillana (bottom).

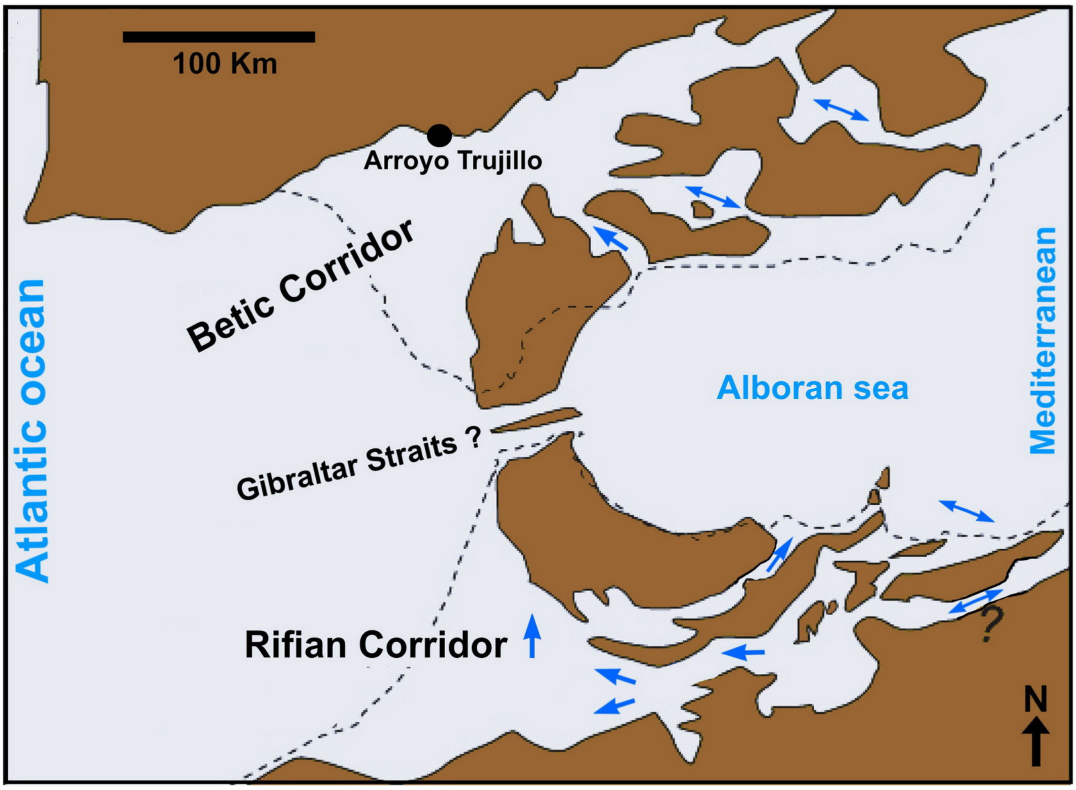

FIGURE 2. Paleogeographic map during the latest Tortonian in the south of the Iberian Peninsula and north Africa, with indication of the studied locality Arroyo Trujillo (modified from Krijgsman *et al.* 2018).

Fossil malacostracan crustaceans from the Neogene strata of the province of Seville were studied by several scholars. Via Boada (1982) mentioned several specimens of a brachyuran crab *Lobocarcinus sismondai* (Meyer, 1843) from the Pliocene of the surrounding of the town of Carmona, located approximately 21 km from the outcrop studied herein, and corresponding lithostratigraphically to the uppermost part of the same formation, i.e. the Écija Formation. Today, the strata studied by Via Boada (1982) are considered of the Messinian age (Sierro *et al.* 1996). Later, Maestre *et al.* (2005) described two specimens of *L. sismondai* also from the upper Tortonian of Lora del Río. From the Pliocene of the Aljarafe area, Mayoral *et al.* (1998) reported on several decapod species, including *Goneplax gulderi* Bachmayer, 1953, *Jaxea nocturna* Nardo, 1847, *Calappa* cf. *saheliensis* Van Straelen, 1937 and Portunidae (sp. indet.) (see also Hyžný 2011 and Díaz-Medina *et al.* 2017 for some comments on these occurrences).

Systematics

Order Isopoda Latreille, 1817

Suborder Cymothoida Wägele, 1989

Family Cirolanidae Dana, 1852

Genus *Bathynomus* A. Milne-Edwards, 1879

Type species: *Bathynomus giganteus* A. Milne-Edwards, 1879, by monotypy.

Remarks: The single specimen shows the 'key' characters for taxonomic attribution to the genus *Bathynomus*, namely a semicircular pleotelson with sinuous lateral margins and distinct, approximately subequal, spines on its posterior margin, not exceeding the number of 13 (Hyžný *et al.* 2013). The number and arrangement of pleotelsonic spines together with the shape of uropod rami allow erection of a new species based on the studied fossil specimen.

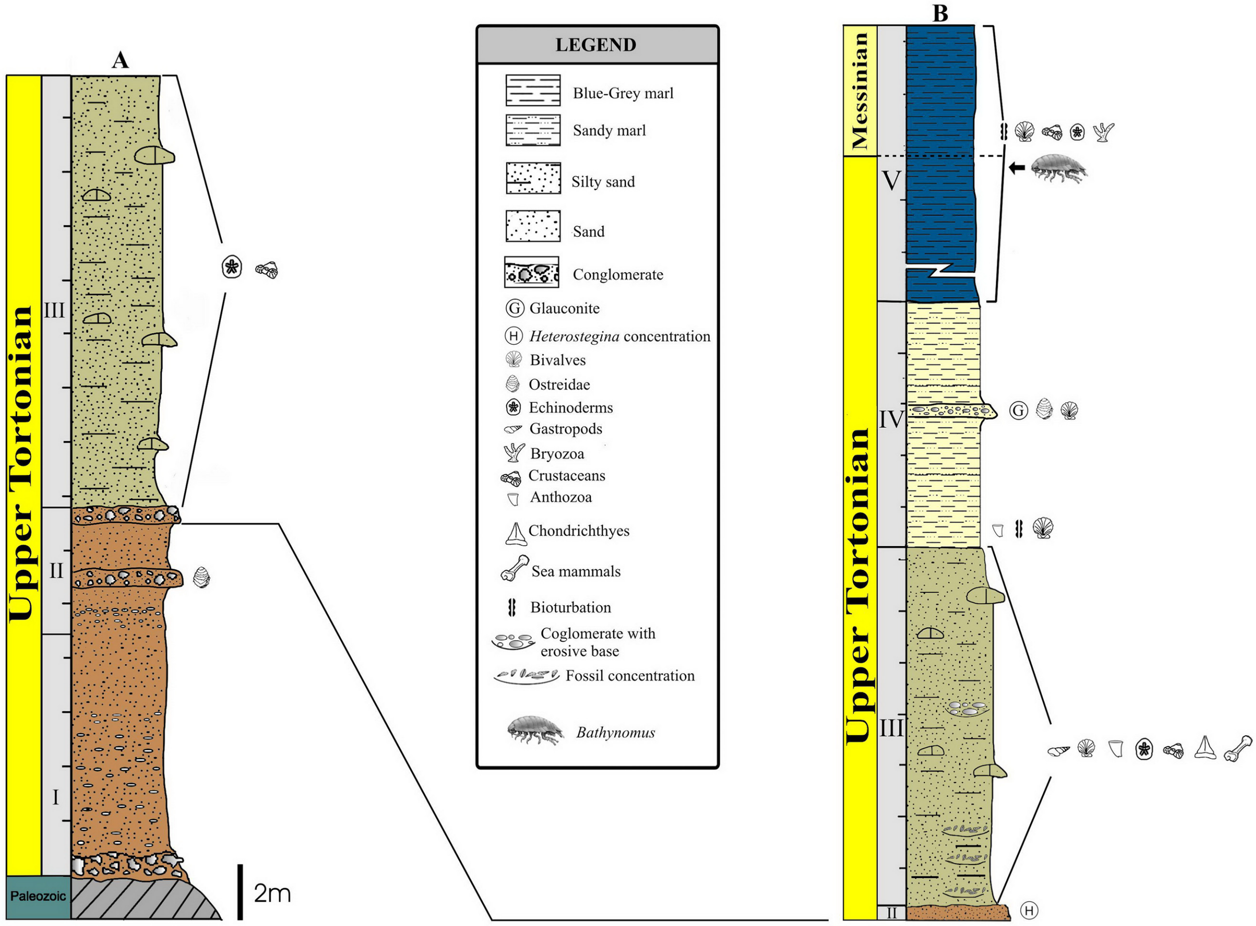

FIGURE 3. Studied section of Arroyo Trujillo (modified from Cárdenas *et al.* 2017). The position of the specimen of *Bathynomus civisi* **sp. nov.** is indicated with an icon (uppermost part of the section). Roman numerals indicate local units. The scheme represents presumed correlation between both sections.

Bathynomus civisi sp. nov.

Figs 4–6

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Material examined: The species is so far represented by the only specimen (measurements: 70.0 x 51.6 mm). The *holotype* (MGM-6636M) represents the posterior moult consisting of pereonites 5–7, pleonites 1–5, and pleotelson; uropods were exposed with further preparation. The specimen consists of part and counterpart (Figs 4B, 5A–B) and was collected by the authors JCC and IBC. GPS coordinates of the type locality (see below): 37°37'1.85"N, 5°47'38.42"W.

Diagnosis: Pleotelson approximately 0.7 as long as wide with indistinct carina and 7 broad, short, straight pleotelsonic spines plus 2 lateral spines; central spine longest, not bifid; gap between second and third side spines wider than between other spines. Uropod with oval exopod and subtriangular endopod, distolateral corners of both elements distinctly produced into tips.

Description: *Pereonites 5–7* poorly preserved, pereonite 5 longer than pereonites 6 and 7 (possibly due to last pereonites being overlapped by preceding ones). *Pleonites* of approximately same length; pleonite 4 slightly overlapping pleonite 5 laterally; pleonites 3–5 reaching to almost same posterior level. *Pleotelson* subcircular in outline, approximately 0.7 as long as wide, dorsal surface finely granulated; posterior margin with 7 broad, short, straight pleotelsonic spines, and 2 smaller lateral spines; central spine longest, simple (not bifid); gap between second and third side spines wider than between other spines (Fig. 6). *Uropodal* exopod with elongate oval outline, lateral margin convex, distolateral corner obtuse with pointed tip, distomedial corner rounded, medial margin straight;

uropodal endopod broadly subtriangular, distolateral corner obtuse, distinctly produced into sharp tip, distomedial corner broadly rounded, median margin straight.

Etymology: In *Memoriam* of Dr. Jorge Civis, professor of Palaeontology at the University of Salamanca and great promoter of Palaeontology in the Neogene of the Guadalquivir Basin.

Remarks: Although the only known specimen is incomplete, there are taxonomically important characters preserved supporting a designation of a new species. Lowry & Dempsey (2006) noted that the shape of the lateral, medial, and distal margins of the uropodal endopods and exopods and the distal corners are important for species identification. The number of pleotelsonic spines are relevant in this matter, especially when combined with the shape of uropod rami (Shipley *et al.* 2016; Hyžný *et al.* 2019). These characters (pleotelsonic spines and uropod rami) are indeed present in the holotype of *Bathynomus civisi* **sp. nov.** and they allow distinguishing the new species from other congeners.

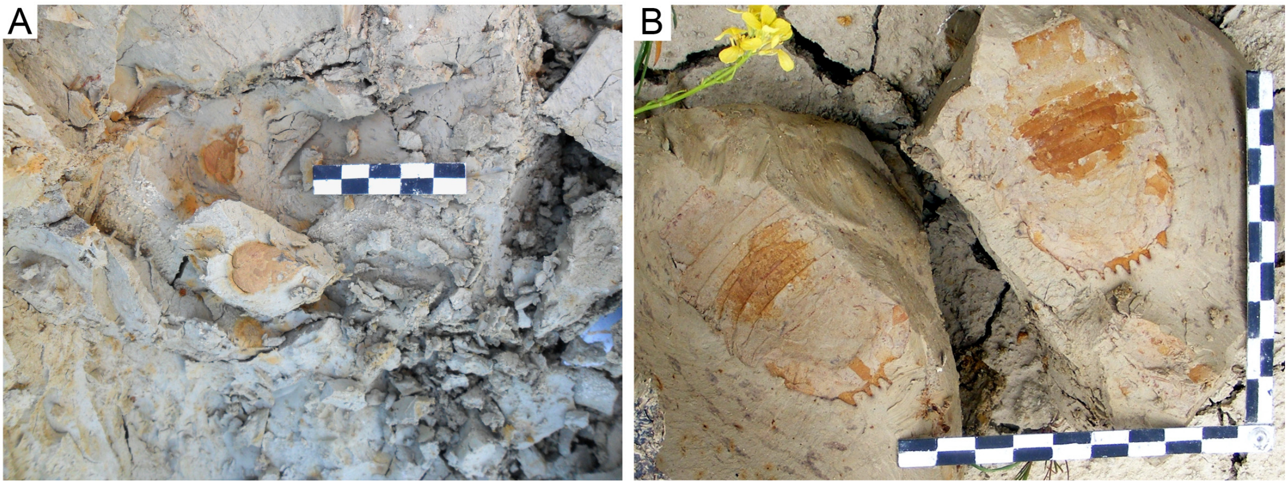

FIGURE 4. Marls of the Écija Formation exposed at the studied section of Arroyo Trujillo. A, marls with bivalve fossils; B, The holotype of *Bathynomus civisi* **sp. nov.** at the time of its finding.

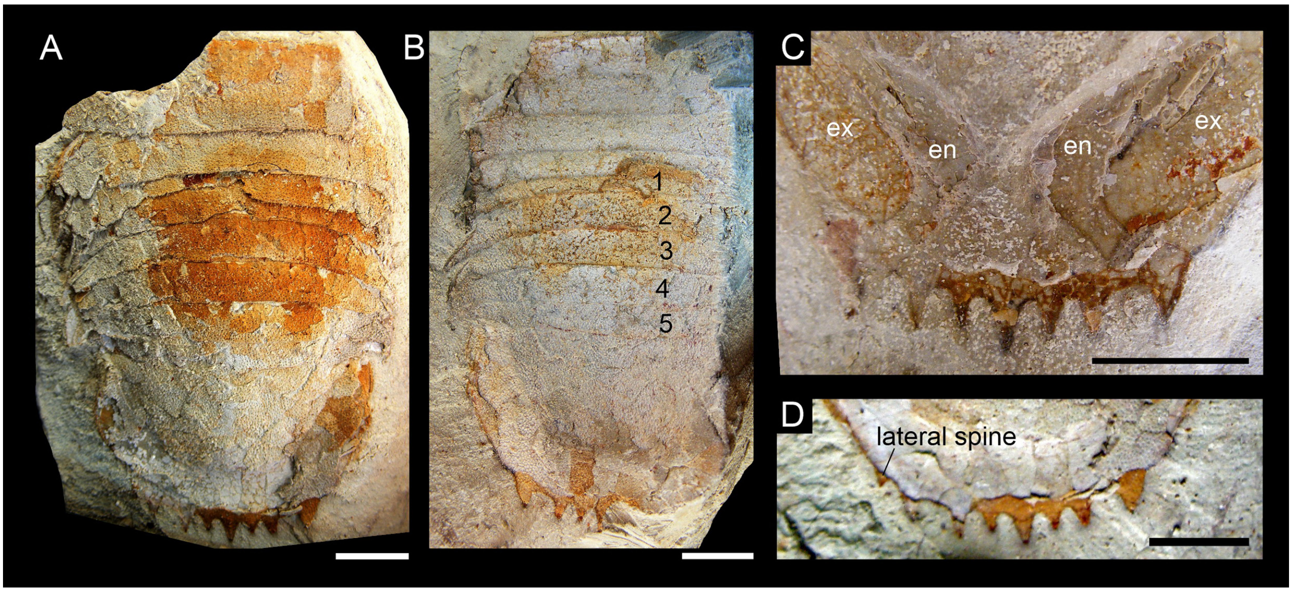

FIGURE 5. *Bathynomus civisi* **sp. nov.**, holotype MGM-6636M. A, part with applied Paraloid B-72 preservative; B, counterpart with applied Paraloid B-72 preservative (numerals 1–5 refer to pleonites). C, part with exposed uropods (en = endopod, ex = exopod) after subsequent preparation; D, counterpart at the time of finding (lateral spine is still present: see the text for more details). Scale bars equal 10 mm.

The new species clearly differs from a number of extant taxa with lanceolate uropod rami, including *Bathynomus affinis* Richardson, 1910; *B. bruscai* Lowry & Dempsey, 2006; *B. decemspinosus* Bruce, 1986; *B. doederleini* Ortmann, 1894; *B. immanis* Bruce, 1986; *B. kapala* Griffin, 1975; *B. maxeyorum* Shipley, Brooks & Bruce in

Shipley *et al.*, 2016; *B. obtusus* Magalhaes & Young, 2003; and *B. pelor* Bruce, 1986. From congeners with oval uropod rami, *B.* c*ivisi* **sp. nov.** is morphologically close to several of them. *Bathynomus brucei* Lowry & Dempsey, 2006 shares the number of pleotelsonic spines (Lowry & Dempsey 2006: fig. 4F); it, however, does not have a wide gap between second and third side distal spines as the new species has. Additionally, the uropodal exopod of *B. civisi* **sp. nov.** is more oval in outline than that of *B. brucei* (Lowry & Dempsey 2006: fig. 5D–E). In this respect, the new species is close to the type species, *B. giganteus* A. Milne-Edwards, 1879, but differs in the number and shape of pleotelsonic spines (Soto & Mincarone 2001: fig. 5; Magalhaes & Young 2003: fig. 1A). The same holds for *Bathynomus jamesi* Kou, Chen, Li, He & Wang, 2017, which is close to *B. civisi* **sp. nov.** as far as the uropod rami concerns (Lowry & Dempsey 2006: fig. 22A–B; Kou *et al.* 2017: fig. 3d, e), but differs in the development of pleotelsonic spines (Kou *et al.* 2017: fig. 4). Concerning the pleotelson outline and the number and development of pleotelsonic spines, the closest extant congener is *Bathynomus miyarei* Lemos de Castro, 1978; it, however, differs with uropodal endopod having distal margin straight (Soto & Mincarone 2001: fig. 5; Magalhaes & Young 2003: fig. 10B), whereas its outline is slightly concave close to distolateral corner (Figs 5C, 6).

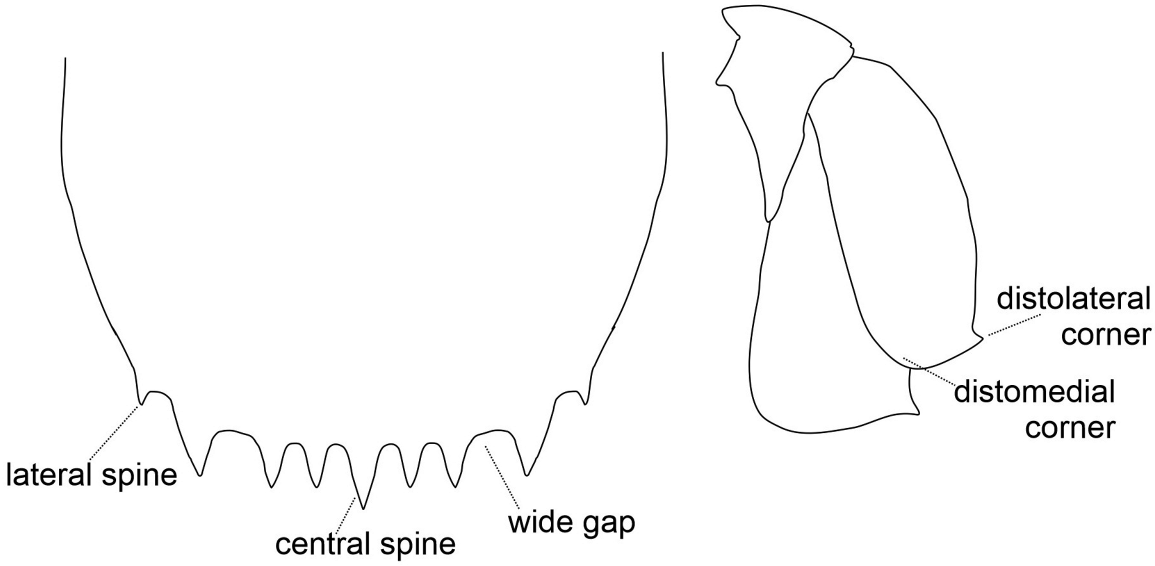

FIGURE 6. *Bathynomus civisi* **sp. nov.**, reconstruction of the pleotelson outline (left) and the shape of uropod rami (right).

Bathynomus civisi **sp. nov.** differs from the fossil congeners; *Bathynomus sismondai* (Ristori, 1891) from the Plio-Pleistocene of Italy has more pleotelsonic spines and uropodal exopod with less obtuse distolateral corner (Hyžný *et al.* 2019: figs. 6A3–A4). *Bathynomus kominatoensis* Kato & Tokita in Kato *et al.*, 2016 from the Miocene of Japan has proportionally wider pleotelson and higher number of pleotelsonic spines (figs. 3.5, 4.1) than *B. civisi* **sp. nov.** No fossil species of *Bathynomus* known to date has a wide gap between second and third side distal spines as the new species has.

Occurrence: *Bathynomus civisi* **sp. nov.** is so far known only from the upper Tortonian marls of the Écija Formation, exposed at the type locality, an old quarry located in the close vicinity of Arroyo Trujillo (Seville, Spain).

Discussion

Palaeoenvironment. The sands of the studied section (Units I–III) correspond to the shallow infralittoral floor (Cárdenas *et al.* 2017, 2019). Large *Crassostrea gryphoides* present in these strata were able to form banks, which could develop from the "intertidal zone" (Harzhauser, *et al.* 2016) to depths close to 35 m (Kauffmann 1969). The silty sands of Unit IV with accumulated mollusc shells correspond to a medium-deep infralittoral floor, deposited in a lesser depth in comparison with previous units (Cárdenas *et al.* 2017, 2019). The marls of Unit V, from which *Bathynomus civisi* **sp. nov.** originates (Fig. 3), were interpreted as formed in distal marine environment (Civis *et al.* 1990). This interpretation is based on the content of benthic foraminifers and molluscs *Korobkovia oblonga*, *Limea strigilata* and *Propeamussium duodecimlamellatum*, which are typical for deep circalittoral to upper bathyal environment (Ruggieri 1981; Scarponi & Di Stefano 2001; Moni 2006). All known fossil occurrences of *Bathynomus* have been reported from the strata deposited in such an environment (e.g., Wieder & Feldmann 1989; Karasawa *et al.* 1995; Kato *et al.* 2016; Hyžný *et al.* 2019). The present occurrence from the Tortonian of Spain further supports the environmental preference of *Bathynomus* for deep-marine settings also in the geological past. Today, *Bathynomus* mainly inhabits muddy bottoms at depths between 170 and 2140 m (Lowry & Dempsey 2006; Sankar *et al.* 2011; Shipley *et al.* 2016; Kou *et al.* 2017).

Taphonomy. Most of *Bathynomus* fossils reported to date (Karasawa *et al.* 1995; Kato *et al.* 2016; Hyžný *et al.* 2019) represent posterior parts of supposedly shed exoskeleton. Isopods normally exhibit biphasic moulting (Tait 1917; Charmantier-Daures & Vernet 2004) and remains of posterior parts of exoskeleton, i.e., pleotelson (sometimes with uropods), pleon and usually the last three pereonites, are interpreted as moults throughout the literature (e.g., Wieder & Feldmann 1989, 1992; Polz *et al.* 2006; Hyžný *et al.* 2013, 2019; Jarzembowski *et al.* 2014; Kato *et al.* 2016). The studied specimen of *Bathynomus civisi* **sp. nov.** is interpreted here also as a moult. Pereonite 5 clearly is preserved without any preceding pereonites (Fig. 4B), no sign of breakage is visible. Thus, moulting process is assumed to produce the remain which fossilized.

Palaeobiogeography of *Bathynomus*. Today representatives of *Bathynomus* inhabit tropical to warm-temperate waters of the West Atlantic and the West Pacific (Lowry & Dempsey 2006; Sankar *et al.* 2011; Shipley *et al.* 2016; Kou *et al.* 2017). It has been, however, demonstrated that in not so distant past the genus was present also in the Mediterranean, as documented from the Plio-Pleistocene of Italy (Hyžný *et al.* 2019). *Bathynomus civisi* **sp. nov.** from the upper Miocene (Tortonian) of southwestern Spain, represents somewhat older occurrence, documenting the presence of the genus in the circum-Mediterranean region at least 7.3 million years ago. The oldest occurrence of the genus from this region, however, is a *Bathynomus* sp. from the lower Oligocene of Italy (Pasini & Garassino 2019). Yet another occurrence of a possible *Bathynomus*, is *Palaega picena* Pasini & Garassino, 2012b, from the Miocene of Italy. As already noted by Pasini & Garassino (2019: p. 97), the confirmation of the assignment of *P. picena* to *Bathynomus* "would attest an uninterrupted presence of *Bathynomus* in the Mediterranean Basin from the early Oligocene to the early Pleistocene".

Although not as old as *Bathynomus* sp. from the Oligocene of Italy (Pasini & Garassino 2019), the occurrence of *Bathynomus civisi* **sp. nov.** comes from the area representing in the Tortonian a part of the Norbetic Strait, a corridor connecting the North-East Atlantic with the Mediterranean (Fig. 2). In this respect, *B. civisi* **sp. nov.** is the first fossil record of the respective genus from the North-East Atlantic.

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