

First occurrence of *Cardilia michelottii* DESHAYES, 1844 (Bivalvia, Cardiliidae) in the Iberian Pliocene

Primera cita de *Cardilia michelottii* DESHAYES, 1844 (Bivalvia, Cardiliidae) en el Plioceno de la península Ibérica

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PALABRAS CLAVE: Cardiliidae, *Cardilia michelottii*, Plioceno, Vale de Freixo, Portugal.

ABSTRACT

The family Cardilidae groups a small number of bivalve species from the superfamily Mactroidea, which have been scarcely found and have a known stratigraphic range from the middle Eocene to the present day. From these stand out *Cardilia michelottii* DESHAYES, 1844, as an extinct valid species only previously known from the Italian Peninsula, where it has been recorded from the Miocene of Emilia-Romagna, the Pliocene of Tuscany and Piedmont, and the Pleistocene of Lazio. The first finding of this species outside the Italian ranges is here reported from a single, but well-preserved left valve collected from the lower Piacenzian molluscan assemblage of Vale de Freixo fossil site (Pombal, West Portugal), in the Pliocene Mondego Basin. This allows to extend the known biogeographic range of this thermophilic species to the Iberian Peninsula, and also to reduce the geographical gap between the Neogene to present-day West African and Mediterranean occurrences of this morphologically very distinctive genus of warm shallow-water bivalve assemblages.

RESUMEN

La familia Cardilidae agrupa un pequeño número de especies de bivalvos de la superfamilia Mactroidea, que apenas se han encontrado de forma muy rara y tienen un rango estratigráfico conocido desde el Eoceno medio hasta nuestros días. De estos se destaca *Cardilia michelottii* DESHAYES, 1844, como una especie extinta válida que antes solo se conocía en la Península Italiana, donde se registró desde el Mioceno de Emilia-Romana, el Plioceno de Toscana y Piamonte y el Pleistoceno de Lazio. Se reporta el primer hallazgo de esta especie fuera de los rangos de Italia, a partir de una valva izquierda bien conservada que ha sido recolectada en la asociación de moluscos fósiles del Piacenziese inferior del yacimiento de Vale de Freixo (Pombal, Oeste de Portugal), en el Plioceno de la Cuenca del Mondego. Esto hallazgo permite extender el rango biogeográfico conocido de esta especie termofílica hasta la Península Ibérica, así como reducir el espacio sin citas entre las ocurrencias oeste-africanas y mediterráneas de este género morfológicamente muy distintivo y que integra asociaciones de bivalvos de aguas cálidas y poco profundas.

I. INTRODUCTION

The numerous previous studies that, over more than a century, have contributed to the knowledge of the bivalve faunas from the marine Pliocene of Portugal (i.e. DOLLFUS & COTTER, 1909; COX, 1936; MORAIS, 1941; ZBYSZEWSKI, 1943, 1959; TEIXEIRA & ZBYSZEWSKI, 1951; MANUPPELLA *et al.*, 1978; SILVA, 1991, 1993a, 1993b, 1995, 2001, 2003; CARVALHO *et al.*, 2005a, 2005b; SILVA *et al.*, 2010; MONEGATTI & RAFFI, 2007; PERNA *et al.*,

2017, 2018) do not include any references to specimens belonging to the family Cardiliidae. Its first discovery is quite recent and has resulted from an extensive study of new bulk samples, carried out as part of an MSc thesis on the bivalves from the Vale de Freixo (Pombal) fossil site (PIMENTEL, 2018), with an updated preliminary list available in PIMENTEL *et al.* (2018).

The family Cardiliidae was proposed by FISCHER (1887: 1120) and has been historically included in the superfamily Mactroidea (e.g. DALL, 1895; LAMY, 1917; KEEN *in* MOORE, 1969; BIELER *et al.*, 2010; CARTER *et al.*, 2011; SIGNORELLI & RAVEN, 2018). According to SIGNORELLI & RAVEN (2018: 142-143), its inclusion in this superfamily needs to be better confirmed. It includes a single genus - *Cardilia* (DESHAYES *in* LAMARCK, 1835: 448-449) - where the type-species is *Isocardia semisulcata* LAMARCK, 1819 (DESHAYES *in* LAMARCK, 1835: 448).

The Cardiliidae share several common characteristics with the remaining Mactroidea families (i.e. Mactridae, Anatinellidae and Mesodesmatidae (SIGNORELLI & CARTER, 2016), namely an internal *resilium* and a left valve cardinal tooth with an inverted “V” shape. As main characters that define the family, the insertion of the posterior adductor in myophorus, the existence of three distinct sculpture areas in the shell surface, the outline of the valves and the heavily inflated, prosogyre umbones are considered (SIGNORELLI & RAVEN, 2018: 131).

The bivalves of the family Cardiliidae are known to have a stratigraphic range that begins at the Middle Eocene and persists to the present day. Their biogeographic distribution during this interval is wide. It includes several European basins, many Neogene and recent areas of Southeast Atlantic, and part of the Indo-Pacific realm, including Japan. In a recent work, SIGNORELLI & RAVEN (2018) have validated 11 extinct species (i.e. *Cardilia michelini* (DESHAYES *in* MICHELIN, 1825); *C. michelottii* DESHAYES, 1844; *C. laeviuscula* SOWERBY *in* DIXON, 1850; *C. deshayesi* HÖRNES, 1859; *C. krawangensis* OOSTINGH, 1934; *C. ludwigi* OOSTINGH, 1934; *C. bruneiana* BEETS, 1944; *C. palembangensis* BEETS, 1944; *C. sundai-ca* REGTEREN, ALTENA & BEETS, 1945; *C. toyamaensis* TSUDA, 1959; and *C. edwardsi* nov. sp.), and four extant ones (i.e. *Cardilia semisulcata* (LAMARCK, 1819); *C. inermis* DESHAYES, 1844; *C. martini* DESHAYES, 1844; and *C. atlantica* NICKLÈS, 1955).

Next paragraphs report the first mention of the genus *Cardilia* in the Iberian Pliocene, through the description and figuration of a specimen of *C. michelottii* recently found in the Vale de Freixo fossil site, one of the few outcrops with highly diverse fully marine Piacenzian faunas available in Portugal.

2. GEOGRAPHICAL AND STRATIGRAPHICAL SETTING

The studied fossil site is located in the Beira Litoral ranges of West-Central Portugal (Figure 1A), between the towns of Pombal and Leiria. This area of the Western Meso-Cenozoic Border of the country is characterized by the widespread of a thick post-Mesozoic sedimentary cover, as part of the onshore infill of the west continental margin of Iberia (RIBEIRO *et al.*, 1979). It is also one of the main areas with exposures of marine Piacenzian found in the Mondego Basin (PAIS *et al.*, 2010), a Cenozoic basinal unit with a tectono-sedimentary history related to the subsidence of NE-SW depressions controlled by the reactivation of Variscan reverse structures (RIBEIRO *et al.*, 1990).

During the Piacenzian, the area was strongly affected by several eustatic oscillations of the nearby Atlantic Ocean, which resulted in a marine transgression that reached more than 20 km away from the present-day coastline (e.g. CUNHA, 1992; CUNHA *et al.*, 2008). The correlative stratigraphic record is mostly sandy siliciclastic. It locally begins by conglomeratic facies rich on marine shells, which are the basis of several interesting fossil sites, including those discovered during the 1950's near the locality of Carnide (e.g. Carnide de Cima, Igreja de Carnide, Vale da Bouchada, Vale da Cabra, and Vale Farpado), in the municipality of Pombal (TEIXEIRA & ZBYSZEWSKY, 1951).

The Vale de Freixo fossil site was discovered during the 1980's decade in a clay pit exposed nearly 500 m SW the Carnide church, in the locality of Carnide (Pombal) (Figure 1B). It locally records the “P - Marine Pliocene of Vale de Carnide” unit described in the chart “23-A Pombal” of the 1/50,000 Geological Map of Portugal (MANUPPELLA *et al.*, 1978). The local fossiliferous beds have been assigned to an interval correlative to the Piacenzian lower half, but where the uppermost Zancian can still be represented (CACHÃO, 1990; SILVA, 2001). The lithostratigraphic setting comprises the Carnide Formation (CACHÃO, 1989; PAIS *et al.*, 2010) where three sub-horizontal fossiliferous strata (“Beds 2 to 4”) have been differentiated by authors, with an overall maximal thickness of 1,2 m. Facies are of coarse to fine siliciclastics and their sequential articulation suggests sedimentation in an inner platform context, where the main hydrodynamic oscillations

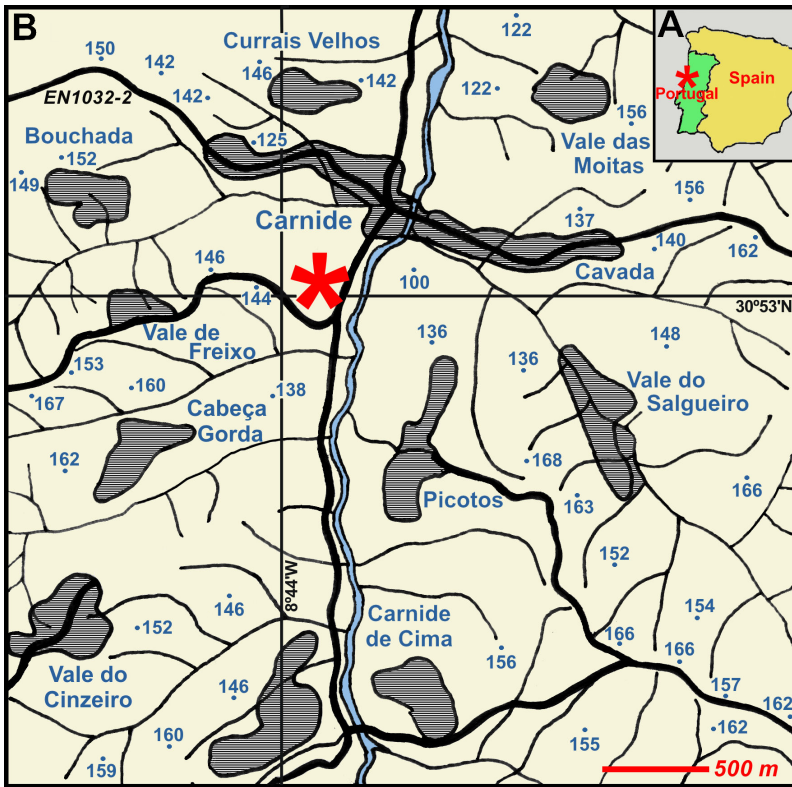


Figure 1. Geographical context of Vale de Freixo (Pombal, Portugal). A – General geographical location. B – Vale de Freixo fossil site location.

are expressed by fining-upwards granulometric changes (CARVALHO, 1998; CARVALHO *et al.*, 2005c). The fossiliferous sequence comprises the following strata, from its base upwards (Figure 2 A-B):

(a) Clast to matrix-supported oligomitic conglomerate, bioclastic rich, with medium to high sphericity, rounded quartz and quartzite clasts. It comprises abundant concentrations of reoriented shells (including large valves of *Glycymeris* with their commissure planes facing downwards) enveloped in a grey sandstone and lutitic matrix (“Bed 2”). This unit rests unconformable on Miocene clayey sediments (“Bed 1”);

(b) Fine to medium-grained greyish sandstone, very friable, with abundant malacofauna (“Bed 3”);

(c) Fine-grained, brown to yellowish sandstone, very friable, also rich on fossil content, including many articulated bivalves (“Bed 4”);

(d) High plasticity brownish claystone, apparently without macrofossils (“Bed 5”). This impermeable stratum has a variable thickness

of 10 a 15 cm and inhibits water circulation from overlying sandy levels, contributing to the excellent local preservation of skeletal remains.

3. SYSTEMATIC PALAEOLOGY

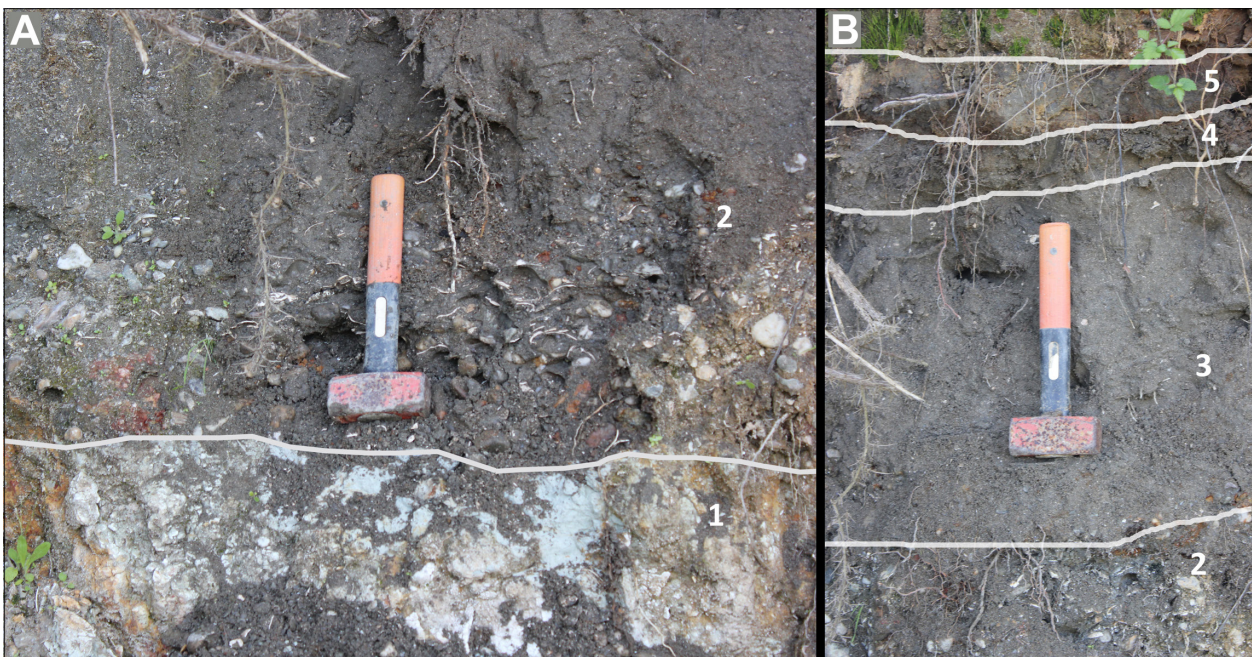


Figure 2. Fossiliferous sequence of Vale de Freixo (Pombal, Portugal). A – Unconformity between the underlying Miocene clayey sediments (1) and the Pliocene basal oligomitic conglomerate (2). B – Fossiliferous conglomerate and sandy beds (2, 3, 4) and overlying impermeable clay bed (5).

The studied specimen is a left valve (RP-VF4-B005) directly collected from “Bed 4”, during the sampling procedures. It is presently housed in the Departamento de Ciências da Terra, Universidade de Coimbra, Portugal, as part of the study collection of the first author, and is available for further researches. The dimensional parameters considered for its description are: (a) the maximum distance between the umbo and the paleal border - umbopaleal diameter; (b) the maximum distance between the anterior and posterior margins - anteroposterior diameter; and (c) the diameter between the highest point of the external face of the valve and the commissural plane - valve height.

Class Bivalvia LINNAEUS, 1758
 Subclass Heterodonta NEUMAYR, 1884
 Superorder Imparidentia BIELER, MIKKELSEN & GIRIBET, 2014
 Superfamily Mactroidea LAMARCK, 1809
 Family Cardiliidae FISCHER, 1887
 Genus *Cardilia* DESHAYES, 1835
 [Type species: *Isocardia semisulcata* LAMARCK, 1819]

Cardilia michelottii DESHAYES, 1844 (Figure 3, 1-4)

- 1844 *Cardilia michelottii* – DESHAYES: 8.
- 1847 *Cardilia michelottii* – SISMONDA: 22.
- 1848 *Cardilia michelottii* – BRONNI: 220.
- 1852 *Cardilia michelottii* – D’ORBIGNY: 183.
- 1855 *Cardilia michelottii* – PICTET: 501.
- 1861 *Cardilia michelottii* – FISCHER: 343.
- 1862 *Cardilia michelottii* – DODERLEIN: 96.
- 1868 *Isocardia* sp. n.? – MANZONI: 19-20.
- 1870 *Cardilia michelottii* – MANZONI: 24-25; pl. II, fig. 3.
- 1874 *Cardilia michelottii* – DE STEFANI: 10, 78.
- 1887 *Cardilia michelottii* – PONZI & MELI: 678.
- 1888 *Cardilia michelottii* – CLERICI: 113, 127; pl. IV, fig. 38.
- 1891 *Cardilia michelottii* – FUCINI: 85.
- 1892 *Cardilia michelottii* – PANTANELLI: 239.
- 1889 *Cardilia michelottii* – SACCO: 346.
- 1901 *Cardilia michelottii* – SACCO: 32; pl. VI, figs. 26-30.
- 1909 *Cardilia michelottii* – CERULLI-IRELLI: 145 [161]; pl. XVI [XXVI], fig. 6.
- 1941 *Cardilia michelottii* – SOCIN: 8.
- 1975 *Cardilia michelottii* – PAVIA: 116; pl. XIII, fig. 6.
- 1983 *Cardilia michelottii* – AIMONE & MORTARA: 301.
- 2007 *Cardilia michelottii* – MERLINO: 154.
- 1983 *Cardilia michelottii* – CAVALLO & REPETTO: 206; fig. 615.
- 2015 *Cardilia michelottii* – CHIRLI: 83; pl. 19, figs. 7-10.
- 2018 *Cardilia michelottii* – SIGNORELLI & RAVEN: 2, 9, 13.
- 2018 *Cardilia michelottii* – PIMENTEL: 167; pl. XX, figs. 1-3.
- 2018 *Cardilia michelottii* – PIMENTEL et al.: 226.

Studied material: A single left valve (RP-VF4-B005) well-preserved and showing all morphological details of this very uncommon species.

Dimensions: Umbopaleal diameter (a): 17 mm; anteroposterior diameter (b): 12 mm; valve height (c): 8 mm.

Description: As main external characters, the shell is tumid, fragile, with subcircular-oval outline. Umbopaleal diameter larger than the anteroposterior one, posterior dorsal margin concave and anterior oblique, and anterior and posterior margins curve, although the posterior is less rounded. Arched ventral margin, and umbo conserved in anterior subcentral position, and prosogyrous. External sculpture with concentric and irregular growth lines, more marked in the dorsoposterior zone, between the posterior margin and the radial ribs. Six radial ribs arranged in the central part of posterior half of the valve, along the umbopaleal axis, five of which well-marked and the remain more diffuse. Radial ribs crossed by growth lines



Figure 3. *Cardilia michelottii* Deshayes, 1844 from the lower Piacenzian of Vale de Freixo (Pombal, Portugal) fossil site. RP-VF4-B005 (left valve). Views: 1 – external lateral; 2 – internal lateral; 3 – radial ribs; 4 – anterior lateral. Scale bar: 1 cm.

and intercalated by well-marked but narrower interspaces. As main internal characters the shell hinge is mactroid in shape, with an oblique chondrophore ventrally projected, a typical inverted “V” shape tooth, and a triangular myophore umbonally sharpened.

Distribution: *Cardilia michelottii* was mentioned by DORDELEIN (1862) for the Tortonian beds of Montegibbio (Sassuolo, Italy). Several other authors also refer this rare species for the Pliocene of Italy, namely in the regions of Tuscany and Piedmont (e.g. DESHAYES, 1844; SISMONDA, 1847; BRONN, 1848; D’ORBIGNY, 1852; PICTET, 1855; FISCHER, 1861; MANZONI, 1868, 1870; SACCO, 1889, 1901; PANTANELLI, 1892; CHIRLI, 2015; SIGNORELLI & RAVEN, 2018). It was also signalled by PONZI & MELI (1887), CLERICI (1888) and CERULLI-IRELLI (1909) for the Pleistocene of Lazio. The first known figuration was published by MANZONI (1870).

4. DISCUSSION

The studied specimen is close to those *Cardilia michelottii* described and figured for the Italian Neogene (e.g. SACCO, 1901; CERULLI-IRELLI, 1909; CHIRLI, 2015). Its external sculpture is very identical to those of the Italian specimens. However, there are

a few slightly morphological differences to note, including the less circular outline of the valve, with the anterior and posterior margins less concave and the umbo-paleal diameter much larger than the anteroposterior one. There is also a lateral fracture in the valve surface that could suggest some degree of diagenetic distortion and thus explain the more oval outline. By this way, the above-mentioned differences should be consistent with the individual variation admissible for this species, but future studies on the shell microstructure of both Italian and Portuguese specimens will be very valuable to confirm their affinities.

No other species of *Cardilia* are presently known in the European Pliocene (Figure 4), suggesting that this genus was in decline after the Miocene in the Mediterranean and nearby Atlantic areas, in what appears to be a tendency that culminated with the extinction of *C. michelottii* in the Italian Pleistocene.

It is also interesting to note that the genus *Cardilia* is also represented in the present-day West African tropical fauna (NICKLÈS, 1955), where several thermophilic species integrated the “Senegalese fauna” that colonized many Mediterranean shallow coastal areas during intervals of climatic warming. Thus, the occurrence of *C. michelottii* in the Vale de Freixo fossil site can be an additional indicator that suggests the seasonal prevalence of slightly higher palaeotemperatures in the lower Piacenzian local coastal surface waters (SILVA *et al.*, 2010), when compared with those presently recorded for the same latitude.

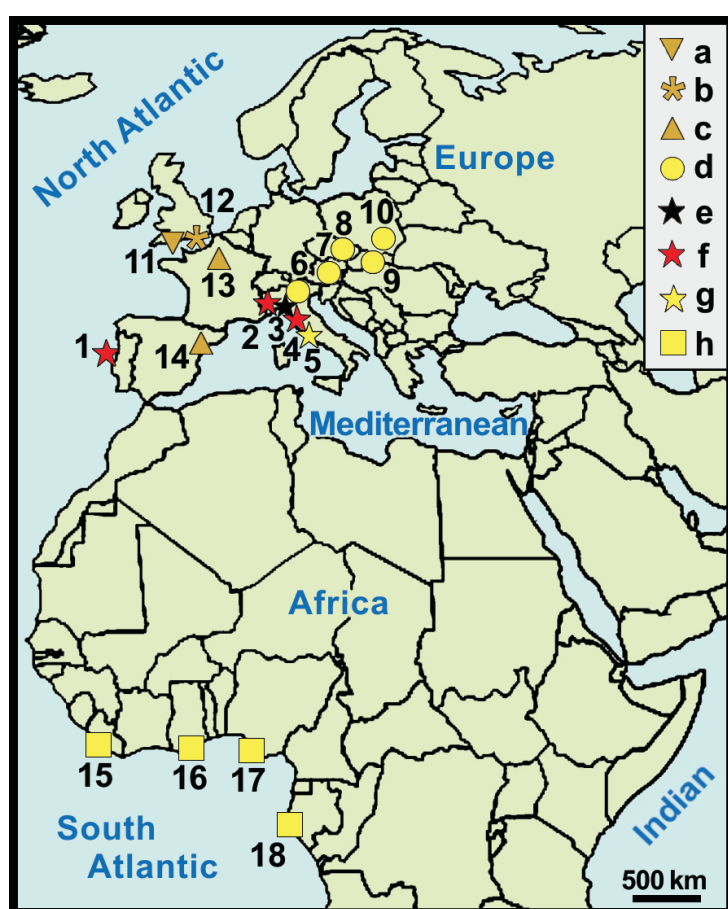


Figure 4. Temporal and geographical distribution of valid *Cardilia* species known to the European and West African basins. a – *C. edwardsi* (Eocene); b – *C. laeviuscula* (Eocene); c – *C. michelini* (Eocene); d – *C. deshayesi* (Miocene); e – *C. michelottii* (Miocene); f – *C. michelottii* (Pliocene); g – *C. michelottii* (Pleistocene); h – *C. atlantica* (Holocene). 1 – Vale de Freixo, Portugal; 2 – Piemonte, Italy; 3 – Montegibbio, Emilia-Romagna, Italy; 4 – Tuscany, Italy; 5 – Monte-Mario, Lazio, Italy; 6 – Venetia, Italy; 7 – Vienna Basin, Austria; 8 – Mikulov, Czech Republic; 9 – Lontov, Slovakia; 10 – Smarzowa, Poland; 11 – Barton-on-Sea, Hampshire, England; 12 – Selsey, West Sussex, England; 13 – Paris Basin, France; 14 – Gerona, Spain; 15 – Liberia; 16 – Ghana; 17 – Nigeria; 18 – Gabon. (SIGNORELLI & RAVEN, 2018, and references therein).

5. CONCLUSIONS

The specimen of *Cardilia michelottii* here described for the Vale do Freixo fossil site is the first to be recorded for this species and genus in the European Pliocene marine molluscan assemblages located outside the Italian Peninsula. Besides its taxonomic relevance and the fact of belonging to a poorly-known family (Cardiliidae) with thermophilic affinities, it allows to enlarge the biogeographical range of this species to the Mondego Basin, in the Atlantic margin of West-Central Portugal. Also considering the Neogene to present day known-occurrences of this genus, our finding also reduces the geographical gap between the West African and Mediterranean occurrences of this morphologically very distinctive genus of warm shallow-water bivalve assemblages.

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