

SYSTEMATICS OF THE ACANTHOCARDIA PAUCICOSTATA GROUP IN THE MEDITERRANEAN PLIO-PLEISTOCENE, WITH DESCRIPTION OF A NEW SPECIES (BIVALVIA, CARDIIDAE)

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Abstract Three *Acanthocardia* species, namely *A. paucicostata* (Sowerby 1841), *A. bianconiana* (Cocconi 1873) and a new species herein described are particularly similar to each other, sharing some shell characters: shell relatively thin-walled, compared with the congeners, tending to be antero-posteriorly elongate, bearing a low number of radial ribs (15–18). *A. paucicostata* is an extant species with a stratigraphic distribution ranging back to the Late Miocene at least. *A. bianconiana*, regarded as a variety or subspecies of *A. paucicostata* in the past literature, had a Plio-Pleistocene Mediterranean distribution. The new species, *A. brunettii* n.sp., the smallest *Acanthocardia* species so far known and with an unusually elongate shape, also had a Plio-Pleistocene distribution. There are evidences that the *paucicostata* group also had representatives in the Miocene, either in the paleo-Mediterranean or the Paratethys.

Key words *Acanthocardia*, Plio-Pleistocene, Mediterranean, systematics, new species

INTRODUCTION

The present work is part of a research program on the Miocene, Pliocene and Pleistocene cardiid fauna from the Mediterranean (D'Abramo, 2012). On this topic, two articles dealing with *Acanthocardia* (La Perna, 2008; La Perna & D'Abramo, 2009) and one on the genus *Nemocardium* (La Perna & D'Abramo, 2011), have been published.

Acanthocardia Gray 1853 is a European genus, which appeared in the Early Miocene or late Oligocene (Studencka & Popov, 1996; Schultz 2003; D'Abramo, 2012). Six extant species are currently assigned to this genus: *A. aculeata* (Linné 1758), *A. spinosa* (Solander 1786), *A. echinata* (Linné 1758), *A. deshayesii* (Payraudeau 1826), *A. paucicostata* (Sowerby 1834) and *A. tuberculata* (Linné 1758) (CLEMAM, WoRMS). Except for *A. deshayesii* and *A. spinosa*, only known from the Mediterranean, the other species occur in the adjacent Atlantic as well, with differing ranges.

In the Mediterranean Pliocene and Pleistocene, the genus was slightly more diverse: all of the extant species were present, together with three extinct species, *A. lunulata* (Seguenza 1879), *A. bianconiana* (Cocconi 1873) and another species, herein described as new.

Of these species, *A. bianconiana*, the new species and the extant *A. paucicostata* are particularly similar to each other, sharing some shell characters:

shell relatively thin-walled, compared with the congeners; tending to be antero-posteriorly elongate; bearing 15–18 radial ribs, arched to roughly triangular in cross-section, instead of somewhat rectangular as in *A. echinata*. The spiny projections on the ribs, typical of *Acanthocardia* (La Perna & D'Abramo, 2009), are similar to those of *A. echinata* but smaller and more delicate. A detailed comparison between *A. paucicostata* and *A. echinata* was reported by Moerdijk & Poorten (2006: tab. 1). As remarked by D'Abramo (2012), some species groups can be identified within *Acanthocardia*, since the Pliocene at least. One of this group is represented by *A. echinata*, *A. deshayesii* and *A. lunulata* in the Mediterranean Plio-Pleistocene (La Perna & D'Abramo, 2009), including *A. sliggersi* Moerdijk & Poorten 2006 from the Plio-Pleistocene of the North Sea basin. The roots of these groups of species should be tracked down among the many species which occurred in the European Miocene.

MATERIAL AND METHODS

The present study is mostly based on museum collections, including type material. The public collections from which the fossil cardiids were studied are: Bellardi & Sacco, Museo Regionale di Storia Naturale, Turin (molluscs from the Miocene and Pliocene of Piedmont and Liguria); Cerulli-Irelli collection (Pleistocene molluscs from Monte Mario, Rome); Cocconi coll. (Miocene

and Pliocene molluscs from Parma and Piacenza, Northern Italy); Hörnes and other collections, Naturhistorisches Museum, Vienna (mainly Miocene molluscs from Paratethys). In addition, Pliocene and Pleistocene material from the private collections of Mauro M. Brunetti (Rioveggio, Bologna) and R. La Perna (Bari), was used.

The following acronyms and abbreviations are used in the present work:

MPP – Museo Paleontologico Parmense, Parma; MPUR – Museo Paleontologico dell'Università di Roma "La Sapienza"; MRSN – Museo Regionale di Storia Naturale, Turin; MZB – Museo di Zoologia, Università di Bologna; NHMW – Naturhistorisches Museum, Vienna; coll. – collection; L – shell length (antero-posterior distance); H shell height (umbo-ventral distance); sh(s) – complete shell(s); v(s) – loose valve(s).

SYSTEMATICS

Family Cardiidae Lamarck 1809

Subfamily Cardiinae Lamarck 1809

Genus *Acanthocardia* Gray 1853

Type species *Cardium aculeatum* Linné 1758 (by subsequent designation, Stoliczka, 1870)
Rudicardium Coen 1914 ex Monterosato ms.
Sphaerocardium Coen 1933

Acanthocardia paucicostata (Sowerby GB II 1834)

Figs 1A,B, 2A–F, I–P, 3A–D, 5M,N

Cardium paucicostatum Sowerby GB II 1834: part 49, catalogue p. 2, fig. 20.

Cardium aculeatum var. *perrugosa* Fontannes 1882: 81–83, pl. 5, figs 3a–c (non fig. 2).

Cardium paucicostatum var. *producta* Bucquoy *et al.* 1892: 270, pl. 44, figs 6–8.

Cardium paucicostatum var. *rotundicosta* Sacco 1899: 36, pl. 8, figs 18a, b.

Cardium paucicostatum Sowerby – Dollfus *et al.* 1903: 43, pl. 15, figs 6, 7; pl. 16, figs 1–3.

Material Bellardi & Sacco coll. (MRSN): 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.005); 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.006); 15 vs, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.007/04); 57 vs, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.007/06); 83 vs, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.007/07); 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.009); 1 v, Rio Torsero (Savona), Zanclean (BS.131.01.009/01); 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.008); 1 v, Albenga (Savona), Early Pliocene (BS.131.01.008/01); 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.008/03); 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.008/02). Cerulli-Irelli coll. (MPUR): 2 vs, Farnesina (Rome), Early Pleistocene. La Perna coll.: 6 vs, Santo Pietro (SE Sicily), Early Pleistocene; 3 vs, Ficarazzi (Catania, E Sicily), Early Pleistocene.

Distribution The modern geographic distribution of *A. paucicostata* is notably wide, ranging

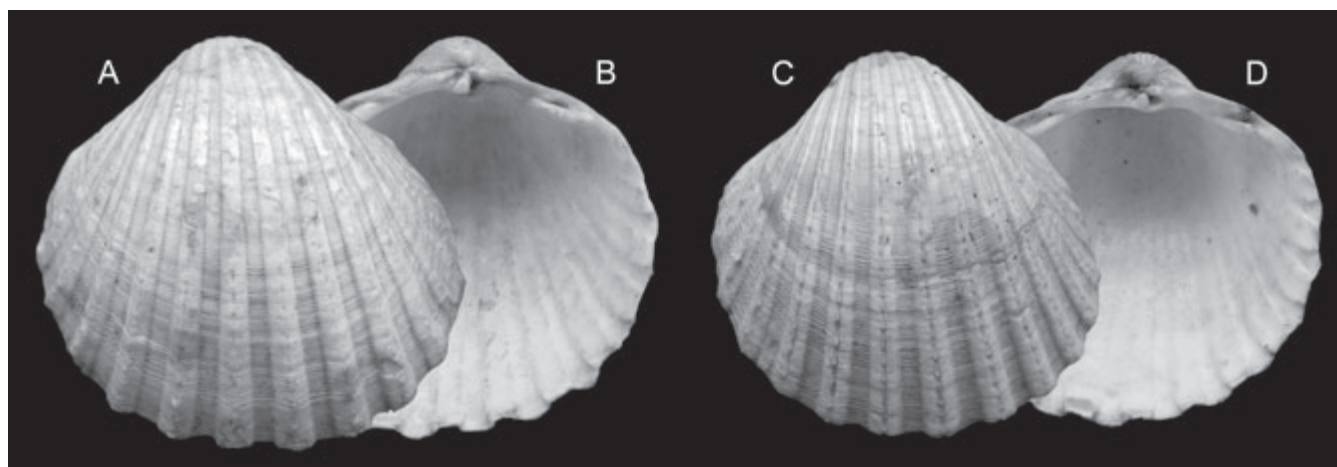


Figure 1 Specimens of *Cardium ciliare* Linné 1758 at the Linnean Society of London. **A, B** *Acanthocardia paucicostata* (Sowerby GB II 1834), L 30.0 mm. **C, D** *Acanthocardia echinata* (Linné 1758), L 27 mm. Source: <http://www.linnean-online.org>.

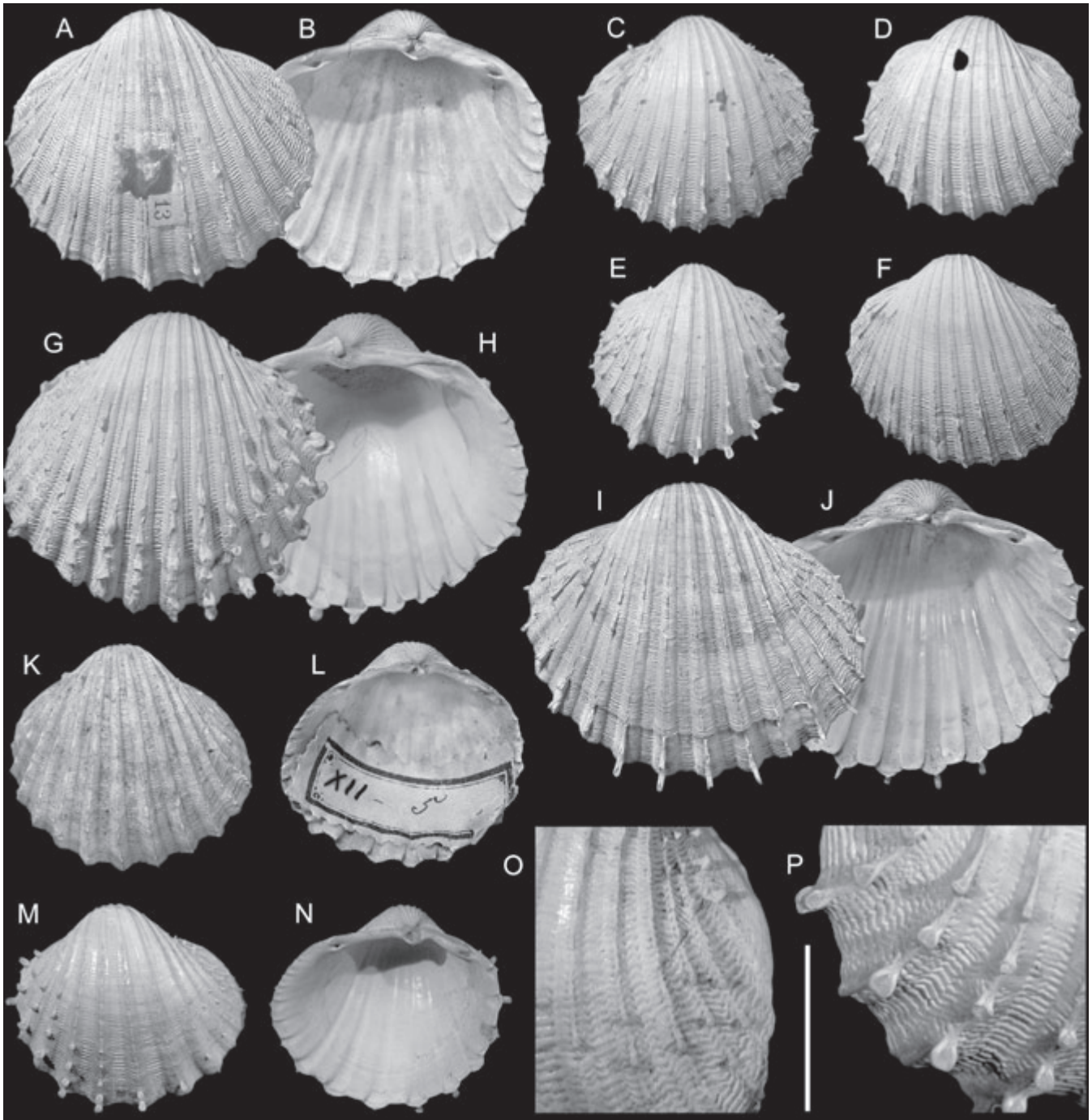


Figure 2 A–F *Acanthocardia paucicostata* (Sowerby GB II 1834). A, B Asti Hills, Late Zanclean–Early Piacenzian, L 29 mm (Bellardi & Sacco coll., MRSN, BS.131.01.006). C Asti Hills, Late Zanclean–Early Piacenzian, L 22 mm (Bellardi & Sacco coll., MRSN, BS.131.01.007/04). D Asti Hills, Late Zanclean–Early Piacenzian, L 20.1 mm (Bellardi & Sacco coll., MRSN, BS.131.01.007/07). E Asti Hills, Late Zanclean–Early Piacenzian, L 19 mm (Bellardi & Sacco coll., MRSN, BS.131.01.007/06). F Asti Hills, Late Zanclean–Early Piacenzian, L 21.5 mm (Bellardi & Sacco coll., MRSN, BS.131.01.007/04). G, H *Acanthocardia echinata* (Linné 1758), Albenga, Early Pliocene, L 29 mm (Bellardi & Sacco coll., MRSN, BS.131.01.008/01). I–P *Acanthocardia paucicostata* (Sowerby GB II 1834). I, J Asti Hills, Late Zanclean–Early Piacenzian, L 31.5 mm (Bellardi & Sacco coll., MRSN, BS.131.01.009). K, L Farnesina (Rome), Early Pleistocene, L 22.5 (Cerulli-Irelli coll., MPUR). M–P Santo Pietro, SE Sicily, Early Pleistocene, 21 mm (details: O Posterior side; P Anterior side; scale bar = 5 mm) (La Perna coll.).

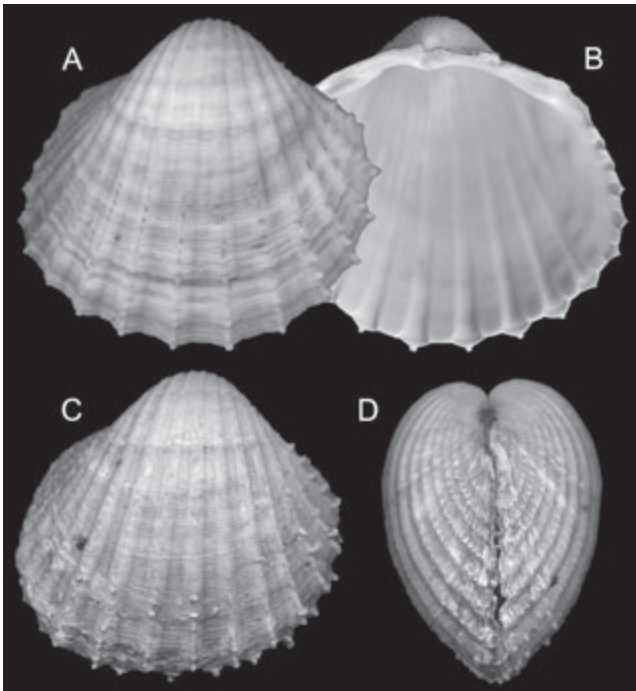


Figure 3 *Acanthocardia paucicostata* (Sowerby GB II 1834). **A, B** West of Paimpol (Brittany, France), at low tide, L 35 mm (Olivier Caro coll. & photo). **C, D** Gulf of Morbihan (Brittany, France), dredged at 8–10 m, L 32 mm (Olivier Caro coll. & photo).

from The Netherlands (Grevelingen) to north-west Africa (Gambia), including the Mediterranean, Black Sea and Sea of Azov (Fischer-Piette, 1977; Voskuil & Onverwagt, 1889; Poorten, 2003; Hylleberg, 2004, 2009; Goud, 2004).

Its stratigraphic distribution is confirmed for the Pliocene and Pleistocene of the Mediterranean. The Miocene records from Paratethys seem all to be based on misidentifications, as discussed under Remarks. The records from the Late Miocene (Tortonian) of Italy by Venzo & Pelosio (1963) and Tavani & Tongiorgi (1963) are doubtful, due to the poor quality of illustrations or bad preservation. For the Miocene, probably only the record by Dollfus *et al.* (1903–1904: 43, pl. 15, figs 6, 7; pl. 16, fig 1–3), from the Tortonian Cacela Fm. (SE Portugal, Gulf of Cádiz: Santos & Mayoral, 2007) is correctly based on *A. paucicostata*.

Remarks *Acanthocardia paucicostata* is relatively small sized for the genus (maximum shell length about 40 mm, frequently not exceeding 30 mm), rather thin-walled and fragile, orbicular to slightly elongate antero-posteriorly. The radial sculpture consists of 15–18 ribs (rarely 19), slightly wider and flatter than in *A. echinata* and

in other congeners, arched to roughly triangular in cross section. Interspaces are about as wide as ribs, with a dense, somewhat wrinkled commarginal sculpture, which also crosses, in part or completely, the radial ribs. The ribs bear sub-cylindrical to spoon-shaped spines, generally more developed anteriorly (Fig. 2O,P). Spines take their origin from a lamellar ridge, running medially the full length of ribs.

Acanthocardia paucicostata and *A. echinata* are both involved in a long-lasting, complex systematic matter: the identity of *Cardium ciliare* Linné 1758 (Hylleberg, 2004, with references). No material of *C. ciliare* is present in the Linnean collection in Uppsala, Sweden (Wallin, 2001), whereas two unmarked valves, closely similar to each other, are present at the Linnean Society of London (<http://www.linnean-online.org>). According to an accompanying label, these valves were selected by Hanley (1855), whose text (p. 48) is confused and of little help. Actually, Hanley's work on the Linnean collection seems to have contributed to its disarrangement, according to Dance (1967). The two valves are very similar to each other in size, shape and sculpture but are distinct species: *A. paucicostata* (Fig. 1A,B), and *A. echinata* (Fig. 1B,C), both rather young. In spite of Dodge's (1952) statement ("The description, although it does not mention the number of ribs, is sufficiently clear to indicate the shell which is universally called *ciliare* today"), in the Linnean description there is no clear evidence for assigning the name *ciliare* to one of the two valves: "*C. testa subcordata: sulcis elevatis triquetris: extimis aculeato-ciliatis. Gualt. test. t. 72, f. C. Habitat in M. Mediterraneo. Simillima duobus precedentibus, sed minor & nivea. Sulci triquetri, latere scilicet altero adnato*" (Linné, 1758). The identity of *Cardium ciliare* was recently discussed by Huber (2010: 680), who wrote: "Hinge, sculpture and fragile texture approach *paucicostata* in some respects, but are not far from certain *echinata* forms either. However, both valves are unmarked and heavy doubts persisted, whether these indeed represent true Linnean *ciliare*. In Sweden no type material is present. Consequently, *Cardium ciliare* is treated as a nom. dub." We agree with Huber about the impossibility of knowing if the two valves are actually Linnean type material (see also Way, 2007) and in considering *C. ciliare* as a *nomem dubium*. The problem was also dealt with by Goud (2004), who proposed to select

“the juvenile syntype [i.e. *A. echinata*, Fig. 1C,D] as lectotype of *C. ciliare* and giving *A. echinata* priority over *C. ciliare*.”.

As a fossil, *Cardium paucicostatum* was included in the monumental work by Sacco (1899), who recorded it as a rare species from the Miocene of Turin Hill and Montegibbio (northern Italy) and frequent in the Pliocene. No Miocene material is present for this species in the Bellardi & Sacco collection (MRSN). Conversely, the Pliocene material is abundant, though mixed with *A. bianconiana* and *A. aculeata*. For *C. paucicostatum*, Sacco made references to four varieties: *bianconiana* Cocconi 1873, *producta* B.D.D. 1892, *rotundicosta* Sacco 1899, and *perrugosa* Fontannes 1880. About var. *bianconiana*, Sacco (1899) hypothesized it was a distinct species (“*an species distinguenda*”), as dealt with in the present work. The variety *producta* (two valves from the Pliocene of Rio Torsero and Asti; Fig. 2I, J), fits *Cardium paucicostatum* var. *producta* of Bucquoy *et al.* (1892): evidently a morphological variation of *A. paucicostata*, more elongate and with a wider posterior side. No material of var. *rotundicosta* (Sacco, 1899: pl. 8, figs 18a, b), described from the Pliocene of Piacenza, is present in the collection. Description and illustrations point to a morphological variation of *A. paucicostata*, with less angular ribs and narrower interspaces. The last variety, *perrugosa*, was described by Fontannes (1882: 81–83, pl. 5, fig. 2, 3a–c), as *Cardium aculeatum* var. *perrugosa* from the Pliocene of SE France (Drôme and Vaucluse). Its description, including size (42 mm in length), points to *A. paucicostata*, but the illustrations suggest two distinct species: fig. 2 is probably a juvenile of *Acanthocardia aculeata*; whereas figs 3a–c could be *A. paucicostata*. It must be noticed that Fontannes probably did not know *Cardium paucicostatum*, as he never mentioned it and also wrote that *Cardium ciliare* of the English authors was the juvenile form of *C. aculeatum*, whereas that of other authors, such as Linné, Philippi, Poli, was the juvenile of *C. echinatum*. Moreover, he compared his var. *perrugosa* with “*Cardium Bianconianum*”, erroneously attributed to Coppi (“*une coquille subappennine de taille plus grande, qui se rattachera sans doute à la forme perrugosa par l’intermédiaire de quelque variété extrême*”). However, the material of var. *perrugosa* in the Bellardi & Sacco coll. proved to consist of *A. echinata* (Fig. 2G, H), with 17–18 ribs (usually 19–22 in this species: La Perna & D’Abramo, 2009) and

robust spines, and of *A. bianconiana*. Identity and taxonomic meaning of var. *perrugosa* Fontannes, 1882 remain doubtful, but *Acanthocardia (A.) perrugosa* reported by Martinell & Domeneq (1984: 12, 13, pl. 5, figs 3, 4) from the Pliocene of Sant Onofre (Baix Ebro, Catalonia, Spain) corresponds to the form of *A. echinata* with a lower number of ribs and robust spines referred to as *Cardium paucicostatum* var. *perrugosa* by Sacco (1899). It is worth remarking that *A. echinata* is notably variable, more than *A. paucicostata* (La Perna, 2008; La Perna & D’Abramo, 2009).

Cardium vidali, described by Cossmann & Peyrot (1909) from the Middle Miocene of the Aquitania basin (Salies-de-Béarn, Orthez, Sallespisse) and of Siurana (Catalonia, Mediterranean Spain) was assumed to be a synonym of *A. paucicostata* by Studencka & Popov (1996). However, this small species seems to differ notably from *A. paucicostata* in size (16 mm) and number of ribs (18, which is the upper limit in *A. paucicostata* at full growth stage). For the moment being, we prefer keeping *Acanthocardia vidali* (Cossmann & Peyrot 1909) as a distinct species. In the same work, Cossmann & Peyrot (1909), reported *Cardium paucicostatum* as notably larger (45 mm in length) than the normal size of *A. paucicostata*, with 15 ribs, and more similar to *A. bianconiana*, as remarked by the authors (“*ressemble plutôt à la variété Bianconiana Cocc. de Monte-Mario (coll. Cossmann) qu’à la forme typique d’Asti*”). In our opinion, this species should also be kept distinct, both from *A. paucicostata* and from *A. bianconiana*.

More recently, Studencka & Popov (1996) considered *A. paucicostata* as widely distributed in the Miocene, after the Burdigalian, including central and eastern Paratethys. They interpreted *A. paucicostata* in a very wide sense, since some distinct species were misidentified as it, whereas none of them is *A. paucicostata*: figs 7A,B, 8C is *Acanthocardia* sp. (*vidali*?); fig. 7C–F is *Acanthocardia clavata* (Hilber 1879) (Fig. 5); fig. 7G,H is *A. aculeata* (Linné, 1758), fig. 8A,B,D is another undetermined *Acanthocardia* species. The small valves illustrated by Studencka (1986) from the Middle Miocene of Poland as *A. paucicostata* are most probably juveniles of *A. clavata*.

The modern specimens typically have a chromatic pattern of light brown concentric stripes on a whitish background (Fig. 3A,B), as in the original illustration by Sowerby (1834). Rarely, the colour pattern is uniformly cream to white (Fig.

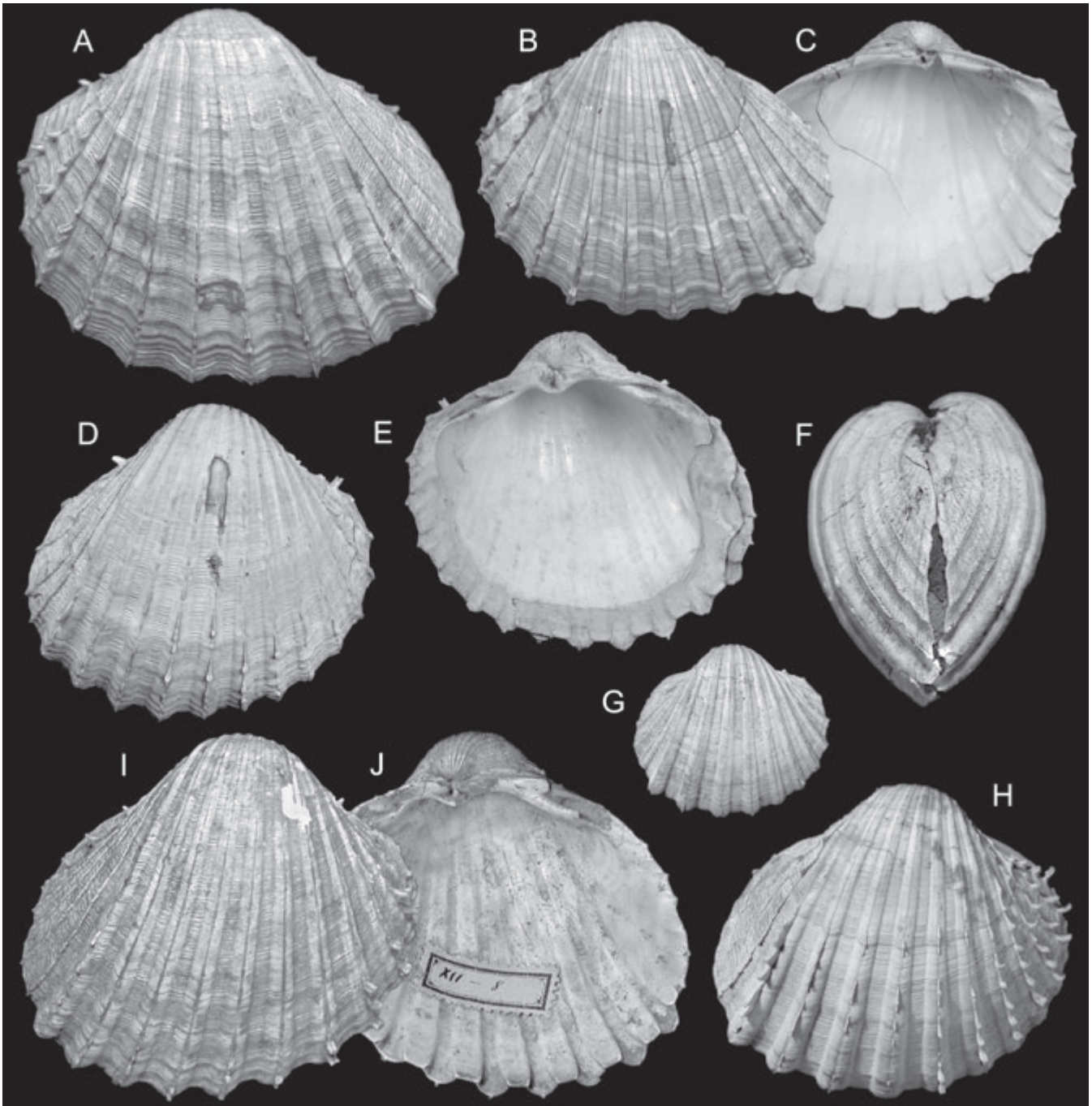


Figure 4 *Acanthocardia bianconiana* (Cocconi 1873). **A** Holotype of *Cardium bianconianum* Cocconi 1873, Lugagnano Val d'Arda, Pliocene, L 73 mm (Cocconi coll., MPP 1768-32-84). **B, C** Lugagnano Val d'Arda, Pliocene, L 57 mm, (Cocconi coll., MPP 1769-32-85). **D, E** Lugagnano Val d'Arda, Pliocene, L 53 mm (Cocconi coll., MPP 1769-32-85). **F** Asti Hills, Late Zanclean-Early Piacenzian, L 52.5 mm (Bellardi & Sacco coll; MRSN, BS.131.01.013/01). **G** Asti Hills, Late Zanclean-Early Piacenzian, L 30 mm (Bellardi & Sacco coll., MRSN, BS.131.01.013). **H** Asti Hills, Late Zanclean-Early Piacenzian, L 57 mm (Bellardi & Sacco coll., MRSN, BS.131.01.011). **I, J** Farnesina, Rome, Early Pleistocene, L 64.5 mm (Cerulli-Irelli coll., MPUR).

3C). Several varieties, based on shape and colour pattern are listed in CLEMAM and WoRMS.

Acanthocardia bianconiana (Cocconi 1873)
Fig. 4A–J

Cardium dilatatum Cocconi ms.

Cardium bianconianum Cocconi 1873: 296, pl. 9, figs 6–9.

Cardium paucicostatum Sowerby var. *bianconiana* Cocconi – Sacco, 1899: 36, pl. 8, figs 20–23.

Cardium paucicostatum Sowerby var. *bianconiana* Cocconi – Cerulli-Irelli, 1908: 19, pl. 2, figs 7–9.

Material Bellardi & Sacco coll. (MRSN): 4 vs, unknown locality, “Astian” (BS.131.01.007/08); 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.007/04); 2 vs, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.010); 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.011); 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.013); 1 sh, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.013/01); 1 v, Asti Hills, Late Zanclean-Early Piacenzian (BS.131.01.003/08). Cocconi coll. (MPP): 1 v, Lugagnano Val d’Arda (Piacenza), Pliocene (holotype, 1768-32-84); 3 vs, Lugagnano Val d’Arda (Piacenza), Pliocene (1769-32-85). Cerulli-Irelli coll. (MPUR): 2 vs, Farnesina (Rome), Early Pleistocene.

Distribution *Acanthocardia bianconiana* is only known for the Mediterranean Early Pliocene-Early Pleistocene.

Remarks In spite of its remarkable size, *Acanthocardia bianconiana* is not well known, probably due to its infrequent occurrence, and also due to conflation with *A. paucicostata*, of which it has been considered as a variety or subspecies in the past literature (Sacco, 1899; Cerulli-Irelli, 1908), and even as a variety of *Cardium mucronatum* (= *A. echinata*, La Perna & D’Abramo, 2009) by Pantanelli (1893) and of *Cardium aculeatum* (= *A. aculeata*) by Foresti (1899).

The material of *Cardium bianconianum* (MPP) consists of holotype (a left valve; Fig. 4A) and three valves from the same locality, Lugagnano Val D’Arda (Piacenza, Northern Italy). The original label accompanying the holotype reads “*Cardium dilatatum mihi*”, evidently a ms name by Cocconi. Apparently, Cocconi did not know *A. paucicostata*, as he compared his species with *Cardium aculeatum*. He also mentioned a variety with larger umbos and shorter posterior, on a single specimen (not present at MPP) from Castell’Arquato (Piacenza). However, the shell usually is less elongate than in the holotype (Fig. 4D,E,H,I,J).

The shell is comparatively thin-walled, more or less elongate antero-posteriorly, with 15–16 notably wide and somewhat flat ribs. Interspaces are wide, with a dense commarginal sculpture similar to that of *A. paucicostata*. Posteriorly, 4–5

ribs are markedly flat and not clearly distinct, but the median ridge is well developed and distinct, even more than the ribs. Also anteriorly the median ridges are well developed, but the ribs are similar in strength to those in central area of shell. Such a radial pattern is also present at a smaller size (Fig. 4G), being a useful character for distinguishing the juveniles of this species from *A. paucicostata*. The spiny projections are mainly spoon-shaped anteriorly, tending to become sharp spines posteriorly. Posteriorly, the shell has a distinct gape (Fig. 4F): such a character seems to be related to the large sizes, up to 75 mm in antero-posterior length, as a similar posterior gape is present in two large Mediterranean species, *A. aculeata* (up to 80 mm) and *A. spinosa* (up to 90 mm).

Acanthocardia brunettii n.sp.

Fig. 5A–L

Holotype Right valve, L 9.8 mm, H 7.7 mm (MZB 49763).

Paratypes All from the type locality: paratype 1, left v, L 10.3 mm, H 9.1 mm (MZB 49764); paratype 2, right v, L 8.4 mm, H 7.2 mm (MZB 49764); paratype 3, sh, L 10.4 mm, H 9.0 mm (MZB 49764); paratype 4, left v, L 7.6 mm, H 6.6 mm (MZB 49764); paratype 5, left v, L 6.2 mm, H 5.3 mm (MZB 49764); paratype 6, right v, L 7.3 mm, H 6.2 mm (La Perna coll.); paratype 7, right v, L 8.5 mm, H 7.4 mm (Brunetti coll.).

Type locality Poggio alla Staffa, San Gimignano (Siena, Tuscany), Early-Middle Pliocene beds (“Crete Senesi”).

Other material Poggio alla Staffa, San Gimignano (Siena, Tuscany), Early Pliocene, about 50 vs (Brunetti coll.); Riparbella (Pisa, Tuscany), Early Pleistocene, 6 vs (Brunetti coll.).

Description Shell notably small for the genus, not exceeding 14 mm, somewhat delicate and fragile, equivalve, moderately elongate, inequilateral, umbo low, moderately large, prosogyrate. Anterior side convex, with well rounded margin. Ventral margin evenly convex, made strongly wavy by rib terminations. Posterior side depressed, wide, ending in a obtusely angulose margin; postero-dorsal margin subtruncate, straight to barely convex. Radial sculpture consisting of 15–17 ribs, each bearing a thin, well

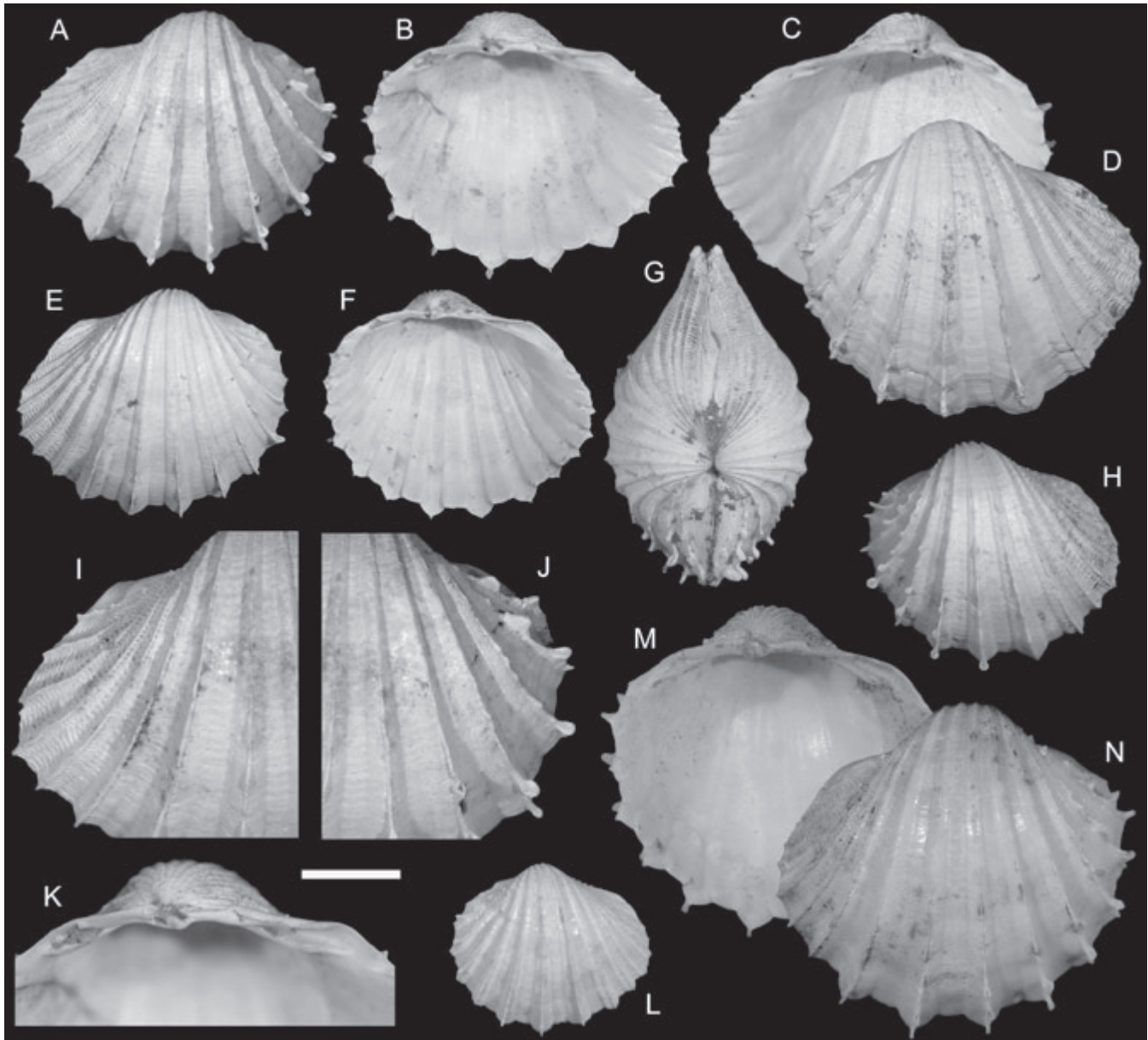


Figure 5 A–K *Acanthocardia brunettii* n. sp. A, B, I–K Holotype, L 9.8 mm (MZB 49763). C, D Paratype 1, L 10.3 mm (MZB 49764) (details: I Posterior side, J Anterior side, K Hinge, scale bar = 2 mm). E, F Paratype 2, L 8.4 mm (MZB 49764). G Paratype 3, L 10.4 mm (MZB 49764). H Paratype 4, L 7.6 mm (MZB 49764). L Paratype 5, L 6.2 mm (MZB 49764). M, N *Acanthocardia paucicostata* (Sowerby GB II 1834), L 10.5 mm, Poggio alla Staffa (Siena, Tuscany), Early-Middle Pliocene (Brunetti coll.).

distinct median ridge, extending almost all the rib length, excluding umbonal area. Central ribs wider and more raised than posteriorly and anteriorly, where ribs mainly consist of their median ridge. Centrally and anteriorly, ribs and interspaces are crossed by rough, irregularly spaced growth lines. A dense, well distinct, slightly rugose commarginal sculpture is present posteriorly, covering 5–7 ribs and their interspaces. A similar sculpture can be also present antero-dorsally, in a narrow area. Spoon-shaped

projections, arising from the median ridge, are only present anteriorly and near the ventral margin. Hinge heterodont, rather delicate. Right and left valve with two cardinal teeth, the lowermost stronger and slightly hook-shaped; anteriorly, on lateral tooth per valve, elongate, triangular; posteriorly, two lateral teeth in the right valve, the lowermost stronger and triangular; one lateral tooth in the left valve, strong, elongate, close to the shell margin. Lunule wide, lanceolate, mostly smooth and flattish; escutcheon narrow, flat, not

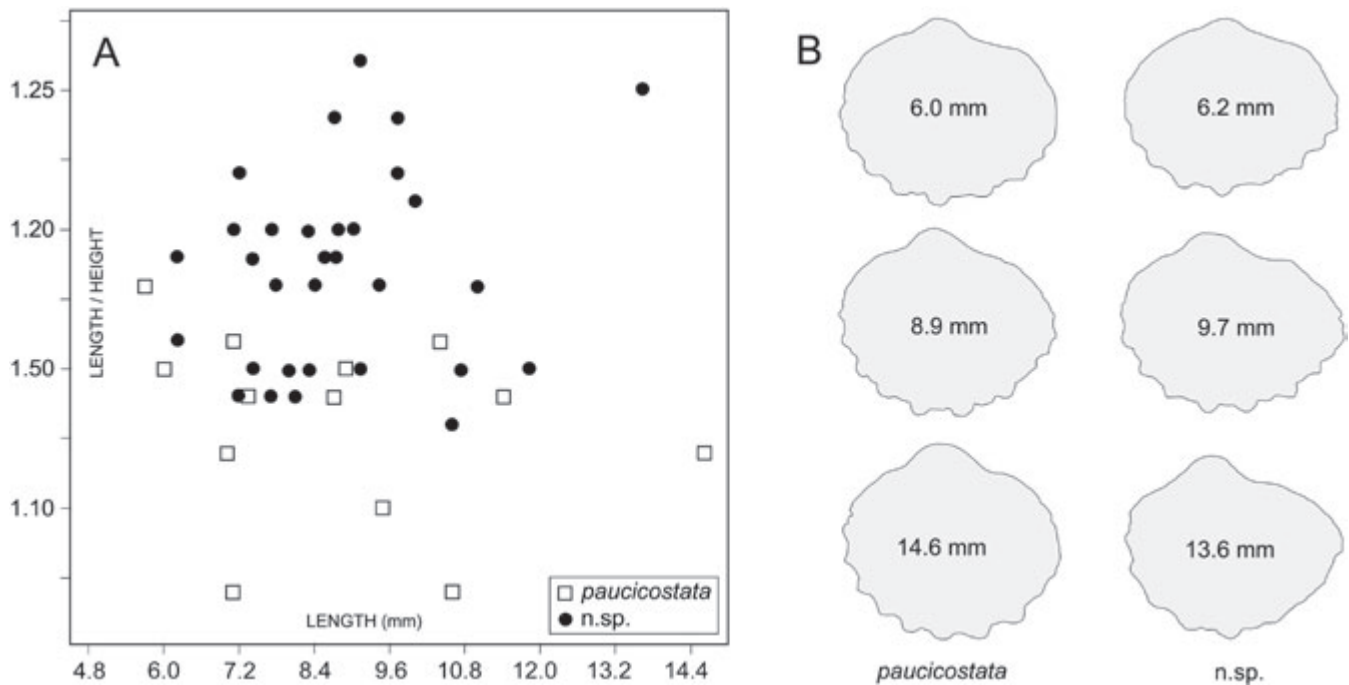


Figure 6 A Scatter plot length/height vs length in 43 valves from Poggio alla Staffa. B Shape differences between *A. paucicostata* and *A. brunettii* n.sp. Valves of different size are drawn at the same scale for allowing ontogenetic changes to be easily detected.

well distinct. Ligament external, opisthodontic. Inner surface deeply reflecting the outer radial sculpture; margin strongly serrate in accordance with radial ribs. Muscle scars ovate, poorly distinct; pallial line not distinct.

Distribution Only known from the Early-Middle Pliocene to the Early Pleistocene of Tuscany (Northern Italy). The type material is from a fine-grained formation, informally known as Crete Senesi, of Early-Middle Pliocene age and shelf deposition (Bossio *et al.*, 1993). The Pleistocene material is from a shelf muddy-sandy succession (Ragaini & Menesini, 1997).

Etymology The new species is named after Mauro M. Brunetti, Italian amateur malacologist.

Remarks The new species has been, most probably, so far misidentified as juvenile stages of *A. paucicostata*. Actually, at a size of about 10 mm, *A. paucicostata* (Fig. 5M,N) can be kept distinct almost only by its shape: markedly more orbicular, less inequilateral and elongate than the new species. The other differences are subtle and difficult to highlight: the new species is slightly less inflated, the posterior commarginal sculpture is more evident, the median ridge on the ribs is slightly better developed, ribs change in width

and height, from one side to the other, more markedly, and they are more deeply reflected internally, than in *A. paucicostata*. Both species share the number of ribs (15–16, but in the adult stages of *A. paucicostata* few, thin and poorly distinct ribs are added dorsally, leading to 18–19 ribs) and “smooth” interspaces, with only coarse growth striae, apart from the posterior side and a small antero-dorsal area. Unfortunately, the juvenile stages of *A. bianconiana* are not known, but we assume they are more similar to *A. paucicostata* than to *A. brunettii* n.sp.

A simple morphometric analysis, based on length and height of 43 valves (all from the type locality of *A. brunettii* n.sp.) supports the separation of two species (Fig. 6A). The valves identified as *A. paucicostata* and those of the new species differ by their length to height ratio: mainly lower than 1.50 in the former, mainly higher in the latter, with partial overlapping at about 1.50. The two groups have significantly different means (t test, significance level 95%). These results confirm the differences in shape, as visually detected between the two species (Fig. 6B). At a small size, 6 mm or smaller in shell length, the two species share a similar outline, though the new species is obscurely more elongate. At a larger size, the differences in outline are

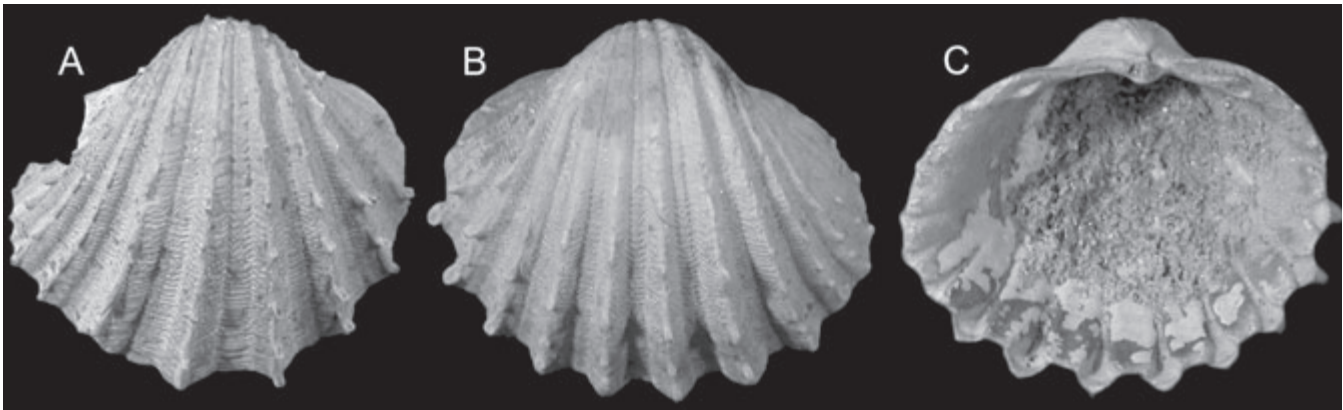


Figure 7 *Acanthocardia clavata* (Hilber 1879). **A** Holotype of *Cardium clavatum* Hilber 1879, Pöls (Austria), Middle Miocene (Early Badenian), L 16.2 mm, Hilber coll. (NHMW, 1861/I/313). **C, D** Grund (Austria), Middle Miocene (Early Badenian), L 17.7 mm, Sieber coll. (NHMW, 1963/493).

much more marked, the new species being more elongate than *A. paucicostata*. Conversely, within this size range *A. paucicostata* maintains a more orbicular shape. In the new species the posterior side grows allometrically, producing a subrostrate margin (Figs 5A–D, 6B). The largest valve is 13.6 mm in length (Fig. 6B), and very similar in shape to paratype 1 (Fig. 5C,D), i.e. proportionally higher than smaller valves and with a more convex ventral margin. Such a change in shape reflects a change in the direction of main growth, from posteriorwards to ventralwards: without such a change, the shell shape would be unusually elongate and rostrate at a size larger than 10 mm in length. This means that the maximum recorded size corresponds to a fully grown stage. *Acanthocardia brunettii* n.sp. is therefore a small species, the smallest so far known for the genus.

DISCUSSION

The morphological similarities between *A. paucicostata*, *A. bianconiana* and *A. brunettii* n.sp. suggest close phyletic relationships between them, with *A. paucicostata* as a possible direct ancestor of both species. The extant *A. paucicostata* seems to be the oldest species, ranging back to the Late Miocene. The stratigraphic distribution of the two other species is largely overlapping through the Pliocene–Pleistocene of the Mediterranean area, as so far known.

Unfortunately, knowledge of the Miocene species of *Acanthocardia* is still poor and confused, compared with the Plio–Pleistocene ones. As a matter of fact, *Acanthocardia* was markedly diverse in the Miocene, with 16 species at least,

many of which were endemic to one or more sectors of the Paratethys (Studencka & Popov, 1996; D’Abramo, 2012). Rather worse is the status of knowledge of the Neogene species from the Atlantic façade.

The working hypothesis of the present work, i.e. that the three species herein dealt with belong to a distinct species group, is supported by the occurrence of a few Miocene species sharing the shell characters of the *paucicostata* group. One of them is *Acanthocardia clavata* (Hilber 1879), from the Middle Miocene of Austria (Vienna Basins, Western Paratethys) (Fig. 7A–C). It is markedly similar to *A. paucicostata*, from which it mainly differs by a smaller size (maximum 24 mm), and slightly wider and more raised ribs, particularly the central ones. Studencka & Popov (1996) included *A. clavata* in the synonymy of *A. paucicostata*. Its distribution is limited to the Badenian of Paratethys, probably only in the western sector (D’Abramo, 2012).

Another species deserving to be considered in the present work is *Acanthocardia andrusovi* (Sokolow 1899), only known from the Eastern Paratethys. As for *A. paucicostata*, Studencka & Popov (1996) apparently used a wide interpretation, since their illustration (fig. 2) seems to include two species at least, one with a more orbicular outline and about 17 ribs (fig. 2a–d), the other more inaequilateral and with about 15 ribs (fig. 2e–j), and notably similar to *A. paucicostata*. In the lack of further data on the correct identity of *Cardium andrusovi*, we can remark the close similarities between *A. andrusovi*, as interpreted by Studencka & Popov (1996), and the *paucicostata* group.

Other Miocene species, either from the Paratethys and the paleo-Mediterranean, mainly recall *A. echinata*, with a more solid, orbicular shell and a higher number of ribs (La Perna & D'Abramo, 2009), such as *A. taurina* (Michelotti 1839) (Middle Miocene of Mediterranean and Western Paratethys; D'Abramo, 2012) and *Acanthocardia ritzingensis* (Sieber 1956) (Middle Miocene of Western and Central Paratethys; D'Abramo, 2012).

Though fragmentary, our data on the Miocene species indicate that in the Middle Miocene, soon after its appearance, *Acanthocardia* underwent a remarkable diversification, mainly in the Paratethys. Both the groups of *A. paucicostata* and *A. echinata* were present, though not so clearly distinct as in the Plio-Pleistocene. More studies on the Miocene representatives of *Acanthocardia* would be useful for a clearer view of origin, evolution and biogeography of this genus in the European area.

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