



Revision of the Nuculanidae (Bivalvia: Protobranchia) from the Cerulli Irelli collection (Mediterranean, Pleistocene)

Rafael LA PERNA

R. La Perna, Dipartimento di Geologia e Geofisica, Università di Bari, Via Orabona 4, I-70125 Bari, Italy; r.laperna@geo.uniba.it

KEY WORDS - Nuculanidae, Saccella, Lembulus, Jupiteria, Early Pleistocene, Italy.

ABSTRACT - The present work completes the revision of the Early Pleistocene (Calabrian) protobranchs from the shallow water deposits of Monte Mario and surrounding localities (Rome), present in the Cerulli Irelli collection. Additional material, mostly from the Bellardi & Sacco collection, was also studied in order to clarify the taxonomic status of some poorly known species described in the early literature. Three nuculanid genera are dealt with: *Saccella* Woodring, 1925, *Lembulus* Risso, 1826, and *Jupiteria* Bellardi, 1875. The Plio-Pleistocene species of *Saccella* have been often confused as a single, notably variable species, usually reported as *Nuculana fragilis* (Chemnitz, 1784) or *N. commutata* (Philippi, 1844). Four species of *Saccella* occurred in the Mediterranean Plio-Pleistocene: *S. commutata* (Philippi, 1844), *S. consanguinea* (Bellardi, 1875), *S. bonellii* (Bellardi, 1875) and *S. calatabianensis* (Seguenza, 1877). Of these, *S. commutata* and *S. calatabianensis* were present in the Early Pleistocene. Other Plio-Pleistocene species of *Saccella* are expected, basing on literature data and on available material. *Lembulus* included a single Plio-Pleistocene and extant species, *L. pella* (Linné, 1758). *Jupiteria* occurred in the Plio-Pleistocene with a single shallow water species, *J. fissistriata* (Foresti, 1897 ex Meneghini ms), but two other deep-water species are known: *J. concava* (Bronn, 1831) and *J. gibba* (Seguenza, 1877). These genera show a general southward shift in distribution through the Miocene-Pleistocene, which led *Saccella* and *Lembulus* to disappear from the North Sea and *Jupiteria* from the Mediterranean and adjacent Atlantic.

RIASSUNTO - [Revisione dei Nuculanidae (Bivalvia: Protobranchia) della collezione Cerulli Irelli (Mediterraneo, Pleistocene)] - Col presente lavoro viene completata la revisione dei protobranchi del Pleistocene inferiore (Calabrian) provenienti dai depositi di piattaforma dell'area di Monte Mario e località limitrofe (Roma), presenti nella collezione Cerulli Irelli (Museo di Paleontologia dell'Università di Roma "La Sapienza"). Allo scopo di chiarire lo status tassonomico di specie poco note descritte nella letteratura più antica, è stato studiato anche altro materiale, in prevalenza appartenente alla collezione Bellardi & Sacco. In questo lavoro sono trattati tre generi della famiglia Nuculanidae: *Saccella* Woodring, 1925, *Lembulus* Risso, 1826 e *Jupiteria* Bellardi, 1875. Le specie plio-pleistoceniche di *Saccella* sono state spesso confuse in un'unica specie molto variabile, generalmente riportata come *Nuculana fragilis* (Chemnitz, 1784) o *N. commutata* (Philippi, 1844). Nel Plio-Pleistocene mediterraneo erano presenti quattro specie del genere *Saccella*: *S. commutata* (Philippi, 1844), *S. consanguinea* (Bellardi, 1875), *S. bonellii* (Bellardi, 1875) e *S. calatabianensis* (Seguenza, 1877). Di queste, *S. commutata* e *S. calatabianensis* erano presenti nel Pleistocene inferiore. Ci sono comunque evidenze o sospetti della presenza di altre specie del genere *Saccella* nel Plio-Pleistocene, sulla base dei dati di letteratura e del materiale disponibile. Il genere *Lembulus* comprende un'unica specie plio-pleistocenica ed attuale: *L. pella* (Linné, 1758). *Jupiteria* era presente nel Plio-Pleistocene con una sola specie a distribuzione superficiale, *J. fissistriata* (Foresti, 1897 ex Meneghini ms), ma sono note altre due specie a distribuzione profonda: *J. concava* (Bronn, 1831) e *J. gibba* (Seguenza, 1877). La distribuzione geografica di questi tre generi ha subito un generale spostamento verso sud nel corso del Miocene-Pleistocene: ciò ha portato alla scomparsa di *Saccella* e *Lembulus* da alte latitudini (Mare del Nord) e di *Jupiteria* dal Mediterraneo e dall'adiacente Atlantico.

INTRODUCTION

The Cerulli Irelli collection (Palaeontological Museum of the University "La Sapienza", Rome) consists of Early Pleistocene (Calabrian) shallow water molluscs from Monte Mario (Rome) and nearby localities. It was originally published by Serafino Cerulli Irelli in *Palaeontographia Italica* between 1907 and 1916. The present revision covers the family Nuculanidae, completing the studies on the protobranch material from this collection (La Perna, 2004, 2007).

Three nuculanid genera are dealt with in the present work, namely *Saccella* Woodring, 1925, *Lembulus* Risso, 1826 and *Jupiteria* Bellardi, 1875, frequently confused with each other in the past literature. The present work focuses on *Saccella* and *Lembulus*, whereas a recent contribution to the knowledge of *Jupiteria* was given by La Perna et al. (2004). A study on the Pleistocene species of these genera cannot leave their older representatives out of consideration, as several Miocene and Pliocene species and varieties were described in the early literature

for these groups. The present work was then conducted jointly with the study of the protobranchs from the Bellardi & Sacco collection (Museo Regionale di Scienze Naturali, Turin) to which a monograph will be devoted. For the sake of completeness, observations on some Miocene and Pliocene species from the Bellardi & Sacco collection are reported in the present work.

MATERIAL AND METHODS

Data on the geological setting of the Plio-Pleistocene deposits in the area of Rome, localities, origin and status of the Cerulli Irelli collection were reported by La Perna (2007).

The study material consists of 7 lots (samples), amounting to about 1,200 specimens as loose valves and complete shells (Tab. 1). The material published by Cerulli Irelli (1907) as *Leda fragilis* var. *inflata* Seguenza, 1877, *L. fragilis* var. *consanguinea* Bellardi, 1875 and *Yoldia mendax* (Meneghini in Appellius, 1871) is missing. The

Sample	Locality	Label	Revision	Material vs+shs
18	Farnesina	<i>Leda fragilis</i> var. <i>calatabianensis</i> Seg.	<i>Saccella calatabianensis</i> (Seguenza, 1877) <i>Saccella</i> sp. A	4+1 0+1
19	Monte Mario	<i>Leda fragilis</i> var. <i>lamellosa</i> Seguenza	<i>Saccella commutata</i> (Philippi, 1844)	6+2
20	Monte Mario	<i>Leda fragilis</i> Chemnitz	<i>Saccella commutata</i> (Philippi, 1844) <i>Saccella</i> sp. B	446+656 1
21	Farnesina	<i>Leda bonellii</i> Bellardi	<i>Saccella</i> sp. A	1
22	Monte Mario	<i>Leda pella</i> Linné	<i>Lembulus pella</i> (Linné, 1767)	69+3
23	Monte Mario	<i>Leda (Jupiteria) concava</i> Bronn	<i>Jupiteria fissistriata</i> (Foresti, 1897)	7
24	Monte Mario	<i>Leda concava</i> var. A Bellardi	<i>Jupiteria fissistriata</i> (Foresti, 1897)	4

Tab. 1 - Nuculanid material in the Cerulli Irelli collection. Sample numeration follows the order adopted by La Perna (2007).

first two taxa were included in the present work, whereas *Yoldia mendax* is the object of a separate work (La Perna & Ragaini, in press).

The following abbreviations are used: coll. = collection; v(s) = valve(s); sh(s) = shell(s), paired valves; MPUR = Museo di Paleontologia dell'Università "La Sapienza", Rome; MRSN = Museo Regionale di Scienze Naturali, Turin.

SYSTEMATICS

Class BIVALVIA Linné, 1758

Subclass PROTOBRANCHIA Pelseneer, 1889

Order NUCULOIDA Dall, 1889

Family NUCULANIDAE H. & A. Adams, 1858

Genus *Saccella* Woodring, 1925

Type species - *Nucula commutata* Philippi, 1844.

Saccella is a replacement name for *Ledina* Sacco, 1898 *non* Dall, 1898. It has been mostly used as a subgenus of *Nuculana* Link, 1807 or confused with *Jupiteria* Bellardi, 1875, as discussed on by La Perna et al. (2004).

The distinctive characters of *Saccella* can be summarised as follows: an anterior keel or fold, a shallow rostral sulcus, a well-defined rostral keel, a pointed, not particularly long rostrum and an internal posterior tubercle. The anterior keel is variable in strength, from well-defined and step-like to feeble, as a shallow flexure. The rostral sulcus can be anteriorly bounded by a weak ridge. The rostral keel is sharp, straight or more commonly curved, delimiting a rather wide, mostly convex and poorly sculptured postero-dorsal area. The rostral tubercle is a shallow, slightly elongate, ridge-like rise, close to the ventral margin. It is believed to correspond with the well-developed rostral ridge occurring in *Nuculana pernula* (Müller, 1771), *Nuculana minuta* (Müller, 1776) and in allied species. According to Savitsky (1974), the nuculanid ridge compensate for the incomplete closure of the inhalant siphon, with the two lateral folds connected to each other by interlocking cilia (Yonge, 1939, p. 96, figs. 14, 18b).

The rostral tubercle of *Saccella* seems to have a relic nature, since it cannot act as a wall to bound the inhalant siphon because of its small size.

Saccella typically has a sculpture of commarginal ribs, more or less coarse, extensive and closely set, becoming somewhat lamellar posteriorly. There is a tendency to the loss or strong attenuation of sculpture, as seen by the present writer in some Miocene species from the Mediterranean, and by Maxwell (1988) and Beu (2006)

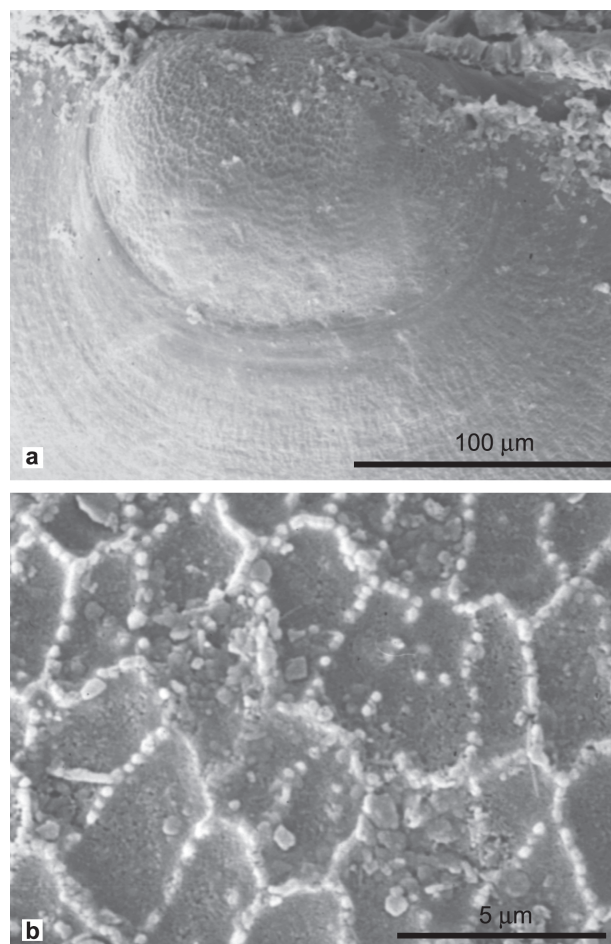


Fig. 1 - *Saccella commutata*, off southeastern Sicily, 110 m. a) prodissoconch; b) prodissoconch sculpture.

in fossil and Recent species from New Zealand. Furthermore, Beu (2006) reported the occurrence of a periostracal microsculpture of pustules and short spines.

The ligament is internal, within a rather wide triangular resilifer, with a small external amphidetic component, relic of the early, mainly external ligament occurring in most nuculanids (Ockelmann & Warén, 1998).

The prodossoconch has a net-like sculpture (Fig. 1), similar to that of *Nuculana* (Ockelmann & Warén, 1998, fig. 5g).

In Europe, the stratigraphic distribution of *Saccella* ranges back to the Eocene (Sacco, 1898; Cossmann & Peyrot, 1913). Two living species are known from the Mediterranean: *Saccella commutata* (Philippi, 1844) and *Saccella illirica* (Carrozza, 1987).

Saccella commutata (Philippi, 1844)

Pl. 1, figs. 1-21; Pl. 2, fig. 20; Figs. 2a-c

- 1784 *Arca fragilis* CHEMNITZ, p. 199, Pl. 55, fig. 546 (non-binominal, rejected by ICZN).
 1814 *Arca minuta* "L." - BROCCHI, p. 482, Pl. 11, fig. 4 (*non Arca minuta* Müller, 1776).
 1844 *Nucula commutata* PHILIPPI, p. 101 (replacement for *Arca minuta* Brocchi, 1814, *non* Müller 1776).
 1875 *Leda commutata* (Philippi) - BELLARDI, p. 17.
 1877a *Leda (Lembulus) commutata* (Philippi) - SEGUENZA, p. 94.
 1877b *Leda (Lembulus) commutata* (Philippi) - SEGUENZA, p. 1172, Pl. 2, fig. 9.
 1877a *Leda (Lembulus) commutata* var. *inflata* SEGUENZA, p. 94.
 1877b *Leda (Lembulus) commutata* var. *inflata* Seguenza - SEGUENZA, p. 1172, Pl. 2, fig. 9b.
 1877a *Leda (Lembulus) commutata* var. *lamellosa* SEGUENZA, p. 94.
 1877b *Leda (Lembulus) commutata* var. *lamellosa* Seguenza - SEGUENZA, p. 1172.
 1898 *Ledina fragilis* (Chemnitz) - SACCO, p. 53, Pl. 11, figs. 41-43.

Material - Cerulli Irelli coll., samples 19, 20, Monte Mario, Early Pleistocene, 452 vs. 658 shs (MPUR).

Stratigraphic and geographic distribution - The stratigraphic distribution, as reported from the classic literature, ranges back to the Early Miocene. However, it is not clear if all the Miocene records (e.g. Sacco, 1898; Cossmann & Peyrot, 1913) are really based on *Saccella commutata* (see remarks).

The modern distribution ranges from the Bay of Biscay south to the Ibero-Moroccan Gulf (Bucquoy et al., 1891; Allen & Sanders, 1996; Salas, 1996). The northernmost record (47.5°N) is from Belle Île, France (Bucquoy et al., 1891). The record by Nicklès (1955) from the Tropical West Africa could be actually based on *Saccella commutata*, but the West African species of this genus are not well known (Cosel, pers. comm.).

It is common in the Mediterranean, mostly at shallow depths on sandy and muddy bottoms (Stolfa Zucchi, 1972; Salas, 1996).

Remarks - This species, often reported as *Nuculana fragilis* (Chemnitz, 1784) or *N. commutata* (Philippi, 1844), has a complex history. According to Dodge (1952, pp. 147-148), *Arca fragilis* Chemnitz, 1784 is the same as *Arca pella* Linné, 1758 and Gmelin, 1791, i.e. *Lembulus pella* (Linné, 1758), whereas according to

Aartsen & Carrozza (1987), it is a different species, as also stated by Bucquoy et al. (1891). The description of *Arca pella* ("*testa ovata ... oblique striata, nitidissima*") by Linné (1758, 1767) corresponds to the species currently known as *Lembulus pella*, whereas the illustration of *Arca fragilis* by Chemnitz (1784) points to a distinct species, with a commarginal sculpture, as noticed by Dodge (1952). On this illustration Gmelin (1791, p. 3307) and Dillwyn (1817, p. 237) based their interpretation of *Arca pella*, but in both cases the description recalls *Saccella commutata* ("*subtrigona: striis subtilissimis transversis semilunatis*" and "*sub-triangular-ovate, minutely striated transversely*", respectively), rather than *Lembulus pella*. However, *Arca fragilis* Chemnitz, 1784 is unavailable according to ICZN (Opinion 183).

Brocchi (1814, p. 482, Pl. 11, fig. 4) reported *Arca minuta* Müller, 1776, wrongly attributed to Linné, based on "Martini's illustration which Chemnitz and Gmelin [wrongly] referred to as *Arca pella*". In the same work, he also reported *Arca pella* as a distinct species. *Arca minuta* Müller (= *Nuculana minuta*) is a Northeast Atlantic species clearly different from Brocchi's species. No material of *Arca minuta* is present in the Brocchi coll. (Museo Civico di Storia Naturale, Milan) (Garassino, 1995 and pers. comm.), but the commarginally ridged species with a curved, pointed rostrum described and illustrated by Brocchi closely matches *Saccella commutata*. This species was reported from Pliocene deposits of Northern Italy, where *Saccella commutata* actually occurs as a common species. Finally, Philippi (1844), replaced the preoccupied *Arca minuta* Brocchi, 1814 with *Nucula commutata*.

Saccella commutata has been generally regarded as markedly variable (Seguenza, 1877b; Sacco, 1898; Cerulli Irelli, 1907, etc.). Actually, variability in shape and sculpture occurs in fossil and modern populations, as well as through the stratigraphic distribution. Moreover, the confusion with other Plio-Pleistocene species, mostly assumed as variations of *Saccella commutata*, have enhanced the idea of a single, highly variable species (e.g. Marasti & Raffi, 1977, p. 52). Sculpture consists of coarse ribs, somewhat variable in spacing, raised and almost lamellar posteriorly, particularly on rostrum, mostly flat anteriorly. Postero-dorsal margin and rostrum are more or less curved, particularly in fully-grown shells. The hinge angle is 130-134° wide. Juveniles have a wide spaced, somewhat lamellar sculpture (Pl. 1, figs. 9, 11, 19), sometimes persisting in later stages (Pl. 1, figs. 10, 13, 14). Anterior keel and rostral sulcus are usually better defined in younger shells. In the Pliocene shells, less commonly also in the Pleistocene ones, there is a weak ridge bounding anteriorly the posterior sulcus and producing an obscure subrostral angularity (Pl. 1, figs. 1, 16, 18). The Recent shells are slightly more elongate and with a straighter rostrum, also at a full growth stage (Pl. 1, figs. 20, 21; see also Giannuzzi Savelli et al., 2001, figs. 36a, 37a, 38-41). Similar differences between the Pliocene and the Recent shells were also remarked by Bellardi (1875).

The Middle Miocene ("Helvetian of the Turin hills") material of *Ledina fragilis* in the Bellardi & Sacco coll.

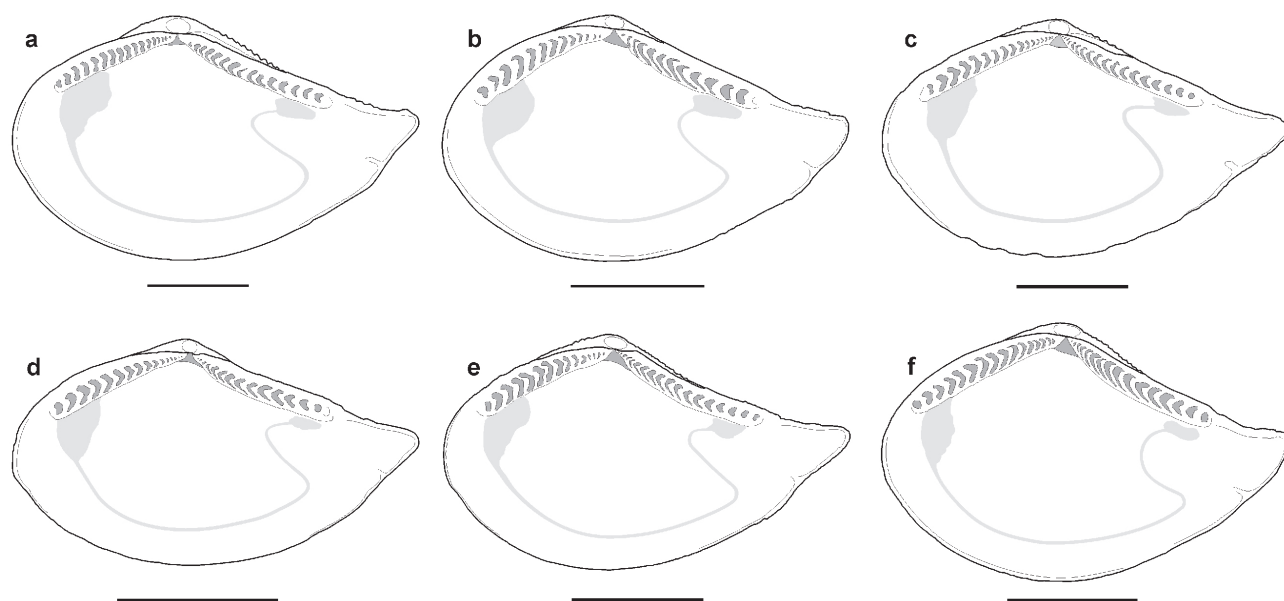


Fig. 2 - Shell outline and internal scars of *Saccella* species. a) *S. commutata*, Asti hills, "Astian", Bellardi & Sacco coll., BS 123.03.003.08 (MRSN); b) *S. commutata*, Monte Mario, Early Pleistocene, Cerulli Irelli coll., sample 20 (MPUR), right-left inverted; c) *S. commutata*, off southeastern Sicily, 110 m, author's coll.; d) *S. calatabianensis*, Grammichele, Early Pleistocene, author's coll.; e) *S. consanguinea*, Albenga, "Piacenzian", Bellardi & Sacco coll., BS 123.03.005/04 (MRSN); f) *S. bonellii*, Bordighera, "Piacenzian", Bellardi & Sacco coll., BS 123.03.011/03 (MRSN), right-left inverted. Scale bars = 2 mm.

is scant, mostly poorly preserved and consisting of two or three distinct species. A few shells are actually notably similar to the Plio-Pleistocene ones and can be assigned, at least tentatively, to *Saccella commutata*.

The main problem involving this species is the taxonomic status of the varieties and closely allied species described in the early literature, mainly by Bellardi (1875), Seguenza (1877a,b), Sacco (1898), and

Cossmann & Peyrot (1913). Of these, Cerulli Irelli (1907) reported *Leda fragilis* var. *consanguinea* Bellardi, 1875, *Leda fragilis* var. *lamellosa* Seguenza, 1877, *Leda fragilis* var. *inflata* Seguenza, 1877 (no material), *Leda fragilis* var. *calatabianensis* Seguenza, 1877 (no material), and *Leda bonellii* Bellardi, 1875.

Saccella consanguinea (Bellardi, 1875) is a Pliocene species, improperly synonymised with *Lembulus*

EXPLANATION OF PLATE 1

figs. 1-21 - *Saccella commutata* (Philippi, 1844).

1-12 - Monte Mario, Cerulli Irelli coll., sample 20 (MPUR).

- 1-2 - 8.4 mm;
- 3-4 - 6.2 mm;
- 5 - 8.4 mm;
- 6-7 - 5.0 mm;
- 8 - 6.2 mm;
- 9 - 2.8 mm;
- 10 - 5.4 mm;
- 11-12 - 2.6 mm.

13-15 - Monte Mario, Cerulli Irelli coll., sample 19 (MPUR).

- 13 - 4.2 mm (Cerulli Irelli, 1907: Pl. 10, fig. 5);
- 14-15 - 4.8 mm.

16-17 - Asti hills, "Astian", Bellardi & Sacco coll., BS 123.03.003/08, 7.8 mm (MRSN). 18 - Poggio alla Staffa (Siena), Zanclean, 6.8 mm (author's coll., ex Brunetti coll.).

19-21 - Off SE Sicily, 110 m.

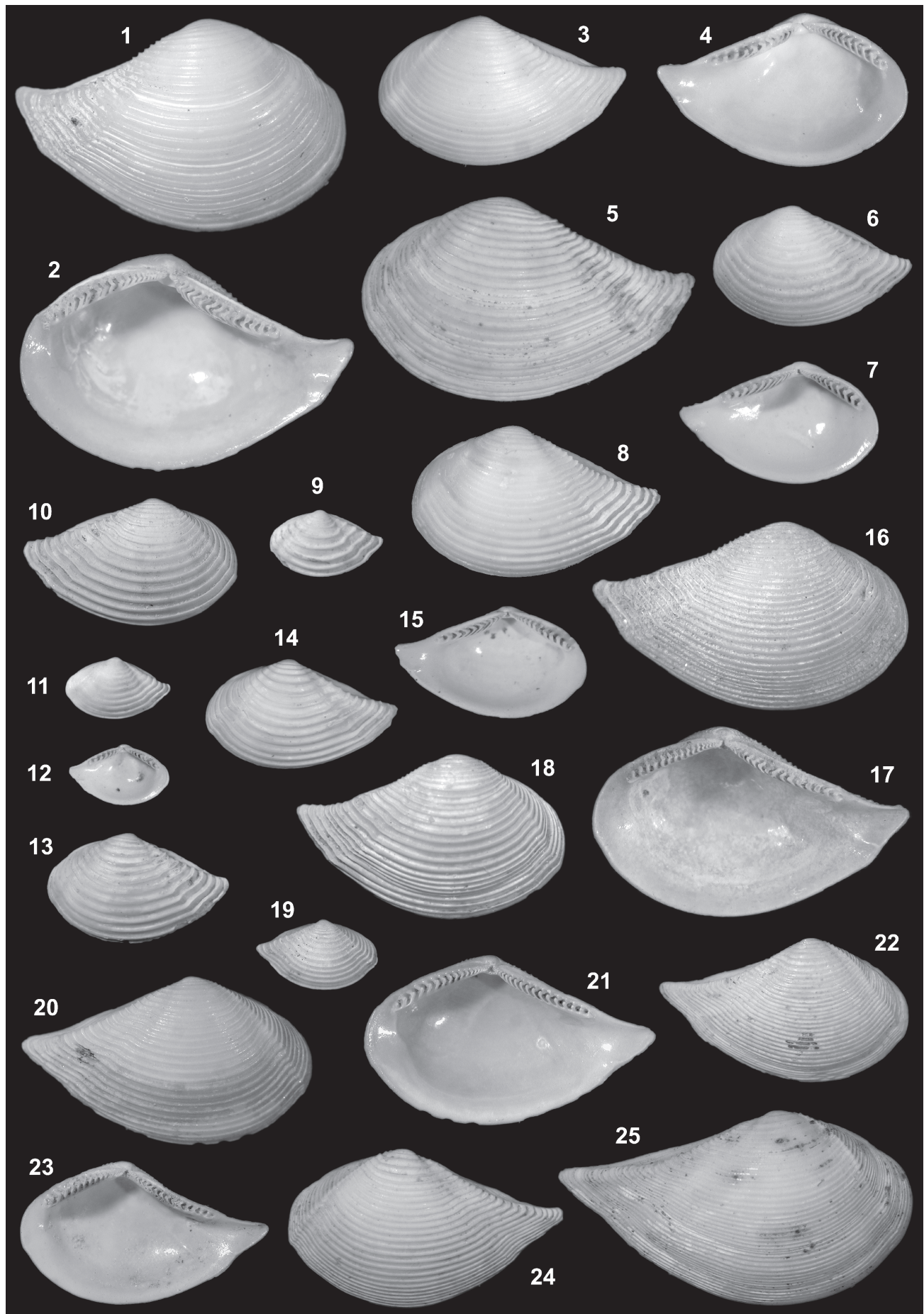
- 19 - 3.0 mm (author's coll.);
- 20-21 - 7.3 mm (author's coll.).

figs. 22-25. *Saccella consanguinea* (Bellardi, 1875).

22-23 - Albenga, "Piacenzian", Bellardi & Sacco coll., BS 123.03.005/04, 6.3 mm (MRSN).

24-25 - Rio Crevaiese (Piacenza), Piacenzian.

- 24 - 6.9 mm (author's coll., ex Brunetti coll.);
- 25 - 9.0 mm (author's coll., ex Brunetti coll.).



deltoideus Risso, 1826 since Sacco (1898). Risso's species corresponds with *Nucula deltoidea* Lamarck, 1819, which was "annexed" by Risso (1826) after changing the genus (Arnaud, 1977; Aartsen & Carrozza, 1987). The description of *Nucula deltoidea*, an Eocene nuculanid from the Paris Basin, points to a totally distinct species, most probably belonging to *Jupiteria* (see below). *Saccella consanguinea* (Pl. 1., figs. 22-25) has a shallow subrostral sinuation, making the rostrum appear notably pointed, a well-defined rostral keel, a rather strong anterior keel and a markedly convex ventral margin. Sculpture is notably variable in spacing, but finer than that of *Saccella commutata*. Description and illustrations of *Leda fragilis* var. *consanguinea* by Cerulli Irelli (1907, Pl. 12, figs. 1, 2) point to *Saccella calatabianensis* (Seguenza, 1877) rather than to *S. consanguinea*.

Leda commutata var. *lamellosa* Seguenza, 1877, from the "Astian" (Plio-Pleistocene) of Southern Italy, was said (Seguenza, 1877a, 1877b) to be short, flat, with a wide-spaced, almost lamellar sculpture, a well distinct anterior ridge and a prominent "lunule" (a misnamed postero-dorsal area). The scant material identified by Cerulli Irelli (1907, Pl. 12, fig. 5) as *Leda fragilis* var. *lamellosa* matches Seguenza's description and consists of relatively small valves (Pl. 1, figs. 13-15), corresponding with juveniles or subadults of *Saccella commutata*. Similar observations can be made about the record of *Leda (Jupiteria) fragilis lamellosa* Seguenza from the Early Pleistocene of Parma by Pelosio (1960, p. 154, pl. 2, fig. 16). Seguenza's var. *lamellosa* is then synonymised with *Saccella commutata*.

Also the extant *Saccella illirica* (Carrozza, 1987) (Carrozza, 1987, p. 159, figs. 1-3; Giannuzzi Savelli et al., 2001, figs. 34-35) has a sculpture of wide spaced, somewhat lamellar ridges, but it is much larger (holotype 10 mm) than the shells of *S. commutata* with a similar sculpture. Moreover, it is more elongate, posteriorly tapering and with a straight, sharply-pointed rostrum.

Leda commutata var. *inflata* Seguenza, 1877 was described from the Late Miocene and Plio-Pleistocene of Southern Italy (Seguenza, 1877a). No type material is known, but it seems to fall within the variability range or ontogenetic changes of *Saccella commutata*, with which it is herein synonymised.

Saccella bonellii (Bellardi, 1875) (Pl. 2, figs. 15-16), is a Pliocene species with a weak, fine sculpture, almost lost in the middle part of shell but always present, and rather strong, in the early stage (umbo). The pallial sinus is U-shaped (Fig. 2f), different from the V-shaped sinus of the other species (Figs. 2a-e). The material of *Ledina bonellii* in the Bellardi & Sacco coll. includes another species, similar to *Saccella bonellii* and undescribed (*Saccella* aff. *bonellii* in Fig. 3). The material reported by Cerulli Irelli (1907, p. 129, Pl. 12, fig. 6) as *Leda bonellii* (sample 21) is a single, rather small, partly smooth valve (Pl. 2, figs. 16-17), somewhat similar to *Saccella bonellii*, also in the shape of the pallial sinus, but with a very weak umbonal sculpture. It is probably a distinct, undescribed species, here kept as *Saccella* sp. A.

A single, partly broken valve (Pl. 2, figs. 17-18) from sample 20 is notably convex, with a short rostrum and a fine, uniform, closely set sculpture. The pallial sinus is shallow and U-shaped. Also this seems a distinct, undescribed species, here kept as *Saccella* sp. B.

Saccella calatabianensis (Seguenza, 1877)
Pl. 2, figs. 1-11; Fig. 2d

- 1877a *Leda (Lembulus) commutata* var. *calatabianensis* SEGUENZA, p. 94.
1877b *Leda (Lembulus) commutata* var. *calatabianensis* Seguenza - SEGUENZA, p. 1172, Pl. 2, fig. 9a.
2000 *Leda (Lembulus) commutata* var. *calatabianensis* Seguenza - BERTOLASO & PALAZZI, p. 11, figs. 113-114.

EXPLANATION OF PLATE 2

figs. 1-11 - *Saccella calatabianensis* (Seguenza, 1877).

1-2 - Fiumefreddo di Sicilia (northeastern Sicily), Early Pleistocene.

1 - 7.6 mm (author's coll.);

2 - 5.2 mm (author's coll.).

3-6 - Grammichele (southeastern Sicily), Early Pleistocene.

3 - 2.7 mm (author's coll.);

4-5 - 5.6 mm (author's coll.);

6 - 5.2 mm (author's coll.).

7-9 - Stirone section (Parma), Gelasian.

7-8 - 6.9 mm (author's coll., ex Brunetti coll.);

9 - 3.8 mm (author's coll., ex Brunetti coll.).

10-11 - Farnesina (Rome), Early Pleistocene, Cerulli Irelli coll., sample 18 (MPUR), 4.7 mm.

figs. 12-14 - *Saccella* sp. A.

12 - Farnesina (Rome), Early Pleistocene, sample 18 (MPUR), 5.2 mm (Cerulli Irelli, 1907: Pl. 9, fig. 4);

13-14 - Farnesina (Rome), Early Pleistocene, sample 19 (MPUR), 4.5 mm (Cerulli Irelli, 1907: Pl. 10, fig. 6).

figs. 15-16 - *Saccella bonellii* (Bellardi, 1875). Bordighera, "Piacenzian", Bellardi & Sacco coll., BS 123.03.011/03, 6.2 mm (MRSN).

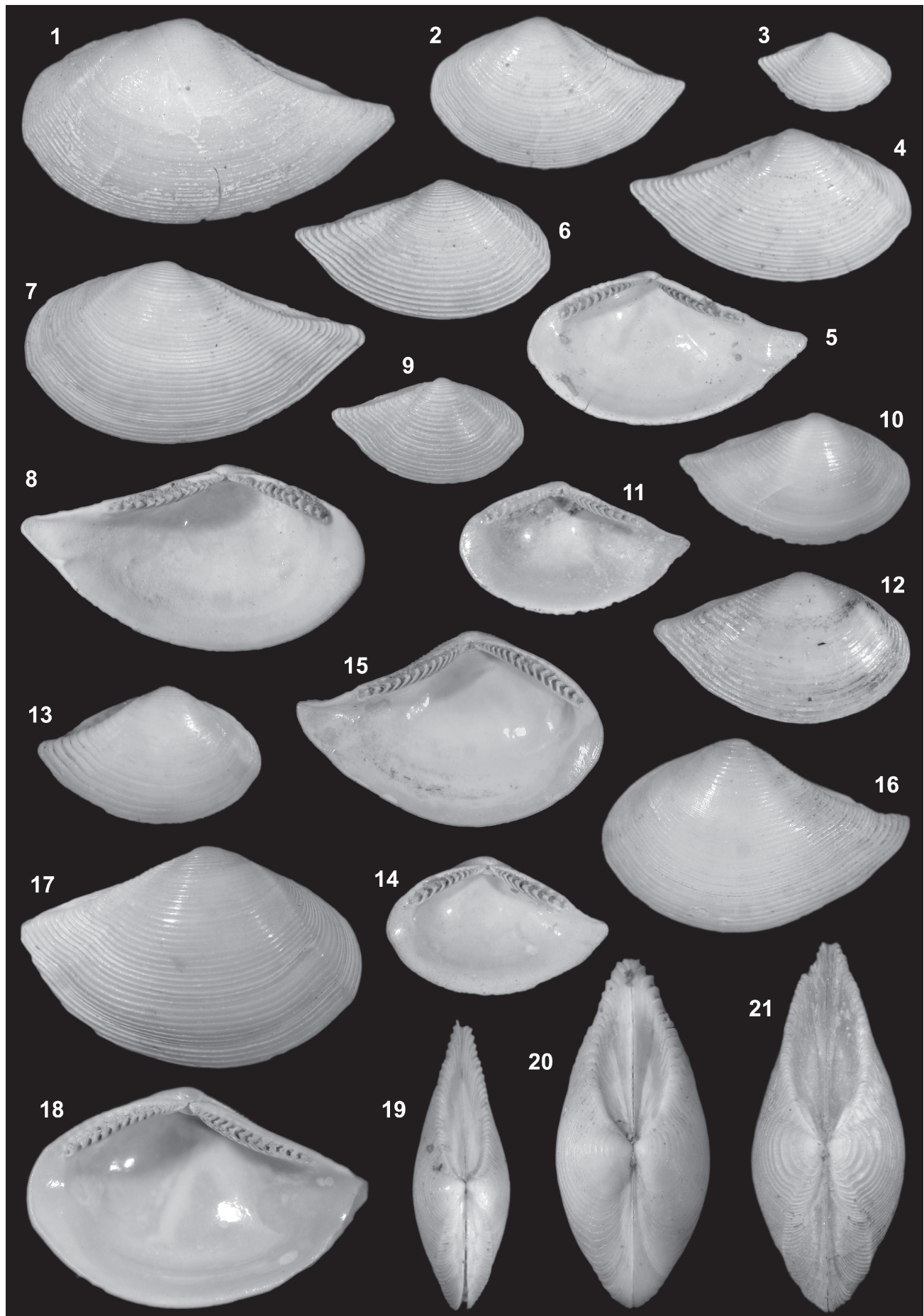
figs. 17-18 - *Saccella* sp. B. Monte Mario (Rome), Early Pleistocene, Cerulli Irelli coll., sample 20 (MPUR), 7.1 mm.

figs. 19-21 - Dorsal views.

19 - *Saccella calatabianensis* (Seguenza, 1877), Grammichele (southeastern Sicily), Early Pleistocene, 5.9 mm (author's coll.);

20 - *Saccella commutata* (Philippi, 1844), Monte Mario (Rome), Cerulli Irelli coll., sample 20 (MPUR), 7.1 mm;

21 - *Saccella consanguinea* (Bellardi, 1875), Rio Stramonte (Piacenza), Piacenzian, 7.4 mm (author's coll., ex Brunetti coll.).



Material - Cerulli Irelli coll., sample 18, Farnesina, Early Pleistocene, 3 vs, 1 sh (MPUR).

Stratigraphic and geographic distribution - *Saccella calatabianensis* is only known from the Late Pliocene and the Early Pleistocene of Italy. It seems much less common than *Saccella commutata*, and with a deeper (outer shelf) distribution.

Remarks - The original, brief description “*Forma depressa, costole ravvicinatissime ed appena distinte quasi scancellate*” (Seguenza, 1877a), together with the extended and illustrated one (Seguenza, 1877b), point to a rather flat shell, with fine, closely set, weak to poorly distinct ridges and an almost straight rostrum. Seguenza (1877b) listed var. *calatabianensis* from a number of localities in Southern Italy and from a long stratigraphic record (Middle Miocene to Pleistocene). It may be suspected that different, closely similar species were involved in the definition of this variety. For example, the Miocene *Ledina fragilis* var. *pseudolaevis* Sacco, 1898, *Ledina sublaevis* (Bellardi, 1875) and *Ledina sublaevis* var. *seguenzai* (Bellardi, 1875) are more or less similar to var. *calatabianensis* in shape and sculpture. In the present work, the interpretation of *Saccella calatabianensis* is based on material from Fiumefreddo di Sicilia (northeastern Sicily, near Calatabiano, after which Seguenza named his variety) (Pl. 2, figs. 1, 2) and Grammichele (southeastern Sicily) (Pl. 2, figs. 3-6), both Early Pleistocene in age, and from Upper Pliocene deposits in the Stirone section (Parma, Northern Italy) (Pl. 2, figs. 7-9). Possible type material of *Leda commutata* var. *calatabianensis* was reported by Bertolaso & Palazzi (2000: p. 11, figs. 113-114) from the Seguenza coll. in Florence (Museo di Geologia e Paleontologia). It is not known if this is original material from the Giuseppe Seguenza coll., as it only bears a label by his son Luigi. However, it corresponds with the original illustration by G. Seguenza and with the present material, particularly to that from Fiumefreddo di Sicilia (Pl. 2, figs. 1, 2), with a markedly weak sculpture and an obscure subrostral angularity. Rather than to *Saccella commutata*, this species is more similar to *Saccella*

consanguinea, from which it differs mainly by being flatter (Pl. 2, fig. 19), less tapering posteriorly and with a less convex ventral margin. Admittedly, the present material referred to as *Saccella calatabianensis* (Pl. 2, figs. 1-11) seems to include more than a single species, mainly differing in sculpture. However, sculpture is variable in *Saccella* and the examined material is not abundant (some 20 valves and a few complete shells). Further studies on new material could be useful for better understanding the morphological range of this species.

Whereas the missing material reported by Cerulli Irelli as *Leda fragilis* var. *consanguinea* (see above) seems to be based on *Saccella calatabianensis*, the scarce material referred to as var. *calatabianensis* (Cerulli Irelli, 1907, p. 129, Pl. 12, fig. 4) seems to include two species. One of them (Pl. 2, figs. 10, 11) is admittedly similar to *S. calatabianensis* to which it is referred. The other species (Pl. 2, fig. 12) seems more similar to *Saccella* sp. A (Pl. 2, figs. 13, 14), to which it is tentatively assigned.

Leda (Jupiteria) consanguinea reported by Pelosio (1960, p. 154, Pl. 2, fig. 17) from the Early Pleistocene of Romagna seems to be *Saccella calatabianensis*.

Genus *Lembulus* Risso, 1826 ex Leach ms

Type species - *Arca pella* Linné, 1758.

Lembulus has been mostly considered a subgenus of *Nuculana* and sometimes misapplied in place of *Saccella*. The characters of *Lembulus* are markedly different from those of *Nuculana* s.s.: the shell is robust, strongly convex, with a short, stout, bicarinate rostrum terminating into a pointed tip. The commarginal sculpture is weak but a dense pattern of well-defined, oblique striae is present. The type species was fixed by Gray (1847) as *Lembulus rossianus* Risso, 1826, which is undoubtedly a junior synonym of *Arca pella* Linné, 1758 (Arnaud, 1977).

In Europe, the stratigraphic distribution of *Lembulus* ranges back to the Early Miocene (Cossmann & Peyrot, 1913). *Lembulus pella* is the sole extant European species, whereas other species are known from West

EXPLANATION OF PLATE 3

figs. 1-9 - *Lembulus pella* (Linné, 1758).

1-7 - Monte Mario, Early Pleistocene, Cerulli Irelli coll., sample 22 (MPUR).

1-3 - 10.3 mm;

4-5 - 10.4 mm;

6 - 11.6 mm;

7 - 5.73 mm;

8-9 - Holotype of *Nucula bicarinata* Borson, 1825, Valle Andona, “Astian”, Bellardi & Sacco coll., BS 123.02.003/06 (MRSN).

figs. 10-16 - *Jupiteria fissistriata* (Foresti, 1897 ex Meneghini ms).

10-11 - Monte Mario, Early Pleistocene, Cerulli-Irelli coll., sample 23 (MPUR): 8.5 mm (Cerulli Irelli, 1907: Pl. 10, fig. 11).

12-13 - Cerulli Irelli coll., sample 24 (MPUR).

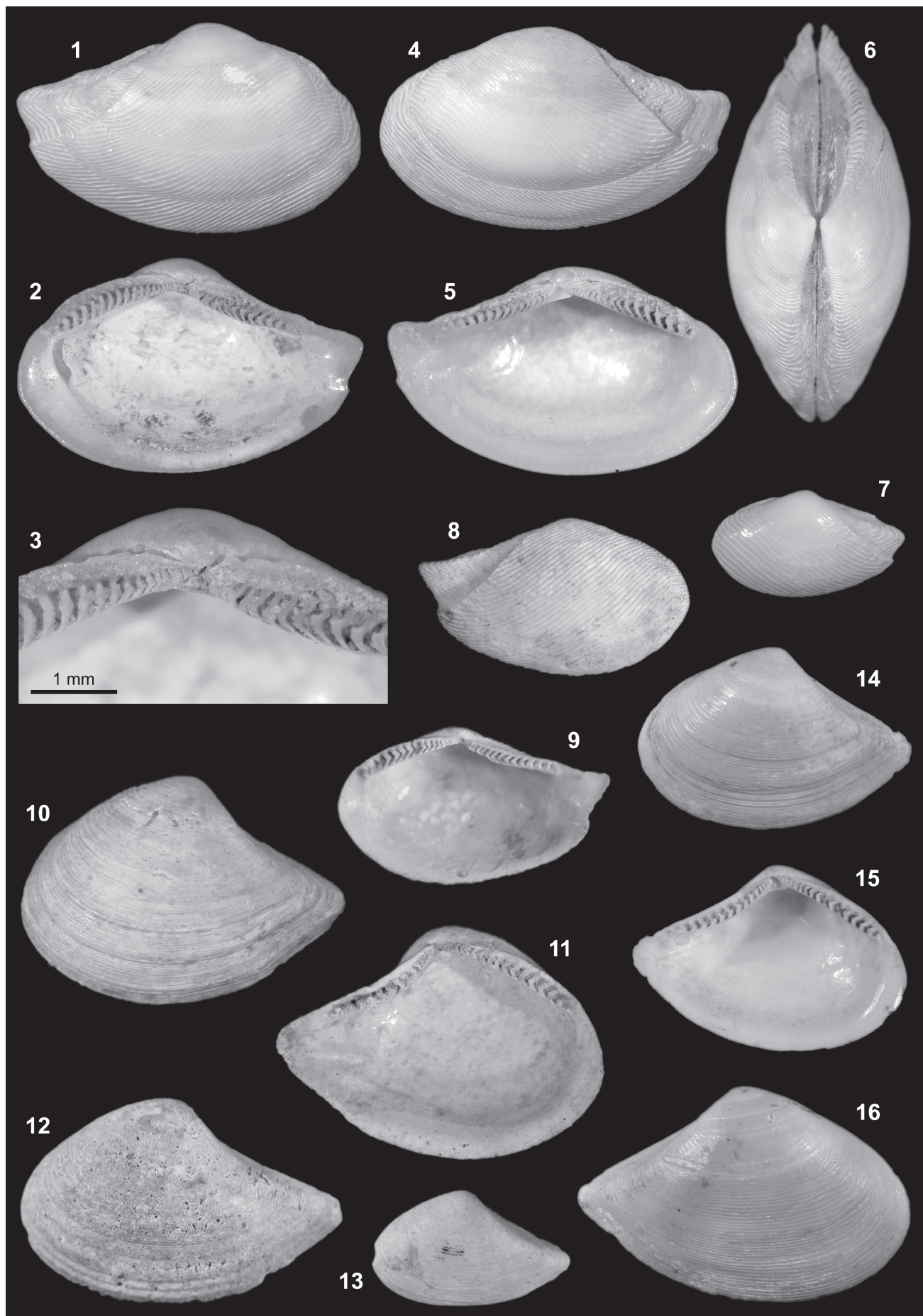
12 - 8.4 mm (Cerulli Irelli, 1907: Pl. 10, fig. 13);

13 - 5.2 mm.

14-16 - Bellardi & Sacco coll., syntypes of *Jupiteria concava* var. *longolaevis* Sacco, 1898 (MRSN), Rio Torsero, “Piacenzian”.

14-15 - BS 123.04.005/03, 7.30 mm;

16 - BS 123.04.005, 8.70 mm (Sacco, 1898: Pl. 12, fig. 5).



Africa, such as *Lembulus bicuspidatus* (Gould, 1845) and *Lembulus wolffi* (Nicklès, 1955).

Lembulus pella (Linné, 1758)
Pl. 4, figs. 1-9

- 1758 *Arca pella* LINNÉ: p. 693.
1767 *Arca pella* LINNÉ: p. 1141.
1795 *Arca interrupta* POLI: p. 136, Pl. 25, fig. 5.
1814 *Arca pella* Linné - BROCCHI: p. 481, Pl. 11, fig. 5.
1819 *Nucula emarginata* LAMARCK, p. 60.
1825 *Nucula bicarinata* BORSON: p. 54; Pl. 11, figs. 44-45.
1826 *Lembulus rossianus* RISSO: p. 320, Pl. 11, fig. 166.
1898 *Lembulus pella* var. *anterotunda* SACCO: p. 52, Pl. 11, figs. 34-36.

Material - Cerulli Irelli coll., Monte Mario, sample 22, 63 vs, 3 shs (MPUR).

Stratigraphic and geographic distribution - The oldest records of *Lembulus pella* are from the Middle Miocene of Austria and Italy (Hörnes, 1865; Sacco, 1898), whereas the latitudinally highest record is from the Late Pliocene of Normandy (Lauriat-Rage, 1986). The modern extra-Mediterranean distribution is not well known, probably ranging from the southern coasts of Iberia (Bucquoy et al., 1891) to Northwest Africa.

It is a shallow water species, occurring on muddy bottoms (Stolfa Zucchi, 1972; Salas, 1996).

Remarks - As remarked by Dodge (1952, p. 147), the description of *Arca pella* by Linné (1758, 1767) is "so clear and characteristic that its identification is free from doubts". However, doubts may be left by the description of *Nucula emarginata* by Lamarck (1819, p. 60), who stated that "*ce n'est point l'arca pella de Linné*". This topic was discussed by Dodge (1952), and previously by Bucquoy et al. (1891, p. 219), with the conclusion that Lamarck's statement was based on a wrong interpretation of *Arca pella* Linné as *Arca fragilis* Chemnitz (see under *Saccula commutata*). *Nucula emarginata* was described as a fossil from the Miocene of Aquitaine, with a reference to Brocchi (1814). The Linnean name was correctly applied by Brocchi (1814, p. 481, Pl. 11, fig. 5), on material from the Pliocene of North Italy (Valle Andona). *Nucula emarginata* has been synonymised either with *Lembulus pella* or *L. undatus* (Defrance, 1825) (e.g. Bellardi, 1875; Sacco, 1898; Bucquoy et al., 1891; Cossmann & Peyrot, 1913; Glibert, 1945). The latter is a Miocene species differing from *L. pella* mainly by the occurrence of coarse, transversal ridges, giving appearance of a wavy surface. This character was clearly remarked in the original description by Defrance (1825, p. 219), who considered "*Nucule ondée*" similar to, but distinct from "*Nucule échancrée*" (*Nucula emarginata*). The clearest statement about the identity of *Nucula emarginata* was written by Payraudeau (1826, p. 65), who reported this species as living remarking that "*elle ne présente nulle différence avec la Nucule échancrée de la collection du Muséum*". The ultimate judgment may come from the examination of the Lamarckian type material, but *Nucula emarginata* can be confidently synonymised with *Lembulus pella*.

Sacco (1898) described *Lembulus pella* var. *anterotunda* on Miocene and Pliocene material. The distinctive character of this variety was said to be the lack, or strong attenuation, of the anterior keel. According to Sacco, the anterior keel became more and more frequent and well developed through the stratigraphic distribution. This morphological trend may be real (see the keeled Mediterranean shells illustrated by Giannuzzi Savelli et al., 2001: figs. 42-45), but anteriorly keeled and smooth shells of *Lembulus pella* are present all through the stratigraphic distribution of the species. The shells from Monte Mario are anteriorly smooth, or with an ill-defined keel. For this reason, var. *anterotunda* Sacco is synonymised with *Lembulus pella*.

Nucula bicarinata Borson, 1825 is a poorly known synonym of *Lembulus pella*. It was described from the Pliocene of Valle Andona (Northern Italy), the same locality from which Brocchi (1814) reported *Arca pella*. The holotype, here illustrated (Pl. 3, figs. 8-9), is in the Bellardi & Sacco coll.

Genus *Jupiteria* Bellardi, 1875

Type species - *Nucula concava* Bronn, 1831.

A study on *Jupiteria* was reported by La Perna et al. (2004), together with a revision of the Plio-Pleistocene species: *Jupiteria concava* (Bronn, 1831), *J. fissistriata* (Foresti, 1897) and *J. gibba* (Seguenza, 1877). Of this species, only *J. fissistriata* had a shallow water distribution.

No living species of *Jupiteria* is known from Europe.

Jupiteria fissistriata (Foresti, 1897 ex Meneghini ms)
Pl. 3, figs. 10-16

- 1875 *Leda (Jupiteria) concava* var. A BELLARDI, p. 21, fig. 15.
1897 *Leda (Jupiteria) fissistriata* FORESTI ex MENEGHINI ms, p. 215, Pl. 9, fig. 1.
1898 *Portlandia (Jupiteria) concava* var. *longolaevis* SACCO, p. 56, Pl. 12, figs. 4-5.
2004 *Jupiteria fissistriata* Foresti ex Meneghini ms - LA PERNA et al., p. 28, figs. 1m-o, fig. 2m.

Material - Cerulli Irelli coll., samples 23, 24, Monte Mario, 11 vs (MPUR).

Stratigraphic distribution - The stratigraphic distribution ranges from the Middle Pliocene to the Early Pleistocene (La Perna et al., 2004).

Remarks - The complex history of this species was traced by La Perna et al. (2004). *Jupiteria concava* (Bronn, 1831) is a Plio-Pleistocene upper bathyal species, with a wide spaced sculpture. Pliocene material of var. *longolaevis* Sacco from the Bellardi & Sacco coll. is here illustrated (Pl. 3, figs. 14-16).

Jupiteria fissistriata is notably variable in shell shape, particularly in elongation and umbo inclination, as seen from the present illustrations and those reported by La Perna et al. (2004).

Leda paucicaelata Nicklès, 1955 (Nicklès, 1955: p. 113, fig. 14) from Sierra Leone and Liberia is clearly a species of *Jupiteria*, particularly similar to *J. fissistriata* in shape and sculpture, even in the occurrence of short, oblique striae on the rostral keel. Apparently, *J. paucicaelata* differs only by being notably smaller (holotype 5.6 mm vs 8-9 mm, maximum size of *J. fissistriata*).

Nucula deltoidea Lamarck, 1819 is probably a species of *Jupiteria*, as suggested by its description ("*N. testa triangulari, inflata; latere antico oblique truncato, acuto; postico brevior rotundato; pube plana*": Lamarck, 1819, p. 60). This is even more obvious from the extended description given by DeFrance (1825, p. 218): it is not known if this description was based on the original material, but DeFrance's description closely recalls *Jupiteria fissistriata*.

DISCUSSION

As previously remarked (La Perna, 2007), the Mediterranean Plio-Pleistocene molluscs, especially some groups, need thorough revisions according to the most recent taxonomic knowledge, strictly critical approach and extensive usage of type material, when available.

Taxonomic complexity, cursory identifications, lack of revisions and excessive trust in literature data, led to consider a single species of *Saccella* from the Mediterranean Plio-Pleistocene. A notable exception is the work by Caprotti (1967) who reported and illustrated, apparently correctly, three species from the Piacenzian stratotype (Northern Italy): *Leda (Jupiteria) commutata*, *L. (J.) deltoidea* and *L. (J.) bonellii*. These species were also reported (with poor illustrations, not useful to assess their identification) from the Piacenzian of Tunisia by Fekih (1975), who also described a new species as *Leda fasciata*. This may actually be a species of *Saccella* with an unusual sculpture of few, coarse, wide spaced ridges in the middle part of valve and fine ridges laterally. Evidently, the knowledge of *Saccella* in the Mediterranean Plio-Pleistocene needs further studies. Some material from the Cerulli Irelli coll. was left in an uncertain status (*Saccella* sp. A, *Saccella* sp. B) and the Plio-Pleistocene species *Leda lamellicostata* Seguenza, 1877 and *L. inaequilatera* Seguenza, 1877, both referable to *Saccella*, are only known from their original descriptions. Another species is *Saccella* aff. *bonellii* from the Bellardi & Sacco coll. For the moment being, five species can be listed for this genus in the Mediterranean Plio-Pleistocene: *Saccella commutata*, *S. consanguinea*, *S. bonellii*, *S. aff. bonellii* and *S. calatabianensis* (Fig. 3). Of these, *Saccella commutata* and *S. calatabianensis* were present in the Early Pleistocene.

The latitudinal distribution of *Saccella* shows marked changes through the Neogene-Pleistocene. During the Miocene, the genus was present in Holland, Belgium and Denmark, with *Saccella westendorpi* (Nyst, 1839) (Kautsky, 1925; Glibert, 1945; Cossmann & Peyrot, 1913), whereas the modern northern limit is within the Bay of Biscay, as reported about *S. commutata*. There are no records of *Saccella* from the Pliocene of Northern

Europe (Heering, 1950; Lauriat-Rage, 1986; Marquet, 2000) and thus the shift to south (some 10°) seems to have occurred in the latest Miocene or earliest Pliocene, apparently pre-dating the Middle Pliocene strong cooling episode at 3.1 My which caused the extinction of warm-water taxa at mid latitudes (Monegatti & Raffi, 2000). However, the stratigraphic pattern of *Saccella* species in the Mediterranean (Fig. 3) appears to have been controlled by the Plio-Pleistocene climate history, taking also account of the low stratigraphic resolution of records (e.g., it is not known if the Piacenzian records are older or younger than 3.1 My). *Saccella commutata* is undoubtedly the most eurythermal and long-lasting representative whereas *S. consanguinea*, *S. bonellii* and *S. aff. bonellii* could be considered as warmer species that suffered the Middle Pliocene cooling. *Saccella calatabianensis* and the Recent *S. illirica* are younger species, probably with a temperate character.

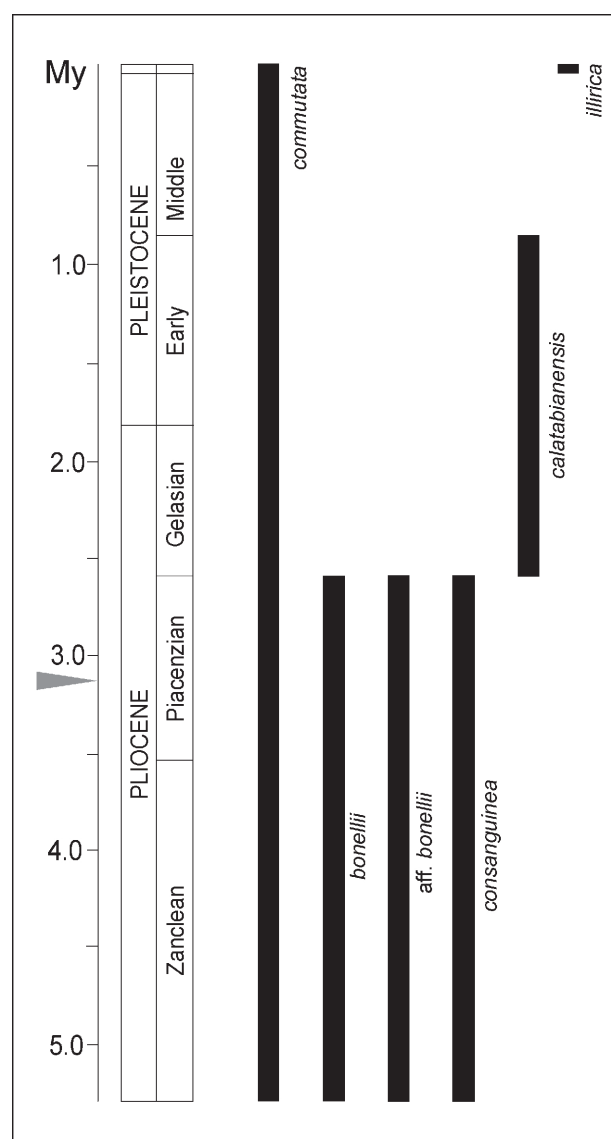


Fig. 3 - Stratigraphic distribution of *Saccella* species in the Mediterranean Pliocene-Quaternary. Appearances and/or extinctions are placed in correspondence with the boundaries of the stages from which the species are recorded. Arrow indicates the Middle Pliocene cooling episode.

The Miocene to Recent history of *Lembulus* is similar to that of *Saccella*. However, the last occurrence of *Lembulus pella* in North Europe (Normandy) dates back to the Late Pliocene according to Lauriat-Rage (1986) who considered this species as a southern immigrant during the Late Pliocene, but definitely absent from The Channel since the Pleistocene, when the North Sea waters became too cold. Actually, a warmer phase occurred in the Late Pliocene (Thunell et al., 1990) and this could explain the temporary northward spreading of *Lembulus pella*.

The palaeogeographic history of *Jupiteria* departs significantly from that of *Saccella* and *Lembulus*. This genus had always a southern distribution in the Pliocene and Pleistocene, with records only from Italy and Southern Spain (La Perna et al., 2004; Vera-Peláez et al., 1995). The oldest record in Europe is from the Middle Miocene of Northern Italy (Bellardi, 1875; Sacco, 1898). Further, unlike *Saccella* and *Lembulus*, *Jupiteria* shows a tendency to colonize deeper waters. It has been hypothesized that *Jupiteria* has an Indo-Pacific (Tethyan) origin, basing on the occurrence of this genus in Australasia since the Palaeogene (La Perna et al., 2004 with references) and in the modern Indian Ocean (Kilburn, 1994). The occurrence of *Jupiteria* in the Tropical West Africa, with a species closely allied to the Plio-Pleistocene *J. fissistriata*, seems a strong argument supporting the warm water character of this genus, or of its shallow water members.

Further studies may be useful to detail the taxonomic and biogeographic knowledge on these groups, as well as to obtain a more realistic view of the diversity of the Mediterranean molluscs through the Neogene-Quaternary.

ACKNOWLEDGEMENTS

I am grateful to Riccardo Manni (MPUR) for assistance in studying the Cerulli Irelli collection, to Daniele Ormezzano and Bruna Merlino (MRSN) for their generous assistance and help in studying the Bellardi & Sacco collection, to Stefano Dominici (Università di Firenze) for help in examining material from the Seguenza collection and to Mauro Brunetti (Rioveggio, Bologna) who kindly sent Pliocene material from Emilia Romagna and Tuscany.

Work supported by Fondi di Ricerca d'Ateneo 2006 (La Perna).

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Manuscript received 23 March 2007

Revised manuscript accepted 18 October 2007

