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Record of marine warm-water species and of other "Pliocene survivors" from the Early Pleistocene of Latium (Central Italy)

Luca Santucci*

* Via Cappuccini 6, 02042 Collevecchio (Rieti), Italy, *luca_santucci@libero.it*

Abstract

This paper describes a marine malacofauna from the Early Pleistocene deposits of the Tiber Valley (Latium, Italy). The fossil assemblage includes some warm-water taxa: *Ficus subintermedia* (d'Orbigny, 1852), *Sveltia varicosa* (Brocchi, 1814), *Metula mitraeformis* (Brocchi, 1814) and other molluscan species considered extinct in the Pliocene: *Nassarius clathratus* (Born, 1788), *Turritella aspera* (Mayer, 1866, Sismonda m.s.) and *Belidaphne semicostata* (Bellardi, 1847). The survival of warm-water taxa at the beginning of the Calabrian age could be related to their greater tolerance to a climate regime of higher seasonality, since the Early Piacenzian.

Key words

Central Italy, Tiber Valley, Early Pleistocene, molluscs, palaeoclimatology.

Riassunto

Viene descritta una malacofauna marina raccolta in depositi della media valle del Tevere, a Nord di Collevecchio (Rieti). Tali sedimenti sono attribuibili al Pleistocene inferiore (Calabriano p.p.). La malacofauna raccolta, con 127 specie finora identificate, contiene alcune specie ad affinità calda: *Ficus subintermedia* (d'Orbigny, 1852), *Metula mitraeformis* (Brocchi, 1814), *Sveltia varicosa* (Brocchi, 1814) ed altre specie ritenute estinte nel Pliocene: *Nassarius clathratus* (Born, 1788), *Turritella aspera* (Mayer, 1866, Sismonda m.s.) e *Belidaphne semicostata* (Bellardi, 1847). Tali specie sono state raccolte in livelli di sabbie fini, limose, giallastre, immediatamente al di sotto di peliti sabbiose contenenti alla base una microfauna a *Bulimina etnea* Seguenza, 1862, marker del Pleistocene inferiore. Si esclude la natura rimaneggiata delle specie in esame, per via del buono stato di conservazione dei gusci. La sopravvivenza di specie ad affinità calda, o comunque segnalate sinora solo nel Pliocene, può essere spiegata alla luce dell'evoluzione paleoclimatica del Mar Mediterraneo, interessato, a partire da circa 3,1-3,0 milioni di anni fa, dal passaggio da un regime climatico tropicale ad un regime temperato caldo, con una sempre più marcata stagionalità.

Parole chiave

Italia centrale, Valle del Tevere, Pleistocene inferiore, molluschi, paleoclimatologia.

Introduction

The fossiliferous Late Cenozoic-Quaternary deposits of the Tiber Valley (Latium, Central Italy) have been the subject of many investigations in the past (i.e. Cerulli Irelli & De Angelis d'Ossat, 1898; Tuccimei, 1880, 1889; Terrenzi, 1886. etc.). Recent fossil collectings, carried out in the sandy and sandy-muddy deposits cropping out in the Campana Stream Valley (coordinates: 42°21'18"N; 0°6'20"E), north of Collevecchio (**Fig. 1**), provided an interesting malacofauna including some warm-water taxa as discussed in the present work.

The main feature of the Neogene-Quaternary Mediterranean malacofauna evolution is a marked faunal impoverishment in taxonomic diversity, since the Pliocene, with the progressive disappearance of tropical taxa. This process has been evidenced since the late 70's of the past century (Marasti & Raffi, 1977; Raffi et al., 1985; Raffi & Monegatti, 1993; Monegatti & Raffi, 2001). The faunal impoverishment is related to the progressive shift, in the Mediterranean Sea, from tropical conditions during the Zanclean-early Piacenzian, to the present-day warm-temperate conditions.

Monegatti & Raffi (2001) defined four Mediterranean Pliocene Molluscan Units (MPMUs), each bounded by disappearance events of warm-water bivalves, which can be related to distinct periods in the climatic-oceanographic evolution of the Mediterranean (**Fig. 2**). However, for most species of gastropods is not yet possible to provide a detailed picture of the times of disappearance with respect to these faunal units (Monegatti & Raffi, 2001; Monegatti et al., 2002).

The Calabrian Mediterranean malacofauna is characterized by the gradual and discontinuous appearance of "Boreal Guests" and the disappearance of Pliocene warm-water survivors (Raffi, 1986).

The setting of the middle Tiber Valley marine molluscs faunas in this palaeoclimatic scenario, however, is made difficult by the lack of Boreal Guests records in over 150 years of researches. On the contrary, several warm-water molluscan taxa are here reported from the Tiber Valley deposits.

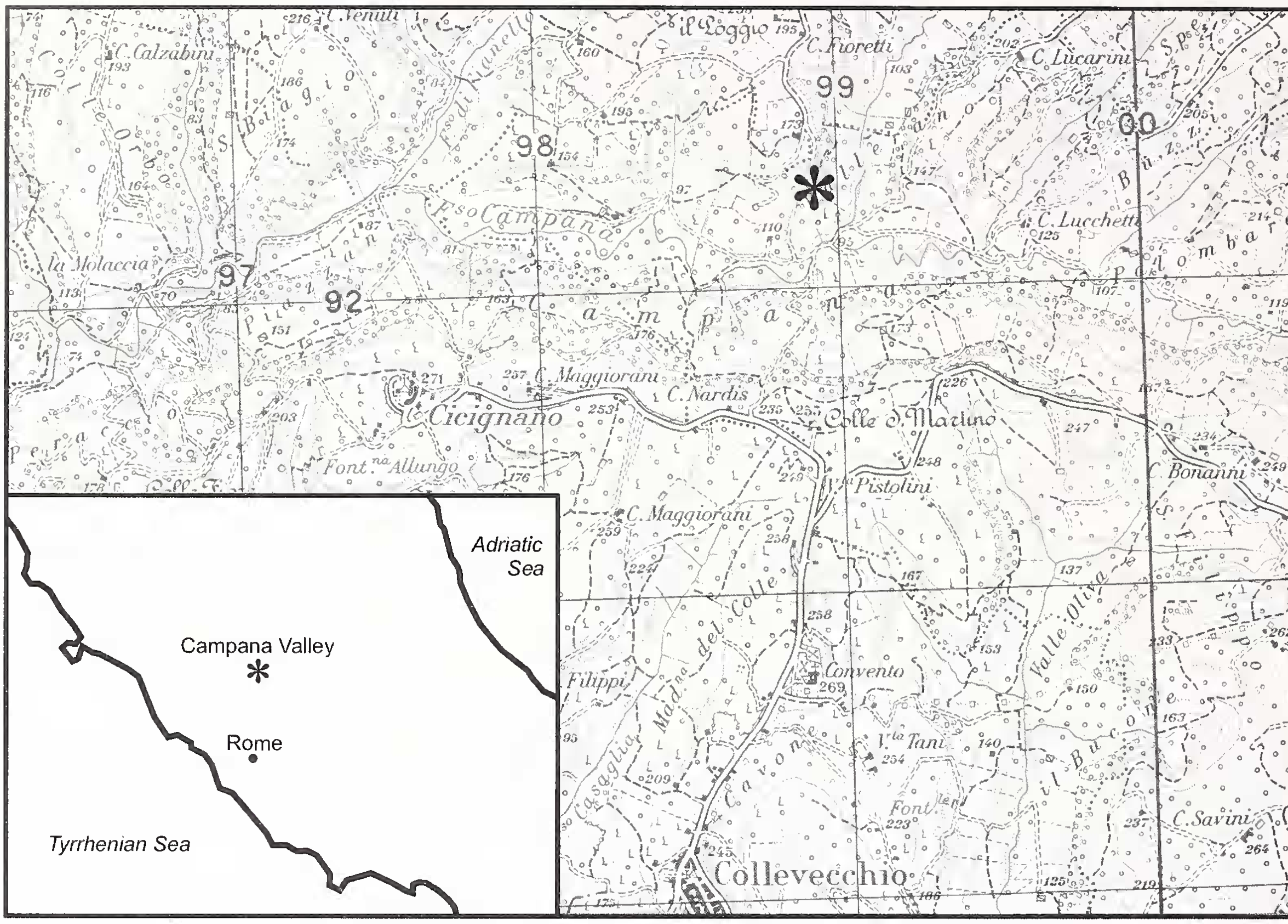

Fig. 1. Location of the study sequence (the asterisk marks the ouctrop).

Fig. 1. Ubicazione della successione studiata (l'asterisco indica l'affioramento).

Geological setting and biostratigraphy

The Chiani-Tevere Basin (Barberi et al., 1994) runs parallel to the present-day Tyrrhenian coastline of Central Italy, bordered by the M. Cetona-M. Rufeno-M. Razzano ridge on the west and the Narnese-Amerina Chain and the Sabini Mountains on the east. The basin is subdivided into two sectors by the NW-SE M. Soratte-M. Cornicolani structural high. In the area, two sedimentary cycles, one Late Zanclean-Early Gelasian and the other Late Gelasian-Early Calabrian, have been recognized (Girotti & Mancini, 2003; Mancini et al., 2004). The investigated succession belongs to the Late Gelasian-Early Calabrian cycle, in particular to Chiani-Tevere Fm. (Girotti & Mancini, 2003; Mancini et al., 2004). It is comprised between the first and the second prograding clastic wedge, according to the stratigraphic scheme (**Fig. 3**) proposed by Girotti & Mancini (2003).

The most complete succession crops out on the right bank of the Campana River (**Fig. 4**). At the base (127 m above sea level) the section includes a 3 m thick level of yellowish, silty fine sands of shallow water deposition, which gradually gives places to blue-grey sandy pelites. The sandy pelitic level, about 21 m thick, become more sandy upwards, where lignite fragments are frequent. A thin, golden, sandy layer (10 cm thick) in the uppermost part of the sandy pelites, with erosional contact and containing clay chips, is considered as a storm layer and a marker bed in the Campana Valley.

The sequence indicates a shallowing trend, from outer shelf (circalittoral) to inner shelf (infralittoral) settings (Carboni, pers. comm.). The section is closed by yellow sands displaying hummocky cross-bedding, and finally medium sands with flat lamination pointing out a transition from the shoreface to the foreshore environment

Because of the absence or scarcity of most reliable biostratigraphic tools in this part of the Chiani-Tevere Basin, such as calcareous nannofossils or planktonic foraminifers, biostratigraphy is based on benthic foraminifers (Di Bella, 1999; Di Bella et al., 2002).

Fortunately, the muddy horizons of the studied section contains some species, such as *Bulimina marginata* d'Orbigny, 1826, *Bulimina elegans marginata* Fornasini, 1902 and *Bulimina etnea* Seguenza, 1862 (Carboni, pers. comm.). *Bulimina etnea* is considered a good marker for the Calabrian, though its first occurrence is not perfectly calibrated (Vaiani & Venezia, 1999). In the Vrica section, GSSP of the Calabrian Stage this bioevent is placed between the "m" and "n" sapropelic layers (Cita, 2010). According to the geochronologic scale of Lourens et al. (1996) it is dated 1.67 Ma.

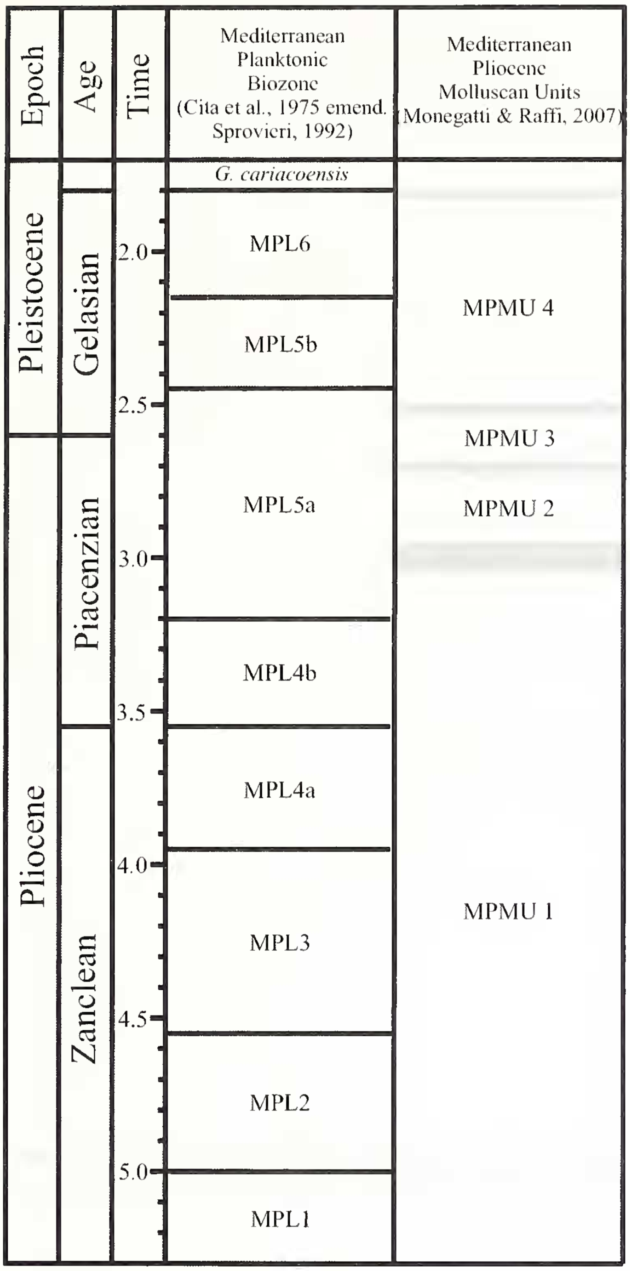

Fig. 2. Molluscan biostratigraphic units in the Mediterranean Pliocene (after Marasti & Raffi, 2007, modified).

Fig. 2. Unità biostratigrafiche a molluschi nel Pliocene del Mediterranean (da Marasti & Raffi, 2007, modificato).

Material and methods

Fifty samples were collected from the section for the micropaleontological studies. The samples were oven dried at 40°C and sieved through a 0.125 mm mesh. Macrofossils were hand picked on the outcrop and are housed in the author's collection.

The list of extant species belonging to the genera *Ficus* Roeding, 1798, *Sveltia* Jousseame, 1887 and *Metula* H. Adams & A. Adams, 1853 are from the World Register of Marine Species - WoRMS (Appeltans et al., 2012). Data on the present-day geographic distributions of the species were obtained from several online databases: Malacolog Version 4.1.1: Western Atlantic Marine Mollusca (Rosenberg G., 2009), OBIS Indo-Pacific Mollusc Database, Check List of Marine Mollusca (CLEMAM) and gastropods.com.

Results

The list of the molluscs collected and identified has been reported in **Tab. 1**.

The upper part of the yellowish silty sands shows a rich molluscan assemblage, with frequent articulated bivalve shells belonging to *Megaxinus transversus* (Bronn, 1831) and *Lucinoma boreale* (Linné, 1797). The molluscan assemblage from the upper two meters of the overlying blue-grey sandy pelites contains frequent *Venus nux* Gmelin, 1791, *Acanthocardia echinata* (Linné, 1758), *Aequipecten opercularis* (Linné, 1758) and *Nassarius gigantulus* (Michelotti, 1840, Bonelli m.s.), together with *Pelecyora brocchii* Deshayes, 1836, *Mimachlamys varia* (Linné, 1758) and *Glossus humanus* (Linné, 1758). In the middle and upper parts of the sandy pelites *Ostrea lamellosa* Brocchi, 1814, *Modiolus barbatus* (Linné, 1758) and *Spisula subtruncata* Da Costa, 1778 become dominant, indicating a decrease in the palaeobathimetry and the transition from circalittoral to infralittoral environments.

The molluscs assemblages contain three warm-water species, namely *Ficus subintermedia* (d'Orbigny, 1852), *Sveltia varicosa* (Brocchi, 1814) and *Metula mitraeformis* (Brocchi, 1814). Furthermore, some species so far considered extinct in the Pliocene, are also present: *Nassarius clathratus* (Born, 1788), *Turritella aspera* (Mayer, 1866, Sismonda m.s.) and *Belidaphne semicostata* (Bellardi, 1847). Due to the pristine conditions of these species, the hypothesis of their reworking from older levels can be excluded. The warm-water meaning of the genera *Ficus*, *Sveltia* and *Metula* can be inferred from the geographical distribution of their living representatives, and basing on the paleobiogeographical distribution of fossil species in the eastern Atlantic-Mediterranean areas, from the Miocene to the present-day.

Ficus subintermedia (D'Orbigny, 1852) (Fig. 5M, O)

WoRMS reports 9 extant species belonging to the genus *Ficus*. The genus has a worldwide distribution, between 35°N and 35°S latitude.

According to Landau et al. (2004b) in the Middle-Late Miocene of the Mediterranean Sea two species were present: *F. subintermedia* and *F. geometra* (Borson, 1825), whereas in the northern European basins the most frequent species was *F. condita*. One or possibly two distinct species occurred in the Miocene of Germany. The specimens from the Paratethys deposits attribuited to *F. geometra* may be related to other species.

In the Early Piacenzian, only two species were still present: *F. subintermedia*, reported from Northern Italy (Brunetti & Vecchi, 2005) and Portugal (Landau et al., 2004b), and *F. geometra*, limited to the Mediterranean (Sacco, 1890; Caprotti, 1973).

According to Landau et al. (2004b), who reviewed the genus *Ficus* in the European Neogene, the Mediterranean Pliocene populations generally referred to as *Ficus con-*

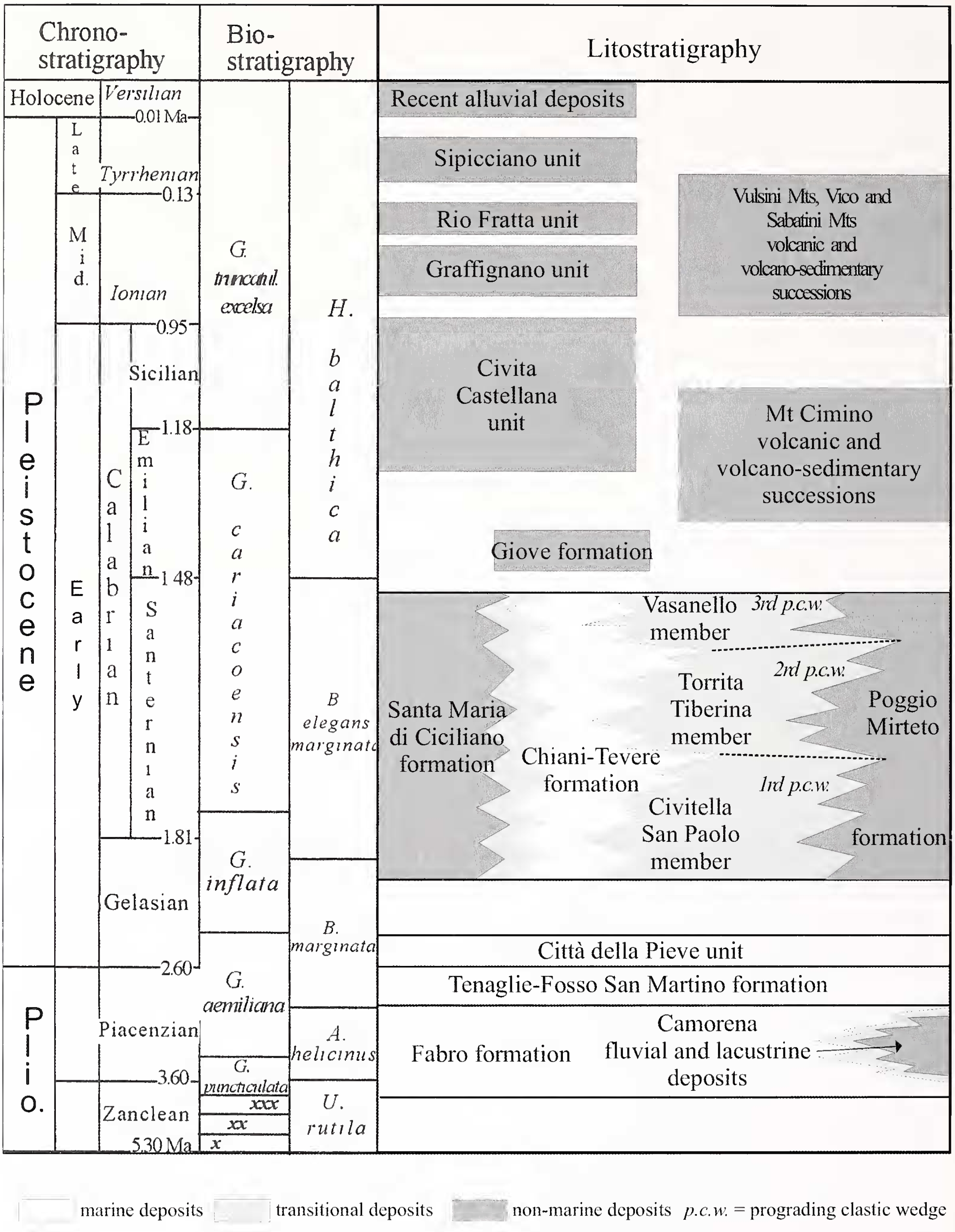

Fig. 3. Litostratigraphic, biostratigraphic and chronostratigraphic scheme of the middle Tiber Valley area (after Mancini & Girotti, 2003, modified).

Fig. 3. Schema litostratigrafico, biostratigrafico e cronostratigrafico della media Valle del Tevere (da Mancini & Girotti, 2003, modificato).

Species	silty sand	clayey silt
Classis BIVALVIA		
Nucula placentina Lamarck, 1819	X	
Nucula sulcata Bronn, 1831		X
Saccella commutata (Philippi, 1844)	X	
Lembulus pella (Linné, 1767)	X	
Dyolia mendax (Meneghini in Appelius, 1870)	X	X
Arca noae Linné, 1758	X	
Ambrogia mytiloides (Brocchi, 1814)		X
Anadara darwini (Mayer, 1868)	X	
Anadara pectinata (Brocchi, 1814)	X	X
Striarca lactea (Linné, 1758)	X	
Limopsis minuta (Philippi, 1836)	X	
Glycymeris insubrica (Brocchi, 1814)	X	
Modiolus barbatus (Linné, 1758)		X
Pecten jacobaeus (Linné, 1758)	X	
Aequipecten opercularis (Linné, 1758)		X
Talochlamys multistriata (Poli, 1795)	X	
Mimachlamys varia (Linné, 1758)	X	X
Flexopecten glaber (Linné, 1758)	X	X
Amusium cristatum (Bronn, 1827)	X	
Spondylus gaederopus Linné, 1758	X	
Anomia ephippium Linné, 1758	X	X
Pododesmus patelliformis (Linné, 1761)	X	X
Ostrea lamellosa Brocchi, 1814		X
Megaxinus transversus (Bronn, 1831)	X	
Myrtea spinifera (Montagu, 1803)	X	
Lucinoma boreale (Linné, 1797)	X	
Chama gryphoides Linné, 1758	X	
Chama placentina Defrance, 1817	X	X
Pseudochama gryphina (Lamarck, 1819)	X	
Cardita calyculata (Linné, 1758)	X	
Cardites antiquatus pectinatus (Brocchi, 1814)	X	
Glans intermedia (Brocchi, 1814)	X	
Cardium indicum Lamarck, 1818	X	X
Acanthocardia bianconiana (Cocconi, 1873)	X	
Acanthocardia echinata (Linné, 1758)	X	X
Plagiocardium papillosum (Poli, 1791)	X	X
Trachycardium multicostatum (Brocchi, 1814)	X	
Mactra stultorum (Linné, 1758)	X	
Spisula subtruncata (Da Costa, 1778)		X
Tellina cf. *donacina* (Linné, 1758)	X	X
Tellina compressa Brocchi, 1814	X	
Tellina serrata (Renier, 1804)	X	
Abra prismatica (Montagu, 1808)	X	
Solecurtus scopula (Turton, 1822)	X	
Azorinus chamasolen (Da Costa, 1778)	X	X
Glossus humanus (Linné, 1758)		X
Venus nux Gmelin, 1791	X	X
Chamelea gallina (Linné, 1758)		X
Chamelea lamellosa (De Rayneval, Van den Hecke & Ponzi, 1854)	X	
Timoclea ovata (Pennant, 1777)	X	X
Gouldia minima (Montagu, 1803)	X	
Pelecyora brocchii (Deshayes, 1836)		X
Corbula gibba (Olivi, 1792)	X	X
Panopea glycimeris (Born, 1778)	X	
Classis GASTROPODA		
Diodora italica (Defrance, 1820)	X	
Clelandella miliaris (Brocchi, 1814)	X	
Diloma patulum (Brocchi, 1814)	X	
Bolma rugosa (Linné, 1758)	X	X
Cerithium varicosum (Brocchi, 1814)	X	X
Cerithium vulgatum (Bruguière, 1792)	X	
Bittium latreillei (Payraudeau, 1826)	X	
Turritella tornata (Brocchi, 1814)	X	
Turritella spirata (Brocchi, 1814)	X	
Turritella aspera (Mayer, 1866 ex Sismonda m.s.)	X	
Turritella tricarinata (Brocchi, 1814)	X	

Species	silty sand	clayey silt
Alvania beani (Hanley in Thorpe, 1844)	X	
Aporrhais pespelecani (Linné, 1758)	X	
Aporrhais uttingeriana (Risso, 1826)	X	X
Calyptraea chinensis (Linné, 1758)	X	X
Crepidula gibbosa Defrance, 1818		X
Crepidula unguiformis Lamarck, 1822	X	
Xenophora crispa (König, 1825)	X	
Capulus ungaricus (Linné, 1758)	X	X
Petaloconchus glomeratus (Linné, 1758)	X	X
Serpulorbis arenaria (Linné, 1767)	X	
Trivia arctica (Pulteney, 1789)	X	
Erato voluta (Montagu, 1803)	X	
Cochlis raropunctata raropunctata (Sasso, 1827)	X	X
Euspira catena (Da Costa, 1778)	X	X
Euspira macilenta (Philippi, 1844)	X	
Ficus subintermedia (d'Orbigny, 1852)	X	
Galeodea echinophora (Linné, 1758)	X	X
Phalium saburon (Bruguière, 1792)	X	
Dizoniopsis bilineata (Hoernes, 1848)	X	
Epitonium commune (Lamarck, 1822)	X	X
Melanella polita (Linné, 1758)	X	X
Niso eburnea (Risso, 1826)	X	
Bolinus brandaris (Linné, 1758)	X	
Hexaplex rudis (Borson, 1821)	X	
Hexaplex trunculus (Linné, 1758)	X	
Muricopsis cristata (Brocchi, 1814)	X	
Hadriania oretea (De Gregorio, 1884)	X	X
Buccinulum corneum (Linné, 1758)	X	
Pollia dorbignyi (Payraudeau, 1826)	X	
Metula mitraeformis (Brocchi, 1814)	X	
Fasciolaria lawleyana (d'Ancona, 1872)	X	
Nassarius gigantulus (Michelotti, 1840, Bonelli m.s.)	X	X
Nassarius incrassatus (Stroem, 1768)	X	X
Nassarius serraticosta (Bronn, 1831)	X	
Nassarius musivus (Brocchi, 1814)	X	
Nassarius macrodon (Bronn, 1831)	X	
Nassarius clathratus (Born, 1788)	X	X
Nassarius mutabilis (Linné, 1758)	X	
Nassarius lima (Dillwyn, 1817)	X	
Mitra cf. *fusiformis* (Brocchi, 1814)	X	
Vexillum pyramidella (Brocchi, 1814)	X	
Vexillum ebenus (Lamarck, 1811)	X	
Sveltia varicosa (Brocchi, 1814)	X	X
Conus cf. *mediterraneus* Hwass in Bruguière, 1792	X	
Haedropleura septangularis (Montagu, 1803)	X	
Bela brachystoma (Philippi, 1844)	X	
Agathotoma angusta (Jan, 1842)	X	
Mangelia attenuata (Montagu, 1803)	X	
Mangelia unifasciata (Deshayes, 1835)	X	
Neoguraleus hispidulus (Jan in Bellardi, 1847)	X	X
Raphitoma echinata (Brocchi, 1814)	X	
Belidaphne semicostata (Bellardi, 1847)	X	
Clathurella gracilis (Montagu, 1803)	X	X
Pyramidella plicosa Bronn, 1838	X	X
Odostomia conoidea (Brocchi, 1814)	X	X
Turbonilla rufa (Philippi, 1836)	X	X
Retusa truncatula (Bruguière, 1792)	X	
Cylichnina umbilicata (Montagu, 1803)	X	
Ringicula auriculata (Ménard de la Groye, 1811)	X	X
Ringicula buccinea (Brocchi, 1814)	X	X
Classis SCAPHOPODA		
Antalis inaequicostatum Dautzenberg, 1891	X	X
Episiphon rubescens (Deshayes, 1825)	X	

Tab. 1. Molluscan species from the study sequence.

Tab. 1. Elenco della malacofauna nella successione studiata.

dita (Brongniart, 1823) should be considered as a distinct species, i.e. *Ficus subintermedia*.
According to Verhaeghe & Poppe (2000), the living Indo-Pacific specimens ascribed at *F. subintermedia* d'Orbigny are not conspecific with the European Neogene fossils and should be referred to *F. ficus* (Linné, 1758).

Sveltia varicosa (Brocchi, 1814)
(Fig. 5G, H)

WoRMS reports 6 extant species for the genus *Sveltia*, with an intertropical distribution, between 30°N and 30°S. In the Middle-Late Miocene, *Sveltia* was present with four species at least in the North Sea Basin, five or six species in the Atlantic basins of France, and six species at least in the Mediterranean (Brunetti et al., 2011).
In the Zanclean, *Sveltia* is represented by only two species in the Mediterranean, *S. varicosa* and *S. lyrata* (Brocchi, 1814), and by a single species in the North Sea, *S. jonkairiana* (Nyst, 1835) (Brunetti et al., 2011).
S. varicosa was recently recorded in the Calabrian of Rhodes (Chirli & Linse, 2011), whereas *S. lyrata* is known from the Calabrian of Tuscany (Menesini & Ughi, 1983). As a living species it is known from West Africa (Verhecken, 2007).
In the Po basin the extinction of *Sveltia varicosa* occurred in MPL5a zone, which is referable to the MPMU2 (Monegatti et al. 1997; Monegatti et al., 2002). According to Brunetti et al. (2011), this species was very common in the Zanclean-Piacenzian, rare in the Gelasian, and not present in the Calabrian.

Metula mitraeformis (Brocchi, 1814)
(Fig. 5C, D)

According to WoRMS, *Metula* includes 28 living species distributed between 30°N and 35°S latitude.
In the European Middle-Late Miocene, *Metula* is represented by *M. mitraeformis* with a distribution limited to the Mediterranean Basin, and by a similar form, or perhaps conspecific, *M. submitraeformis* d'Orbigny, 1852, known from Aquitaine, Germany, Holland and Vienna basins (Malatesta, 1974).
M. mitraeformis was also present in the Mediterranean Pliocene, in the MPL6 zone, related to MPMU4 (Monegatti et al., 1997). This is the first Calabrian record for this species. Bouchet (1988) considered *M. mitraeformis* the direct ancestor to *M. africana* Bouchet, 1988, described from off West Africa.
For the following species, the data on their stratigraphic distribution are scarce, not allowing a well defined palaeoclimatic meaning to be assessed. Their distribution was thought to be limited to the Piacenzian (*Belidaphne semicostata*), or the Gelasian (*Nassarius clathratus* and *Turritella aspera*).

Nassarius clathratus (Born, 1788)
(Fig. 5I, L)

According to Brunetti & Vecchi (2005), this species appeared in the Early Miocene of France. In the Pliocene it

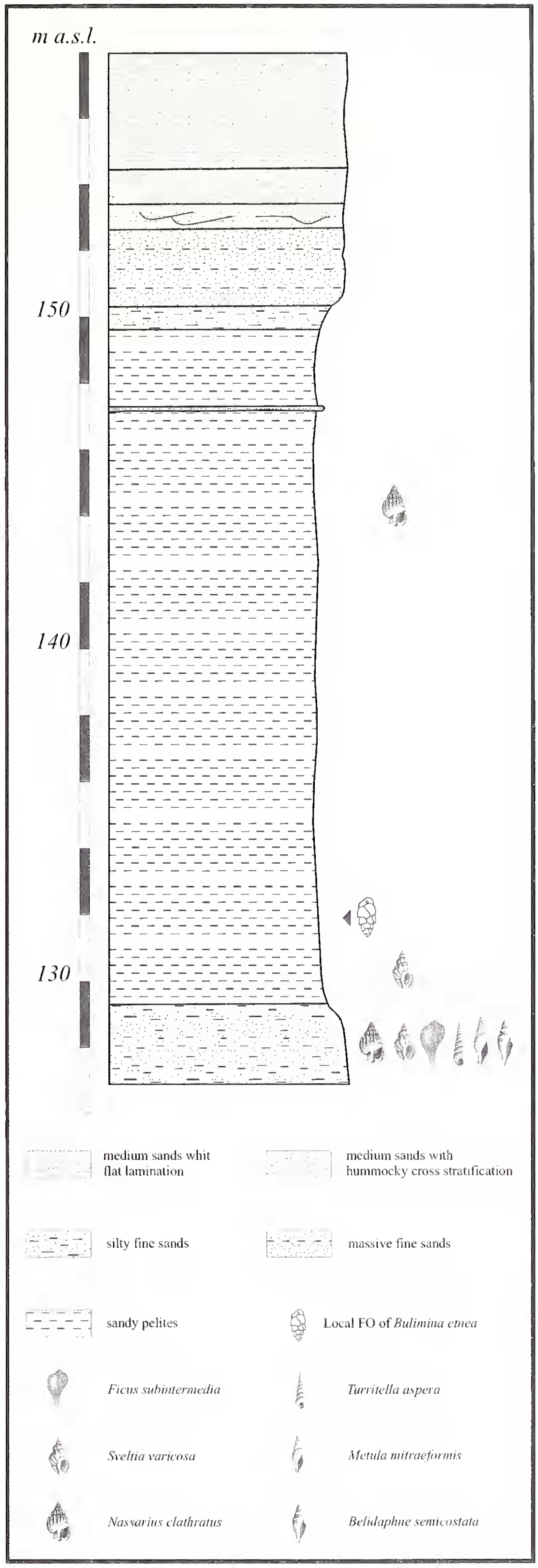

Fig. 4. Litostratigraphy of the investigated succession.

Fig. 4. Litostratigrafia della successione studiata.

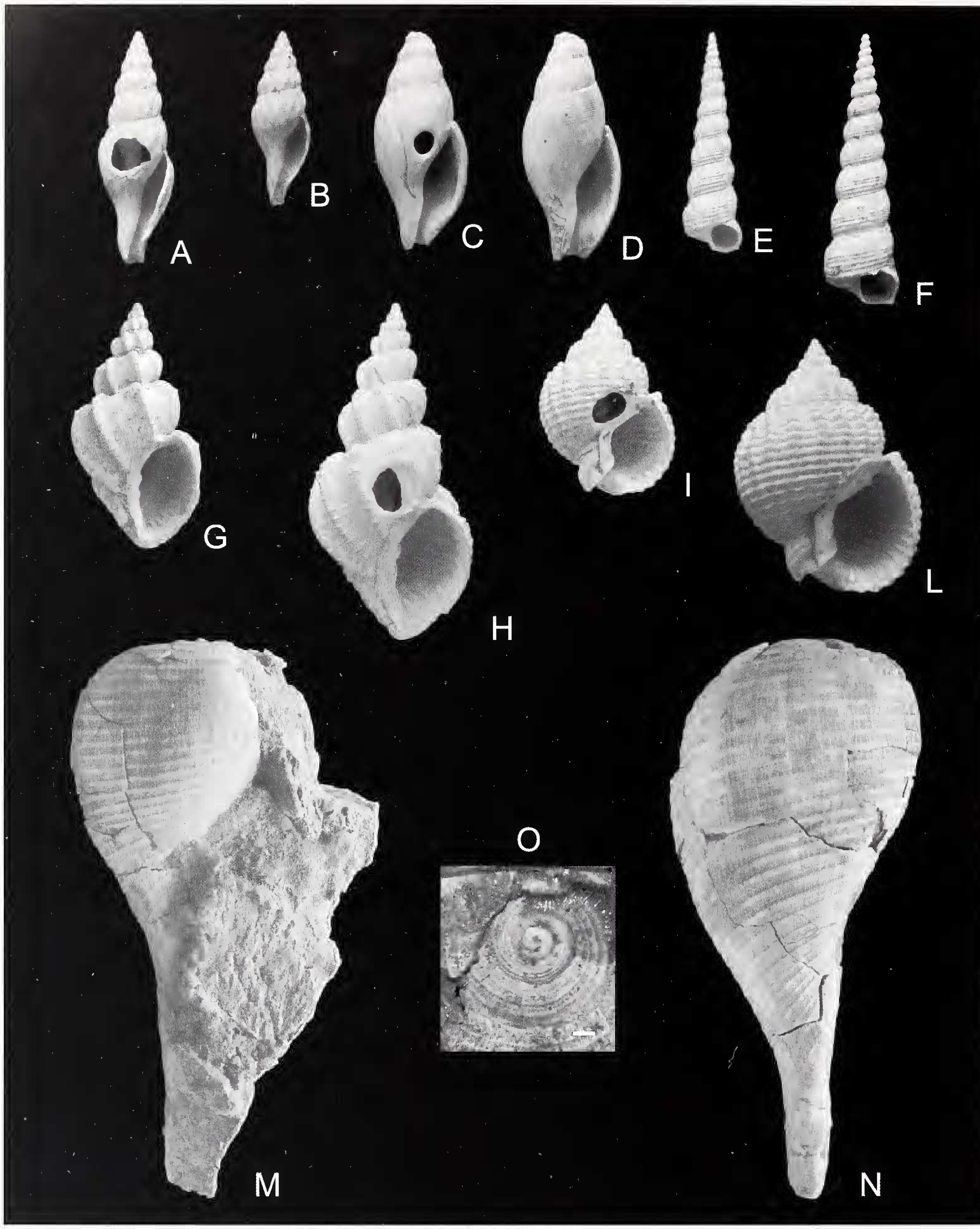

Fig. 5. A, B. *Belidaphne semicostata* (Bellardi, 1847). **A.** Montebuono (Rieti), H = 20 mm (coll. Santucci). **B.** Tarano (Rieti), H = 15 mm (coll. Santucci). **C, D.** *Metula mitraeformis* (Brocchi, 1814). **C.** Tarano (Rieti), H = 25.2 mm (coll. Santucci). **D.** Montebuono (Rieti), H = 26.3 mm (coll. Santucci). **E, F.** *Turritella aspera* (Mayer, 1866, Sismonda m.s.). **E.** Tarano (Rieti), H = 19.2 mm (coll. Santucci). **F.** Tarano (Rieti), H = 26.2 mm (coll. Santucci). **G, H.** *Sveltia varicosa* (Brocchi, 1814). **G.** Montebuono (Rieti), H = 26.3 mm (coll. Santucci). **H.** Montebuono (Rieti), H = 38.4 mm (coll. Santucci). **I, L.** *Nassarius clathratus* (Born, 1788). **I.** Montebuono (Rieti), H = 21.8 mm (coll. Santucci). **L.** Montebuono (Rieti), H = 29.1 mm (coll. Santucci). **M-O.** *Ficus subintermedia* (d'Orbigny, 1852). **M, N.** Tarano (Rieti), H = 96 mm, apertural and dorsal view (coll. Santucci). **O.** Tarano (Rieti), apical whorls (coll. Santucci) (scale bar = 1 mm).

Fig. 5. A, B. *Belidaphne semicostata* (Bellardi, 1847). **A.** Montebuono (Rieti), H = 20 mm (coll. Santucci). **B.** Tarano (Rieti), H = 15 mm (coll. Santucci). **C, D.** *Metula mitraeformis* (Brocchi, 1814). **C.** Tarano (Rieti), H = 25,2 mm (coll. Santucci). **D.** Montebuono (Rieti), H = 26,3 mm (coll. Santucci). **E, F.** *Turritella aspera* (Mayer, 1866, Sismonda m.s.). **E.** Tarano (Rieti), H = 19,2 mm (coll. Santucci). **F.** Tarano (Rieti), H = 26.2 mm (coll. Santucci). **G, H.** *Sveltia varicosa* (Brocchi, 1814). **G.** Montebuono (Rieti), H = 26,3 mm (coll. Santucci). **H.** Montebuono (Rieti), H = 38,4 mm (coll. Santucci). **I, L.** *Nassarius clathratus* (Born, 1788). **I.** Montebuono (Rieti), H = 21,8 mm (coll. Santucci). **L.** Montebuono (Rieti), H = 29,1 mm (coll. Santucci). **M-O.** *Ficus subintermedia* (d'Orbigny, 1852). **M, N.** Tarano (Rieti), H = 96 mm, vista aperturale e dorsale (coll. Santucci). **O.** Tarano (Rieti), giri apicali (coll. Santucci) (scala = 1 mm).

reached a pan-European distribution, from England to Mediterranean, with a last occurrence in the Early Pleistocene of Sicily (Monte Navone), where the species was recorded by Di Geronimo (1969). According to Monegatti et al. (1997), *Nassarius clathratus* was still present in the Gelasian (MPL6 zone), related to MPMU4.

According to Di Geronimo (1975), the specimens from Monte Navone show the shell characters of *N. clathratus* f. *obtusepercostata* Sacco, 1890 (= *N. clathratus*), but he remarked some small, constant differences in the protoconchs. Size and shape of protoconch are important characters for identification in the "*N. clathratus* species group" (Adam & Glibert, 1976), as well as in most gastropods in the modern systematic views. The identity of the M. Navone specimens thus remains doubtful.

Turritella aspera (Mayer, 1866 ex Sismonda m.s.)
(Fig. 5E, F)

According to Monegatti et al. (1997), *Turritella aspera* is still present in the MPL5b zone and the related molluscan unit (MPMU3). Since its appearance in the Late Miocene, its distribution has been limited to the Mediterranean (Malatesta, 1974; Landau et al., 2004a).

Among the fossil and extant Mediterranean Turritellidae, only *T. tricarinata* Brocchi, 1814 is markedly similar to *Turritella aspera*. The former is an extant species, typical to soft, muddy bottoms where the Coastal Terrigenous Muds biocoenosis thrives (Pérès & Picard, 1964).

According to Allmon (1992), the extinction pattern of the Early Neogene turritellinae in North and Central America was strictly controlled by changes in nutrients, rather than by temperature. Probably, also for the European species *T. aspera* other limiting factors, in addition to temperature, may have played a determinant role in its extinction.

Belidaphne semicostata (Bellardi, 1847)
(Fig. 5A, B)

Belidaphne semicostata has a controversial systematic arrangement. Originally referred to *Raphitoma* Bellardi, 1847, it has been moved among several genera: *Homotoma* Bellardi, 1875, *Defrancia* Millet, 1827, *Bellardiella* Fischer, 1883 and *Daphnella* Hinds, 1844 (Scarponi, 2012, pers. comm). Recently, Vera-Pelaez (2002) erected *Raphitoma semicostata* Bellardi, 1847 as type species of the new genus *Belidaphne* Vera-Pelaez, 2002, including few fossil species from Italy and Spain.

Two species, *Belidaphne desmoulinsi* (Bellardi, 1847) and *B. saldubensis* Vera-Pelaez, 2002, are present in the Zanclean-Early Piacenzian of Spain (Vera-Pelaez, 2002), whereas *B. semicostata* and *B. desmoulinsi* are present in the Zanclean-Piacenzian of Italy (Bellardi, 1847; Brugnone, 1862; Cipolla, 1914; Chirli, 1997).

Discussion

Considering the Early Pleistocene age of the sequence, as indicated by the presence in the blue-grey sandy pelites of *Bulimina etnea*, and the lack of reworking as evidenced by the good preservation, the presence of warm-water taxa can be explained with their survival up to the Early Pleistocene (Calabrian).

The faunal units MPMU3 and MPMU4 include a typical Mediterranean fauna, even if some warm-water taxa are still present (Monegatti & Raffi, 2001). According to Raffi (1986), the coexistence of Boreal Guests and subtropical taxa in the Mediterranean Early Pleistocene may be better explained by the establishment of a higher seasonality climate regime, rather than by a drop in temperature. In particular, this hypothesis is mainly related to the first phase of Boreal Guests in the Calabrian (Santernian substage).

The discovery of warm-water molluscs taxa in the Early Pleistocene (Calabrian p.p.) fossil assemblages of the Tiber Valley represents an element of newness in the knowledge of Pliocene-Pleistocene marine malacofaunas of Central Italy. Three species, *F. subintermedia*, *S. varicosa* and *M. mitraeformis*, though belonging to tropical-warm temperate affinity families, endured the Pliocene cooling phases which, since 3.0-3.1 Ma, caused the extinction of most warm-water taxa and marked the transition from a climate regime with low amplitude oscillations to a regime with higher amplitude variations (Monegatti & Raffi, 2001). For these species, a greater thermal tolerance can be assumed, compared with the other species of their respective families. The survival in the Early Calabrian of these marine molluscs can be explicated with the model of high seasonality outlined by Raffi (1986) and with the Mediterranean sea-surface paleotemperatures proposed by Monegatti & Raffi (2001).

Finally, the finding of *F. subintermedia*, *S. varicosa*, *M. mitraeformis*, *T. aspera*, *N. clathratus* and *B. semicostata* in Calabrian deposits enlarge the list of the Mediterranean Pliocene survivors.

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