

Fossil starfishes (Echinodermata Asteriidae) and paleontological analysis of the Pliocene of Cherasco, Piedmont region (NW Italy)

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ABSTRACT

The remarkable discovery of two fossil starfishes in the Pliocene clay of Cherasco (NW Italy), allowed to analyze in detail the sediment and paleontological material associated (malacofauna and foraminifers assemblages), aiming at reconstructing paleoenvironmental conditions in which these organisms lived. Furthermore biostratigraphic analysis based on planktonic foraminiferal assemblages, allowed the recognition of the MPI2 biozone of lower Pliocene.

KEY WORDS

Astropecten; malacofauna; Foraminifera; paleoenvironmental reconstruction; Pliocene.

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INTRODUCTION

The structure of starfish bodies is maintained by soft tissues that rapidly disaggregate after death and the discovery of remains relies on exceptional conditions of preservation. In the Pliocene clay of Cherasco (Cuneo, Piedmont region, NW Italy), these exceptional conditions allowed the discovery of two fossil starfishes, attributed to Asteroidea. The fossil record of starfishes is very sparse in Piedmont region. In the literature only two other discoveries of Asteroidea are known in the area albese-braidese: *Astropecten bispinosus* (Otto, 1823), reported by Sacco (1893) for the Pliocene of Bra, and a print, unfortunately devoid of significant details, illustrated by Cavallo et al. (1986), found in the Tortonian marls at Alba.

The remarkable discovery allowed to be analyzed in detail the sediment and paleontological material associated. The analysis focused first on the paleontological study of fossil starfish, and in a second step

on malacofauna and foraminiferal assemblages in order to characterize these clays of Cherasco from paleocologic and biostratigraphic points of view, for which no specific data exist in the literature.

MATERIAL AND METHODS

Cherasco (Cuneo, Piedmont region, NW Italy) (Fig. 1) is located in a plain extending towards the South West, bordered in the North West by the Stura of Demonte river and in the East by the Tanaro river. In the western part of Cherasco, the plain is strongly incised by "Rii di San Giovanni" (30-40 meters depth). The fossil starfishes have been discovered on the left side of the Rio Crosio, one of the "Rii di San Giovanni" (3.5 km long). The outcrop (20 m long) is located at 240 m a.s.l. (44°38'48" N; 7°51'7" E), and it is composed of grey-blue muddy clays which are continuous and homogenous, 15 m thick (Figs. 2, 3). The Pliocene

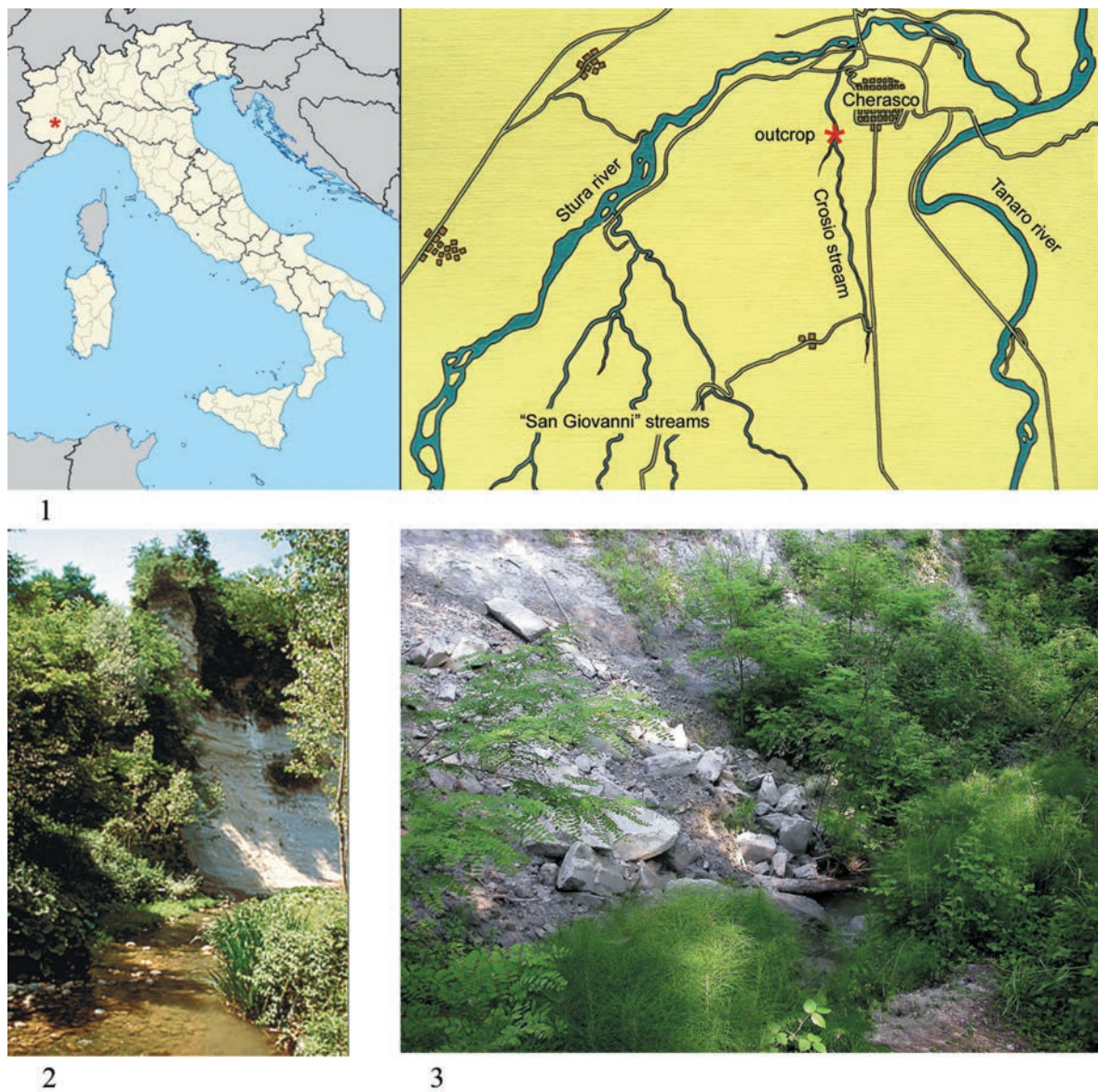


Figure 1. Location of Pliocene outcrop near Cherasco (Piedmont region, NW Italy). Figures 2, 3. Outcrop view of the Pliocene clays.

muddy clays are outcropped by quaternary alluvions (see geological map of Italy, foglio 80 Cuneo).

The two fossils were found in the upper meter of the outcrop. The oral ventral sides of the two specimens were visible and in discrete preservation. The better preserved specimen has a diameter of 60 mm (Fig. 4), while the other one is 55 mm (Fig. 5). The muddy clay matrix, including specimens, was disaggregated and observed under a microscope to analyze the malacofauna and

foraminiferal assemblages. For the malacofauna, 3 liters of sediment were observed after being water sieved.

For foraminiferal assemblages, a sample of 300 g was previously disaggregated in hydrogen peroxide (120% by volume), for about 1 hour. Later it was divided into four size fractions: $>315 \mu\text{m}$, 150-315 μm , 125-150 μm , 63-125 μm . For the $>315 \mu\text{m}$, 150-315 μm , 125-150 μm fractions, a quantitative study was performed on a volume of residue after drying, split with an Otto microsplitter (Scott

et al., 1980) in order to obtain a representative quantity of the particle size fraction. This allowed to be evaluated the abundance of the residue, the state of preservation of tests of foraminifera and the presence of any other organogenic and inorganic components. The foraminiferal assemblages were subsequently the subject of specific determination and quantitative analysis. For the fraction 63-125 μm , which consists almost exclusively of biogenic fragments and minute foraminifera shells, that only in rare cases allow attribution of precise species (Schönfeld et al., 2012), specific determinations were not performed.

RESULTS

ECHINODERMATA ASTERIIDAE

Astropecten cf. *irregularis pentacanthus* (Delle Chiaje, 1825)

The starfish, belonging to the same species, were attributed without doubt to the genus *Astropecten* Gray, 1840; this systematic group currently includes, worldwide, more than a hundred species living in muddy and sandy bottoms of the littoral system, with the exception of some species which are bathyfile (Tortonese, 1965).

The comparison, as far as possible, with the species of *Astropecten* currently present in the Mediterranean, is particularly difficult in the absence of the clear visibility of anatomical structures useful for this purpose. Nevertheless the *Astropecten* analyzed can be attributed to the species *A. irregularis* (Pennant, 1777) and more precisely to the subspecies *A. irregularis pentacanthus* (Delle Chiaje, 1825). Fossil specimens from Cherasco, in addition to the general morphological characteristics, showed strong similarities with the subspecies mentioned in: a) the apices of the arms, more or less rounded; b) the size of the individuals close to the dimension of individuals currently living in the Mediterranean, which generally have a diameter of 80-120 mm; c) the ratio R/r 4.4 to 4.7 which seems consistent with their stage of growth, considering that it tends to be greater in the larger specimens (Borghi & Bajo Campos, 2008); and finally, d) because this subspecies, which in the Mediterranean appears to be the most frequent Asteroidea, is present on the muddy or sandy-clay seabed at depths from 2 to 200 m (Riedl, 1991). The brick-red color of the fossil specimens is probably due to the processes of oxidation of organic tissues.

Unfortunately, the clay investigated did not return ossicles of Asteroidea which, if present, could possibly provide additional information for a more exact specific determination.



Figure 4. *Astropecten* cf. *irregularis pentacanthus*, D 60 mm, from Cherasco, ventral side. Figure 5. Other specimen of *A. cf. irregularis pentacanthus*, D 55 mm, from Cherasco, ventral side.

MALACOFAUNA

Given the extreme fragility of the shells, it was hardly possible to isolate whole shells: even the species of a few millimeters not resisted to the usual treatments of water clay filtration, so it can be retrieved only in fragments. In association with bivalve fragments, have been found carbon wood, parts of claws and fragments of crustaceans decapods arts and a dozen calcareous tubes of *Ditrupa* sp. A list in systematic order of the species is found below (Figs. 6-19)

Turritella spirata (Brocchi, 1814)

EXAMINED MATERIAL. 1 specimen (teleoconch almost complete) (Fig. 14).

REMARKS. Although it is sometimes present in shallower environments and not in pelitic facies, generally outcrops where the species is found indicate a muddy circalittoral-bathyal environment (Borghi & Vecchi, 2005). This species, in fact, is characteristic of shale and marl facies of the Miocene and Pliocene (Malatesta, 1974).

Aporrhais uttingerianus peraraneosus (Sacco, 1893)

EXAMINED MATERIAL. 2 specimens (fragments).

REMARKS. The fragments of *Aporrhais* Da Costa, 1778 found, show long and thin digits, which allow to assign them to the subspecies *peraraneosus*. The presence of this subspecies in the Rio Crosio is already mentioned by Charrier (1953). Probably the long and thin digits are an adaptive character that promotes the activities of these animals in the particular seabed in which they live. In fact, the large surface area between the coil and the digits tips line, and the thinness of digits in proportion to their very low weight, allows the bivalve, during their reptation (movements), to "float" more smoothly on the soft mud of seabed (Damarco, 1994). The ecological niche of *A. uttingerianus peraraneosus* is now occupied by *A. serresianus* (Michaud, 1828), species originating from the Atlantic Ocean and which occasionally penetrated into the Mediterranean during the Pliocene (Forli, 1989). This species developed and proliferated later in the Quaternary (Ruggieri, 1971), and it is currently living in the mud-detritic

bottoms of the circalittoral zone also deep (Terreni, 1981; Brunetti & Forli, 2013).

Euspira sp.

EXAMINED MATERIAL. 1 specimen, in poor preservation.

REMARKS. The specimen found was too deteriorated and specific determination was impossible.

Phalium saburon (Bruguière, 1792)

EXAMINED MATERIAL. 1 specimen (protoconch more than 3 whorls of teleoconch).

REMARKS. It is a euribate species, being correlated to the deep muddy bottoms, in the circalittoral and in the bathyal zones (settings) (Pérès & Picard, 1964). In fact it lives in the Mediterranean Sea on sandy muddy bottoms of the circalittoral zone (Chirli, 2008).

Nassarius elatus (Gould, 1845)

EXAMINED MATERIAL. 2 specimens (1 juvenile) (Figs. 6, 7). In the protoconch of the figure 7, the slight rib characterizes the first whorls of teleoconch.

REMARKS. The species has been reported by Adam & Glibert (1975) for a dozen Italian fossil localities, both of the Lower and Upper Pliocene and it can be confused with *N. semistriatus* (Brocchi, 1814). It still lives in the Mediterranean sandy-muddy infra-circalittoral seabed.

Bela nitida Pavia, 1976

EXAMINED MATERIAL. 2 specimens (1 juvenile) (Fig. 8).

REMARKS. According to Pavia (1976) this species is present in the lower and middle Pliocene of the Piedmont (Monteu Roero, Valle Botto-Asti) and of the Liguria (Rio Torsero-Ceriale).

Raphitoma leufroyi (Michaud, 1828)

EXAMINED MATERIAL. 2 specimens (1 juvenile). (Figs. 9, 10). In figure 10 is illustrated planktotrophic multispiral with 3 whorls, the first decorated by microgranules arranged in spirals, while the subsequent whorls show sculpture canceled trending sigmoidal.

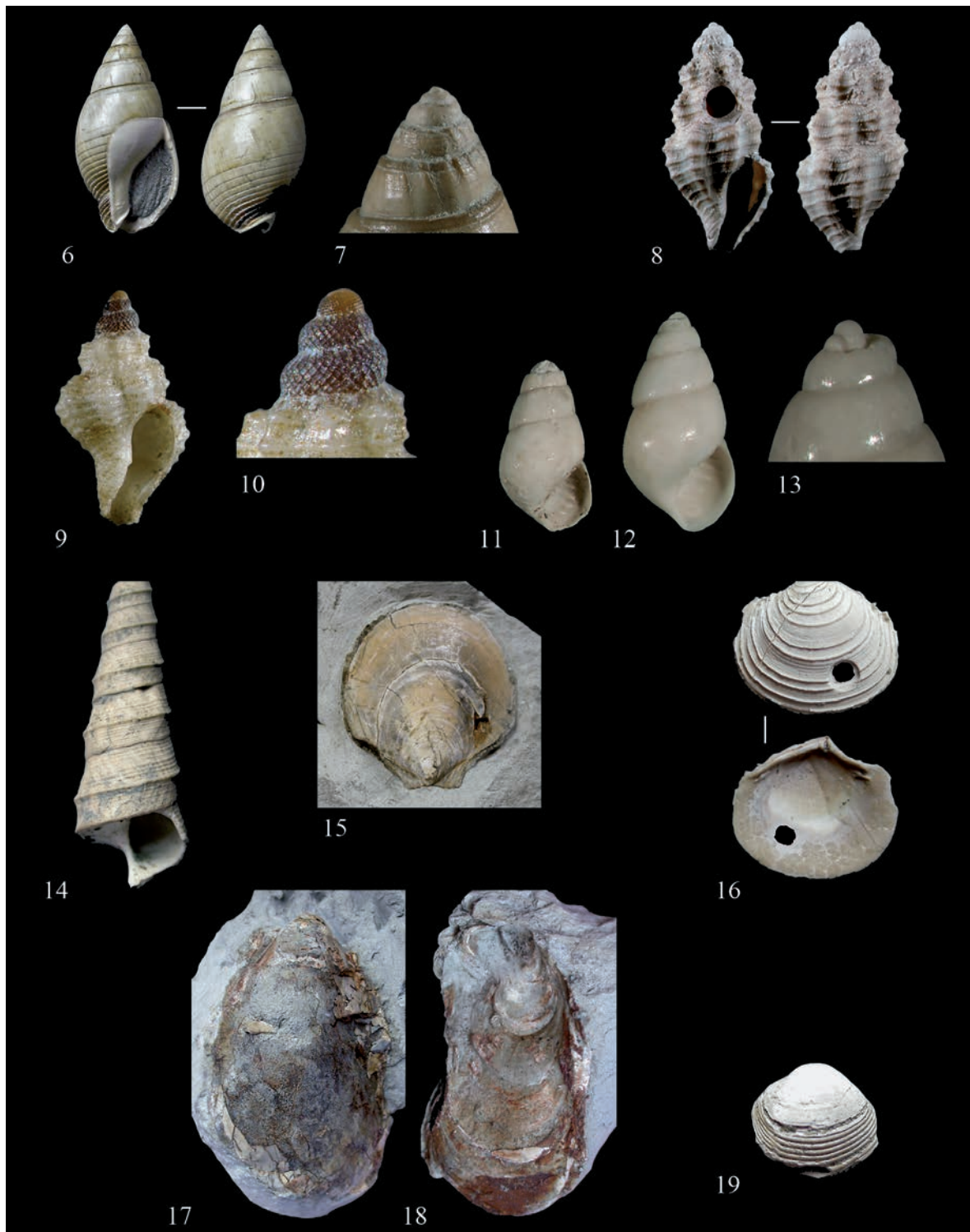


Figure 6. *Nassarius elatus*, h 11.2 mm. Figure 7. Protoconch of *N. elatus*, magnification 9x. Figure 8. *Bela nitida*, h 3 mm, predation hole on the penultimate whorl. Figure 9. *Raphitoma leufroyi*, h 2.3 mm. Figure 10. Protoconch of *R. leufroyi*, magnification 37x. Figure 11. *Odostomia conoidea*, h 1.4, Figure 12. *Idem*, h 1.8 mm. Figure 13. Protoconch of *O. conoidea*, magnification 29x. Figure 14. *Turritella spirata*, h 23 mm. Figure 15. *Korobkovia oblonga*, right valve, D 24.6 mm. Figure 16. *Myrtea spinifera*, D 6.9 mm, external and internal view of left valve, with predation hole. Figure 17. *Neopycnodonte navicularis*, external view of left valve D 62.8 mm. Figure 18. *Idem*, right valve D 45.4 mm. Figure 19. *Corbula gibba*, D 4.4 mm, external view of right valve.

REMARKS. The specimen sampled, with two whorls of teleoconch, is rather young, but its preservation is excellent. This species lives on all types of bottoms, from a few meters to about 150 m in depth (Poppe & Goto, 1991).

Odostomia conoidea (Brocchi, 1814)

EXAMINED MATERIAL. 2 specimens (Figs. 11-13). The protoconch of the figure 13 consists of 2 whorls, the first of which is wound in a spiral with the axis approximately at right angles to the axis of the shell, well represents the protoconch of “type A”, according to van Aartsen (1987).

REMARKS. According to Scaperrotta et al. (2011) and Chirli & Micali (2011), this species lives in the Mediterranean sea on the muddy-sandy bottoms of the infra-circalittoral zone.

Philine* cf. *scabra (Müller O.F., 1784)

EXAMINED MATERIAL. 1 specimen (fragments).

REMARKS. Living on sandy and mud-sandy bottoms at lower depths (Thompson, 1976).

Roxania utriculus (Brocchi, 1814)

EXAMINED MATERIAL. 1 specimen (juvenile).

REMARKS. Living on the mud bottoms of the circalittoral zone (150 m depth) (Ardovini & Cossignani, 1999).

Yoldia nitida (Brocchi, 1814)

EXAMINED MATERIAL. 1 specimen: fragments of the right valve.

REMARKS. The genus *Yoldia* is found on the muddy-sandy bottoms of the infralittoral zone.

Aequipecten angelonii (De Stefani et Pantanelli, 1878)

EXAMINED MATERIAL. 1 specimen: fragments of the left valve.

REMARKS. It seems that this species was found exclusively in clay-marl outcrops attributed to the Pliocene: in the “turquoise clays” of Colle Melamenda of coralligenous area (De Stefani & Pantanelli, 1878); in clays of Castelnuovo d’Asti, in Fornaci di Savona and in Piacenza area (Sacco,

1897); in the marl of Rio Torsero in Savona (Andri et al., 2005).

Flabellipecten bosniasckii (De Stefani et Pantanelli, 1880)

EXAMINED MATERIAL. 1 specimen: fragments of left and right valves.

REMARKS. The *Flabellipecten* Sacco, 1897 constitute a group adapted to live on soft bottoms, therefore characterize all sandy-clayey facies of the Upper Miocene and Pliocene (Malatesta, 1974).

Mimachlamys* cf. *varia (Linnaeus, 1758)

EXAMINED MATERIAL. 3 partials valves, 1 right.

REMARKS. The species is ubiquitous: it lives on rocky-gravelly-muddy bottoms, often with fine bisset attached to the sponges (Malatesta, 1974). Some authors (Tebble, 1966; Poppe & Goto, 1993), referring especially to the Atlantic Ocean, reported *M. varia* at 83 m maximum depth, and Terreni (1981) reported this species in Mediterranean area living on the muddy-sandy bottoms in the infra-circalittoral zone. Parenzan (1974) reports it from 1350 m deep, but adds that the normal environment does not exceed perhaps a hundred meters.

Korobkovia oblonga (Philippi, 1844)

EXAMINED MATERIAL. 1 specimen: right valve (Fig. 15).

REMARKS. This species is restricted to the silts and fine-grained calcarenites of the base of the Pliocene (Jiménez et al., 2009).

Neopycnodonte navicularis (Brocchi, 1814)

EXAMINED MATERIAL. 7 right valves (3 partials and 1 juvenile) and 2 left valves (only 1 with umbonal area) (Figs. 17, 18).

REMARKS. It seems certain, as reported by Malatesta (1974), that the actual *N. cochlear* (Poli, 1795) result from a genetic mutation of *Neopycnodonte navicularis* extinct in the late Pliocene; regarding *N. cochlear*, Parenzan (1974) and Terreni (1981) reported that it lives from a hundred feet to over 1000 m depth, on the muddy-debris bottoms of the deep circalittoral zone.

Myrtea spinifera (Montagu, 1803)

EXAMINED MATERIAL. 1 specimen: left valve (Fig. 16).

REMARKS. In the Mediterranean it has been found in the biocenosis of unstable bottom sediments (Malatesta, 1974); in the British Islands it has been found to a maximum depth of 110 m (Tebble, 1966), on the Tuscan coast (Italy); it lives in the detritic mud-bottom of infra-circalittoral zone (Terreni, 1981).

Clausinella fasciata (Da Costa, 1778)

EXAMINED MATERIAL. 1 specimen: fragments of the left valve.

REMARKS. The species lives burrowing into the gravelly, gravelly-stony, stony or sandy-muddy sediment, up to about 110 m depth (Tebble, 1966). According to Scaperrotta et al. (2009), it prefers waters with coarse gravel or gravel and mud, from a few meters to over 100 m in depth.

Timoclea ovata (Pennant, 1777)

EXAMINED MATERIAL. 3 valves (partials)

REMARKS. Euribathyal species, reported for the Mediterranean from a few meters up to 700 meters depth, on the muddy-debris bottoms (Malatesta, 1974).

Corbula gibba (Olivi, 1792)

EXAMINED MATERIAL. 1 right valve (partial) e 3 left (juveniles and partial). The external view of right valve (Fig. 19) is characterized by a large ventral rib concentric sculpture.

REMARKS. In the Mediterranean it is found in the biocenosis of the seabed debris (80-130 m) of the infralittoral zone; with the polychaete *Ditrupa arietina* (O.F. Müller, 1776) this species is characteristic of the biocenosis of instable bottoms (Malatesta, 1974). This species seems to prefer muddy or sandy-muddy bottoms (Scaperrotta et al., 2009).

The polychaete *Ditrupa* sp., of which we found a dozen specimens, also lives in sandy-muddy bottoms and constitutes an indicator of the depth range of substrate. It is a genus characteristic of biocenosis of unstable bottom which Pérès & Picard (1964) placed at depths between 35 to just over 100 m.

FORAMINIFERA

The residue of the sample is quantitatively scarce. For the three fractions considered, the inorganic materials are predominantly made up of abundant particles of iron oxides, frequent angular particles of quartz and lamellae of muscovite, some rare granule mineralized with pyrite and glauconite. The percentage of the inorganic fraction constitutes 60% of the residue for the >315 µm fraction, it tends to decrease to about 40% in the 150-315 µm fraction, to increase up to 80% of the residue in the 125-150 µm fraction. This increase is marked by an abundance of muscovite flakes lamellae that become prevalent.

The organogenic residue consists mainly of abundant fragments of pyritized and partially oxidized plant frustules, frequent fragments of echinoderm spines and prevailing benthic foraminifera, generally very well preserved. Sometimes there are rare individuals mineralized with pyrite and glauconite. The planktonic foraminifera, in all fractions analyzed, were extremely rare.

Benthic foraminifera

The benthic foraminiferal assemblages (44 species, Table 1) were represented principally by hyaline species. Only two agglutinated species were present, but rare (*Bigenerina nodosaria* and *Textularia* sp.). The porcellanaceous species were absent. Species more abundant than 4% of the assemblage of at least one station were described and considered as dominant: *Bolivina anaeriensis*, *B. punctata*, *Bulimina aculeata*, *B. lappa*, *B. inflata*, *Stainforthia complanata*, *Uvigerina peregrina* and *Valvulineria bradyana* (Figs. 20-35; Fig. 36). In the coarser fraction (>315 µm) *Uvigerina peregrina* (~34%) and *Valvulineria bradyana* (~20%) prevailed. *Bulimina aculeata* was almost frequent (~11%), while the species of genus *Bolivina* d'Orbigny, 1839 and *Stainforthia complanata* were rare (<3%) (Fig. 36). In the 150-315 µm fraction the percentage of *Uvigerina peregrina* was similar to the coarser fraction, while the percentage of *Valvulineria bradyana* decreased considerably (~13.5%). The species of genus *Bulimina* d'Orbigny, 1826 showed a variable trend. *Bulimina aculeata* decreased (5%), while *Bulimina lappa* increased strongly (~8%). *Lenticulina calcar*, absent in the

Benthic foraminifera	>315µ	150-315µ	125-150µ	>315µ	150-315µ	125-150µ
Split	.1/2	.1/8	.1/8	%	%	%
Hyaline species						
<i>Ammonia tepida</i> (Cushman, 1926)			1	0.0	0.0	0.4
<i>Amphicoryna scalaris</i> (Batsch, 1791)		2		0.0	0.7	0.0
<i>Asterigerinata mammilla</i> (Williamson, 1848)			1	0.0	0.0	0.4
<i>Bolivina punctata</i> d'Orbigny, 1839 (Fig. 22)	8	27	6	2.9	9.7	2.3
<i>Bolivina albatrossi</i> Cushman, 1922 (Fig. 21)			6	0.0	0.0	2.3
<i>Bolivina alata</i> (Seguenza, 1862)			9	0.0	0.0	3.4
<i>Bolivina anaeriensis</i> (Costa, 1856) (Fig. 23)	4	8	11	1.4	2.9	4.1
<i>Bolivina dilatata</i> Reuss, 1850			7	0.0	0.0	2.6
<i>Bolivina spathulata</i> (Williamson, 1858) (Fig. 24)	1	2	7	0.4	0.7	2.6
<i>Bulimina aculeata</i> d'Orbigny, 1826 (Fig. 25)	30	15	4	10.8	5.4	1.5
<i>Bulimina lappa</i> Cushman et Parker, 1937 (Fig. 20)	4	23	20	1.4	8.2	7.5
<i>Bulimina inflata</i> Seguenza, 1862 (Fig. 26)	13	11	14	4.7	3.9	5.3
<i>Cassidulina carinata</i> Silvestri, 1896			1	0.0	0.0	0.4
<i>Chilostomella oolina</i> Schwager, 1878	3			1.1	0.0	0.0
<i>Cibicides kullenbergi</i> Parker, 1953	7			2.5	0.0	0.0
<i>Cibicides</i> sp.	1		9	0.4	0.0	3.4
<i>Dentalina leguminiformis</i> (Batsch, 1791)	1		1	0.4	0.0	0.4
<i>Florilus boueanum</i> (d'Orbigny, 1846)	1	3	1	0.4	1.1	0.4
<i>Globobulimina affinis</i> (d'Orbigny, 1839)	4	1		1.4	0.4	0.0
<i>Gyroidina altiformis</i> (R.E. et K.C. Stewart, 1930)	1			0.4	0.0	0.0
<i>Gyroidinoides umbonatus</i> (Silvestri, 1898)		5	8	0.0	1.8	3.0
<i>Heterolepa floridana</i> (Cushman, 1922)	5			1.8	0.0	0.0
<i>Lenticulina calcar</i> (Linnaeus, 1767) (Fig. 28)	1	19	2	0.4	6.8	0.8
<i>Marginulina hirsuta</i> d'Orbigny, 1826 (Fig. 31)		3		0.0	1.1	0.0
<i>Marginulina costata</i> (Batsch, 1791) (Fig. 32)	6			2.2	0.0	0.0
<i>Melonis padanum</i> (Perconig, 1952) (Fig. 29)	8			2.9	0.0	0.0
<i>Oridorsalis umbonatus</i> (Reuss, 1851)	4	4	3	1.4	1.4	1.1
<i>Pandaglandulina dinapolii</i> Loeblich et Tappan, 1955	2			0.7	0.0	0.0
<i>Planularia</i> sp.			1	0.0	0.0	0.4

<i>Pullenia bulloides</i> (d'Orbigny, 1846)	5	6	3	1.8	2.2	1.1
<i>Rectuvigerina bononiensis</i> (Fornasini, 1888)	1			0.4	0.0	0.0
<i>Rectuvigerina siphogenerinoides</i> (Lipparini, 1932)		1	1	0.0	0.4	0.4
<i>Saracenaria italica</i> Defrance, 1824		1		0.0	0.4	0.0
<i>Sphaeroidina bulloides</i> d'Orbigny, 1826	4			1.4	0.0	0.0
<i>Stainforthia complanata</i> (Egger, 1893) (Fig. 27)	1	3	13	0.4	1.1	4.9
<i>Stilostomella advena</i> (Cushman et Laiming, 1931)	6	5	2	2.2	1.8	0.8
<i>Stilostomella</i> sp.	1			0.4	0.0	0.0
<i>Trifarina angulosa</i> (Williamson, 1858)			1	0.0	0.0	0.4
<i>Uvigerina auberiana</i> d'Orbigny, 1839		1	3	0.0	0.4	1.1
<i>Uvigerina peregrina</i> Cushman, 1923 (Fig. 33)	95	98	27	34.3	35.1	10.2
<i>Valvulineria bradyana/complanata</i> (Fig. 30)	58	38	104	20.9	13.6	39.1
Agglutinated species						
<i>Bigenerina nodosaria</i> d'Orbigny, 1826		2		0.0	0.7	0.0
<i>Textularia</i> sp.	2	1		0.7	0.4	0.0
Total number of specimens	277	279	266	100.0	100.0	100.0

Table 1. Benthic foraminifera from Pliocene of Cherasco, Piedmont region (NW Italy).

Planktonic foraminifera	>315μ	150-315μ	125-150μ
Split	.1/2	.1/8	.1/8
<i>Globigerina bulloides</i> d'Orbigny, 1826	2	2	2
<i>Globigerina falconensis</i> Blow, 1959	2	2	2
<i>Globigerina glutinata</i> (Egger, 1893)			1
<i>Globigerinoides obliquus extremus</i> Bolli et Bermudez, 1965 (Fig. 35)	2		
<i>Globigerinoides elongatus</i> (d'Orbigny, 1826)	1		
<i>Globorotalia</i> cf. <i>magaritae</i> (Bolli et Bermudez, 1965)	1		
<i>Neogloboquadrina acostaensis</i> Blow, 1959	1		1
<i>Orbulina universa</i> d'Orbigny, 1839 (Fig. 34)	3	1	
<i>Sphaeroidinellopsis dehiscens</i> (Parker et Jones, 1865)		3	1
Total number of specimens	12	8	7

Table 2. Planktonic foraminifera from Pliocene of Cherasco, Piedmont region (NW Italy).

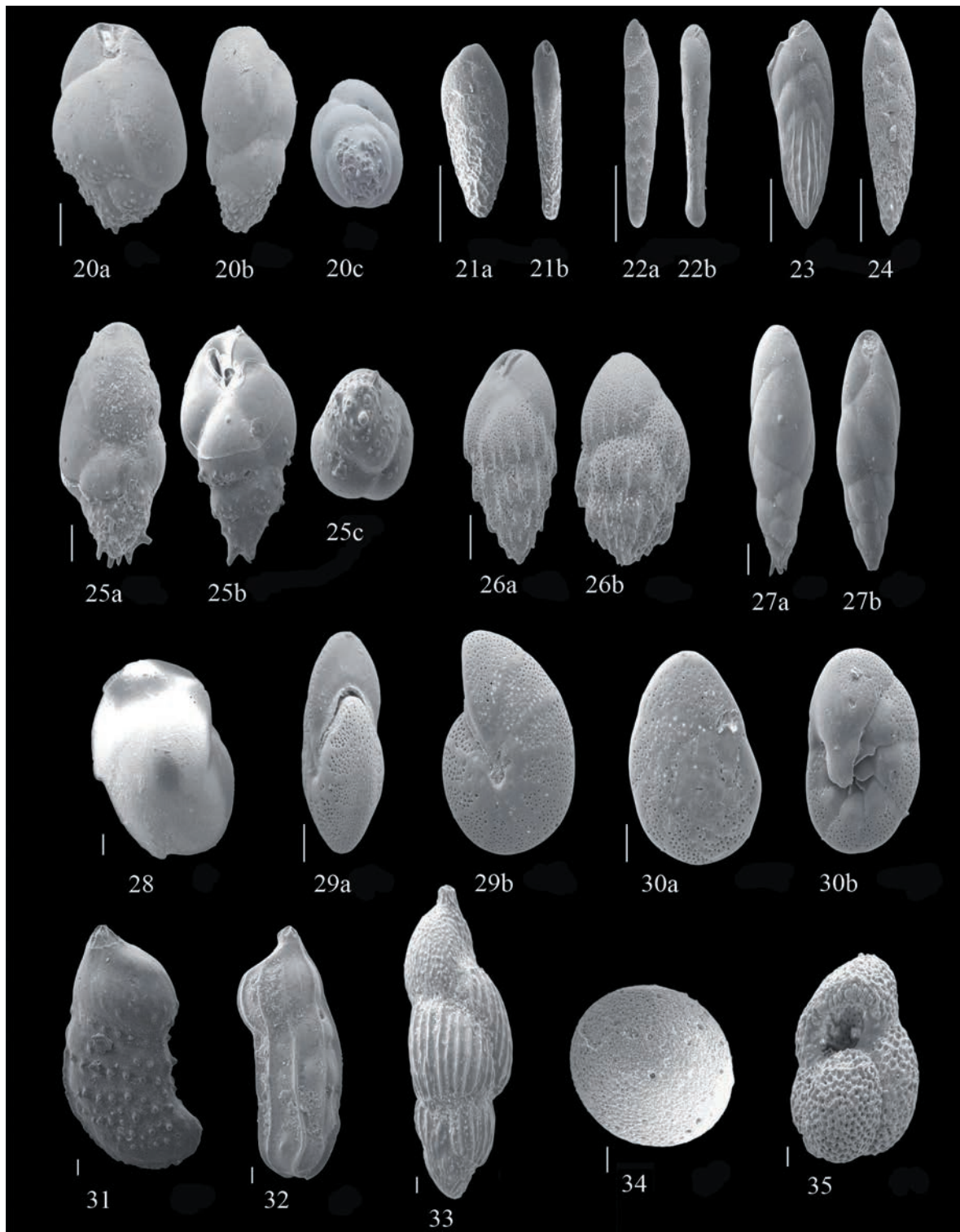


Figure 20. *Bulimina lappa*. Figure 21. *Bolivina albatrossi*. Figure 22. *Bolivina punctata*. Figure 23. *Bolivina anaeriensis*. Figure 24. *Bolivina spathulata*. Figure 25. *Bulimina aculeata*. Figure 26. *Bulimina inflata*. Figure 27. *Stainforthia complanata*. Figure 28. *Lenticulina calcar*. Figure 29. *Melonis padanum*. Figure 30. *Valvulineria bradyana*. Figure 31. *Marginulina hirsuta*. Figure 32. *Marginulina costata*. Figure 33. *Uvigerina peregrina*. Figure 34. *Orbulina universa*. Figure 35. *Globigerinoides obliquus extremus*. Each scale bar represents 100 μm .

coarser fraction, was present with a value of ~5%. The percentage of *Bulimina inflata* was constant in the three fractions considered (4-5%) (Fig. 37). In the 125-150 µm fraction *Uvigerina peregrina* decreased with a minimum of 10%, while *Valvulineria bradyana* increased with a maximum of 39%. *Bulimina aculeata* decreased strongly (~1%); *Bulimina lappa*, on the contrary, increased (5%). *Lenticulina calcar* was still present, but with an extremely low percentage (~0.5%). The genus *Bolivina* and *Stainforthia*, due to their natural small dimensions, were more frequent in the finer fraction (Fig. 37).

In the thanathocenosis the species allochthonous were rare. Among these *Ammonia tepida*, *Asterigerinata mammilla* have been recognized and individuals belonging to the genus *Cibicides* de Montfort, 1808, typical of infralittoral zone. It showed clearly signs of transport, highlighted by the poor preservation of the shell. The autochthonous fauna was represented by species typical of an outer continental shelf and an upper continental slope. For example the agglutinated *Bigenerina nodosaria*, *Uvigerina peregrina*, *Valvulineria bradyana*, *Bulimina* spp., *Lenticulina* and *Bolivina* spp. *Uvigerina peregrina*, a shallow infaunal species living close to the sediment-water interface, is characteristic of mesotrophic to eutrophic continental slope settings (Lutze & Coulbourn, 1984; Corliss, 1985, 1991; Lutze, 1986; Corliss & Emerson, 1990; Mackensen et al., 1995; Schmiedl & Mackensen, 1997; Jannik et al., 1998; Kuhnt et

al., 1999; De Rijk et al., 2000; Schmiedl et al., 2000; Morigi et al., 2001; Huang et al., 2002; Fontanier et al., 2003).

Valvulineria bradyana is a typical species of pelitic-sandy bottoms, characterized by low oxygen content and rich in organic matter (Bergamin et al., 1999). *B. aculeata* is generally also considered as a eutrophic species, typical of low-oxygen environments (Murray, 1991). The *Bolivina* species (ex. *B. aenariensis* and *B. punctata*), infaunals, are characteristics of muddy bottoms and they are particularly tolerant to reduced oxygenation levels, in environments such as meso-eutrophic (Blanc-Vernet, 1969; di Napoli Alliata et al., 1970; Van der Zwaan, 1983; Murray, 1991; Barmawidjaja et al., 1992; Sen Gupta & Machain-Castillo, 1993).

Planktonic foraminifera

Planktonic foraminiferal assemblages were extremely poor in the three fractions considered (9 species, Table 2). Individuals, sometimes strongly pyritized or glauconitized of *Orbulina universa* were found in association with rare *Globigerina bulloides*, *G. falconensis* and *G. glutinata*, as well as rare *Globigerinoides obliquus extremus*, *G. elongatus* e *Sphaeroidine- llopsis dehischens*. Only one specimen of *Globorotalia* cf. *margaritae* was found in the coarser fraction. The genus *Neogloboquadrina* Frerichs et Vincent, 1967 was also extremely rare. Indeed only two specimens of *N. acostaensis* were identified. *Globigerinoides obliquus extremus* and *Orbulina universa* are represented in the figures 34, 35.

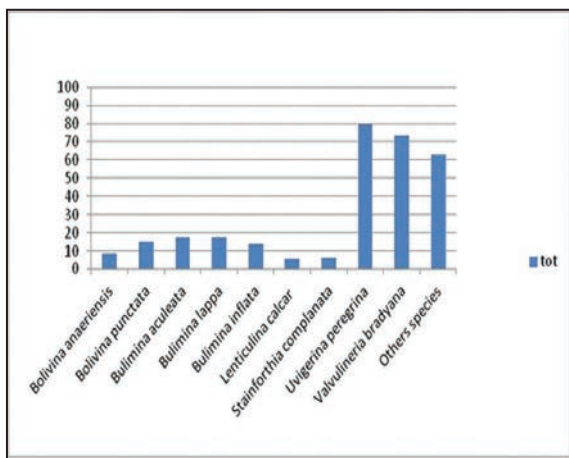


Figure 36. Total percentage of benthic foraminiferal dominant species.

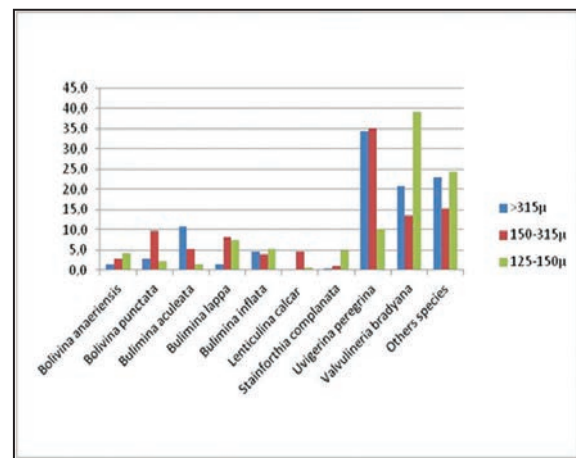


Figure 37. Percentage of benthic foraminifera dominant species for all studied fraction (>315 µm, 150-315 µm, 125-150 µm).

DISCUSSION AND CONCLUSION

In an outcrop of Pliocene clays near Rio Crosio (Cherasco, Piemonte, NW Italy) two specimens of fossil starfish were found, attributed to *Astropecten irregularis pentacanthus* (Delle Chiaje, 1825).

The analysis of the malacofauna and the benthic foraminiferal assemblages has provided paleoecological and paleoenvironmental data indicating a circalittoral deep environment, little more than 100 m depth and characterized by a muddy bottom; the trophic conditions were from meso to eutrophic, with a rather low level of oxygenation, which thus enabled the survival of upper and intermediate infaunals tolerant species, such as *Uvigerina peregrina*, *Valvulineria bradyana*, various species of the genus *Bulimina* and genus *Bolivina*. On the base of planktonic foraminiferal assemblages (*Globigerinoides obliquus extremus*, *G. elongatus*, genus *Sphaeroidinellopsis* Banner et Blow, 1959 and *Globorotalia margaritae*), the samples are attributed to biozone MPI2 of lower Pliocene (Zanclean) which, according to Violanti (2012) in the NW Italy, correspond to 5.08 and 4.52 Ma. The absence of species such as *Globorotalia inflata* and *Bulimina marginata*, very frequent in the upper Pliocene (Lentini, 1969), allows to confirm this datation.

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REFERENCES

- Aartsen J.J. van, 1987. European Pyramidellidae: III. *Odostomia* and *Ondina*. Bollettino Malacologico, 23: 1-33.
- Adam W. & Glibert M., 1975. Contribution à la connaissance de *Nassarius semistriatus* (Brocchi, 1814) (Mollusca: Gastropoda). Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, 50: 1-78.
- Andri E., Tagliamacco A., Testa M. & Marchini A., 2005. Le malacofaune fossili del Rio Torsero. Regione Liguria, Catalogo dei beni naturali, 5. Nuova Editrice Genovese, Ceriale, 286 pp.
- Ardevini R. & Cossignani T., 1999. Atlante delle conchiglie di profondità del Mediterraneo. L'Informatore Picens Ed., Ancona, 111 pp.
- Barmawidjaja D.M., Jorissen F.J., Puskaric S. & Van der Zwaan G.J., 1992. Microhabitat selection by benthic foraminifera in the northern Adriatic sea. Journal of Foraminiferal Research, 22: 297-317.
- Bergamin L., Di Bella L. & Carboni M.G., 1999. *Valvulineria bradyana* (Fornasini) in organig matter-enriched environment (Ombrone river mouth, Central Italy). Il Quaternario, Italian Journal of Quaternary Sciences, 12: 51-56.
- Blanc-Vernet L., 1969. Contribution à l'étude de foraminifères de Méditerranée. Recueil des Travaux de la Station Marine d'Endoume, 64: 1-315.
- Borghi E. & Bajo Campos I., 2008. Asteroidei fossili dell'Emilia. Notiziario della Società Reggiana di Scienze Naturali, 13-29.
- Borghi M. & Vecchi G., 2005. La malacofauna plio-pleistocenica del torrente Stirone (PR). Cerithiidae - Turritellidae. Parva Naturalia, 7: 3-46.
- Brunetti M.M. & Forli M., 2013. The genus *Aporrhais* Da Costa, 1778 (Gastropoda Aporrhaidae) in the Italian Plio-Pleistocene. Biodiversity Journal, 4: 183-208.
- Cavallo O., Macagno M. & Pavia G., 1986. Fossili dell'Albese: aspetti geologici, e paleontologici delle Langhe e del Roero. Famija Albeisa, Alba, 223 pp.
- Charrier G., 1953. Brevi note sulle forme del gen. *Aporrhais* (*Chenopus*) della fauna pliocenica di San Gaudenzio (Lessona) nel Biellese. Rivista Italiana di Paleontologia e Stratigrafia, Milano, 59: 195-202.
- Chirli C., 2008. Malacofauna pliocenica toscana. Neotaenioglossa. Vol. 6. Grafiche PDB, Tavernelle, 128 pp.
- Chirli C. & Micali P., 2011. Malacofauna pliocenica toscana. Pyramidelloidea. Vol. 8. Grafiche PDB, Tavernelle, 132 pp.
- Corliss B.H., 1985. Microhabitats of benthic foraminifera within deep-sea sediments. Nature, 314: 435-438.
- Corliss B.H., 1991. Morphology and microhabitat preferences of benthic foraminifera from the northwest Atlantic Ocean. Marine Micropaleontology, 17: 195-236.
- Corliss B.H. & Emerson S., 1990. Distribution of Rose Bengal stained deep-sea benthic foraminifera from the Nova Scotian continental margin and Gulf of Maine. Deep-Sea Research, 37: 381-400.
- Damarco P., 1994. Alcuni esemplari eccezionali di Aporrhaidae fossili del Pliocene piemontese. World Shells, 3: 28-30.

- De Rijk S., Jorissen F.J., Rohling E.J. & Troelstra S.R., 2000. Organic flux control on bathymetric zonation of Mediterranean benthic foraminifera. *Marine Micropaleontology*, 40: 151-166.
- De Stefani C. & Pantanelli D., 1878-80. Molluschi pliocenici dei dintorni di Siena. *Bollettino della Società malacologica italiana*, 4 (1-6): 5-48 [1878], 4 (7-14): 49-112 [1879], 4 (15-20): 113-160 [1879], 4 (21-30): 161-215 [1880].
- Di Napoli Alliata E., Stefanini S. & Fioramonti G., 1970. Étude de quelques carottes du plateau et du talus continental de la Sardaigne méridionale. *Bollettino della Società Geologica Italiana*, 89: 209-232.
- Fontanier C., Jorissen F.J., Chaillou G., David C., Anschutz P. & Lafon V., 2003. Seasonal and interannual variability of benthic foraminiferal faunas at 550 m depth in the Bay of Biscay. *Deep-Sea Research, Part I: Oceanographic Research Papers*, 50: 457-494.
- Forli M., 1989. Considerazioni filogenetiche su alcune specie del genere *Aporrhais* da Costa, 1778 (Mollusca: Gastropoda) (ultima parte). *Argonauta*, 5: 49-54.
- Huang B., Jian Z., Cheng X. & Wang P., 2002. Foraminiferal responses to upwelling variations in the South China Sea over the last 220000 years. *Marine Micropaleontology*, 47: 1-15.
- Jannik N.T., Zachariasse W.J. & Van der Zwaan G.J., 1998. Living (Rose Bengal stained) benthic foraminifera from the Pakistan continental margin (northern Arabian Sea). *Deep-Sea Research Part I. Oceanographic research Papers*, 45: 1483-1513.
- Jiménez A.P., Aguirre J. & Rivas P., 2009. Taxonomic study of scallops (Pectinidae: Mollusca, Bivalvia) from Pliocene deposits (Almería, SE Spain). *Revista Española de Paleontología*, 24: 1-30.
- Kuhnt W., Hess S. & Jian Z., 1999. Quantitative composition of benthic foraminiferal assemblages as a proxy indicator for organic carbon flux rates in the South China Sea. *Marine Geology*, 156: 123-157.
- Lentini F., 1969. Sezioni stratigrafiche plioceniche nella Val d'Agri presso Gannano (Matera). *Atti dell'Accademia Gioenia di Scienze Naturali di Catania*, 20 (Suppl. Sc. Geolog.): 19-79.
- Lutze G.F., 1986. *Uvigerina* species of the eastern North Atlantic. In: Van der Zwaan G.J., Jorissen F.J., Verhallen P.J.J.M. & von Daniels C.H. (Eds.), *Atlantic - European Oligocene to Recent Uvigerina*. *Utrecht Micropaleontological Bulletins*, 35: 21-46.
- Lutze G. & Coulbourn W., 1984. Recent benthic foraminifera from the continental margin off north-west Africa: community structure and distribution. *Marine Micropaleontology*, 8: 361-401.
- Mackensen A., Schmiedl G., Harloff J. & Giese M., 1995. Deep-sea foraminifera in the South Atlantic Ocean: ecology and assemblage generation. *Micropaleontology*, 41: 342-358.
- Malatesta A., 1974. Malacofauna pliocenica umbra. *Memorie per servire alla descrizione della carta geologica d'Italia*: 13: XI+498.
- Morigi C., Jorissen F.J., Gervais A., Guichard S. & Borsetti A.M., 2001. Benthic foraminiferal faunas in surface sediments off NW Africa: relationship with the organic flux to the ocean floor. *Journal of Foraminiferal Research*, 31: 350-368.
- Murray J.W., 1991. Ecology and distribution. *Benthos 90*, Tokai University Press, Sendai.
- Parenzan P., 1974. Carta d'identità delle conchiglie del Mediterraneo. Vol. II. Bivalvi (prima parte). *Bios Taras Editrice*, Taranto, 280 pp.
- Pavia G., 1976. I Molluschi del Pliocene inferiore di Monteu Roero (Alba, Italia NW). *Bollettino della Società Paleontologica Italiana*, 14: 99-175.
- Pérès J.M. & Picard J., 1964. Nouveau manuel de Biologie benthique de la Mer Méditerranée. *Recueil des Travaux de la Station Marine d'Endoume*, 31: 1-137.
- Poppe G.T. & Goto Y., 1991. *European Seashells. Vol. 1 (Polyplacophora, Caudofoveata, Solenogastrea, Gastropoda)*. Verlag Christa Hemmen, Wiesbaden, 352 pp.
- Poppe G.T. & Goto Y., 1993. *European Seashells. Vol. 2. (Scaphopoda, Bivalvia, Cephalopoda)*. Verlag Christa Hemmen, Wiesbaden, 221 pp.
- Riedl R., 1991. *Fauna e Flora del Mediterraneo*. Franco Muzzio Editore, Padova, 777 pp.
- Ruggieri G., 1972. Considerazioni su alcune *Aporrhais* del Neogene italiano e sul loro significato stratigrafico. *Rivista Mineraria Siciliana*, Palermo, 22: 14-20.
- Sacco F., 1893. Sopra alcuni Asteroidei fossili. *Atti Regia Accademia delle Scienze*, Torino, 28: 739-745.
- Sacco F., 1897. I Molluschi dei terreni terziari del Piemonte e della Liguria. Parte XXIV. (Pectinidae). Carlo Clausen, Torino, 84 pp., 21 pls.
- Scaperrotta M., Bartolini S. & Bogi C., 2009. Accrescimenti. Stadi di accrescimento dei molluschi marini del Mediterraneo. Vol. I. *L'Informatore Piceno Ed.*, Ancona, 167 pp.
- Scaperrotta M., Bartolini S. & Bogi C., 2011. Accrescimenti. Stadi di accrescimento dei molluschi marini del Mediterraneo. Vol. III. *L'Informatore Piceno Ed.*, Ancona, 184 pp.
- Schmiedl G. & Mackensen A., 1997. Late Quaternary paleoproductivity and deep water circulation in the eastern South Atlantic Ocean: evidence from benthic foraminifera. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 130: 43-80.
- Schmiedl G., De Bovée F., Buscail R., Charrière B., Hemleben C., Medernach L. & Picon P., 2000. Trophic control of benthic foraminiferal abundances and microhabitat in the bathyal Gulf of Lions, western Mediterranean Sea. *Marine Micropaleontology*, 40: 167-188.

- Schönfeld J., Alve E., Geslin E., Jorissen F., Korsun S., Spezzaferri S. and members of the FOBIMO group, 2012. The FOBIMO (FORaminiferal BIO-MONitoring) initiative - Towards a standardised protocol for soft-bottom benthic foraminiferal monitoring studies. *Marine Micropaleontology*, 94-95: 1-13.
- Scott D.B., Schafer C.T. & Medioli F.S., 1980. Eastern Canadian estuarine foraminifera: a framework for comparison. *Journal of Foraminiferal Research*, 10: 205-234.
- Sen Gupta B.K. & Machain-Castillo M.L., 1993. Benthic foraminifera in oxygen-poor habitats. *Marine Micropaleontology*, 20: 183-201.
- Tebble N., 1966. *British Bivalve Seashells*. The British Museum of Natural History, London, 212 pp.
- Terreni G., 1981. Molluschi conchiferi del mare antistante la costa toscana (Gastropoda, Scaphopoda, Amphineura, Bivalvia, Cephalopoda). Tip. Benvenuti & Cavaciocchi, Livorno, 106 pp.
- Thompson T.E., 1976. *Biology of Opisthobranch Molluscs*. Vol. I. The Ray Society, London, 206 pp.
- Tortonese E., 1965. Echinodermata. *Fauna d'Italia*, Vol. VI. Calderini Ed., Bologna, 422 pp.
- Van der Zwaan G.J., 1983. Quantitative analyses and the reconstruction of benthic foraminiferal communities. *Utrecht Micropaleontological Bulletin*, 26: 49-69.
- Violanti D., 2012. Pliocene Mediterranean Foraminiferal Biostratigraphy: A Synthesis and Application to the Paleoenvironmental Evolution of Northwestern Italy, *Stratigraphic Analysis of Layered Deposits*. 123-160. Dr. Ömer Elitok (Ed.), InTech, Available from: http://cdn.intechopen.com/pdfs/36321/InTech-Pliocene_mediterranean_foraminiferal_biostratigraphy_a_synthesis_and_application_to_the_paleoenvironmental_evolution_of_northwestern_italy.pdf