

PALEOBIOLOGY FROM MUSEUM COLLECTIONS: COMPARING HISTORICAL AND NOVEL DATA ON UPPER MIOCENE MOLLUSCS OF THE LIVORNO HILLS

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Abstract. The upper Miocene mollusc collection from Monti Livornesi, Italy, collected more than a century ago, is confronted with new collections coming from the same localities of Popogna and Quarata. The study concerns the comparison of abundance data of three distinct fossil assemblages from the three vertically-stacked stratigraphic units called Luppiano, Rosignano and Raquese, of upper Tortonian-early Messinian age. Literature and museological data allowed to attribute most museum specimens to one and only one fossil assemblage. Museum collections preserve roughly the same dominant species, with similar ranks as the new quantitative field collections. Significant differences are however evident in the Luppiano assemblage from brackish-water, shallow subtidal bottoms, because new samples yield many species of small size, some of which with high dominance, that are completely lacking in museum collections, suggesting a bias due to size sorting and hinting at the overwhelming contribution of small-sized species to global mollusc diversity. On the other hand the Raquese assemblage, from an open marine shelf setting, can be similarly interpreted from the study of either the museum or new collection, yielding a similar species list and rank. The Rosignano mollusc assemblage, from a bioclastic bottom near a coral patch reef and characterised by fossils with a distinct taphonomic signature, is insufficiently represented in both historical and new collections. The systematics of the three assemblages are revised. The study contributes to the growing literature on museum “dark data” by showing that museum collections may yield abundance data significant for paleobiological analysis.

INTRODUCTION

Museums of palaeontology are an immense repository of evidences relating to organisms no longer living on the planet, for the largest part hidden from the public eye and forming a huge set of “dark data” (Marshall 2018). Connected to the genotype of a former organism, matter and form of a fossil bear information on a past taxonomic entity.

Museum “dark data”, however, pertains not just to the genetic (Allmon 2005), but also to the ecological level, when fossil specimens are thought of as elements of former ecological entities, such as populations or multi-species assemblages (Harnik 2009). Palaeontologists are used at extracting paleoecological data from controlled samples of fossil assemblages, but what happens when it comes to museum collections assembled before the emergence of paleoecology during the seventies (Lawrence 1971)? How faithfully do they represent original fossil assemblages? In this sector of museum stud-

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ies skepticism has ruled, if we are to judge from the very few numbers of dedicated studies. Answers however must be sought from case to case, considering the complex interplay between the type of data one wants to extract from a given collection, what is known about the sampling design adopted by the collector and how that collection and its metadata have been kept. On one extreme there are collections formed by uncured fossil specimens from unspecified localities. While perhaps retaining historical or taxonomic information, these bear little or no scientific value as a proxy of a given fossil assemblage. On the other hand there are collections that have been gathered by professional geologists who have taken notes and kept a record of the exact provenance. If these are well-curated, they potentially constitute a valuable sample of one or more fossil assemblages, offering the opportunity to study paleoecological parameters such as abundance distributions. Case studies concerned with the quantitative comparison of historical and novel collections are very few, some helping to understand sampling bias (Dulai 1996; Hunter & Donovan 2005; Harnik 2009; Nawrot & Studencka 2017; Frisone et al. 2018), others focusing on the lag between published data and data actually stored in museums (Davis & Pyenson 2007). With specimens dating back to the seventeenth century, the Museo di Storia Naturale (MSN) of the University of Florence keeps paleontological collections gathered during centuries of naturalistic and geological research, by people pursuing different scopes in different ways (see Dominici & Cioppi 2018 for a partial review). Some of these collections relate to paleontological sites that are no longer outcropping as in the past (some examples in Dominici et al. 2018) or hardly reachable in our days (e.g., sites sampled during the 1913-1914 De Filippi expedition to Karakorum: Gaetani 2011; Fabbi et al. 2019), constituting unique repositories of data of potential paleoecological importance. This paper proposes a case study where valuable paleoecological data have been found in a dusty repository. It deals with upper Miocene molluscs collected more than a century ago in the Monti Livornesi, in Western Tuscany (Italy), and today stored at MSN. These fossils were collected in the late nineteenth and early twentieth centuries (Dominici 2011). Coming from three different stratigraphic units, the collection can be related to different stratigraphic units,

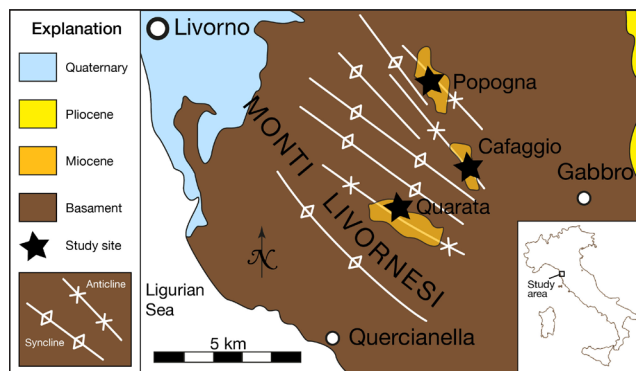


Fig. 1 - Location map of the three studied localities. Scale is 5 km.

yielding three distinct fossil assemblages, based on the descriptions given by Trentanove (1901; 1911). These units outcrop today only in a limited way with respect to the past. The fidelity of the collections to each one of the three different fossil assemblages is tested by comparing the distribution of abundances of individual species in historical and new quantitative collections. The revision of the systematics is also presented. Opportunities and shortcomings in the use of this particular historical set as a tool for modern paleobiological studies and as a case study to understand potential biases hidden in museum collections are explored.

GEOLOGICAL SETTING

The upper Miocene continental, restricted and fully marine sediments of the Monti Livornesi are today poorly exposed in limited patches, resting unconformably over the bedrock in the three distinct areas of Quarata, Popogna and Poggio Cafaggio (Fig. 1; Dominici et al. 2019). The stratigraphic succession reconstructed from the three areas is up to 60 m-thick and formed by three unconformity-bounded fining-upward units matching in their main part the three lithostratigraphic units recognized by Trentanove (1901, 1911). From lowermost to uppermost, these are the upper Tortonian-lowermost Messinian Luppiano Unit (LUP), and the early Messinian Rosignano (ROS) and Raquese units (RAQ; Fig. 2). LUP is formed by a coarse-grained lower part (conglomerate, sandstone and mudstone: LUP_a) and an upper mudstone with abundant sparse molluscs (LUP_b). The overlying Rosignano unit is formed by a basal conglomerate (ROS_a) sharply overlain by a bioclastic unit

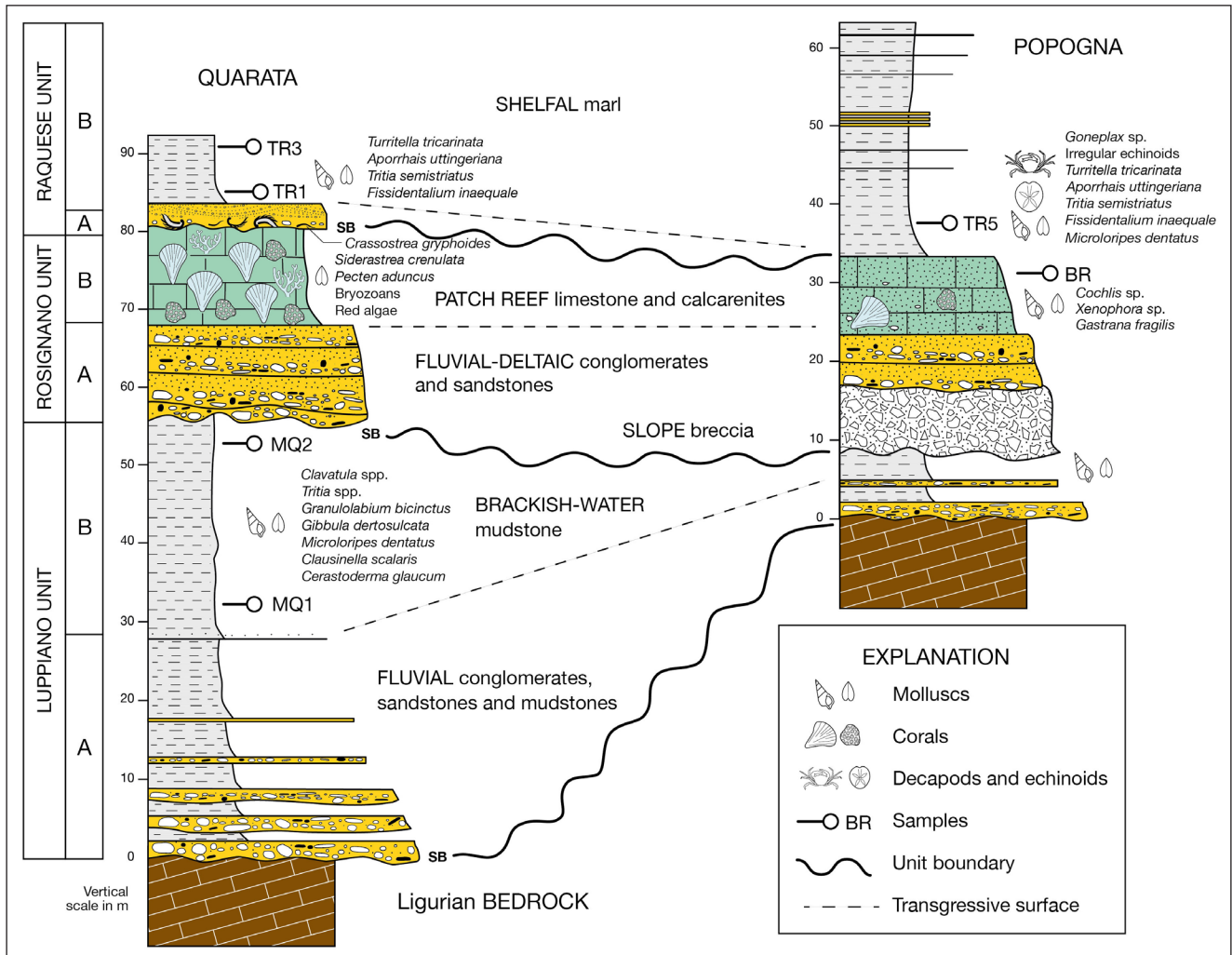


Fig. 2 - Schematic stratigraphic logs of the upper Miocene of the Monti Livornesi, with paleoenvironmental interpretation of the three main units and the main sequence-stratigraphic surfaces. SB: sequence boundary.

(biohermal limestone, marl and a calcarenite with molluscs and other macrofauna: ROS₅; Trentanove 1911). The youngest unit of the succession also contains a lower monospecific *Crassostrea gryphoides* shell bed and a conglomerate (RAQ₄) passing upward to a massive mudstone with sparse molluscs (RAQ₅). The upper Miocene macrofauna of the Monti Livornesi has been fully described by Trentanove (1901, 1911) in a systematic study of the three assemblages, all interpreted as Tortonian, and by Ruggieri (1956) and Monegatti and Raffi (2010), who have reviewed existing lists and interpreted the faunas as a single Messinian assemblage. Other authors have published only partial lists (e.g., Capellini 1878; see also Dominici et al. 2019). New field work and correlations with nearby upper Miocene basins has allowed to restore Trentanove’s interpretation of three distinct faunal assemblages, while keep-

ing for at least the two younger units the Messinian age assigned by more recent authors (Dominici et al. 2019). Field work included new samplings of the fossil faunas prompting a comparison between modern and historical collections, exploring the possibility to use abundance data contained in museum collections as a tool for modern studies.

Abbreviations: Stratigraphic abbreviations: LUP= Lupiano stratigraphic unit (late Tortonian-earliest Messinian); ROS = Rosignano unit (early Messinian); RAQ = Raquese unit (early Messinian); MQ = sample from LUP; BR = sample from ROS; TR = sample from RAQ; LUP_{hist} = historical sample from LUP; ROS_{hist} = historical sample from ROS; RAQ_{hist} = historical sample from RAQ; LUP_{nov} = new sample from LUP; ROS_{nov} = new sample from ROS; RAQ_{nov} = new sample from RAQ. Institutional abbreviations: MSN = Museum of Natural History, University of Florence; IGF = acronym for “Istituto Geologico di Firenze”, initials of MSN catalogue number for paleontological specimens. Abbreviations for quantitative analyses: SAD = species abundance distribution; NMDS = Non-metric Multidimensional scaling.



Fig. 3 - Metadata associated with the Monti Livornesi museum collection. A-C) three labels associated with IGF 103075 (*Circomphalus subplicatus*), the first handwritten in 1863, the second revealing the name of the collector (Igino Cocchi) and the third indicating the type of study carried out by Giorgio Trentanove around 1900, including systematics and the lithology associated with the specimen; D) Cocchi's handwritten note relating to the collection of IGF 11860 (*Streptochetus ornatus*) in 1863; E) Trentanove's interpretation of "*Pecten vigolensis*", corrected around 1910 by Carlo De Stefani, the author of "*Pecten etruscus*".

MATERIALS AND METHODS

At the Museo di Storia Naturale (MSN) of the University of Florence we analysed each fossil of the historical collection in relationship to the box in which it was stored, correcting any eventual misplacing based on a revised taxonomy and counting the abundance of each species. MSN specimens were catalogued (see chapter "Systematic descriptions", catalogue numbers starting with "IGF"). We recorded associated metadata, i.e., labels and hand-written notes relating to the site of collection and the name of the collector. The content of each box was cross-checked against the systematic descriptions published by Trentanove (1901; 1911), where the locality and stratigraphic unit of provenance of the fossils were noted. This procedure allowed to subdivide the historical collection in three samples: LUP_{hist}, ROS_{hist} and RAQ_{hist}. Two five-litres bulk samples were collected in the field, the first in LUP_b mudstones at Quarata (sample MQ1) and the second in RAQ_b mudstones at Popogna (sample TR5; Fig. 2). They were washed and sieved (1mm mesh size) and the content determined to the species level and counted. Three additional samples were hand-picked in the field, one in LUP_b (sample MQ2, locality Quarata), one in ROS_b (sample BR, locality Popogna) and two in RAQ_b (samples TR1, TR3, locality Quarata; Tab. 1). During picking we collected all visible fossils within an area of a few square meters, allowing to refer each sample to one of the three fossil assemblages. Bivalve individuals were calculated as the sum of articulated specimens and the highest number of left or right valves. Gastropod individuals were equated to the number of apices. For purposes of comparison samples coming from different units were also lumped together to form samples LUP_{nov} (= MQ1 + MQ2), ROS_{nov} (= BR) and RAQ_{nov} (= TR1 + TR2 + TR5).

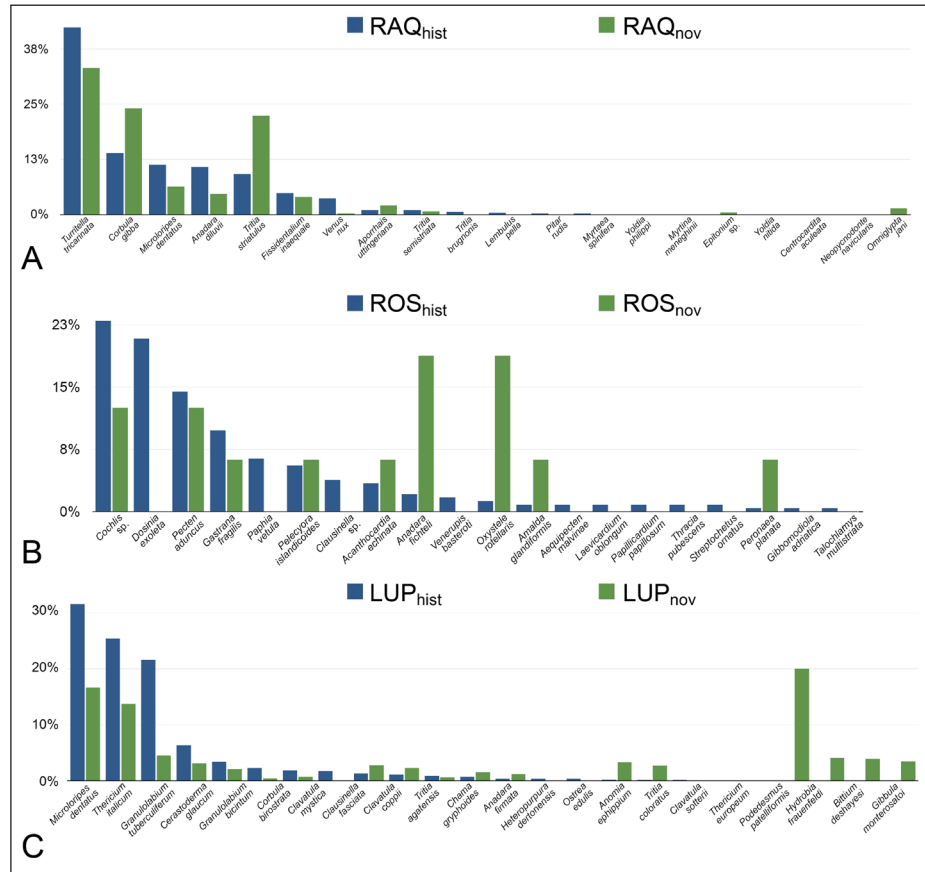
The resulting abundance data were used to assess the similarity between historical and new collections through the univariate study of species abundance distribution (SAD), rarefaction curves and a multivariate ordination of genera. SAD characterises patterns in the commonness and rarity of all species within an ecological community providing a basic tool in biogeography and community ecology (Matthews & Whittaker 2014) frequently applied in paleoecology of shell beds (e.g., Zuschin et al. 2014; Frisone et al. 2018). The rarefaction sampling standardization protocol provides a second tool to evaluate the sensitivity of biodiversity estimates to sampling effort (Harnik 2009; Nawrot & Studencka 2017). The multivariate analysis of abundances of genera within a dataset of 93 fossil assem-

blages, including eight out of nine presented here, was the base to frame the Monti Livornesi collections within Mediterranean upper Neogene paleoenvironmental gradients (Dominici et al. 2019). Non-metric multidimensional scaling (NMDS) was used as an ordination method, based on the Bray-Curtis similarity coefficient applied to standardized and square root transformed abundances, to de-emphasize the influence of the most abundant taxa (Patzkowsky & Holland 2012). Analyses were performed with the computer software package Past 3.23 (Hammer 2019) and PRIMER 6 (Clarke & Warwick 1994).

RESULTS

The historical collection was contained in 239 labelled boxes, each yielding one or more hand-written notes. The collector was Igino Cocchi in 28 cases (specimens collected during 1863 field excursions; Fig. 3), Giorgio Trentanove in eight cases and Giorgio Enrico Levi in four cases, all authors being known as significant contributors to the building of the MSN collections (Cioppi & Dominici 2011, Dominici 2011). The remaining metadata did not allow to know the name of the collector. However, "Trentanove" handwritten in red ink, alongside a systematic note contained in each box, reveals that the author of the Monti Livornesi systematic monographs based his study on an analysis of the whole MSN Monti Livornesi collection. Thanks to Trentanove (1901, 1911) systematic and stratigraphic descriptions of all species were retraced, suggesting that during the intervening century the collection has been well-curated. The systematic revision allowed to ascertain that the historical material amounts to 8537 individuals belonging to 64 species. The list was increased by 30 new species found only in new

Fig. 4 - Frequency distribution of the most abundant species of the Raquese (A), Rosignano (B) and Luppiano fossil assemblages (C).



bulk samples, all belonging to small-sized molluscs. Field samples collectively yielded 2416 specimens, for a total abundance of 10886 individuals belonging to 94 different species. Lithologic descriptions given by Trentanove (1901, 1911) were compared with the results of novel fieldwork, so as to allow to assign species found in historical collections to one of the three different fossiliferous units LUP_b, ROS_b and RAQ_b. *Microripipes dentatus* was the only species found in two distinct assemblages, LUP_b and RAQ_b. Since all specimens were grouped in museum collection, their distributions among the two above assemblages could not be ascertained and the specimens were thus arbitrarily split among samples LUP_{hist} and RAQ_{hist}. Two species of the historical collection could not be assigned to a specific unit, but their very low abundance suggests they would have not influenced the final outcome of the study (Tab. 1). *Crassostrea gryphoides* was excluded from the comparison, coming from a monospecific shell bed and being absent in the three fossil assemblages. These can be differentiated on paleoecological and taphonomic grounds (Dominici et al. 2019).

The fossil association of LUP_b mudstones is dominated by a few small-sized molluscs. LUP_{hist} includes 2169 specimens belonging to 19 species.

LUP_{nov} includes 1996 specimens and 44 species, most of which are small-sized molluscs not included in LUP_{hist} (Fig. 4). Differences are important: if the ten most important species are the same, their sum amounts to the 96,8% in the case of LUP_{hist}, exactly the half in LUP_{nov} (46,3%), indicating a larger dominance in the historical collection. The ten most abundant species unrecorded among museum specimens, mostly belonging to small-sized gastropods typical of vegetated bottoms (e.g., rissoids, hydrobiids, *Bittium*), amount to 41% of the total abundance of LUP_{nov}.

The fossil assemblage of ROS_b calcarenites is poor in individuals, but rich in species with respect to assemblages from upper Miocene mudstones. ROS_{hist} specimens are 235, species 24, whereas ROS_{nov} are only 16 belonging to 10 species. Dominance is very low, with species abundances being more evenly distributed than in the other two fossil assemblages (Fig. 5). The mollusc association found in RAQ_b mudstones is dominated by a different set of species than older assemblages. RAQ_{hist} contains 6050 individuals belonging to 19 species, whereas RAQ_{new} contains 404 individuals belonging to 11 species. The situation is somehow reversed with respect to LUP collections, with fewer species in nov-

	HISTORICAL COLLECTIONS				LUP _{nov}			ROS _{nov}	RAQ _{nov}			
	LUP _{hist}	ROS _{hist}	RAQ _{hist}	Unknown	MQ1	MQ2	LUP _{pooled}	BR	TR1	TR3	TR5	RAQ _{pooled}
<i>Gibbula dertosulcata</i> (Sacco, 1896)	0	0	0	0	28	34	62	0	0	0	0	0
<i>Gibbula monterosatoi</i> (Sacco, 1896)	0	0	0	0	0	79	79	0	0	0	0	0
<i>Oxysteles rotellaris</i> (Michelotti, 1847)	0	3	0	0	0	0	0	3	0	0	0	0
<i>Turritella tricarinata</i> (Brocchi, 1814)	0	0	2568	0	0	0	0	0	21	16	104	141
<i>Tenagodus anguinus</i> (Linnaeus, 1758)	0	0	0	9	0	0	0	0	0	0	0	0
<i>Theridium europaeum</i> (Mayer, 1878)	3	0	0	0	0	1	1	0	0	0	0	0
<i>Theridium italicum</i> (Mayer, 1878)	552	0	0	0	15	260	275	0	0	0	0	0
<i>Bittium deshayesi</i> Cerulli Irelli, 1912	0	0	0	0	82	0	82	0	0	0	0	0
<i>Granulolabium bicinctum</i> (Brocchi, 1814)	74	0	0	0	12	29	41	0	0	0	0	0
<i>Granulolabium tuberculiferum</i> (Cocconi, 1873)	469	0	0	0	45	45	90	0	0	0	0	0
<i>Epitonium</i> sp.	0	0	2	0	0	0	0	0	0	0	2	2
<i>Cochlis</i> sp.	0	54	0	0	0	0	0	2	0	0	0	0
<i>Alvania</i> cfr <i>A. cioppii</i> Chirli, 2006	0	0	0	0	1	0	1	0	0	0	0	0
<i>Alvania</i> cfr <i>A. granosa</i> Tabanelli et al., 2011	0	0	0	0	3	0	3	0	0	0	0	0
<i>Pusillina</i> sp.	0	0	0	0	43	0	43	0	0	0	0	0
<i>Setia turriculata</i> Monterosato, 1884	0	0	0	0	13	0	13	0	0	0	0	0
<i>Hydrobia frauenfeldi</i> Hörnes, 1856	0	0	0	0	400	0	400	0	0	0	0	0
<i>Stenothyrella schwartzi</i> (Frauenfeld in Hörnes, 1856)	0	0	0	0	12	0	12	0	0	0	0	0
<i>Tornus subcarinatus</i> (Montagu, 1803)	0	0	0	0	11	0	11	0	0	0	0	0
<i>Xenophora</i> sp.	0	0	0	0	0	0	0	1	0	0	0	0
<i>Aporrhais uttingeriana</i> (Risso, 1826)	0	0	61	0	0	0	0	0	9	0	0	9
<i>Amalda glandiformis</i> Lamarck 1810	0	2	0	0	0	0	0	1	0	0	0	0
<i>Streptochetus ornatus</i> (d'Orbigny, 1852)	2	0	0	0	0	0	0	0	0	0	0	0
<i>Heteropurpura dertonensis</i> (Mayer in Bellardi, 1873)	8	0	0	0	4	20	24	0	0	0	0	0
<i>Hexaplex austriacus</i> (Tournoüer, 1875)	0	0	0	1	0	1	1	0	0	0	0	0
<i>Tritia agatensis</i> (Bellardi, 1882)	24	0	0	0	10	36	46	0	0	0	0	0
<i>Tritia brugnonis</i> (Bellardi, 1872)	0	0	38	0	0	0	0	0	0	0	0	0
<i>Tritia striatulus</i> (Eichwald, 1829)	0	0	560	0	0	0	0	0	21	27	47	95
<i>Tritia coloratus</i> (Eichwald, 1830)	4	0	0	0	60	6	66	0	0	0	0	0
<i>Tritia semistriata</i> (Brocchi, 1814)	0	0	61	0	0	0	0	0	0	0	3	3
<i>Clavatula coppii</i> Bellardi, 1878	28	0	0	0	39	16	55	0	0	0	0	0
<i>Clavatula mystica</i> (Doderlein in Manzoni, 1869)	41	0	0	0	9	5	14	0	0	0	0	0
<i>Clavatula sotterii</i> (Michelotti, 1847)	3	0	0	0	23	31	54	0	0	0	0	0
<i>Brachystomia</i> cfr <i>B. carrozzai</i> (van Aartsen, 1987)	0	0	0	0	2	0	2	0	0	0	0	0
<i>Nisosyrnola concava</i> (Boettger, 1907)	0	0	0	0	18	0	18	0	0	0	0	0
<i>Parthenina indistincta</i> (Montagu, 1808)	0	0	0	0	2	0	2	0	0	0	0	0
<i>Parthenina terebellum</i> (Philippi, 1844)	0	0	0	0	1	0	1	0	0	0	0	0
<i>Ebala pointeli</i> (de Folin, 1868)	0	0	0	0	31	0	31	0	0	0	0	0
<i>Henrya wareni</i> Landau et al., 2013	0	0	0	0	2	0	2	0	0	0	0	0
<i>Acteocina lajonkaireana</i> (Basterot, 1825)	0	0	0	0	6	0	6	0	0	0	0	0
<i>Retusa truncatula</i> (Bruguière, 1792)	0	0	0	0	2	0	2	0	0	0	0	0
<i>Ringicula minor</i> (Grateloup, 1838)	0	0	0	0	8	0	8	0	0	0	0	0
<i>Nucula</i> sp.	0	0	0	0	0	0	0	0	0	1	0	1
<i>Lembulus pella</i> (Linnaeus, 1758)	0	0	25	0	0	6	6	0	0	0	0	0
<i>Yoldia nitida</i> (Brocchi, 1814)	0	0	2	0	0	0	0	0	0	0	0	0
<i>Yoldia philippi</i> Bellardi, 1875	0	0	8	0	0	0	0	0	0	0	0	0

Tab. 1 - Raw abundance data of the museum collections divided by fossil assemblage LUP_{hist}, ROS_{hist} or RAQ_{hist}. Subdivision was based on documental data (Trentanove 1901, 1911) and type of preservation. Species that could not be assigned to a given assemblage are listed in the fourth column; the last columns list raw abundance data of new samples, also divided by relative stratigraphic unit (LUP_{nov}, ROS_{nov}, RAQ_{nov}).

	HISTORICAL COLLECTIONS				LUP _{nov}			ROS _{nov}	RAQ _{nov}			
	LUP _{hist}	ROS _{hist}	RAQ _{hist}	Unknown	MQ1	MQ2	LUP _{pooled}	BR	TR1	TR3	TR5	RAQ _{pooled}
<i>Anadara diluvii</i> (Lamarck, 1805)	0	0	652	0	0	0	0	0	0	20	0	0
<i>Anadara firmata</i> (Mayer, 1868)	15	0	0	0	0	31	31	0	0	0	0	0
<i>Anadara fichteli</i> (Deshayes, 1850)	0	5	0	0	0	0	0	3	0	0	0	0
<i>Limaria hians</i> (Gmelin, 1790)	0	0	0	1	0	0	0	0	0	0	0	0
<i>Gibbomodiola adriatica</i> (Lamarck, 1819)	0	1	0	0	0	0	0	0	0	0	0	0
<i>Pecten aduncus</i> Eichwald, 1830	0	34	0	0	0	0	0	2	0	0	0	0
<i>Talochlamys multistriata</i> (Poli, 1795)	0	1	0	0	0	0	0	0	0	0	0	0
<i>Aequipecten malvinae</i> (Dubois de Montpéroux 1831)	0	2	0	0	0	0	0	0	0	0	0	0
<i>Anomia ephippium</i> Linnaeus, 1758	7	0	0	0	0	1	1	0	0	0	0	0
<i>Podedesmus patelliformis</i> (Linnaeus, 1758)	1	0	0	0	0	0	0	0	0	0	0	0
<i>Ostrea edulis</i> Linnaeus, 1758	8	0	0	0	0	0	0	0	0	0	0	0
<i>Crassostrea gryphoides</i> (Schloteim, 1813)	0	0	0	5	0	0	0	0	0	0	0	0
<i>Neopycnodonte navicularis</i> (Brocchi, 1814)	0	0	1	0	0	0	0	0	0	0	0	0
<i>Centrocardita aculeata</i> (Poli, 1795)	0	0	2	0	0	0	0	0	0	0	0	0
<i>Chama gryphoides</i> Linnaeus, 1758	19	0	0	0	0	13	13	0	0	0	0	0
<i>Microlophes dentatus</i> (DeFrance, 1823)	685	0	684	0	100	232	332	0	0	27	0	27
<i>Myrtea spinifera</i> (Montagu, 1803)	0	0	12	0	0	0	0	0	0	0	0	0
<i>Myrtina meneghini</i> (De Stefani & Pantanelli, 1888)	0	0	4	0	0	0	0	0	0	0	0	0
<i>Hemilepton nitidum</i> (Turton, 1822)	0	0	0	0	1	0	1	0	0	0	0	0
<i>Lepton squamosum</i> (Montagu, 1803)	0	0	0	0	1	0	1	0	0	0	0	0
<i>Phascoliohyla phascolionis</i> (Dautzenberg & H. Fischer, 1925)	0	0	0	0	1	0	1	0	0	0	0	0
<i>Cerastoderma glaucum</i> (Bruguière, 1789)	138	0	0	0	0	62	62	0	0	0	0	0
<i>Procardium</i> cfr. <i>P. danubianum</i> (Mayer, 1866)	0	1	0	0	0	0	0	0	0	0	0	0
<i>Acanthocardia echinata</i> (Linnaeus, 1758)	0	8	0	0	0	0	0	1	0	0	0	0
<i>Laevicardium oblongum</i> (Chemnitz, 1791)	0	2	0	0	0	0	0	0	0	0	0	0
<i>Papillicardium papillosum</i> (Poli, 1791)	0	2	0	0	0	0	0	0	0	0	0	0
<i>Parvicardium minimum</i> (Philippi, 1836)	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gastrana fragilis</i> (Linnaeus, 1758)	0	23	0	0	0	0	0	1	0	0	0	0
<i>Peronaea planata</i> (Linnaeus, 1758)	0	1	0	0	0	0	0	1	0	0	0	0
<i>Thracia pubescens</i> (Pultney, 1799)	0	2	0	0	0	0	0	0	0	0	0	0
<i>Pelecycora islandicoides</i> (Lamarck, 1818)	0	13	0	0	0	0	0	1	0	0	0	0
<i>Clausinella fasciata</i> (da Costa, 1778)	0	9	0	0	0	0	0	0	0	0	0	0
<i>Clausinella</i> sp.	38	0	0	0	7	62	69	0	0	0	0	0
<i>Venus nux</i> Gmelin, 1791	0	0	221	0	0	0	0	0	0	1	0	1
<i>Pitar rudis</i> (Poli, 1826)	0	0	16	0	0	0	0	0	0	0	0	0
<i>Gouldia minima</i> (Montagu, 1803)	0	0	0	0	25	0	25	0	0	0	0	0
<i>Paphia vetula</i> (Basterot, 1825)	0	15	0	0	0	0	0	0	0	0	0	0
<i>Circomphalus subplicatus</i> (d'Orbigny, 1852)	0	1	0	0	0	0	0	0	0	0	0	0
<i>Venerupis</i> cfr. <i>V. basteroti</i> (Mayer, 1857)	0	4	0	0	0	0	0	0	0	0	0	0
<i>Dosinia exoleta</i> (Linnaeus, 1758)	0	49	0	0	0	0	0	0	0	0	0	0
<i>Timoclea ovata</i> (Pennant, 1777)	0	1	0	0	0	0	0	0	0	0	0	0
<i>Lutreria oblonga</i> (Chemnitz, 1791)	0	1	0	0	0	0	0	0	0	0	0	0
<i>Corbula birostrata</i> Trentanove, 1901	50	0	0	0	0	9	9	0	0	0	0	0
<i>Corbula gibba</i> (Olivi, 1792)	0	0	846	0	0	0	0	0	8	26	68	102
<i>Clavagella bacillum</i> (Brocchi, 1814)	0	0	0	1	0	0	0	0	0	0	0	0
<i>Fissidentalium inaequale</i> (Bronn, 1831)	0	0	293	0	0	0	0	0	0	1	16	17
<i>Omniglypta jani</i> (Hörnes, 1853)	0	0	0	0	0	0	0	0	0	6	0	6
S = 94	961	175	2731	7	135	410	545	9	8	81	84	153

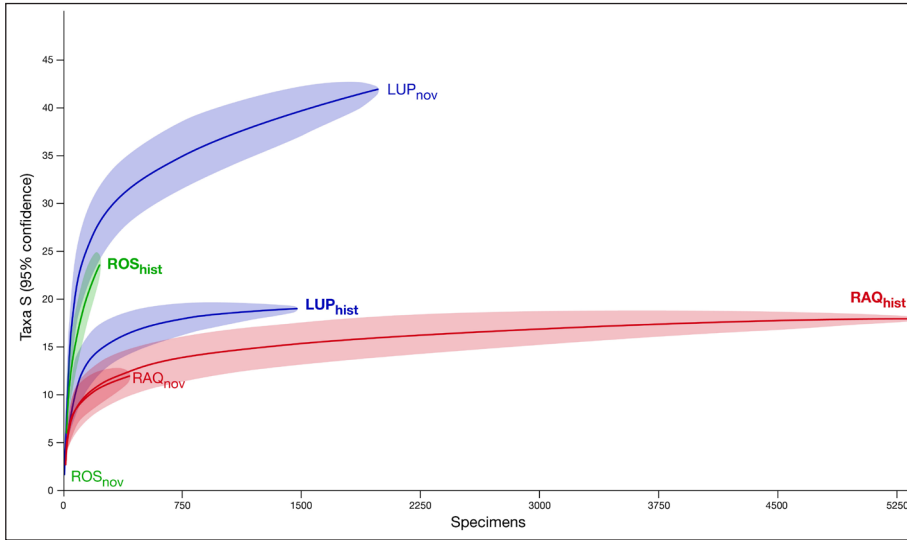


Fig. 5 - Rarefaction curves relative to the three museum collections (LUP_{hist} , ROS_{hist} , RAQ_{hist}) and the three new pooled collections (LUP_{nov} , ROS_{nov} , RAQ_{nov}).

el samples and one important species, *Andara diluvii*, no longer recovered. Differences in species richness between museum and novel collections are evident from the analysis of the rarefaction curves. The two

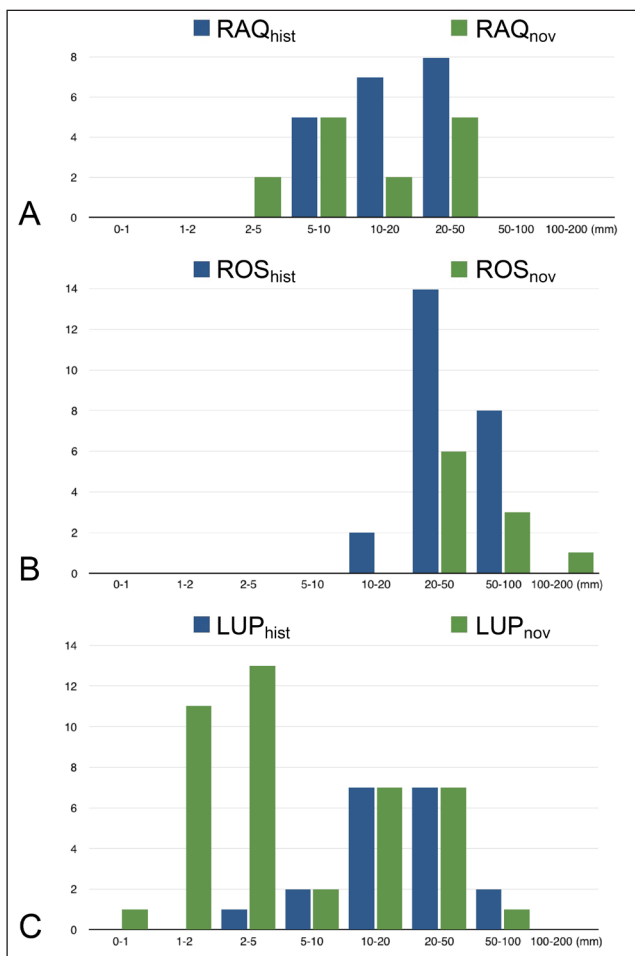
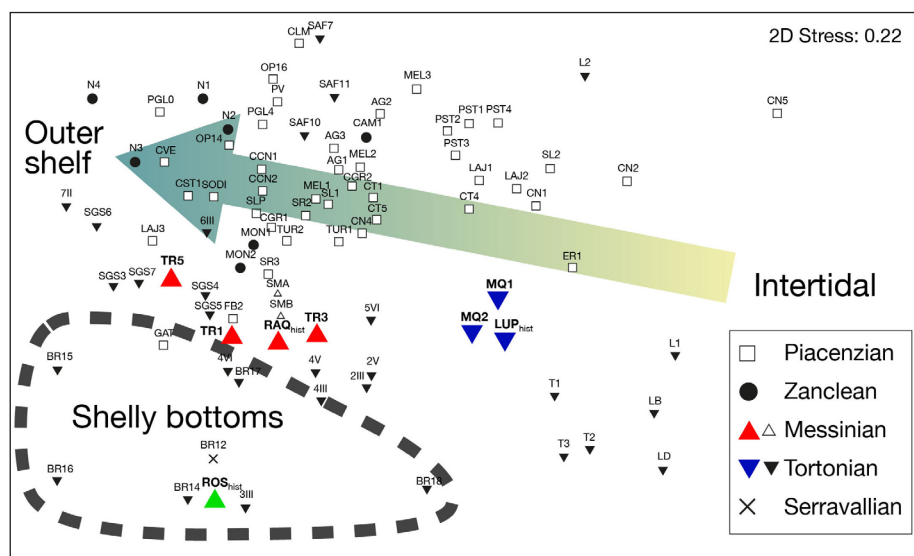


Fig. 6 - Size-structure of molluscs of the Raques (A), Rosignano (B) and Luppiano fossil assemblages (C), shown as species richness per size-class (in mm).

units yielding the richest assemblages are LUP and ROS, having the steepest slope of the curves. Both show that an increase in sampling effort would lead to further finds of new species, but where the slope relative to LUP_{hist} and LUP_{nov} curves already start to decrease, the opposite happens with ROS_{hist} and ROS_{nov} curves, still very steep and too brief to affirm that all available collections give a satisfying account of the relative fossil assemblage. The magnitude of the difference between LUP_{hist} and LUP_{nov} curves indicates that the museum collection is heavily biased, clearly due to the lack of species smaller than 1 cm so common in bulk-samples. Finally, RAQ_{hist} and RAQ_{nov} match to a large extent. The slope of the line is getting shallow towards the end, so that most of the species of the RAQ fossil assemblage were found and are present in museum collection, whereas only a few are missing in novel samples. The relative role of size is evident when we divide species richness per size class (Fig. 6), so as to reach an intuitive conclusion: associations dominated by small-sized molluscs, like those from seagrass bottoms, are likely heavily biased if fossils were not collected through sieving and picking specimens under a microscope. On the other hand, chances are higher to have a more decent figure of diversity and abundance distributions if only species larger than 1 cm form the bulk of the total richness of a given assemblage.

Finally, differences between museum collections and new samples are evened out in multivariate analyses based on genus-level distributions. The results of the NMDS ordination, carried out on eight Monti Livornesi samples (BR was exclud-

Fig. 7 - Non-metric multidimensional ordination of 93 Miocene-Pliocene collections (Bray-Curtis coefficient, standardised and square-root transformed abundance data). The arrow points to a depth-gradient, whereas another environmental gradient is highlighted by the clustering of samples associated with bioclastic bottoms in the lower left corner of the ordination.



ed being too small, with only 16 specimens) and 85 other Pliocene and Miocene samples, show that samples coming from the same fossil assemblage, being museum collections or the result of controlled field-picking and bulk-sampling, are more similar to each other than to any other group of assemblages of the dataset. This is evidenced in the NMDS plot when considering that the distance between samples is a measure of the differences in frequency distribution of the different genera, with similar samples coming closer in the multidimensional space (as many dimensions as 304 genera: Fig. 7).

DISCUSSION

The evaluation of the paleoecological potential hidden in museum collections adds value to ongoing projects on the digitisation of museum “dark data” (Marshall 2018). The present study offers new evidences on vantages and shortcomings of historical collections as tools to reconstruct the frequency distribution of species in fossil assemblages. The case of the upper Miocene Monti Livornesi mollusc collection studied by Trentanove (1901, 1911) suggests that the potential increases if the nature of the collection has been published with details on the lithology and stratigraphy of the encasing units, and if this has been well-kept by museum curators, as is the case presented here. Differences are evident with respect to previous case studies. In a comparison among museum and novel collections of middle Miocene bivalves, in some aspects simi-

lar to the case presented here, Dulai (1996) carried out a paleoecological study of museum data without giving details on the sampling techniques and taphonomy of the fossil assemblages. Differences between historical and new data remained high, particularly regarding species richness and dominance, with 1628 individuals belonging to 66 species in the museum collection against 4478 belonging to only 29 species in the washed sample. Novel sampling methods were not specified, however, and the chance is high that the historical collections came from one or more species-rich fossil assemblages, whereas the new one came from a low-diversity, *Corbula*-dominated one (see data in Dulai 1996). Hunter & Donovan (2005) confronted presence/absence data from collections of Campanian echinoderms coming from coeval, but distant formations in four distinct basins, lumping specimens collected during two centuries by many collectors and confronting them with a fossil assemblage collected by the authors. Sampling bias was assumed to be important in explaining the differences that were found, but differences in substrata could not be ruled out. In another multi-locality, but methodologically sound and stratigraphically well-constrained study, Harnik (2009) amassed a huge dataset on the abundances of Eocene and Oligocene molluscs, confronting the results obtained by different authors that had used slightly different bulk-sampling techniques, with faunal lists from museum collections from the same stratigraphic units. The final conclusion is that museums host presence/absence information on rare species that can be grouped to abundance data, maximising the detection of faunal change across

the middle Eocene-Oligocene transition. Nawrot & Studencka (2017) bulk-sampled middle Miocene shelly beds at two localities and confronted their abundance data with those from museum collections. They found substantial differences between the two sets, but, while indicating that different facies were sampled, they did not consider a possible facies control. Frisone et al. (2018) studied Eocene sponge faunas from a single stratigraphic horizon at two close-by localities, finding that museum collections preserve a higher richness and evenness with respect to bulk samples of the same fossil assemblage (the opposite result with respect to that of Dulai, 1996). Our study shows that facies can be a predictor of the quality of historical collections as a record of richness and abundance distributions. Intertidal and shallow subtidal fossil associations from seagrass fine-grained bottoms, like that found in the LUP_b mudstone, host a variety of species smaller than 1 cm that go unnoticed when not using a magnification glass. Small sized shells are known to represent the greatest part of the modern malacological biodiversity, as demonstrated by Bouchet et al. (2002) for the Recent fauna of New Caledonia. Similar conclusions are reached by Kantor & Sysoev (2005) in their comparison of the distribution of sizes of the molluscs of the Russian Far-East seas with that of tropical regions. Low-diversity, open marine communities living in muddy bottoms where depositional rate is high lead to the formation of fossil assemblages similar to that found in RAQ_b mudstone, dominated by a few suspension feeders (like *Turritella tricarinata*, *Anadara diluvii*, *Venus nux* and *Corbula gibba*) that are usually well-represented in old collections. Fossil assemblages associated with bioclastic units, like the ROS_b calcarenite, have been often deprived of species with aragonitic shells, particularly if small-sized, lost during diagenesis. In this case, a museum collection of poor and hardly-earned fossil specimens is an important means to represent the original biotic community. Although possibly representing only a limited part of the whole fossil assemblage, it may include species that can be hard to find by modern collectors. Above all, our study confirms that the type of preservation of aragonitic and calcitic shells is of paramount importance in guiding the museologist in search of data hidden in museum collections.

CONCLUSIONS

The systematic and quantitative study of the historical collection of upper Miocene molluscs from the localities of Popogna and Quarata, in the Monti Livornesi (Western Tuscany, Italy), hosted at the Museum of Natural History of Florence and of new material coming from the same stratigraphic units allowed to test if museum collections preserve comparable abundance distributions with respect to new field samples. By studying the frequency distribution of the most abundant species and through a comparison of rarefaction curves, we found that modern bulk samples collected in the Luppiano mudstones yielded a richer fauna than museum collections, due to the inclusion of species smaller than 1 cm. Size selectivity is less influential in the case of the two overlying fossil assemblages. The mollusc fauna of the Rosignano calcareous sandstones, associated with a coral reef, includes a distinctive fauna of large molluscs. Rarefaction curves reveal that both museum and new samples are insufficient to represent the totality of species of the fossil assemblage. Finally, the most important species of the topmost Raquese fossil assemblage are similarly ranked in museum and new collections. The upper Miocene-Pliocene faunal gradient revealed by a multivariate, genus-level study of the Monti Livornesi fauna and 85 other similar collections confirms that well-studied and well-cured museum collections are valuable paleobiological tools. The study helps to widen the scanty knowledge currently available on the nature of museum “dark data”.

SYSTEMATIC PALEONTOLOGY OF THE LUPPIANO UNIT (LATE TORTONIAN-EARLIEST MESSINIAN)

Class **GASTROPODA** Cuvier, 1795

Subclass **VETIGASTROPODA** Salvini-Plawen, 1980

Order **Trochida** [unassigned]

Superfamily Trochoidea Rafinesque, 1815

Family Trochidae Rafinesque, 1815

Subfamily Cantharidinae Gray, 1857

Genus *Gibbula* Risso, 1826

Type species - *Trochus magus* Linnaeus, 1758

Fig. 8 - Trochidae of the Luppiano unit (LUP_b) and MRST type-material for comparison. A-B) *Gibbula dertosulcata* (Sacco, 1896), LUP_b, MQ2, mm 4.5; C-D) *Gibbula dertosulcata* (Sacco, 1896), LUP_b, MQ1, mm 4.6; E-G) *Gibbula dertosulcata* (Sacco, 1896), MRST, syntype (BS.076.12.001), mm 4.1; H) MRST, original label from Bellardi & Sacco collection; K-I) *Gibbula monterosatoi* (Sacco, 1896), MRST, syntype (BS.076.15.002), mm 4.6; L) MRST, original label from Bellardi & Sacco collection; M-P) *Gibbula monterosatoi* (Sacco, 1896), LUP_b, MQ2, mm 5.1.



Gibbula dertosulcata (Sacco, 1896)

Fig. 8A-B; C-D

1896 *Tumulus dertosulcatus* Sacco, p. 35, pl. 4, figs 6a-c.
 1984 *Tumulus dertosulcatus* - Ferrero Mortara et al., p. 268, pl. 47, figs 9a-c.

Material: 62 spms found in samples MQ1-MQ2 from unit LUP_b.

Distribution. According to Sacco (1896, p. 35), the report of *Trochus sulcatus* Brocchi by Doderlein (1862) is to be referred to *G. dertosulcata*, which is thereby frequent in the Tortonian of Stazzano, Santa Maria and Montegibbio. For comparison we also show a syntype (BS.076.12.001) from the Bellardi et Sacco collection, by MRST (Fig. 8, E-H).

Gibbula monterosatoi (Sacco, 1896)

Fig. 8M-P

1896 *Glomulus? monterosatoi* Sacco, p. 30, pl. 4, fig. 19.
 1984 *Glomulus? monterosatoi* - Ferrero Mortara et al., p. 269, pl. 48, figs 3a-d.
 2009 *Glomulus monterosatoi* - Zunino & Pavia, p. 356.

Material: 79 spms found in sample MQ2 (LUP_b).

Distribution. Before now, the species was known only from the Burdigalian-Langhian of the Torino Hills (Zunino & Pavia 2009). For compar-

ison we show a syntype (BS.076.15.002) from the Bellardi et Sacco collection, by MRST (Fig.8, K-L).

Subclass **CAENOGASTROPODA** Cox, 1960

Order **Caenogastropoda** [unassigned]

Superfamily Cerithioidea Fleming, 1822

Family Cerithiidae Fleming, 1822

Genus *Bittium* Gray, 1847

Type species - *Strombiformis reticulatus* da Costa, 1778

Bittium deshayesi Cerulli Irelli, 1912

Fig. 9A-B

1912 *Bittium deshayesi* Cerulli Irelli, p. 331, pl. 44, figs 32-37.
 2006 *Bittium deshayesi* - Chirli, p. 90, pl. 36, figs 6-15 (cum syn.).

Material: 82 spms found in sample MQ1 (LUP_b). Maximum size = 13.2 mm, average size = 10 mm.

Description. Small and elongated turreted shell with a sharp apex and convex and deeply incised whorls. Sculpture made of thin axial riblets and fine spiral stripes (four or five in the last whorl) lying over the riblets (the last two well-marked abapically). Oval aperture with a slight, beak-like inferior depression; thin and arched external lip. Four or five spiral cords on the base, the peripheral cord in evidence.

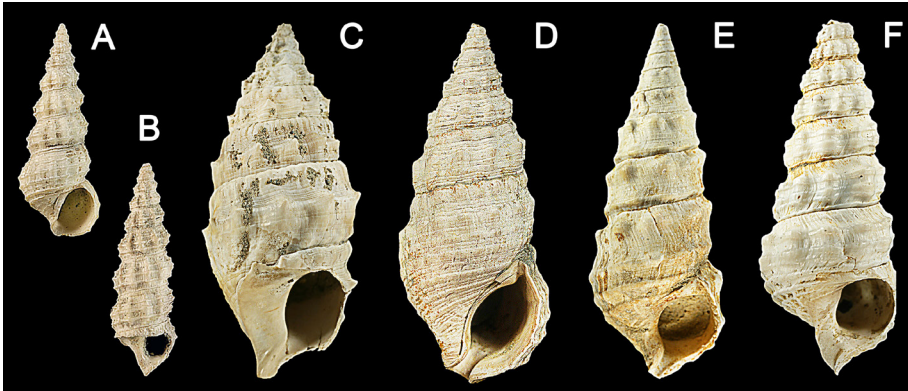


Fig. 9 - Cerithioidea of the Luppiano unit (LUP_v). A-B) *Bittium deshayesi* Cerulli Irelli, 1912, MQ1-MQ2, respectively 5 and 4 mm; C) *Theridium europaeum* (Mayer, 1878), MQ2, mm 20; D) *Theridium italicum* (Mayer, 1878), MQ1, mm 14; E) *Granulolabium bicinctum* (Brocchi, 1814), MQ1, mm 17.5; F) *Granulolabium tuberculiferum* (Cocconi, 1873), MQ1, mm 17.5.

Discussion. Specimens of larger dimensions with respect to those described by Cerulli Irelli for the lower Pleistocene of Farnesina (Roma), but with the same diagnostic characters (two spiral cords in evidence and aperture slightly widening in the lower part). The size is similar to that of specimens described for the upper Pliocene of Tuscany (Chirli 2006).

Distribution. Pliocene (Benvenuti & Dominici 1992) and Pleistocene of the Mediterranean area (Emilia, Toscana, Romagna, Umbria, Lazio, Calabria, Sicilia), first record for the Miocene. Modern species of *Bittium* live epiphytally feeding on microalgae (Houbrick 1993).

Genus *Theridium* Monterosato, 1890

Type species: *Cerithium vulgatum* Bruguière, 1792

Theridium europaeum (Mayer, 1878)

Fig. 9C

- 1878 *Cerithium europaeum* Mayer, p. 89, Pl. 2, fig. 5.
 1911 *Cerithium europaeum* - Trentanove, p. 69, pl. 4, fig. 9.
 2012 *Cerithium europaeum* - D'Amico et al., p. 159, pl. 1, fig. 4. (cum syn.).

Material: 2 spms (IGF 11957) (LUP_{hist}); 1 spm in sample MQ2 (LUP_v).

Discussion. Harzhauser (2002), among other authors, places this species in synonymy with *Cerithium vulgatum* Bruguière, 1792, but Baluk (2006), who is followed here, reassessed the two species as distinct (see also D'Amico et al. 2012). We use genus *Theridium*, Monterosato, 1890, in place of *Cerithium* Bruguière, 1789 for species of the Mediterranean area, following Harzhauser et al. (2013) and Landau et al. (2013).

Distribution. Aquitanian of the Aquitaine Basin (France), upper Burdigalian of the Paratethys

(Harzhauser 2002), up to the Pliocene of the Mediterranean area (references in D'Amico et al. 2012).

Theridium italicum (Mayer, 1878)

Fig. 9D

- 1878 *Cerithium italicum* Mayer, p. 178, pl. 4, fig. 6.
 1895 *Pitocerithium italicum* - Sacco, p. 29, pl. 2, fig. 63.
 1895 *Pitocerithium* cf. *costatum* - Sacco, p. 114.
 1911 *Cerithium italicum* - Trentanove, p. 67, pl. 4, figs 10-14, 20-22.
 1963 *Cerithium* (*Theridium*) *italicum* - Venzo & Pelosio, p. 70, pl. 3, figs 34-38.
 1968 *Cerithium* (*Theridium*) *italicum* - Robba, p. 518, pl. 40, fig. 4a,b.

Material: About 500 spms (IGF 11959-11963) (LUP_{hist}); 275 spms in samples MQ1 and MQ2 (LUP_v).

Distribution. Tortonian at Stazzano, S. Agata-Fossili and Vigoleno, Pliocene in Piedmont and Tuscany (Robba 1968).

Family Batillariidae Thiele, 1929

Genus *Granulolabium* Cossmann, 1889

Type species - *Cerithium plicatum* Bruguière, 1792

Granulolabium bicinctum (Brocchi, 1814)

Fig. 9E

- 1814 *Murex bicinctum* Brocchi, p. 446, pl. 9, fig. 13.
 1911 *Cerithium bicinctum* - Trentanove, p. 65, pl. 4, figs 15-19.
 1956 *Pirenella bicincta* - Ruggieri, p. 148.
 1968 *Pirenella bicincta* - Robba, p. 514, pl. 39, fig. 14a,b.
 2012 *Granulolabium bicinctum* - D'Amico et al., p. 162, pl. 1, fig. 11, pl. 2, figs 12-16.
 2013 *Granulolabium bicinctum* - Landau et al., p. 45-47, pl. 4, figs 3-4 (cum. syn.).
 2013 *Granulolabium bicinctum* - Tâmaş et al., p. 71, figs 2i-j (cum. syn.).

Material: 74 spms (IGF 11944-11945, 11964) (LUP_{hist}); 41 spms in sample MQ1 and MQ2, all from LUP_v.

Discussion. See Lozouet (1986) for a list and a discussion of European synonyms of *G. bicinctum* (Brocchi, 1814). The species occurs both



Fig. 10 - Littorinimorpha of the Luppiano unit (LUP.). A) *Alvania* cfr. *A. cioppii* Chirli, 2006, MQ1, mm 2.6; B) *Alvania* cfr. *A. granosa* Tabanelli, Bongiardino & Perugia, 2011, MQ1, mm 2.5; C) *Pusillina* sp., MQ1, mm 2.6; D) *Setia turriculata* Monterosato, 1884, MQ1, mm 1.3; E) *Hydrobia frauenfeldi* (Hörnes, 1856), MQ1, mm 2.8; F) *Stenothyrella schwartzi* (Frauenfeld in Hörnes, 1856), MQ1, mm 1.1; G) *Tornus subcarinatus* (Montagu, 1803), MQ1, mm 1.8.

in subtidal, fully marine associations (Robba 1968) and with brackish-water, mud flat species such as *Hydrobia frauenfeldi* (Hörnes, 1856), in low-richness associations (Harzhauser & Kowalke 2002; D'Amico et al. 2012), or in estuarine facies as early as the Burdigalian (Zuschin et al. 2014).

Distribution. *G. biconctum* has a wide European distribution from the early Miocene to the Pliocene (references in D'Amico et al. 2012; Tămaş et al. 2013). Preference for intertidal and shallow subtidal settings are confirmed by congeneric species, from the early Eocene to the Recent (references in Dominici & Kowalke 2014; Thivaïou et al. 2019).

Granulolabium tuberculiferum (Cocconi, 1873)

Fig. 9F

- 1873 *Cerithium tuberculiferum* Cocconi, p. 177, pl. 4, figs 14-15.
 1895 *Pirenella bidisjuncta* Sacco, p. 59, Pl. 3, figs 48-51.
 1911 *Cerithium tuberculiferum* - Trentanove, p. 66, pl. 4, figs 4-8.
 1956 *Pirenella tuberculifera* - Ruggieri, p. 148.
 1963 *Pirenella tuberculifera* - Venzo & Pelosio, p. 68, pl. 33, figs 45-47.
 1968 *Pirenella tuberculifera* - Robba, p. 515, pl. 39, figs 15a,b.

Material: Almost 500 spms (IGF 11954-11955) (LUP_{hist}); 90 spms in samples MQ1-MQ2 (LUP_v).

Discussion. According to Robba (1968) and Venzo & Pelosio (1963), all Sacco (1895) varieties, with the exception of his *Pirenella bidisjuncta colligens*, belong to the same species.

Distribution. Tortonian (Montegibbio) to early Messinian (Sacco 1895; Robba 1968).

Order **Littorinimorpha** Golikov & Starobogatov, 1975

Superfamily Rissoidea Gray J.E., 1847

Family Rissoidae Gray J.E., 1847

Genus *Alvania* Risso, 1826

Type species - *Alvania europea* Risso, 1826

***Alvania* cfr. *A. cioppii* Chirli, 2006**

Fig. 10A

2006 *Alvania cioppii* Chirli, p. 18, pl. 8, figs 1-12.

Material: 1 spm in sample MQ1 (LUP_v).

Description. Small and solid conical shell, with whorls slightly convex divided by well-marked sutures. The protoconch of our specimen is poorly preserved. Teleoconch with 14 axial ribs as wide as the interspaces, orthocline, interrupted at the periphery. The spiral sculpture consists of dense cords (about 16 on the last whorl) of which the peripheral little more pronounced. Aperture oval, narrow at the top with the outer lip thickened and denticulate internally. Base spirally striated, umbilicus barely hinted.

Discussion. The holotype of *A. cioppii* illustrated by Chirli (2006, pl. 7, figs 1-3) could not be retraced at MSN, its catalogue number corresponding to another species (the author reports only one and the same catalogue number IGF 14273E for at least five new species of *Alvania*; four of these holotypes were retraced at MSN, and the correct access number is now known). According to Chirli (2006), *Alvania curta* (Dujardin, 1837) (Strausz 1966, pl. 46, figs 8-9: middle Miocene of Poland and France; Kowalke & Harzhauser 2004, cum syn.: Langhian of Central Paratethys) is distinguished by having stronger and more oblique axial ribs and the

aperture adapically wider. *A. discors* (Allan, 1818) has larger and less convex whorls, fewer and more robust spiral cords, and the aperture adapically wider.

Distribution. *A. cioppii* (Chirli 2006) was reported only in the Pliocene of Tuscany, where it seems frequent (eight different localities). *A. curta* from the Pliocene of Piedmont (Cavallo & Repetto 1992: p. 52, fig. 074) may also be included in synonymy with *A. cioppii*. Many species of *Alvania* live epiphytally in shallow marine settings, where they feed on microalgae and foraminifera (Ponder 1984), consistently with their sinecological distributions, at least since the early Miocene (Thivaïou et al. 2019; Garilli 2011).

Alvania cfr. *A. granosa* Tabanelli, Bongiardino & Perugia, 2011

Fig. 10B

2011 *Alvania granosa* Tabanelli et al., p. 39, pl. 3, figs 15-16.

Material: 3 spms in sample MQ1 (LUP_p).

Discussion. Size and ornaments correspond to the Pliocene species first described by Tabanelli et al. (2011), but longitudinal cords are fewer in number (12 per whorl, instead of 14) and the aperture is slightly smaller. The protoconch is not visible in our specimens and cannot be used for comparison. *Monodonta tauroparva* (Sacco 1895) from the Burdigalian of the Torino Hills (Ferrero Mortara et al. 1984; Zunino & Pavia 2009), differs in its larger size (about 3 mm). *Alvania (Alvania) ampulla* (Eichwald, 1853) shows similar characters of the telococonch (Tămaş et al. 2013), with granulose knots present in the subsutural cord, but absent at the intersection between axial costae and spiral cords.

Distribution. Early-middle Piacenzian of Northern Apennines (Tabanelli et al. 2011).

Genus *Pusillina* Monterosato, 1884

Type species - *Rissoa pusilla* Philippi, 1836

Pusillina sp.

Fig. 10C

Material: 43 spms in sample MQ1 (LUP_p).

Description. Profile ovate-conical, convex whorls and suture marked. Protoconch smooth as the rest of the shell. Height / width ratio variable.

Last whorl over 50% of the total height. Aperture oval with outer lip thin, simple, columella arched, umbilicus evident.

Discussion. Our specimens of this small Rissoidae show some variability in outline. Our specimens differ from *Pusillina nilae* Bogi & Chirli, 2004 for the different protoconch and less convex whorls. A stubby and completely smooth form of *Pusillina sulzeriana* (Risso, 1826), without axial costae similar to the Monti Livornesi specimens, is reported and illustrated by Pavia (1975, Pl. 3, figs 23a-b) for the Pliocene of Monteu Roero, Villalvernia and Masserano. Modern species of genera *Pusillina* and *Alvania* show similar distributions (Garilli 2011).

Genus *Setia* H. Adams H. & A. Adams, 1854

Type species - *Rissoa pulcherrima* Jeffreys, 1848

Setia turriculata Monterosato, 1884

Fig. 10D

1884 *Setia turriculata* Monterosato, pag. 279.

2006 *Setia turriculata* - Chirli, p. 50, pl. 22, figs 15-16.

Material: 13 spms in sample MQ1 (LUP_p).

Description. Shell with some variability in outline and sculpture. Characterised by 4- 4.5 convex whorls with deep suture, some of the specimens collected have a slight subsutural shoulder, a character often reported in recent specimens. Protoconch prominent, with about 18 thin spiral cords. Round aperture with well developed umbilicus. A slight axial sculpture originated by an evident growth striae may be present.

Discussion. We found many specimens of this small Rissoidae, which presents a considerable intraspecific variability.

Distribution. Found in the Pliocene of Tuscany (Chirli 2006), the species presently lives in the Mediterranean in infralittoral algal bottoms (Monterosato 1884; Terlizzi et al. 2005).

Superfamily Truncatelloidea Gray, 1840

Family Hydrobiidae Troschel, 1857

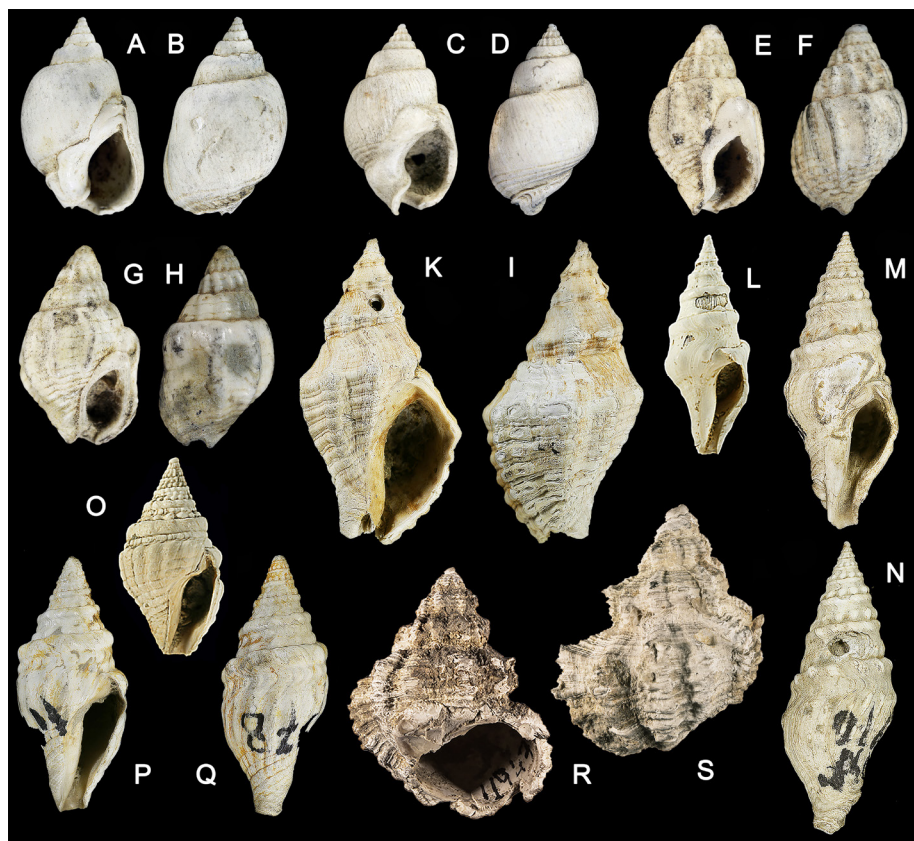
Genus *Hydrobia* Hartman, 1821

Type species - *Cyclostoma acutum* Draparnaud, 1805

Hydrobia frauenfeldi (Hörnes, 1856)

Fig. 10E

Fig. 11 - Neogastropoda of the Lupiano unit (LUP₁). A-B) *Tritia agatensis* (Bellardi, 1882), IGF 103070 [*N. saccoi* in Trentanove, 1911], mm 14; C-D) *Tritia agatensis* (Bellardi, 1882), IGF 103072 [*N. saccoi* in Trentanove, 1911], mm 13; E-F) *Tritia coloratus* (Eichwald, 1830), IGF 103065 [*N. manzonii* in Trentanove, 1911], mm 9.8; G-H) *Tritia coloratus* (Eichwald, 1830), IGF 103067 [*N. manzonii* in Trentanove, 1911], mm 10.3; K-I) *Heteropurpura dertonensis* (Mayer in Bellardi, 1873), IGF11948, mm 23; L) *Clavatula coppii* Bellardi, 1877, MQ1, mm 12; M-N) *Clavatula mystica* (Doderlein, in Manzoni, 1869), IGF 11976, mm 23; O) *Clavatula sotterii* (Michelotti, 1847), MQ1 [*C. turgidula* in Bellardi, 1877; *C. pugilis* Bellardi, 1877], mm 10.7; P-Q) *Clavatula sotterii* (Michelotti, 1847), IGF 11978, mm 17; R-S) *Hexaplex austriacus* (Tournoüer, 1875), IGF 11947, mm 19.



1856 *Paludina frauenfeldi* Hörnes, p. 272, pl. 47, figs 18a-b.
 1966 *Hydrobia frauenfeldi* - Strausz, p. 63, fig. 36.
 1970 *Hydrobia frauenfeldi* - Baluk, p. 117, pl. 9, figs 3a-b.
 2012 *Hydrobia frauenfeldi* - D'Amico et al., p. 165, pl. 2, fig. 22.
 2013 *Hydrobia frauenfeldi* - Tămaş et al., p. 75, fig. 3, k (cum syn.).

Material: About 400 spms in sample MQ1 (LUP₁).

Description. Species with intraspecific variability in outline, slender profile, formed by six convex whorls separated by deep suture. Protoconch of about 1.5 straight whorls. Surface of the teleoconch with only streaks growth. Last whorl about 50% of the total. The aperture is oval with a continuous peristome and a simple outer lip. Umbilicus barely visible.

Discussion. Hydrobiids live on muddy substrata of brackish-water environments (references in D'Amico et al. 2012). In the Tortonian it is typically associated with *G. bicinctum* (Harzhauser & Kowalke 2002; D'Amico et al. 2012), suggesting similar intertidal or shallow subtidal distributions.

Distribution. Abundant in the middle Miocene of Paratethys (Zagyvai & Gábor 2008; Tămaş et al. 2013) and the Tortonian of Calabria (D'Amico et al. 2012).

Family Stenothyridae Tryon, 1866

Genus *Stenothyrella* Wenz, 1939

Type species - *Nematuroa lubricella* Sandberger, 1859

Stenothyrella schwartzi (Frauenfeld in Hörnes, 1856)

Fig. 10F

1856 *Paludina schwartzi* Frauenfeld in Hörnes, p. 589, pl. 47, figs 25a-c.
 1966 *Stenothyra schwartzi* - Strausz, p. 66, fig. 38, pl. 13, figs 24-27.
 1970 *Stenothyrella schwartzi* - Baluk, p. 117, pl. 9, fig. 12.
 2002 *Stenothyrella schwartzi* - Harzhauser, p. 84, pl. 12, fig. 3.
 2012 *Stenothyrella schwartzi* - D'Amico et al., p. 166, pl. 2, fig. 25.

Material: 12 spms in sample MQ1 (LUP₁).

Description. Small size, solid, cylindrical shell with three convex teleoconch whorls separated by deep sutures, apex large and rounded, last whorl high a little less than total height, ending with a roundish aperture not adherent to the last whorl; peristome margin strongly thickened.

Discussion. This species has been assigned to several genera: *Paludina*, *Nodulus*, *Stenothyra*, *Anabathron*, *Stenothyrella*. The Monti Livornesi specimens correspond to the description of *S. schwartzi* collected in Tortonian strata at Cessaniti, Calabria (D'Amico et al. 2012). Modern Stenothyridae inhabit rivers, streams and estuarine environments (Strong et al 2008).

Distribution. This species has been reported in the early Miocene of the North Alpine Foreland Basin (Harzhauser 2002), middle Miocene of the Vienna Basin and Paratethys (Strausz 1966), and Tortonian of Calabria (D'Amico et al. 2012).

Family Tornidae Sacco 1896

Genus *Tornus* Turton & Kingston, 1830

Type species - *Helix subcarinata* Montagu, 1803

Tornus subcarinatus (Montagu, 1803)

Fig. 10G

1803 *Helix subcarinata* Montagu, p. 438, pl. 7, fig. 9.

1999 *Tornus subcarinatus* - Anistratenko, p. 54.

Material: 11 adult spms in sample MQ1 (LUP_b).

Discussion. Widely distributed in Europe from the Pliocene to the modern, the species is reported only once for the Miocene (Anistratenko 1999).

Distribution. Middle Miocene of Ukraine (Anistratenko 1999), Pliocene to Recent in Europe (Chirli 2006).

Order **Neogastropoda** Wenz, 1938

Superfamily Muricoidea Rafinesque, 1815

Family Muricidae Rafinesque, 1815

Genus *Chicoreus* Montfort 1810

Type species - *Murex ramosus* Linnaeus, 1758

Hexaplex austriacus (Tournoüer, 1875)

Fig. 11R-S

1875 *Murex austriacus* Tournoüer, p. 158.

1911 *Murex Austriacus* - Trentanove, p. 63-64.

1956 *Murex (Hexaplex) austriacus* - Ruggieri, p. 148.

Material: One spm (IGF 11947); a fragment in sample MQ2.

Discussion. The Quarata specimen is less globular than the typical form (Hörnes 1856, pl 23, figs 1-5; Landau et al. 2013, pl 21, fig 4) and has an evident spiral spiny sculpture that is missing in specimens referred to *H. austriacus* by Merle and co-authors (2011, pl 37, Fig. 7). It is similar to the specimen figured in Kovács et al. (2018, Fig. 2 J-K). We agree with the interpretation given by Trentanove (1911), until better material is available.

Distribution. Early-Middle Miocene. Burdigalian of Germany (Moths et al. 2010), Langhian

of Piedmont (Zunino & Pavia 2009). Paratethys. Middle Miocene: (Austria, Bosnia, Bulgaria, Hungary, Poland, Romania), Proto-Mediterranean Sea (Turkey: Kovács et al. 2018).

Genus *Heteropurpura* Jousseau, 1880

Type species - *Murex polymorphus* Brocchi, 1814

Heteropurpura dertonensis (Mayer in Bellardi, 1873)

Fig. 11K-J

1873 *Murex dertonensis* Mayer in Bellardi, p. 107, pl. 7, figs 12a-b.

1911 *Murex dertonensis* - Trentanove, p. 62.

1935 *Ocenebra dertonensis* - Montanaro, p. 36, pl. 3, figs 1-2a-b.

1935 *Ocenebra dertonensis* f. *crassa* - Montanaro, p. 36, pl. 3, figs 3a-b.

1956 *Tritonalia (T.) dertonensis* - Ruggieri, p. 148.

2011 *Ocenebrina dertonensis* - Caprotti, p. 63, figs 6 O-P.

2012 *Ocenebrina dertonensis* - D'Amico et al., p. 168, pl. 3, figs 30-32. (cum syn.).

Material: 8 spms (IGF 11948) (LUP_{hist}); 24 spms in samples MQ1-MQ2 (LUP_b).

Discussion. Tortonian of Montegibbio, showing a wide variability (Montanaro 1935). We assign the species to genus *Heteropurpura* Jousseau, 1880, instead of *Ocenebrina* Jousseau, 1880, for the general shape of the shell and for having the anterior siphonal canal always open, as in the type species.

Distribution. Common in the Tortonian at Stazzano and Sant'Agata (Bellardi 1873; Bernasconi & Robba 1993), Montegibbio (Montanaro 1935) and Cessaniti (Vazzana & Cecalupo 2007; D'Amico et al. 2012).

Superfamily Buccinoidea Rafinesque, 1815

Family Nassariidae Iredale, 1916 (1835)

Genus *Tritia* Risso, 1826

Type species - *Buccinum reticulatum* Linnaeus, 1758

Tritia agatensis (Bellardi, 1882)

Fig. 11A-B; C-D

1847 *Nassa Dujardini* - Michelotti, p. 210, pl. 12, fig. 5.

1882 *Nassa agatensis* Bellardi, p. 27, pl. 1, figs 22a-b.

1882 *Nassa pulchra* - Bellardi, p. 29, pl. 1, figs 24a-b.

1911 *Nassa Saccoi* Trentanove, p. 55, pl. 4, figs 34-37.

1911 *Nassa Cocchii* Trentanove, p. 58, pl. 4, figs 32-33, 38.

2013 *Nassarinus agatensis* - Harzhauser et al., p. 361, pl. 1, fig. 11 (cum syn.).

Material: 24 spms (IGF 11970-71, IGF 103069-72, IGF 103079) (LUP_{hist}); 46 spms in samples MQ1 and MQ2 (LUP_b).

Discussion. Trentanove (1911) described this species under the names *N. saccoi* n. sp. and *N. cocchii*, distinguishing them for their more or less globular profile (Harzhauser & Cernohorsky 2011; Harzhauser et al. 2013). Following the recent revision of family Nassariidae based on molecular data, we assign all species previously belonging to genus *Nassarius* (a waste-basket genus) to genus *Tritia* Risso, 1826 (Galindo et al. 2016).

Distribution. Tortonian of the Mediterranean area (Quarata, Montegibbio, S. Agata, Stazzano), Messinian of Emilia (Venzo & Pelosio 1963) and Sicily (Harzhauser et al. 2013).

Tritia coloratus (Eichwald, 1830)

Fig. 11E-F; G-H

1830 *Buccinum coloratum* Eichwald, p. 222.

1869 *Buccinum Dujardini* var. - Manzoni, p. 487, pl. 1, fig. 8

1911 *Nassa manzonii* Trentanove, p. 59, pl. 4, figs 42-45.

2004 *Nassarius coloratus* - Harzhauser & Kowalke, p. 17-18, pl. 2, fig. 5.

Material: 4 spms (IGF 11967, 103065-67) (LUP_{hist}); 66 spms in samples MQ1-MQ2 (LUP_p).

Discussion. Highly variable species described under the name *N. manzonii* by Trentanove (1911), based on *Nassa Dujardini* non Desh. (var. 3) in Manzoni (1869), from the Tortonian of Sogliano (FC). Trentanove reports that his species differs from *N. vindobonensis* Mayer, 1860 by a thinner columellar callus, a less elongated opening and shallower ribs. These characters are not diagnostic and we place *N. manzonii* in synonymy with *N. coloratus* (Eichwald, 1830) (= *N. vindobonensis* Mayer, 1860, see Harzhauser & Kowalke 2004).

Distribution. The species is described from the Middle Miocene of the Vienna Basin and the entire Central Paratethys (Harzhauser & Kowalke 2004).

Superfamily Conoidea [unassigned]

Family Clavatulidae Gray, 1853

Genus *Clavatula* Lamarck, 1801

Type species - *Clavatula coronata* Lamarck, 1801

Clavatula coppii Bellardi, 1877

Fig. 11L

1877 *Clavatula Coppii* Bellardi, p. 163, pl. 5, fig. 25.

1911 *Clavatula Coppii* - Trentanove, p. 53, pl. 4, figs 23-25.

1960 *Clavatula coppii* - Glibert, p. 38.

1982 *Clavatula Coppii* - Ferrero Mortara et al., p. 75, pl. 14, fig. 8.

Material: 28 spms (IGF 11973-74) (LUP_{hist}); 45 spms in samples MQ1-MQ2 (LUP_p).

Description. Medium or large fusiform shell, paucispiral protoconch with two smooth whorls. Adult shell of about seven whorls, the last about half of total spire height. Impressed sutures with two rows of 12-14 large nodes, one row below the suture, the second in the middle of the whorl. Faint or no ornaments between the rows. Growth lines on the outer surface, marked by the sinuous impression of the anal fasciole. Last whorl with two carina and rhomboidal peristome, anteriorly elongated.

Discussion. It is distinguished from *C. sotterii* (Michelotti, 1847) from the Tortonian of Montegibbio by its fusiform shape and the lack of ornaments between the nodes. *C. mystica* (Doderlein in Manzoni, 1869) from the Messinian of Sogliano (near San Marino) is smaller and has only one row of nodes below the suture (see also Bellardi 1877, p. 163, and discussion below).

Distribution. Tortonian of Emilia (Montegibbio).

Clavatula mystica (Doderlein in Manzoni, 1869)

Fig. 11M-N

1869 *Pleurotoma intersecta* vel *mystica* Doderlein in Manzoni, p. 18, pl. 2, figs 5-6.

1877 *Pl. intersecta* - Bellardi, p. 164.

1911 *Clavatula mystica* - Trentanove, p. 54, pl. 4, figs 28-31.

1911 *Clavatula pugilis* - Trentanove, p. 53 [non *Clavatula pugilis* (Doderlein in Bellardi, 1877)].

1911 *Clavatula Cocchii* - Trentanove, p. 53.

Material: 41 spms (IGF 11976-11981) (LUP_{hist}); 14 spms in samples MQ1-MQ2 (LUP_p).

Description. Turreted and fusiform shell of rather small dimensions, with paucispiral protoconch. Six or seven whorls in adult shell, the last whorl about half of the whole spire. Its early four teleoconch whorls have a subparallel periphery, the following three whorls have a gradate outline, caused by a thickening of the subsutural margin when this becomes nodulose and bulgy, with a rather large anal fasciole. Spiral ornaments formed by contiguous and shallow costae. Subcircular peristome, elongated towards the short anterior canal.

Discussion. As recognized by Manzoni (1869), it differs from *C. sotterii* (Michelotti, 1847) from the Tortonian of Montegibbio for its gradate outline. Bellardi (1877) recognized similitudes with

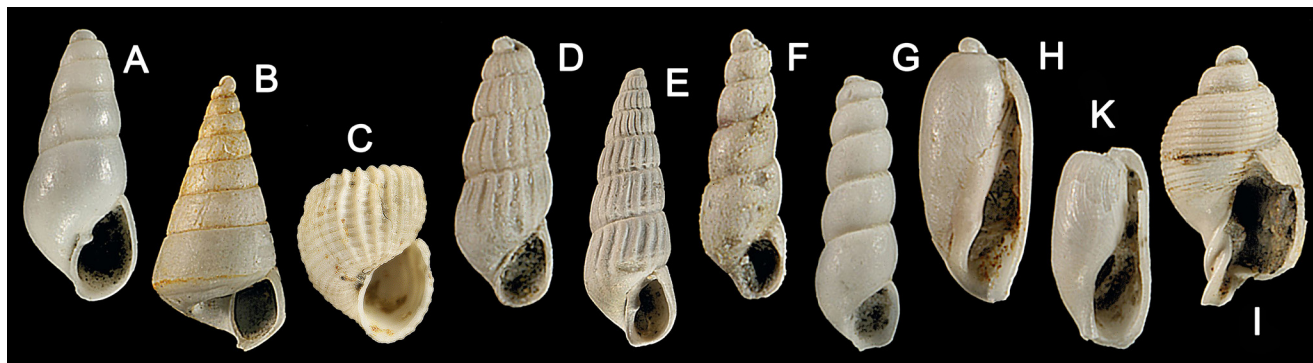


Fig. 12 - Heterobranchia of the Luppiano unit (LUP_v) A) *Brachystomia* cfr. *B. carrozzai* (van Aartsen, 1987), LUP_v, MQ1, mm 2; B) *Nisosyrnola concava* (Boettger, 1907), LUP_v, MQ1, mm 3; C) *Chrysallida* cfr. *C. pygmaea* (Grateloup, 1838), LUP_v, MQ1, Ø mm 2; D) *Parthenina indistincta* (Montagu, 1808), LUP_v, MQ1, mm 1.5; E) *Parthenina terebellum* (Philippi, 1844), LUP_v, MQ1, mm 3.5; F) *Ebala pointeli* (de Folin, 1868), LUP_v, MQ1, mm 1.6; G) *Henrya wareni* Landau et al., 2013, LUP_v, MQ1, mm 1.3; H) *Acteocina lajonkairana* (Basterot, 1825), LUP_v, MQ1, mm 1.5; K) *Retusa truncatula* (Bruguière, 1792), LUP_v, MQ1, mm 0.9; I) *Ringicula minor* (Grateloup, 1838), LUP_v, MQ1, mm 1.7.

his *C. cocchii*, justifying the identification of juvenile specimens of *C. mystica* (IGF 11981) with *C. cocchii* Bellardi, 1877 (Trentanove 1911). Specimens with a squat shape, but still retaining the diagnostic gradate outline and the presence of elongated costae, in the place of nodes, in the middle of the last whorl, allow to reinterpret specimens included by Trentanove (1911) and place them in *C. pugilis* Doderlein, 1862 (IGF 11977-11979).

Distribution. Upper Miocene of Emilia Romagna (Vigoleno, Sassuolo, Sogliano: Manzoni 1869).

Clavatula sotterii (Michelotti, 1847)

Fig. 11O-Q

- 1847 *Pleurotoma sotterii* Michelotti, p. 302.
 1853 *Pleurotoma sotterii* - Hörnes, p. 338, pl. 36, fig. 16.
 1877 *Clavatula sotterii* - Bellardi, p. 159, pl. 5, fig. 15.
 1877 *Clavatula calcarai* Bellardi, p. 159, pl. 5, fig. 16.
 1877 *Clavatula turgidula* Bellardi, p. 159, pl. 5, fig. 17.
 1896a *Clavatula* cf. *Sotteri* - Sacco, p. 214.
 1911 *Clavatula turgidula* - Trentanove, p. 53.
 1937 *Clavatula sotterii* - Montanaro, p. 117-118, pl. 5, figs 2-18.
 1982 *Clavatula calcarai* - Ferrero Mortara et al., p. 75, pl. 12, fig. 11.
 1982 *Clavatula turgidula* - Ferrero Mortara et al., p. 75, pl. 14, fig. 2.
 2011 *Clavatula sotterii* - Caprotti, p. 69, figs 8M-N.
 2013 *Clavatula sotterii* - Landau et al., p. 287, pl. 7, figs 7-12.

Material: 3 spms (IGF 11975; LUP_{hist}); 54 spms in MQ1-MQ2 (LUP_v).

Discussion. Wide variability of shape and spiral and longitudinal sculpture (Montanaro 1937; Ferrero Mortara et al. 1981) suggesting to abandon the use of *Clavatula calcarai* Bellardi, 1877 and *C. turgidula* Bellardi, 1877 as junior synonyms of *C. sotterii*. Three specimens referred to *C. turgidula* by Trentanove

(1911) are characterised by a squat shape, a short siphonal canal and a minute secondary spiral sculpture, also typical of Turkish specimens from brackish-water paleoenvironments (Landau et al. 2013). A comparison with the latter suggests differences in the form of the protoconch worth of further scrutiny.

Distribution. Middle Miocene of the Vienna Basin and Turkey (Landau et al. 2013); late Miocene of Piedmont (Bellardi 1877).

Subclass **HETEROBRANCHIA** Gray, 1840

Superfamily Pyramidelloidea Gray, 1840

Family Pyramidellidae Casey, 1904

Genus *Brachystomia* Monterosato, 1884

Type species - *Odostomia scalaris* MacGillivray, 1843

Brachystomia cfr. *B. carrozzai* (van Aartsen, 1987)

Fig. 12A

Material: 2 spms in sample MQ1 (LUP_v).

Description. Small species, generally of elongated shape, smooth. Protoconch type B, large (> 300 microns). The whorls are a little convex, suture marked, the last whorl is about 60% of the total. Elongated opening with inner tooth at one half of the columella. Umbilicus barely hinted.

Discussion. The living species is present throughout the Mediterranean, at infralittoral and upper circalittoral depths. Very variable in shape, it is characterised by the large protoconch, the last whorl quite high and a columellar tooth inside the aperture, details found in the few specimens collected at Quarata.

Distribution. Known for the Pliocene in Italy (Chirli & Micali 2011), *B. carrozzai* is presently distributed throughout the Mediterranean, particularly in the western sector (van Aartsen 1987).

Genus *Nisosyrnola* Landau, Harzhauser, İslamoğlu & Marques da Silva, 2013

Type species - *Nisosyrnola concava* (Boettger, 1907)

Nisosyrnola concava (Boettger, 1907)

Fig. 12B

1907 *Niso concava* Boettger, p. 107, no. 377.

1934 *Niso concava* - Zilch, p. 233, pl. 11, fig. 94.

2013 *Nisosyrnola concava* - Landau et al., p. 307, fig. 28, pl. 52, figs 7-8, pl. 74, fig. 11 (cum syn.).

Material: 18 spms in sample MQ1 (LUP_p).

Description. Shell small, solid, conical profile, flat whorls with incised suture, last whorl with angled base at the periphery, widely and deeply umbilicated. Aperture subquadrangular with columella smooth and arched outer lip smooth. Protoconch heterostrophic of about 1.5 whorls, elevated, with an angle of about 30° (see Boettger 1907, pl. 52, figs 7-8; pl. 74, fig. 11).

Discussion. The genus *Nisosyrnola* is characterised by shells with a conical (coeloconoid) profile, heterostrophic protoconch and columella smooth (*N. concava* is the Type species - by monotypy: Landau et al. 2013). This new pyramidellid genus is similar to species of eulimid genus *Niso* Risso, 1826. However, *N. concava* has a typical type 2-pyramidellid protoconch (following van Aartsen 1987).

Distribution. *N. concava* has been described for the Langhian-Serravallian of Romania (Boettger 1907) and (Zilch 1934) and the Serravallian of Turkey (Landau et al. 2013).

Genus *Chrysallida* Carpenter, 1856

Type species - *Chemnitzia communis* C. B. Adams, 1852

Chrysallida* cfr. *C. pygmaea (Grateloup, 1838)

Fig. 12C

Material: 1 fragment in sample MQ1 (LUP_p).

Description. The fragment, barely more than a whorl, conforms to a scalariform shell outline with incised sutures typical of the species. The axial ribs are stronger than the spiral, narrower than

the interspaces, continue to the base and are a little crowned near the suture. The spiral sculpture consists in a number of incised lines. Oval aperture, columella with a small tooth, several teeth are sometimes visible inside the outer lip. Umbilicus wide. Type B protoconch, tending to type C.

Discussion. Species described under the name of *Rissoa costulata* S. Wood, 1848, in the Miocene of France and the Pliocene (Crag) of England, it possibly corresponds to *C. stefanisi* (Jeffreys, 1869) according to Aartsen (1987). The average size, up to 4 mm in *Chrysallida pygmaea subtypica* Sacco, 1892 (frequent in the Tortonian at Montegibbio), exceeds that of our specimen.

Distribution. Middle Miocene of the Vienna Basin and Peratethys (Strausz 1966).

Genus *Parthenina* Bucquoy, Dautzenberg & Dollfus, 1883

Type species - *Odostomia interstincta* (Adams J., 1797)

Parthenina indistincta (Montagu, 1808)

Fig. 12D

1808 *Turbo indistinctus* Montagu, p. 129.

2014 *Parthenina indistincta* - Høisæter, p. 15, fig. 5. (cum syn.).

Material: 2 spms in sample MQ1 (LUP_p).

Description. Profile elongated, turritiform, with flat or slightly convex whorls, suture not very deep, narrower on the adapical zone. Axial sculpture of about 20 ribs, orthocline, straight or slightly flexuous, reaching the basal zone. Two spiral ribs on the adapical zone of the penultimate whorl, three or, more rarely, four spiral ribs on the last whorl. Faint umbilicus and columnellar folds. Type C protoconch.

Distribution. The species is widespread, but never abundant, in the infralittoral of the modern Mediterranean (Giannuzzi Savelli et al. 2014).

Parthenina terebellum (Philippi, 1844)

Fig. 12E

1844 *Chemnitzia terebellum* - Philippi, p. 136, pl. 24, fig. 12.

Material: 1 spm in sample MQ1 (LUP_p).

Description. Profile very elongated, turritiform, flat or slightly convex whorls, suture marked, but not deep. Axial sculpture of 20 nearly flat,

opisthocline ribs, which end before they reach the base. Two very close spiral cordlets on the median zone on the last whorl, one abapical cordlet on the upper whorls. Columellar lip with one well-marked fold. The umbilicus is very narrow. Type B protoconch.

Distribution. In the Mediterranean this species is the largest of its genus. Uncommon, it is more frequent in the Adriatic Sea. It prefers lagoons and low-energy areas sheltered from the open sea (Giannuzzi-Savelli et al. 2014).

Superfamily Murchisonelloidea Casey, 1904

Family Murchisonellidae Casey, 1904

Genus *Ebala* Gray, 1847

Type species - *Ebala pointeli* (de Folin, 1868)

Ebala pointeli (de Folin, 1868)

Fig. 12F

1868 *Turbonilla pointeli* de Folin, p. 100, pl. 11, fig. 4.

Material: 31 spms in sample MQ1 (LUP_p).

Description. Profile elongated and subcylindrical with the whorls very convex, suture deep, shell hyaline. The surface with prosocline growth lines. Aperture subcircular. The protoconch is of the type B, planorbid and inclined.

Discussion. This polymorphic species, with some varieties and subspecies with no taxonomic value, is very similar to *E. nitidissima* Montagu, 1803, which is distinguished by having a very fine spiral striation covering the whole surface.

Distribution. Presently common in the infralittoral throughout the Mediterranean (Van Aartsen 1994).

Genus *Henrya* Bartsch, 1947

Type species - *Henrya henryi* Bartsch, 1947

Henrya wareni Landau, Harzhauser, İslamoğlu & Marques da Silva, 2013

Fig. 12G

2001 *Murchisonella* cfr. *bezanconi* - Lozouet

2013 *Henrya wareni* Landau et al., p. 322, pl. 76, figs 10a-d.

Material: 2 spms in sample MQ1 from Quarata (LUP_p).

Description. Shell very small, elongated, cylindrical profile. Apex with blunt protoconch of

about one whorl, smooth. Teleoconch about 5.5-6 convex whorls, suture marked and oblique. Last whorl rounded, oval aperture with thin outer lip. Smooth surface.

Discussion. Based on the majority of characters, we included our specimens in *H. wareni*, although the fine spiral sculpture is unclear. Genus *Henrya* Bartsch, 1947, is placed in family Ebalidae by Warén (1994), whereas Rosenberg et al. (2009) assigned it to the Murchisonellidae. It is characterised by shells with an elongate-pupoid outline and by strongly inflated teleoconch whorls. The apex is blunt, the protoconch consisting of a single rounded whorl (Bartsch 1947). Its geologically oldest record is in the Aquitanian of France, described as *Murchisonella* cfr. *bezanconi* (Cossmann, 1892) by Lozouet et al. (2001). The presence of a distinct keel in the middle of the whorl prevents the attribution of this species to *Murchisonella*. The three Caribbean species *H. henryi* Bartsch, 1947, *H. goldmani* Bartsch, 1947 and *H. morrisoni* Bartsch, 1947 are differentiated by their weak spiral sculpture and a more conical profile.

Distribution. Aquitanian of France (Lozouet et al. 2001) and Serravallian of Turkey (Landau et al. 2013).

Superfamily Bulloidea Gray, 1827

Family Acteocinidae Dall, 1913

Genus *Acteocina* Gray, 1847

Type species - *Acteon wetberellii* Lea, 1833

Acteocina lajonkaireana (Basterot, 1825)

Fig. 12H

1825 *Bullina lajonkaireana* Basterot, p. 22, pl. 1, fig. 25.

2002 *Acteocina lajonkaireana* - Harzhauser, p. 127, pl. 11, fig. 18.

2012 *Acteocina lajonkaireana* - D'Amico et al., p. 172, pl. 3, fig. 39.

2013 *Acteocina lajonkaireana* - Landau et al., p. 333, pl. 53, figs 3, 4, pl. 77, fig. 9 (cum syn.).

Material: 6 incomplete spms in sample MQ1 (LUP_p).

Discussion. The few fragments are referable to this species from the peculiar characteristic of the protoconch which protrudes from the upper part of the teleoconch spirals which has a canalized suture.

Distribution. The species has been reported in the early Miocene of France, Italy and Austria (Burdigalian), middle Miocene of France, Italy, Germany, Turkey and the Paratethys, late Miocene of Portugal and Italy (Tortonian: D'Amico et al. 2012).

Family Retusidae Thiele, 1925

Genus *Retusa* T. Brown, 1827

Type species - *Bulla obtusa* Montagu, 1803

Retusa truncatula (Bruguière, 1792)

Fig. 12K

1792 *Bulla truncatula* Bruguière, p. 377.

2012 *Retusa truncatula* - D'Amico et al., p. 171, pl. 3, fig. 38.

2013 *Retusa truncatula* - Chirli, p. 49, pl. 11, figs 11-18.

2013 *Retusa truncatula* - Landau et al., p. 337, pl. 77, fig. 11(cum syn.).

Material: 2 spms and few fragments in sample MQ1.

Distribution. Reported in the early Miocene of the Mediterranean area (see discussions in D'Amico et al. 2012; Landau et al. 2013), the species presently lives in the Black Sea, Mediterranean, central and northeastern Atlantic.

Superfamily Ringiculoidea Philippi, 1853

Family Ringiculidae Philippi, 1853

Genus *Ringicula* Deshayes in Lamarck, 1838

Type species - *Marginella auriculata* Ménard de la Groye, 1811

Ringicula minor (Grateloup, 1838)

Fig. 12I

1838 *Auricula ringens* var. b. *minor* Grateloup, p. 286, pl. 6, fig. 8.

2012 *Ringicula minor* - D'Amico et al., p. 170, pl. 3, fig. 36.

2019 *Ringicula minor* - Thivaïou et al., p. 346, fig. 7C1, C2 (cum syn.).

Material: 8 incomplete spms in sample MQ1 (LUP_p).

Description. Shell small, conical, globose, whorls convex, the last well developed, acute spire, apex prominent. Paucispiral protoconch consisting of about 1.5 whorls. Surface crossed by spiral lines. Aperture elongated, below canaliculate. Outer lip thickened, swollen in the middle, inside smooth. Columellar lip callous, with one tooth on the upper third and two oblique columellar fold on the lower, converging to the inner (See D'Amico et al. 2012, pl. 3, fig. 36).

Discussion. In the Aquitanian of Greece, the species is frequently associated with a shallow marine assemblage (Thivaïou et al. 2019). Modern deep sea species of *Ringicula* feed on benthic foraminifera (Chaban et al. 2017).

Distribution. This species is widespread in the Aquitanian of France (Grateloup 1838) and Greece (Thivaïou et al. 2019), the middle Miocene of Turkey and Paratethys (Landau et al. 2013) and

the Tortonian of Italy (D'Amico et al. 2012). The early Pleistocene record of Monte Mario (Cerulli Irelli 1912) is doubtful.

Class **BIVALVIA** Linnaeus, 1758

Subclass **PROTOBRANCHIA** Pelseneer, 1889

Order **Nuculanida** Carter, Campbell & Campbell, 2000

Family Nuculanidae Adams & Adams, 1858 (1854)

Genus *Lembulus* Risso, 1826

Type species - *Arca pella* Linnaeus, 1758

Lembulus pella (Linnaeus, 1758)

1901 *Leda pella* var. *antecarinata* Trentanove, p. 533, pl. 9, figs 4-6.

1911 *Leda pella* var. *antecarinata* - Trentanove, p. 74.

1956 *Leda pella* - Ruggieri, p. 146.

Material: 25 articulated spms (IGF 11810-11812, 11923, 102901) (LUP_{hist}); 6 spms in sample MQ2 (LUP_p).

Distribution. Middle Miocene of Austria and Italy; Pliocene of Normandy (Lozano-Francisco 1997, and La Perna 2007, cum syn.) and Italy (Lozano-Francisco 1997; Dominici et al. 2018); modern Atlantic, from Angola to Portugal, and Mediterranean (Lozano-Francisco 1997; Poppe & Goto 1993).

Subclass **PTERIMORPHIA** Beureln, 1944

Order **Arcida** Lamarck, 1809

Superfamily Arcoidea Lamarck, 1809

Family Arcidae Lamarck, 1809

Genus *Anadara* Gray, 1847

Type species - *Arca antiquata* Linnaeus, 1758

Anadara firmata (Mayer, 1868)

Fig. 13A-B

1868 *Arca firmata* Mayer, p. 16, 70.

1868 *Arca syracusensis* Mayer, p. 18, 72.

1878 *Arca Breislaki* - Capellini, p. 5, 6, 10.

1878 *Arca turonica* - Capellini, p. 6, 10.

1901 *Arca syracusensis* - Trentanove, p. 532, pl. 8, fig. 4.

1911 *Arca syracusensis* - Trentanove, p. 74.

1963 *Arca (Arca) turonica varanensis* - Venzo & Pelosio, p. 142, pl. 42, figs 15, 19.

2013 *Anadara firmata* - Harzhauser et al., p. 365, pl. 2, figs 6-7 (cum syn.).

Material: Three valves (Popogna: IGF 102898, 102900; LUP_{hist}); one articulated juvenile, four disarticulated juvenile valves,

eight valves and fragments of adults (Quarata: IGF 11911; LUP_{hist}); 31 spms in sample MQ2. All Quarata shells are matrix-free and in original aragonite. All Popogna specimens are associated with a lithified sandy matrix.

Discussion. Some specimens show a more pronounced oblique trapezoidal shape, posterior side being more developed. Costae are from 32 (Trentanove 1901, pl. 8, Fig. 4) to 37-38 (Trentanove 1901, pl. 2, figs. 1a). *Anadara breislaki* (Basterot, 1825) is a non-valid species according to Cossmann & Peyrot (1912, p. 274, 286). *Anadara turonica* (Dujardin, 1837), found in lower Miocene of Paratethys (Zuschin et al. 2004), is smaller, thinner, with 26-28 costae and lacking medial sulcus. Harzhauser et al. (2013) recognised that Tortonian and Messinian specimens attributed to *Anadara turonica* are to be understood as *Anadara firmata* (Mayer, 1868). The same authors pose the problem of the conspecificity between *Anadara firmata* and *Anadara darwini* (Mayer, 1868), both first described form specimens collected at the same Miocene locality, the second eventually being a junior synonym. A relationship between upper Miocene *A. firmata* (Livorno Hills and Sicily: Harzhauser et al. 2013) and Pliocene *Anadara pectinata* (Brocchi, 1814) is also underlined. Differences are subtle (a more pronounced medial sulcus in *Anadara pectinata* and a more inflated shell: Harzhauser et al. 2013) and may just fall within infraspecific variability, in which case *Anadara pectinata* would be a junior synonym. The latter is very common in the Mediterranean Pliocene (Brocchi, 1814; Sacco, 1898b), also under the synonyms *Anadara darwini* (Mayer, 1868) and *Anadara empolensis* Micheli & Torre, 1965 (e.g., Benvenuti & Dominici 1992, Pl. 1, figs 2, 4). *Anadara syracusensis* (Mayer, 1868) is synonymised with *Anadara firmata* (Mayer, 1868) by Harzhauser et al. (2013), and with *Anadara pectinata* (Brocchi, 1814) by Garilli (2011), who recognises the frequent misunderstandings have concerned species of this thermophilic genus.

Order **Pectinida** Gray, 1854
 Superfamily Anomioidea Rafinesque, 1815
 Family Anomiidae Lamarck, 1809
 Genus *Anomia* Linnaeus, 1758
 Type species - *Anomia ephippium* Linnaeus, 1758

Anomia ephippium Linnaeus, 1758

1911 *Anomia ephippium* - Trentanove, p. 71-72.

Material: Seven valves (IGF 11935; LUP_{hist}); one valve in sample MQ2.

Distribution. Early Oligocene of the Paratethys and Northern Sea Basin (Harzhauser & Mandic 2001), Langhian of Central and Eastern Paratethys (Studencka et al. 1998; Mandic & Harzhauser 2003); Pliocene of Tuscany (Dominici et al. 2018); modern Northeastern Atlantic (Hansson 1998) and Mediterranean (Poppe & Goto 1993).

Genus *Pododesmus* Philippi, 1837
 Type species - *Pododesmus rudis* (Broderip, 1834)

Pododesmus patelliformis (Linnaeus, 1758)

1911 *Anomia patelliformis* - Trentanove, p. 72.

Material: One valve (IGF 11936; LUP_{hist}).

Distribution. Burdigalian of the Torino Hills (Zunino & Pavia 2009), Pliocene of the Mediterranean (Lozano-Francisco 1997, cum syn.); modern Northeastern Atlantic and Mediterranean (Poppe & Goto 1993; Howson & Picton 1997).

Order **Ostreida** Férussac, 1822
 Superfamily Ostreioidea Rafinesque, 1815
 Family Ostreidae Rafinesque, 1815
 Genus *Ostrea* Linnaeus, 1758
 Type species - *Ostrea edulis* Linnaeus, 1758

Ostrea edulis Linnaeus, 1758

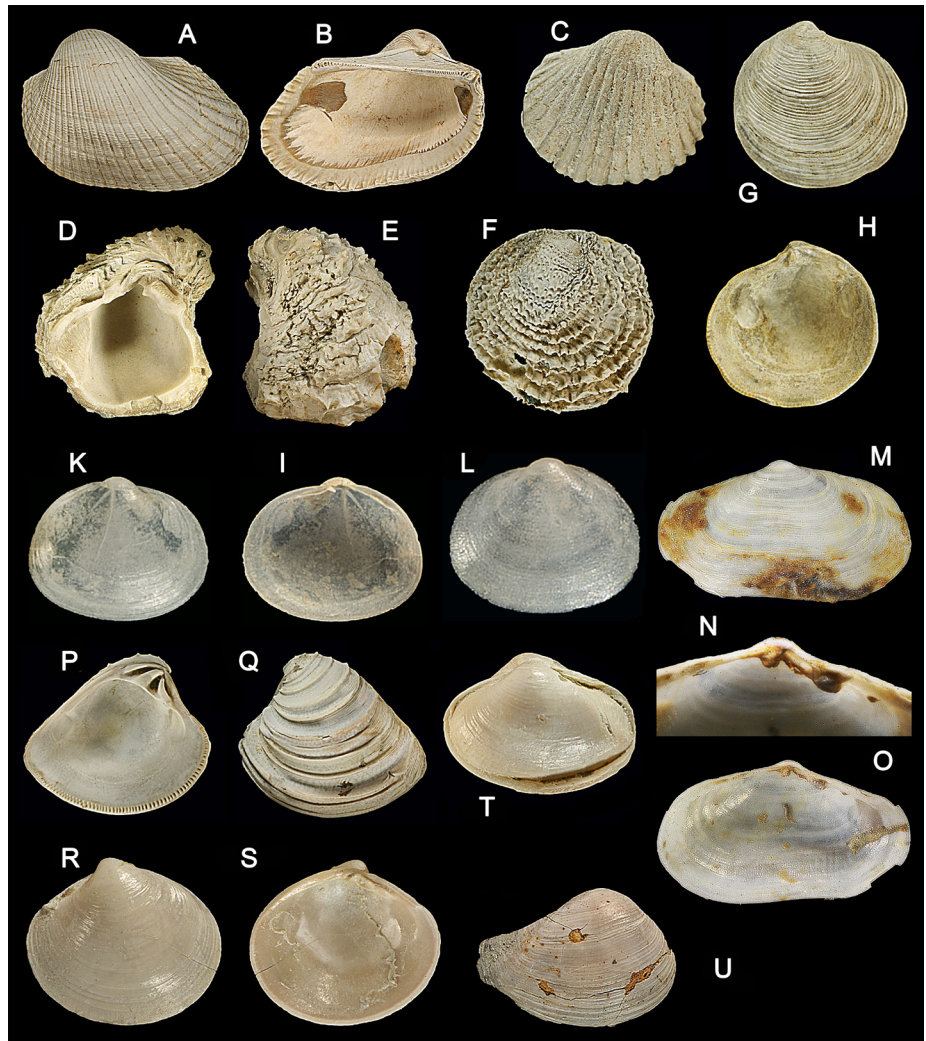
1814 *Ostrea lamellosa* Brocchi, p. 564.
 1901 *Ostrea lamellosa* - Trentanove, p. 524.

Material: Eight valves (IGF 11847; LUP_{hist}).

Distribution. From the Burdigalian of the Vienna Basin (Mandic & Steininger 2003) to the Pleistocene of Senegal and Sicily (Lozano-Francisco 1997, cum syn.). Eurytopic in the modern North Atlantic, from Norway to Spain, Mediterranean and Black Sea (Poppe & Goto 1993).

Subclass **HETERODONTA**
 Order **Cardiida** Ferussac, 1822
 Superfamily Cardioidea Lamarck, 1809
 Family Cardiidae Lamarck, 1809
 Subfamily Lymnocardiinae Stoliczka, 1870

Fig. 13 - Bivalvia of the Luppiano unit (LUP₁). A-B) *Anadara firmata* (Mayer, 1868), MQ2, mm 50.7; C) *Cerastoderma glaucum* (Bruguière, 1789), MQ2, mm 9; D-E, F) *Chama gryphoides* Linnaeus, 1758, MQ2, respectively 30 and 10 mm; G-H) *Microloripes dentatus* (DeFrance, 1823), MQ2, mm 5.8; K-I) *Hemilepton nitidum* (Turton, 1822), MQ1, mm 1.5; L) *Lepton squamosum* (Montagu, 1803), MQ1, mm 1.2; M-O) *Phasciophila phasciionis* (Dautzenberg & H. Fischer, 1925), MQ1, mm 1.6; P-Q) *Clausinella* sp. (Trentanove, 1901), MQ2, mm 22; R-S) *Gouldia minima* (Montagu, 1803), MQ1, mm 2.4; T-U) *Corbula birostrata* Trentanove, 1901, MQ1, mm 4.4.



Genus *Cerastoderma* Poli, 1795

Type species - *Cardium edule* Linnaeus, 1758

Cerastoderma glaucum (Bruguière, 1789)

Fig. 13C

1789 *Cardium glaucum* Bruguière, p. 221.

1845 *Cardium lamarckii* Reeve, p. 218, pl. 18, fig. 93.

1911 *Cardium lamarckii* var. *quaratensis* Trentanove, p. 75, pl. 4, figs 1-3.

1956 *Cardium lamarckii quaratense* Ruggieri, p. 149.

Material: 32 articulated spms (IGF 11915) and others 106 disarticulated valves (LUP_{hist}); 62 spms in sample MQ2.

Discussion. Differs from *Cerastoderma edule* (Linnaeus, 1758) by its elongated posterior end, shorter hinge, sharper ribs, with small triangular scales close together. Small size of the Monti Livornesi specimens can be caused by hydrodynamic sorting.

Distribution. The Neogene distribution of *Cerastoderma glaucum* might be obscured by its misidentification with *C. edule*, common in the Piacen-

zian of Tuscany (Dominici et al. 2018). Tortonian of Cessaniti (D'Amico et al. 2012); Holocene of the Po Plain (Scarponi & Kowalewski 2004); the species presently lives in brackish waters of the Mediterranean Sea (Weber & Zuschin 2013) and the north-eastern Atlantic, from Morocco to Norway (Malham et al. 2012).

Superfamily Chamoidea Lamarck, 1809

Family Chamidae Lamarck, 1809

Genus *Chama* Linnaeus, 1758

Type species - *Chama lazarus* Linnaeus, 1758

Chama gryphoides Linnaeus, 1758

Fig. 13D-E, F

1758 *Chama gryphoides* Linnaeus, p. 682.

1899 *Chama gryphoides* - Sacco, p. 61, pl. 13, figs 1-4.

1911 *Chama gryphoides* - Trentanove, p. 76.

Material: 14 valves and 5 articulated spms (IGF 11900; LUP_{hist}); 13 valves in sample MQ2.

Distribution. Middle Miocene of France (Cossmann & Peyrot 1912) and Paratethys (Mandic & Steininger 2003); Burdigalian of Torino Hills (Zunino & Pavia 2009); Tortonian of Northern Italy (Sacco 1899) and France (Cossmann & Peyrot 1912); Messinian of San Marino (Moroni 1956); Pliocene and Pleistocene of the Mediterranean (Lozano-Franco 1997, cum syn.); modern Atlantic, Mediterranean and Indian Ocean (Poppe & Goto 1993).

Order **Lucinida** Gray, 1854

Superfamily Lucinoidea Fleming, 1828

Family Lucinidae Fleming, 1828

Subfamily Lucininae Fleming, 1828

Genus *Microloripes* Cossmann, 1910

Type species - *Lucina dentata* DeFrance, 1823

Microloripes dentatus (DeFrance, 1823)

Fig. 13G-H

1823 *Lucina dentata* DeFrance, pag. 275.

1825 *Lucina neglecta* Basterot, p. 18, pl. 6, fig. 18.

1878 *Lucina dentata* - Capellini, p. 10.

1901 *Lucina dentata* - Trentanove, p. 5447-548.

1956 *Loripes dentatus* - Ruggieri, p. 147.

1912 *Loripes (Microloripes) dentatus* - Cossmann & Peyrot, p. 644, pl. 26, figs 81-87.

2003 *Loripes (Microloripes) dentatus* - Mandic & Harzhauser, p. 103, pl. 7, figs 1-3.

Material: Over 1300 spms (IGF 11839-11849, 11845; LUP_{his}); 332 spms in samples MQ1-MQ2 (LUP_p), 27 spms in sample TR5 (RAQ_p).

Dimensions. Average size is about 6 mm, the illustrated specimen measures 5.8 mm antero-posteriorly.

Description. Shells small, convex, suborbicular; beaks strongly prosogyrate; lunular region concave, exterior smooth with fine commarginal lirae passing partly to fine projecting lamellae; interior shell margin crenulated; hinge teeth prominent.

Discussion. Very high dominance of this species is recorded in early Miocene tidal flats deposits, in association with *Diplodonta rotundata* (Montagu, 1801) (Zuschin et al. 2004) and in organic-rich infralittoral settings with seaweeds, in association with *Corbula gibba* (Olivier, 1792) and *Gouldia minima* (Montagu, 1803) (Mandic & Harzhauser 2003). The species, as all extant lucinids (Taylor & Glover 2006), hosted chemi-symbionts.

Distribution. *Microloripes dentatus* (DeFrance, 1823) ranges from the early Miocene of Parateth-

ys (Zuschin et al. 2004) to the Zanclean of Turkey (Büyükmeriç et al. 2017). D'Amico and co-authors (2012) mention a late Pliocene record.

Order **Venerida** Gray, 1854

Superfamily Galeommatoidea Gray, 1840

Family Lasaeidae Gray, 1842

Genus *Hemilepton* Cossmann, 1912

Type species - *Lepton longifossula* Cossmann, 1895

Hemilepton nitidum (Turton, 1822)

Fig. 13K-I

1822 *Lepton nitidum* Turton, p. 63.

Material: One valve in sample MQ1 (LUP_p).

Description. Shell brittle, equivalve, nearly equilateral, oval in outline, umbo almost central, with valves compressed. Surface smooth and glossy, but are not rare specimens with punctiform sculpture. Ventral margin almost straight, side edges and dorsal rounded. Hinge with one cardinal tooth in the both valves and two lateral teeth (anterior and posterior).

Discussion. Similar to *Lepton squamosum* (Montagu, 1803), it is smaller and with a less sculptured surface.

Distribution. Reported fossil for the Crag, in England, from Wood (1851), and also in post glacial sediments at Christiania, Denmark, from Sars (1878). In Italy it is found in Pliocene intertidal sediments of the Elsa Valley (Dominici 1994) and at Estepona, in Spain (Vera-Peláez et al. 1995), in the Pleistocene at Monte Mario (Roma), Babbaurra (Caltanissetta), Monte Pellegrino, Ficarazzi (Palermo), Reggio Calabria (Cerulli Irelli 1908) and Cava Lustrelle (Lecce: Brunetti 2011). Modern shells of the species are found on a variety of substrata, from intertidal-shallow subtidal (Weber & Zuschin 2013), up to 200 m-depth, in the Mediterranean Sea and the Northern Atlantic (Hansson 1998).

Genus *Lepton* Turton, 1822

Type species - *Solen squamosus* Montagu, 1803

Lepton squamosum (Montagu, 1803)

Fig. 13L

1803 *Solen squamosus* Montagu, p. 565.

Material: One valve in sample MQ (LUP_p).

Discussion. Characterised by its typical and brittle valves ornamentation made by numerous small pits puncturing the entire shell surface but the umbo; the valves are extremely flat and their outline is rather quadrangular.

Distribution. Commensal with and attached to the undersides of the burrowing callianasid shrimps *Upogebia deltaura* and *U. stellata*, from intertidal to shelf depths in the Northeastern Atlantic and Mediterranean (Kallonas et al. 1999).

Genus *Phascoliophila* Nordsieck, 1969

Type species - *Montacuta phascolionis* Dautzenberg & H. Fischer, 1925

Phascoliophila phascolionis (Dautzenberg & H. Fischer, 1925)

Fig. 13M-O

1925 *Montacuta phascolionis* Dautzenberg & H. Fischer, p. 127, figs 2-3.

2007 *Montacuta phascolionis* - Margelli et al., p. 97, fig. 4c-d.

Material: One right valve in sample MQ1 (LUP_p).

Description. Profile sub-rectangular with the right valve slightly bigger than the left. The umbo is projected and placed almost centrally, the ventral edge is slightly concave. In both the valves there is an anterior tooth, that in the right valve is bigger. Outer surface crossed by only slight growth striae.

Discussion. This little-known species has been placed in different genera, including *Tellimya*, *Montacuta*, *Myoericina*, *Kellia*, *Phascoliophila* (Huber 2015). Following Janssen & Slik (1971) and van Aartsen (1996), the correct name is *Myoericina cortata* (Wood, 1851), described from the Pliocene. *P. phascolionis* is a junior synonym. Profile sub-rectangular, the right valve slightly bigger than the left. The umbo is projected and placed almost centrally, the ventral edge is slightly concave. In both the valves there is an anterior tooth, bigger in the right valve. Outer surface crossed only by slight growth striae.

Distribution. Wide modern distribution in the Northeastern Atlantic and Mediterranean (Carrozza 1983; van Aartsen 1996; Margelli et al. 2007), but rare.

Superfamily Veneroidea Rafinesque, 1815

Family Veneridae Rafinesque, 1815

Genus *Clausinella* Gray, 1851

Type species - *Pectunculus fasciatus* da Costa, 1778

Clausinella sp. (da Costa, 1778)

Fig. 13P-Q

1901 *Venus pseudoscalaris* Trentanove, p. 538, pl. 8, figs 1-3

1911 *Venus pseudoscalaris* - Trentanove, p. 77

1956 *Venus (Clausinella) pseudoscalaris* - Ruggieri, p. 147.

Material: 23 right valves, 35 left valves, 3 articulated spms (IGF 11917-119118) (LUPhist); 37 spms in samples MQ1 and MQ2.

Discussion. The shell closely resembles *C. basteroti* (Deshayes, 1850), among fossil forms, which however differs for the less triangular, more rounded outline, for having more and more pronounced costae, for a longer posterior tooth. Among extant species, it resembles *C. fasciata* (da Costa, 1778), differing for its more rounded outline. Trentanove (1911) reports that the specimens of *V. pseudoscalaris* come from the sandstone facies at both Popogna and Quarata, whereas only at Quarata, is found in association with the mudstone facies (in correspondence with LUPb sample MQ).

Genus *Gouldia* C. B. Adams, 1847

Type species - *Thetis cerina* C. B. Adams, 1845

Gouldia minima (Montagu, 1803)

Fig. 13R-S

1803 *Venus minima* Montagu, p. 121, Pl. 3, fig. 3.

1900 *Gouldia minima* - Sacco, 1900, p.47, pl. 11, figs 1-4.

1908 *Gouldia minima* - Cerulli Irelli, p. 44, pl. 9, figs 12-19.

1986 *Gouldia (Gouldia) minima* - Studencka, p. 96, pl. 14, fig. 7.

1995 *Gouldia minima* - Vera-Peláez et al., p. 102.

2000 *Gouldia minima* - Popa & Chira, p. 398, pl. 3, fig. 1.

2003 *Gouldia (Gouldia) minima* - Mandic & Harzhauser, p. 105, pl. 8, figs 3-8.

Material: 25 spms in sample MQ1 (LUP_p).

Distribution. The species is found in the Burdigalian/Langhian Antwerp Fm., in Belgium (Louwye et al. 2010), the Langhian Gairdorf Fm., in Austria (Mandic & Harzhauser 2003) and the Tortonian Breda Fm., in Belgium (Vandenberghe et al. 2005). In Italy it is reported in the middle Miocene of Turin Hills (Piedmont), Tortonian of Montegibbio (Sacco 1900), and many Mediterranean Pliocene (Sacco 1900; Dominici 1994; Vera-Peláez et al. 1995; Dominici et al. 2018) and Pleistocene localities (Cerulli Irelli 1908). Modern descendants live in the Mediterranean and Northern Atlantic, from the Azores to Scandinavia (Ávila & Azevedo 1997; Hansson 1998), from intertidal to shelf depths.

Order **Myida** Stoliczka, 1870
 Superfamily Myoidea Lamarck, 1809
 Family Corbulidae Lamarck, 1818
 Genus *Corbula* Bruguière, 1797

Corbula birostrata Trentanove, 1901
 Fig. 13T-U

1878 *Corbula carinata* - Capellini, p. 10.
 1901 *Corbula birostrata* Trentanove, p. 546, pl. 9, figs 7-9.
 1911 *Corbula birostrata* - Trentanove, p. 80.
 1956 *Aloidis (Aloidis) gibba* - Ruggieri, p. 147.

Material: 49 spms (IGF 11890, IGF 103076-103125; LUP_{hist}); nine spms in sample MQ2.

Discussion. More equivalent than *Corbula gibba* (Olivi, 1792), it is also distinguished by its longer posterior end, with two opposing carinae giving it a rostrate appearance. Capellini (1878) identified it with *Corbula carinata* Dujardin, 1837, an Oligocene-Middle Miocene species. Trentanove (1911) reports also *C. gibba* and *Corbula deshayesi* Sismonda in Sacco, 1891 from the same units. Ruggieri (1956) considers *C. birostrata* a younger synonym of *C. gibba*.

SYSTEMATIC PALAEOONTOLOGY OF THE ROSIGNANO UNIT (BIOCLASTIC CALCARENITE, ROS_B)

Class **GASTROPODA** Cuvier, 1795
 Subclass **VETIGASTROPODA** Salvini-Plawen, 1980

Order **Trochida** Bouchet et al., 2017
 Superfamily Trochoidea Rafinesque, 1815
 Family Trochidae Rafinesque, 1815
 Subfamily Cantharidinae Gray, 1857
 Genus *Oxyste* Philippi, 1847
 Type species - *Trochus sinensis* Gmelin, 1791

Oxyste rotellaris (Michelotti, 1847)

1847 *Trochus rotellaris* Michelotti, p. 182.
 1901 *Oxyste rotellaris* - Trentanove, p. 520-521.
 1956 *Monodonta (Diloma) rotellaris* - Ruggieri, p. 144.

Material: Three spms (IGF 11859); 3 spms in sample BR.

Distribution. From the Burdigalian of Piedmont (Zunino & Pavia 2009) to the upper Miocene of the Canary Islands (Martín-González et al. 2018)

and Sicily (Harzhauser et al. 2013).

Subclass **CAENOGASTROPODA** Cox, 1960
 Order **Littorinimorpha** Golikov & Starobogatov, 1975

Superfamily Naticoidea Guilding, 1834
 Family Naticidae Guilding, 1834
 Genus *Cochlis* Röding, 1798
 Type species - *Cochlis flammea* Röding, 1798

***Cochlis* sp.**

1901 *Natica millepunctata* - Trentanove, p. 520.
 1956 *Natica raropunctata* - Ruggieri, p. 144.
 1956 *Natica pseudoepiglottina* - Ruggieri, p. 144.

Material: 54 spms (IGF11870, 11939; ROS_{hist}); two spms in sample BR.

Description. We assign the spotted naticids of the Livorno hills described in the literature to genus *Cochlis*, following Pedriali & Robba (2005) and Landau et al. (2013).

Distribution. *Natica millepunctata* Lamarck, 1822 is a taxonomic wastebasket. Both *Cochlis raropunctata* (Sacco, 1827) and *Cochlis pseudoepiglottina* (Sacco, 1890) (= *Natica pseudoepiglottina* Sismonda, 1847) have a late Miocene-Pliocene record throughout the Mediterranean area (Pedriali & Robba 2005).

Superfamily Xenophoroidea Troschel, 1852
 Family Xenophoridae Troschel, 1852
 Genus *Xenophora* Fischer von Waldheim, 1807

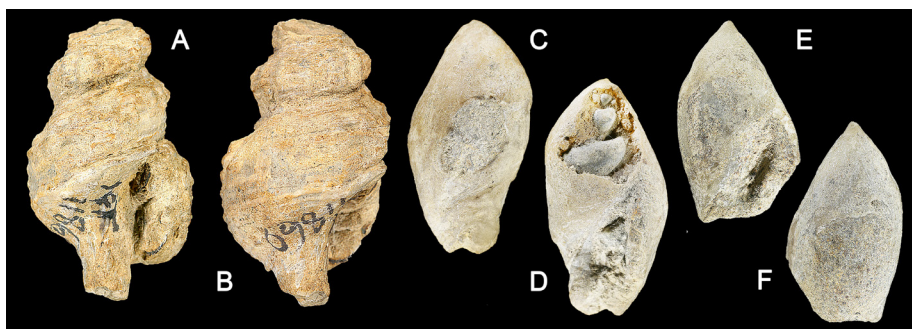
***Xenophora* sp.**

Material: One spm in sample BR (IGF 103431).

Discussion. *Xenophora* sp., with a size of 100 - 120 mm, has a shape similar to *X. plioitalica* Sacco, 1896, but the loss of the original aragonite shell and the strong compression do not allow a specific attribution. It is the first record for the genus in the Rosignano limestone.

Distribution. *X. plioitalica*, originally recorded for the Lower Pliocene of Piedmont and Liguria, was subsequently reported from the "Middle Miocene" of Montebello (Ermilia Romagna) by Moroni (1957) and the "Upper Miocene" of Dar-bel-Hamri (Morocco: references in Manganelli et al. 2003) but, both reports must be considered with prudence.

Fig. 14 - Gastropoda of the Rosignano unit (ROS_h). A-B) *Streptochetus ornatus* (d'Orbigny, 1852), IGF 11860, mm 30; C-D) *Amalda glandiformis* (Lamarck, 1810), IGF 11867, mm 30; E-F) *Amalda glandiformis* (Lamarck, 1810), IGF 11867, mm 18.



Upper Miocene of the Torrente Stirone and the Pliocene of Siena Basin (Manganelli et al. 2003).

Order **Neogastropoda** Wenz, 1938
 Superfamily **Buccinoidea** Rafinesque, 1815
 Family **Fasciolaridae** Gray, 1853
 Genus *Streptochetus* Cossman, 1889
 Type species - *Latirus aurantiacus* Montfort, 1810

Streptochetus ornatus (d'Orbigny, 1852)

Fig. 14A-B

1878 *Fusus valenciennesi* - Capellini, p. 6
 1901 *Fusus valenciennesi* - Trentanove, p. 513
 1911 *Fusus valenciennesi* - Trentanove, p. 54.
 1956 *Lathyrus* (L.) *valenciennesi* - Ruggieri, p. 143.
 1963 *Latirus* (*Latirus*) *valenciennesi* - Steininger, p. 55.
 2013 *Streptochetus ornatus* - Landau et al., p. 201-202, pl. 31, figs 7-9; pl. 67, fig. 9; pl. 80, fig. 1.

Material: Two spms (IGF 11860).

Locality: Cafaggio (43°26'56.4"N 10°26'50.3"E). The original label reports: "Along the road below the farmhouse, excursion - February 14, 1863" (Fig. 6 D).

Discussion. Ruggieri (1956), recognising that "*Lathyrus*" *valenciennesi* (Grateloup, 1840) is not reported in strata younger than Tortonian, mentions a specimen in the Capellini collection, but questions its identification. Trentanove (1901) reports the very rare presence of the species both at Popogna (Cafaggio) and Quarata. The specimens can be ascribed to unit ROS_h based on the type of fossilisation.

Distribution. Early Miocene (Steininger 1963) and middle Miocene of the Paratethys (Hörnes 1853), Tortonian of Italy (Landau et al. 2013, cum syn.).

Superfamily **Olivoidea** Latreille, 1825
 Family **Ancillariidae** Swainson, 1840
 Genus *Amalda* H. Adams & A. Adams, 1853
 Type species - *Amalda tankervillei* (Swainson, 1825)

Amalda glandiformis (Lamarck, 1810)

Fig. 14C-D; E-F

1901 *Ancillaria glandiformis* - Trentanove, p. 513.
 2013 *Amalda glandiformis* - Landau et al., p. 222-224, pl. 32, figs 9,10; pl. 68, fig. 4; pl. 80, fig. 6 (cum syn.).

Material: 2 incomplete spms (IGF 11867); 1 spm from sample BR (ROS_h).

Discussion. The species is very rare in both museum collections and in new samples. Whereas Trentanove (1901, p. 511) places his two specimens in upper "clayey marls" (RAQ_b), we found a specimen in calcarenitic deposits clearly referable to the underlying unit ROS_h. Since also museum specimens exhibit the same type of fossilization, museum specimens were included in the ROS_h fossil assemblage.

Distribution. Early Miocene to late Pliocene from the Northeastern Atlantic to the Mediterranean (Landau et al. 2013; Martín-González et al. 2018).

Class **BIVALVIA** Linnaeus, 1758
 Subclass **PTERIMORPHIA** Beureln, 1944
 Order **Mytilida** Férussac, 1822
 Family **Mytilidae** Rafinesque, 1815
 Genus *Gibbomodiola* Sacco, 1898a
 Type species - *Arca taurarcuata* Sacco, 1898a

Gibbomodiola adriatica (Lamarck, 1819)

1819 *Modiola adriatica* Lamarck, p. 112.
 1878 *Modiola brocchii* - Capellini, p. 9 (non *Modiola brocchii* Hörnes).
 1878 *Modiola* sp. - Capellini, p. 10.
 1898a *Modiola adriatica* - Sacco, p. 38-39, pl. 9, figs 20-23.
 1901 *Modiola Rosignani* Trentanove, p. 528, pl. 9, figs 1, 12.
 1911 *Modiola adriatica* - Martelli & Nelli, p. 528.
 2013 *Gibbomodiola adriatica* - Harzhauser et al., p. 364-365, pl. 2, fig. 1 (cum syn.).

Material: One left valve (IGF 11857; ROS_h).

Discussion. The species is very rare at Popogna (Trentanove 1901). Capellini (1878) lists *Modiola brocchii* Mayer, from the Rosignano Limestone, possibly also belonging to *Gibbomodiola adriatica*.

Distribution. Present in the Mediterranean during the Messinian (Harzhauser et al. 2013) and the Pliocene (Sacco 1898a, reporting on concentrations of many specimens in life position; Vera-Peláez et al. 1995; Harzhauser et al. 2013), and now distributed in the Mediterranean, the Black Sea and the Northeastern Atlantic, where is however uncommon.

Subclass **PTERIMORPHIA** Beureln, 1944

Order **Arcida** Lamarck, 1809

Superfamily Arcoidea Lamarck, 1809

Family Arcidae Lamarck, 1809

Genus *Anadara* Gray, 1847

Type species - *Arca antiquata* Linnaeus, 1758

Anadara fichteli (Deshayes, 1850)

1850 *Arca fichteli* Deshayes, p. 360.

1898b *Arca fichteli* - Sacco, p. 23, Pl. 5, figs 1-4, 6-8.

1901 *Arca corbuloides* - Trentanove, p. 531-532.

1911 *Arca corbuloides* - Trentanove, p. 74.

1911 *Arca (Anadara) fichteli* - Cossmann & Peyrot, p. 276-277, pl. 8, figs 26-30, pl. 10, fig. 62.

1956 *Arca (Arca) fichteli* - Moroni, p. 123.

1956 *Arca (Arca) fichteli sanmarinensis* Moroni, p. 124-126, pl. 9, figs 61-63, pl. 12, fig. 68, pl. 13, fig. 71.

1956 *Arca (A.) fichteli sanmarinensis* - Ruggieri, p. 145.

2001 *Anadara fichteli* - Schultz, p. 54-56, pl. 1, fig. 2 (cum syn.).

2009 *Anadara fichteli* - Hölzke, p. 71-72, fig. 3.

2009 *Anadara fichteli* - Zunino & Pavia, p. 360.

Material: Three articulated spms and a left valve (IGF 11807), one articulated fragmentary spm (IGF 11808; ROS_{hist} according to Trentanove 1901, p. 510); three articulated spms in sample BR.

Discussion. Trentanove (1901) had at first assigned Popogna specimens to *Arca fichteli*, but then discarded the idea on the basis of characters such as inflation, roundness of the ventral margin, umbo size and width of costae. The living *Anadara corbuloides* (Monterosato, 1881) is smaller and with up to 36 costae. Unknown in Miocene strata, it is considered the hypothetical descendant of Miocene *Anadara fichteli* by Sacco (1898b, p. 25). Differences mentioned by Trentanove (1901) incorporate intraspecific variation, confirmed by the presence during the Miocene of as many as five varieties recognized by Cossmann & Peyrot (1911) and one

subspecies by Moroni (1956) and Ruggieri (1956).

Distribution. Burdigalian of the Vienna Basin (Schultz 2001; Mandic & Steininger 2003; Hölzke 2009), Langhian of Turin Hills (Zunino & Pavia 2009), and Tortonian of Stazzano and Sassuolo (Sacco 1898b).

Order **Pectinida** Gray, 1854

Superfamily Pectinoidea Rafinesque, 1815

Family Pectinidae Rafinesque, 1815

Subfamily Pectininae Rafinesque, 1815

Genus *Pecten* Müller, 1776

Type species - *Ostrea maxima* Linnaeus, 1758; subsequent designation by Schmidt, 1818. Recent, eastern Atlantic

Pecten aduncus Eichwald, 1830

1830 *Pecten aduncus* Eichwald, p. 213.

1878 *Pecten aduncus* - Capellini, p. 5.

1878 *Pecten* sp. - Capellini, p. 10.

1878 *Pecten* cf. *aduncus* - Fuchs, p. 439.

1896 *Pecten vigolensis* - Simonelli, p. 328, fig. 1.

1896 *Pecten vigolensis* - Ugolini, p. 178-179.

1901 *Pecten* sp. - Fuchs in Trentanove, p. 510.

1901 *Pecten vigolensis* - Trentanove, p. 510, 526-527, pl. 9, figs 13-14.

1911 *Pecten etruscus* - Martelli & Nelli, p. 524, pl. 11, fig. 1.

1911 *Pecten etruscus* - Trentanove, p. 72-73, pl. 5, figs 1-6.

1956 *Pecten vigolensis* - Moroni, p. 129-130.

1956 *Pecten vigolensis* - Ruggieri, p. 145.

2013 *Pecten aduncus* - Harzhauser et al., p. 368, pl. 3, figs 1-2 (cum syn.).

Material: Two articulated spms (IGF 102897; ROS_{hist} according to Trentanove 1901, p. 510), 32 valves; two valves in sample BR (ROS_v).

Dimensions. Antero-posterior dimension 75 mm, dorso-ventral dimension 65 mm.

Discussion. Capellini (1878) found *Pecten* in both “Leithekalk” and overlying “Sarmatian” of the Livorno hills. He referred the first, associated with corals of the Rosignano Limestone, to *Pecten aduncus* Eichwald, 1830, and the second, found at Popogna and Cafaggio, in association with a soft-bottom, open marine fauna, to *Pecten* sp. Both forms are to be understood as *P. aduncus*, as already recognized by Fuchs (1878) for the Rosignano Limestone. Trentanove (1901) reproduces under the name *Pecten* sp. two figures from an unpublished manuscript by Fuchs, corresponding to two specimens now housed in Florence (IGF 102897). The name *Pecten etruscus*, chosen by De Stefani for specimens from the Rosignano Limestone hosted at the museum of the University of Pisa, but never published, was resurrected by Martelli & Nelli (1911) and used

by Trentanove (1911) for the Popogna specimens (IGF 102897), and many others collected at Quarata (Fig. 6 E). A longer list of *P. aduncus* synonyms, comprising *Pecten vigolensis* Simonelli, 1896 used by many authors (e.g., Trentanove 1901; Moroni 1956; Monegatti & Raffi 2010), is given by Harzhauser et al. (2013) in the description of the early Messinian fauna of Sicily. According to Capellini (1878) and Trentanove (1901), the species is typical of the Rossignano limestone (unit ROS).

Subfamily Pedinae Bronn, 1862

Genus *Talochlamys* Iredale, 1929

Type species - *Chlamys famigerator* Iredale, 1925

Talochlamys multistriata (Poli, 1795)

1795 *Ostrea multistriata* Poli, p. 164, pl. 28, fig. 14.

1901 *Pecten multistriatus* Poli - Trentanove, p. 526.

Material: One valve (IGF 11854; ROS_{hist} according to Trentanove 1901, p. 526).

Distribution. Ranging from the Aquitanian to the modern in the Mediterranean and Northeastern Atlantic (Lozano-Francisco 1977, cum syn.).

Subfamily Aequipectinini F. Nordsieck, 1969

Genus *Aequipecten* Fischer, 1886

Type species - *Ostrea opercularis* Linnaeus, 1758

Aequipecten malvinae (Dubois de Montpéroux, 1831)

Fig. 15A

1831 *Pecten Malvinae* Dubois de Montpéroux, p. 213.

1901 *Pecten Malvinae* - Trentanove, p. 526, pl. 8, fig. 11.

1956 *Chlamys (Aequipecten)* sp. Ruggieri, p. 145.

2004 *Aequipecten malvinae* - Mandic, p. 138-140, pl. 5, figs 3-4.

2007 *Aequipecten malvinae* - Rico-García, p. 116.

2018 *Aequipecten* aff. *malvinae* - Vescogni et al. p. 439.

Material: Two incomplete spms (IGF 11850; ROS_{hist} according to Trentanove 1901, p. 526).

Discussion. Differs from *A. opercularis* (Linnaeus, 1758) for its more impressed costae (Stefanini 1917; Freinex et al. 1987a).

Distribution. Possibly migrating from the paleo-Mediterranean in the early Miocene, it is frequent in the Paratethys during the Langhian-early Serravallian (Mandic 2004); reported in the Mediterranean in the early Messinian (Rico-García 2007).

Order **Ostreida** Férussac, 1822

Superfamily Ostreioidea Rafinesque, 1815

Family Ostreidae Rafinesque, 1815

Genus *Crassostrea* Sacco, 1897

Type species - *Crassostrea virginica* (Gmelin, 1791)

Crassostrea gryphoides (Schloteim, 1813)

1819 *Ostrea crassissima* Lamarck, p. 217

1896a *Ostrea crassissima* - Sacco, p. 214.

1897 *Ostrea crassissima* - Sacco, p. 15.

1911 *Ostrea crassissima* - Trentanove, p. 71.

Material: Five spms from Quarata and Cafaggio (IGF 11898, 103477-103478).

Discussion. The largest *Crassostrea* known so far commonly formed nearly mono-specific biostromes in the Tethyan realm, during the early (Burdigalian: Harzhauser et al. 2016), middle (El-Sabbagh & El Hedeny 2016), and late Miocene (Tortonian: D'Amico et al. 2012). It also formed part of estuarine communities, dominated by gastropods (Zuschin et al. 2004; 2014). In the Monti Livornesi the species occurs as a monospecific assemblage at the passage from ROS and RAQ and its interpretation is not clear (Fig. 2, see also Dominici et al. 2019; from "clayey marls" according to Trentanove 1911).

Distribution. Late Oligocene to Tortonian (D'Amico et al. 2012, cum syn.). The Pliocene record is doubtful (Harzhauser et al. 2016).

Subclass **HETERODONTA** Neumayr, 1884

Order **Cardiida** Ferussac, 1822

Superfamily Cardioidea Lamarck, 1809

Family Cardiidae Lamarck, 1809

Subfamily Cardiinae Lamarck, 1809

Genus *Procardium* Poorten & La Perna, 2017

Type species - *Cardium indicum* Lamarck, 1819

Procardium* cfr. *P. danubianum (Mayer, 1866)

1901 *Cardium bians* Brocc. var. *Danubianum* - Trentanove, p. 536.

1956 *Cardium (Rhingicardium) bians* - Ruggieri, p. 146.

Material: One articulated spm (IGF 11832; ROS_{hist} based on Trentanove 1901, p. 510).

Discussion. Recently (2017) ter Poorten & La Perna have revised the group of early Miocene to Recent large cardiids, subfamily Cardiinae, ad-

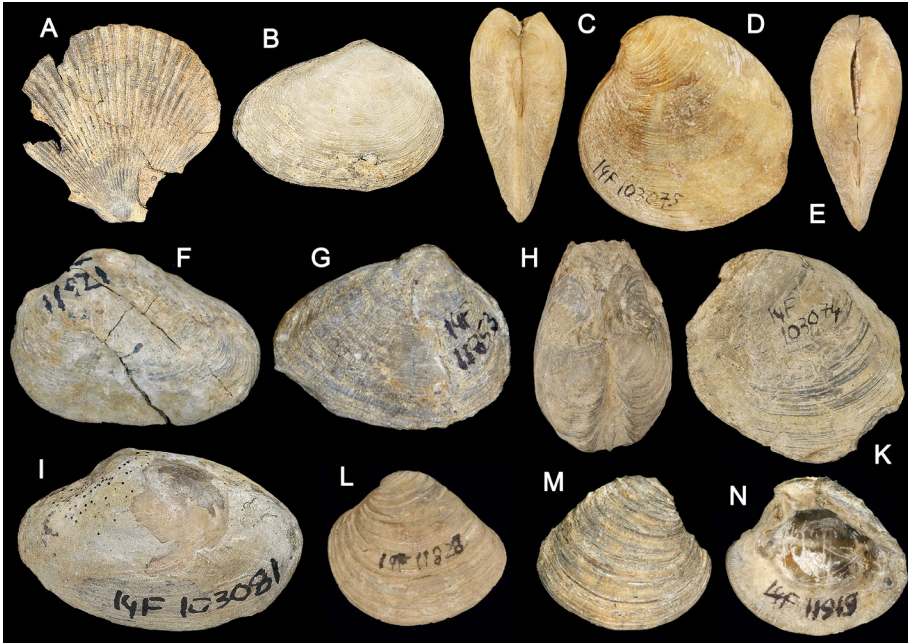


Fig. 15 - Bivalvia of the Rosignano unit (ROS₁). A) *Aequipecten marinae* (Dubois de Montpéroux 1831), IGF 11850, mm 28; B) *Gastrana fragilis* (Linnaeus, 1758) juv., IGF 11853, mm 20; C-E) *Circumphalus subplicatus* (d'Orbigny, 1852), IGF 103075, mm 51; F-G) *Gastrana fragilis*, IGF 11921, mm 41; IGF 11853, mm 38; H) *Venus* cfr. *V. nux*, IGF 11829, mm 50; K) *Pelecypora islandicoideus* (Lamarck, 1818), IGF 11825, mm 51; J) *Venerupis* cfr. *V. basteroti* (Mayer, 1857), IGF 103081, mm 35; L) *Clausinella fasciata* (da Costa, 1778), IGF 11828, mm 34; M-N) *C. fasciata* (da Costa, 1778), IGF 11919, mm 26.

vancing the new genus *Procardium*, with a wide distribution in Europe, during the Miocene. They include in the genus both *P. danubianum* (Mayer, 1866) and *P. avisanense* (Fontannes, 1879), this last with distribution during the Tortonian. We refer our specimen to *P. danubianum* with some incertitude, due to bad preservation of the specimen.

Distribution. *P. danubianum* is found in the Langhian-middle Serravallian of Austria (Central Paratethys); *P. avisanense* comes from the Tortonian of Portugal, France and Italy (ter Poorten & La Perna 2017).

Genus *Acanthocardia* Gray, 1851
Type species - *Cardium aculeatum* Linnaeus, 1758

Acanthocardia echinata (Linnaeus, 1758)

1901 *Cardium labronicum* Trentanove, p. 534-535, pl. 9, figs 10-11.
1911 *Cardium labronicum* - Trentanove, p. 75.
1956 *Cardium (Cardium) echinatum* - Moroni, p. 133.
1956 *Cardium mucronatum* - Ruggieri, p. 146.

Material: Eight articulated spms (IGF 11830, IGF 11912; ROS_{hist} based on Trentanove 1901, p. 510). One spm in sample BR.

Distribution. From Langhian of Poland to the modern Northeastern Atlantic and Mediterranean (Chirli 2016), where it lives on mud, sand and gravel bottoms at 4-350 m depth (Poppe & Goto 1993).

Subfamily Lymnocardiinae Stoliczka, 1870

Genus *Papillicardium* Sacco, 1899

Type species - *Cardium papillosum* Poli, 1791

Papillicardium papillosum (Poli, 1791)

1911 *Cardium papillosum* - Trentanove, p. 75.
1956 *Corculum (Papillicardium) papillosum* - Ruggieri, p. 149.

Material: Two spms from Quarata (IGF 11914).

Distribution. Tortonian at Stazzano (Sacco 1899); Modern Atlantic, from Mauritania (Michel et al. 2011) to about 50°N (Monegatti & Raffi 2001), and Mediterranean, from Alboran Sea (Rueda et al. 2009) to Greece (Romani et al. 2017). Trentanove (1911, p. 75) reports the species from "blue marls" (RAQ_b).

Subfamily Laevicardiinae Keen, 1951

Genus *Laevicardium* Swainson, 1840

Type species - *Cardium oblongum* Gmelin, 1791

Laevicardium oblongum (Gmelin, 1791)

1901 *Cardium (Laevicardium) oblongum* - Trentanove, p. 536.
1956 *Cardium (Laevicardium) oblongum* - Ruggieri, p. 146.

Material: Two articulated spms from Popogna (IGF 11831; ROS_{hist} based on Trentanove 1901, p. 536).

Distribution. Reported from the Pliocene to the Present. It lives in muddy sand from the subtidal zone down to 250 m (Poppe & Goto 1993).

Superfamily Tellinoidea Blainville, 1814

Family Tellindae Blainville, 1814

Subfamily Tellininae Blainville, 1814

Genus *Peronaea* Poli, 1791

Type species - *Tellina planata* Linnaeus, 1758

Peronaea planata (Linnaeus, 1758)

1878 *Tellina* sp. - Capellini, p. 10.

1901 *Tellina planata* - Trentanove, p. 549.

1956 *Tellina planata* - Ruggieri, p. 147.

Material: One spm in sample BR.

Discussion. Trentanove (1901, p. 549) reports “several specimens” from the Popogna calcarenites (ROS_h). These specimens have probably been lost.

Distribution. Widespread in Europe from the Burdigalian of Germany to the Present (Chirli 2015). It lives from intertidal to 20 m deep, on fine-grained sandy bottoms, from Gibraltar to south of Angola, in West Africa, and in the Mediterranean (Poppe & Goto 1993).

Subfamily Gastraninae M. Huber, Langleit & Kreipl, 2015

Genus *Gastrana* Schumacher, 1817

Type species - *Gastrana donacina* Schumacher, 1817

Gastrana fragilis (Linnaeus, 1758)

Fig. 15B, F-G

1911 *Gastrana fragilis* - Trentanove, p. 80.

1956 *Gastrana fragilis* - Ruggieri, p. 149.

Material: Seven articulated spms (IGF 11921-11922; ROS_{hist} based on Trentanove 1911, p. 81), 16 fragmented valves (IGF 11922, 103068); one spm in sample BR.

Distribution. Reported from Miocene of Morocco to the Present (Lozano-Francisco 1997). From the Norwegian Sea and the Baltic south to Morocco and the Canaries and into the Mediterranean and the Black Sea. Canaries. The species is mainly intertidal or shallow subtidal and prefers muddy bottoms (Poppe & Goto 1993).

Order **Venerida** Gray, 1854

Superfamily Veneroidea Gray, 1854

Family Veneridae Rafinesque, 1815

Genus *Venus* Linnaeus, 1758

Type species - *Venus verrucosa* Linnaeus, 1758

Venus* cf. *V. nux Gmelin, 1791

Material: One articulated specimen with open valves (IGF 11829).

Discussion. The specimen, filled with a sandstone matrix, was in the same box with IGF 103075 (mm 50).

Genus *Clausinella* Gray, 1851

Type species - *Pectunculus fasciatus* da Costa, 1778

Clausinella fasciata (da Costa, 1778)

Fig. 15L-N

1778 *Pectunculus fasciatus* da Costa, p. 188, pl. 3, fig. 3.

1831 *Venus scalaris* Bronn, p. 100

1911 *Venus scalaris* - Trentanove, p. 76-77.

Material: Six articulated spms and 3 valves (two right, one left: IGF 11828, 11919, 103080), all from ROS_{hist}.

Distribution. The fossil record of this extant species is discontinuous, with a report in the Burdigalian of the Torino Hills (Zunino & Pavia 2009), the Tortonian of Belgium (Vandenberghe et al. 2005) and sparse findings in the Pliocene (Lozano-Francisco 1997) and Pleistocene of Italy (Cerulli Irelli 1908). Harzhauser et al. (2013, Pl. 4, fig. 10) mention *C. fasciata* in the early Messinian of Faro Santa Croce (Sicilia), but their silicon cast of the external part of a right valve does not allow a meaningful comparison with our specimens. The species is widespread in modern European seas, from the Lofoten Islands, Norway, south to western Morocco and into the Mediterranean (Poppe & Goto 1993).

Genus *Circumphalus* Mörch, 1853

Type species - *Venus plicata* Gmelin, 1791

Circumphalus subplicatus (d'Orbigny, 1852)

Fig. 15C-E

1852 *Venus subplicata* d'Orbigny, p. 107.

1901 *Venus pliocenica* var. *Popognae* Trentanove, p. 539-542, pl. 8, fig. 16.

1956 *Venus (Circumphalus) pliocenica Popognae* - Ruggieri, p. 146.

1986 *Circumphalus subplicatus* - Studencka, p. 94, pl. 16, figs 1-3, 6-9.

2012 *Circumphalus subplicatus* - D'Amico et al., p. 175-176, fig. 4.

Material: One articulated spm (IGF 103075, in the same box of IGF 11829; ROS_{hist} based on sandstone associated with the specimen; see also Fig. 6A-C for metadata).

Distribution. Reported from the Early Miocene to Early Pliocene (Studencka 1986). Congeneric *C. foliaceolamellosus* (Dillwyn, 1817), present in the Mediterranean until the late Pliocene (Vittorio Garilli 2019, personal communication), lives in the modern eastern Atlantic at tropical-subtropical latitudes (Monegatti & Raffi 2001, 2007).

Genus *Venerupis* Lamarck, 1818
Type species - *Venus perforans* Montagu, 1803

Venerupis* cfr. *V. basteroti (Mayer, 1857)

Fig. 15I

1857 *Taper Basteroti* Mayer, p. 181, 183.
1860 *Tapes Basteroti* - Hörnes, p. 113, pl. 10, figs 8, 9.
1901 *Tapes Basteroti* var. *brevior* - Trentanove, p. 545, pl. 8, fig. 12.
1956 *Pullastra* (?) sp. ind. - Ruggieri, p. 147.
2015 *Venerupis basteroti* - Harzhauser et al., p. 167, fig. 3 (4).

Material: Four articulated spms from Popogna (IGF 11852-11853; ROS_{hist} based on Trentanove, 1901, p. 545).

Distribution. The species is found in the Paratethys, in the Burdigalian (Harzhauser et al. 2015) and Langhian (Studencka et al. 1998), and in the Western Mediterranean, in the Messinian (Freneix et al. 1987b; Jiménez & Braga 1993).

Genus *Pelecycora* Dall, 1902
Type species - *Pelecycora hatchetigbeensis* (Aldrich, 1886)

Pelecycora islandicoides (Lamarck, 1818)

Fig. 15H-K

1901 *Venus islandicoides* - Trentanove, p. 538.
1956 *Pitaria (Amiantis) islandicoides* - Moroni, p. 136.
1956 *Pitaria (Amiantis) islandicoides* - Ruggieri, p. 146.
1987 *Pelecycora (Cordiopsis) islandicoides* - Freneix et al., p. 435, pl. 3, fig. 9.
2015 *Cordiopsis islandicoides* - Harzhauser et al., p. 167.

Material: 13 articulated spms (IGF 11825-11826, 103073-103074; ROS_{hist}); one spm sample BR.

Distribution. The species is found in the Paratethys, in the Burdigalian (Harzhauser et al. 2015), and in the Mediterranean area, in the Tortonian (Bernasconi & Robba 1993), Messinian (Freneix et al. 1987b) and Piacenzian (Dominici et al. 2018).

Genus *Paphia* Röding, 1798
Type species - *Paphia rotundata* (Linnaeus, 1758)

Paphia vetula (Basterot, 1825)

1901 *Tapes vetula* var. *Vindobonensis* - Trentanove, p. 544-545.
1956 *Paphia vetula* var. *Vindobonensis* - Ruggieri, p. 146.

Material: 15 articulated spms (IGF 11851; ROS_{hist} based on Trentanove 1901, p. 545).

Distribution. *Paphia vetula* (Basterot, 1825) is reported in the Langhian of the Paratethys (Studencka et al. 1998), Tortonian (Merle et al. 1989; Bernasconi & Robba 1993), Messinian (Merle et al. 2002; Lacour et al. 2002) and late Zanclean-early Piacenzian of the Mediterranean area (Vera-Peláez et al. 1995; see Aguirre et al. 2005; preglacial Pliocene: Monegatti & Raffi 2007).

Genus *Dosinia* Scopoli, 1777
Type species - *Dosinia concentrica* (Born, 1778)

Dosinia exoleta (Linnaeus, 1758)

1901 *Dosinia exoleta* - Trentanove, p. 537.
1956 *Dosinia* sp. - Ruggieri, p. 146.

Material: 49 articulated spms from Popogna (IGF 11815-11817, 103464).

Discussion. Trentanove (1901, p. 511, 537) reports the species from the “marly clays” (RAQ_p). It was not recovered during field activity.

Distribution. Widely distributed from the lower Miocene to modern Europe (Chirli 2016).

Superfamily Mactroidea Lamarck, 1809

Family Mactridae Lamarck, 1809

Genus *Lutraria* Lamarck, 1799

Type species - *Lutraria lutraria* (Linnaeus, 1758)

Lutraria oblonga (Gmelin, 1791)

1878 *Lutraria oblonga* - Capellini, p. 10.
1901 *Lutraria oblonga* - Trentanove, p. 545.
1956 *Lutraria oblonga* - Ruggieri, p. 147.

Material: One articulated spm (IGF 11858; ROS_{hist} based on Trentanove 1901, p. 545):

Distribution. From the Burdigalian of Paratethys (Mandic & Steininger 2003) to the modern Eastern Mediterranean (Zenetos et al. 2005).

Superorder **Anomalodesmata**

Superfamily Thracioidea Stoliczka, 1870 (1839)

Family Thraciidae Stoliczka, 1870 (1839)

Genus *Thracia* Blainville, 1823

Type species - *Mya pubescens* Pulteney, 1799

Thracia pubescens (Pulteney, 1799)

1901 *Thracia pubescens* - Trentanove, p. 550.

1956 *Thracia pubescens* - Ruggieri, p. 147.

Material: Two incomplete spms from Popogna (IGF 11862; ROS_{hist}) based on Trentanove 1901, p. 550).

Distribution. From the Burdigalian of Parathys (Mandic & Steininger 2003) to the modern Eastern Mediterranean (Zenetos et al. 2005).

SYSTEMATIC PALAEOLOGY OF THE RAQUESE UNIT (MARLY MUDSTONE, RAQ_B)

Subclass CAENOGASTROPODA Cox, 1960

Order Caenogastropoda [unassigned]

Superfamily Cerithioidea Fleming, 1822

Family Turritellidae Lovén, 1847

Genus *Turritella* Lamarck, 1799

Type species - *Turritella terebra* (Linnaeus, 1758)

Turritella tricarinata (Brocchi, 1814)

1814 *Turbo tricarinatus* Brocchi, p. 374, pl. 6, fig. 21.

1895a *Turritella tricarinata* - Sacco, p. 14.

1901 *Turritella communis* - Trentanove, p. 517-518, pl. 8, figs 7,8.

1901 *Turritella tricarinata* - Trentanove, p. 519, pl. 8, figs 9,10.

1901 *Turritella Capellinii* Trentanove, p. 519, pl. 8, figs 5,6.

1911 *Turritella communis* - Trentanove, p. 70.

1911 *Turritella tricarinata* - Trentanove, p. 70.

1911 *Turritella Capellinii* - Trentanove, p. 70.

1956 *Turritella (Turritella) tricarinata* - Ruggieri, p. 144.

1956 *Turritella (Turritella) tricarinata* cfr. *communis* - Ruggieri, p. 144.

1956 *Turritella (Turritella) tricarinata capellinii* - Ruggieri, p. 144.

1956 *Turritella (Turritella) tricarinata* - Moroni, p. 98, pl. 2, figs 6-7, 10-11.

1956 *Turritella (Turritella) clarae* Moroni, p. 90, pl. 2, fig. 13.

1990 *Turritella capellinii* - Ruggieri, p. 351.

2004 *Turritella tricarinata* - İslamoğlu, p. 143, pl. 1, fig. 3.

Material: More than 2500 spms (IGF 11953, 11973, 11976-11978) (RAQ_{hist}); 141 spms in samples TR1-TR3-TR5.

Discussion. *T. capellinii* and *T. clarae* introduced by Trentanove (1901) and Moroni (1956), respectively, are to be considered varieties of the the species by Brocchi (1814), as partly recognised by Ruggieri (1956). Curiously, Ruggieri recognised species-status to *T. capellinii* Trentanove, 1901, in a study on the up-

per Miocene of Sicily (Ruggieri 1990).

Distribution. Burdigalian of Turkey (İslamoğlu 2004) and Italy (Zunino & Pavia 2009), Serravallian of Greece (Dermitzakis & Georgiades-Dikeoulia 1987), Tortonian of Piedmont (Sacco 1895a) and Denmark (Roth & Hoedemakers 2005), Messinian, Pliocene and early Pleistocene of the Mediterranean (e.g., Ruggieri 1990; Ferrero et al. 2005; Ragaini et al. 2006) where it is presently abundant (Poppe & Goto 1993).

Superfamily Epitonioida Berry, 1910 (1812)

Family Epitoniidae Berry, 1910 (1812)

Genus *Epitonium* Röding, 1798

Type species - *Turbo scalaris* Linnaeus, 1758

***Epitonium* sp.**

1901 *Scalaria subtrevelyanoides* - Trentanove, p. 521-522, pl. 9, figs 2-3.

1956 *Scala* sp. ind. - Ruggieri, p. 144.

Material: Two spms (IGF 11856) (RAQ_{hist}); two spms in sample TR5 (RAQ_B).

Discussion. Trentanove (1901) compared the two specimens to an unpublished figure by Theodor Fuchs, portraying a specimen from the Rosignano limestone (ROS). However, the two specimens were from the overlying mudstone (RAQ). Ruggieri (1956) recognised a similarity with *Epitonium elegans duplex* (Nelli, 1922), discussed and figured by Moroni (1956) for the Messinian of San Marino.

Distribution. *Epitonium elegans* (Risso, 1826) is a Pliocene species found in Italy, similarly to *Epitonium subtrevelyanoides* (Sacco, 1891), who might have also a Tortonian record (Sacco 1891). Nelli's subspecies is possibly a new species, from the early Messinian (Moroni 1956; Ruggieri 1956; Monegatti & Raffi 2010).

Order Littorinimorpha Golikov & Starobogatov, 1975

Superfamily Stromboidea Rafinesque, 1815

Family Aporrhaidae Gray, 1850

Genus *Aporrhais* Da Costa, 1778

Type species - *Aporrhais quadridus* da Costa, 1778

Aporrhais uttingeriana (Risso, 1826)

1897 *Chenopus (Rostellaria) thersites* Brives, p. 122, pl. 4, figs 18-19.

1901 *Chenopus uttingerianus* var. - Trentanove, p. 516-517.

1911 *Chenopus uttingerianus* - Trentanove, p. 64-65.
 1956 *Aporrhais thersites* - Ruggieri, p. 54.
 1956 *Aporrhais thersites* - Moroni, p. 104-105, pl. 9, figs 52-53.

Material: 61 fragmentary spms (IGF 11863-11864, 11943) (RAQ_{hist}); nine spms in TR1.

Discussion. *Aporrhais thersites* Brives, 1897 is characterised by a very marked columellar callus and a more pronounced spiral sculpture. Our specimens are fragmentary but it is still possible to see that they do not have these characteristics.

Distribution. Stratigraphic distribution from the Tortonian to the Calabrian of Italy (Brunetti & Forlì 2013).

Order **Neogastropoda** Wenz, 1938
 Superfamily Buccinoidea Rafinesque, 1815
 Family Nassariidae Iredale, 1916 (1835)
 Genus *Tritia* Risso, 1826
 Type species - *Buccinum reticulatum* Linnaeus, 1758

Tritia brugnonis (Bellardi, 1882)

Fig. 16A-B

1878 *Nassa prismatica* - Capellini, p. 10.
 1882 *Nassa Brugnonis* Bellardi, p. 73, pl. 5, fig. 2.
 1901 *Nassa Brugnonis* - Trentanove, p. 515.
 1956 *Nassa (Hima) brugnonis* - Ruggieri, p. 143.
 1982 *Nassarius Brugnonis* - Ferrero Mortara et al., p. 107, pl. 24, fig. 4.
 2018 *Tritia brugnonis* - Vescogni et al., p. 7/21.

Material: 38 spms from Popogna (IGF 11885-11888; RAQ_{hist} based on Trentanove 1901, p. 511).

Discussion. This species differs from the middle Miocene *Tritia subprismaticus* (Hörnes & Aunger 1882) in its low spire, the moderately convex whorls and the weak apertural sculpture (Harzhauser & Kowalke 2004). Common in the Trentanove (1901) collection, it was not recovered in new samples.

Distribution. Upper Miocene of Piedmont, Emilia (Montegibbio); Serravallian-Tortonian of Salento (Apulia, Italy: Vescogni et al. 2018).

Tritia striatulus (Eichwald, 1829)

1829 *Buccinum striatulum* Eichwald, p. 297, pl. 5, fig. 7.
 1901 *Nassa Hoernesii* - Trentanove, p. 514-515, pl. 8, figs, 18,19.
 1956 *Nassa (Amycla) semistriata* - Ruggieri, p. 143 (pars).
 2004 *Nassarius striatulus* - Harzhauser & Kowalke, p. 19-20, pl. 2, figs. 8-14.

Material: 576 spms (IGF 11884); 88 spms (IGF 11880-11882; 103284) (RAQ_{hist}); 95 spms in samples TR1, TR3, TR5 (RAQ_h).

Description. “A conspicuous spiral furrow is usually developed close to the posterior suture, separating an adsutural band of slightly more prominent and rarely even pointed nodes. There is also a strong tendency to reduce the axial sculpture towards the body whorl, resulting in rather smooth late teleoconchs. These shells lack the pointed nodes but do always develop the axial sculpture on early whorls” (Harzhauser & Kowalke 2004). The above description corresponds to forms with reduced ornamentation of *Tritia striatulus* (Eichwald, 1829), formerly also known as “*Nassarius*” *hoernesii* (Mayer) (e.g., Trentanove 1901; see discussion in Harzhauser & Kowalke 2004).

Distribution. Middle Miocene of Paratethys (Harzhauser & Kowalke 2004, cum syn.), Langhian of the Torino Hills (Zunino & Pavia 2009).

Tritia semistriata (Brocchi, 1814)

1911 *Nassa semistriata* - Trentanove, p. 55

Material: 61 spms from both Popogna and Quarata (IGF 11965, IGF 1184) (RAQ_{hist}); three spms in sample TR5.

Description. Due to poor quality of the preservation this species has been confused by Trentanove (1911) with the similar *Tritia striatulus* (Eichwald, 1829). See Landau et al. (2009) for a comparison with similar species.

Distribution. From Late Miocene (Tortonian) to Lower Pleistocene (Landau et al. 2009).

Superfamily Muricoidea Rafinesque, 1815
 Family Muricidae Rafinesque, 1815
 Genus *Chicoreus* Montfort 1810
 Type species - *Murex ramosus* Linnaeus, 1758

Hexaplex austriacus (Tournouer, 1875)

Fig. 11R-S

1875 *Murex austriacus* Tournouer, p. 158.
 1911 *Murex Austriacus* - Trentanove, p. 63-64.
 1956 *Murex (Hexaplex) austriacus* - Ruggieri, p. 148.

Material: One spm (IGF 11947); a fragment in sample MQ2.

Discussion. The Quarata specimen is less globular than the typical form (Hörnes 1856, pl 23,

figs 1-5; Landau et al. 2013, pl 21, fig 4) and has an evident spiral spiny sculpture that is missing in specimens referred to *H. austriacus* by Merle and co-authors (2011, pl. 37, Fig. 7). It is similar to the specimen figured in Kovács et al. (2018, Fig. 2 J-K). We agree with the interpretation given by Trentanove (1911), until better material is available.

Distribution. Early-Middle Miocene. Burdigalian of Germany (Moths et al. 2010), Langhian of Piedmont (Zunino & Pavia 2009). Paratethys. Middle Miocene: (Austria, Bosnia, Bulgaria, Hungary, Poland, Romania), Proto-Mediterranean Sea (Turkey: Kovács et al. 2018).

Class **BIVALVIA** Linnaeus, 1758

Subclass **PROTOBRANCHIA** Pelseneer, 1889

Order **Nuculanida** Carter, Campbell & Campbell, 2000

Family Sareptidae Stoliczka, 1870 in 1870–1871

Subfamily Yoldiinae Dall, 1908

Genus *Yoldia* Möller, 1842

Type species - *Yoldia hyperborea* Torell, 1859

Yoldia nitida (Brocchi, 1814)

1901 *Yoldia nitida* - Trentanove, p. 534, pl. 9, figs 4-6.

1956 *Yoldia nitida* - Ruggieri, p. 146.

Material: Two spms (RAQ_{hst}).

Distribution. Burdigalian of the Torino Hills (Zunino & Pavia 2009); middle Miocene of Sardinia (Spano 1989); Tortonian and Messinian of Italy; Pliocene of Spain and Italy (Lozano-Francisco 1997, cum syn.)

Yoldia philippi Bellardi, 1875

1875 *Yoldia philippi* Bellardi, p. 25, fig. 22.

1898 *Yoldia philippi* - Sacco, p. 59, pl. 12, figs 25, 26.

1901 *Yoldia philippi* - Trentanove, p. 533, pl. 9, figs 4-6.

1956 *Yoldia philippi* - Ruggieri, p. 146.

Material: Nine articulated spms, one valve (IGF 11813-11814; RAQ_{hst}).

Discussion. We follow Sacco (1898) in distinguishing this species from *Yoldia nitida* in being smoother, more swollen and subtriangular, maintaining also his skepticism (“[...] I observed specimens with hints of transitory characters for which some doubts arise about the interpretation of this form”:

Sacco 1898, p. 59).

Distribution. Reported by Bellardi (1875) and Sacco (1898) from the middle Miocene of Torino Hills to the early Pliocene of Piedmont and Liguria.

Subclass **PTERIMORPHIA** Beureln, 1944

Order **Arcida** Lamarck, 1809

Superfamily Arcoidea Lamarck, 1809

Family Arcidae Lamarck, 1809

Genus *Anadara* Gray, 1847

Type species - *Arca antiquata* Linnaeus, 1758

Anadara diluvii (Lamarck, 1805)

1901 *Arca diluvii* - Capellini, p. 10.

1901 *Arca (Anomalocardia) diluvii* - Trentanove, p. 530-531.

1956 *Arca (Arca) diluvii* - Moroni, p. 127-128.

1956 *Arca (Arca) diluvii* - Ruggieri, p. 145.

2010 *Scapharca (Scapharca) diluvii* - Moths et al., p. 530-531.

Material: About 650 spms, mostly articulated (IGF 11805-11806, 103282; RAQ_{hst}).

Distribution. Lower Miocene of the Tethys (Bernasconi & Robba 1993; Zunino & Pavia 2009), lower and middle Miocene of the Paratethys (Mandic & Harzhauser 2003; Zuschin et al. 2004;), upper Miocene and Pliocene of the Mediterranean basin (Stefanini 1917; Freneix et al. 1987a; Bernasconi & Robba 1993; Dominici et al. 2018). Records for the Pleistocene in the tropical Atlantic (Lecointre et al. 1967) and the modern Eastern Mediterranean (Zenetos et al. 2005) must be confirmed against misidentification with *Anadara polii* (Mayer, 1868) (see Oliver and Van Cosel 1992).

Order **Ostreida** Férussac, 1822

Superfamily Ostreoidea Rafinesque, 1815

Family Gryphaeidae Vialov, 1936

Genus *Neopycnodonta* Stenzel, 1971

Type species - *Ostrea cochlear* Poli, 1795

Neopycnodonte navicularis (Brocchi, 1814)

1814 *Ostrea navicularis* Brocchi, p. 565.

1878 *Ostrea cochlear* - Capellini, p. 10.

1897 *Ostrea cochlear* var. *navicularis* - Sacco, p. 22, pl. 8, figs 2-6.

1901 *Ostrea navicularis* - Trentanove, p. 524-525.

1968 *Pycnodonte navicularis* - Robba, p. 494-495.

2009 *Neopycnodonte cochlear* - Zunino & Pavia, p. 360.

2015 *Neopycnodonte navicularis* - De Bortoli & Sarka, p. 41, pl. 1, figs i-r; pl. 3, figs a,e.

Material: One valve (IGF 11855; RAQ_{hst}).

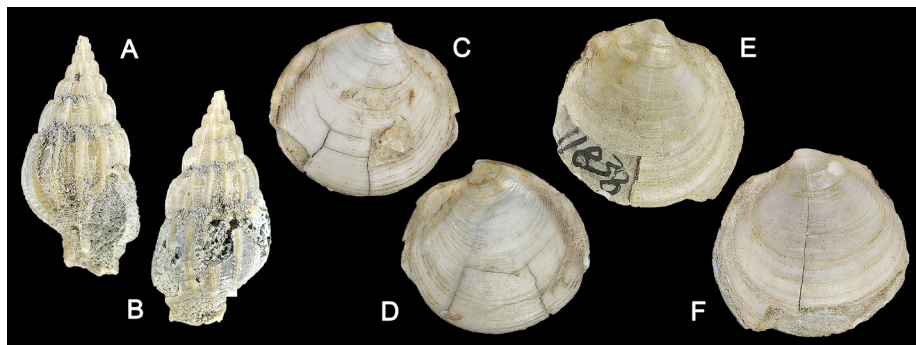


Fig. 16 - Mollusca of the Raques unit (RAQ). A-B) *Tritia brugnonis* (Bellardi, 1882), IGF 11885, ROS_v, mm 16.5; C-D) *Myrtina meneghinii* (De Stefani & Pantanelli, 1888), IGF 11837, RAQ_v, mm 12.6; E-F) *Myrtina meneghinii* (De Stefani & Pantanelli, 1888), IGF 11838, RAQ_v, mm 14.3.

Distribution. Burdigalian of the Torino hills (Zunino & Pavia 2009). Reported in the Miocene and Pliocene in the Atlantic and Mediterranean areas (Lozano-Francisco 1997, cum syn.).

N. navicularis is sometimes considered in synonymy with the modern and very similar species *N. cochlear* (Poli, 1795) living in Atlantic and Mediterranean Sea (De Bortoli & Sarka 2015).

Subclass **HETERODONTA**

Order **Carditida** Dall, 1889

Superfamily Carditoidea Férussac, 1822

Family Carditidae Férussac, 1822

Genus *Centrocardita* Sacco, 1899

Type species - *Chama aculeata* Poli, 1795

Centrocardita aculeata (Poli, 1795)

1901 *Cardita globulina* var. *Taurosimplex* - Trentanove, p. 534.

1956 *Begonia globulina* - Ruggieri, p. 146.

2009 *Glans aculeata* - Zunino & Pavia, p. 360.

Material: One articulated spm and one valve (IGF 11833; RAQ_{hist}).

Distribution. *Centrocardita aculeata* is reported from the Burdigalian of the Torino hills (Zunino & Pavia 2009) to the modern Mediterranean and Atlantic (South of Portugal to Senegal: Poppe & Goto 1993).

Order **Lucinida** Gray, 1854

Superfamily Lucinoidea Fleming, 1828

Family Lucinidae Fleming, 1828

Subfamily Myrteinae Chavan, 1969

Genus *Myrtea* Turton, 1822

Type species - *Venus spinifera* Montagu, 1803

Myrtea spinifera (Montagu, 1803)

1878 *Lucina miocenica* - Capellini, p. 10.

1901 *Lucina spinifera* - Trentanove, p. 548-549.

1956 *Myrtea spinifera* - Ruggieri, p. 147.

2018 *Myrtea spinifera* - Cresti & Forli, p. 413, figs 2-8.

Material: Eight articulated spms, four disarticulated valves (IGF 11835-11835; RAQ_{hist}).

Distribution. From the Burdigalian of the Mediterranean (Zunino & Pavia 2009) and North-eastern Atlantic (France), to the modern, with a similar distribution (Lozano-Francisco 1997, and references therein).

Subfamily Leucosphaerinae Taylor & Glover, 2011

Genus *Myrtina* Glover & Taylor, 2007

Type species - by original designation: *Myrtina porcata* Glover & Taylor, 2007

Myrtina meneghinii (De Stefani & Pantanelli, 1888)

Fig. 16A-B; C-D

1878 *Lucina dentata* - Capellini, p. 10.

1901 *Lucina spinifera* var. *Meneghinii* - Trentanove, p. 549.

1956 *Myrtea spinifera meneghinii* - Ruggieri, p. 147.

1956 *Gonimyrtea meneghinii meneghinii* - Ruggieri, p. 147.

1989 *Gonimyrtea meneghinii* - Spano, p. 362, pl. 5, figs 6-7.

1998 *Gonimyrtea meneghinii* - Studencka et al., p. 298.

2018 *Gonimyrtea ? meneghinii* - Cresti & Forli, p. 413-415, figs 9-12, 14-19, 20-27.

Material: Four articulated spms (IGF 11837-11838; RAQ_{hist}).

Discussion. The genus *Myrtina* was originally described for New Caledonia (Glover & Taylor 2007) and now is reported throughout the Indo-West Pacific and in the Atlantic. Recently assigned to subfamily Leucosphaerinae (Taylor & Glover in Taylor et al. 2011), these lucinids have

“shells small, subcircular with fine commarginal lamellae that are often elevated along the dorsal margins. Radial sculpture absent. Lunule strongly asymmetric. Hinge, RV with one cardinal tooth, LV with two cardinal teeth, small lateral teeth in both valves, anterior lateral teeth usually more prominent in right valve. Anterior adductor scar short, pallial line continuous or beaded, shell margin smooth” (Taylor & Glover 2016). This description fits *Myrtina meneghinii* (J. D. Taylor, personal communication, January 2019). The same authors attribute for the Pliocene of Italy *Dentilucina submichelotti* Sacco, 1901, originally described as a variety of *D. meneghinii*, closely related with the Miocene species *Dentilucina michelotti* (Mayer, 1858).

Distribution. Langhian-Serravallian of Paratethys (Studencka et al. 1998) and Mediterranean (Spano 1989) to Pliocene of Tuscany (De Stefani & Pantanelli 1888).

Order **Venerida** Gray, 1854
 Superfamily Veneroidea Gray, 1854
 Family Veneridae Rafinesque, 1815
 Genus *Venus* Linnaeus, 1758
 Type species - *Venus verrucosa* Linnaeus, 1758

Venus nux Gmelin, 1791

1901 *Cytherea multilamella* - Trentanove, p. 543-544.
 1956 *Venus (Ventricola) multilamella* - Moroni, p. 135-136.
 1956 *Venus (Ventricola) multilamella* - Ruggieri, p. 147.
 1997 *Venus (Ventricoloidea) nux* - Lozano-Francisco, p. 689-695, pl. 49, figs 7-8.
 1998 *Venus (Ventricoloidea) nux* - Studencka et al., p. 319.
 2009 *Venus multilamella* - Zunino & Pavia, p. 361.

Material: About 200 articulated spms (IGF 11819, 11821, 11931, 103285; RAQ_{hist}); one valve in sample TR3.

Distribution. From the Langhian of the Torino Hills (Zunino & Pavia 2009) to the modern Atlantic, from Senegal to Portugal, and Mediterranean (Poppe & Goto 1993). It is often reported as *Venus multilamella* (Lamarck, 1801) by authors describing fossil occurrences (see Lozano-Francisco 1997, for a list of occurrences).

Genus *Pitar* Römer, 1857
 Type species - *Venus tumens* (Gmelin, 1791)

Pitar rudis (Poli, 1795)

1901 *Cytherea rudis* - Trentanove, p. 544.
 1956 *Pitaria (Amiantis) rudis* - Ruggieri, p. 147.
 2009 *Pitar rudis* - Zunino & Pavia, p. 361.

Material: 16 articulated spms (IGF 11822-11822, 11930, 103283; RAQ_{hist}).

Distribution. From the Burdigalian of the Torino Hills (Zunino & Pavia 2009) to the modern Atlantic, from Senegal to Scandinavia, and Mediterranean (Chirli 2015).

Genus *Timoclea* T. Brown, 1827
 Type species - *Venus ovata* Pennant, 1777

Timoclea ovata (Pennant, 1777)

1901 *Venus ovata* Penn. - Trentanove, p. 537-538.
 1956 *Venus (Timoclea) ovata* - Ruggieri, p. 146.

Material: One valve from Popogna (IGF 11827).

Distribution. Trentanove (1901) reports this specimen from the upper “clayey marls” (RAQ_b).

Distribution. Widespread in Europe, from the Miocene (Lozano-Francisco 1997) it is presently eurytopic in the Atlantic from northern Norway and Iceland, to Angola, West Africa, and in the Mediterranean and the Black Sea (Poppe & Goto 1993).

Order **Myida** Stoliczka, 1870
 Superfamily Myoidea Lamarck, 1809
 Family Corbulidae Lamarck, 1818
 Genus *Corbula* Bruguière, 1797

Corbula gibba Olivi, 1792

1878 *Corbula gibba* - Capellini, p. 10.
 1901 *Corbula gibba* - Trentanove, p. 545-546.
 1956 *Alodis (Alodis) gibba* - Ruggieri, p. 147.

Material: 846 articulated spms (IGF 11892, 11894-11896, IGF 11926; RAQ_{hist}); 102 spms in samples TR1, TR3, TR5.

Distribution. The species is an opportunistic form, eurytopic in the Northeastern Atlantic, the Mediterranean and Paratethys since the Miocene (Benvenuti & Dominici 1992; Dominici 2001; Fuksi et al. 2019).

Class **SCAPHOPODA** Bronn, 1862
 Order **Dentaliida** Starobogatov, 1974
 Family Dentaliidae Chistikov, 1975
 Genus *Fissidentalium* Fischer, 1885
 Type species - *Dentalium ergasticum* Fischer, 1883

Fissidentalium inaequale (Bronn, 1831)

- 1901 *Dentalium inaequale* - Trentanove, p. 522-523.
 1911 *Dentalium inaequale* - Trentanove, p. 71.
 1956 *Dentalium inaequale* - Moroni, p. 123, pl. 11, figs 64-67.
 1956 *Dentalium inaequale rotundatior* - Moroni, p. 123, pl. 13, figs 72-74.
 1956 *Dentalium inaequale* - Ruggieri, p. 145.
 2012 *Fissidentalium inaequale* - Janssen & Krylova, p. 92.

Material: 293 spms (IGF 103163-103164; RAQ_{hist}); 17 spms in samples TR3 and TR5.

Distribution. Messinian of San Marino (Moroni 1956); Zanclean of France (Janssen & Krylova 2012); Piacenzian of Italy (Ragaini & Mariani 1992).

Family Omniglyptidae Chistikov, 1975

Genus *Omniglypta* Kuroda & Habe in Habe, 1953

Type species - *Dentalium cerinum* Pilsbry, 1905

Omniglypta jani (Hörnes, 1956)

- 1901 *Dentalium jani* - Trentanove, p. 523.
 1956 *Dentalium jani* - Moroni, p. 122, pl. 12, figs 69-70.
 1956 *Dentalium jani* - Ruggieri, p. 145.
 1991 *Gadilina jani* - Pavia, p. 128-130, pl. 6, figs 7-10, pl. 7, figs 1-2.
 2012 *Omniglypta jani* - Janssen & Krylova, p. 92.

Material: Six spms in samples TR3.

Distribution. From the middle Miocene of the Torino Hills to the Pliocene of the Mediterranean (Pavia 1991; Janssen & Krylova 2012).

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