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"PSEUDO-SARMATIAN" MOLLUSC ASSEMBLAGES FROM THE EARLY MESSINIAN OOLITE SHOALS OF SICILY (ITALY)

MATHIAS HARZHAUSER [1], MARKUS REUTER [2], OLEG MANDIC [1], SIMON SCHNEIDER [3], WERNER E. PILLER[2] & MARCO BRANDANO [4]

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Abstract. We present a revision of the Late Miocene mollusc assemblages from Faro Santa Croce (FSC) in SE Sicily. The FSC-section exposes lower Messinian coastal marine limestones of the Monte Carrubba Formation. Whilst the lowermost part is characterised by in situ occurrences of pen shells (*Atrina fragilis*), the larger part comprises cross-bedded oolites alternating with rock-forming cardiid-venerid coquinas. Due to their superficial similarity with Paratethyan Sarmatian assemblages, the taxa were partly identified as Sarmatian species in previous literature, resulting in a surprisingly diachronous occurrence of otherwise endemic Paratethyan species in the early Messinian Mediterranean Sea. Therefore, in respect to the ongoing discussion on Mediterranean-Paratethyan faunal exchange during Messinian times, a critical taxonomic re-evaluation of the mollusc assemblage appeared crucial for palaeo(bio)geographic interpretations. The revision of the fauna proofs the absence of any relations with the Sarmatian faunas of the Paratethys Sea; about 20% of the species from the Messinian part of the section are restricted to the Late Miocene and are typical Mediterranean elements. Similarly, no hint to lowered salinities can be deduced from the normal marine stenohaline assemblages. Their co-occurrence in oolitic shoals may rather point to somewhat hypersaline and alkaline settings in a strongly agitated environment.

Riassunto. Viene presentata la revisione dell'associazione a molluschi del Miocene proveniente dalla località di Faro Santa Croce (FSC) nel SE della Sicilia. La sezione FSC mette in esposizione calcari di ambiente marino costiero del Messiniano inferiore riferibili alla Formazione Monte Carrubba. Mentre la parte basale è caratterizzata dalla presenza in situ di conchiglie di *Atrina fragilis*, la porzione più consistente comprende livelli oolitici a stratificazione incrociata che si alternano con coquine di cardiidi e veneridi, formanti corpi rocciosi. Per la loro apparente somiglianza con le associazioni del Sarmatiano della Paratetide, una parte dei taxa vennero identificati con specie del Sarmatiano nella letteratura precedente, con il sorprendente risultato di una distribuzione marcatamente diacrona di specie endemiche della Paratetide nel Messiniano del Mediterraneo. Di conseguenza, di fronte alla discussione in atto sugli scambi faunistici durante il Messiniano tra Mediterraneo e Paratetide, appare cruciale la loro revisione tassonomica per una corretta interpretazione paleo(bio)geografica. La revisione della fauna prova l'assenza di ogni relazione con la fauna del Sarmatiano della Paratetide. Circa il 20% delle specie rinvenute nella porzione messiniana della sezione sono limitate al Miocene superiore e sono tipici elementi mediterranei. Ugualmente, nessuna indicazione per salinità ridotte può essere dedotta dalle associazioni stenohaline di salinità normale. Anzi, il loro rinvenimento nelle barre oolitiche potrebbe suggerire l'esistenza di ambienti ipersalini ed alcalini, in acque fortemente agitate.

Introduction

The connectivity between the Mediterranean Sea and the neighbouring Paratethys Sea and Lake Pannon during the Late Miocene is still controversially discussed (Popov et al. 2004; Krijgsman et al. 2010; Suc et al. 2011). Whilst the palaeogeographic frame is not yet resolved, undoubted Paratethyan affinities are well documented for the late Messinian Mediterranean mollusc and ostracods assemblages (Esu 2005, 2007; Esu & Girotti 2008; Taviani et al. 2007; Grossi et al. 2008). This biogeographic pattern is explained by the fact that fol-

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1 Natural History Museum Vienna, Geological-Palaeontological Department, Burgring 7, 1010 Vienna, Austria.
E-mail: mathias.harzhauser@nhm-wien.ac.at; oleg.mandic@nhm-wien.ac.at

2 Institute of Earth Sciences, University of Graz, Heinrichstrasse 26, 8010 Graz, Austria. E-mail: markus.reuter@uni-graz.at; werner.piller@uni-graz.at

3 CASP, University of Cambridge, West Building, 181A Huntingdon Road, Cambridge, CB3 0DH, UK.
E-mail: simon.schneider@casp.cam.ac.uk

4 Dipartimento di Scienze della Terra, La Sapienza Università di Roma, P. A. Moro 5, 00185 Roma, Italy.
E-mail: marco.brandano@uniroma1.it

lowing the hypersaline conditions of the Messinian Salinity Crisis, the Mediterranean Sea water became diluted by freshwater from rivers and – probably – the Paratethyan basins between 5.50 and 5.33 Ma (Krijgsman et al. 1999; Roveri et al. 2008). This event gave rise to a (bio)facies, termed "Lago Mare" by Ruggieri (1962). Although the Paratethyan influence is accepted by most authors, the ratio between Paratethyan species-level immigrants versus autochthonous endemic evolution in the saline lakes of the Mediterranean is still under debate (see Orszag-Sperber 2006). Similarly, the ecological conditions in the "Lago Mare" environments are difficult to evaluate as marine fishes appear together with clearly polyhaline invertebrates (Carnevale et al. 2006).

In contrast, early Messinian mollusc faunas, as reviewed by Monegatti and Raffi (2001), lack any indication for faunistic exchange or relation with the Paratethys. An interesting exception, however, was reported by Grasso et al. (1982) and Pedley et al. (2007) from the limestones of the Monte Carrubba Formation, which form the coastal cliff at Faro Santa Croce at Augusta (SE Sicily). A main feature of this outcrop is the occurrence of dense venerid-cardiid coquinas in association with cross-bedded oolite deposits. Fuchs (1874a, b) was the first to visit the locality and discussed the assemblages from Faro Santa Croce (in two identical papers in German and Italian). At that time, Fuchs had already extensively studied the Volhynian and Bessarabian (upper Serravallian and lower Tortonian) deposits of Russia (now Ukraine and Moldova), which are also characterised by oolites and venerid-mactrid-cardiid coquinas. Due to very similar morphologies represented in the Sicilian assemblages, he concluded that the molluscs were conspecific with those from the Paratethyan assemblages. Consequently, the list given by Fuchs (1874a, b) comprised 55% of Sarmatian Paratethyan species. Although Grasso et al. (1982) and Pedley et al. (2007) proposed an early Messinian age for the Monte Carrubba Formation at Faro Santa Croce, they mainly reproduced the influential identifications of Fuchs (1874a, b), including endemic Paratethyan/Euxinian cardiid genera such as *Obsoletiforma*, *Didacna* and *Euxinicardium*. Grasso et al. (1982) referred to this Sarmatian-type fauna as an "interesting local development" implying a close (on the species level) Mediterranean-Paratethyan faunistic relation between 6.4 to 5.96 Ma along with the alleged Paratethyan influence during the late Messinian Lago Mare phase. This is in striking contrast to the age of the endemic Sarmatian assemblages, which developed roughly between 12 and 10 Ma (Harzhauser & Piller 2004; Popov et al. 2004). Additionally, the oolite-associated assemblages in the Monte Carrubba Formation were interpreted as evidence for reduced (mesohaline) salinity (Grasso et al. 1982; Pedley et al. 2007). The proposed oolite-associated Sarmatian taxa were, however, documented to have dwelled in the Paratethys under normal to hypersaline conditions (Piller & Harzhauser 2005) [only *Didacna* and *Euxinicardium* would point to euxinian conditions but have never been found associated with carbonate oolites]. The age discrepancy and the resulting problem that a fully endemic Sarmatian mollusc assemblage re-appears as "Lazarus-fauna" in the Messinian Mediterranean Sea at a time when it is completely replaced by other endemites in the Paratethys Sea, were the main reason for us to revise the existing identifications.

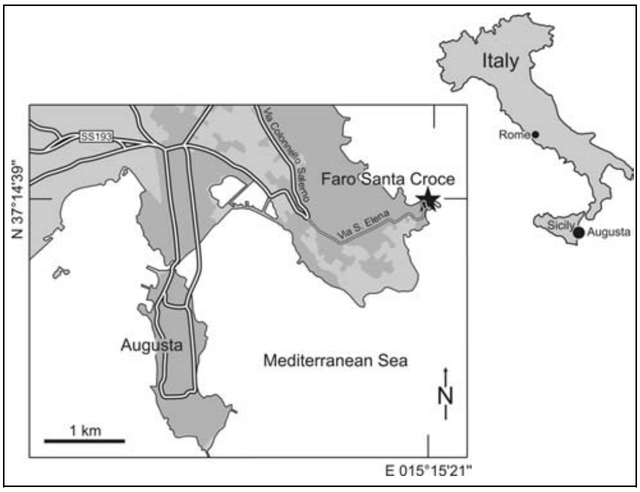
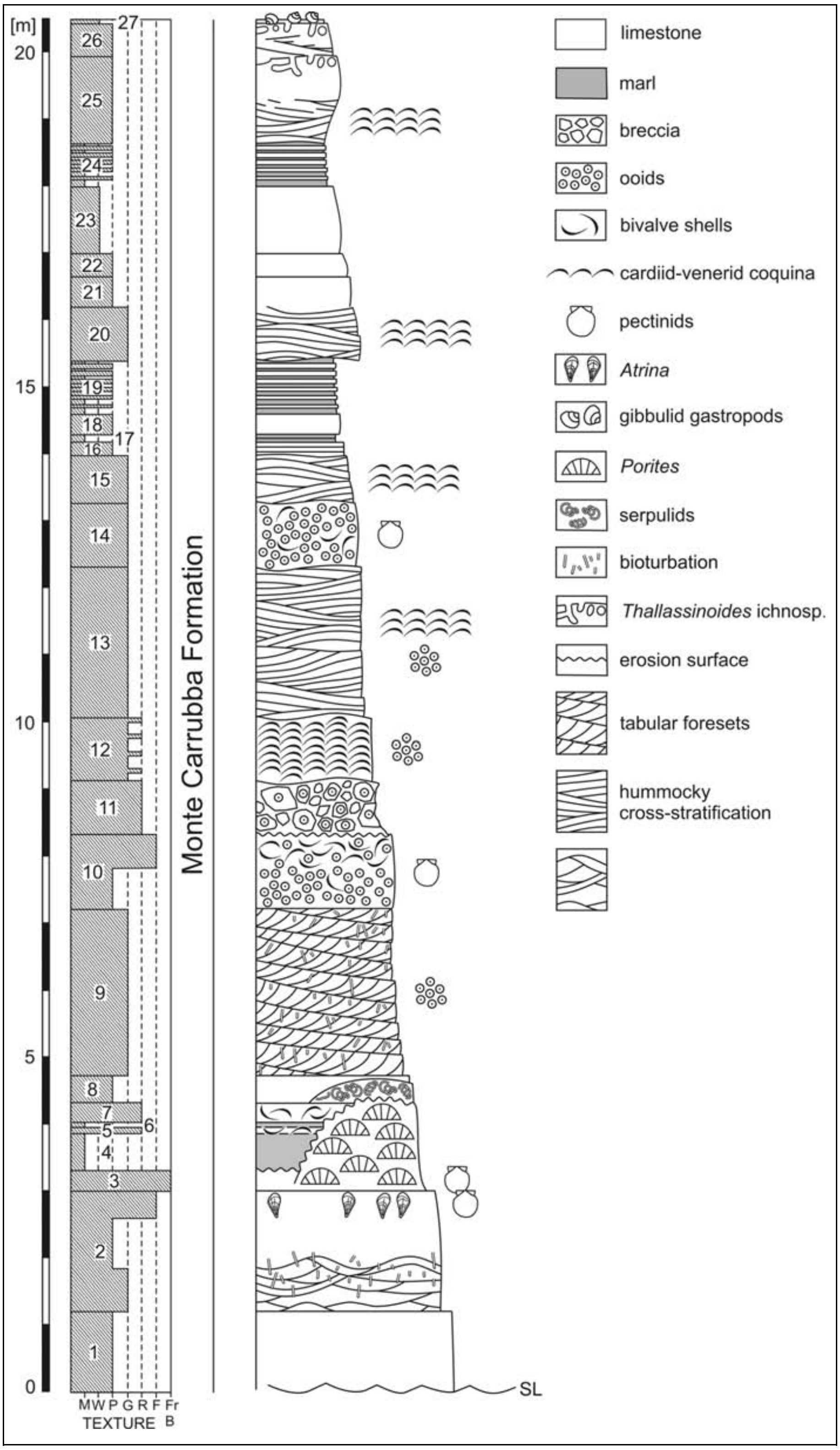


Fig. 1 - Geographic setting of the Faro Santa Croce section.

Geological setting and stratigraphy

The Monte Carrubba Formation in SE Sicily represents the inner part of a distally steepened carbonate ramp that developed on the tectonically stable foreland margin of the African Plate (Pelagian Block) during the late Tortonian and Messinian (Grasso et al. 1982; Pedley et al. 2007). Above its basal Tortonian parts, the Monte Carrubba Formation comprises the entire *Globorotalia mediterranea* Subzone and the major part of the *Globigerina multiloba* Subzone (Pedley et al. 2007), indicating an early Messinian age for most of its deposits (Iaccarino 1985; Sierro et al. 2001). One of the best outcrops of the Monte Carrubba Formation is at Faro Santa Croce (= FSC-section; N37°14'38.8", E15°15'20.8"; Fig. 1; the bed numbers in Fig. 2 correspond to the sample numbers given in the systematic part). Pedley et al. (2007, fig. 5) differentiated a basal "open marine unit", characterised by matrix-rich limestones with pectinids and coral patch reefs, and a "restricted marine unit", represented by oolitic shoals and lagoonal mudstones with low-diversity cardiid-venerid-mactrid bivalve assemblages. The "open marine unit" comprises a 4-m-thick succession (beds FSC 1-3 in Fig. 2) and the 16-m-thick succession of beds FSC 4-26 corresponds to the so-called "restricted marine unit". The two units are separated by an erosional surface, which

Fig. 2 - Lithology and sedimentary features of the Monte Carrubba Formation at the Faro Santa Croce section based on logging in April 2012. Numbers in the left column (texture) correspond to the sample numbers in the text (FSC = Faro Santa Croce); SL = sea level.



indicates subaerial exposure and weathering. The erosional surface and the 0.7-m-thick overlying marlstone represent the "first emergence unit" of Pedley et al. (2007) and have been correlated with the global sea level lowstand at 6.8 Ma (TB 3.3 cycle) in this paper. Therefore, despite its non-indicative fauna, the beds FSC 1-3 are considered also as Messinian by Pedley et al. (2007), which is followed herein.

Litho- and biofacies

Beds FSC 1 to FSC 3

The lowermost part of the succession is exposed along the shoreline and comprises beds FSC 1 to FSC 3. These beds are dominated by thick-bedded homogeneous packstones and mollusc floatstones. As an exception, the base of bed FSC 2 shows wave-rippled cross-lamination that gradually disappears due to upsection

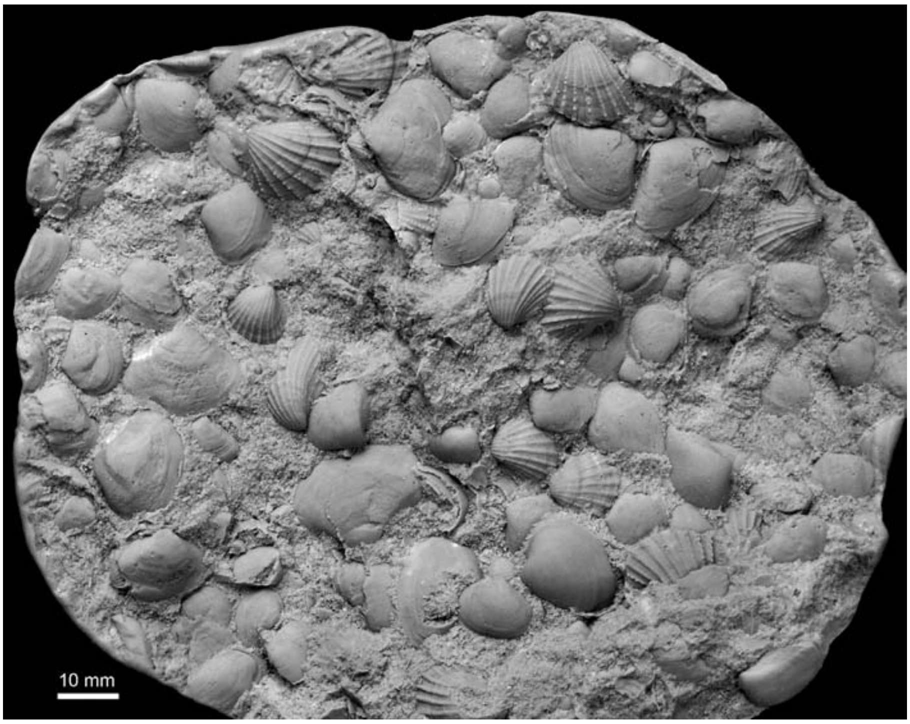


Fig. 3 - Silicone cast of a bivalve coquina from bed FSC 15, consisting mainly of *Acanthocardia paucicostata* (Sowerby, 1834), *Ervilia* sp. A, *Spisula subtruncata* (Da Costa, 1778) and *Polititapes eremita* (Brocchi, 1814).

increasing bioturbation. Scattered *Paroxystele rotellaris* (Michelotti, 1847) and rare naticids represent the identifiable gastropod fauna. Among the bivalves numerous, often articulated specimens of the lucinid *Lucina columbella* Lamarck, 1818 along with pectinids and rare *Loripes lucinalis* (Lamarck, 1818), *Acanthocardia turonica* (Hörnes, 1862) and *Callista italica* (Defrance, 1818) occur associated with in situ *Atrina fragilis* (Pennant, 1777) in the upper part of bed FSC 2. A small *Porites* patch reef, which was raised above the sea floor, is developed at the top of bed 3. Articulated *Pecten aduncus* Eichwald, 1830 and *Talochlamys multistriata* (Poli, 1795) are frequently found in the surrounding sediment.

Beds FSC 4 to FSC 27

A 0.7-m-thick marlstone (bed FSC 4) follows above an erosional surface. A low-diversity *Acanthocardia-Polititapes* coquina with scattered batillariids (*Lampanella*) and unidentifiable cerithiids covers the marlstone and onlaps towards the coral patch reef (bed FSC 7). Both facies are encrusted by a cushion-shaped serpulid reef, which is embedded in poorly cemented bioclastic grainstone. Typically, the molluscs in this deposit (bed FSC 8) preserved relics of their original skeletal aragonite. Above, a 2.5-m-thick oolite succession (bed FSC 9) follows, showing shallowly inclined tabular foresets. It is terminated by a mollusc-rich homogeneous oolite bed (bed FSC 10). All ooids are multilayered and formed around thick-shelled miliolid foraminifers. The amount of bivalve shells is increasing upsection in bed 10. *Acanthocardia turonica* is among the most frequent species followed by the large venerids *Callista italica* and *C. chione* (Linnaeus, 1758) along with the arcid *Anadara firmata* (Mayer, 1868). These are always disarticulated and most abundant at the top of the bed. Pectinids are also occurring. Bed FSC 10 is truncated by an erosive surface that exhibits a 20 cm high relief and is covered by a coarse-grained poorly sorted oolite breccia.

The following part of the section is characterised by hummocky cross-stratification and dense cardiid-venerid coquinas, which were the reason for the erroneous comparison with Paratethyan faunas by Fuchs (1874a, b). The coquinas are distinct layers and the bivalve shells occur typically in convex-up orientation (Fig. 3). The dominant taxa are *Acanthocardia paucicostata* (Sowerby, 1834), *Ervilia* sp., *Spisula subtruncata* (Da Costa, 1778) and *Polititapes eremita* (Brocchi, 1814). Especially *Polititapes* and *Acanthocardia* can form almost monospecific layers. Ooids are still the main components in the lower part of the hummocky cross stratified unit but disappear above bed FSC 14. The ooid-free upper part comprises two depositional cycles (beds FSC 16-23 and FSC 24-26). Each is starting with an alternation of marlstone and centimetre-thick mollusc-rich packstones, passing gradually into thick-bedded packstones and grainstones with hummocky cross-stratification. Towards the top of such a depositional cycle the internal stratification becomes increasingly destroyed due to bioturbation. The measured section ends with a 4-cm-thick gastropod packstone (bed FSC 27) with numerous small *Gibbula* and opisthobranch gastropods (Fig. 4) as well as patchy concentrations of randomly orientated and poorly sorted *Acanthocardia* and *Polititapes* bivalve shells.

Fig. 4 - Silicone cast of the surface of bed FSC 27 with numerous *Gibbula* cf. *turbinoides* (Deshayes, 1833) and opisthobranchs.

Palaeoecology

Beds FSC 1 to FSC 3

Within this part of the section the taphonomic loss of aragonitic shells and especially of small species is considerable. Nevertheless, the remaining assemblage is indicative pointing to a shallow marine, sublittoral, low energy environment. In contrast to the closely related genus *Pinna*, *Atrina* is not obligatorily associated with seagrasses but may also dwell between rocks and corals in sublittoral settings at few meters water depth (Bosch et al. 1995; Hewitt et al. 2002; Zuschin & Oliver 2003). Its co-occurrence with lucinid bivalves, which are adapted to low oxygen conditions (Taylor & Glover 2000), however, might suggest a seagrass meadow environment. Even though *Talochlamys multistriata* and modern relatives of *Pecten aduncus* can be found in several tens to hundreds of meters water depth (Dijkstra & Kilburn 2001) the associated *Porites* patch reef clearly proofs a shallow water depth for the top of this unit. The presence of wave ripples indicates a shallow environment with weak currents where water motion is dominated by wave oscillations. The following erosive surface is interpreted to result from subaerial exposure during a relative sea level fall.

Beds FSC 4 to FSC 27

An erosive surface separates the underlying *Porites* reef and the correlative bed FSC 3 from the oolitic part of the section. The relief of the *Porites* reef is overgrown by a polychaete bioherm; bed FSC 7, which is a lateral equivalent of the small polychaete bioherm, is dominated by low diversity *Acanthocardia-Polititapes* coquinas. The occurrence of batillariid (*Lampanella*) and cerithiid gastropods in the coquinas points to the presence of intertidal sand or mudflats (D'Amico et al. 2012). The assemblages of the overlying ooid bars, as represented by bed FSC 10, differ distinctly in their higher diversity. The ecological requirements of extant *Callista chione* and various *Acanthocardia* species point to shallow sublittoral settings. Rufino et al. (2010) report a preferred water depth of 10-15 m for these taxa. Similar environments are expected for the frequent *Anadara firmata* (Mayer, 1868) as its modern congeners of comparable shape and size occur in sandy and muddy substrates from few meters water depths down to several tens of meters (Zuschin & Oliver 2003). The overall assemblage, however, is clearly mixed with littoral taxa, such as *Diodora gibberula* (Lamarck, 1822), which prefers intertidal rocks and stones (Rolán 2005). Large sized species are entirely missing or only represented by fragments or juveniles [(e.g. *Truncularìopsis trunculus conglobatus* (Michelotti, 1841)]. This points to a considerable taphonomic bias by size sorting. All species of bed FSC 15 are infaunal, dwelling preferentially in muddy sand. The extant *Spisula subtruncata* prefers shallow muddy sand bottoms where it forms populations of thousands of individuals per square meter (Fraschetti et al. 1997; Cardoso et al. 2007). Rufino et al. (2010) document densest populations of *Acanthocardia paucicostata* in around 10-12 m water depth whilst *Spisula subtruncata* was found in 5-10 m. A comparable spatial separation might be responsible for the different predominance of species in certain coquinas.

The topmost bed FSC 27 is outstanding in its composition and lithology. It is dominated by huge numbers of small gibbulid and opisthobranch gastropods. Laterally, patches with *Acanthocardia* and *Polititapes* shells occur in the middle of the bed but are absent on the surface. There, no size sorting, winnowing or orientation

Tab. 1 - Species-level mollusc taxa detected at Faro Santa Croce. The numbers indicate only the amount of investigated specimens (now stored in the collections of the Natural History Museum in Vienna). These numbers do not necessarily reflect the percentage of the taxa in the total assemblage. For example, moulds of *Callista* shells are very abundant in the top of bed FSC 10, but due to the strong weathering only very few specimens were appropriate for silicone casts. Similarly, *Pecten aduncus* is frequently found throughout the section, but shells were collected only in beds FSC 3 and FSC 7, where preservation was best.

Species	**FSC 2**	**FSC 3**	**FSC 7**	**FSC 10**	**FSC 10 top**	**FSC 14**	**FSC 15**	**FSC 27**
Diodora gibberula (Lamarck, 1822)				1				
Gibbula magus (Linnaeus, 1758)						4		
Gibbula cf. *turbinoides* (Deshayes, 1833)								pl.
Paroxystele rotellaris (Michelotti, 1847)	3			7		7		
Thericium vulgatum (Bruguière, 1792)				1				
Ptychocerithium sp.			1					
Lampanella obliquistoma (Seguenza, 1880)			1					
Turritella sp.				2				
Tanea koeneni (Sacco, 1891)				4				
Euspira cf. *exturbinoides* (Sacco, 1890)		1				1		
Nassarius agatensis (Bellardi, 1882)				7				
Nassarius edlaueri (Beer-Bistrický, 1958)								1
Truncularìopsis trunculus conglobatus (Michelotti, 1841)				2				
Clavatula pugilis Bellardi, 1877				2				
Cylichna ? sp.								pl.
Antalis vulgaris (Da Costa, 1778)		1						
Gibbomodiola adriatica (Lamarck, 1819)				3				
Septifer plioblitus Sacco, 1898				1				
Musculus costulatus (Risso, 1826)				1				
Anadara firmata (Mayer, 1868)				6				
Atrina fragilis (Pennant, 1777)	pl.							
Pecten aduncus Eichwald, 1830		8	1					
Talochlamys multistriata (Poli, 1795)		3						
Lucina columbella Lamarck, 1818	4			20		3		
Loripes lucinalis (Lamarck, 1818)	1			23				
Ctena decussata (O. G. Costa, 1829)				1				
Acanthocardia paucicostata (G. B. Sowerby II, 1834)			13				33	19
Acanthocardia turonica (Hörnes, 1862)	1			26	2	3		
Moerella donacina (Linnaeus, 1758)				6				
Angulus sp.				2				
Ervilia sp. A							17	
Spisula subtruncata (da Costa, 1778)							43	
Clausinella fasciata (da Costa, 1778)				1				
Callista italica (Defrance, 1818)	1			3	7			
Callista chione (Linnaeus, 1758)				11				
Dosinia lupinus (Linnaeus, 1758)				1				
Polititapes eremita (Brocchi, 1814)			4				44	

can be observed and the facies suggests a very shallow setting with minor water energy. The palaeoecological interpretation of the assemblage, however, is hampered by the poor taxonomic level of the identifications. Gibbulids are usually most abundant along rocky shores and in the intertidal phytal zone (Riedl 1983; Evans et al. 2011). A rocky shore can be excluded based on sedimentological features. Moreover, such an environment would not fit to the extremely abundant opisthobranch *Cylichna*? sp. Although opisthobranchs like *Cylichna* may be important constituents of coastal and lagoonal settings (Melo et al. 2013), they shun littoral environments. The striking dominance of only two species, occurring in huge numbers is a clear indication of a restricted environment and the absence of any seagrass dwelling taxa restricts the presumed phytal to algae or bacterial mats. Therefore, we interpret the topmost bed of the succession to have formed in a strongly restricted, subtidal lagoonal setting with phytal cover.

Concluding, the shallow marine lower part with *Porites* patch reefs is truncated by an erosive surface related to a retreat of the sea. The subsequent transgression into this part of the Hyblean plateau allowed the establishment of small polychaete bioherms on the relief formed by the *Porites* reefs, which were surrounded by soft sediment inhabited by cardiid bivalves. With the ongoing transgression, an agitated oolite shoal within the wave base developed. The mollusc assemblages point to a water depth of about 10-20 meters. Fully marine or slightly hypersaline conditions are indicated by the mollusc fauna, which lacks any brachyhaline taxa, and by the oolites, which form in tidal and very shallow subtidal high-energy settings (Flügel 2004) and typically develop in carbonate saturated water with high alkalinity and increased salinity (Rankey & Reeder 2009).

The overlying coquina layers already indicate a ceasing accommodation space with only few meters water depth. Still, high water energy is indicated by the convex-up position of the shells in the dense coquinas, which might have been formed by winnowing. Finally, the water energy decreases distinctly and a shallow sublittoral lagoonal environment with dense phytal cover developed.

Discussion and conclusion

The early Messinian mollusc assemblages of Faro Santa Croce section are characterised by a rather low diversity and the predominance of few, rock-forming bivalves. Most of the 32 species listed in Tab. 1 are very rare and taphonomic bias by synsedimentary breakage and postsedimentary dissolution is considerable. In the field, the coquinas are indeed superficially similar to Sarmatian coquinas from the Paratethyan basins due to comparable morphologies and due to some parallels in their supra-specific composition. The poor preservation of most of the material is a further handicap for a proper identification. Since the influential misidentifications of Fuchs (1874a, b), the existing literature suggested a close (on the species level) Mediterranean-Paratethyan faunistic relation between 6.4 to 5.96 Ma comparable to the alleged Paratethyan influence during the late Messinian Lago Mare phase between 5.50 and 5.33 Ma.

After revising the fauna, not a single Paratethyan Sarmatian species was detected in the assemblage. Instead, all species represent typical Mediterranean species. The biostratigraphic value of the assemblages is low but has a clear Late Miocene flair. About 50% of the 32 species-level taxa have roots in Early and Middle Miocene times and 53% of the species are still distributed in the Mediterranean Sea and the Eastern Atlantic. About 50% have their first occurrence in the Tortonian and c. 19% do not cross the Miocene/Pliocene boundary, clearly limiting the fauna to the Late Miocene. None of the species, however, is limited to the Messinian, which makes a separation from Tortonian faunas impossible.

In contrast to the interpretations of Grasso et al. (1982) and Pedley et al. (2007), no indications for lowered salinities during the Messinian interval at Faro Santa Croce can be documented. Alleged brackish water taxa, such as *Didacna* and *Euxinicardium*, turned out to represent species of *Acanthocardia*. Comparable Messinian coquinas with *Acanthocardia paucicostata* have been also described and illustrated by Venzo and Pelosio (1963) from Vigoleno in Italy, documenting that this biofacies was widespread in the Messinian Mediterranean Sea. The occurrence of stenohaline marine mollusc assemblages in oolitic deposits clearly points to the presence of normal to slightly hypersaline, agitated shoals along the foreland margin of the African Plate prior to the onset of the Messinian Salinity Crisis. Consequently, the term "restricted marine unit", as proposed by Pedley et al. (2007), is misguiding and should be abandoned.

Material: To overcome the dissolution of the primary aragonitic shells, large numbers of silicone casts were taken systematically from mollusc moulds of all investigated beds. This sampling technique allows restoring hinge details and surface sculpture, which are crucial for a reliable identification. These casts along with rock samples are stored at the Natural History Museum Vienna (Inv. NHMW 2013/0306/0001- 2013/0306/0040); FSC-numbers given in the material paragraphs refer to the beds in the section as indicated in Fig. 2.

Systematic palaeontology

Class **Gastropoda** Cuvier, 1795
Subclass **Vetigastropoda** Salvini-Plawen, 1980
Superfamily Fissurelloidea Fleming, 1822
Family Fissurellidae Fleming, 1822
Subfamily Diodorinae Gray, 1821
Genus *Diodora* Gray, 1821

Type species: *Patella apertura* Montagu, 1803 [= *Diodora graeca* (Linnaeus, 1758)]; monotypy (Rehder 1980). Recent, Eastern Atlantic and Mediterranean Sea.

Diodora gibberula (Lamarck, 1822)

Pl. 1, fig. 1

1822 *Fissurella gibberula* Lamarck, p. 15.

2003 *Diodora gibberula* – Landau et al., p. 25, pl. 4, fig. 3 (cum syn.).

2004 *Diodora gibberula* – Chirli, p. 29, pl. 10, figs 1-2.

Material: FSC 10; 1 silicone mould (NHMW2013/0306/0001); maximum width of fragment: ~14 mm.

Discussion. Despite the fragmentary preservation, the small size and regular sculpture allows a separation of the specimen from *Diodora graeca* (Linnaeus, 1758) and *D. italica* (Defrance, 1820).

Distribution. The earliest occurrence of this extant species is mentioned from the Middle Miocene of Italy by Sacco (1897). During the Tortonian it is recorded from Stazzano and Montegibbio in Italy (Chirli 2004). It becomes frequent in the entire Mediterranean area and eastern Atlantic from the Pliocene and Pleistocene onwards (Landau et al. 2003). Another Messinian record of a *Diodora* without species identification is mentioned by Saint Martin and Cornee (1996) from Melilla in Morocco. In the modern Mediterranean faunas *Diodora gibberula* is found mainly on infralittoral rocky bottoms (Milazzoa et al. 2000).

Superfamily Trochoidea Rafinesque, 1815
Family Trochidae Rafinesque, 1815
Genus *Paroxystele* Schultz, 1969

Type species: *Trochus patulus* Brocchi, 1814; original designation. Pliocene, Italy.

Paroxystele rotellaris (Michelotti, 1847)

Pl. 1, fig. 2

1847 *Trochus rotellaris* Michelotti, p. 182.

1874a *Trochus patulus* – Fuchs, p. 108 (non *Trochus patulus* Brocchi, 1814).

1874b *Trochus patulus* – Fuchs, p. 375 (non *Trochus patulus* Brocchi, 1814).

1896 *Oxystele rotellaris* - Sacco, p. 27, pl. 3, fig. 23.

1963 *Diloma* (*Oxystele*) *rotellaris* – Venzo & Pelosio, p. 60, pl. 33, figs 2-7.

2011 *Diloma* (*Oxystele*) *rotellaris* – Caprotti, p. 48, figs 1C-D.

Material: FSC 2: 3 silicone moulds; FSC 10: 7 silicone moulds; FSC 14: 7 silicone moulds (NHMW2013/0306/0002); largest specimen height: ~17 mm, width: ~25 mm.

Discussion. *Paroxystele rotellaris* represents a Late Miocene offshoot of a Miocene lineage, which is rooted in the Burdigalian *P. amedei* (Brongniart, 1823) and *P. burdigalensis* (Cossmann & Peyrot, 1917), leading via the Middle Miocene *P. orientalis* (Cossmann & Peyrot, 1917) to the Pliocene *P. patula* (Brocchi, 1814). According to Schultz (1971) it is separated from this lineage by the solid and fully calcified columella, which lacks any cavities. Another characteristic feature is the thin, shield-like, glossy circum-umbilical callus that is sharply demarcated from the base, which it covers largely. This species was listed from Faro Santa Croce by Fuchs (1874a, b) erroneously as *Trochus patulus*.

Distribution. This species is recorded from several Tortonian localities in Italy (Stazzano, San Agata, Montegibbio; Sacco 1896; Caprotti 2011), Portugal (Dollfus et al. 1903-1904) and Turkey (Adana Basin; Erünal-Erentöz 1958). At Faro Santa Croce it is also very abundant and associated with in situ *Atrina* and pectinids. During the early Messinian it seems to be a very successful species, which is recorded from Borelli and Vigoleno in Italy and from Melilla in Morocco (Ben Moussa et al. 1988). Zunino and Pavia (2009) list this species also from the Burdigalian of the Turin Hills.

Genus *Gibbula* Risso, 1826

Type species: *Trochus magus* Linnaeus, 1758; subsequent designation by Herrmannsen, 1847. Recent, Mediterranean Sea.

Gibbula magus (Linnaeus, 1758)

Pl. 1, figs 3-4

1758 *Trochus Magus* Linnaeus, nr. 507, p. 757.

1896 *Gibbula magus* - Sacco, p. 29, pl. 3, fig. 32.

2003 *Gibbula* (*Gibbula*) *magus* – Landau et al., p. 46, pl. 10, fig. 4 (cum syn.).

2010 *Gibbula magus* - Sosso & Dell'Angelo, p. 19, unnumbered figure page 30.

Material: FSC 14: 4 silicone moulds (NHMW2013/0306/0003); largest specimen height: > 15 mm, width: ~18 mm.

Distribution. This extant species is wide spread in the Mediterranean Sea and along the eastern Atlantic coast (Poppe & Goto 1991). Its first occurrence is mentioned by Sacco (1896) and Chirli (2004) from the Tortonian of Montegibbio in Italy. The shells from Faro Santa Croce represent the second Messinian record along with shells from Melilla in Morocco (Ben Moussa et al. 1988). From the Early Pliocene onwards it is a very common species throughout the Mediterranean Sea (Landau et al. 2003; Chirli 2004).

Gibbula cf. turbinoides (Deshayes, 1833)

Fig. 4

cf. 1833 *Trochus turbinoides* Deshayes, p. 143, pl. 18, figs 28-30.

1874a *Trochus pictus* – Fuchs, p. 108 (non *Trochus pictus* Wood, 1828, non *Trochus pictus* Eichwald, 1830, non *Trochus pictus* Philippi, 1846).

1874b *Trochus pictus* – Fuchs, p. 375 (non *Trochus pictus* Wood, 1828, non *Trochus pictus* Eichwald, 1830, non *Trochus pictus* Philippi, 1846).

cf. 2004 *Gibbula* (*Gibbula*) *turbinoides* – Chirli, p. 67, pl. 26, figs 5-10.

Material: FSC 27: numerous silicone moulds; maximum height: 10 mm, maximum width: 9 mm; most shells range around 7-8 mm in height.

Discussion. The very top of the Faro Santa Croce section bears a few-cm-thin limestone layer, which is dominated by small gibbulid shells along with opisthobranchs and subordinate bivalves. The trochids display a considerable variability concerning the convexity of the last whorl but most shells have a weak angulation close to the base. The shells bear faint spiral ribs, which are visible only under magnification and are slightly more prominent at the base. Umbilicus reduced to a narrow chink. These features fit well to *Gibbula turbinoides*, whilst the reminiscent *Gibbula adansoni* (Payraudeau, 1826), is slightly larger, has a wider umbilicus, a more trochiform outline and stronger spiral ribs. This group appears already during the Early Miocene in the proto-Mediterranean Sea, described as varieties of *Gibbula adansoni* by Sacco (1896). The preservation of the Messinian material does not allow a clear identification; especially the weaker spiral sculpture differs from typical *G. turbinoides*.

Fuchs (1874a, b) identified this species as *Trochus pictus* without adding an author. From the context it is clear that he referred to *Trochus pictus* Eichwald, 1830, which is an endemic Sarmatian Paratethyan species (now treated as *Timisia* Jekelius, 1944). Aside from the huge stratigraphic gap of c. 5 million years, the Sarmatian species differs clearly from the Messinian species in its much broader turbiniform outline and the narrow sutural ramp.

Distribution. The extant Mediterranean *Gibbula turbinoides* is known at least since the Pliocene and is recorded from Sicily, the Piedmont and the Toscana in Italy (Chirli 2004).

Subclass **Caenogastropoda** Cox, 1960

Order **Sorbeoconcha** Ponder & Lindberg, 1997

Superfamily Cerithioidea Fleming, 1822

Family Batillariidae Thiele, 1929

Genus *Lampanella* Mörch, 1876

Type species: *Murex minimus* Gmelin, 1791;
subsequent designation by Wenz (1940). Recent, W-Atlantic.

Lampanella obliquistoma (Seguenza, 1880)

Pl. 1, fig. 5

1863 *Cerithium mayeri* Doderlein: 101 (nomen nudum).

1874a *Cerithium* sp. cfr. *nodoso-plicatum* - Fuchs, p. 108 (non *Cerithium nodosoplicatum* Hörnes, 1856).

1874b *Cerithium* sp. cfr. *nodoso-plicatum* - Fuchs, p. 376 (non *Cerithium nodosoplicatum* Hörnes, 1856).

1880 *Cerithium obliquistoma* Seguenza, p. 155, pl. 11, fig. 25.

1895 *Pithocerithium obliquistoma* var. *Mayeri* - Sacco, p. 34, pl. 2, fig. 87.

1895 *Pithocerithium obliquistoma* var. *subturrita* Sacco, p. 34, pl. 2, fig. 88.

1895 *Pithocerithium obliquistoma* var. *inflatovula* Sacco, p. 34, pl. 2, fig. 81.

1958 *Cerithium* (*Pithocerithium*) *obliquistoma* var. *mayeri* – Erünal-Erentöz, p. 32, pl. 3, figs 13-19.

1968 *Cerithium* (*Thericium*) *obliquistoma* – Robba, p. 519, pl. 40, fig. 5.

2012 *Lampanella obliquistoma* - D'Amico et al., p. 162, pl. 1, figs 8-10 (cum syn.).

Material: FSC 7: 1 silicone mould (NHMW2013/0306/0004); height: 6.9 mm; width: 4.6 mm.

Discussion. Fuchs (1874a, b) seems to have detected this not very common species at Faro Santa Croce but erroneously has identified it as *Granulolabium nodosoplicatum* (Hörnes, 1856). This species is typical for the Sarmatian Paratethys Sea and, despite some superficial similarities with *Lampanella obliquistoma*, differs in its slender shape and regular sculpture of two prominent spiral rows of blunt nodes at the sutures (cf. Švagrovský, 1971). Ozawa et al. (2009) have pointed out that the European species attributed to "*Batillaria*" – such as the Early Miocene "*Batillaria*" *pupaeformis* (Basterot, 1825) – might be better placed in *Lampanella*, which is restricted today to the western Atlantic region.

Distribution. This polymorphic species was frequently recorded from the Tortonian of the Mediterranean Sea and is documented from Turkey (Erünal-Erentöz 1958) and Italy (e.g.: Stazzano, S. Agata, Messina, Cessaniti) (Seguenza 1880; Robba 1968; D'Amico et al. 2012). It might have its roots in the Middle Miocene of the Paratethys Sea, where closely related or even conspecific specimens have been described as *Pithocerithium pseudobliquistoma* Szalai, 1926 from Hungary and as *Cerithium* (*Pithocerithium*) *attritum* Boettger, 1906 from Poland and Romania. D'Amico et al. (2012) interpret this species as littoral element similar to the extant *L. minima* (Gmelin, 1791), which prefers sand and mud of the lower intertidal zone.

Family Cerithiidae Fleming, 1822

Subfamily Cerithiinae Fleming, 1822

Genus *Ptychocerithium* Sacco, 1895

Type species: *Cerithium granulinum* Bellardi & Michelotti, 1840;
original designation. Late Miocene, Italy.

Ptychocerithium sp.

Pl. 1, fig. 6

Material: FSC 7: 1 silicone mould (NHMW2013/0306/0005); height of spire fragment: 7.5 mm, width: 3.5 mm.

Discussion. The identification of this single cast is problematic. The overall shape is reminiscent of the Tortonian to Pliocene *Ptychocerithium granulinum* (Bellardi & Michelotti, 1840), which however is larger and develops narrower spiral ribs and pointed nodes (see Robba 1968; Ferrero-Mortara et al. 1984).

Genus *Thericium* Monterosato, 1890

Type species: *Cerithium vulgatum* Bruguière, 1792;
original designation. Recent, Europe.

Thericium vulgatum (Bruguière, 1792)

Pl. 1, fig. 7

1792 *Cerithium vulgatum* Bruguière, p. 481.

1874a *Cerithium rubiginosum* – Fuchs, p. 108 (non *Cerithium rubiginosum* Eichwald, 1830).

1874b *Cerithium rubiginosum* – Fuchs, p. 375 (non *Cerithium rubiginosum* Eichwald, 1830).

1974 *Thericium* (*Thericium*) *vulgatum* - Malatesta, p. 205, pl. 15, figs 6a-6b.

1997 *Cerithium* (*Thericium*) *vulgatum* - Anistratenko, p.69, fig. 1a.

2004 *Cerithium* (*Thericium*) *vulgatum* – Landau et al., p. 8, pl. 1, figs 10-11.

2006 *Cerithium vulgatum* – Chirli, p. 87, pl. 35, figs 7-15.

Material: FSC 10: 1 silicone mould of an incomplete specimen (NHMW2013/0306/0006); height: > 36 mm, width: ~16 mm.

Discussion. The silicone mould represents a moderately slender morph. Its sculpture is strongly reduced to a row of blunt nodes in the middle of the whorls, a weak band of beads along the upper suture and numerous spiral threads of which the one passing the nodes is slightly raised. On the last whorl the nodes disappear. A comparable morphology seems to occur in the Messinian of Morocco, judging from the description of Ben Moussa et al. (1988) [mentioned as *Thericium vulgatum uninodosa* (Sacco, 1895)].

This species is not rare in the Messinian oolites of Faro Santa Croce, but usually only weathered cavities of the former shells are visible on the rock surface. Fuchs (1874a, b) seems to have identified the poorly preserved specimens erroneously as *Cerithium rubiginosum* (Eichwald, 1830), which is an about 5 million years older endemic species of the Sarmatian Paratethys Sea (Harzhauser & Kowalke 2002; Lukeneder et al. 2011).

Distribution. The relation of this extremely polymorphic species with its Early and Middle Miocene relatives is not resolved. Many Middle Miocene taxa, that are treated as subspecies of *Thericium vulgatum* in the literature, represent distinct species such as *Thericium miospinosum* (Sacco, 1895), *T. miocenicum* (Vignal, 1911) and *T. europaeum* (Mayer, 1878) (Landau et al. 2013). Undoubted occurrences of *Thericium vulgatum* sensu stricto seem to date back to the Tortonian (Sacco 1895; Landau et al. 2004). Messinian occurrences of the species are recorded by Ben Moussa et al. (1988) and Saint Martin and Cornee (1996) from Melilla in Morocco. From the Pliocene onwards, this extant species is wide spread in the Mediterranean Sea and the Black Sea (Anistratenko 1997; Landau et al. 2004; Chirli 2006).

Family Turritellidae Lovén, 1847

Genus *Turritella* Lamarck, 1799

Type species: *Turbo terebra* Linnaeus, 1758; monotypy.
Recent, Indo-West Pacific.

Turritella sp.

Pl. 1, fig. 8

1874a *Turritella bicarinata* - Fuchs, p. 109.
1874b *Turritella bicarinata* - Fuchs, p. 376.

Material: FSC 10: 2 silicone moulds of spire fragments (NHMW2013/0306/0007); height: > 11 mm.

Discussion. The spire fragments are unidentifiable; the prominent angulation in the middle of the early whorls and the keel at that position are reminiscent of early spire whorls of the mainly Early to Middle Miocene *Archimediella bicarinata* (Eichwald, 1830), but they are also reminiscent of *Turritella spirata* (Brocchi, 1814), which is wide spread in Miocene and Pliocene deposits (Landau et al. 2004).

Order **Littorinimorpha** Golikov & Starobogatov, 1975

Superfamily Naticoidea Guilding, 1834

Family Naticidae Guilding, 1834

Subfamily Naticinae Guilding, 1834

Genus *Tanea* Marwick, 1931

Type species: *Natica zelandica* Quoy & Gaimard, 1832;
original designation. Recent, New Zealand.

Tanea koeneni (Sacco, 1891)

Pl. 1, fig. 9

1891 *Natica (Natica) epiglottina* var. *koeneni* Sacco, p. 63.
2008 *Tanea dillwyni koeneni* - Pedriali & Robba, p. 104, pl. 1, figs 9-11, pl. 2, fig. 16, pl. 3, figs 8, 14 (cum syn.).

Material: FSC 10: 4 silicone moulds (NHMW2013/0306/0008); largest specimen: height: 25 mm; width: 29 mm.

Discussion. A moderately large naticid which is quite common in the Messinian oolite dunes of Faro Santa Croce. Silicone moulds of the cavities reveal a broad globular shell with moderately elevated spire. Its umbilicus is wide but largely filled by the broad funicle, which passes more or less continuously into the prominent parietal callus without marked sulcus. Shell outline and umbilical features are reminiscent of the Pliocene *Natica plicatula* (Bronn, 1831) sensu Chirli (2008) and Pedriali and Robba (2005) [as *Cochlis* Röding, 1798 in Pedriali and Robba (2005) but Torigoe and Inaba (2011) and WoRMS (2013) treat *Cochlis* as synonym of *Natica* Scopoli, 1777]. A distinct difference is the broad umbilical opening with small umbilical callus of *Natica plicatula* [the identification is based on personal communication with Elio Robba].

According to Pedriali and Robba (2008), the Pliocene shells of this species differ from the extant *Natica dillwynii* Payraudeau, 1826 in their protoconch, with only two instead of three whorls.

Distribution. This species occurs from the latest Burdigalian to the early Tortonian in the North Sea area and is wide spread in the Pliocene of the Mediterranean Sea (Pedriali & Robba 2008).

Subfamily Polinicinae Gray, 1847

Genus *Euspira* Agassiz in Sowerby 1838

Type species: *Natica glaucinoides* Sowerby, 1812; subsequent designation by Bucquoy, Dautzenberg & Dollfus, 1883. Eocene, Great Britain.

Euspira cf. exturbinoides (Sacco, 1890)

Pl. 1, fig. 10

cf. 1890 *N.* [*aticina*] *hemiclausa* (Sow.) var. *exturbinoides* Sacco, p. 31 (as subgenus of *Natica*).
cf. 1891 *N.* [*aticina*] var. *exturbinoides* Sacco, p. 77, pl. 2, fig. 49 (as subgenus of *Natica*).
cf. 2009 *Euspira exturbinoides* – Pedriali & Robba, p. 390, pl. 1, figs 5-6, pl. 3, fig. 24, pl. 4, fig. 1 (cum syn.).

Material: FSC 3: 1 silicone mould; FSC 14: 1 silicone mould (NHMW2013/0306/0009); height: 20 mm, width: > 16 mm.

Discussion. The aperture is missing in all available specimens and a clear specific identification is impossible. The ovoid shape and the subsutural depression are reminiscent of *Euspira exturbinoides* and *E. macilenta* (Philippi, 1844) but differ clearly from the more globular coeval *E. helicina* (Brocchi, 1814). According to Pedriali and Robba (2009), *E. exturbinoides* is the Late Miocene to Pliocene ancestor of the Pleistocene to Recent *E. macilenta* and therefore all pre-Pleistocene literature-records of *E. macilenta* might rather represent *E. exturbinoides.*

Distribution. *Euspira exturbinoides* appears during the Tortonian when it is recorded from Montegibbio in Italy and becomes wide spread in the Mediterranean during the Pliocene (Pedriali & Robba 2009).

Subclass **Caenogastropoda** Cox, 1960

Order **Neogastropoda** Wenz, 1938

Superfamily Buccinoidea Rafinesque, 1815

Family Nassariidae Iredale, 1916

Genus *Nassarius* Duméril, 1805

Type species: *Buccinum arcularia* Linnaeus, 1758;
subsequent monotypy by Froriep, 1806. Recent, Indo-Pacific.

Nassarius agatensis (Bellardi, 1882)

Pl. 1, fig. 11

1847 *Nassa Dujardini* Michelotti, p. 210, pl. 12, fig. 5 (non *Buccinum Dujardinii* Deshayes, 1844).

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

1882 *Nassa coarctata* Varietà A. Bellardi, p. 28 (non *Nassa coarctata* Eichwald, 1830).

1882 *Nassa pulchra* [sic!] – Bellardi, p. 29, pl. 1, figs. 24 a-b (non *Nassa pulcra* "Ancona" De Stefani & Pantanelli 1878).

1904 *Nassa* (*Arcularia*?) *coarctata* Eichw. var. *acuminata* Sacco, p. 63, pl. 15, figs. 31-32 (non *Nassa acuminata* Marrat 1880).

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

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

1939 *Nassa agatensis* - Montanaro, p. 138, pl. 8, fig. 32.

1956 *Nassa* (*Sphaeronassa*) *Saccoi* – Moroni, p. 73, pl. 1, figs 4-4a.

1963 *Sphaeronassa Saccoi* – Venzo & Pelosio, p. 96, pl. 36, figs 7-9.

1963 *Nassarius* (*Nassarius*) *schoenni* - Venzo & Pelosio, p. 101, pl. 36, figs 1-2 (non *Buccinum* (*Niotha*) *Schönni* Hoernes & Auinger, 1882).

1981 *Nassa agatensis* - Ferrero-Mortara et al., p. 226, pl. 20, figs 10a-b.

2011 *Nassarius agatensis* – Harzhauser & Cernohorsky, p. 31.

Material: FSC 10: 7 silicone moulds (NHMW2013/0306/0010), maximum height: 9 mm, width: 6.5 mm.

Discussion. The specimens from Faro Santa Croce represent two morphotypes: a more abundant rather smooth and globular one and a more slender one. These morphotypes correspond to the Tortonian taxa *Nassarius saccoi* (Trentanove, 1911) and *Nassarius cocchii* (Trentanove, 1911). Already Trentanove (1911) emphasised the occurrence of transitional specimens connecting these two morphologies. Similarly, Bellardi (1882) proposed several names for the various morphologies. Of these, *Nassa agatensis* Bellardi, 1882 gains priority, whilst other names proposed by Bellardi (1882) and Sacco (1904) are not available (see Harzhauser & Cernohorsky, 2011 for detailed discussion).

Distribution. Widespread in the Tortonian of the Mediterranean Sea (e.g.: Stazzano, Montegibbio, S Agata). Messinian occurrences are documented for Faro Santa Croce and Vigoleno (Venzo & Pelosio 1963).

Nassarius edlaueri (Beer-Bistrický, 1958)

Pl. 1, fig. 12

1958 *Hinia* (*Hinia*) *edlaueri* Beer-Bistrický, p. 55, pl. 2, fig. 11.

2004 *Nassarius edlaueri* – Harzhauser & Kowalke, p. 25, pl. 3, figs 13-14.

2011 *Nassarius edlaueri* - Harzhauser & Cernohorsky, p. 32.

2012 *Nassarius* (*Nassarius*) *edlaueri* – D'Amico et al., p. 167, pl. 2, figs 26-27 (cum syn.).

Material: FSC 27: 1 silicone mould (NHMW2013/0306/0011); height: 8.5 mm, width: 6 mm.

Discussion. This nassariid is typically found in coastal mudflat deposits of the Miocene Paratethys and seems to have preferred intertidal environments (Harzhauser & Kowalke 2004; Zuschin et al. 2004). D'Amico et al. (2012) report a comparable setting for the Tortonian assemblages from Cessaniti in Italy. At Faro Santa Croce it is restricted to the top bed FSC 27, which indicates a calm and shallow lagoonal environment.

Distribution. *Nassarius edlaueri* is known from the Burdigalian (Karpatian) of the Paratethys Sea and is wide spread during the Langhian and Serravallian in the Paratethys and the Mediterranean Sea (Harzhauser & Kowalke 2004; Landau et al. 2013). Its last occurrences are known from the Late Miocene (Tortonian, Messinian) of the Mediterranean Sea (D'Amico et al. 2012; and this paper).

Superfamily Muricoidea Rafinesque, 1815

Family Muricidae Rafinesque, 1815

Subfamily Muricinae Rafinesque, 1815

Genus *Truncularioposis* Cossmann, 1921

Type species: *Murex trunculus* Linnaeus, 1758; original designation.
Recent, Mediterranean Sea.

Truncularioposis trunculus conglobatus (Michelotti, 1841)

Pl. 1, fig. 13

1841 *Murex conglobatus* Michelotti, p. 16, pl. 4, fig. 7.

2007 *Hexaplex* (*Truncularioposis*) *trunculus conglobatus* - Landau et al., p. 13, pl. 3, figs 1-2 (cum syn.).

2011 *Hexaplex* (*Truncularioopsis*) *trunculus conglobatus* – Merle et al., p. 324, pl. 40, figs 2-4.

Material: FSC 10: 2 silicone moulds (NHMW2013/0306/0012); estimated diameter: 20 mm.

Discussion. The available material is very fragmentary, consisting of a spire fragment and a part of the last whorl with spines. This is characterised by a prominent angulation, which would be more typical for the coeval *Truncularioopsis pecchiolanus* (D'Ancona, 1871) as defined by Landau et al. (2007) and Merle et al. (2011). The rather high and gradate spire, however, does not agree with the stout spire of *Truncularioopsis pecchiolanus.* A comparable morphology, combining small size, a high spire and a strongly angulated last whorl with rapidly contracting base is documented also from modern representatives of *T. trunculus trunculus* (Linnaeus, 1758) (e.g.: Merle et al. 2011, pl. 41, fig. 8), supporting the identification of the Messinian shells.

Distribution. This species appears during the Tortonian when it is found in the Mediterranean Sea (Montegibbio in Italy) and along the Atlantic coast (Cacela in Portugal); it becomes very common in both regions during the Pliocene and is replaced by the modern *T. trunculus* thereafter (Landau et al. 2007). Another Messinian occurrence was reported by Venzo and Pelosio (1963) from Vigoleno in Italy. The modern T. *trunculus* occurs in the intertidal and infralittoral zones down to 120 m depth but is most common at 0.3-30 m depth on hard- and soft substrates (Houart 2001).

Superfamily Conoidea Fleming, 1822

Family Clavatulidae Gray, 1853

Genus *Clavatula* Lamarck, 1801

Type species: *Murex turris coronata* Lamarck, 1801 [Chemnitz, 1795]; by monotypy. Recent, Guinea.

Clavatula pugilis Bellardi, 1877

Pl. 1, fig. 14

1863 *Pleurotoma pugilis* Doderlein, p. 20 (nomen nudum).

1877 *Clavatula pugilis* – Bellardi, p. 169.

1904 *Clavatula Agassizi* (Bell.) var. *variecingulata* Sacco, p. 47, pl. 12, figs 61-62.

1937 *Clavatula Agassizi* Bell. var. *pugilis* – Montanaro, p. 122, pl. 5, figs 35-38.

Material: FSC 10: 2 silicone moulds (NHMW2013/0306/0013); height: 10.1 mm, width: 5.5 mm.

Discussion. The species is not rare in the section but only two silicone moulds could be taken from this stout shell. Its early three teleoconch whorls are smooth with subparallel periphery; the following three whorls are rapidly increasing in diameter causing a gradate outline. A distinct keel with wide spaced nodes appears along the upper suture; a weak rim along the lower suture causes a slight concavity of the whorls, which becomes most prominent on the last whorl, where the rim bears faint nodes. The base contracts rapidly into a short siphonal canal; aperture largely destroyed.

Clavatula pugilis from Montegibbio sensu Montanaro (1937) is characterised by a small size, a conical spire, a gradate outline of the last two teleoconch whorls, a short siphonal canal and moderately prominent nodes. This morphology agrees well with the Messinian shells from Faro Santa Croce and allows a clear separation from the larger and slender *Clavatula agassizi* Bellardi, 1877 and *C. coppii* Bellardi, 1877 from the Tortonian of Italy. *Clavatula consularis* Bellardi, 1877 from the Tortonian and Messinian of Italy (Venzo & Pelosio 1963) is superficially similar but differs in its blunt nodes along both sutures and the less gradate spire. Trentanove (1911) illustrates two Late Miocene shells from Quarata in Italy as *C. pugilis*, which lack the above described features and might rather belong to *C. agassizi.*

Distribution. *Clavatula pugilis* is reported from the Late Miocene of the Mediterranean Sea (Montegibbio, Stazzano, Tortona, S. Agata) (Montanaro 1937).

Subclass **Heterobranchia** Gray, 1840

Infraclass **Opisthobranchia** Milne Edwards, 1848

Order **Cephalaspidea** Fischer, 1883

Superfamily Philinoidea Gray, 1850

Family Cylichnidae H. & A. Adams, 1854

Genus *Cylichna* Lovén, 1846

Type species: *Bulla cylindracea* Pennant, 1777; subsequent designation by Herrmannsen, 1852. Recent, Mediterranean Sea.

Cylichna? sp.

Pl. 1, fig. 15

1874a *Bulla Lajonkaireana* - Fuchs, p. 108 (non *Bulla Lajonkaireana* Basterot, 1825).

1874b *Bulla Lajonkaireana* - Fuchs, p. 375 (non *Bulla Lajonkaireana* Basterot, 1825).

Material: FSC 27: 3 silicone moulds (NHMW2013/0306/0014); height: 7.8 mm, width: 4.4 mm.

Discussion. The species is very abundant in the uppermost layer of the section where it co-occurs with masses of small trochids. Unfortunately, all specimens are deformed. Therefore, an identification is impossible and even the generic assignment is problematic although the thickened columellar margin and anteriorly rounded aperture fit well to *Cylichna* as defined by Valdés (2008).

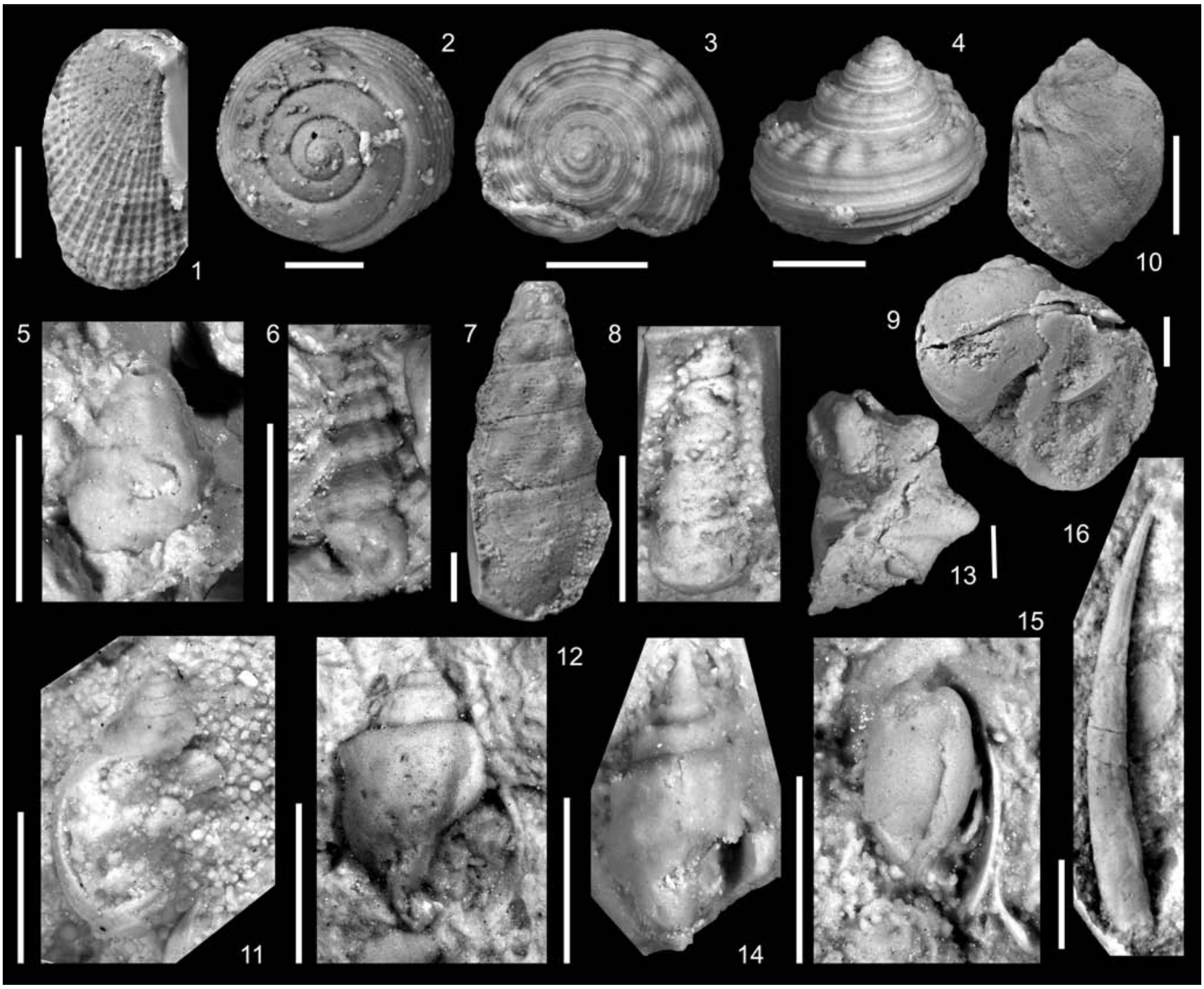


PLATE 1

Typical gastropods and scaphopods from the Faro Santa Croce section (Scale bar = 5 mm).

Fig. 1 - *Diodora gibberula* (Lamarck, 1822), FSC 10; NHMW2013/0306/0001.
Fig. 2 - *Paroxystele rotellaris* (Michelotti, 1847), FSC 14; NHMW2013/0306/0002.
Figs 3-4 - *Gibbula magus* (Linnaeus, 1758), FSC 14; NHMW2013/0306/0003.
Fig. 5 - *Lampanella obliquistoma* (Seguenza, 1880), FSC 7; NHMW2013/0306/0004.
Fig. 6 - *Ptychocerithium* sp., FSC 7; NHMW2013/0306/0005
Fig. 7 - *Thericium vulgatum* (Bruguière, 1792), FSC 10; NHMW2013/0306/0006.
Fig. 8 - *Turritella* sp., FSC 10; NHMW2013/0306/0007.
Fig. 9 - *Tanea koeneni* (Sacco, 1891), FSC 10; NHMW2013/0306/0008.
Fig. 10 - *Euspira* cf. *exturbinoides* (Sacco, 1890), FSC 14; NHMW2013/0306/0009.
Fig. 11 - *Nassarius agatensis* (Bellardi, 1882), FSC 10; NHMW2013/0306/0010.
Fig. 12 - *Nassarius edlaueri* (Beer-Bistrický, 1958), FSC 27; NHMW2013/0306/0011.
Fig. 13 - *Trunculariopsis trunculus conglobatus* (Michelotti, 1841), FSC 10; NHMW2013/0306/0012.
Fig. 14 - *Clavatula pugilis* Bellardi, 1877, FSC 10; NHMW2013/0306/0013.
Fig. 15 - *Cylichna*? sp., FSC 27; NHMW2013/0306/0014.
Fig. 16 - *Antalis vulgaris* (Da Costa, 1778), FSC 23; NHMW2013/0306/0041.

Fuchs (1874a, b) seems to have identified this species erroneously as *Acteocina lajonkaireana* (Basterot, 1825). This Early to Middle Miocene species becomes very large and frequent in Sarmatian deposits of the Paratethys Sea, which might have been the reason for the misidentifications by Fuchs (1874a, b). The misidentification is obvious as the Messinian shells lack the typical heterostrophic protoconch of *Acteocina lajonkaireana.*

The Messinian *Cylichnina miopliocenica* (Moroni, 1956) is smaller, more slender and has a conical upper part. *Cyclichnina umbilicata* (Montagu, 1803), from the Messinian of Vigoleno in Italy, is also much smaller (Venzo & Pelosio 1963).

The Recent Mediterranean *Cylichna cylindracea* (Pennant, 1777), which is frequently found in intertidal sandy mud (Poirier et al. 2009) differs in its slender outline.

Class **Scaphopoda** Bronn, 1862
Order **Dentaliida** Starobogatov, 1974
Family Dentaliidae Children, 1834
Genus *Antalis* H. & A. Adams, 1854

Type species: *Dentalium entalis* Linnaeus, 1758; subsequent designation by Pilsbry & Sharp (1897). Recent, European seas.

Antalis vulgaris (Da Costa, 1778)

Pl. 1, fig. 16

1778 *Dentalium vulgare* Da Costa, p. 24, pl. 2, fig. 10.

1979 *Dentalium (Antalis) vulgare* - Caprotti, p. 238, pl. 9, figs 1-4, 6-7 (cum syn.).

2010 *Antalis vulgare vitreum* – Sosso & Dell'Angelo et al., p. 70, unnumbered figure p. 72.

Material: FSC 3: 1 silicone mould (NHMW2013/0306/0041); lenght: 25 mm, diameter: 2.6 mm.

Discussion. A single cast was found in the beds below the *Porites* reef. No scaphopods have been found at Faro Santa Croce in the overlying oolitic deposits. Note that several authors such as Pavia (1991) and Sosso & Dell'Angelo (2010) treat the Miocene and Pliocene shells of this species as (chrono)-subspecies *Antalis vulgaris vitrea* (Gmelin, 1791) or even as full species (Pelosio 1966). Overall shell shape, the rapidly increasing diameter and the sculpture of the apical part, which becomes weak to absent during ontogeny, fit well to *Antalis vulgaris*.

Distribution. This species appears already during the Langhian in the Mediterranean Sea (Monte Cappuccini section; Caprotti 1979), is also known from the Middle Miocene of the North Sea Basin and is frequently documented from the Late Miocene and Pliocene (Caprotti 1979; Vera-Peláez et al. 1993). A Messinian occurrence is described by Pavia (1991) from Borelli in Italy. The extant *Antalis vulgaris* occurs in all European seas (WoRMS 2013) from 5-1000 m water depth (Öztürk 2011).

Class **Bivalvia** Linnaeus, 1758
Subclass **Autobranchia** Grobben, 1894
Infraclass **Pteriomorphia** Beurlen, 1944
Order **Mytilida** Férussac, 1822
Family Mytilidae Rafinesque, 1815
Genus *Gibbomodiola* Sacco, 1898a

Type species: *Gibbomodiola taurarcuata* Sacco, 1898a; original designation. Early Miocene, Italy.

Gibbomodiola adriatica (Lamarck, 1819)

Pl. 2, fig. 1

1819 *Modiola adriatica* Lamarck, p. 112.

1874a *Modiola Volhynica* – Fuchs, p. 108 (non *Modiola volhynica* Eichwald, 1829).

1874a *M*[*odiola*] *marginata* – Fuchs, p. 107 (non *Modiola marginata* Eichwald, 1830).

1874b *Modiola Volhynica* – Fuchs, p. 375 (non *Modiola volhynica* Eichwald, 1829).

1874b *M*[*odiola*] *marginata* – Fuchs, p. 375 (non *Modiola marginata* Eichwald, 1830).

1901 *Modiola Rosignani* Trentanove, p. 528, pl. 9, figs 1, 12.

1910 *Modiola adriatica* – Martelli & Nelli, p. 528.

1963 *Modiolus* (*Modiolus*) *adriaticus* - Venzo & Pelosio, p. 147, pl. 43, figs 4-5, pl. 50, fig. 4.

1988 *Modiolus* (*Modiolus*) *adriaticus* – Ben Moussa et al., p. 341.

1994 *Modiolus* (*Modiolus*) *adriaticus* – Ben Moussa, p. 72, pl. 2, fig. 11.

2007 *Modiolus*? – Pedley et al., p. 371.

Material: FSC 10: silicone casts of 3 juvenile right valves (NHMW2013/0306/0015); length (max) = 11 mm, height (max) = 9 mm.

Discussion. The modioliform shell shape and comparably strongly inflated, near-terminal umbones, combined with a smooth interior dorsal margin, reveal the specimens from Faro Santa Croce as juveniles of *Gibbomodiola adriatica*. The specimen from Popogna, described and figured as *Modiola rosignani* n. sp. by Trentanove (1901), closely resembles *Gibbomodiola adriatica*, and certainly has to be assigned to the latter species.

Distribution. *Gibbomodiola adriatica* has previously been recorded from the Tortonian of Popogna in Italy (Trentanove 1901) and from the Messinian of Morocco (Ben Moussa et al. 1988; Ben Moussa 1994). From the Pliocene onward, it becomes a relatively common species in the Mediterranean Sea (Monegatti & Raffi 2001; personal observation). Its present distribution encompasses the Baltic and North seas, the eastern

Atlantic down to the Canaries, and the Mediterranean and Black seas (Poppe & Goto 1993).

Genus *Septifer* Récluz, 1848

Type species: *Mytilus bilocularis* Linnaeus, 1758; subsequent designation by Stoliczka (1871). Recent, Indo-West Pacific.

Septifer plioblitus Sacco, 1898

Pl. 2, fig. 5

1898a *Septifer plioblitus* Sacco, p. 37, pl. 11, figs 9-13.
1927 *S*[*eptifer*] *plioblitus* – Hornung, p. 298.
1997 *Septifer* (*Septifer*) *plioblitus* – Lozano Francisco, p. 215, pl. 9, figs 3-6.

Material: FSC 10: silicone cast of a juvenile right valve (NHMW2013/0306/0018); length = 6 mm, height = 5 mm.

Discussion. The juvenile individual is relatively short and high, and ornamented with more than 60 densely spaced radial riblets; it closely resembles the Pliocene specimens figured by Sacco (1898a).

Distribution. *Septifer plioblitus* has previously been recorded from the Upper Miocene to Pliocene of the Mediterranean region (Monegatti & Raffi 2001), e.g. from Rio Torsero in Liguria in Italy (Sacco 1898a; Hornung 1927) and from the Lower Pliocene of Estepona in southern Spain (Lozano Francisco 1997).

Genus *Musculus* Röding, 1798

Type species: *Mytilus discors* Linnaeus, 1767; subsequent designation by Iredale, 1915. Recent, European seas.

Musculus costulatus (Risso, 1826)

Pl. 2, fig. 3

1826 *M*[*odiolus*]. *costulatus* Risso, p. 324, no. 874, pl. 11, fig. 165.
1890 *Modiolaria costulata* – Bucquoy et al. p. 168, pl. 29, figs 23-28.
1920 *Modiolaria costulata* – Dollfus & Dautzenberg, p. 387, pl. 35, figs 16-23.
1981 *Musculus* (*Musculus*) *costulatus* – Lauriat-Rage, p. 40.

Material: FSC 10: silicone cast of a single right valve (NHMW2013/0306/0017); length = 8 mm, height = 5 mm.

Discussion. The slightly more elongate shell and near-terminal umbo, both observable in the specimen from Faro Santa Croce, clearly distinguish *Musculus costulatus* (Risso) from the superficially similar *M. discors* (Linnaeus).

Distribution. This species thrives in Europe since the Middle Miocene (Lauriat-Rage 1981), and has been mentioned to occur in the Messinian of Tunisia (Moissette et al. 2010). Today, this species occurs along the eastern Atlantic coast from Great Britain down to West Africa, and in the Mediterranean (Poppe & Goto 1993).

Order **Arcida** Gray, 1854

Family Arcidae Lamarck, 1809

Genus *Anadara* Gray, 1847

Type species: *Arca antiquata* Linnaeus, 1758; original designation. Recent, Indo-West Pacific Region.

Anadara firmata (Mayer, 1868)

Pl. 2, figs 6-7

1868 *Arca firmata* Mayer, p. 16, 70.
1868 *Arca Darwini* Mayer, p. 18, 71.
1868 *Arca Syracusensis* Mayer, p. 18, 72.
1898b *Anadara firmata* – Sacco, p. 25, pl. 5, fig. 20.
1901 *Arca Syracusensis* – Trentanove, p. 532, pl. 8, fig. 4.
1963 *Arca* (*Arca*) *turonica varanensis* Venzo & Pelosio, p. 142, pl. 42, figs 15, 19.
? 1973 *Anadara* (*Anadara*) cf. *turoniensis* – Marasti, p. 100, pl. 22, figs 4, 10.
? 1987a *Anadara* (*Anadara*) *turonica* - Freneix et al., p. 12, pl. 1, figs 10a, b.

Material: FSC 10: silicone casts of 3 left and 3 right valves. FSC 14: silicon casts of 2 juvenile left valves; length (max) = 57 mm, height (max) = 32 mm (NHMW2013/0306/0019, NHMW2013/0306/0020).

Discussion. The specimens show the typical morphology of *Anadara firmata*, i.e. a well-inflated, inaequilateral shell, eventually with an ill-defined median sulcus, and a ventrally extending, sloping posterior part. The outside of the shell is ornamented with radial costae [up to 32 costae can be distinguished in the incompletely preserved specimens from Sicily; Mayer (1868) reports 37 costae] with relatively narrow and smooth interspaces. Costae are slightly flattened on top and gradually broadened in the region of the posterior-ventral extension of the shell. The shell of *A. diluvii* (Brocchi, 1814) is sub-aequilateral in outline, with a curved ventral margin, lacks a median sulcus, and has well-rounded ribs; it is thus easily distinguished from *A. firmata*. *Anadara pectinata* (Brocchi, 1814) differs from *A. firmata* in being much less inflated and more elongate, with a distinct median sulcus and a marked, merely auriculate, posterior-dorsal corner.

Anadara firmata and *A. darwini* (Mayer, 1868) have both been established on specimens from the Tortonian of Stazzano. In our opinion, *A. darwini* simply describes subadult specimens, while the large adult, slightly less inaequilateral shells are attributed to *A. firmata* (see the specimens figured by Sacco 1898b for comparison). Herein, we thus regard *A. darwini* as a junior synonym of *A. firmata*. Whether all Pliocene records of *Anadara darwini* actually also belong to *A. firmata* has to be proven; we thus refuse to include them in the synonymy and distribution sections.

Most likely, the specimens from the Tortonian of the Stirone section (N Italy), described as *Anadara* (*A.*) cf. *turoniensis* by Marasti (1973), and those from the Messinian of Algeria attributed to *A.* (*A.*) *turonica* by Freneix et al. (1987a) also belong to *A. firmata*.

Distribution. This species has been reported from several Tortonian localities in Italy, i.e. Stazzano, Sassuolo, Montegibbio, S. Agata, Popogna and the Stirone section (Mayer 1868; Sacco 1898b; Trentanove 1901; Marasti 1973). Moreover, the species has been recorded from the Messinian of Vigoleno (Venzo & Pelosio 1963) and from Algeria (Freneix et al. 1987a).

Order **Ostreida** Férussac, 1822

Suborder **Malleidina** Gray, 1854

Family Pinnidae Leach, 1819

Genus *Atrina* Gray, 1842

Type species: *Pinna nigra* Dillwyn, 1817 [= *Atrina vexillum* (Born, 1778)]; subsequent designation by Gray, 1840. Recent, Indo-West Pacific Region.

Atrina fragilis (Pennant, 1777)

Pl. 2, fig. 4

1777 [*Pinna.*] *Fragilis* Pennant, p. 114, pl. 69, fig. 80.

1852 [*Pinna*] *Brocchii* d'Orbigny, p. 125, no. 2361.

1910 *Pinna brocchii* – Martelli & Nelli, p. 529.

1914 *Atrina ferelaevis* Cossmann & Peyrot, p. 266, pl. 11, fig. 9.

1914 *Atrina basteroti* Cossmann & Peyrot, p. 267, pl. 11, figs 31-32.

1963 *Pinna pectinata brocchii* – Tavani & Tongiorgi, p. 12, pl. 3, fig. 1, pl. 5, fig. 6, pl. 6, fig. 8.

1963 *Pinna* (*Pinna*) *pectinata brocchii* - Venzo & Pelosio, p. 148, pl. 43, fig. 14.

1994 *Pinna* (*Pinna*) *pectinata* – Ben Moussa, p. 74, pl. 3, fig. 2 (non *Pinna pectinata* Linnaeus, 1767).

2001 *Atrina pectinata brocchii* – Schultz, p. 133, pl. 10, figs 5-6, pl. 11, fig. 1 (cum syn.).

Material: FSC 2: 1 single silicone cast of a fragmentary left valve (NHMW2013/0306/0042); length = 95 mm, height = 51 mm. In the field, however, this species is represented by a dense gallery of in-situ shells in the lower part of the succession close to the sea-level.

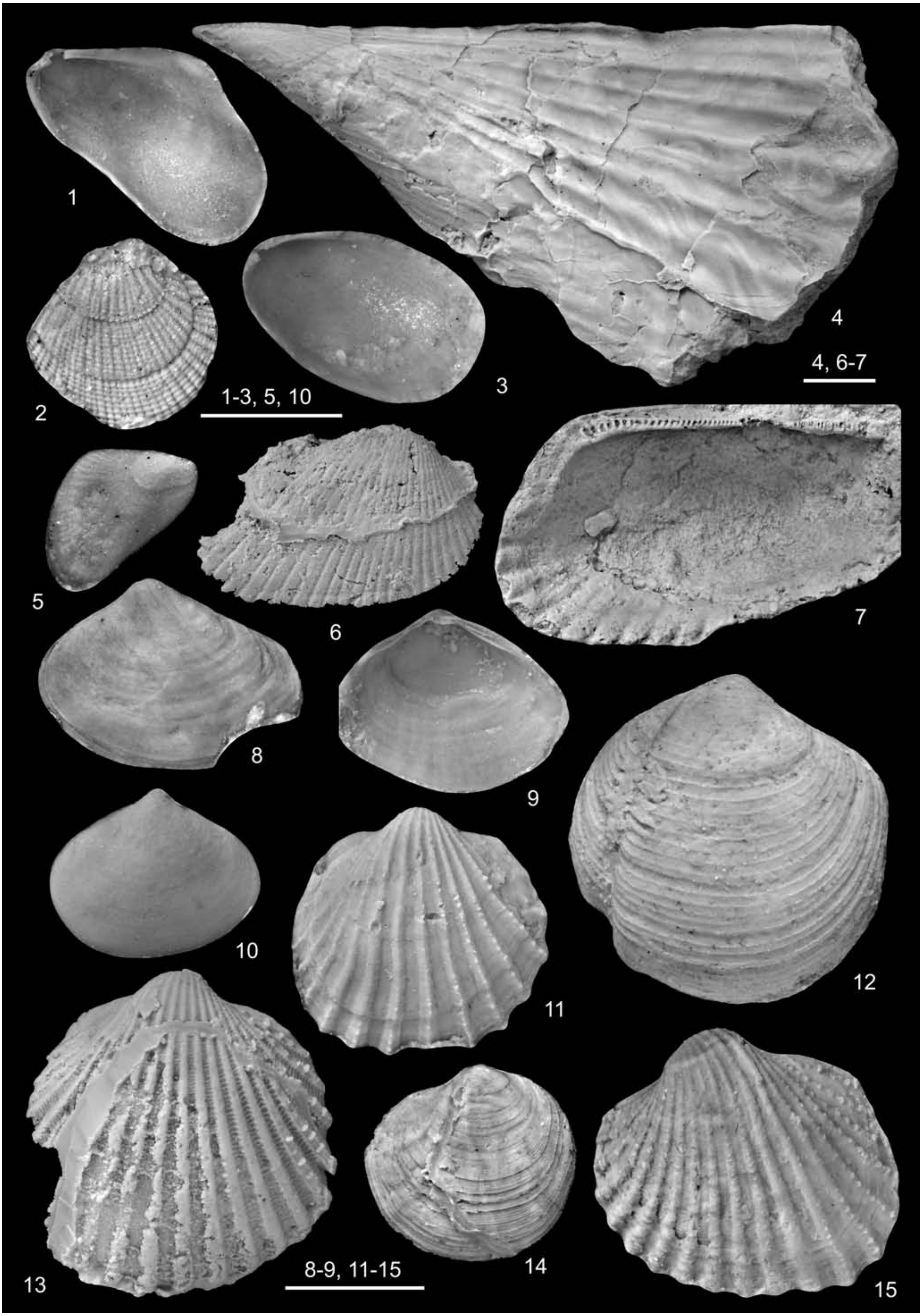
Discussion. The well-preserved umbonal fragment clearly shows the typical, slightly prosogyrous umbo and characteristic ornamentation, composed of eight prominent, undulating, fold-like radial costae on the posterior-dorsal two thirds of the shell and delicate, wrinkled growth lines on the anterior-ventral shell portion. As can be inferred from extant material, the strength of this ornamentation is highly variable (Poppe & Goto 1993), which has, together with the rather plastic outline, provoked the establishment of several synonyms. Actually most, if not all Neogene European Atlantic and Mediterranean *Atrina* may belong to this species. The name *Atrina pectinata* (Linnaeus, 1767), which has often been misapplied for fossil and Recent European *Atrina*, refers to an Indo-Pacific species (Poppe & Goto 1993; WoRMS 2013).

Distribution. *Atrina fragilis* is a genuine European species that has been reported from the Aquitanian onward (Schultz 2001). The earliest records come from the Aquitaine Basin in western France (named *Atrina basteroti* by Cossmann & Peyrot 1914). At least by the Burdigalian, the species had reached the Mediterranean and Paratethys realms. Today, *Atrina fragilis* occurs in the Atlantic from Great Britain southward to Mauritania, and in the Mediterranean Sea (WoRMS 2013).

PLATE 2

Bivalves from the Faro Santa Croce section (scale bar = 10 mm except for figs. 1, 2 and 10 = 6.5 mm).

Fig. 1	- *Gibbomodiola adriatica* (Lamarck, 1819); interior view of the right valve; FSC 10; NHMW2013/0306/0015.
Fig. 2	- *Ctena decussata* (O. G. Costa, 1829); exterior view of the right valve; FSC 10; NHMW2013/0306/0016.
Fig. 3	- *Musculus costulatus* (Risso, 1826); interior view of the right valve; FSC 10; NHMW2013/0306/0017.
Fig. 4	- *Atrina fragilis* (Pennant, 1777); exterior view of the left valve; FSC 2; NHMW2013/0306/0042.
Fig. 5	- *Septifer plioblitus* Sacco, 1898; exterior view of the right valve, FSC 10; NHMW2013/0306/0018.
Fig. 6	- *Anadara firmata* (Mayer, 1868); exterior view of the right valve; FSC 10; NHMW2013/0306/0019.
Fig. 7	- *Anadara firmata* (Mayer, 1868); interior view of the left valve; FSC 10; NHMW2013/0306/0020.
Fig. 8	- *Ervilia* sp. A; exterior view of the left valve; FSC 15; NHMW2013/0306/0021.
Fig. 9	- *Ervilia* sp. A; interior view of the left valve; FSC 15; NHMW2013/0306/0022.
Fig. 10	- *Spisula subtruncata* (Da Costa, 1778); exterior view of the left valve; FSC 15; NHMW2013/0306/0023.
Fig. 11	- *Acanthocardia paucicostata* (G. B. Sowerby II, 1834); exterior view of the left valve; FSC 15; NHMW2013/0306/0024.
Fig. 12	- *Lucina columbella* Lamarck, 1818; exterior view of the right valve; FSC 10; NHMW2013/0306/0025.
Fig. 13	- *Acanthocardia turonica* (Hörnes, 1862); exterior view of the right valve; FSC 10; NHMW2013/0306/0026.
Fig. 14	- *Loripes lucinalis* (Lamarck, 1818); exterior view of the right valve; FSC 10; NHMW2013/0306/0027.
Fig. 15	- *Acanthocardia paucicostata* (G. B. Sowerby II, 1834); exterior view of the left valve; FSC 27; NHMW2013/0306/0028.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Order **Pectinida** Gray, 1854

Family Pectinidae Rafinesque, 1815

Subfamily Pectininae Rafinesque, 1815

Tribe Pectinini Rafinesque, 1815

Genus *Pecten* Müller, 1776

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

Pecten aduncus Eichwald, 1830

Pl. 3, figs 1-2

1830 *Pecten aduncus* Eichwald, p. 213.

1876 *Pecten* (*Neithea*) *Stazzanensis* Mayer, p. 171.

1874a *Pecten Besseri* - Fuchs, p. 109 (non *Pecten besseri* Andrzejowski, 1830).

1874a *Pecten aduncus* - Fuchs, p. 109.

1874b *Pecten Besseri* - Fuchs, p. 377 (non *Pecten besseri* Andrzejowski, 1830).

1874b *Pecten aduncus* - Fuchs, p. 376.

1896 *Pecten vigolenensis* Simonelli, p. 328, fig. 1.

1897 *Pecten subgrandis* Brives, p. 13, pl. 2, fig. 9.

1910 *Pecten etruscus* – Martelli & Nelli, p. 524, pl. 11, fig. 1.

1920 *Pecten praebenedictus* – Dollfus & Dautzenburg, p. 403, pl. 36, figs 7-9, pl. 37, figs 1-4, 6.

1963 *Pecten aduncus* - Venzo & Pelosio, p. 153, pl. 44, figs 1, 1a,b, 3, 3a,b, pl. 50, fig. 3.

1963 *Pecten vigolenensis* – Venzo & Pelosio, p. 154, pl. 32, fig. 3, pl. 44, figs 2, 4-5, pl. 45, figs 1, pl. 46, figs 1, 3-6, pl. 47, figs 1, 4, 7-8, pl. 48, figs 1-5, pl. 49, figs 1-6, pl. 50, figs 1-2, 5-8, pl. 51, fig. 6 (cum. syn.).

1963 *Pecten* n. sp. aff. *vigolenensis*- Venzo & Pelosio, p. 159, pl. 51, fig. 2.

1963 *Pecten gortanii* Venzo & Pelosio, p. 160-161, pl. 45, figs 3-4, pl. 46, fig. 2.

1972 *Pecten benedictus*- Comaschi Caria, p. 16-17, pl. 1, figs 11-15, pl. 2, figs 1-2, 5 (non *Pecten benedictus* Lamarck, 1819).

1972 *Pecten aduncus* - Comaschi Caria, p. 19, pl. 3, fig. 9.

1972 *Pecten vigolenensis* - Comaschi Caria, p. 21, pl. 4, figs 1-6

1972 *Pecten praebenedictus* – Comaschi Caria, p. 21, pl. 4, figs 7-9

1982 *Pecten aduncus* - Grasso et al., p. 292.

1982 *Pecten vigolenensis* - Grasso et al., p. 292.

2001 *Oppenheimopecten aduncus* – Schultz, p. 257-261, pl. 43, figs 1-2 (cum. syn.).

2007 *Pecten vigolensis* (= *P. aduncus* Eichwald) – Pedley et al., p. 370.

Material: FSC 7: 1 fragmented right valve, FSC 3: 6 fragmented right valves and 2 complete and 1 fragmented left valves; right valve (Pl. 3, Fig. 1) height (reconstructed): 63 mm, length: 67 mm, left valve (Pl. 3, Fig. 2) height: 53.1 mm, length: 59.4 mm (NHMW2013/0306/0029, NHMW2013/0306/0030). This species is found with articulated and disarticulated shells in nearly all beds.

Discussion. The proximally concave, distally flattened left valves, with 14 low, flat-topped primary ribs intercalated by secondary ribs in interspaces, shows convex marginal disc areas and highly concave ears, both ornamented with weak radial striae; the highly concave, strongly proximally projecting right valve shows a smooth exterior surface with 18 low, top-flattened ribs that are distinctly wider than the interspaces, and has highly convex ears. This combination of characters points to a close relationship of the Miocene species *Pecten vigolenensis* Simonelli, 1896 and *Pecten aduncus* Eichwald, 1830, and the Pliocene *Pecten benedictus* Lamarck, 1819. All three species are characterised by high morphologic variation, in particular with regard to shell convexity and the prominence and shape of primary ribs and secondary sculpture. Both Miocene species have been identified from the investigated sediments at Faro Santa Croce by previous authors (Fuchs 1874a, b; Grasso et al. 1982, Pedley et al. 2007).

A detailed documentation of numerous different morphs of *Pecten vigolenensis* from its type locality (Vigoleno Hills near Piacenza/N Italy; Messinian/Late Miocene) has been presented by Venzo and Pelosio (1963). The morphological variation displayed by these specimens coincides exactly with the variability documented by numerous authors for *Pecten aduncus* and *Pecten praebenedictus* Tournouer in Dollfus and Dautzenberg, 1920 from the Middle Miocene of the Paratethys (e.g. Csepreghy-Meznerics 1960; Nicorici 1977) and observed in the collection material at the NHM Vienna. Therefore, beyond confirming the opinion of Schultz (2001) who reunited the latter two species, we now also consider *Pecten vigolenensis* as a synonym of *Pecten aduncus*. Furthermore, to our opinion *Pecten gortanii* Venzo & Pelosio, 1963 and *Pecten aduncus* from Vigoleno (Venzo & Pelosio, 1963) represent one and the same species.

A comparable assemblage has been described from the Late Miocene locality Capo San Marco in Sardinia where *Pecten aduncus*, *P. vigolenensis*, *P. praebenedictus* and *P. benedictus* have been identified by Comaschi Caria (1972), which, however, again represent a single species.

Pecten benedictus Lamarck, 1819, with the type locality in the Early Pliocene (Gibert et al. 2007) of the Roussillon Basin (SW France) is distinctly larger; adult specimens attain lengths of distinctly more than 100 mm. This species obviously is a direct successor of *Pecten aduncus*, although subadult shells are hardly distinguishable from the latter (e.g. Lecointre 1952); based also on the stratigraphic difference we preserve both names herein.

Distribution. Middle to Late Miocene of NE Atlantic, Mediterranean and Paratethys seas.

Subfamily Pedinae Bronn, 1862

Tribe Chlamydini Teppner, 1922

Genus *Talochlamys* Iredale, 1929

Type species: *Chlamys famigerator* Iredale, 1929; original designation. Holocene of southern and eastern Australia.

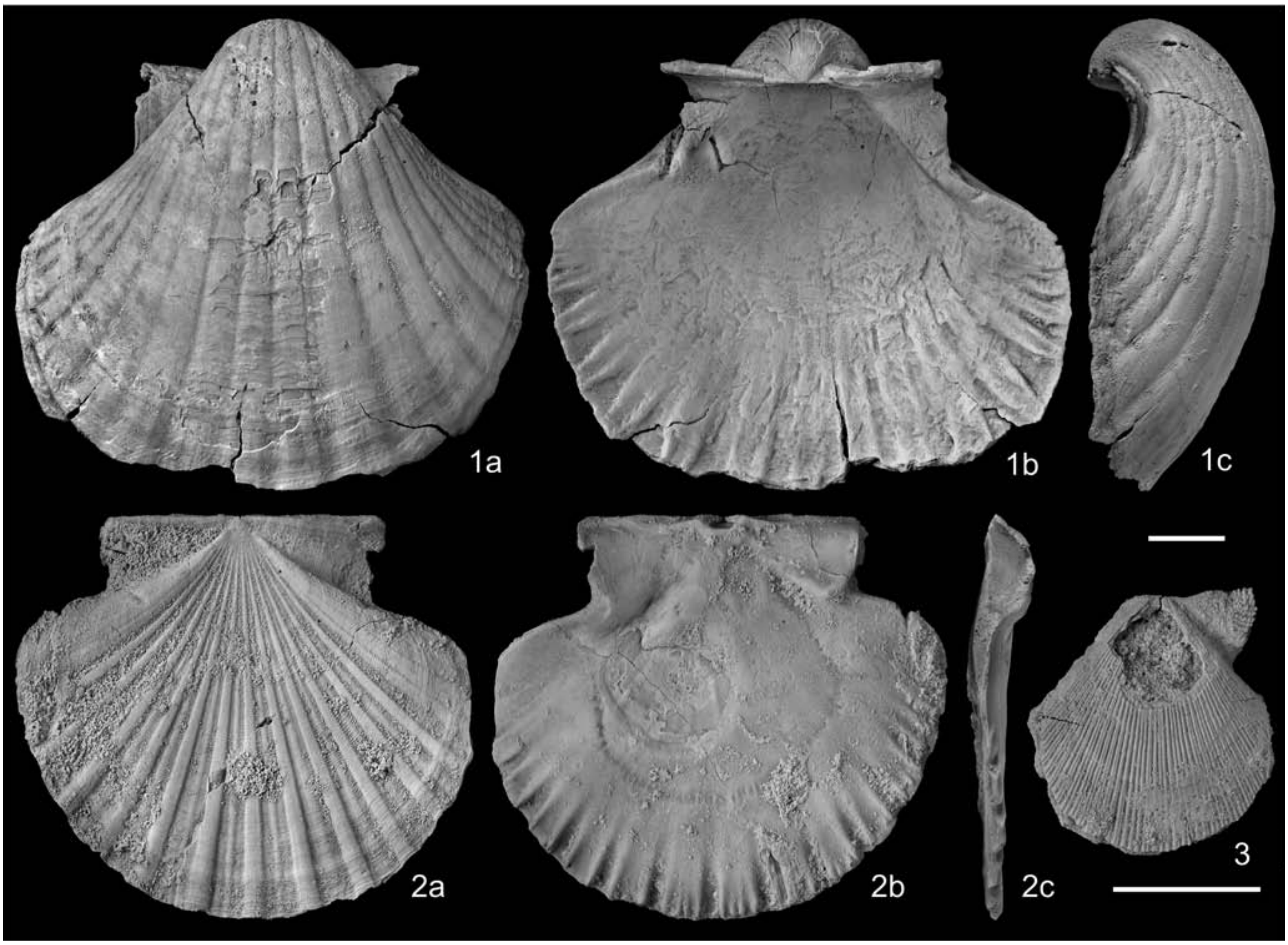

PLATE 3

Pectinidae from the Faro Santa Croce section (scale bar = 10 mm).

Fig. 1 - *Pecten aduncus* Eichwald, 1830; right valve – 1a exterior view, 1b interior view, 1c posterior view; FSC 3; NHMW2013/0306/0029.
Fig. 2 - *Pecten aduncus* Eichwald, 1830; left valve – 2a exterior view, 2b interior view, 2c posterior view; FSC 3; NHMW2013/0306/0030.
Fig. 3 - *Talochlamys multistriata* (Poli, 1795); exterior view of the right valve; FSC 3; NHMW2013/0306/0031.

Talochlamys multistriata (Poli, 1795)

Pl. 3, fig. 3

1795 *Ostrea mvltistriata* [sic!] Poli, p. 164, pl. 28, fig. 14.
1993 *Crassadoma multistriata* – Waller, p. 212, figs 5a, d, g; 6c-j.
2001 *Crassadoma*? *multistriata* s.l. – Schultz, p. 176, pl. 16, figs 6, 9-12, pl. 17, figs 1-4 (cum syn.).
2001 *Talochlamys multistriata* - Dijkstra & Kilburn, p. 300-302, figs 38-39 (cum syn.).

Material: FSC 3: 1 fragmented right valve and 2 fragmented left valves; right valve height: 17.6 mm, length: 15.8 mm, left valve height (reconstructed): 22 mm, length: 19.4 mm (NHMW2013/0306/0031).

Discussion. The specimens are ornamented with about 60 narrow ribs, which are bifurcated in the RV and composed of two intercalating sets of different strength in the left valve; moreover, they are characterised by anti-marginal microsculpture in the rib interspaces, a deep byssal notch and 7 scaly ribs on the strongly protruding anterior ear of the right valve. Thus, the specimens can be clearly attributed to *Talochlamys multistriata* (Poli, 1795), a long-lived, highly variable species that is the only representative of its genus in European Neogene deposits. We follow Dijkstra & Kilburn (2001) in combining this species with the genus *Talochlamys* Iredale, 1929. The latter authors proved the previous recombination by Waller (1993, 1996) with the NE Pacific genus *Crassadoma* Bernard, 1986 to be erroneous.

Distribution. This is a common shallow water species in the Mediterranean, Paratethys and SE Atlantic since the Burdigalian (Lower Miocene). Today it occurs in the Mediterranean and along the temperate eastern Atlantic coast, and in the SW Indian Ocean where it is restricted to South Africa (Dijkstra & Kilburn 2001). It lives byssally attached to primary and secondary hardgrounds from the subtidal zone to the inner continental shelf (Dijkstra & Kilburn 2001).

Infraclass **Heteroconchia** Hertwig, 1895

Cohort **Cardiomorphi** Férussac, 1822

Order **Lucinida** Gray, 1854

Family Lucinidae Fleming, 1828

Genus *Lucina* Bruguière, 1797

Type species: *Venus pensylvanica* Linnaeus, 1758; subsequent designation; ICZN opinion 1095 (1977). Recent, Western Atlantic.

Lucina columbella Lamarck, 1818

Pl. 2, fig. 12

1818 *Lucina columbella* Lamarck, p. 543.

1874a *Lucina columbella* – Fuchs, p. 108.

1874b *Lucina columbella* – Fuchs, p. 375.

1987b *Linga* (*Linga*) *columbella* – Freneix et al., p. 417, pl. 1, figs 2-5.

2003 *Linga* (*Linga*) *columbella* - Schultz, p. 390, pl. 57, figs 4-6 (cum syn.).

2007 *Linga* (*Linga*) *columbella* – Santos & Mayoral, p. 44.

Material: FSC 2: Silicone casts of 1 left valve and 3 right valves; FSC 10: silicone casts of 6 left valves, 14 right valves; length (max) = 23 mm, height (max) = 24 mm (NHMW2013/0306/0025).

Discussion. *Lucina columbella* is easily identified from other Lucinidae by its almost circular, strongly globose shell with a large, distinct lunule and a broad area, which is set off from the main shell portion by a deep and relatively sharp radial sulcus, and extends over ca 20 % of the total shell surface. The shell is ornamented with regular commarginal ribs.

Distribution. *Lucina columbella* is a European Aquitanian to Pliocene species (Schultz 2003). Whether it is conspecific with the extant *Lucina adansoni* (d'Orbigny, 1839), living today from the Canaries to the south along the western African coast as well as in the Caribbean, has to be clarified. Fossil shells have been recorded from the European Atlantic, the Mediterranean and the Paratethys, including the upper Tortonian of Cacela (S Portugal; Santos & Mayoral 2007) and the Messinian of Algeria (Freneix et al. 1987b). From the Messinian of Sicily, the species has already been mentioned by Fuchs (1874a, b).

Genus *Loripes* Poli, 1791

Type species: *Tellina lactea* Poli, 1791; original designation. Recent, Eastern Atlantic and Mediterranean Sea.

Loripes lucinalis (Lamarck, 1818)

Pl. 2, fig. 14

1818 *Amphidesma lucinalis* Lamarck, p. 491.

1987b *Loripes* (*Loripes*) *lacteus dujardini* – Freneix et al., p. 416, pl.1, fig. 1.

Material: FSC 2: a single specimen with contiguous valves; FSC 10: 7 left valves, 12 right valves (NHMW2013/0306/0025), 4 specimens with contiguous valves; FSC 14: 3 left valves; length (max) = 15 mm, height (max) = 14.5 mm.

Discussion. The specimens from Faro Santa Croce display the typical, irregularly circular shell shape with a prosogyrous, hardly protruding umbo and an internal ligament. This species has often been listed as *Loripes lacteus* (Linnaeus, 1758). *Tellina lactea* Linnaeus, 1758, however, is considered as a nomen dubium; as a result, the next available name becomes valid (WoRMS 2013).

As noted by Poppe and Goto (1993), *Loripes lucinalis* is relatively variable in shell shape and particular individuals may thus display a less rounded outline and extended anterior shell portion (see the specimens from Algeria, described by Freneix et al. 1987b, for an example). This kind of morphology is commonly seen in the potential Early to Middle Miocene ancestor of *L. lucinalis*, *L. dujardini* (Deshayes, 1850). At Faro Santa Croce, *L. lucinalis* occurs in considerable abundance.

Distribution. *Loripes lucinalis* is a common Late Miocene to Recent species, occurring today from the North Sea south to the West African coast as well as in the Mediterranean and Black seas (Poppe & Goto 1993). From the Miocene, the species has previously been reported from the Messinian of Algeria (Freneix et al. 1987b).

Genus *Ctena* Mörch, 1861

Type species: *Lucina pectinata* Carpenter, 1857; subsequent designation by Dall, Bartsch & Rehder (1938). Recent, West Atlantic.

Ctena decussata (Costa, 1829)

Pl. 2, fig. 2

1829 *Lucina decussata* Costa, p. 8 (not seen, fide Cossmann & Peyrot 1911, p. 299).

1911 *Codakia* (*Jagonia*) *decussata* - Cossmann & Peyrot, p. 299, pl. 28, figs 30-32.

1987b *Codakia* (*Ctena*) *decussata* - Freneix et al., p. 418, pl. 1, fig. 6.

1994 *Ctena* (*Ctena*) *decussata* – Ben Moussa, p. 118, pl. 7, figs 9-12.

2003 *Ctena* (*Ctena*) *decussata* - Schultz, p. 387, pl. 57, figs 7-8 (cum syn.).

Material: FSC 10: a single silicone cast of a right valve fragment (NHMW2013/0306/0016); length = 9.5 mm.

Discussion. The characteristic reticulate ornamentation composed of radial ribs and prominent rather regular growth lines clearly distinguishes this species from other Lucinidae.

Distribution. *Ctena decussata* is a Burdigalian to Recent European species and has been reported from the North Sea Basin, the Atlantic coast and the Mediterranean (Schultz 2003). Today, it occupies a similar area, but seems to be absent from the North Sea (Poppe & Goto 1993). Messinian records come from Morocco (Ben Moussa 1994) and Algeria (Freneix et al. 1987b).

Order **Cardiida** Férussac, 1822

Family Cardiidae Lamarck, 1809

Genus *Acanthocardia* Gray, 1851

Type species: *Cardium aculeatum* Linnaeus, 1758; subsequent designation by Tryon, 1869 (see Hylleberg 2004 for discussion). Recent, Mediterranean Sea.

Acanthocardia paucicostata (G. B. Sowerby II, 1834)

Pl. 2, figs 11, 15

1834 C[*ardium*]. *Paucicostatum* G. B. Sowerby II, p. 2, no. 29, fig. 20.

1841 *Cardium paucicostatum* – G. B. Sowerby II, p. 106.

1874a *Cardium obsoletum* – Fuchs, p. 107 (non *Cardium obsoletum* Eichwald, 1830).

1874b *Cardium obsoletum* – Fuchs, p. 375 (non *Cardium obsoletum* Eichwald, 1830).

1994 *Acanthocardia* (*Acanthocardia*) *paucicostata* – Ben Moussa, p. 15, pl. 8, figs 22-23.

1963 *Cardium* (*Acanthocardia*) *paucicostatum* – Venzo & Pelosio, p. 172, pl. 31, fig. 1, pl. 52, fig. 5, pl. 54, fig. 5, pl. 55, figs 8, 20, 22-23.

1982 *Euxinicardium* sp. – Grasso et al., p. 292.

1982 *Didacna* – Grasso et al., p. 293.

1982 *Cardium obsoletum* – Grasso et al., p. 293 (non *Cardium obsoletum* Eichwald, 1830).

1996 *Acanthocardia* (*Acanthocardia*) *paucicostata* - Studencka & Popov, p. 28-31, figs 7-8.

2007 *Cerastoderma* - Pedley et al., p. 369.

2007?*Lymnocardium* - Pedley et al., p. 369.

Material: FSC 7: 13 valves, FSC 15: 53 valves, FSC 27: 19 valves – all silicon casts; height: 17.5 mm, length: 18.7 mm (NHMW2013/0306/0024, NHMW2013/0306/0028).

Discussion. The shell of *Acanthocardia paucicostata* is suborbicular and ornamented with prominent, triangular ribs bearing minute spines on top, and wide, flat interspaces showing fine growth lines. Typical specimens have 16 ribs, but according to Studencka and Popov (1996) the number of ribs together with the overall shell shape is highly variable. Hence the specimens from bed FSC 27, which display an increased number of ribs and resemble *Acanthocardia turonica* (Hörnes, 1862) (Pl. 2, fig. 15) are considered as morphs of *Acanthocardia paucicostata* based on similar outline shape, and the shape and sculpture of the posterior ribs and interspaces.

Acanthocardia paucicostata has been originally defined from the Recent Mediterranean by illustration in G B Sowerby II (1834 – date according to Shaw 1909). Its first description followed in G.B. Sowerby II (1841).

There are a number of taxa with partly Paratethyan provenance described from the studied deposits. In our opinion, these records are most probably based on erroneous identifications of this highly variable species. Hence, *Euxinicardium* Ebersin, 1947 with the type species *Lymnocardium* (*Euxinicardium*) *subsyrmiense* Andrussoff, 1903 has also trigonal ribs with interspaces that can be wide and flattened, yet the ribs lack spines on their tops (Nevesskaja et al. 1997).

Some shells with increased rib-number basically resemble *Obsoletiforma obsoleta* (Eichwald, 1830) or *Cerastoderma edule* (Linnaeus, 1758). Yet, although *Obsoletiforma obsoleta* may indeed exhibit a similar pattern of elongated anterior and pointed posterior scales, adult specimens always display much narrower interspaces and a higher number of ribs (20-34; Nevesskaja et al. 1993). Members of the genus *Cerastoderma* Poli, 1795, including the type species *C. edule*, have either smooth ribs or bear delicate elongated scales on top of the ribs, but are never ornamented with spines.

The identifications of *Didacna* Eichwald, 1838 are most surprising and are probably based on poorly preserved, secondarily compressed specimens. The representatives of this endemic euxinic genus with the type species *Didacna trigonoides* Pallas, 1771 often show an anteriorly pointed, posteriorly broadened outline, transversal ridge and a similar number of ribs as seen in *A. paucicostata*, but the ribs are flattened and show no secondary sculpture (Nevesskaja et al. 1997).

Distribution. Early Miocene to Recent of NE Atlantic, Mediterranean and Paratethys. Today, *A. paucicostata* lives as a shallow burrower in muddy and sandy bottoms from the intertidal zone down to the shallow shelf (Oliver et al. 2010).

Acanthocardia turonica (Hörnes, 1862)

Pl. 2, fig. 13

1862 *Cardium turonicum* Hörnes, p. 188, pl. 27, figs 3a-e.

1996 *Acanthocardia* (*Acanthocardia*) *turonica* – Studencka & Popov, p. 32, figs 5a, 5d, 11.

2003 *Acanthocardia* (*Acanthocardia*) *turonica* – Schultz, p. 531, pl. 77, figs 2-4.

Material: FSC 2: 1 valve, FSC 10: 26 valves, FSC 10 above oolite: 2 valves (NHMW2013/0306/0026), FSC 14: 3 valves – all silicon casts; height: 22.7 mm, length: 22.4 mm

Discussion. Shell suborbicular, prosogyrous, with diagonal posterodorsal ledge; ornamented with 19 to 20 moderately prominent, proximally weakly convex, distally and laterally subtrigonal ribs with scales on tops and narrow flattened interspaces displaying growth lines. We follow the taxonomic concept by Studencka and Popov (1996) in identifying this species as *Acanthocardia turonica*. *Acanthocardia brocchii* (Mayer, 1866) can be similar in outline but has more numerous, subquadrangular and more densely spaced ribs. *Acanthocardia andreae* (Dujardin, 1837) from the Middle Miocene and Pliocene of NW France has more numerous ribs but otherwise resembles the studied specimens and is closely related to *Acanthocardia turonica* (Dollfus & Dautzenberg 1920; Lauriat-Rage 1981; Studencka & Popov 1996). *Acanthocardia echinata* (Linnaeus, 1758) from the Messinian of NE Marocco (Ben Moussa 1994) and the Pliocene of central Italy (Malatesta 1974) is similar to the present specimens but shows fewer ribs in the central part of the shell.

Distribution. Middle Miocene to Pliocene of NE Atlantic, Mediterranean and Paratethys (Studencka & Popov 1996).

Family Tellinidae Blainville, 1814

Genus *Moerella* Fischer, 1887

Type species: *Tellina donacina* Linnaeus, 1758; by monotypy (see Nordsieck, 1969). Recent, European seas.

Moerella donacina (Linnaeus, 1758)

Pl. 4, figs 1-2

1758 [*Tellina.*] *donacina* Linnaeus, p. 676, nr. 46.

1963 *Angulus* (*Moerella*) *donacinus* - Venzo & Pelosio, p. 193.

1994 *Tellina* (*Moerella*) *donacina* – Ben Moussa, p. 148, pl. 9, figs 4-5.

2005 *Tellina* (*Moerella*) *donacina* - Schultz, p. 705, pl. 98, figs 1-3.

2007 *Angulus* (*Moerella*) *donacinus* - Santos & Mayoral, p. 45.

Material: FSC 10: 3 left valves, 3 right valves (NHMW2013/0306/0032, NHMW2013/0306/0033); L (max) = 23.5 mm, H (max) = 9 mm.

Discussion. This is the most common Neogene European tellinid, which is well characterised by its outline shape and ornamentation.

Distribution. *Moerella donacina* is a common species of the Aquitanian to Recent seas of Europe (Schultz, 2005). Today, it occurs from Great Britain south to Angola, as well as in the Mediterranean and Black seas (Poppe & Goto 1993). From the Tortonian it has previously been recorded from Cacela (S Portugal; Santos & Mayoral 2007).

Genus *Angulus* Megerle von Mühlfeld, 1811

Type species: *Tellina lanceolata* Gmelin, 1791; subsequent designation by Gray, 1847. Recent, Indo-West Pacific Region.

Angulus sp.

Material: FSC 10: Fragments of a single left and right valve.

Discussion. One of the silicon casts shows the exterior of a relatively large and high, slightly fragmented tellinid shell, which is likely assignable to *Angulus*. In the other cast, the hinge region, including the characteristic incurvature of the dorsal shell margin directly behind the umbo, is clearly visible. However, both specimens are too poorly preserved to be determined at species level, and may even belong to different species.

Family Semelidae Stoliczka, 1870

Genus *Ervilia* Turton, 1822

Type species: *Mya nitens* Montagu, 1808; monotypy. Recent, Western Atlantic and Caribbean Sea.

Ervilia sp. A

Pl. 2, figs 8-9

1874a *Ervilia podolica* – Fuchs, p. 108 (non *Crassatella podolica* Eichwald, 1830).

1874b *Ervilia podolica* – Fuchs, p. 375 (non *Crassatella podolica* Eichwald, 1830).

2007 *Ervilia podolica* (Eichwald) - Pedley et al., p. 369 (non *Crassatella podolica* Eichwald, 1830).

Material: FSC 15: Silicone casts of 8 left valves and 9 right valves; length (max) = 22.5 mm, height (max) = 17 mm (NHMW2013/0306/0021, NHMW2013/0306/0022).

Discussion. The shells of *Ervilia* sp. A are less equilateral than those of *Spisula subtruncata* (see below), with a slightly tapering posterior end, and the posterior carina is less pronounced. If not well preserved, however, it is almost impossible to distinguish the casts of *Ervilia* from those of *Spisula*. Thus, some of the individuals may have been misidentified with either of the species.

Ervilia shells from the Messinian of Italy have usually been misidentified with the Sarmatian Paratethys species *Ervilia podolica* (Eichwald, 1830) (see synonymy above). However, *E. podolica* has a markedly opisthogyrous shell and distinctly tapering posterior end, while the specimens from Faro Santa Croce are almost rectigyrous or even slightly prosogyrous. In the Pliocene to Recent *E. castanea*, the shell is also more or less rectigyrous, but the umbo is hardly pronounced, and the entire shell is oval and elongate in outline. Individuals of *E. pusilla* (Philippi, 1836) from the Miocene of the Atlantic or North Sea Basin, which occur as subordinate associates within diverse fully marine communities (S.S. personal observation), show a similarly pointed umbo as observed in the juveniles from Sicily, but are much smaller than the specimens from Faro Santa Croce. Summarizing these observations, the *Ervilia* specimens from Faro Santa Croce seem to belong to a yet undescribed species that resembles *E. podolica* in overall appearance and size, but clearly differs from the latter in having rectigyrous to prosogyrous umbones. Since the specimens from Faro Santa Croce are exclusively preserved as moulds and properly preserved hinges are lacking, we refrain from formal description.

Family Mactridae Lamarck, 1809

Genus *Spisula* Gray, 1837

Type species: *Cardium solidum* Linnaeus, 1758; subsequent designation by Gray (1847). Recent, British seas.

Spisula subtruncata (Da Costa, 1778)

Pl. 2, fig. 10

1778 *T*[*rigonella*]. *Subtruncata* Da Costa, p. 198.

1814 *Mactra triangula* – Brocchi, p. 535, pl. 13, fig. 7.

1874a *Mactra podolica* – Fuchs, p. 108 (non *Mactra podolica* Eichwald, 1830).

1874b *Mactra podolica* – Fuchs, p. 375 (non *Mactra podolica* Eichwald, 1830).

1963 *Spisula* (*Spisula*) *subtruncata* - Venzo & Pelosio, p. 186.

1982 *Mactra podolica* - Grasso et al., p. 293 (non *Mactra podolica* Eichwald, 1830).

1994 *Spisula* (*Spisula*) *subtruncata* – Ben Moussa, p. 142, pl. 8, figs 29-30.

2003 *Spisula* (*Spisula*) *subtruncata triangula* - Schultz, p. 657, pl. 91, figs 1-4, pl. 92, figs 1-4 (cum syn.).

2007 *Spisula* (*Spisula*) *subtruncata* - Santos & Mayoral, p. 45.

Material: FSC 15: silicone casts of 26 left valves and 17 right valves (NHMW2013/0306/0023); internal moulds of two specimens with contiguous valves; length (max) = 19 mm, height (max) = 13.5 mm.

Discussion. *Spisula subtruncata* is a relatively variable species, especially with regard to shell outline, size and thickness. Miocene specimens, as well as Recent Mediterranean individuals are usually small, not heavy-shelled and relatively trigonal in outline, and thus often considered as a subspecies, named *S. s. triangula* (Renier, 1804). Following WoRMS (2013), *Mactra triangula* Brocchi, 1814 (this is the correct authorship) is herein considered as a synonym of *Spisula subtruncata*.

Messinian specimens from Italy have previously been misidentified with *Mactra podolica* Eichwald, 1830 (Fuchs 1874a, b; Grasso et al. 1982).

Distribution. *Spisula subtruncata* is a common species of European seas since the Aquitanian (Schultz 2003). Today, the species occurs in the Atlantic from Norway south to Senegal, as well as in the Mediterranean and Black seas (Poppe & Goto 1993).

Family Veneridae Rafinesque, 1815

Subfamily Venerinae Rafinesque, 1815

Tribe Venerini Rafinesque, 1815

Genus *Clausinella* Gray, 1851

Type species: *Venus fasciata* Da Costa, 1778; monotypy. Recent, European seas.

Clausinella fasciata (Da Costa, 1778)

Pl. 4, fig. 10

*1778 *P*[*ectunculus*]. *Fasciatus* Da Costa, 188, pl. 13, fig. 3.

1874a *Venus multilamella* – Fuchs, p. 108 (non *Cytherea multilamella* Lamarck, 1818).

1874b *Venus multilamella* – Fuchs, p. 376 (non *Cytherea multilamella* Lamarck, 1818).

1900 *Clausinella fasciata* – Sacco, p. 39, pl. 9, fig. 36-43.

1903 *Venus* (*Clausinella*) *fasciata* – Dollfus et al., p. 39, pl. 12, figs 7-13.

1974 *Clausinella fasciata* – Malatesta, p. 149-150, pl. 12, fig. 4.

Material: FSC 10: 1 silicone cast of a right valve (NHMW2013/0306/0040); length: 27 mm, height 23.5 mm.

Discussion. Although poorly preserved, the specimen shows the typical broad and prominent commarginal costae of *Clausinella*. The trigonal shell outline and markedly prosogyrous umbo are indicative of *Clausinella fasciata* and prevent from confusion with the more oval, less protruding *Clausinella scalaris* (Bronn, 1831).

We follow Malatesta (1974) in considering the Portuguese Tortonian occurrence documented by Dollfus et al. (1903) as the earliest record of this species. Dollfus and Dautzenberg (1920) included it later on in the synonymy of the closely related Early to Late Miocene *Clausinella basteroti* (Deshayes, 1848). However, *C. basteroti*, originally described from the Burdigalian of the Touraine (western France), has been considered as an independent species in all previous studies. Typical specimens from the Early to Middle Miocene of the Atlantic coast and the North Sea Basin differ from *C. fasciata* in having a well-rounded, non-trigonal shell and usually more prominent commarginal ribs that are strongly flexed in dorsal direction in their top part. The latter feature can also be expressed in *C. fasciata*, but occurs rather as an exception than the rule. The specimens from the Miocene of the Paratethys, identified as *C. basteroti*, *C. basteroti latilamellata* (Kautsky, 1936) or *C. basteroti taurinensis* Sacco, 1900 (see Schultz 2005 for an overview) are in fact closely similar to *C. fasciata*, and may well turn out to be synonyms of the latter after a thorough study considering intraspecific variability.

Distribution. *Clausinella fasciata* lives in the Mediterranean and NE Atlantic since the Tortonian. This thick-shelled, shallow infaunal species occurs commonly in gravel bottoms between 4 and 100 m water depth, where it is characteristic for the *Clausinella fasciata* community (Malatesta 1974; Rufino et al. 2010).

Genus *Callista* Poli, 1791

Type species: *Venus chione* Linnaeus, 1758; subsequent designation by Meek, 1876. Recent. Mediterranean Sea.

Callista italica (Defrance, 1818)

Pl. 4, figs 5, 7

1818 *Cytheraea italica* Defrance, p. 422.

1818 *Cyprina Pedemontana* Lamarck, p. 558.

1845 *Cytherea pedemontana* - Agassiz, p. 38, pl. 8.

1874a [cf.] *Cytherea Pedemontana* – Fuchs, p. 108.

1874b [cf.] *Cytherea Pedemontana* – Fuchs, p. 376.

1900 *Callista pedemontana* – Sacco, p. 14, pl. 2, figs 15-18, pl. 3, figs 1-5.

1906 *Meretrix italica* - Dollfus & Dautzenberg, p. 213, pl. 15, figs 1-7.

1910 *Meretrix* (*Callista*) *italica* - Cossmann & Peyrot, p. 395, pl. 15, fig. 19, pl. 16, figs 5-6.

1973 *Callista* (*Costacallista*) *erycinoides* – Marasti, p. 110, pl. 26, fig. 11 (non *Cytherea erycinoides* Lamarck, 1818).

1974 *Callista* (*Callista*) *italica* – Malatesta, p. 138, pl. 11, figs 2a-b.

2005 *Callista* (*Callista*) *italica* – Schultz, p. 890, pl. 128. figs 4-5, pl. 129, figs 1-5.

Material: FSC 2: 1 valve fragment (silcone cast), FSC 10 above oolite: 7 valves (5 silicone casts and 2 steinkerns), FSC 10: 3 valves (2 silicone casts and 1 steinkern); length: 46.5 mm, height: 37.7 mm (NHMW2013/0306/0036).

Discussion. Sub-orbicular, anteriorly shortened shells with a massive hinge and prominent concentric ribs on the outer surface distinguish this species from the closely related *Callista chione* (Linnaeus, 1758). A few specimens with more prominent concentric ribs resemble *Callista erycinoides* (Lamarck, 1818) (= Cythérée bordelaise of Lamarck, 1806). However, the latter species, originally described from the Lower and Middle Miocene of SE France, is more elongated, has a less prominent hinge and its concentric ribs are much more regular (Cossmann & Peyrot 1910).

Already Kautsky (1936) concluded that the three aforementioned species are highly variable and considered their differentiation as very difficult throughout the Miocene of Europe. Consequently, he regarded all Miocene records of *Callista chione* as morphs of *Callista italica*. Schultz (2005) likely considered all Paratethys records of *Callista chione* and *Callista erycinoides* for erroneous identifications of *Callista italica*. In contrast, Nevesskaja et al. (1993), as well as the majority of other authors, considers these taxa as three independent species. This concept is also followed herein.

Distribution. Early Miocene to Pliocene of NE Atlantic, Mediterranean and Paratethys.

Callista chione (Linnaeus, 1758)

Pl. 4, figs 6, 8

1758 [*Venus.*] *Chione* Linnaeus, p. 686.

1974 *Callista* (*Callista*) *chione* - Malatesta, p. 137, pl. 11, fig. 3.

1981 *Callista* (*Callista*) *chione* - Lauriat-Rage, p. 102, pl. 16, fig. 2.

1994 *Callista* (*Callista*) *chione* - Ben Moussa, p. 162, pl. 10, figs 7-8.

2007 *Callista* cf. *chione* - Pedley et al., p. 371.

2007 *Callista chione* - Santos & Mayoral, p. 35, 45, pl. 2, fig. 2.

Material: FSC 10: 11 valves (10 silicone casts and 1 steinkern); length: 42.7 mm, height: 30.8 mm (NHMW2013/0306/0038).

Discussion. The elongated-elliptical shells are ornamented with faint concentric ribs on the exterior surface. The hinge shows a massive posterior and slender anterior cardinal tooth in the left valve. The strongly elongated anterior shell portion together with the distinctly less prominent concentric sculpture allows a clear differentiation from *Callista italica* (Defrance, 1818). Similarly, the concentric sculpture of *C. chione* is much less prominent and regular as in *Callista erycinoides* (Lamarck, 1818). A few specimens with stronger ribs basically resemble *Paphia vetula* (Basterot, 1825), which, however, differs in the presence of a lunula and a hinge with three equally prominent cardinal teeth.

Distribution. From the Pliocene to Recent, *Callista chione* is distributed along the Atlantic coast from south of the British Islands down to Morocco and in the Mediterranean Sea. Its occurrence in the Upper Miocene has been confirmed for the Tortonian of Cacela in SE Portugal (Santos & Mayoral 2007) and the Messinian of NE Morocco (Ben Moussa 1994). Today it lives from the sublittoral down to 200 m depth as a shallow burrower in sandy bottoms (Oliver et al. 2010).

Tribe Dosiniini Deshayes, 1853

Genus *Dosinia* Scopoli, 1777

Type species: *Chama dosin* Scopoli, 1777 [ex Adanson, 1757]; monotypy [= *Dosinia concentrica* (Born, 1778)]. Recent, Caribbean Sea.

Dosinia lupinus (Linnaeus, 1758)

Pl. 4, fig. 9

1758 [*Venus.*] *Lupinus* Linnaeus, p. 689.

1900 *Dosinia lupinus* - Sacco, 49, pl. 11, figs 11-20.

1906 *Dosinia lupinus* - Dollfus & Dautzenberg, p. 228, pl. 16, figs 27-35.

1911 *Dosinia lupinus* – Cossmann & Peyrot, p. 410, pl. 18, figs 31-32.

1963 *Dosinia* (*Orbicularis*) *lupinus* – Venzo & Pelosio, p. 178, pl. 43, fig. 12, pl. 52, fig. 2, pl. 53, figs 7-8, pl. 54, figs 12-15.

1981 *Dosinia* (*Asa*) *lupinus* - Lauriat-Rage, p. 103, pl. 16, fig. 5.

1993 *Dosinia* (*Pectunculus*) *lupinus* – Nevesskaja et al., p. 158, pl. 26, fig. 15, pl. 37, figs 1-13.

2003 *Dosinia* (*Asa*) *lupinus austriaca* – Schultz, p. 924, pl. 136, figs 1-2.

2003 *Dosinia* (*Asa*) *lupinus lincta* - Schultz, p. 925, pl. 136, figs 3-4.

2003 *Dosinia* (*Asa*) *lupinus miolincta* – Schultz, p. 926, pl. 136, figs 5-6.

Material: FSC 10: 1 left valve – silicone cast (NHMW2013/0306/0039); height: 18.2 mm, length: 18.0 mm.

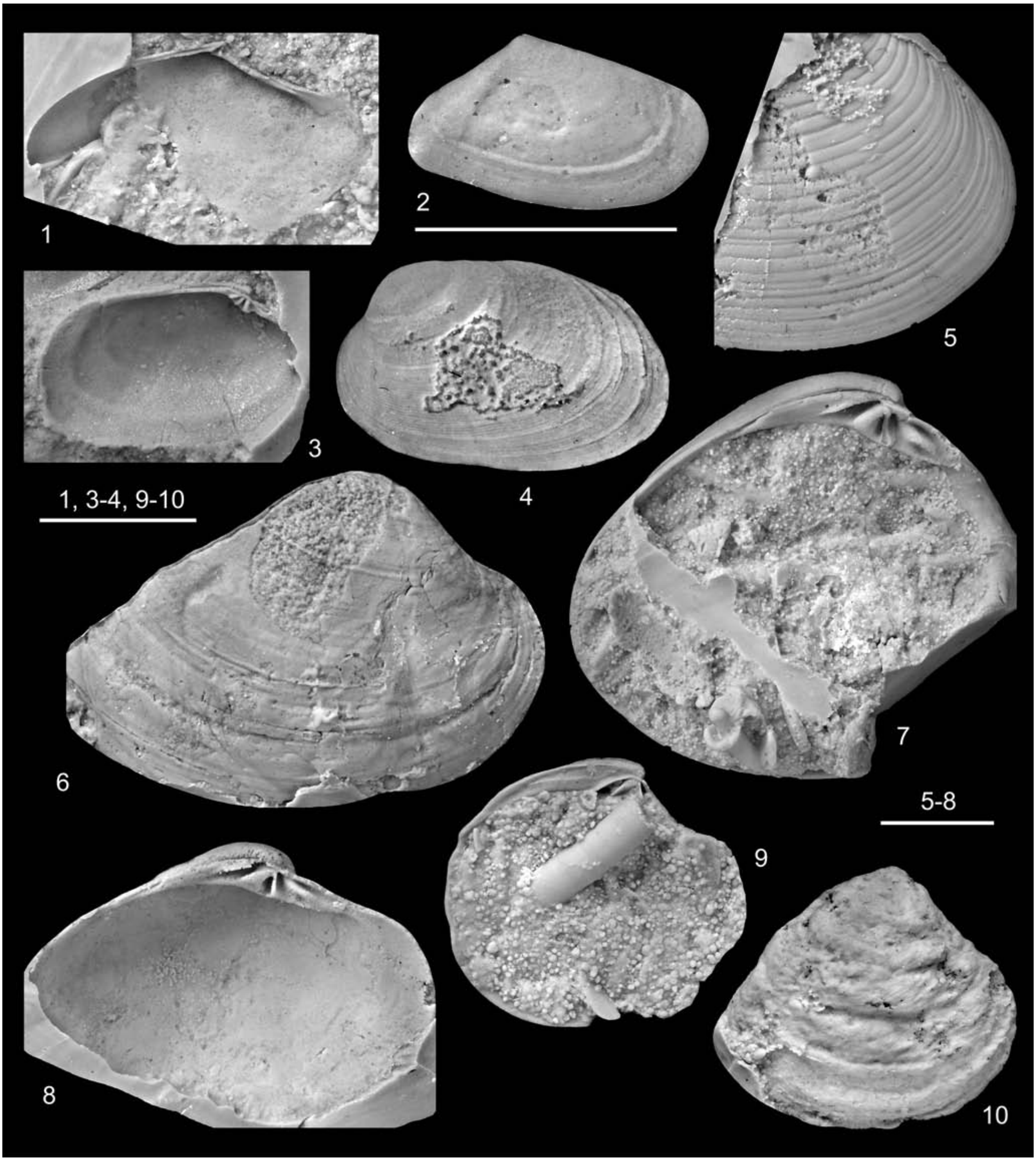

PLATE 4

Bivalves from the Faro Santa Croce section (scale bar = 10 mm).

Fig. 1 - *Moerella donacina* (Linnaeus, 1758); interior view of the right valve; FSC 10; NHMW2013/0306/0032.
Fig. 2 - *Moerella donacina* (Linnaeus, 1758); exterior view of the right valve; FSC 10; NHMW2013/0306/0033.
Fig. 3 - *Polititapes eremita* (Brocchi, 1814); interior view of the left valve; FSC 27; NHMW2013/0306/0034.
Fig. 4 - *Polititapes eremita* (Brocchi, 1814); exterior view of the left valve; FSC 27; NHMW2013/0306/0035.
Figs 5, 7 - *Callista italica* (Defrance, 1818); left valve – 5 exterior view, 7 interior view; FSC 10; NHMW2013/0306/0036.
Fig. 6 - *Callista chione* (Linnaeus, 1758); exterior view of the right valve; FSC 10; NHMW2013/0306/0037.
Fig. 8 - *Callista chione* (Linnaeus, 1758); interior view of the left valve; FSC 10; NHMW2013/0306/0038.
Fig. 9 - *Dosinia lupinus* (Linnaeus, 1758); interior view of the left valve; FSC 10; NHMW2013/0306/0039.
Fig. 10 - *Clausinella fasciata* (Da Costa, 1778); exterior view of the right valve; FSC 10; NHMW2013/0306/0049.

Discussion. The shell is small, orbicular and slightly inequilateral, with strongly prosogyrous umbones, and ornamented with faint regular growth lines. The prominent hinge shows a massive central tooth and thin elongated posterior and anterior cardinal teeth. This set of characters supports the identification with *Dosinia lupinus* (Linnaeus, 1758).

In contrast to Schultz (2003), we consider *Dosinia lupinus austriaca* Kautsky, 1936, *Dosinia lupinus lincta* (Pulteney, 1799) and *Dosinia lupinus miolincta* Schaffer, 1910 as synonyms of *Dosinia lupinus*. This is in accordance with WoRMS (2013) and with Nevesskaja et al. (1993).

Distribution. Lower Miocene to Recent of NE Atlantic, Mediterranean and the Paratethys seas. Today, *Dosinia lupinus* lives as a deep burrower in different kinds of sandy and muddy substrates from the lower intertidal to the outer shelf down to 200 m water depth (Oliver et al. 2010).

Tribe Tapetini Gray, 1851

Genus *Polititapes* Chiamenti, 1900

Type species: *Venus aurea* Gmelin, 1791; original designation, Recent, European seas.

Polititapes eremita (Brocchi, 1814)

Pl. 4, figs 3-4

1814 *Venus eremita* Brocchi, p. 546, pl. 14, fig. 4.

1874a *Tapes gregaria* – Fuchs, p. 108 (non *Venus gregaria* Goldfuss, 1841).

1874b *Tapes gregaria* – Fuchs, p. 375 (non *Venus gregaria* Goldfuss, 1841).

1900 *Tapes* (?) *eremita* – Sacco, p. 54-55, pl. 12, figs 12-22.

1908 *Tapes eremita* – Cerulli-Irelli, p. 60-61, pl. 12, fig. 18.

1952 *Tapes eremita* – Rossi Ronchetti, p. 75, fig. 29.

1963 *Tapes eremita praecedens* Venzo & Pelosio, p. 185, pl. 27, figs 4-5.

1982 *Tapes gregaria* - Grasso et al., p. 293 (non *Venus gregaria* Goldfuss, 1841).

Material: FSC 7: 2 left and 2 right valves; FSC 15: 1 left valve, FSC 15: 43 valves – all silicone casts; length: 21.9 mm, height: 13.6 mm (NHMW2013/0306/0034, NHMW2013/0306/0035).

Discussion. Strongly posteriorly elongated shell with broadly inflated, prosogyrous umbo; thin-walled, elongate, subquadrangular. The ornamentation consists of fine growth lamellae that are usually interrupted by 3 to 4 growth constrictions. The elegant hinge comprises three cardinal teeth. The shells show considerable variation in outline and, in particular, may be somewhat shortened anteriorly. These characters allow identification with *Polititapes eremita* (Brocchi, 1814) and its different subspecies established by Sacco (1900) and Venzo and Pelosio (1963).

The Early to Middle Miocene *Polititapes taurelliptica* (Sacco, 1900) is closely related to *P. eremita* but differs in outline; it is more elongate and strongly anteriorly produced. The Late Miocene to Recent *Polititapes aureus* (Gmelin, 1791) and *Polititapes senescens* (Doderlein in Cocconi, 1873) also differ in outline, being shorter, subtrigonal and posteriorly pointed (Sacco 1900; Cerulli-Irelli 1908; Heering 1950). The Late Miocene Paratethys species *Polititapes tricuspis* (Eichwald, 1829) [syn.: *Polititapes gregarius* (Partsch in Goldfuss, 1841)] has a much shorter, more rounded outline, thicker shell and distinctly more massive hinge (see Schneider et al. 2013; Neubauer et al. 2013). The manifold other representatives of *Polititapes* from the Miocene of the Paratethys, which were revised by Nevesskaja et al. (1993) differ from *P. eremita* with regard to outline and/or hinge characters.

Distribution. Late Miocene to Pliocene of the Mediterranean.

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