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PALAEONTOLOGY OF THE UPPER PLIOCENE MARINE DEPOSITS OF RIO VACCARUZZA, VILLALVERNIA (PIEDMONT, NW ITALY)

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Abstract. The topmost Argille Azzurre (beds 1-2) and the basal Sabbie di Asti (beds 3-9) formations in the Villalvernia area are analysed in terms of palaeoecological and taxonomic features; the succession is 6 m thick and dates back to the middle Piacenzian within the *Globorotalia bononiensis* acme. The upper boundary of the clayey Bed 2 corresponds to an unconformity reflecting Pliocene tectonic activity. The study is focused on the fossil assemblages of beds 3, 4 and 9. The sandy Bed 3 yields 362 mollusc taxa; the assemblage is allochthonous and mixes infra- to circalittoral species accumulated by hyperpycnal mass-transport. The same mechanism is responsible for the origin of the overlying fossil unit (Bed 4) with numerous specimens of the *Entobia-Gastrochaenolites* ichnofacies. The autochthonous fossil assemblage of Bed 9 yields 308 molluscs, plus three brachiopods and ten fish taxa; most of them refer to the *Posidonia* meadow (HP), and their autochthony is shown by taphonomic features as skeletal integrity, mixing of successive generations or the limitation to juvenile ontogenetic stages of vagile and temporarily byssate species for which the HP performs a nursery function. Three brachiopods and 52 molluscs are here reported for the first time from the Pliocene of Piedmont. In the final chapter "Systematic Palaeontology" four brachiopods and 29 molluscs are described, among which there are eight new gastropod species: *Crepidula bellardii* n. sp., *Conus dellabellai* n. sp., *Conus villalvernensis* n. sp., *Odetta chirlii* n. sp., *Ondina curta* n. sp., *Ondina elongata* n. sp., *Ondina pseudovitrea* n. sp., *Anisocycla subcylindrica* n. sp.

INTRODUCTION

The toponym Villalvernia is known in the palaeontological literature for its rich Pliocene mollusc record. The conspicuous monographs by Bellardi (1872-1888), Bellardi & Sacco (1890) and Sacco (1890-1904) provided a detailed analysis of the fossil assemblages, which includes the identification of a large number of new taxa, listed in the catalogues of the celebrated Bellardi & Sacco collection (Ferrero Mortara et al. 1981, 1984; Merlino 2007). Several outcrops of the Villalvernia area were listed by Sacco (1889-90), which also provided a short description of their facies in his monumental "Bacino Terziario e Quaternario del Piemonte". Many years later Brambilla (1976) described a short-living outcrop exposed on the left side of the Rio Vaccaruzza, in the vicinity of the village of Villalvernia, which

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produced a large number of bivalves, resulting in a much diverse assemblage compared to those reported from the same area by Sacco's monographs. Although no subsequent palaeontological studies have been realized in the Villalvernia area since 1976, the Villalvernia toponym is well known in the geological literature as referred to a multistage E-W striking fault-zone, the "Villalvernia-Varzi Line", which separates the external Ligurian units and the Epiligurian units of the Northern Apennines from the Tertiary Piedmont Basin succession (TPB; Festa et al. 2015).

The Pliocene marine sedimentary units cropping out in the surroundings of Villalvernia are typical of the uppermost part of the TPB succession. It consists of the Argille Azzurre Formation (FAA) in the basal part of the succession, and the Sabbie di Asti Formation (AST) in the upper part, both of which were recently revised by Irace et al. (2017) for the eastern sector of the TPB. In the Villalvernia area only the occurrence of the FAA is confirmed in the recent literature (Ghibaudo et al. 1985; Festa et al. 2015), whereas Sacco (1889-90: 487-488) described sandy outcrops in the hills surrounding the village.

After Brambilla (1976), who described the fossiliferous content of the AST, the site of Villalvernia was sampled only during in the last two decades (see Pedriali & Robba 2005; Sosso et al. 2013), especially by Master students of the Università degli Studi di Torino (e.g., Bedin 2011; Passone 2012). In general, the gentle morphology of the Villalvernia area does not favour natural outcrops of the stratigraphic succession, except for small exposures of clay facies along riverbanks. Recently, deep excavations for agricultural activity along the right side of the Rio Vaccaruzza led to the exposure of a thin stratigraphic interval of the AST containing a mollusc assemblage remarkably different from those reported in the literature (Brambilla 1976; Bedin 2011; Passone 2012). Consequently, a detailed excavation was realized by the senior author, resulting in a considerably rich palaeontological dataset composed by foraminifers, brachiopods, molluscs and fish otoliths that were in part unexpected in this area and, more generally, in the whole Pliocene succession of the TPB.

The goal of this paper is therefore to describe the main palaeontological features of the fossil assemblages sampled from the FAA and the AST of the Rio Vaccaruzza section. The taphonomic analysis, identification and palaeoecologic analysis of fossils found in those layers lead to the palaeoenvironmental interpretation of this interval of the Pliocene succession. Furthermore, the identification of a stratigraphic discontinuity at the boundary between the FAA and the AST provides new information on the relationships between tectonics and sedimentation and, particularly, on the role of the NW-SE striking faults in controlling the Pliocene depositional setting.

Geological Setting

The Rio Vaccaruzza site (Fig. 1) is located some 800 m northward of the village of Villalvernia (Piedmont, northern Italy) and pertains to the eastern sector of the TPB (Polino 2002). The exposed outcrops comprise the Pliocene marine succession that records, in the whole Piedmont area, the post-orogenetic, pre-Quaternary evolution of the Padane structural margin at the Alps-Apennines boundary (d'Atri et al. 2002). The Pliocene of Villalvernia represents the easternmost outcrop of the so-called "Alessandria Basin" (cf., Irace et al. 2017; and references therein). This basin and its western equivalent "Savigliano Basin" represent two Pliocene-Quaternary depocenters that were developed among the northern Apennines, the TPB and the western Alps; they were separated from each other by the Asti swell (Bertotti & Mosca 2009). D'Atri et al. (2016: 179) described the evolution of the Alessandria Basin, which constituted a large thrust-top basin characterized by widespread deposition. During the Pliocene, the tectonic activity lead to a regional scale change in the sedimentation rate. This led to a northward basin-scale regression (Irace et al. 2010; Vigna et al. 2010) from deep to shallow marine depositional systems that become continental around the Pliocene-Pleistocene boundary. The Pliocene regressive succession is represented by a set of formations that progressively pinch out towards the margins: the Argille Azzurre Formation (FAA; basin to outer shelf deposits: thickness up to 250 m), the Sabbie di Asti Formation (AST; inner shelf deposits: thickness 70-150 m), the Sabbie di Ferrere Formation (SFR; tide-dominated deposits: thickness max 50 m) and the Silt di San Martino Formation (SSM; coastal plain deposits: thickness

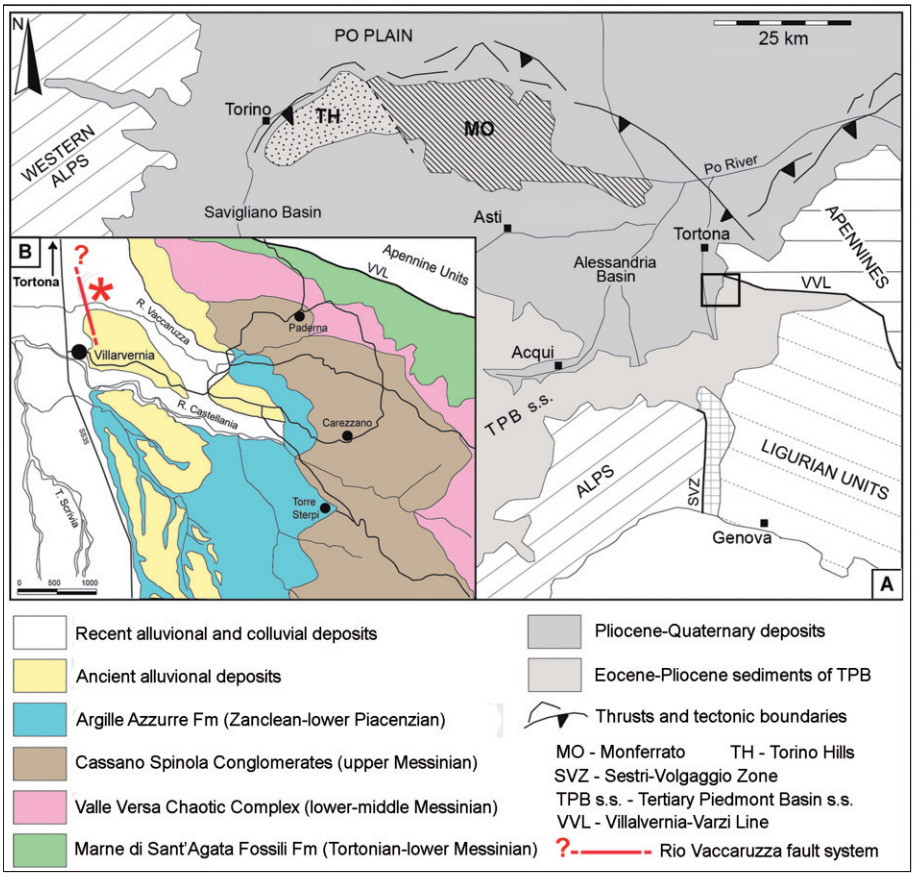

Fig. 1 - Regional geological sketch of (A) the main structural units of the southern Piedmont, (B) the geological map of the Villalvernia area where the study section is marked by a red asterisk. (A, from Polino et al. 2002. B, from Ghibaudo et al. 1985 and Festa et al. 2015).

max 30 m). The transition between the FAA and the AST is classically assigned to the MPl4a foraminiferal zone, corresponding to the late Zanclean age (d'Atri et al. 2016), whereas to the east, in the area of Voghera (Vercesi et al. 2015), the FAA dates back to the Zanclean-Piacenzian and the AST to the Piacenzian-Calabrian.

The SFR and the SSM were never documented in the Villalvernia area, possibly because of the replacement by different continental deposits in response to repeated uplifts related to the regional tectonic activity of the Villalvernia-Varzi Fault system, and/or because of their erosion during the regional-scale Pleistocene uplifting. According to Festa et al. (2015), the extensional tectonics acted since the Early Pliocene in response to a regional tilting as suggested by the occurrence of N-S striking faults in the FAA (ranging from NW-SE to NE-SW trends). Faults with the same trend, probably younger than Early Pliocene, were also documented to the ENE of the Villalvernia sector (e.g., the Schizzola valley fault, see Perotti & Vercesi 1991; Vercesi et al. 2015; Barbero et al. 2017).

MATERIALS AND METHODS

The studied section is located northwards of the village of Villalvernia on the right bank of the Rio Vaccaruzza at 44°49'19.82" N – 8°51'28.85" E, 170 m above sea-level. The equivalent site studied by Brambilla (1976) was located on the left bank of the same stream.

Natural outcrops are uncommon in the Villalvernia area, and they are totally absent along the lower part of the Rio Vaccaruzza. Consequently, the study of the stratigraphic succession and the palaeontological analyses were performed by digging an appropriate trench with a mechanical excavator and, subsequently, by an accurate bulk-sampling and superficial hand-collecting. The research was authorized by the Soprintendenza ai Beni Archeologici del Piemonte, Torino (Pavia 2016). After field works, the excavation was closed in order to restore the original morphology.

The palaeontological study of the Rio Vaccaruzza succession was made by both superficial hand-collecting and standardised bulk-sampling, both useful to obtain a taxonomic representation as complete as possible of every fossiliferous bed. The sample size was calibrated on the mollusc record so that their palaeoecological significance could be properly evaluated; besides, all the same samples provided a large amount of other taxonomic groups (foraminifers, brachiopods, fishes) that greatly improved the study.

Taphonomy of the fossil assemblages

During the field work a preliminary taphonomic analysis, limited by the reduced exposures, was carried out to describe the fabric (bioclast orientation, articulation, packing, sorting), shell accumulation and sedimentological features of beds adopting the classification proposed by Kidwell and co-authors (Kidwell et al. 1986; Kidwell & Bosence 1991; Kidwell & Holland 1991; see also Dominici 2001). Five types of mollusc assemblages were recognized:

Type 1 - Mixed assemblage: dispersed, in situ well preserved shells in a homogenous muddy lithology; evidence of transport by fossil breakage.

Type 2 - Mixed assemblage: high concentration of densely packed biofabric with heterometric fossils in a muddy matrix; fossils finely preserved with common fragmented specimens; large bivalves stacked in life position; densely packed bioclasts and bioturbations; both in situ and transported fossils.

Type 3 - Allochthonous assemblage: muddy sands with irregular geometries and without internal partition/structure; irregular, erosive lower boundary; unsorted and dispersed biofabric; bioclasts altered by weak-to-modest abrasion; transported fossils.

Type 4 - Autochthonous assemblage: scattered fossils of varying size in life position dispersed in medium-to-coarse sand; bedding plains poorly visible.

Type 5 - Autochthonous assemblage: densely packed and unsorted biofabric in muddy bed with dispersed sand grains; articulated bivalves and gastropods in life position; fossils both in situ and showing very weak evidence of transport. This assemblage may be compared to the "neighbourhood assemblages" of Brenchley & Harper (1998).

Biocoenotic approach to the mollusc fossil assemblages

As far as concerns the biocoenotic assessment and the palaeoecology of the fossil assemblages recognized in the Rio Vaccaruzza section, we follow the general approach of the bionomic model of the Endoume School applied to the extant Mediterranean bottom communities (Pérès & Picard 1964; Picard 1965). A considerable number of studies based on the upper Neogene marine mollusc assemblages have been performed adopting the Endoume biocoenotic categories (see Table 1) including, among the others, Di Geronimo & Robba (1976), Pavia (1976), Corselli (1978), Di Geronimo (1979a, b), Montefameglio et al. (1980), Benigni & Corselli (1981), Di Geronimo et al. (1982), Caldara (1986), Robba (1987), Bernasconi (1989), Pavia et al. (1989), Barrier et al. (1990), Bonfiglio et al. (1990), Ferrero & Merlino (1992), Di Geronimo et al. (1993), Basilici et al. (1997), Purcheddu et al. (1997), Dominici (2001), Monegatti & Raffi (2001), Basso & Corselli (2002), Brunetti & Vecchi (2005), Ferrero Mortara et al. (2005), Trono (2006), Ceregato et al. (2007), Bequiraj et al. (2008), Mazziotti et al. (2008), Brunetti (2011), Bellagamba et al. (2013), Trono & Macrì (2013), Ciampalini et al. (2014), Repetto et al. (2017), Macrì (2018), Bellagamba et al. (2018), and Bracchi et al. (2020).

The molluscs from the two most productive fossiliferous beds sampled in the Rio Vaccaruzza section (Bed 3 and Bed 9) are listed in Appendix. The fossiliferous content of the other beds is discussed directly in the bed description. Every taxon is associated with the acronyms of the biocoenotic categories recognized by Pérès & Picard (1964), which were obtained from literature data (Table 1). A few taxa are marked by a univocal biocoenotic signature, but in most cases the taxon is associated to more acronyms synthetized from papers focused on both extant and fossil assemblages. An aspect that prevents or at least hinders the direct application of extant parameters refers to the documented change of the auto- and synecological parameters through time, namely from Pliocene to Pleistocene and Recent. For instance, Robba (1987) discussed some selected taxa (e.g., *Nassarius semistriatus*, *Venus nux*) that changed their ecological habits from infralittoral to circalittoral or even bathyal muddy bottoms.

In conclusion, as far as the biocoenotic interpretation is concerned, we analysed the taxonomic content using two different procedures: (1) the biocoenotic assesment of the fossil assemblage is based on the taxa characterized by exclusive or preferential signatures according to a "traditional" procedure (e.g., Bracchi et al. 2020); (2) due to the frequent difficulty to refer univocally to the biocoenotic categories by Pérès & Picard (1964), we propose here to group the taxa with dominance (percent abundance) D > 0.1 into "biocoenotic clusters"; these higher sets are entitled by a distinct biocoenosis (Table 2), which is stable and well defined both in present-day bottom communities as well as in Mediterranean Pliocene-Pleistocene fossil assemblages. The clusters are justified where the grouped biocoenoses are linked in edaphic and topographic continuity on the sublittoral bottom. Two examples of ecological relationships among acronyms may explain the logic of joining them in a cluster that is entitled by the selected acronym HP: (1) the couple AP and HP constitutes an ecotone widely defined (e.g., Di Geronimo 1979b) with taxa mutually distributed; (2) the biocoenotic set "HP, SGCF, C" refers to taxa that live either in the HP meadows on leaves or at the bottom (e.g., Moissette et al. 2007), in the intermatte channels (SGCF) where the coarse sand is remobilized by canalized currents (Pérès & Picard 1964; Biagi & Corselli 1978; Corselli 1981; Ciampalini et al. 2014), or on the hard substrate at the base of the meadow (Idato et al. 1983) that may be assimilated to a coralligenous biofacies (C) in semi-sciaphilous conditions (Bracchi et al. 2020).

	ACRONYM MEANING
AP	Photophilic algae
C	Coralligenous
DC	Coastal detritic; additional Maerl facies (M)
DE	Muddy coastal detritic
GSO	Semi-dark caves
HP	*Posidonia* meadow complex
LEE	Eurithermal, euyrihaline lagoons
PE	Heterogeneous assemblages
SFBC	Fine well-sorted sands
SFHN	Fine sands of high level
SGCF	Coarse sands and fine gravels with bottom currents
SVCM	Muddy sands in shelterd areas
VTC	Coastal muddy (terrigenous) bottom
lre	Large ecological distribution

Tab. 1 - Acronyms and corresponding full names of the biocoenoses defined by Pérès & Picard (1964) for the extant Mediterranean bottom communities.

Sampling and classification of the fossil assemblages

Micropaleontological residues were prepared by washing the bulk samples with a 63 μm sieve under tap water. The residues were dried in an oven for 24 hours and subdivided in three size fractions: <63, 63-125 and > 500 μm. The intermediate size fraction was successively split apart to obtain aliquots yielding ca. 300 benthic foraminifera, that were hand-picked under a light microscope and classified following Milker and Schmiedl (2012). The proportion of planktonic foraminifera counted in the study aliquots were used to calculate the P/B ratio as number of planktic foraminifera divided for the sum of planktonic and benthic foraminifera multiplied for 100 (P/(P+B) *100). Following Van der Zwaan et al. (1990) infaunal benthic foraminifera were excluded from the calculation of the P/B ratio. Planktonic foraminifera were qualitatively studied in order to identify the biostratigraphic marker species and support the age determination of the studied material.

BIOCOENOTIC CLUSTERS	
AP	AP / AP, DE / AP, C / AP, DE, C / AP, HP, DC
DC - DE	DC / DE / DC, DE / DC, DL / DC, DE, DL / DC, C / C / DE, VTC / DC, DL, VTC / DL, VTC
HP	HP / SFHN, HP / AP, HP / AP, HP, C / AP, HP, C, M / AP, HP, SGCF / HP, SGCF / HP, SGCF, DC / HP, DC / HP, SGCF, C / HP, SGCF, C, M / HP, C, M / HP, C
PE	PE / PE, SFBC / PE, VTC
SFBC	SFBC / SFBC, AP / SFBC, HP / SFBC, DC / SFBC, DE / SFBC, SGCF
SGCF	SGCF / SGCF, DE / SGCF, DC / SGCF, DE, DC / SGCF, DC, C / SGCF, C / SGCF, VTC
SFHN	SFHN / SFHN, HP
SVMC	SVMC / LEE / SVMC, LEE/ HP, SVMC / SGCF, SVMC / LEE, HP
VTC	VTC / VTC, HP / VTC, DC / VTC, C

Tab. 2 - Clusters of biocoenotic acronyms of the most significant biocoenosis.

The macrofossils from beds 3 and 9 (brachiopods and molluscs) were sampled by hand-collecting and bulk-sampling (Di Geronimo & Robba 1976). Each bulk sample was composed by sub-samples depending on the discontinuous or homogeneous distribution of fossils in the bed; in the first case, the number of sub-samples is increased. In the beds with fossils regularly packed (Bed 9), we applied the procedure of the so-called “minimum volume”, described by Picard (1965) for extant biocoenoses and applied by Robba (1978, see also Ferrero & Merlino 1992) to the Pliocene fossil assemblages, that reduces the quantity of sediment to a volume sufficient to provide (at the 95% confidence) the overall taxonomic content of the examined fossil assemblage. We proceeded by steps: (1) the selection of a 42.88 cm^3 cube (3.5 cm per side) useful to calculate the specific-weight of the sediment (s-w); (2) the collection of a volume of sediment composed by a set of sub-samples showing uniform texture; (3) the washing of each sub-sample and its sieving with the minimal mesh 0.87 mm (exceptionally, mesh 0.50 mm to get information on the microscopic shells); (4) the picking of all the fossils derived from step 3. The Table 3 summarizes the collecting procedures for Bed 3 and Bed 9.

Mollusc taxa obtained from beds 3 and 9 are listed in Appendix with their absolute and relative frequencies, respectively abundance (Ab: number of specimens) and dominance (D: percent abundance). Exclusive (excl.) and preferential (pref.) taxa express the ecological affinity to a specific biocoenosis.

Specimen counting follows the criteria suggested by Basso & Corselli (2007): (1) gastropods were counted as single unit when the complete shell or at least 2/3 of the abapical shell portion was present, (2) articulated bivalves are counted as one, (3) fragmented bivalves were counted only if the hinge area was preserved, (4) in case of small samples, left and right valves were counted separately and combined to obtain the minimal number of specimens, (5) in case of large samples, the number of bivalves was obtained by 3/4 of the total valves plus the articulated specimens (Di Geronimo 1979a: 44; Bracchi et al. 2020: 43).

sampled beds	sub-samples	weight	specific-weight	volume
Bed 3	10	45.0 kg	1.35 gr/cm^3	33.33 dm^3
Bed 9	7	10.0 kg	1.40 gr/cm^3	7.14 dm^3

Tab. 3 - Details of the sampling procedures of beds 3 and 9.

Molluscs in Appendix are listed according to the classifications adopted by Carter et al. (2011) for Bivalvia and by Gofas et al. (2011) for Scaphopoda and Gastropoda. Generic and specific definitions have been verified through the site WoRMS. The classification of the Superfamily Conoidea follows the scheme proposed by Bouchet et al. (2011), except for the Family Conidae. The classification of the latter family is still in course of definition trying to conciliate classical shell parameters (protoconch and shell architecture), anatomical characters (e.g., radula) and molecular phylogeny (Tucker & Tenorio 2009; Puillandre et al. 2015); waiting for a more consolidate scheme, the conoidean taxa from Villalvernia are referred herein to the single genus *Conus*.

Abbreviations: Stratigraphical terms according to the Italian project CARG (Cartografia geologica e geotematica): FAA = Argille Azzurre Formation; AST = Sabbie di Asti Formation; SFR = Sabbie di Ferrere Formation; SSM = Silt di San Martino Formation; TPB = Tertiary Piedmont Basin. Institutional terms: BS = Bellardi & Sacco collection stored at the Museo Regionale di Storia Naturale di Torino (MRSN); GDB = Giano Della Bella collection, Bologna; HNHM = Hungarian Natural History Museum, Budapest; MGPT = Museo di Geologia e Paleontologia, Dipartimento di Scienze della Terra of the Torino University, where the palaeontological material described herein is housed and catalogued with the acronym MGPT-PU and a sequential registration number; WoRMS = World Register of Marine Species (marinespecies.org).

LITHOLOGY, PALAEONTOLOGY AND BIOCHRONOLOGY OF THE RIO VACCARUZZA SECTION

The studied section (Fig. 2) comprises the upper portion of the FAA (beds 1-2) and the basal AST (beds 3-9). It measures 5.50 m and consists of incoherent beds gently dipping (8-10°) to WSW. Observations were possible only after excavation since the whole area is covered by alluvial deposits that hamper to examine any layer above Bed 9.

Bed 1 (1.20 m-thick)

The facies of this bed has never been related in the literature on the Pliocene deposits of the Villalvernia area. The topmost layer (0.20 m) was manually excavated, whereas the rest of the bed was sampled on 1.00 m thickness using a hand-drilling tool. The obtained core (a few dm^3) was enough to obtain information for the definition of the bio-

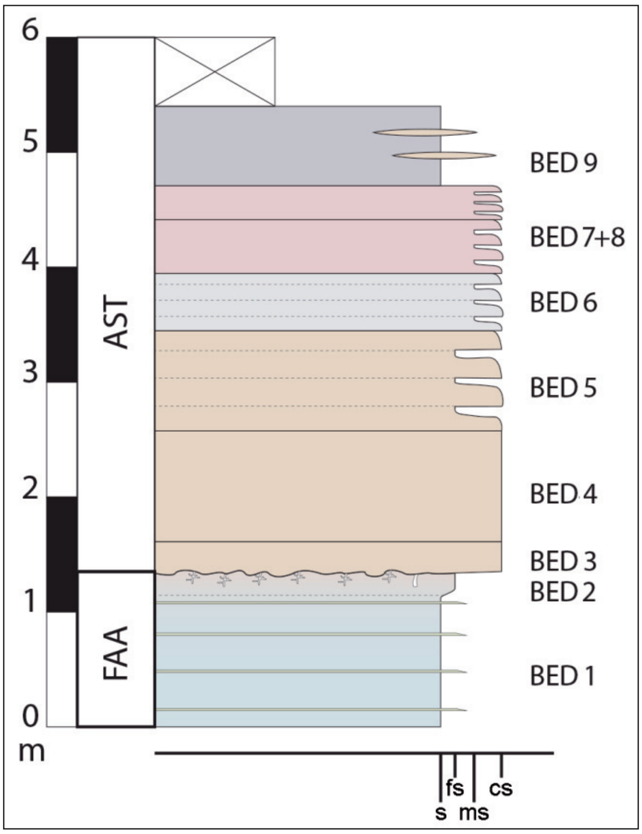

Fig. 2 - Stratigraphic log of the Rio Vaccaruzza section. Lithological acronyms: s = shales, fs = fine sands, ms = medium sands, cs = coarse sands.

and lithofacies. The lithology shows the typical facies of the FAA referred to the outer shelf, with grey clay and a significant fraction of fine sand to silt. The fossil assemblage is mainly composed of foraminifers and molluscs; it is mixed showing the features of the Type 1.

The molluscs are limited to *Nassarius semistriatus* and *Varicorbula gibba* to which the ostreid *Neopycnodonte cochlear* is sparsely associated. The palaeocommunity *N. semistriatus* - *V. gibba* is known in the Mediterranean Plio-Pleistocene successions and is considered (Di Geronimo & Robba 1988; Moraitis et al. 2018; Bracchi et al. 2020) indicative of bottom-instability conditions corresponding to the "Heterogenous Assemblage" (PE) of Pérès & Picard (1964). Nevertheless, *N. cochlear* (cf., Angeletti & Taviani 2020) suggests a parallelism with the biocoenosis DE defined by Pérès & Picard (1964) (cf., Picard 1965) in the upper circalittoral at the passage to infralittoral environments.

The microfossil content was analysed from two samples collected respectively at -100 cm and -50 cm from the top of the bed (Violanti in Passone 2012). Apart from bioclasts of bryozoans, bivalves and echinoids, the micro-components are represented by foraminifers, to which scattered ostracods are associated. As far as foraminifers are concerned:

Sample A (-100 cm) - In this sample benthic taxa are quite abundant and represented by the following taxa: *Ammonia beccarii*, *Bolivina* sp., *Buccella granulata*, *Bulimina elongata lappa*, *Cibicidoides lobatulus*, *Elphidium crispum*, *Fijiella simplex*, *Globocassidulina crassa*, *Loxostoma perforatum*, *Neoconorbina terquemi*, *Nonion boueanum*, *Quinqueloculina seminulum*, *Rectuvigerina bononiensis*, *Textularia* sp. Planktonic taxa are less common: *Globigerina bulloides, Globoturborotalia apertura*, *G. decoraperta*, *Neogloboquadrina acostaensis*, and *Turborotalia quinqueloba*.

Sample B (-50 cm) - Benthic taxa are represented by *Ammonia tepida*, *Bolivina* sp., *Lenticulina* sp., *Loxostoma perforatum*, *Planulina ariminensis*, *Rectuvigerina bononiensis*, *Reussella spinulosa*, *Rosalina globularis*, whereas the planktonic taxa are *Globorotalia bononiensis*, *G.* cf. *scitula*, *Globoturborotalia apertura*, *Turborotalia quinqueloba*. Moreover, a single specimen of the Miocene *Globorotalia acrostoma* is regarded as reworked.

It is worth noting the occurrence of *G. bononiensis*: it is a biostratigraphic marker of the Piacenzian to basal Gelasian stages, and it ranges from the top of the MPl4b biozone up to the bottom of the MPl5b biozone (Lirer et al. 2019).

The mollusc assemblage is a mixing of taxa attesting alternation of intervals of low sedimentation rates (*Neopycnodonte*) and phases of bottom instability (*Varicorbula*). Moreover, the recurrent shell fractures and the benthic taxa living at different depths and substrates of the shelf suggest deposition controlled by low density turbidity currents.

The analysis of the micropalaeontological content lead to a similar conclusion. The P/B ratio is close to 50% and suggests an open marine setting, possibly circalittoral (Murray 2006). However, infralittoral epiphytes are quite common (e.g.: *C. lobatulus*, *N. terquemi*, *Textularia* sp., and *R. globularis*; Langer et al. 1993), as well as the shallow water *A. beccarii* and *A. tepida*, which together suggest a moderate downslope transport by means of low-density turbidity currents. The same indication is provided by the presence of infaunal taxa able to use both degraded and unaltered (i.e.: phytodetritus) organic matter, such as *B. elongatea lappa* and *R. bononiensis* or *Bolivina* sp., respectively (Murray 2006).

Bed 2 (max 0.15 m)

The boundary between beds 1 and 2 cannot be precisely defined because of bioturbation. The lithofacies, which is comparable with that of the FAA, shows a bit larger sandy fraction with respect to that of Bed 1 and the sediment shows a brownish-grey colour. The upper boundary of the bed is marked by an erosional surface. The sediment is extensively bioturbated and, in the upper part, it shows *Thalassinoides* burrows filled by minute bioclasts in a sandy-muddy matrix (Fig. 3). Bioclasts are quite common, produced by burrowing activity but also transported by bottom currents. Complete mollusc shells are present with bivalves progressively more abundant upwards; the unit shows an upward increase in fossiliferous content that locally produces a shell-supported texture (Fig. 4). Aragonitic shells show an intense dissolution due to sediment loading and fluid circulation at the passage between the muddy Bed 2 and the overlying sandy Bed 3, with subsequent cementation of the internal mould of aragonite-shelled fossils such as *Bolinus brandaris*, *Mytilus scaphoides* (Fig. 5), *Venus nux* and *Pelecyora brocchii*. A large shell of *Ostrea edulis* at the top of the bed is bioeroded by *Lithophaga* sp. and preserves the internal moulds of the *Gastrochaenolithes torpedo* borings (see the palaeoichnological section below). Many fossils are autochthonous, but a fraction of mollusc specimens was transported by currents from the infralittoral. The mollusc assemblage is mixed, showing Type 2 features.

Hand-collecting was the only possible sampling due to reduced exposure of the bed. Fifty-nine taxa have been identified; they are listed in Table 4 with their associated palaeobiocoenotic acronyms and relative frequency. Dominance has not been calculated because a large number of specimens of the fossil assemblage is affected by shell fragmentation and diagenetic dissolution.

Other fossils were obtained from the sediment sieving that produced a large micropalaeontological record; it includes many well-preserved foraminifers, ostracods and fish otoliths. As to the foraminifers, the P/B ratio of 5.6% indicates the predominance of the benthic taxa over planktonic ones. Benthic foraminifers are dominated by far by two taxa: *Ammonia tepida* (19.4 %) and *Cribroelphidium incertum* (15.6 %), although *Cibicidoides lobatulus*, *Neoconorbina terquemi*, *Nonion boueanum* and *Textularia sagittula* are quite common. As far as the microhabi-

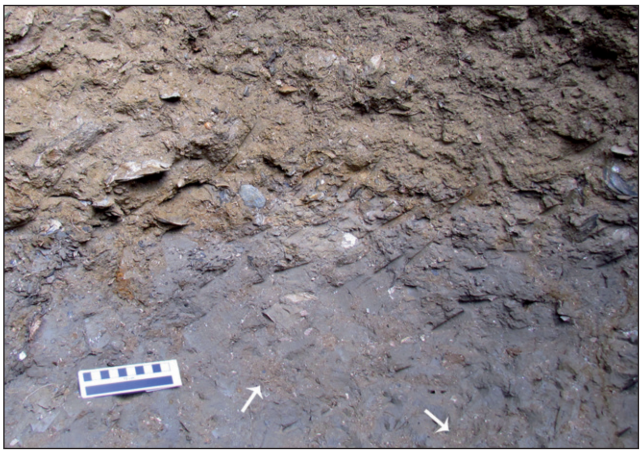

Fig. 3 - Sharp contact between the grey-blue Argille Azzurre Formation (Bed 2) and the brownish Sabbie di Asti Formation (Bed 3) on the right bank of the Rio Vaccaruzza. Note the *Thalassinoides* burrows (arrows) with light-reddish infilling of bioclastic sands. Scale bar: 10 cm.

Fig. 4 - Erosive boundary at the contact between beds 2 and 3 of the Rio Vaccaruzza section. The concentration of uni- and bivalve specimens of *Ostrea edulis* Linnaeus, 1758 and *Mytilus scaphoides* Bronn, 1831 generates a shell-supported texture at the topmost Bed 2. Scale bar: 10 cm.

Fig. 5 - Cluster of bivalve shells of *Mytilus scaphoides* Bronn, 1831 at the topmost Rio Vaccaruzza Bed 2. Scale bar: 10 cm.

tat is concerned, the epiphytic and infaunal taxa are equally present (Murray 2006); among the epiphytes the abundance of motile and temporary motile specimens (Langer 1993) suggests the presence of arborescent algae in an infralittoral setting. However, the high percentage of infaunal mud-dweller genera (e.g., *Ammonia*, *Bolivina*, *Bulimina*, *Nonion*) also indicates a substantial input of fine terrigenous sediment.

Concerning the depositional environment, foraminifers indicate a slightly shallower depth compared with Bed 1, due to the increase of infralittoral taxa and the reduction of planktonic forms.

As to the mollusc assemblage, most of gastropods and bivalves shows an infralittoral to circalittoral affinity. The infralittoral taxa are numerous (e.g., *Anadara pectinata*, *Bornia sebetia*, *Spisula subtruncata*, *Chamelea gallina*) although the circalittoral taxa are still abundant, including *Anadara diluvii*, *Cuspidaria cuspidata* and *Teinostoma minutum*, the latter being supposed to pertain to the DE biocoenosis (for the first time proposed herein together with data from the overlying Bed 3). Concerning the palaeobiocoenotic significance of Bed 2 fossil assemblage, the dominant molluscs pertain to the DC-DE communities with an estimate value of 41% (Tab. 3), to which taxa from HP (13%) and SFBC (14 %) are associated.

Summarizing, both the foraminifers and molluscs suggest a mixing of taxa from different depths and biocoenotic levels produced by the action of bottom currents. SFBC and SGCF shells were included as transported entities in Bed 2 mixed fossil assemblage with the molluscs of the upper circalittoral zone.

Thalassinoides burrows suggest a soft- to firmground condition at the top Bed 2 that was sufficiently consolidated by the reduction of sediment input and compaction to support a burrow net with open lumens to favour their infilling (Fürsich 1979). The arrested sedimentation is also testified by the *Gastrochenolithes torpedo* ichnofossil at the topmost

IDENTIFIED TAXA	Freq	BIOCOENOSIS
GASTROPODA		
Cerithium varicosum (Brocchi, 1814)	RR	SGCF, DC, DE
Cerithidium submammillatum (Rayn. & P., 1854)	R	pref. DC, DE
Turritellinella tricarinata (Brocchi, 1814)	R	PE, pref. VTC
Teinostoma minutum (Conti, 1864)	R	(?) DE
Caecum trachea Montagu, 1803	R	SGCF, DC, C
Aporrhais pespelecani (Linnaeus, 1758)	RR	
Calyptraea chinensis (Linnaeus, 1758)	R	lre
Petaloconchus intortus (Lamarck, 1818)	RR	SFBC, DE
Cochlis propinqua (Pecchioli, 1864)	R	SGCF, VTC
Bolinus brandaris torularius (Lamarck, 1822)	RR	AP, DE
Fusinus clavatus (Brocchi, 1814)	RR	
Aplus ansus (De Gregorio, 1884)	RR	(?) HP
Nassarius semistriatus (Brocchi, 1814)	C	escl. DE
Nassarius serraticosta (Bronn, 1831)	RR	
Crassispira brocchii (Bellardi, 1847)	R	SGCF, DC
Chrysallida chlathrata (Philippi, 1844)	RR	
Pyramidella plicosa Bronn, 1838	RR	
Megastomia conoidea (Brocchi, 1814)	RR	lre
Turbonilla lactea (Linnaeus, 1758)	RR	SFBC
Pyrgiscus rufus (Philippi, 1836)	RR	PE
SCAPHOPODA		
Antalis fossilis (Schroeter, 1784)	R	SFBC
BIVALVIA		
Nucula jeffreysi Bellardi, 1875	R	
Nucula nucleus (Linnaeus, 1758)	R	pref. DC, C
Lembulus pella (Linnaeus, 1767)	C	escl. PE, SFBC
Saccella commutata (Philippi, 1844)	F	DC, DE, DL
Anadara diluvii (Lamarck, 1805)	R	DC, DL, VTC
Anadara pectinata (Brocchi, 1814)	R	
Striarca lactea (Linnaeus, 1758)	RR	HP, C
Glycymeris bimaculata (Poli, 1795)	R	SGCF
Modiolus mytiloides (Bronn, 1831)	C	pref. DC, C
Mytilus scaphoides (Bronn, 1831)	F	DE
Pteria hirundo (Linnaeus, 1758)	RR	VTC, acc. HP
Meleagrina studeri (Mayer, 1894)	RR	DE
Mimachlamys varia (Linnaeus, 1758)	RR	pref. DC
Talochlamys multistriata (Poli, 1795)	R	HP, pref. DC
Aequipecten seniensis (Lamarck, 1819)	R	DC
Plicatula mytilina Philippi, 1836	RR	
Ostrea edulis Linnaeus, 1758	C	
Cardites antiquatus (Linnaeus, 1758)	R	HP, DC
Glans rudista (Lamarck, 1819)	C	HP, SGCF
Lucina orbicularis Deshayes, 1836	RR	
Bornia sebetia (Costa, 1830)	R	SFHN, acc. HP
Lepton squamosum (Montagu, 1803)	RR	
Acanthocardia paucicostata (Sowerby II, 1834)	R	DC, VTC
Spisula subtruncata (Da Costa, 1778)	R	excl. SFBC
Moerella donacina (Linnaeus, 1758)	R	pref. DC
Abra alba (Wood, 1832)	R	lre
Venus nux Gmelin, 1791	F	DE, pref. VTC
Circomph. foliaceolamellosus (Dillwyn, 1817)	RR	pref. SFBC
Chamelea gallina (Linnaeus, 1758)	R	pref. SFBC
Timoclea ovata (Pennant, 1777)	F	lre
Dosinia lupinus (Linnaeus, 1758)	R	pref. SFBC, DE
Pitar rudis (Poli, 1795)	RR	SFBC, pref. DC
Callista chione (Linnaeus, 1758)	RR	SFBC, SGCF
Pelecyora brocchii Deshayes, 1836	R	DE
Varicorbula gibba (Olivi, 1792)	FF	pref. PE, lre
Hiatella arctica (Linnaeus, 1767)	RR	SGCF, C
Hiatella rugosa (Linnaeus, 1767)	RR	C
Cuspidaria cuspidata (Olivi, 1792)	RR	VTC, DL

Tab. 4 - Taxonomic composition of the mollusc assemblage of the Rio Vaccaruzza Bed 2. Relative abundance (Freq) of specimens. RR = <0.9%, R = 1.0-4.9%, C = 5.0-14.9%, F = 15.0-28.9%, FF = > 29.0%. For the biocoenotic acronyms see Table 1.

bed. In other words, the irregular upper boundary of Bed 2 (figs. 4 and 5) corresponds to an omission surface resulting from reduced sedimentation rate, bottom compaction and subsequent erosion related to the overlying Bed 3 depositional event. A similar Upper Pliocene unconformity surface with bivalve borings was described in the upper part of the Argille di Lugagnano Formation (eastern equivalent of the FAA) at the very base of the Piacenzian stratotype in the Arda Valley (Raffi et al. 1989); that stratigraphic discontinuity was interpreted as the product of tectonic activity affecting different structural blocks along the north-western sector of the northern Apennines (Raffi 1982). A similar, though a bit older tectonic phase may be supposed affecting the western part of the southern margin of the Pliocene-Quaternary Alessandria Basin and connected with a regional scale tilting related to the northward migration of the Apennine frontal thrust (e.g. Festa et al. 2015).

Beds 3-4 (1.30 m)

This interval is relatively homogeneous in texture and lithology, characterized by muddy ochraceous sand arranged into two layers, and separated by an indefinable boundary. Bed 3 shows a finer granulometry. Macrofossils are frequent mainly in Bed 3; they are represented by molluscs and, subordinately, by bioclasts of bryozoans, very scattered brachiopods and fragments of echinoids. At the outcrop scale, *Ostrea edulis* is the most common fossil, represented by both complete shells and single valves; this oyster is more frequent in the upper part of Bed 4 where their shells are intensively bioeroded by boring organisms, whose variety is described in the following chapter. The mollusc assemblages are allochthonous, showing Type 3 features.

Bed 3 (0.30 m) - This fossiliferous horizon, varying in thickness and characterized by shells and bioclasts of *Ostrea edulis* (Figs. 3, 4), lies upon the erosive basal boundary of the bed. The palaeontological content is broadly diverse, with 362 mollusc taxa listed herein in the taxonomic Appendix. Shells are very finely preserved; only scattered fossils are broken and in general they do not show any trace of abrasion. All the fossils are allochthonous and document a mixing of taxa pertaining to different bottoms and biocoenoses of the infralittoral-circalittoral. Such a situation is discussed in detail below; however, it is worth noting that the taphonomic mixing (allochthonous assemblage of the Type 3) is clearly demonstrated by the biocoenotic significance of taxa with D > 1, an index proposed by Di Geronimo (1979a) to characterize a benthic mollusc assemblage. According to this method, the following 20 taxa may be assumed as representatives of Bed 3: *Cerithidium submamillatum* (pref. DC, DE), *Turritellinella tricarinata* (PE, pref. VTC), *Caecum trachea* (SGCF, DC, C), *Calyptraea chinensis* (lre), *Nassarius semistriatus* (excl. DE), *Nassarius serratus* (pref. VTC), *Ringicula* gr. *auriculata* (lre), *Lembulus pella* (excl. PE, SFBC), *Saccella commutata* (pref. DC, DE, DL), *Glycymeris bimaculata* (SGCF), *Glans rudista* (HP, SGCF), *Bornia sebetia* (SFHN, acc. HP), *Spisula subtruncata* (excl. SFBC), *Moerella distorta* (PE, SFBC), *Abra alba* (lre), *Gari uniradiata, Timoclea ovata* (lre), *Dosinia lupinus* (pref. SFBC, DE), *Callista chione* (SFBC, SGCF), and *Varicorbula gibba* (pref. PE).

The fossil assemblage of Bed 3 contains also rare specimens of the gastropod *Bufonaria marginata* that, based on their preservational features such as shell fragmentation and alteration and encrustation by bryozoans with unaltered skeletal structures, must be regarded as reworked elements that were eroded from an Upper Miocene or Pliocene marine deposit outcropping in a surrounding location, placed eastward of the Villalvernia area, transported, encrusted and buried in the new sedimentation place. A similar reworked record pertains to isolated valves of *Cardites antiquatus* extensively worn after exhumation and transport. *B. marginata* disappeared approximately at the *Globorotalia puncticulata* LAD, i.e. at the Zanclean-Piacenzian boundary (Basilici et al. 1997: 48). Its presence as reworked element within the fossil assemblage does not affect the biochronostratigraphic attribution of Bed 3 to the Piacenzian, already stated by the occurrence of *G. bononiensis* in Bed 1.

Bed 4 (1.00 m) - The arenaceous concretions, which randomly occur, are originated by cementation of crustacean domichnia with irregular size and shape. Such concretions are interpreted as transported structures, not produced in place but transported by the same mechanism that generated the allochthonous mollusc assemblage. The mollusc diversity of the assemblage of Bed 4 is very reduced compared to that of Bed 3. *Ostrea edulis* associated to *Glycymeris bimaculata, Pecten flabelliformis* and *Chama*

Fig. 6 - Right valve of *Ostrea edulis* Linnaeus, 1758 (MGPT-PU 143072) showing intense bioerosion by *Entobia* sp. and *Gastrochaenolites dijugus* Kelly & Bromley, 1984, and encrustations by *Ostrea edulis* Linnaeus, 1758 and *Chama gryphoides* Linnaeus, 1758. Rio Vaccaruzza Bed 4. Scale bar: 1 cm.

gryphoides are quite abundant, especially in the upper part of the bed. Their shells are steadily bioeroded and colonized by a large variety of boring and encrusting invertebrates (Fig. 6) that are discussed below in the section on the *Entobia-Gastrochaenolites* ichnofacies.

Genesis of beds 3 and 4 - The origin of beds 3 and 4 seems to be related to a process of mass transport that transferred a huge quantity of sediment and specimens through the shelf from the coastal environments to the infra- to circalittoral bottoms. This might be explained by the action of sufficiently strong offshore storm currents (Aigner 1985; Pavia 1994; Basilici et al. 1997) able to remobilize and/or erode the onshore material (shells, sediments, and fossils too) and to transfer it to the outer shelf with consequent mixing of allochthonous (the mass of taxa of Bed 3) and reworked fossils (the specimens of the cited *Bufonaria marginata* and *Cardites antiquatus*). However, the Villalvernia sediments lack of any diagnostic features of the turbiditic deposits, such as the graded bedding. In addition, the Padane Gulf (and the Adriatic Sea) was out of the latitudinal belt for hurricanes or tropical storms (Dominici 2001) powerful enough to trigger bottom movements of large mass of sediments. A second, more convincing hypothesis points to catastrophic hyperpycnal flows (Mutti et al. 1996, 2000, 2003; Crippa et al. 2018) that, during intense river flooding, discharged in the coastal marine bottoms huge quantity of continental water with suspended material, which promoted the transport of clasts and heavy specimens, such as the large ostreid shells.

A complete shell of *Panopea glycimeris* was found in life position burrowed at the top of Bed 4 (Passone 2012). This palaeobiological colonisation intermediate between the deposition of Bed 4 and the overlying Bed 5 represents a well-defined step in the sedimentary evolution of the Rio Vaccaruzza section. The palaeobiocoenotic assessment of *P. glycimeris* (pref. SFBC: Basilici et al. 1997: 44) testifies the regressive trend of the succession, from the circa- to infralittoral transition to a definitive infralittoral settlement.

Bed 5 (0.90)

This massive bed consists of a whitish, calcareous, bioclastic, coarse to fine sand with a limited fraction of fine quartz grains. It contains rhodophytes (Fig. 7), mineralized crustacean domichnia (Fig. 8) and bivalve or disarticulated specimens of *Pecten flabelliformis*, *Ostrea edulis* and *Chama gryphoides* that are more frequent in the lower part of the bed. The most common bioclasts are rounded rhodolitic nodules or part of them, shell fragments mostly derived from bivalves, worn tests of benthic and rare planktonic foraminifers. Apart from ostreids and pectinids, all the aragonitic shells show diagenetic dissolution. The bed is intensively cemented; the concretionary structures incorporate any kind of biogenic entities and show an irregular development and arrangement within the bed. The concretions are usually irregularly dispersed, but locally their alignments simulate bedding plains. The biogenic structures strictly recall the Maërl facies of the Coastal Detritic biocoenosis described for the Mediterranean mid-sublittoral bottoms by Pérès & Picard (1964) and more recently by Basso & Brusoni (2004), Bracchi et al. (2014), Bracchi et al. (2016). The mollusc assemblage is allochthonous, showing Type 3 features.

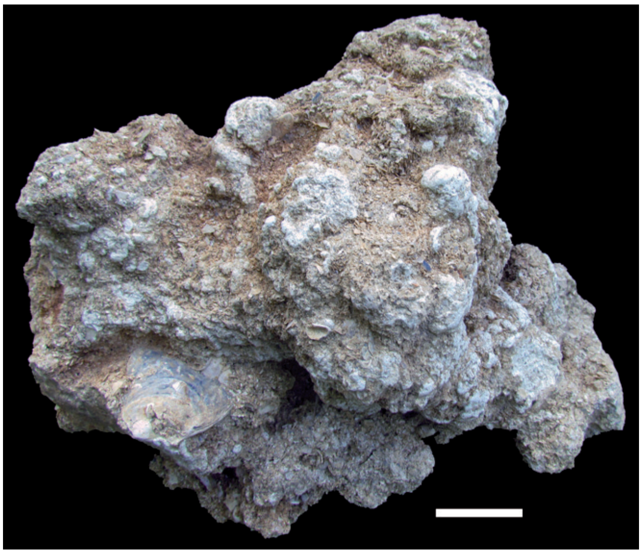

Fig. 7 - Globular carbonate structures of rhodophytes from the Rio Vaccaruzza Bed 5. Note the coarse bioclastic sandy matrix. Scale bar: 3 cm.

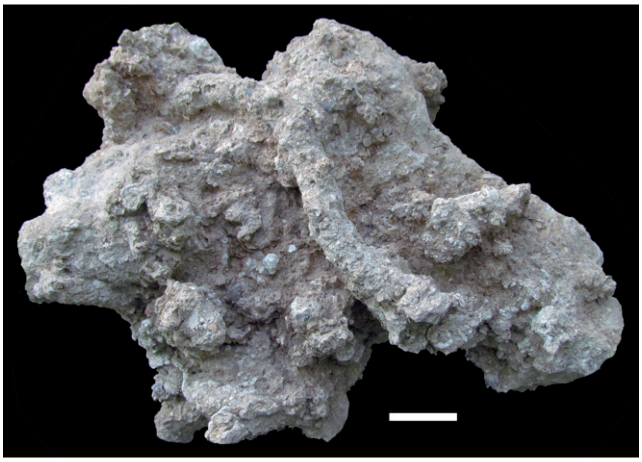

Fig. 8 - Mineralized crustacean *domichnia* associated with calcareous structures of rhodophytes and bioclasts in the Rio Vaccaruzza Bed 5. Scale bar: 3 cm.

The origin of Bed 5 can be referred to a mass-transport of onshore sediments to deeper bottom conditions within the infralittoral zone by a catastrophic hyperpycnal flows, as suggested for beds 3 and 4.

Bed 6 (0.50 m)

The boundary with the underlying bed was not clearly defined in the trench; it seems to be transitional because of the similar granulometry. The bed consists of medium to coarse-grained, greyish sand with homogeneous structure due to bioturbation (Fig. 9). The palaeontological record is very poor, except for a bivalve specimen of *Panopea glycimeris*.

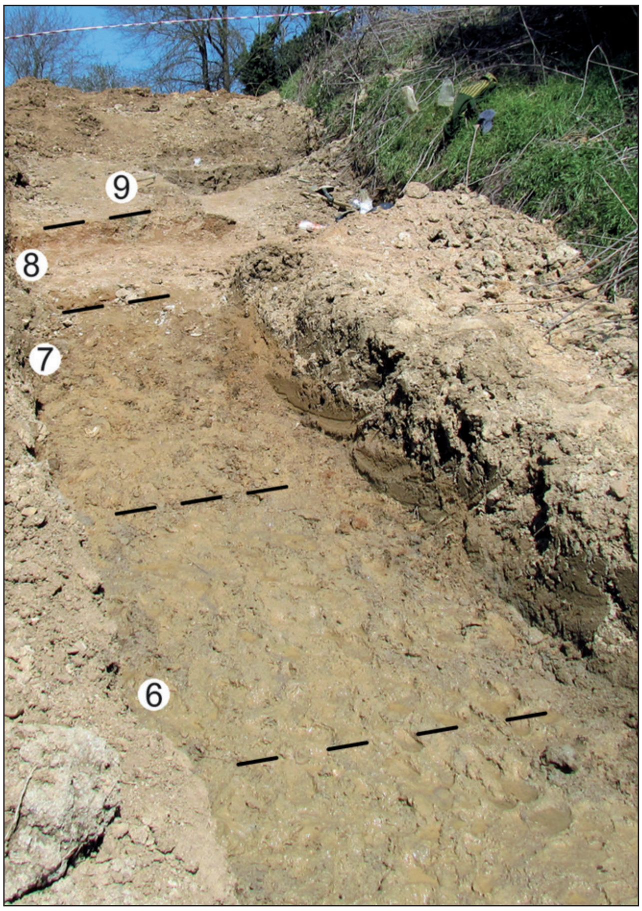

Fig. 9 - Exposure by a caterpillar of the upper part (beds 6 to 9) of the Rio Vaccaruzza section.

Beds 7-8 (0.75 m)

These two beds (45 + 30 cm thick) are relatively homogeneous in texture and lithology, characterized by light brown to reddish, coarse to medium-grained sand without a clear boundary in between (Fig. 9). Fossils are scarce, represented by autochthonous bivalve specimens of *Glycymeris bimaculata* (SGCF) and *Pelecyora gigas* (pref. SBCF) in the lower bed, and *Atrina pectinata* (pref. DE) in the upper one (Fig. 10 a). The first two taxa are indicative of the influence of bottom currents in the infralittoral zone, whereas the pinnid suggests the presence of a vegetate bottom (Zuschin et al. 1999; Dominici 2001) from where the muddy component was occasionally removed by currents that may explain the loss of life-position of the specimen of *A. pectinata*. The mollusc assemblage is autochthonous, showing Type 4 features.

Bed 9 (0.70 m)

The bed consists of sandy, bioclastic, pink-brownish clay with variable texture and undefinable structure. The bed shows lenticular organisation with overlapping sedimentary units showing a limited lateral development (Figs. 9, 10 a, 10 b); thin discontinuous lenses intercalate showing coarser texture, large bioclasts, centimetric rhodolitic nodules and occasional small quartz pebbles. Fossils are very abundant and diversified (Figs. 10 c, 10 d): benthic foraminifers mainly pertaining to Cibicidae, bryozoans, frequent terebratulid brachiopods, ostracods, disarticulated decapod elements, fish otoliths and very abundant molluscs, among which 308 taxa of gastropods, scaphopods and bivalves have been recognized and listed in the Appendix. Bed 9 is characterized by the presence of abundant, finely preserved (mummified according to Mustoe 2018: Martinetto, pers. comm.) remains of *Posidonia* sp. that locally constitute a bioclastic carpet of rhizomes and shreds of leaves testifying the action of waves and currents on the seagrass meadow (Fig. 10f). Most fossils are regarded as autochthonous though they could have been transferred on the bottom over short distance from the living places around the seagrass meadow. Fossils in life position are also present, such as a bivalve specimen of *Lutraria oblonga* and a cluster of *Tenagodus obtusus* preserved in situ after decomposition of the guest-sponge (Pansini et al. 1999; ?*Holoxea* sp.: cf. Schiaparelli 2002; Gofas et al. 2011: 145). The mollusc assemblage is autochthonous, showing Type 5 features.

Di Geronimo's (1979a) index with D > 1, used to characterize benthic mollusc assemblages, circumscribes to 13 species the definition of the autochthonous mollusc assemblage of Bed 9: *Jujubinus striatus* (AP, HP, C), *Tricolia tenuis* (AP, HP), *Bittium latraillei* (AP, HGP, C, M), *Bittium reticulatum* (AP, HP), *Rissoa guerinii* (AP, HP), *Pusillina sulzeriana* (AP, HP), *Alvania cimex* (HP, C, M), *Alvania pagodulina* (?HP), *Alvania thalia* (?HP), *Granulina clandestina* (AP, HP, C), *Gibberula jriae* (AP, HP), and *Parvicardium scriptum* (AP, HP). All of these taxa refer to the biocoenotic *Posidonia* meadow complex (HP). It is worth noting the high frequency of *B. latraillei* (D = 10.98), a dominant taxon in the modern *Posidonia* beds (Martini et al. 2001).

BED 9: BENTHIC FORAMINIFERANS	Freq
Ammonia beccarii (Linnaeus, 1758)	R
Bolivina plicatella Cushman, 1930	R
Bolivina spathulata (Williamson, 1858)	RR
Bolivina variabilis (Williamson, 1858)	R
Bulimina aculeata d'Orbigny, 1826	RR
Cancris auricula (Fichtel & Moll, 1798)	RR
Cibicides refulgens Montfort, 1808	C
Cibicidoides lobatulus (Walker & Jacob, 1798)	FF
Cibicidoides pseudoungeriana (Cushman, 1922)	RR
Cribroelphidium incertum (Williamson, 1858)	R
Elphidium advenum (Cushman, 1922)	R
Elphidium complanatum (d'Orbigny, 1839)	R
Elphidium crispum (Linnaeus, 1758)	R
Elphidium macellum (Fichtel & Moll, 1798)	RR
Fissurina marginata (Montagu, 1803)	R
Fissurina sp.	RR
Fursenkoina subacuta (d'Orbigny, 1852)	RR
Gavelinopsis praegeri (Heron-Allen & Earland, 1913)	RR
Hanzawaia boueana (d'Orbigny, 1846)	RR
Hyalinea balthica (Schröter, 1783)	RR
Lagena spp.	RR
Neoconorbina terquemi (Rzehak, 1888)	C
Nonion boueanum (d'Orbigny, 1846)	R
Planorbulina mediterranensis d'Orbigny, 1826	R
Porosononion granosum (d'Orbigny, 1846)	RR
Quinqueloculina seminulum (Linnaeus, 1758)	RR
Reussella laevigata Cushman, 1945	RR
Rosalina anomala Terquem, 1875	F
Rosalina bradyi (Cushman, 1915)	R
Rosalina globularis d'Orbigny, 1826	R
Rosalina williamsoni (Chapman & Parr, 1932)	RR
Textularia pala Cžjžek, 1848	R
Textularia sagittula Defrance, 1824	C
Tretomphalus sp.	RR
Trifarina angulosa (Williamson, 1858)	RR
Valvulineria sp.	RR

Tab. 5 - List of the foraminiferan taxa and related dominance (Freq) of the Rio Vaccaruzza Bed 9. RR = <0.9%, R = 1.0-4.9%, C = 5.0-14.9%, F = 15.0-28.9%, FF = > 29.0%.

Benthic foraminifers are abundant and generally well preserved compared to the planktonic ones, which are scarce and usually characterized by a recrystallized wall. The P/B ratio is 1.8 % and the percentage of fragmented test on the total assemblage is 12.9 %. Despite 36 species of benthic foraminifers have been identified (Table 5, Fig. 11), three taxa make up 60.1 % of the total assemblage including *Cibicidoides lobatulus* (29.7 %), *Rosalina anomala* (18.8 %) and *Cibicides refulgens* (11.6 %). The *Elphidium* group (*E. advenum, E. complanatum, E. crispum*, *E. macellum*, and *Cribroelphidium incertum*) is also common (9.1 %). Other common taxa are *Neoconorbina terquemi* (5.4 %), *Textularia sagittula* (5.0 %) and the *Bolivina* group (5.9 %: *Bolivinella plicatella*, *B. spathulata, B. variabilis,* and *Bolivinella seminuda*).

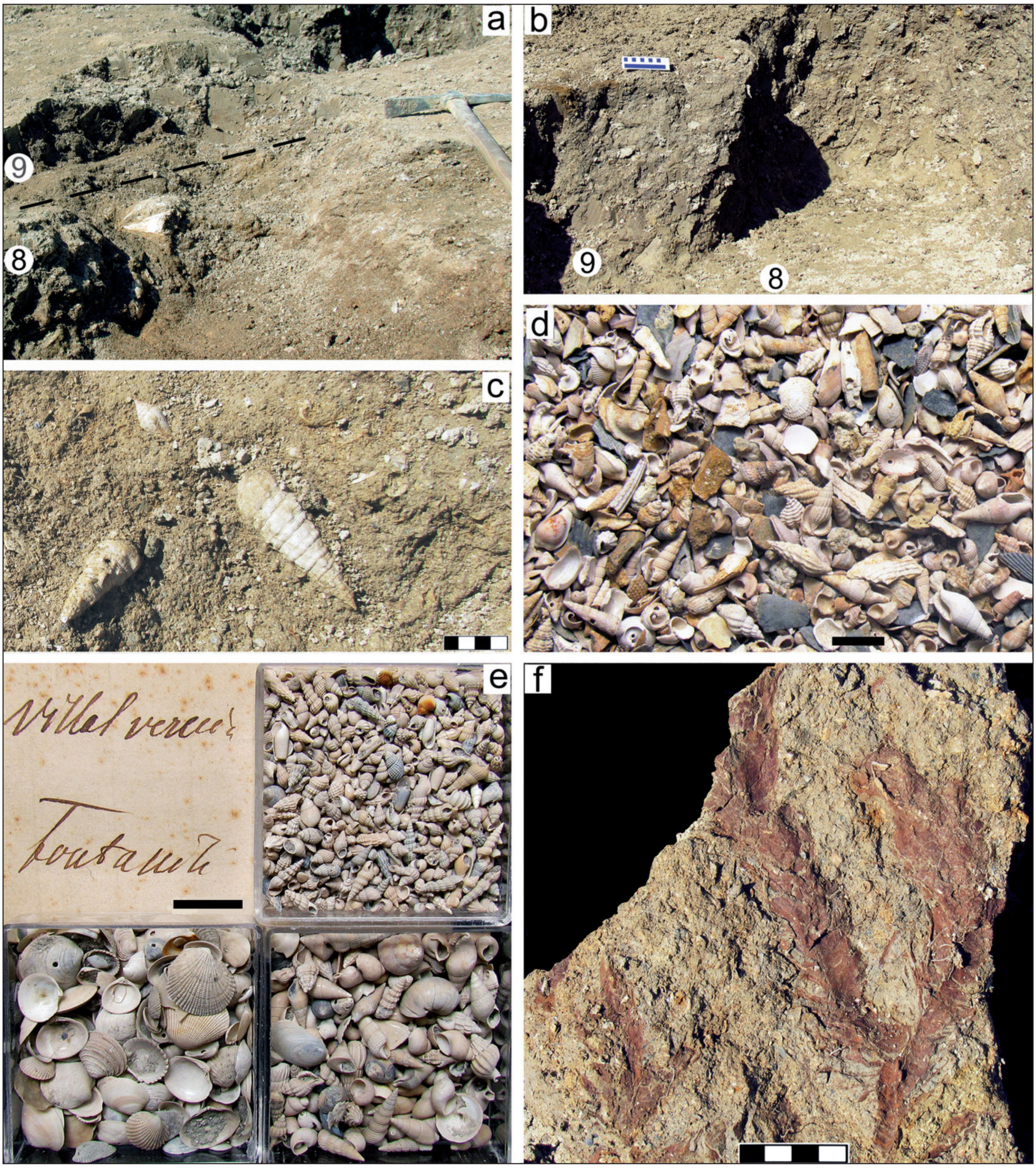

Fig. 10 - Outcrops and fossils of the Rio Vaccaruzza Bed 9 and the Fontanili site.
(a) Stratigraphic boundary between beds 8 and 9; note the autochthonous specimen of *Atrina pectinata* (Linnaeus, 1767) in the upper part of Bed 8. (b) The main body of Bed 9. (c) Gastropods of Bed 9: *Cerithium vulgatum* Bruguière, 1792 (2 specimens) and *Conus dellabellai* n. sp. (d) Washed samples at 2 mm sieve from Bed 9. (e) Historical sample (MGPT-PU 143274-143276) from the unlocated site of Fontanili near Villalvernia; note the label autographed by Bellardi (1887 in 1872-1888, p. 60). (f) Mummified rhizomes of *Posidonia* sp. (MGPT-PU 143277). The scale bars are centimetric (d, e) or pluricentimetric.

The rest of the species scores less than 1 % (one or two specimens among the 278 counted). The assemblage is by far dominated by species having an epiphytic lifestyle (Murray 2006), which requires a vegetated substratum; the remaining taxa are either epibenthic or shallow infaunal. According to Langer

Fig. 11 - Selected foraminifers recovered from the studied samples.
(a-c) *Ammonia beccarii* (Linnaeus, 1758), spiral and umbilical views. (d) *Elphidium crispum* (Linnaeus, 1758), spiral view. (e) *Cribroelphidium incertum* (Williamson, 1858), spiral view. (f-g) *Rosalina anomala* Terquem, 1875, spiral and umbilical views. (h-i) *Rosalina globularis* d'Orbigny, 1826, spiral and umbilical views. (j-k) *Cibicidoides lobatulus* (Walker & Jacob, 1798), spiral and umbilical views. (l-m) *Neoconorbina terquemi* (Rzehak, 1888), spiral and umbilical views. (n-o) *Cibicides refulgens* Montfort, 1808, spiral and lateral views. (p) *Bulimina aculeata* d'Orbigny, 1826, lateral view. (q-r) *Nonion boueanum* (d'Orbigny, 1846), lateral and spiral views. (s) *Quinqueloculina seminulum* (Linnaeus, 1758), lateral view. (t-u) *Textularia pala* Cžjžek, 1848, lateral and apertural views. Scale bars: 100 µm.

(1993), most of the epiphytic benthic foraminifers of Bed 9 can be grouped as temporary motile (*Cibicidoides*, *Rosalina*, etc.), which are typically abundant in modern infralittoral setting where phytal surfaces with flat leaves (e.g., *Posidonia*, *Sargassum*) are present.

Biochronology

The age of the Rio Vaccaruzza succession is constrained by three pieces of evidences:

1 - The micropalaeontological assemblage of Bed 1 is characterized by the presence of *Globorotalia bononiensis* (Dondi, 1963), whose biostratigraphical range encompasses the topmost MPl4b biozone and the lower part of the MPl5b biozone; its Acme Zone comprises the whole Piacenzian and the basal Gelasian (Lirer et al. 2019; Cau et al. 2020: 27).

2 - Given that globorotalids are deep dwellers, we expect that its occurrence in a shelf envi-

MOLLUSCS OF THE MPMU-1	Bed 2	Bed 3	Bed 9
Terebra acuminata Borson, 1820		x	
Barbatia candida (Chemnitz, 1784)		x	x
Mytilus scaphoides Bronn, 1831	x	x	
Pinctada margaritifera studeri (Mayer, 1894)	x	x	
Isognomon maxillatus (Lamarck, 1801)		x	
Gigantopecten latissimus (Brocchi, 1814)		x	
Lissochlamys excisa (Bronn, 1831)		x	
* *Lucina orbicularis* Deshayes, 1836	x	x	
Ctena decussata (Costa, 1829)		x	x
* *Trachycardium multicostatum* (Brocchi, 1814)		x	
* *Circomphalus foliaceolamellosus* (Dillwyin, 1817)	x	x	
* *Callista puella* (Philippi, 1844)		x	
* *Pelecyora gigas* (Lamarck, 1818)		x	

Tab. 6 - Molluscs of the MPMU-1 found in beds 2, 3 and 9 of the Rio Vaccaruzza succession. The species *M. margaritifera studerii*, *I. maxillatus*, *G. latissimus* were found from Bed 3 during past field workings (fide, P. Giuntelli and M. Rocca).

ronment such as that of Bed 1 may correspond to the time interval between the FCO (3.31 Ma) and the LCO of *G. bononiensis* in the Mediterranean (Lirer et al. 2019).

3 - Some molluscs of beds 2, 3 and 9 show a stratigraphic distribution in the Mediterranean that is limited to the lower part of the Piacenzian, up to an age of approximatively 3.0 Ma. In fact, at the passage from the Zanclean to the Piacenzian, the Lower Pliocene mollusc faunas suffered an important phase of depauperation with extinction, or migration towards the northwestern African coasts, due to the progressive water-cooling consequent to the climatic changes in the Northern Hemisphere (Monegatti & Raffi 2001). Such events caused pulses of extinction or at least local disappearance of thermophilic taxa among shallow marine molluscs.

These molluscs, encountered in the Rio Vaccaruzza section (Table 6), are components of the lowermost Mediterranean Pliocene Molluscan Unit (MPMU-1 in Monegatti & Raffi 2001, 2007; Dominici et al. 2020) that extends from the Zanclean up to the bottom third/half of the Piacenzian. Most of them disappeared during the 3.0 Ma faunal crisis, whereas five species (asterisks in Table 6) survived or are represented by extant descendants in the western Atlantic coasts.

In conclusion, the information from foraminifers and molluscs co-support a Late Pliocene age for the Rio Vaccaruzza succession with precise reference to the middle part of the Piacenzian.

Brachiopod record from the Rio Vaccaruzza beds 3 and 9

Although the significance of Cenozoic brachiopods is rather limited compared with Palaeozoic and partly Mesozoic assemblages, several Pliocene localities from Italy have provided abundant brachiopods. Accordingly, the number of scientific papers dealing with Pliocene brachiopods of Italy is remarkable (e.g. Gaetani & Saccá 1985; Borghi 2001; Pavia & Zunino 2008; Bertolaso et al. 2009; Dulai 2016 and references therein). However, there are still lots of undisclosed results concerning Pliocene brachiopods, especially the small-sized, so-called micromorphic brachiopods that are poorly known. For example, description of some new micromorphic species from Marmorito in Piedmont, Altavilla and Capo Milazzo in Sicily is currently in progress.

During the present research we paid particular attention to the micromorphic brachiopods commonly found in the residues of the Rio Vaccaruzza Bed 9. These fossils derive by picking from both the bulk-sample analysed for molluscs (350 specimens) and supplementary samples treated in laboratory (more than 500 specimens). Two micromorphic species have been identified, including *Argyrotheca cuneata* and *Joania cordata* together with some juveniles of ?*Terebratula* sp. A further taxon comes from Bed 3 with a single specimen: *Terebratula calabra* Seguenza, 1871.

All these taxa are described in the Systematic Palaeontology chapter. Here, we try to delineate the palaeoenvironmental meaning of the micromorphic *Joania cordata* - *Argyrotheca cuneata* assemblage from Bed 9.

Brachiopods in Recent seagrass meadows

Brachiopod assemblages of Recent shallow-water environments are mostly dominated by megathyridid species. These micromorphic brachiopods are generally known mainly from coralligenous substrates and protected environments such as caves, fissures and beneath boulders (Logan 1979). Only some rare reports were published on their occurrence in *Posidonia* meadows. Taddei Ruggiero (1985) has found death assemblages in S Italy, while Evangelisti et al. (2011) reported both living specimens and shells from the seagrass covered areas of an offshore reef in the Tyrrhenian Sea.

Recently Albano & Stockinger (2019) reported an abundant *Joania cordata - Argyrotheca cuneata* population in the rhizome layer of *Posidonia oceanica* meadow in Plakias, SW Crete. The living specimens were attached to any hard substrates available in the rhizome level (rhizome fragments, coralline algae, foraminifers, bryozoans, inside of empty gastropod shell). Six living specimens were also found above the sediment surface, on *Posidonia* leaves, but the brachiopods definitely prefer the rhizomes and their low hydrodynamism and dim light. Both *Joania* and *Argyrotheca* were abundant in all rhizome samples (from 5–20 m depth), with a peak at 15 m depth. The size of both living specimens and empty shells rarely exceeds 4 mm. Additional brachiopod species (*Megathiris detruncata*, *Novocrania anomala*) are extremely rare. Albano & Stockinger (2019) concluded that, although literature record on the occurrence of brachiopods from this habitat is very limited, *Posidonia* rhizomes offer a particularly suitable infralittoral habitat for these micromorphic species.

Brachiopods connected to fossil seagrass assemblages

The studied assemblage from Bed 9 of the Rio Vaccaruzza succession is especially important because it represents the first known *Posidonia* seagrass-associated fossil brachiopod assemblage from the Mediterranean Neogene. The number of specimens is high, comparable to the recent one from Plakias, SW Crete (Albano & Stockinger 2019). Their taxonomic composition is very similar at genus level and both assemblages are dominated by the megathyridid *Joania* and *Argyrotheca*, associated by one or two additional species represented by a very limited number of specimens. However, they differ in the proportion of the two taxa; although *Joania* is the sharply dominant taxon in the Recent assemblage, *Argyrotheca* is also present in about 25%; conversely, *Joania* is autocratic (99%) in the Rio Vaccaruzza assemblage and *Argyrotheca* is represented solely by three specimens (0.4%).

Large-sized terebratulids are not rare in the Mediterranean Neogene, and they probably lived also somewhere near to the *Posidonia* meadows. However, the dense seagrass environment, which was ideal for micromorphic megathyridids, was unfavourable for large brachiopods. Sometimes some terebratulid larvae swam above the seagrass and settled in the meadow, but in the absence of large enough hard surfaces they were very short-lived.

Pliocene seagrass-associated communities were discussed from Rhodes, Greece by Moissette et al. (2007); however, possible brachiopods were only mentioned in a table without any detail or species names. According to this paper, *Posidonia* rhizomes provide microenvironments for sessile organisms, such as micromorphic brachiopods.

There are several *Joania-Argyrotheca* assemblage records from the Middle Miocene Central Paratethys, and some independent studies also referred the presence of seagrass at some of these localities. However, until now the occurrence of these micromorphic brachiopods has never been connected directly to the special environment of seagrass rhizomes. For example, seagrass-associated macrobenthic assemblages were identified in several studies at the famous Polish Middle Miocene Korytnica Clay (e.g., Bałuk & Radwański 1977; Hoffman 1979; Zágoršek et al. 2012). The brachiopod assemblage of the Korytnica Clay was described by Barczyk & Popiel-Barczyk (1977) who documented a sharp dominance by megathyrid brachiopods (89% of the recognized specimens), mainly *Joania* and *Argyrotheca* with few *Megathiris* and two other taxa with limited abundance. Regarding the taxonomic composition of the brachiopod assemblage from the Korytnica Clay, and the several independent indications of seagrass associate benthic assemblages, we can suppose that the micromorphic megathyridid brachiopods possibly lived at least partly in the rhizome level of the seagrass. Many other Middle Miocene *Joania*- and *Argyrotheca*-dominated brachiopod records were published from the Central Paratethys (cf. Dulai 2007 for references). There, the presence of seagrass is not always documented unambiguously but, for example: at Radmanówka in the Roztocze Hills, Poland, the presence of submarine flora was suggested by Pisera (1985); at Niechobrz, SE Poland foraminifers indicated the important role of non-calcified submarine flora (Gonera 1994); at Bánd (Hungary, Dulai 2007) several gastropod taxa referred to possible seagrass environment (*Smaragdia*, *Bittium*, *Cerithium*: Kókay 1966; *Oligodia bicarinata*, *Archimediella carpathica*: Kovács & Vicián 2021; Columbellidae and *Modulus basteroti*: Kovács pers. comm.).

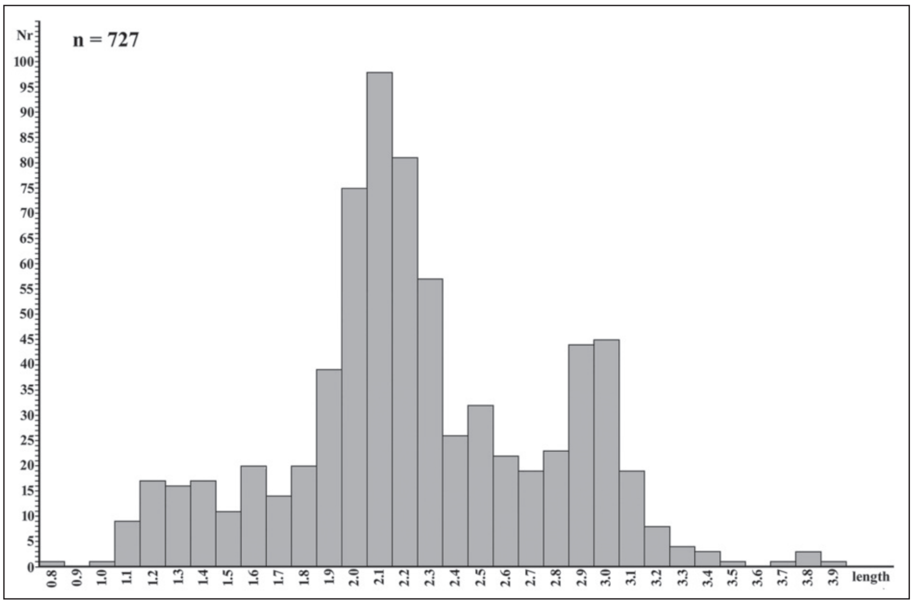

Fig. 12 - Size frequency of *Joania cordata* (Risso, 1826) from the Upper Pliocene of Rio Vaccaruzza, Bed 9. The sample is composed by 727 specimens; their distribution shows a clear bimodal pattern. Length in mm.

Size-frequency distribution of seagrass-associated *Joania cordata*

Size-frequency distributions of brachiopods are frequently used for studies of population dynamics (e.g., Thayer 1975; Noble & Logan 1981; Bitner 2002). Larger peak in smaller size classes generally is typical for samples collected from marly deposits. Small brachiopods settled on soft bottoms are more vulnerable to burial and/or to clogging effects on the lophophore apparatus (Bitner 2002). Cryptic habitats of reef cavities produced bell-shaped size-frequency distribution with lower juvenile mortality and more brachiopods enable to reach a larger size (Bitner 2002). Polymodal distribution is typical for samples with small specimen number (Bitner & Pisera 2000). Fossil *Joania cordata* from the Central Paratethys Miocene was used several times for size-frequency distribution studies and the results are rather variable because of different factors (see in Bitner 2002).

J. cordata size distribution was also studied in recent environments of the Mediterranean Sea. Although the studied sample size was not very large, Asgaard & Broomly (1991) have found three peaks for *J. cordata* along the coasts of Rhodes, Greece: widths 0.5 mm for newly settled larvae, 1.2 mm for juveniles and 2.4-2.8 mm for mature specimens. According to these authors, the lifespan of *J. cordata* does not exceed two years. Recently Evangelisti et al. (2013) have studied *J. cordata* size-distribution from three different environments of the Tyrrhenian Sea (coralligenous substrate, *Posidonia* meadows and sandy channels). Unfortunately, the *Posidonia* meadows sample was the less representative (73 specimens): a clear peak was found at 3.0 mm and other, less evident peaks were also distinguishable (Evangelisti et al. 2013, fig. 3 C).

Several factors can influence the results of size-frequency studies (sampling bias, taphonomic processes, diagenetic dissolution, mechanical degradation, predation; see details in Bitner 2002) but the *Joania* assemblage from Rio Vaccaruzza suits all these requirements. The dominant species is *Joania cordata* with more than 800 specimens, so sufficiently numerous for size-frequency studies. The assemblage is obtained from bulk samples, washed on 0.87 mm sieve and only partially on 0.5 mm; therefore, the sampling method is fully adequate (although the very small-sized specimens may be under-represented because of the sieve size). About 93% of the *Joania* specimens are articulated (and most of the isolated valves were separated in the ultrasonic bath), which suggests an autochthonous assemblage without significant transport and mechanical destruction. The associated mollusc and other faunal elements yielded also well-preserved calcitic and aragonitic shells, thereby revealing that the diagenetic dissolution did not change the composition of the assemblage. Predation was also a limited factor, only 1.4% of *Joania cordata* specimens were drilled by predatory gastropods. All these circumstances justify that the size-frequency distributions of *Posidonia*-associated *Joania* assemblage gives reasonable results. All *J. cordata* specimens are rather small, their length varies between 0.8 mm and 3.9 mm (the smallest specimens may be under-represented because of the used mesh size). The distribution pattern (Fig. 12) seems to be bimodal, with the higher peak at 2.1 (2.0-2.2) mm, and the smaller peak at 2.9-3.0 mm. These two peaks may correspond to young adult and mature specimens. Similar peaks were observed also in Recent *Posidonia* meadows assemblage by Evangelisti et al. (2013), although in their sample the 3.0 mm peak was higher, and the peaks at 2.0 and 2.3 mm are not so unambiguous (perhaps affected by the small specimen number). The (probably) low juvenile mortality and the large number of adult and mature specimens confirm that rhizome layer of the Pliocene *Posidonia* meadows (similarly to the recent situation) was ideal for the development of a stable, long-lived megathyridid assemblage.

Mollusc assemblages of the Rio Vaccaruzza Beds 3 And 9

The two most diverse fossil assemblages of the Rio Vaccaruzza succession are discussed in detail and compared to each other in order to define the palaeoenvironmental evolution of the basal AST in the Villalvernia area.

Overall, these beds provided 504 mollusc taxa, of which 362 pertain to Bed 3, 308 to Bed 9, and 166 are shared by the two assemblages (see Appendix). Among the 504 taxa, 350 gastropods, 9 scaphopods, and 145 bivalves have been recognized.

Such a large number of molluscs is a unique feature of this site, being by far the most diverse in the Pliocene of the TPB (e.g., Montefameglio et al. 1980). The monographic works of Bellardi (1872-1888), Bellardi & Sacco (1890) and Sacco (1890-1904) listed not more than 153 taxa from the outcrops around Villalvernia, of which 92 gastropods, 1 scaphopod and 30 bivalves are also present in the assemblages described herein (see Appendix, B-S column), whereas other 22 gastropod and 8 bivalve taxa have not been recognized in our survey. Both Bellardi and Sacco described their material from the sites "Salita della Braia" and "Fontanili" whose palaeontological content is roughly equivalent, in terms of preservation, to that of the Rio Vaccaruzza beds 3 and 9, respectively. Unfortunately, these sites cannot be studied because Salita della Braia is an unknown toponym in the municipal territory, whereas Fontanili is a still unlocated site westward of the village of Villalvernia. However, despite the impossibility to lo-

IDENTIFIED TAXA	BED 3	BED 9	CLUSTER	BIOCOENOSIS
GASTROPODA				
Clanculus corallinus		0.54	HP	HP, C, M
Gibbula seguenzai		0.33	HP	(?) AP, HP
Jujubinus striatus		11.7	HP	AP, HP
Calliostoma gualterianum		0.22	HP	AP, HP, C, M
Bolma rugosa		0.28	SGCF	SGCF, DC, C
Skenea bogii		0.44	HP	(?) HP
Tricolia tenuis		2.32	HP	AP, HP
Cerithium crenatum	0.13		AP	AP
Cerithium vulgatum		0.70	HP	HP, SVMC
Bittium latraillei	0.20	10.98	HP	AP, HP, C, M
Bittium reticulatum	0.20	3.19	HP	AP, HP
Cerithidium submamillatum	1,00		DC - DE	pref. DC, DE
Archimediella subvaricosa		0.36	HP	(?) HP
Helminthia vermicularis	0.29		lre	lre
Turritellinella tricarinata	1.51		VTC	PE, pref. VTC
Monophorus cristulatus		0.13		
Monophorus perversus		0.12	HP	AP, HP, C
Rissoa angulatacuta		0.21	HP	(?) AP, HP
Rissoa guerinii		1.66	HP	AP, HP
Pusillina interrupta		0.12	SVCM	SVCM, LEE
Pusillina lineolata		0.35	HP	HP, SGCF
Pusillina sulzeriana		4.13	HP	AP, HP
Alvania bonellii		0.32	HP	(?) HP
Alvania cancellata		0.18	HP	lre
Alvania cimex	0.29	13.89	HP	HP, C, M
Alvania lactea		0.74	HP	HP
Alvania pagodulina		1.18	HP	(?) HP
Alvania punctura		0.20	DC - DE	DC, DE
Alvania thalia	0.39	19.66	HP	(?) HP
Manzonia crassa		0.25	HP	AP, HP, C, M
Rissoina bruguierei		0.36	HP	AP, HP
Rissoina pusilla		0.27	HP	HP
Teinostoma minutum	0.38		DC - DE	(?) DE
Caecum trachea	5.89	0.15	SGCF	SGCF, DC, C
Aporrhais pespelecani	0.26			
Calyptraea chinensis	1.96	0.33	lre	lre
Crepidula gibbosa	0.10		lre	lre
Crepidula bellardii		0.21	HP	(?) HP
Petaloconchus intortus	0.40		SFBC	SFBC, DE
Erato pernana		0.22	HP	(?) HP
Cochlis propinqua	0.55		SGCF	SGCF, VTC
Tectonatica prietoi		0.10		(?) HP
Tectonatica tectula	0.58		DC - DE	DC
Euspira nitida	0.16			
Neverita olla	0.16		SFBC	escl. SFBC
Bolinus brandaris torularius	0.22		DC - DE	AP, DE
Ocinebrina aciculata		0.76	HP	HP, C
Heteropurpura polymorpha	0.37			
Typhinellus labiatus		0.12	SVCM	HP, pref. SVCM
Aplus ansus		0.80	HP	(?) HP
Aplus nilus		0.23	HP	(?) AP, HP
Chauvetia brunnea		0.40	HP	AP, HP
Nassarius asperatus		0.11	HP	pref. HP
Nassarius bugellensis	0.36		SGCF	SGCF
Nassarius clathratus	0.20		SFBC	pref. SFBC, DC
Nassarius incrassatus	0.61		HP	pref. HP
Nassarius lima	0.10		DC - DE	DE
Nassarius musivus	0.12		SFBC	SFBC
Nassarius semistriatus	1.69		DC - DE	escl. DE
Nassarius serraticosta		0.25		
Nassarius serratus	1.03		VTC	pref. VTC

Tab. 7 - List of the taxa with dominance D > 0.1 of the Rio Vaccaruzza beds 3 and 9. For the biocoenotic acronyms see Table 1.

IDENTIFIED TAXA	BED 3	BED 9	CLUSTER	BIOCOENOSIS
Nassarius turgens		0.12	HP	(?) AP, HP
Anachis corrugata		0.14		
Mitrella astensis		0.54	SFBC	SFBC, HP
Mitrella minor		0.41	HP	(?) HP
Mitrella scripta		0.21	HP	AP, HP
Mitrella villalvernensis		0.39	HP	(?) HP
Pusia ebenus		0.10	HP	AP, HP
Pusia savignyi		0.21	AP	AP
Bivetiella cancellata	0.16		AP	AP, DE, C
Gibberula jriae		1.46	HP	AP, HP
Granulina clandestina		5.55	HP	AP, HP, C
Clavatula rustica	0.24	0.13	HP	(?) AP, HP
Conus dellabellai		0.14	DC - DE	DC, DE
Crassispira brocchii	0.36	0.18	SGCF	SGCF, DC
Mangelia clathrata		0.81	HP	AP, HP
Mangelia unifasciata		0.15	HP	AP, HP, C
Mitromorpha columbellaria		0.16	HP	HP, C
Strioreterebrum reticulare	0.28		SFBC	pref. SFBC
Subula fuscata	0.10		SFBC	pref. SFBC
Chrysallida curvicostata	0.25			
Chrysallida fenestrata	0.24		DC - DE	DC, C
Megastomia conoidea	0.48	0.49	Ire	Ire
Odetta chirlii		0.19		
Ondina pseudovitrea		0.17	HP	(aff.) HP, DC
Turbonilla astensidelicata	0.23			
Turbonilla bilineata		0.35	HP	(?) AP, HP
Turbonilla internodula		0.17		
Turbonilla lanceae	0.10			
Acteon semistriatus	0.37		SFBC	escl. SFBC
Ringicula gr. *auriculata*	1.17		Ire	Ire
Retusa decussata		0.34	HP	HP
Retusa truncatula	0.70		DC - DE	DE
Acteocina spirata	0.56			
SCAPHOPODA				
Antalis fossilis	0.24		SFBC	SFBC
Antalis inaequicostata		0.10	HP	HP, DC
Antalis vitrea	0.15			
BIVALVIA				
Nucula jeffreysi	0.36			
Nucula nitidosa	0.16	0.10	DC - DE	DC, DE
Nucula nucleus	0.29		DC - DE	pref. DC, C
Lembulus pella	3.20		PE	escl. PE, SFBC
Saccella commutata	2.34		DC - DE	DC, DE, DL
Barbatia candida	0.66	0.21		
Anadara diluvii	0.28		DC - DE	DC, DL, VTC
Anadara pectinata	0.45			
Striarca lactea	0.47	0.14	HP	HP, C
Glycymeris bimaculata	1.53		SGCF	SGCF
Glycymeris inflata	0.11			
Modiolus adriaticus	0.10		DC - DE	pref. DC, C
Gregariella petagnae	0.16		AP	AP
Flexopecten hyalinus		0.20	HP	escl. HP, C
Flexop. inaequicostalis	0.13			
Talochlamys multistriata		0.17	DC - DE	HP, pref. DC
Aequipecten opercularis	0.20		DC - DE	pref. DC
Aequipecten seniensis	0.40		DC - DE	DC
Ostrea edulis	0.16			
Cardita elongata		0.27	HP	AP, HP
Cardites antiquatus	0.51		HP	HP, DC
Glans rudista	4,00		HP	HP, SGCF
Lucina orbicularis	0.11			
Anodontia fragilis	0.12		SFBC	SFBC, DE
Loripinus dentatus	0.19			
Ctena decussata		0.95	SGCF	SVCM, SGCF
Lucinella divaricata	0.38			
Myrtea spinifera	0.11		DC - DE	SGCF, pref. DC
Diplodonta intermedia	0.18		Ire	Ire
Chama gryphoides	0.10		HP	AP, pref. HP
Bornia sebetia	1.43		SFHN	SFHN, acc. HP
Kellia suborbicularis	0.29		DC - DE	pref. DC
Scacchia oblonga	0.16		AP	AP
Kurtiella bidentata		0.23	VTC	escl. VTC
Papillicardium papillosum	0.20	0.12	DC - DE	HP, pref. DC
Parvicardium roseum	0.21	0.16	HP	AP, HP
Parvicardium scriptum		1.35	HP	AP, HP
Spisula subtruncata	21.22		SFBC	excl. SFBC
Oudardia compressa	0.23		SFBC	excl. SFBC
Moerella distorta	4.42		PE	PE, SFBC
Tellina nitida	0.61		SFBC	excl. SFBC
Macoma elliptica	0.14			
Arcopagia corbis	0.10		DC - DE	escl. DC
Abra alba	1.17		Ire	Ire
Abra prismatica	0.29		DC - DE	SGCF, pref. DC
Abra stricta	0.22		HP	HP
Gari fervensis	0.80		DC - DE	SGCF, escl. DC
Gari uniradiata	1.14			
Azorinus chamasolen	0.20		DC - DE	pref. DC, DE
Venus nux	0.81		VTC	DE, pref. VTC
Venus verrucosa		0.33	HP	pref. HP
Circom. foliaceolamellosus	0.18		SFBC	pref. SFBC
Chamelea gallina	0.66		SFBC	pref. SFBC
Clausinella fasciata	0.10		SGCF	pref. SGCF, DC
Timoclea ovata	4.95	0.59	Ire	Ire
Dosinia lupinus	1.08		SFBC	pref. SFBC, DE
Pitar rudis	0.75		DC - DE	SFBC, pref. DC
Callista chione	1.08		SFBC	SFBC, SGCF
Callista puella	0.63		SFBC	escl. SFBC
Gouldia minima		0.11	HP	HP, SGCF, DC
Varicorbula gibba	8.17		PE	pref. PE, Ire
Rocellaria dubia	0.16			
Hiatella arctica	0.50		SGCF	SGCF, C
Ensis ensis	0.16		SFBC	SFBC

Tab. 7 - List of the taxa with dominance D > 0.1 of the Rio Vaccaruzza beds 3 and 9. For the biocoenotic acronyms see Table 1.

cate these old sites, it is possible to observe the palaeobiological features of Fontanili on the basis of a small collection present in the MGPT (Fig. 10-e). According to Bellardi (1887 in 1872-1888: 60): the Fontanili site is "… an extremely rich deposit with very fine bluish sands that are chock full of countless small molluscs … that lays above the Lower Pliocene muddy marls and is particularly characterized by its fauna: this inexhaustible mine is situated on the right side of the road from Tortona to Serravalle-Scrivia, therefore on the right bank of the Scrivia River, on the slope of the small hill on which the Villalvernia village is built; the area is not so far from the river and is known with the toponym Fontanili (= springs) because of the many sources …”. The sample of Bellardi (Fig. 10-e) shows significant lithological and taxonomic differences compared to the material from Bed 9. A further problem prevents any direct usage of specimens cited in the monographies of Bellardi and Sacco: the source of Villalvernia fossils (Salita della Braia or Fontanili) is described in detail only in Bellardi (1872-1888) and Bellardi & Sacco (1890) papers, whereas in the descriptions by Sacco (1890-1904) the fossils are labelled with the generic toponym “Villalvernia”.

A subsequent study on the Pliocene fossils from the Villalvernia area was published by Brambilla (1976) who reported a rich bivalve assemblage coming from a short-living outcrop on the left side of the Vaccaruzza stream, in front of our site. Brambilla’s site is discussed below and compared in detail with Bed 3.

The mollusc assemblages of beds 3 and 9 are analysed in terms of bathymetry and biocoenotic structure. The taxa with a well-established palaeoenvironmental meaning represent the majority in each assemblage. In Bed 3, 270 taxa (74.59% on 362 with D = 98.41) provide consistent bathymetric data and 202 taxa (55.80% on 362 with D = 91.39) provide biocoenotic indications. In Bed 9, 221 taxa (71.75% on 308 with D = 97.15) are indicative for bathymetry and 178 taxa (57.79% on 308 with D = 96.35) for biocoenosis.

The bathymetric analysis allows a clear distinction among the different sublittoral environments, from mesolittoral to circalittoral, and even bathyal zone. As far as concerns the biocoenotic analyses, the two procedures described in the Material and Methods section have been carried out taking into account the indications for taxa with exclusive and preferential meanings as well as the taxa with D > 0.1 grouped in “biocoenotic clusters” (Table 7).

It is worth noting that the taxonomic reduction made with the second procedure does not affect the results because most of the taxa with D < 0.1 cannot be associated to specific biocoenotic parameters.

Bed 3

The bed was analysed with a composite bulk-samples of 33.33 dm^3 (Table 3). The biofacies counts 362 molluscs with 231 gastropods, 8 scaphopods and 124 bivalves (see Appendix).

BED 3: palaeobathymetry of 270 taxa	
mesolittoral	2 taxa (0.74%), D = 0.61
infralittoral	88 taxa (32.59%), D = 29.72
infral.-circalittoral	160 taxa (59.26%), D = 65.57
circalittoral	12 taxa (4.44%), D = 0.98
infral.-bathyal	2 taxa (0.74%), D = 0.51
circal.-bathyal	6 taxa (2.22%), D = 1.02

Tab. 8 - Palaeobathymetric distribution of the Rio Vaccaruzza Bed 3: taxa and related dominances D.

BED 3: 68 exclusive and preferential taxa					
AP	3 tx,	D = 0.11	SFBC	21 tx,	D = 26.79
DC	22 tx,	D = 7.02	SGCF	5 tx,	D = 0.23
DE	2 tx,	D = 1.76	SVCM	2 tx,	D = 0.04
HP	4 tx,	D = 0.78	VTC	7 tx,	D = 3.56
PE	2 tx,	D = 11.37			

Tab. 9 - Palaeobiocoenotic distribution of the Rio Vaccaruzza Bed 3: exclusive and preferential taxa and related dominances D. For the biocoenotic acronyms see Table 1.

Six biocoenotic categories are recognized according to the bathymetric affinity of the taxa (Table 8). The assemblage is a mixture of taxa typical of the circalittoral to infralittoral zones (D = 65.57). However, it is worth noting the presence of a few taxa derived from mesolittoral (2 taxa) and circalittoral-bathyal (6 taxa) bottoms, the presence of the formers being explained considering the mass transport by currents to the outer shelf biotopes.

The biocoenotic parameters are consistent with the bathymetric affinity of the taxa in recognizing the heterogeneous origin of the molluscs, which are derived from all the sublittoral bottoms. The palaeobiocoenotic analyses of tables 9 and 10 have been done according to the two procedures already discussed:

- (Table 9) 68 molluscs (D = 51.66) representing the 18.78% of the whole assemblage; the most abundant biocoenotic categories are DC (D = 7.02), PE (D = 11.37), SFBC (D = 26.79), VTC (D = 3.56);
- (Table 10) 70 molluscs (D = 77.17) representing the 19.33 % of the whole assemblage and the 70.71 % of the 99 taxa with D > 0.1; the most significant biocoenotic clusters are DC-DE (D =

BED 3: biocoenotic clusters of 70 taxa (D > 0.1)					
AP	5 tx,	D = 0.83	SFBC	18 tx,	D = 27.84
DC - DE	21 tx,	D = 11.20	SFHN	1 tx,	D = 1.43
HP	12 tx,	D = 7.44	SGCF	7 tx,	D = 9.29
PE	3 tx,	D = 15.79	VTC	3 tx,	D = 3.35

Tab. 10 - List of the mollusc taxa and related dominance D of the Rio Vaccaruzza Bed 3 according to the biocoenotic clusters (see Table 2).

11.20), HP (D = 7.44), PE (D = 15.79), SFBC (D = 27.84), SGCF (D = 9.29).

Both methods provide similar results. Nevertheless, the former, being limited to exclusive/preferential tags, does not take into account some significant taxa that are not associated with distinctive biocoenotic values. This is the case of the taxa referred to as HP and SGCF biocoenoses; only a small number of them (9 taxa, D = 1.01) is marked by an exclusive/preferential tag, although they have a significant meaning in Bed 3 assemblage reaching the value D = 16.73 with the latter procedure. The clusters provide more consolidate information against this limitation.

In general, the mixed, allochthonous assemblage of Bed 3 is primarily represented by SFBC taxa such as the veneroid *Spisula subtruncata* (the commonest fossil of the assemblage) to which the taxa influenced by bottom currents (SGCF: *Caecum trachea* and *Glycymeris bimaculata*) are associated and, significantly, by taxa reflecting bottom instability (PE) including *Lembulus pella*, *Moerella distorta*, *Varicorbula gibba*. The mixing of sublittoral representatives is also testified by the presence of many taxa belonging to "transitional" communities at the passage between infralittoral and circalittoral zones such as those of the DC and DE biocoenoses as, for example, *Nassarius semistriatus* and *Saccella commutata*. The mixing of components from different biocoenoses is further highlighted by the VTC preferential taxa, especially *Turritellinella tricarinata*, *Nassarius serratus*, and *Venus nux*.

Autoecological parameters, such as habitus, textural affinity and trophism of mollusc taxa are not considered due to the total allochthony of the fossil assemblage of Bed 3. A preliminary investigation of the textural affinity carried out by Passone (2011) revealed a substantial imbalance in the various autecological categories. In particular, despite the dominance of the sand-related taxa (45%) is consistent with the substantially sandy composition of the bed, mixed-substrate molluscs are also abundant (31%) as well as mud-related ones.

Brambilla's fossiliferous site of the Rio Vaccaruzza - Brambilla in 1976 described a set of fossiliferous beds from a presently missing outcrop on the left side of the Rio Vaccaruzza (44°49'17.50"N - 8°51'25.69"E) 200 m south-westwards of the units 3 and 4 to which it could be approximately compared. The section described by Brambilla (1976: 83-84) consisted of four sandy beds (referred to as beds A to D: 5.50 m thick) with arenaceous concretions at the base- and top-section; fossils were mostly frequent in Bed B and at the passage between beds C and D. The taxonomic content of the sandy layers is similar in both sections on the opposite banks of the Rio Vaccaruzza: Brambilla listed 113 bivalves, 81 of which are in common with Bed 3. It is worth nothing that a direct comparison of the two data sets is not easy because Brambilla (1976) limited his research to hand-collection without any bulk-sampling, so that only a semi-quantitative analysis can be produced.

The analysis was limited to the bathymetry and the biocoenotic significance and to taxa with exclusive and preferential signatures. It has been based on the dominance of each species calculated after transforming in percentage the raw numbers of the 1091 specimens mentioned by Brambilla (1976).

- Bathymetric signature: 84 taxa (74.34% on 113) with D = 92.13 among which 29 infralittoral (34.52%, D = 15.53), 51 infralittoral-circalittoral (60.71%, D = 72.94), 2 circalittoral (2.38%, D = 0.82), 1 infralittoral-bathyal (1.19%, D = 0.09), 1 circalittoral-bathyal (1.19%, D = 2.75).

- Biocoenotic parameters: 34 taxa (30.08% on 113) with exclusive and preferential signatures (D = 44.07) pertaining to DC (14 taxa, 41.12%, D = 13.48), DE (1 taxon, 2.94%, D = 0.18), HP (1 taxon, 2.94%, D = 2.47), PE (2 taxa, 5.88%, D = 12.84), SFBC (10 taxa, 29.41%, D = 9.15), SGCF (4 taxa, 11.76%, D = 3.11), VTC (1 taxon, 2.94%, D = 2.75), and VP (1 taxon, 2.94%, D = 0.09).

The two procedures provide similar results. The bivalve assemblage described by Brambilla (1976) comprises a mixture of taxa that refer to different biocoenoses of the continental shelf (SFBC, DC and PE), which is consistent with the bathymetric spectrum that assign the highest value of D (72.94) to the infralittoral and circalittoral zones.

Based on these palaeoecological information, it is possible to conclude that the fossil assemblage described by Brambilla (1976), although limited to bivalves, is consistent with the assemblage documented herein for Bed 3, at least in terms of depositional mechanism, since its origin was likely related to a mass transport from the middle-upper sublittoral sectors to the outer parts of the continental shelf as in the case of beds 3 and 4 documented herein (hyperpycnal flows of Mutti et al. 1996, 2000, 2003).

The outcrop on the left side of the Rio Vaccaruzza described by Brambilla (1976) remained open for some years after his paper publication, and two of us (G. P. and M. P.) visited the outcrop in 1978 and collected a number of gastropod, scaphopod and bivalve specimens that constitute a reference collection stored at the MGPT. The preservation of these specimens is fully consistent with that of Bed 3.

Some doubts remain in correlating beds B and C described by Brambilla (1976) with our beds 3 and 4 due to different thickness of the two sections. However, both the sandy beds A and D appear to be equivalent to our Bed 5 because of the coarse sandy sediment and the recurrent concretions. The dip direction is WSW and the bed angle 8-10^0 (Brambilla 1976, p. 83; see also the present Fig. 10), i.e. the dip direction of the beds is oblique compared to the axis of the Rio Vaccaruzza. Taking into account quotes and coordinates of the two sites, the outcrop described by Brambilla (1976) should coincide with the edge of the riverbed about ten meters below the registered position. In conclusion, it is reasonable to hypothesize that a fault separates and uplifts, with about 15 m of displacement, beds A-D with respect to the section documented herein (see the “Vaccaruzza fault system” in Fig. 1). Although the vegetation cover does not allow to recognize this fault in the outcrop, a NW-striking morphological scarp located to the NE of the Villalvernia municipality may support its occurrence and trend. This interpretation well agrees with the occurrence of N-striking faults (ranging from NW-SE to NE-SW trends), which displace the FAA in both the studied area (see Festa et al. 2015) and to the ENE of the Villalvernia sector (e.g., the Schizzola valley fault, see Perotti & Vercesi 1991; Vercesi et al. 2015; Barbero et al. 2017). They represent the product of the extensional tectonics, which acted since the Early Pliocene time in response to a regional tilting (Festa et al. 2015). A minor fault, probably sub-parallel to the main one, may also explain the repetition of the sandy and concretionary Bed A that is doubled as Bed D in the section described by Brambilla (1976); the surface of this minor fault would roughly lie at the transition between level A and level B.

If this structural conclusion is correct, the inclusion of the fossils described by Brambilla (1976) would increase to 156 the number of bivalves recognized from Bed 3. Moreover, seven additional taxa might be included in the list considering those reported by Sacco (1890-1904) that are missing in the present study. With these additions, that from Bed 3 constitutes the richest bivalve assemblage known from the Pliocene sandy deposits of the TPB (cf. Montefameglio et al. 1980), which includes only a few less taxa than those described in the monographs published by Sacco (1890-1904).

Bed 9

The bed was analysed with a composite bulk-samples of 7.14 dm^3 (Table 3). The biofacies counts 308 molluscs with 227 gastropods, 2 scaphopods and 79 bivalves (see Appendix). In Table 7, 77 taxa with D > 0.1 are listed associated with their biocoenotic parameters: 62 gastropods, 1 scaphopod, 14 bivalves.

Five categories (221 taxa) have been recognized based on the bathymetric affinity of the taxa (Table 11). The spectrum of data derived from the composite bulk-sample covers the whole sublittoral domain. Except for a single mesolittoral taxon (*Truncatella subcylindrica*) clearly transported by waves/currents, the majority of the species points to a generic infralittoral-circalittoral context (D = 50.89). However, the input of infralittoral taxa is much relevant (D = 45.27) compared with Bed 3 (D = 29.72 in Table 8), suggesting that the deposition of Bed 9 took place at a reduced bathymetry within the regressive trend of the whole Rio Vaccaruzza succession.

The analysis of the biocoenotic parameters provides additional detailed information. We elaborated the taxonomic data of Bed 9 by means of the procedures applied to the assemblage of Bed 3:

(1) 26 molluscs represent the 8.50% of the

BED 9: palaeobathymetry of 221 taxa	
mesolittoral	1 taxon (0.45%), D = 0.01
infralittoral	87 taxa (39.36%), D = 45.27
infral.-circalittoral	124 taxa (56.11%), D = 50.89
circalittoral	8 taxa (3.62%), D = 0.49
infral.-bathyal	1 taxon (0.45%), D = 0.49

Tab. 11 - Palaeobathymetric distribution of the Rio Vaccaruzza Bed 9: taxa and related dominances D.

BED 9: 26 exclusive and preferential taxa					
AP	3 tx,	D = 0.08	SFBC	6 tx,	D = 0.81
C	1 tx,	D = 0.01	SGCF	1 tx,	D = 0.01
DC	8 tx,	D = 0.44	SVCM	1 tx,	D = 0.12
HP	4 tx,	D = 0.59	VTC	1 tx,	D = 0.23
PE	1 tx,	D = 0.01			

Tab. 12 - Palaeobiocoenotic distribution of the Rio Vaccaruzza Bed 9: exclusive and preferential taxa and related dominances D. For the biocoenotic acronyms see Table 1.

BED 9: biocoenotic clusters of 65 taxa (D > 0.1)					
AP	1 tx,	D = 0.21	SGCF	4 tx,	D = 1.56
DC - DE	5 tx,	D = 0.73	SVCM	2 tx,	D = 0.24
HP	51 tx,	D = 88.57	VTC	1 tx,	D = 0.23
SFBC	1 tx,	D = 0.54			

Tab. 13 - List of the mollusc taxa and related dominance D of the Rio Vaccaruzza Bed 9 according to the biocoenotic clusters (see Table 2).

whole assemblage with exclusive/preferentia target and total D = 2.30 (Table 12); among these, only seven taxa have D > 0.1 and pertain to DC (2 taxa, D = 0.29), HP (1 taxon, D = 0.40), SFBC (1 taxon, D = 0.76), SVCM (1 taxon, D = 0.12), VTC (1 taxon, D = 0.23);

(2) 65 molluscs, equivalent to the 85.52% of the 76 taxa with D > 0.1 and the 20.69% of the whole assemblage, total D = 92.08 (Table 13); the more representative biocoenotic cluster is HP with 51 taxa and D = 88.57.

The two methods provide non-comparable results mainly due to the HP biocoenosis input. This difference derives from the low number of species with exclusive/preferential tag that are commonly referred to as HP in the literature: only the gastropod *Nassarius asperatus* and the bivalves *Flexopecten hyalinus*, *Limaria hians*, *Chama gryphoides* and *Venus verrucosa*. The analysis is different if we expand the selection (Table 12) to the taxa for which the acronym HP is considered as a reference and not only an exclusive parameter; regardless of the D value, they are 73 in Bed 9 and total D = 88.66. On the other hand, it is evident that most mollusc taxa are not restricted to seagrass meadows (Reich 2014) so that the necessity/opportunity to consider the data with a large spectrum of related biocoenotic inputs can lead to a more realistic conclusion.

In addition, the palaeobiocoenotic analysis of Bed 9 allows to consider as characteristic elements of the HP biocoenosis some taxa commonly not regarded to as closely associated to this biocoenosis (cf. the mark "?" in Appendix), including *Skenea bogii*, *Archimediella subvaricosa*, *Alvania bonellii*, *A. pagodulina*, *A. thiala*, *Rissoina pusilla*, *Crepidula bellardii*, *Erato pernana*, *Natica virguloides*, *Tectonatica prietoi*, *Tarantinaea subfimbriata*, *Aplus ansus*, *Mitrella minor*, *M. villalvernensis*, *Conus dellabellai*, *Turbonilla postacuticostata*, *T. pusilla*, *T. striatula*, *Retusa decussata*, *Limaria hians*. With the already cited *N. asperatus*, *F. hyalinus*, *L. hians*, *C. gryphoides* and *V. verrucosa*, the characteristic molluscs of HP are 24 and total D = 26.69. Furthermore, the abundance of *Pusillina* spp. (*P. lineolata* and *P. sulzeriana* total 4.48%) reflects a large input from the *Posidonia* meadows (Basso et al. 2008).

The autecological constraints of molluscs that compose the fossil assemblage of Bed 9 have been examined. The lifestyle is largely dominated by the epifaunal taxa, whereas the textural affinity and the trophism need a detailed analysis. The distribution of the taxa for these two parameters is the following:

- textural affinity: 62.53% compact-substrate dwellers, 8.39% sand dwellers (mainly tolerant forms), 18.03% mixed-substrate dwellers, 2.72% mud dwellers;
- trophism: 12.15% carnivores + necrophages, 2.32% ectoparasites, 75.21% deposit feeders + herbivores, 5.78% suspension feeders.

Overall, the sharp dominance of epifaunal taxa characteristic of compact substrates with a score of 83.91% and, from a trophic point of view, of deposit feeders and herbivores is fully consistent with *Posidonia* meadow environments (see Moisette et al. 2007: 205; Koskeridou et al. 2019: 4).

In conclusion, substantial evidence suggests that the mollusc assemblage of Bed 9 documents a Lower Piacenzian (passage MPl4b to low-MPl5a biozones, Upper Pliocene) *Posidonia* meadow. It represents an autochthonous fossiliferous complex in which the overwhelming majority of fossils must be regarded as in situ fossils or just moved entities derived from taxa living in the different compartments of the seagrass environment, deposited on the meadow bottom together with *Posidonia* rhizomes and mixed with scattered mollusc bioclasts transported during occasional influx by bottom currents.

The environmental features of the seagrass meadows have been extensively explored resulting in a conspicuous literature developed over the last decades (e.g., Brasier 1975; Den Hartog 1979; Ivany et al. 1990; Moissette et al. 2007; Relini 2008). A large number of papers has been focused on the mollusc communities living in these extremely rich environment (e.g., Spada 1971; Bedulli et al. 1992, 1993a, 1993b, 1994, 1995; Russo & Terlizzi 1997; Martini et al. 2001; Russo et al. 2002; Koskeridou et al. 2019). As far as to the Cenozoic record is concerned, many papers discussed the direct or indirect evidence of fossil seagrass meadows all around world (e.g., Reuter et al. 2010; Harzhauser 2014; Reich et al. 2014, 2015).

As to the presence of seagrass meadows in the Pliocene-Pleistocene of the Mediterranean region, in-situ rhizomes and leaves associated to mollusc assemblages of the HP biocoenosis have been reported from the Upper Pliocene of Rhodes (Moissette et al. 2007) and the Lower Pleistocene of Rhodes (Koskeridou et al. 2019) and of Eastern Sicily (Di Geronimo 1984). The mollusc records of Rhodes from the Pliocene and, similarly, from the Lower Pleistocene contain *Jujubinus striatus*, *Bittium latraillei*, *Barbatia barbata*, *Glycymeris glycymeris*, *Flexopecten hyalinus*, *Talochlamys multistriata*, *Venus verrucosa* fully consistent with those of Bed 9 of the Rio Vaccaruzza section. Di Geronimo (1984) described the mollusc assemblages from three Pleistocene localities of the Hyblean Plateau, two of which refer to fossiliferous beds dominated by taxa indicative of DC biocoenoses with *Posidonia* leaves and rhizomes imported by storm currents. The third Sicilian locality (Fontana Pietrobutera) closely resembles Bed 9 of the Rio Vaccaruzza with the in-situ rhizomes and leave shreds of *Posidonia oceanica* in carbonate silts associated with a rich autochthonous mollusc assemblage including *Jujubinus striatus*, Rissoidae, *Arca noae*, *Flexopecten hyalinus*, *Papillicardium papillosum*, *Venus verrucosa*, *Gouldia minima*.

Another peculiar feature of Bed 9 mollusc assemblage concerns the abundance of juvenile forms of two sets of bivalves, the infaunal-vagile *Glycymeris bimaculata*, *G. glycymeris*, *Cardites antiquatus*, and the epifaunal, byssate *Arca noae*, *Barbatia candida*, *Flexopecten inaequicostalis*, *Mimachlamys varia* whose size is very reduced compared to that of the specimens commonly found in the Pliocene sandy deposits of the TPB. Seagrass meadows act as nurseries for many infralittoral biota (e.g., Ivany et al. 1990: 251; Relini 2008) that find protection during their growth; this function may be hypothesized also for the Pliocene *Posidonia* meadow of the Rio Vaccaruzza, at least for these taxa.

The thin discontinuous lenses with coarse texture and large bioclasts represent occasional episodes of high energy due to channelled currents that developed bottom conditions analogous to those described for SGCF biocoenosis (Corselli 1981). Moreover, the presence of centimetric rhodolitic nodules recalls the Coralligenous biocoenosis (Pérés & Picard 1964). In such discontinuous lenses mollusc shells are usually fragmented and abraded; the taxonomic differences with respect to the main body of Bed 9 mostly consist of the quantitative reduction of smaller forms, in particular *Jujubinus striatus*, *Tricolia tenuis*, and Rissoidae, as well as of the increased abundance of *Bolma rugosa*, *Caecum trachea*, *Crassispira brocchii*, *Gouldia minima* testifying a SGCF condition in the channels, which may be considered equivalent of the so-called “intermates” of the *Posidonia* meadows (see Biagi & Corselli 1978; Ciampalini et al. 2014).

Fontanili - The fossiliferous outcrop described by Bellardi (1887 in 1872-1888: 60), referred to as Fontanili, was reported as “an extremely rich deposit with very fine bluish sands that are chock full of countless small molluscs” (see the beginning of the section) and shows undeniable analogies with the Bed 9 of the Rio Vaccaruzza in terms of shared taxa. Nevertheless, based on the historical sample stored in the MGPT (Fig. 10e), the two assemblages differ for the higher percentage of the sandy

Tab. 14 - Fish taxa encountered in beds 2, 3 and 9 of the Rio Vaccaruzza section.

Family	Taxon	Bed 2	Bed 3	Bed 9
Congridae	*Conger* sp.			2
Ophidiidae	*Ophidion* cf. *barbatum* Linnaeus, 1758			1
Atherinidae	*Atherina boyeri* Risso, 1812		1	
Apogonidae	*Apogon* sp.			1
Sparidae	*Diplodus* sp.	2		5
	?*Spicara* sp.			6
Gobiidae	*Callogobius weileri* (Bauza-Rullan, 1955)			2
	Chromogobius cf. *zebratus* (Kolombatovic, 1891)			1
	Gobius geniporus Valenciennes, 1837	11	8	44
	Lesueurigobius suerii (Risso, 1810)	12	35	15
Pleuronectidae	?*Glyptocephalus* sp.	1		1

fraction compared to the muddy matrix of Bed 9 and for the foraminifer content.

A sample for micropalaeontological analysis has been prepared after processing the sample collected by Bellardi (1887) using a < 0.5 mm sieve. The foraminifer content is characterized by lower diversity and disappearance of many facultative epiphytes (*Rosalina*, etc.); the assemblage includes *Elphidium crispum* (32%), miliolids (18%), *Nonion boueanum* (18%), *Ammonia beccarii* (13%) and *Cibicidoides lobatulus* (9%) and lacks planktonic forms. From a palaeoecological point of view, foraminifers are largely represented by epiphytic taxa, although motile groups are predominant (*Elphidium* and miliolids) suggesting the occurrence of abundant detrital fraction. Other important elements include the occurrence of larger foraminifera with respect to beds 3 and 9, as well as the lack of small fragments of the tests. Overall, these features can be interpreted as the product of sorting of both entire and fragmented tests, pointing to a more energetic environment, probably influenced by wave actions more than bottom currents.

All these aspects allow to conclude that the fossiliferous deposit of Fontanili represents an allochthonous assemblage of the Type 3 composed by different taxonomic stocks remobilized by (currents?) waves with consequent mixing of taphonomic elements deriving from infralittoral settings.

The Fontanili deposit has a considerable relevance in the study of the Pliocene succession of Villalvernia; its detailed analysis increases the data provided herein through the addition of new stratigraphic and palaeobiocoenotic elements. Moreover, the Fontanili site might be combined with those of the Rio Vaccaruzza and the Scrivia River between Villalvernia and Cassano Spinola (cf., Boano et al. 2015; Negri et al. 2013; Pellegrino et al. 2017; Silvano & Boano 2008; Treggiari et al. 2013) in the perspective to increase the scientific importance of that area as suggested by the Mayor of Villalvernia and the local stakeholders.

FISH OTOLITHS OF THE RIO VACCARUZZA BEDS 2, 3 AND 9

About 150 fish otoliths have been discovered from the residues of the samples collected from beds 2, 3 and 9. Considering the huge amount of processed sediment and the abundant to very abundant amount of aragonitic shells of gastropods and bivalves, it is reasonable to conclude that the number of encountered otoliths is rather low. Tab. 14 lists the recognized taxa (see Fig. 13). Each held between three to ten species-level taxa from two to six families. More than half of the otoliths pertain to the assemblage from Bed 9, which is the most diverse in terms of recognized taxa. The majority of the specimens pertain to the benthic family Gobiidae that is strongly dominant in all the assemblages, representing from 79 to 97% of the available otoliths. All the other families, with the exception of the Sparidae and Pleuronectidae, are restricted to a single assemblage. Two gobies, *Gobius geniporus* and *Lesueurigobius suerii*, have been recognized in all the assemblage, and the sparid *Diplodus* sp. and pleuronectid ?*Glyptocephalus* sp. occur in the assemblages of beds 2 and 9. Overall, the family Gobiidae is represented by five taxa, Sparidae by two and all the remaining families (Apogonidae, Atherinidae, Congridae, Ophidiidae, and Pleuronectidae) by a single species-level taxon each.

As discussed above, the allochthonous and transported nature of the mollusc assemblages of

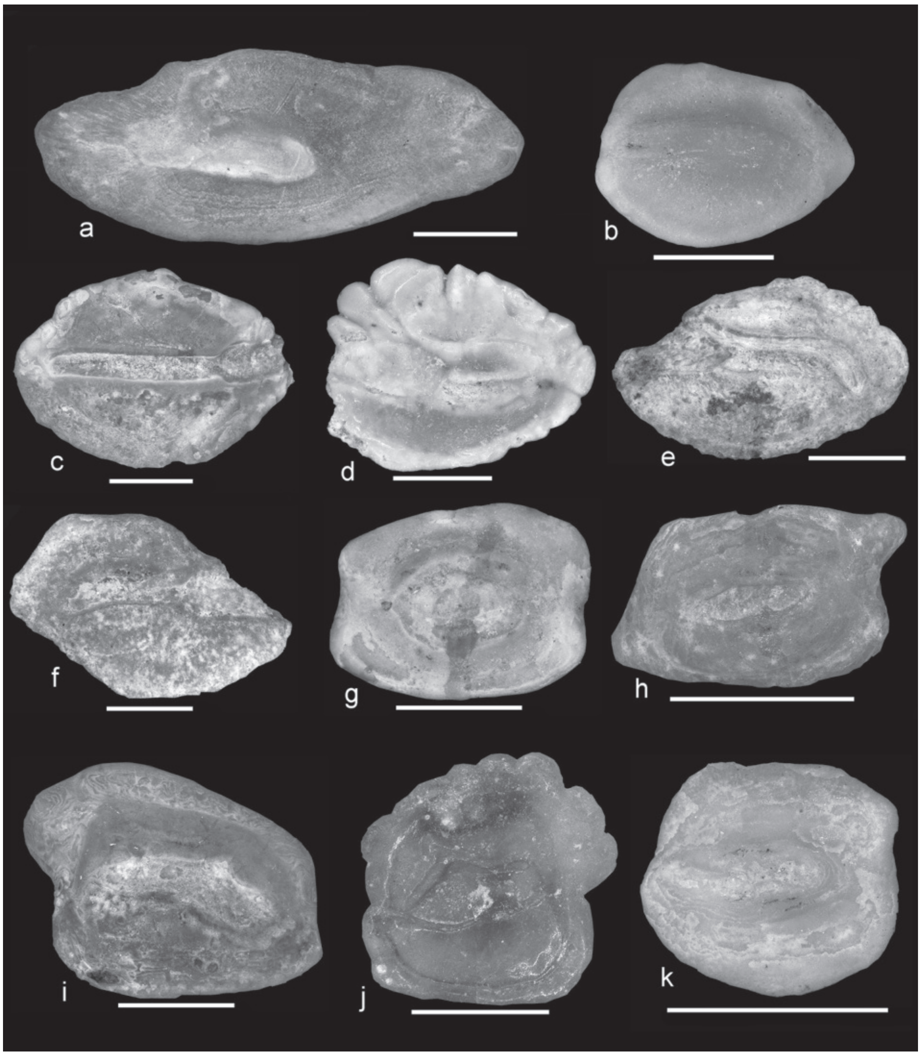

Fig. 13 - Fish otoliths from the Upper Pliocene of Rio Vaccaruzza. a) *Conger* sp., MGPT-PU 130391, Bed 9. b) *Ophidion* cf. *barbatum* Linnaeus, 1758, MGPT-PU 130392, Bed 9. c) *Atherina boyeri* Risso, 1812, MGPT-PU 130401, Bed 3. d) *Apogon* sp., MGPT-PU 130393, Bed 9. e) *Diplodus* sp., MGPT-PU 130399, Bed 9. f) ?*Spicara* sp., MGPT-PU 130400, Bed 9. g) *Callogobius weileri* (Bauza-Rulan, 1955), MGPT-PU 130394, Bed 9. h) *Chromogobius* cf. *zebratus* (Kolombatovic, 1891), MGPT-PU 130395, Bed 9. i) *Gobius geniporus* Valenciennes, 1837, MGPT-PU 130396, Bed 3. j) *Lesueurigobius suerii* (Risso, 1810), MGPT-PU 130397, Bed 9. k) ?*Glyptocephalus* sp., MGPT-PU 130398, Bed 9. Scale bars: 1.00 mm.

beds 2 and 3, which document a mixing of taxa pertaining to different sublittoral biocoenoses, is indicative of their limited value for palaeoenvironmental interpretation. Both the fish assemblages of beds 2 and 3 are dominated by benthic taxa primarily inhabiting mixed and vegetated bottoms within a broad bathymetric spectrum, ranging from a few meters down to more than 330 meters, as in the case of *Lesueurigobius suerii* (e.g., Mytilineou et al. 2005).

Conversely, the molluscs of Bed 9 are regarded as autochthonous, documenting a considerably diverse assemblage that inhabited a *Posidonia* seagrass meadow. Compared to those of beds 2 and 3, the fish assemblage of Bed 9 is much diverse in terms of number of recognized taxa and discovered specimens. The fish assemblage of Bed 9 is made up of 10 species-level taxa, four of which (representing 79% of the specimens) pertain to the Gobiidae (*Callogobius weileri*, *Chromogobius* cf. *zebratus*, *Gobius geniporus*, and *Lesueurigobius suerii*), two to the Sparidae (*Diplodus* sp. and ?*Spicara* sp.), and a single one to the Apogonidae (*Apogon* sp.), Congridae (*Conger* sp.), Ophidiidae (*Ophidion* cf. *barbatum*), and Pleuronectidae (?*Glyptocephalus* sp.). Therefore, there is a clear dominance of benthic taxa primarily inhabiting vegetated bottoms, whereas demersal ones are solely represented by *Apogon* sp. and the sparids. There are many small-sized otoliths that clearly indicate the juvenile nature of a part of the fish assemblage, including several gobies, all the sparids and the single available specimen of the pleuronectid ?*Glyptocephalus* sp.

Seagrass meadows are characterized by high abundance and density of fishes, related to the high structural complexity of these habitats, which provide shelter from predators and food resources (e.g., Kikuchi & Pérès 1977; Robertson 1980; Francour 1997; Guidetti 2000). In addition, these habitats represent high quality nurseries for several fish species being crucial for the recruitment of juveniles and, consequently, for the survival of fish populations (e.g., García-Rubies & Macpherson 1995; Pihl & Wennhage 2002).

The structure and ecological features of the fish assemblages of the *Posidonia* meadows of the Mediterranean have been extensively discussed in many studies (e.g., Zei 1962; Bell & Harmelin-Vivien 1982; Francour 1997; Bussotti & Guidetti 1999; Guidetti 2000; Frau et al. 2003; Kalogirou et al. 2010). The composition of the fish assemblage fits well with the seagrass meadow palaeobiotope hypothesized for Bed 9. However, when compared with those inhabiting the Mediterranean *Posidonia* meadows today, it is evident that the assemblage of Bed 9 of the Rio Vaccaruzza succession is characterized by a much diverse and abundant gobiid component as well as by the complete absence of wrasses (family Labridae). Gobies are usually present in seagrass habitats although their actual abundance and biomass are probably underestimated by the use of visual census techniques because of their small size and cryptic behavior (see, e.g., Ackerman & Bellwood 2000). Some gobies select the seagrass meadows as their reproductive habitat (e.g., Malavasi et al. 2002), thereby suggesting the existence of a close and stable association between these benthic fishes and the seagrasses (see also Malavasi et al. 2005). Therefore, the remarkable abundance of gobies in the assemblage of Bed 9 can be easily explained, also taking into account that their benthic lifestyle is strongly conducive to the post-mortem accumulation of their otoliths (e.g., Schwarzhans et al. 2020). Conversely, the absence of labrids appears to be much difficult to explain. Labrid otoliths are only sporadically found in siliciclastic sediments and, consequently, they are rare in the fossil record (Nolf 2013). Therefore, considering their general rarity in the record together with the limited number of otoliths encountered in Bed 9, the absence of labrid otoliths does not appear so striking. Intriguingly, labrid otoliths seems to be also absent in the seagrass-associated fossil assemblage recently described by Koskeridou et al. (2019) from the Early Pleistocene of Rhodes, where abundant gobies have been reported.

As discussed above, the family Sparidae is solely represented by small otoliths belonging to juvenile individuals and otoliths of clear juvenile affinity have been observed for the Gobiidae as well as for the available specimens of ?*Glyptocephalus* sp. These observations are consistent with the firmly established notion that seagrass represent nursery habitats for many fish species. According to Francour (1997) in the Mediterranean *Posidonia* meadows only the settings shallower than 15 meters are important as a nursery habitat for fishes.

Seagrass fish assemblages usually include taxa from different trophic levels (Bell & Harmelin-Vivien 1983). Epibenthic invertebrates, especially small crustaceans and worms are extensively consumed (see Bell & Pollard 1989), representing the favoured food of the seagrass fishes, whereas the infaunal invertebrates are commonly under-preyed (Hemminga & Duarte 2000). Extant relatives of the recognized taxa are predators, whose food mostly consisted of epibenthic invertebrates and other fishes. Among the recognized taxa, *Conger* sp. and *Ophidion* cf. *barbatum* can be regarded as (nocturnal) macrophagic predators with a diet based on polychaete worms, a variety of crustaceans and fishes (see Bell & Harmelin-Vivien 1983), whereas the gobies, *Apogon* sp., *Diplodus* sp. and the pleuronectid ?*Glyptocephalus* sp. can be considered as mesophagic predators feeding primarily on polychaetes, gastropods, bivalves, brachiopods, and crustaceans (?mostly amphipods). ?*Spicara* sp. is the only putative microphagic predator of the assemblage, whose diet was likely based on small crustaceans, particularly copepods.

THE *ENTOBIA-GASTROCHAENOLITES* ICHNOFACIES OF THE RIO VACCARUZZA BED 4

Encrusting and boring ichnofossils are rather abundant in the fossil assemblage of Bed 4 (Fig. 6), and they are occasionally found also in Bed 3 (Bedin 2011). Boring activity affects all kind of mollusc structures with the obvious preference on thick bivalve shells such as those of *Glycymeris bimaculata*, *Ostrea edulis* and *Chama gryphoides*, which are sufficiently thick to host both shallow and deep borings. Boring structures were produced by different kinds of endoskeletozoans including the sponges of the family Clionidae (ichnogenus *Entobia*), the annelid *Polydora* of the family Spionidae (ichnogenera *Caulostrepsis* and *Maeandropolydora*), and the bivalves *Rocellaria dubia* and *Lithophaga* sp. (ichnogenus *Gastrochaenolites*). These ichnogenera are frequently described in literature (e. g., de Gibert et al. 2007; Belaústegui et al. 2018 and references therein) under the morpho-descriptive set known as *Entobia-Gastrochaenolites* ichnofacies. The products of their bioerosional activity are usually represented by (1) holes in the host structure, occasionally with calcareous internal coatings, (2) shells of the boring mollusc, (3) internal moulds of the holes. The encrusting structures affect all the mollusc shells present in the fossiliferous bed and constitute the normal corollary of the *Entobia-Gastrochaenolites* ichnofacies; they were produced by zoantharian corals, bryozoans, gastropods, bivalves and balanid barnacles.

The following descriptions concern only the boring ichnofossils due to their relevance in the palaeoecological analysis of the Rio Vaccaruzza fossil assemblage.

Several dozens of specimens were collected, some of which obtained through the sampling activity on the section and some others collected in the field as abandoned traces of previous excavations. The preservation is good especially due to the depositional mechanism of the sandy Bed 4. The mass transport by currents with a huge amount of suspended fine sediment and its sudden deposition with the absence of pebbles prevented the erosion and the breakage of the mollusc host structures, thereby favouring the integrity of the ichnofossils. Borings are very common in the shells of *O. edulis*, which are primarily represented by the left valves, i.e. those that fix to the substrate; this taphonomic selection is the consequence of the recurrent loss of the mobile right valve that easily disarticulates post-mortem (Zitt & Nekvasilova 1996).

For the study, the superficial encrustations due to diagenesis were removed from samples in order to obtain clean surfaces and observe the texture on which the drilling activity was developed. Serial cuts were made on extensively colonized samples in order to reconstruct the shape of the borings, which is of prime importance to distinguish among the taxa of the ichnogenus *Gastrochaenolites*. Such a procedure is necessary as single ichnospecies can be generated by the activity of different bioeroders (Haentzschel 1975).

In the *Entobia-Gastrochaenolites* ichnofacies of Bed 4 we have recognized different ichnogenera and ichnospecies.

Ichnogenus *Entobia* (Figs. 14 a, 15 b)

It consists of a complex network of millimetric sub-circular chambers and tunnels bored into calcareous substrates (shell or rockground). The external surface of the colonized host is perforated by tiny holes that enter the bored system; the globular chambers are separated by thin walls in turn pierced by connecting channels. *Entobia* is interpreted as produced by the sponges of the family Clionaidae (Martinell & Domènech 1998) that live inside the carbonate substrates which offer protected space against competitors (Zundelevich et al. 2007). In general, *Entobia* is the most active pioneer on carbonate substrates. It may be the single borer of the internal side of ostreid valves, i.e. its structures develop (growth phase A of Bromley & d'Alessandro 1984) just after death and before burial of the host.

Many ichnospecies of *Entobia* are described in the literature (e.g., Bromley & d'Alessandro 1984, 1987; Radwanski et al. 2011; Demircan 2012) based on shape, size and relationship of the internal structures.

Entobia represents the most frequent tracemaker of Villalvernia Bed 4 fossil assemblage, both on gastropods and bivalves. Compared with description and figures published by Belaústegui et al. (2018), *E. geometrica* Bromley & d'Alessandro, 1984 is the commonest ichnospecies (Fig. 14 a). The alignment of the apertures along the shell growth layers reflects a dense and regular internal distribution of chambers interconnected by short galleries visible where the shell is damaged. *E. cateniformis* Bromley & d'Alessandro, 1984 is also present (Fig. 15 b) though less frequent than the former; it may be distinguished by the apertures randomly distributed and not necessarily aligned according to the internal structure of the host.

Ichnogenera *Caulostrepsis* (Figs. 14 b, 14 d) and *Maeandropolydora* (Fig. 14 c)

The polychaete annelid *Polydora* drills the calcareous substrates from which the animals protrude short tubes of calcareous mud used as apertures (Sato-Okoshi & Okoshi 2000). The boring activity proceeds chemically and/or mechanically (Blake & Evans 1972); the worms produce galleries that were defined by Bromley & d'Alessandro (1983) as axial or lateral borings. The basic structure of the latter pertains to *Caulostrepsis*; its gallery is a long, narrow, U-shaped tube where the host structure between the two limbs of the gallery is progressively reduced to a sort of septum ("vane"). Conversely, the axial borings refer to multiple galleries (*Maeandropolydora*) growing by successive extensions from the limbs of a branched structure

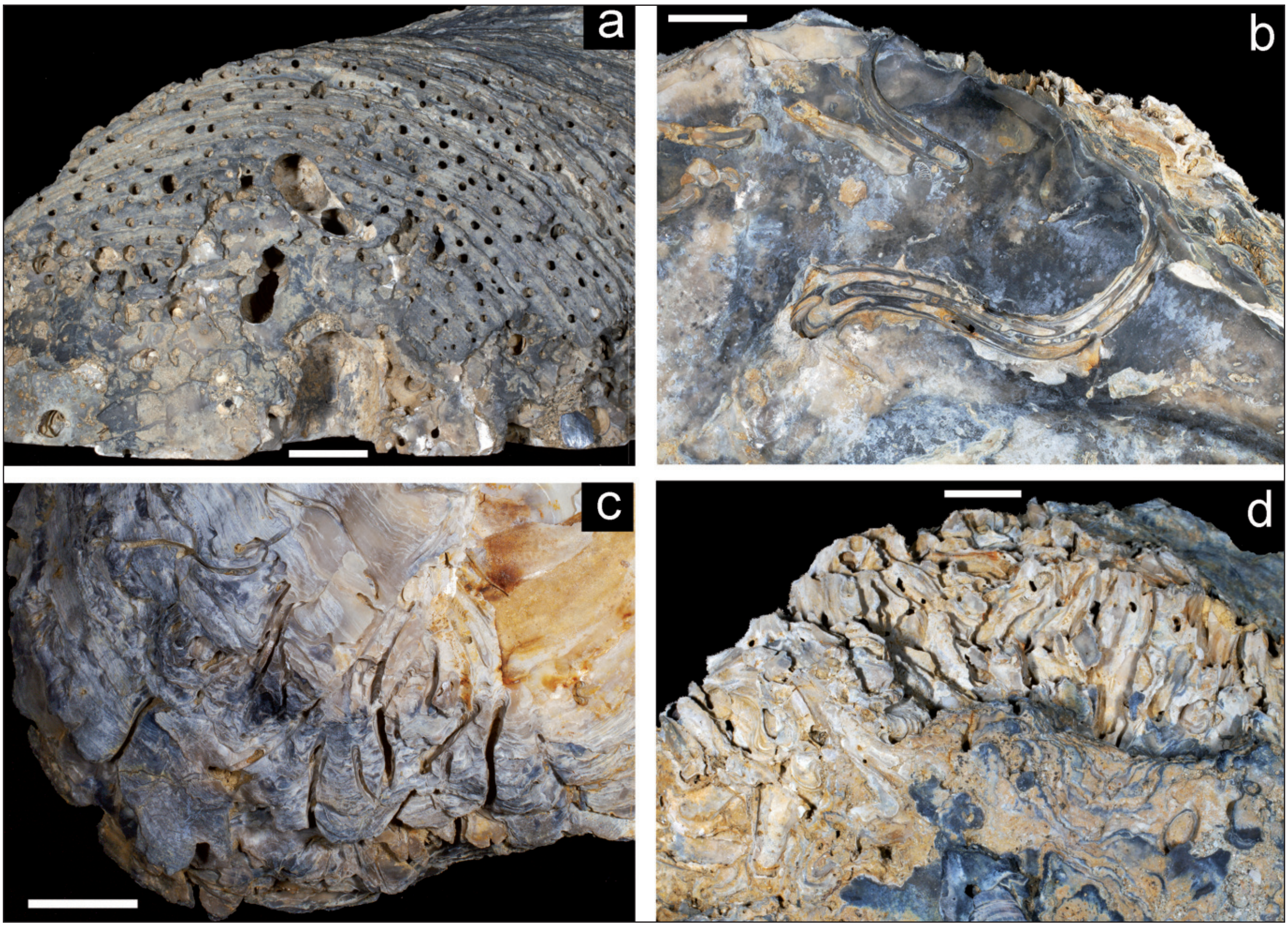

Fig. 14 - Bioerosional structures on *Ostrea edulis* Linnaeus, 1758 from Bed 4 of the Rio Vaccaruzza section.
a) *Entobia geometrica* Bromley & d'Alessandro, 1984. b) *Caulostrepsis taeniola* Clarke, 1808, single specimen. c) *Maeandropolydora* sp., a colony. d) *Caulostrepsis* sp., intense colonization. Scale bars: 10 mm.

that may become convolute up to a loose hank with circular apertures. Both ichnogenera are largely known in literature from the Devonian (*Caulostrepsis*) and the Jurassic (*Maeandropolydora*) to the Recent (e.g., de Gibert et al. 2007; Santos & Mayoral 2008; Demrican 2012; El-Sabbagh et al. 2015; Belaústegui et al. 2018).

Both the ichnogenera are relatively common borers into *O. edulis* shells of the fossil assemblage of Bed 4. *Caulostrepsis* and *Maeandropolydora* develop "basic" forms (respectively Fig. 14 b and Fig. 14 c) in which galleries are usually well distinct within the shell laminar structure. In some cases, the degree of colonization is so advanced and superimposed in levels that the shell laminae appear to be frayed (Fig. 14 d). As to gallery distribution, the taxa show a clear preference for the ventral portion of the valves, in which the galleries tend to follow the growth lines and the apertures are directed toward the shell margin. This particular arrangement suggests that the colonisation occurred during the life of the host, so that the worms could benefit of the nutritional charge suspended in the water currents produced by the mollusc filtering activity (Santos & Mayoral 2008).

Ichnogenus *Gastrochaenolites* (Figs. 6, 15, 16)

This is the most representative ichnotaxon of Bed 4 fossil assemblage. The *Entobia-Gastrochaenolites* ichnofacies of the Rio Vaccaruzza mainly results from the boring action of the bivalves *Lithophaga* sp. and *Rocellaria dubia* (Pennant, 1777: generic revision of *Gastrochaena dubia* by Carter et al. 2008).

Both *Lithophaga* sp. and *R. dubia* are widespread in the Bed 4 assemblage, but the latter is more frequent due to its smaller size and ecological plasticity. Such disparity depends on the substrate availability. *R. dubia* may develop also in hosts of smaller size, whereas the genus *Lithophaga* needs

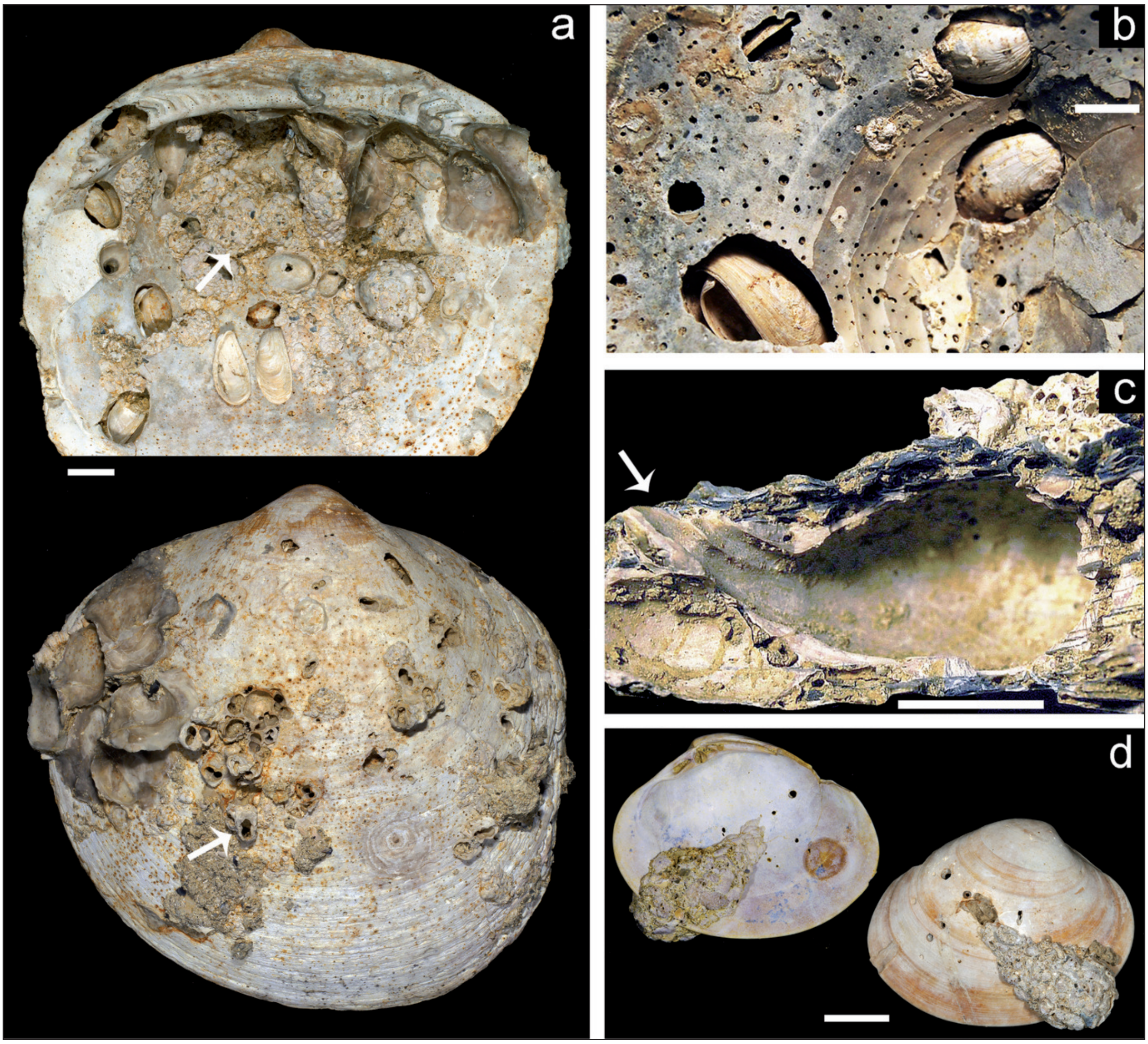

Fig. 15 - *Gastrochaenolites dijugus* Kelly & Bromley, 1984 from Bed 4 of the Rio Vaccaruzza section.
a) Left valve of *Glycymeris bimaculata* (Poli, 1795): (above) calcareous crypts (arrow) partially closing the bores; (below) protruding siphonal necks with eight-shaped edges (arrow). b) Inner side of a right valve of *Chama gryphoides* Linnaeus, 1758: bores are still occupied by the bivalve shells of *Rocellaria dubia* (Pennant, 1777). Note the irregular perforation by *Entobia cateniformis* Bromley & d'Alessandro, 1984. c) Longitudinal section of *G. dijugus* in *Ostrea edulis* Linnaeus, 1758: note the clavate chamber and the apertural septum separating the siphons which give rise to the eight-shaped edge (arrow). d) Nearly free crypt of *G. dijugus* in a right valve of *Callista chione* (Linnaeus, 1758): the larva of *R. dubia* fixed on the outer surface of the bivalve and, with growth, made up the external crypt walls because of the lacking hard substrate. Scale bars: 10 mm.

large and thick substrates as for example big *O. edulis* specimens. The two boring bivalves perforate the calcareous substrate (mollusc shells in the Villalvernia samples) by chemical action; during the ontogeny, with the deepening and widening of the dwelling room, the space between the shell and the hole walls becomes larger and the animal produces an aragonitic deposit close-fitting the space. The features of this "lining" are diagnostic, given that *R. dubia* may extend beyond the bore aperture forming a protective tube for siphons (Savazzi 1982, 1999; Morton et al. 2011; Rahman et al. 2015; Fig. 15 a), whereas in *Lithophaga* sp. the internal deposit ends at the aperture (Figs. 16 b, d).

In *Rocellaria dubia* the bivalves may protect the body overflowing the host structure with a double-layered carbonate structure (crypt in Warme 1970; Savazzi 1982; flask-shaped structure in Belaústegui et al. 2013) formed by an internal aragonitic sleeve and an external agglutinated layer.

Different solutions are recorded (La Perna 2005):

- fully endolithic with the hole totally contained in the hard substratum; intrastereom clavate borings in Belaústegui et al. (2013) (Fig. 15 c);
- semi-endolithic with partial crypt overflowing the host shell; semi-endoskeletal dwelling in Belaústegui et al. (2013); intraskeleton clavate boring in Rahman et al. (2015) (Fig. 15 a, b);
- free tube-dwelling characterized by the whole crypt sunk in the soft substrate with animal in semi-infaunal position; full-body enveloping calcareous crypt in Belaústegui et al. (2018) (Fig. 15 d).

Lithophaga borings are concentrated in the sector where the shells of *O. edulis* are thicker and more compact, such as the umbonal area of the left, fixed valve. Borers tend to cluster and are arranged side by side with a roughly radiating orientation from the centre towards the edges of the valve (Fig. 16 e). There are also frequent interpenetrations of cavities related to distinct boring phases of colonization that affected the host; in these cases, the valves of the ostreids appear intensely bored and lack a considerable portion of the original shell (Fig. 16 c). According to the study of Simunovic & Grubelic (1992) the substrate being colonized must be "prepared" by the action of pioneering organisms such as the clionaid sponges that create the microcavities necessary for the implantation of the larvae of *Rocellaria* and, subsequently, of *Lithophaga*; the larvae of both these bivalves are rugophilic (Bien et al. 1999) and prefer rough surfaces that protect them by the action of grazers.

A further bivalve involved in the ichnofacies is the myid *Sphenia testarum* (Michelotti, 1839), the Pliocene ancestral of the extant *Sphenia binghami* (Turton, 1822). The species is known to live byssate in the shallow cavities with large and circular apertures resulting from the partial erosion of the distal part of holes left by *Lithophaga* and *Rocellaria*. *Sphenia* adjusts its shells to the holes, and this explains the morphological variability of the species. *S. testarum* is rare in the fossil assemblage of Bed 4 (Fig. 16 a).

In summary, the ichnogenus *Gastrochaenolites* includes bioerosional structures characterized by chambers from globose (bottle-like or clavate) to subcylindrical, narrow aperture showing a circular to oval or eight-shaped edge, internal surface smooth or ornated by oblique striae (Fig. 16 c) reflecting successive perforation stages.

Among the *Gastrochaenolites* taxa recorded by Kelly & Bromley (1984), two different ichnospecies are identified herein:

- *G. dijugus* Kelly & Bromley, 1984 (Figs. 6, 15, 16) - It is the most frequent taxon and is attributed to *R. dubia*. The globose-to-clavate chamber (up to 25 mm in length and 12-14 mm in width) ends into a long siphonal neck and opens with an eight-shaped edge due to the presence of two internal septa that subdivide the space for the siphons.
- *G. torpedo* Kelly & Bromley, 1984 (Fig. 16) - It is the bioerosional structure produced by the genus *Lithophaga*. The elongated chamber shows a parabolic bottom and ends in a short neck; the aperture is reduced by a couple of wedge-shaped elements (Fig. 16 d).

The specimens of *G. dijugus* and *G. torpedo* from Bed 4 are empty or still retain the shell structures in place (Figs. 15 a, b, Figs. 16 b, d) suggesting that they were buried with the borers still alive, in place. In a different case (Bed 2 in the lithostratigraphy section), a cluster of *G. torpedo* was found within a thick shell of *Ostrea edulis* with the holes full of silty sediment and the internal moulds diagenetically coherent (Fig. 16 e); these autochthonous fossils from Bed 2 reflect a low sedimentation rate connected with a discontinuity at the passage to the overlying Bed 3.

The previous descriptions of the sedimentological and palaeobiological features of Bed 4 suggest that a huge quantity of sediments and taphonomic elements was transferred through the shelf from the coastal environments to the infra- to circalittoral bottoms. The palaeoichnological results (1) clarify the environmental parameters under which those bioerosional structures were produced, and (2) contribute to underscore a Late Pliocene tectonic phase affecting this eastern sector of the TPB.

According to several authors (e.g., Bromley & d'Alessandro 1983; de Gibert & Martinell 1996, 1998; Rahman et al. 2015) the *Entobia-Gastrochaenolites* ichnofacies recurs in environments subjected to high energy with conspicuous presence of encrusting bivalves (mainly *Ostrea edulis*) pointing to shallow infralittoral bottoms. On the other hand, the time available for colonization was very long: Kleeman (1973) documented that the extant *Lithophaga lithophaga* grew up to 10 mm in five years on carbonate substrate and, even, Galinou-Mitsou-

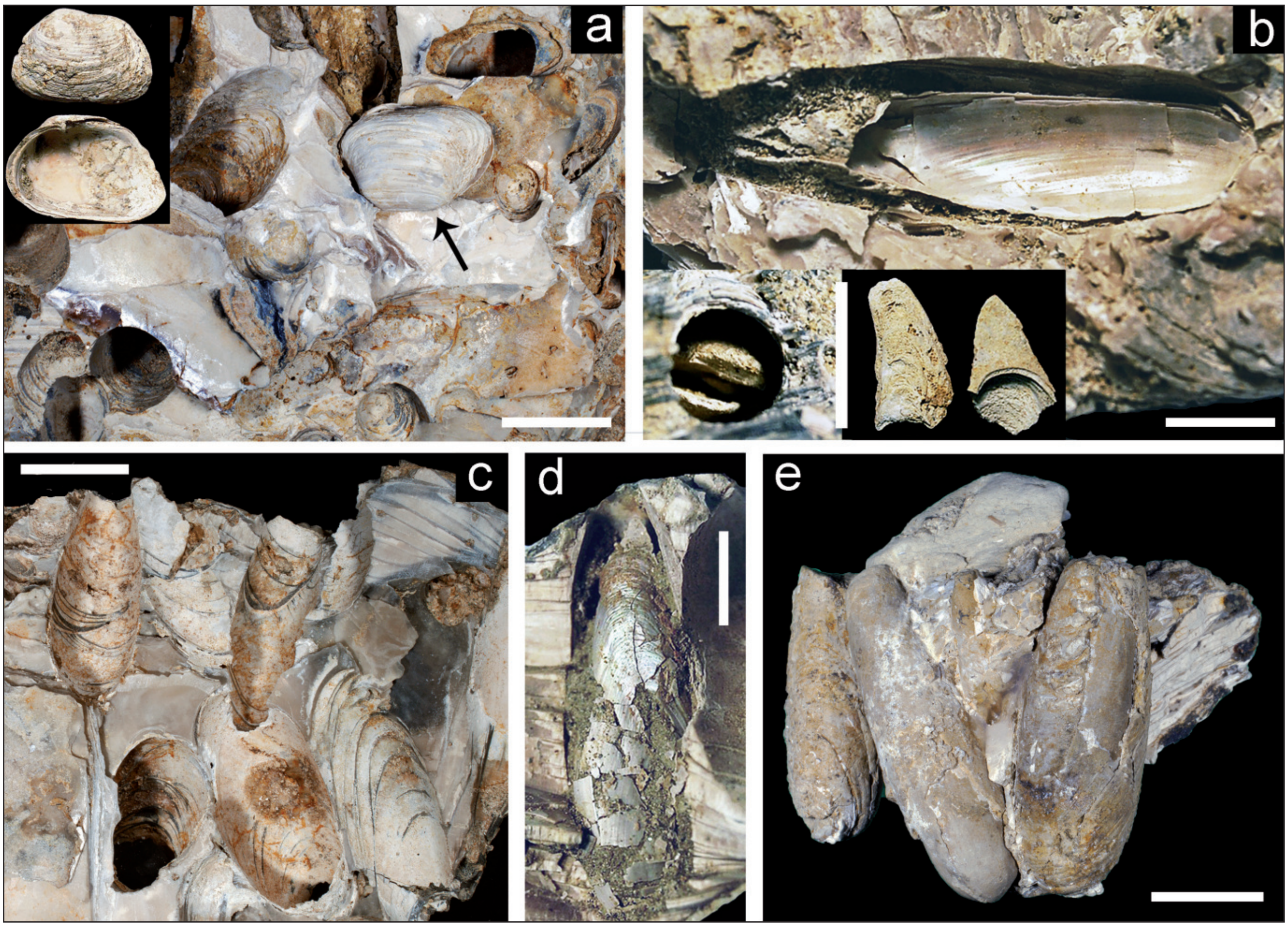

Fig. 16 - Bioerosional structures on *Ostrea edulis* Linnaeus, 1758, from Bed 2 (e) and Bed 4 (a-d) of the Rio Vaccaruzza section.
a) The opportunistic *Sphenia binghami* (Turton, 1822) occasionally in place (arrow) inside a structure of *Gastrochenolites dijugus* abandoned by the borer *R. dubia*; note the high boring rate on the shell. b) A bivalve specimen of *Lithophaga* sp. inside a structure of *G. torpedo* drilled in a *O. edulis* shell (the sample is rotate counterclockwise): note the wedge-shaped apertural elements in the small boxes, in place (left box) and isolated after extraction from the bore (central box). c) Cluster of empty *Gastrochaenolites torpedo* Kelly & Bromley, 1984. d) *Lithophaga* sp. preserved in life position. e) A cluster of internal moulds of *G. torpedo* at different growth stages (a fragment of the host *O. edulis* is visible on the right); the sediment at the top of the sample is the grey clay with silty fraction of Bed 2. Scale bars: 10 mm.

di & Sinis (1995) described a specimen of *L. lithophaga* 8.2 cm long with an age of about 54 years; this is consistent with a low sedimentation rate.

In conclusion, the bioerosional structures of Bed 4 suggest that the taphonomic production of the ichnofossils reflects a phase of reduced sedimentation rate and that a sedimentary slowdown occurred at the top Bed 2 just below the unconformity at the passage to Bed 3.

CONCLUDING REMARKS

The section on the right-side of the Rio Vaccaruzza shows a stratigraphic discontinuity at the boundary between the outer-shelf FAA (Bed 2) and the infralittoral AST (beds 3 to 9); the unconformity at the topmost Bed 2 is associated with a reduction of the sedimentation rate testified by *Gastrochenolithes torpedo* borings. The overlying beds 3 to 5 are interpreted as connected to catastrophic hyperpycnal flows (cf. Mutti et al. 1996; Crippa et al. 2017) that moved a high-density mass of sediments from the coastal environments towards the external part of the continental shelf and produced the allochthonous fossil assemblages of beds 3 to 5. The stratigraphic discontinuity and the overlying high-density transport can be regarded as episodes related to the tectonic instability of the Villalvernia sector in Late Pliocene time, which turns out to record regional tilting and related faulting processes (Festa et al. 2015). On the other hand, the inferred NW-striking fault system displacing the Rio Vaccaruzza succession on the left side of the stream is a further evidence of this activity.

The chronostratigraphic attribution of the Rio Vaccaruzza succession to the middle part of the Piacenzian, based on both the presence of *Globorotalia bononesis* and many molluscs representatives of the MPMU-1, is unusual for the Pliocene of the TPB where the basal AST is commonly restricted to the Zanclean Stage (Irace et al. 2017: 181). On the other hand, this age is consistent with the well-documented easternward rejuvenation of the bathyal to circalittoral formations of the Padane Basin (FAA to AST) from the Pliocene up to the Pleistocene.

The fossil record of *Posidonia* meadows in the Mediterranean Basin is quite limited and generally refers to allochthonous or mixed deposits. Conversely, the Villalvernia Bed 9 documents the autochthony of almost all its fossil components. The *Posidonia* rhizomes are also considered as autochthonous although not preserved in life position; these basal structures, according to their state of preservation, were only moved to a short distance from the living place of the phanerogams, sometime broken into bioclasts but frequently lying down intact without preferential orientation in a context characterized by a low hydrodynamic energy (waves and/or tidal currents), whereas the leaves were reduced to shreds and are therefore rare in the fossil assemblage. However, occasionally the increased environmental energy resulted in the formation of intermatte channels and the consequent reworking episodes are testified by the thin discontinuous lenses with coarser texture.

Clear evidences of autochthony in Bed 9 derive from the study of the brachiopods (mainly *Joania cordata*) that highlights the concomitant presence of different generations in a single volumetric sample of sediment. The same condition has been observed for many molluscs represented in the fossil assemblage by both juvenile and adult specimens of taxa that are presently known, or are interpreted as closely associated to *Posidonia* meadows, including *Archimediella subvaricosa*, many rissoids, *Crepidula bellardii*, *Aplus ansus*, *Mitrella villalvernensis*, *Conus dellabellai*, *Mitromorpha columbellaria*, *Antalis inaequicostata*.

Another palaeoecological aspect revealed by the study of the mollusc assemblage from Bed 9 is related to the function of nursery habitat of the *Posidonia* meadows, which is well known in the present days (see Hemminga & Duarte 2000; Relini 2008). Many vagile and temporary byssate taxa (e.g., *Haliotis tuberculata*, *Arca noae*, *Barbatia candida*, *Glycymeris bimaculata*, *G. glycymeris*, *Flexopecten inaequicostalis*, *Mimachlamys varia*, *Talochlamys multistriata*, *Cardites antiquatus*) are represented only by juvenile individuals; these specimens are in-situ elements, which developed on the *Posidonia* fronds or at the bottoms in-between up to the emergence of their adult habitus and functional autonomy.

Joania cordata dominates the brachiopod assemblage of Bed 9 in association with the less common *Argyrotheca cuneata*. They constitute an autochthonous record of a population that lived in the *Posidonia* meadow during the Late Pliocene.

About 150 fish otoliths have been discovered from the residues of the samples collected from beds 2, 3 and 9, among which 11 taxa have been recognized. Gobies consistently dominate the assemblages of these three beds. The composition of the fish assemblage of Bed 9 is fully consistent with the seagrass meadow palaeobiotope.

Molluscs comprise a remarkably high number of taxa, representing the most diverse assemblage known in the Pliocene of the TPB. The high taxonomic diversity of Bed 3 assemblage (362 taxa) is the consequence of the taphonomic mixing of entities pertaining to different infralittoral and circalittoral palaeobiocoenoses. In Bed 9 the 88.47 % of the 308 molluscs refers to the *Posidonia* meadows and to biocoenoses edaphically connected to it, such as the C and SGCF environments.

Finally, in this paper, 55 taxa (3 brachiopods, 46 gastropods, 6 bivalves) are documented for the first time in the Pliocene of the TPB (cf. asterisks in Appendix), including the new species of gastropods *Crepidula bellardii* n. sp., *Conus dellabellai* n. sp., *Conus villalvernensis* n. sp., *Odetta chirlii* n. sp., *Ondina curta* n. sp., *Ondina elongata* n. sp., *Ondina pseudovitrea* n. sp., *Anisocycla subcylindrica* n. sp.

Systematic Palaeontology

This section of the paper deals with the descriptions of the brachiopods and the most significant species among molluscs collected in the Rio Vaccaruzza outcrop. The fossils derived from digging, sieving and picking in beds 3 and 9, and the complementary specimens coming from different outcrops of the Piedmont Pliocene constitute the "Villalvernia Collection" that is stored within the collections of the Museo di Geologia e Paleontologia at the Dipartimento di Scienze della Terra of the Torino University with the acronym MGPT-PU. Two specimens of brachiopods are stored at the Hungarian Natural History Museum in Budapest.

TAXONOMY OF BRACHIOPODS FROM THE RIO VACCARUZZA BEDS 3 AND 9 (by A. Dulai)

Hundreds of small-sized (mostly micromorphic) brachiopods were selected from the residues of the Rio Vaccaruzza Bed 9, among which three species have been identified: ?*Terebratula* sp., *Argyrotheca cuneata* (Risso, 1826), and *Joania cordata* (Risso, 1826).

A single large terebratulid specimen from Bed 3 was provided by Bruno Dell'Angelo to the Hungarian Natural History Museum, Budapest. Since no additional terebratulids were known from this locality, this *Terebratula* specimen is briefly described below.

Abbreviations in the following description:
L: length; W: width; T = thickness.

Phylum **BRACHIOPODA** Duméril, 1805
Subphylum **RHYNCHONELLIFORMEA**
Williams, Carlson, Brunton, Holmer & Popov, 1996
Class **RHYNCHONELLATA** Williams, Carlson, Brunton, Holmer & Popov, 1996
Order **Terebratulida** Waagen, 1883
Suborder **Terebratulidina** Waagen, 1883
Superfamily Terebratuloidea Gray, 1840
Family Terebratulidae Gray, 1840
Subfamily Terebratulinae Gray, 1840
Genus *Terebratula* Müller, 1776

Type-species: *Anomia terebratula* Linnaeus, 1758

Terebratula calabra Seguenza, 1871

Fig. 17 a-c

1871 *Terebratula calabra* Seguenza, p. 138, pl. 5, fig. 5-8.
1985 *Terebratula calabra* Seguenza, 1871 - Gaetani & Saccà, p. 7, text-fig. 5, pl. 1, fig. 7-12 (cum syn.).
2018 *Terebratula* cf. *calabra* Seguenza - Giannetti et al., p. 24, fig. 6.11a-c.
2020 *Terebratula calabra* Seguenza, 1871 - García-Ramos, p. 22-25, text-fig. 1 (cum syn).

Diagnosis: Testa ovata ad frontem truncata. Valvis aequaliter convexis, acute unitis; valva dorsali subpentagona, obscure biplicata, medio depressionem longitudinalem inter plicas; valva majori plicis tribus obscurioribus; lineis incrementi tenuibus, numerosis, aliis paucis distinctissimis intermixtis, superficie signata; majori valva ad frontem incurvata, linea commissurale ad latera arcuata, ad frontem flexuosa. Apice prominente incurvato, foramine mediocre, deltidio lato concavo, plicis duobus obscuris, depressionem triangularem cingentibus. Brachyorum fulcro magis longo quam lato, lamellis lateralibus latis acuminatis, curviusculis. Musculosis signis adductorum in minori valva profunde impressis, parvis, ovato-elongatis, vix divergentibus, area lata disgiuntis (Seguenza, 1871: p. 138).

Type: No data are available from the literature.

Material: 1 articulate specimen from Bed 3 of the Rio Vaccaruzza succession (HNHM 2021.1.1).

Size: HNHM 2021.1.1: L = 43 mm, W = 38 mm, T = 24 mm.

Remarks. Large-sized terebratulids are common and conspicuous members of the Mediterranean Neogene brachiopod assemblages. Their identification is often problematic, due to the inadequate quality of original descriptions, missing type specimens, unknown type locality, and unknown internal morphological characteristics (Garcia-Ramos 2020). Some *Terebratula* species are in the focus of a long and seemingly never-ending nomenclatural debate (e.g., Lee & Brunton 1998; Lee et al. 2001; García-Ramos 2006, 2020; Taddei Ruggiero et al. 2008, 2019). Lee & Brunton (1998) and Lee et al. (2001) designated *T. terebratula* as the type of the genus and erected a neotype. They synonymized some species with *T. terebratula* (*T. sinuosa*, *T. calabra*, *T. costae*), but the validity of *T. ampulla* and *T. scillae* was confirmed. García-Ramos (2006) concluded that the anteriorly folded Pliocene specimens in Spain belong to *Terebratula calabra* and rejected its synonymy with *T. terebratula*. Later Taddei Ruggiero et al. (2008) compared four late Cenozoic *Terebratula* species from Italy (*T. ampulla*, *T. scillae*, *T. sinuosa* and *T. terebratula*) by a morphometric study and argued for the validity of *T. sinuosa*, further confirmed by Taddei Ruggiero et al. (2019). According to García-Ramos (2020) the terebratulids from the Pliocene of the Asti basin were attributed to *T. ampulla* by Sacco (1902) and his followers. However, García-Ramos (2020) showed that Brocchi (1814) did not consider the typical *T. ampulla* as a biplicate taxon, and instead these forms are consistent with the features of *T. calabra*.

The only available specimen from Rio Vaccaruzza is medium-sized, smooth and rounded subpentagonal in outline. The anterior commissure is sulciplicate, and the very shallow dorsal folds developed only at the anterior third. Following the opinion by García-Ramos (2006, 2020), this specimen is therefore assigned to *T. calabra*.

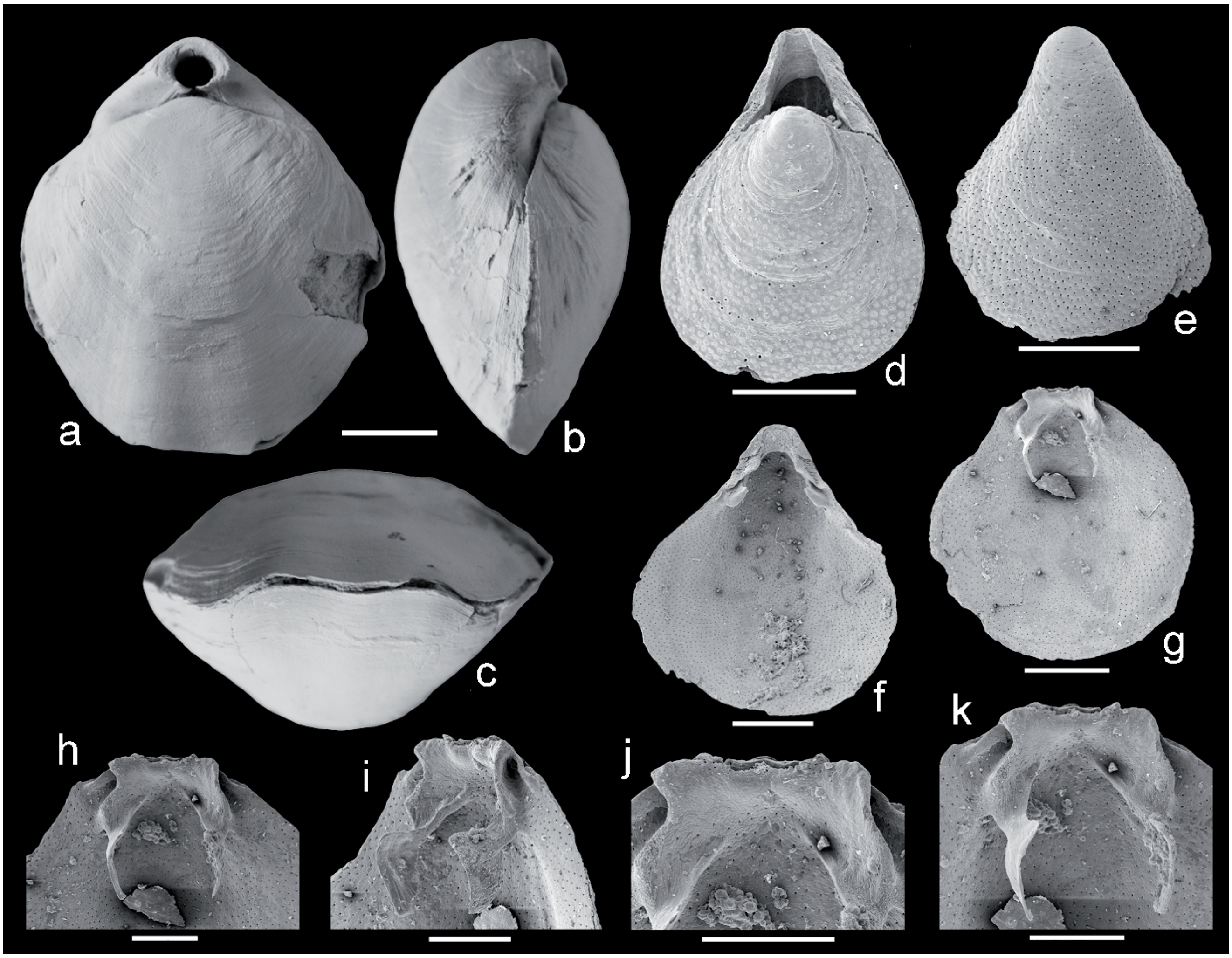

Fig. 17 - [a-c] *Terebratula calabra* Seguenza, 1871, articulated specimen, Rio Vaccaruzza, Bed 3, HNHM 2021.1.1: (a) dorsal, (b) lateral and (c) anterior views. [d-k] ?*Terebratula* sp., Rio Vaccaruzza, Bed 9. (d) articulated specimen HNHM 2021.1.2., dorsal view. (e) Articulated specimen MGPT-PU 143169, ventral view. [f-k] Separated valves of the articulated specimen MGPT-PU 143170: (f) ventral valve, internal view; (g) dorsal valve, internal view; (h-k) details of the posterior part of the dorsal valve, internal and oblique internal views. Scale bars: a-c = 10 mm; d-k = 1.00 mm.

Distribution. *Terebratula calabra* is common in the Pliocene of the Mediterranean (Italy, Spain), but careful revision of several literature data is necessary (see García-Ramos 2020).

?***Terebratula*** sp.

Fig. 17 d-k

Material: 8 articulated specimens from Bed 9 of the Rio Vaccaruzza succession (HNHM 2021.1.2, Fig. 17 d; MGPT-PU 143169, Fig. 17 e; MGPT-PU 143170, Fig. 17 f-g; MGPT-PU 143171).

Size: The largest specimen HNHM 2021.1.2 measures: L = 2.8 mm, W = 2.1 mm.

Description. The shells show a rounded subtrigonal outline and large triangular foramen. Pedicle collar is relatively large, longer than wide. Both valves are smooth with some weak growth lines and densely punctate. Anterior and lateral commissures are straight. The small teeth of the ventral valve are obliquely inserted in narrow and deep sockets. The small initial cardinal process can be seen. Outer socket ridges are short, low, and slightly oblique; inner socket ridges are stronger and more oblique.

Remarks. The prepared residue of Bed 9 contained some very small, juvenile terebratulid specimens, which can be tentatively identified as juveniles of ?*Terebratula*.

Terebratula is an extinct genus, which is rather common in the Neogene and Pleistocene marine deposits of the Mediterranean, as well as in the Miocene of the Central Paratethys. Accordingly, it has abundant records in the palaeontological literature; however, in nearly all cases only the large-sized adult specimens are illustrated and discussed, therefore no comparative materials for juvenile *Terebratula* specimens are available. Bitner et al. (2013) illustrated a single juvenile *Terebratula* sp. from the Middle Miocene of Kralice (Czech Republic); its preservation is not very good, but the external morphology is comparable with the Villalvernia specimens that have slightly larger ventral beak and foramen.

Suborder **Terebratellidina** Muir-Wood, 1955
Superfamily Megathyridoidea Dall, 1870
Family Megathyrididae Dall, 1870
Genus *Argyrotheca* Dall, 1900

Type-species: *Terebratula cuneata* Risso, 1826

Argyrotheca cuneata (Risso, 1826)

Fig. 18 a-d

1826 *Terebratula cuneata* Risso, p. 388.

1990 *Argyrotheca cuneata* (Risso, 1826) - Bitner, p. 138-140, text-fig. 5-6, pl. 4, fig.1. (cum syn.).

2016 *Argyrotheca cuneata* (Risso, 1826) - Bitner & Motchurova-Dekova, p. 12, fig. 4A-R (cum syn.).

2016 *Argyrotheca cuneata* (Risso, 1826) - Alvarez, p. 72-74, pl. 33II, NN, 34V-GG, 35A-G (cum syn.).

Diagnosis: Testa glabra, rotundata, superne truncata; valvis ambabus costis latis, depressis, divaricantibus, longitudinaliter striatis sculptis; lateribus rotundatis; epidermide lutescente, radiis ruberrimis (Risso, 1826: 388).

Type: Risso's type specimens are missing (Logan 1977; Emig 2012). No further data are available from the literature.

Material: Three articulated specimens from Bed 9 of the Rio Vaccaruzza succession (MGPT-PU 143172-143174).

Size: MGPT-PU 143172 (Fig. 18 a): L = 2.5 mm, W = 3.2 mm; MGPT-PU 143173 (Fig. 18 b-d): L = 2.6 mm, W = 3.4 mm.

Remarks. The brachiopod assemblage of the Rio Vaccaruzza is dominated by megathyridid specimens, although *A. cuneata* is extremely rare compared to *J. cordata*. Several *Joania-Argyrotheca* assemblages were published from the Middle Miocene of the Central Paratethys that contain only or mainly *Joania cordata* and *Argyrotheca cuneata* (see discussion above), but the ratio of these two species can be very variable.

A. cuneata can be easily distinguished from *J. cordata*: it is wider than long, the shell surface is ornamented by some stronger ribs, and the internal side of both valves are without the anterior tubercles' characteristic for species of *Joania*.

Distribution. *A. cuneata* is known from Late Oligocene (Dulai 2010; Bitner et al. 2013) and it was common in Neogene of the Mediterranean and the Central Paratethys (Bitner 1990). In modern seas, it lives in the Mediterranean and the North Atlantic Ocean (Logan 2007).

Genus *Joania* Alvarez, Brunton & Long, 2008

Type-species: *Terebratula cordata* Risso, 1826.

Joania cordata (Risso, 1826)

Fig. 18 e-n

1826 *Terebratula cordata* Risso, p. 389.

1990 *Argyrotheca cordata* (Risso, 1826) - Bitner, p. 140-143, text-fig. 7-8, pl. 5. fig. 1-14, pl. 7, fig. 1 (cum syn.).

2008 *Joania cordata* (Risso) - Alvarez et al., p. 400-402, fig. 4C-D, 5A-F, 11-13.

2016 *Joania cordata* (Risso, 1826) - Alvarez et al., p. 74-76, pl. 35H-FF, 36A-Z (cum syn.).

Diagnosis: Testa glaberrima, cordata, lucida; valvis ambabus punctulis albis impressis sculptis; epidermide fulvescente pellucida (Risso, 1826: 389).

Type: Risso's type specimens are missing (Logan 1977; Emig 2012). No further datum is available from the literature.

Material: 747 articulated specimens, 54 dorsal valves, 44 ventral valves from Bed 9 of the Rio Vaccaruzza succession (MGPT-PU 143175-143180).

Size: MGPT-PU 143175 (Fig. 18 e): L = 2.2 mm, W = 2.3 mm; MGPT-PU 143176 (Fig. 18 f, g): L = 3.1 mm, W = 2.8 mm; MGPT-PU 143177 (Fig. 18 h): L = 3.2 mm, W = 3.0 mm; MGPT-PU 143178 (Fig. 18 i, j): L = 1.6 mm, W = 1.5 mm; MGPT-PU 143179 (Fig. 18 k-n): L = 3.6 mm, W = 3.6 mm.

Remarks. Shallow-water brachiopod assemblages are dominated by micromorphic megathyridid species (*Megathiris*, *Argyrotheca*, *Joania*) both in the Neogene Mediterranean and Central Paratethyan assemblages (e.g., Bitner 1990, 1993; Bitner & Pisera 2000; Bitner & Kaim 2004; Dulai 2007) and the Recent Mediterranean Sea (Logan 1979; Logan et al. 2004). The genus *Joania* was erected by Alvarez et al. (2008) for those *Argyrotheca* that differ in their adult crural development, characteristic dorsal median septum and tuberculate radial ridges which terminate in tubercles at the anterior margin.

A wide variability of outline and ornamentation can be observed. Most of the specimens are slightly elongated, some of them rounded, others slightly squared. Sometimes the anterior outline is slightly wavy. The surface of the valves is smooth or ornamented by a few weak, rounded ribs.

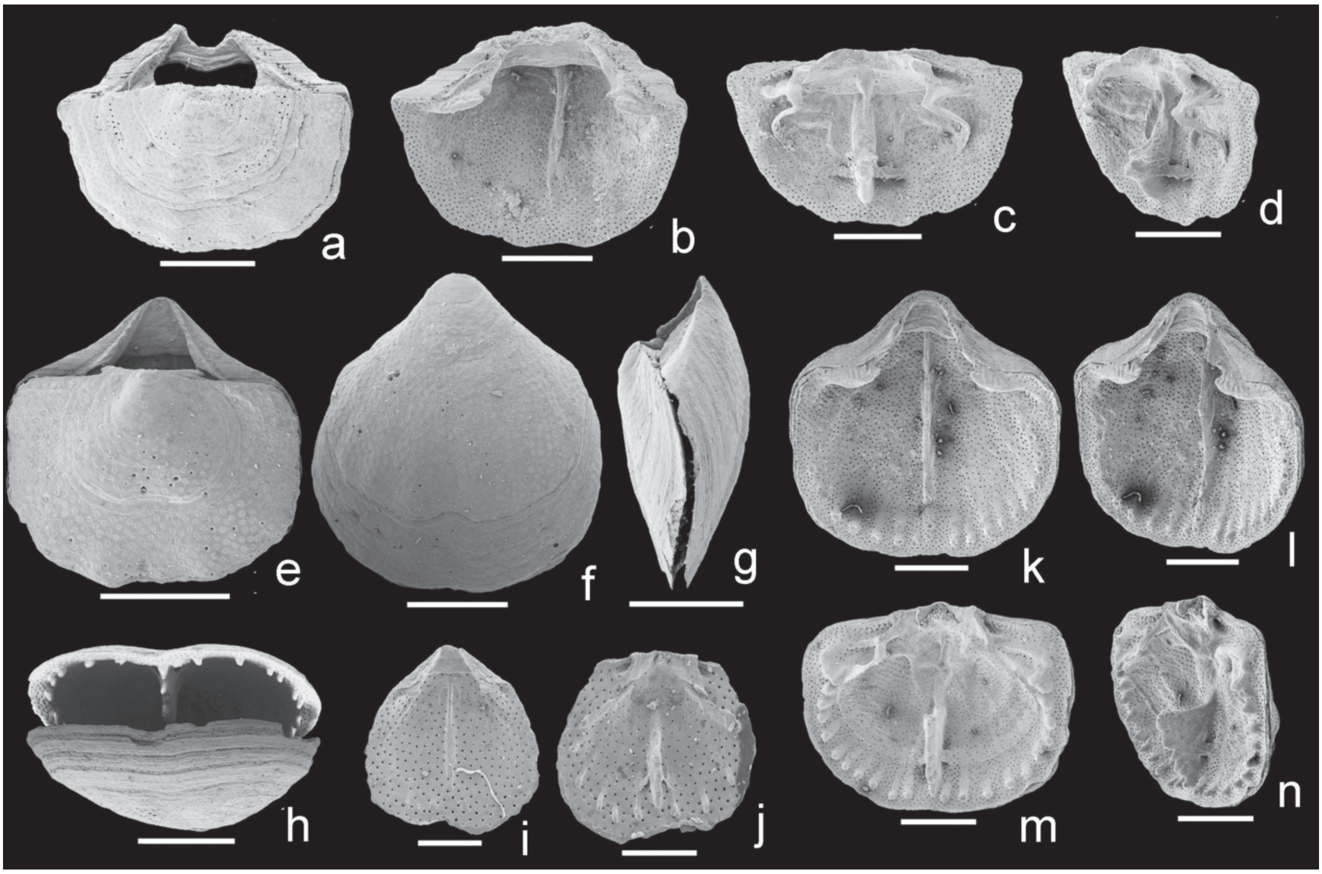

Fig. 18 - [a-d] *Argyrotheca cuneata* (Risso, 1826), Rio Vaccaruzza, Bed 9: (a) articulated specimen MGPT-PU 143172, dorsal view; (b-d) separated valves of the articulated specimen MGPT-PU 143173 with (b) ventral valve, internal view, (c-d) dorsal valve, internal and oblique internal views. [e-n] *Joania cordata* (Risso, 1826), Rio Vaccaruzza, Bed 9: (e) articulated specimen MGPT-PU 143175, dorsal view; (f, g) articulated specimen MGPT-PU 143176, ventral and lateral views; (h) opened articulated specimen, MGPT-PU 143177, anterior view; (i-j) separated valves of the articulated specimen MGPT-PU 143178 with (i) ventral valve, internal view, (j) dorsal valve, internal view; (k-n) separated valves of the articulated specimen MGPT-PU 143179 with (k, l) ventral valve, internal and oblique internal views, (m, n) dorsal valve, internal and oblique internal views. Scale bars: 1.00 mm.

Distribution. *J. cordata* is known from the Late Oligocene (Dulai 2010; Bitner et al. 2013) and it was very common in the Neogene of the Mediterranean and the Central Paratethys (Bitner 1990). Recently it occurs in the Mediterranean Sea, Red Sea and eastern North Atlantic (Logan 2007; Logan et al. 2008).

TAXONOMY OF SELECTED MOLLUSCS FROM THE RIO VACCARUZZA BEDS 3 AND 9 (By G. Pavia)

The following 29 taxonomic descriptions concern both the eight new species of gastropods, and the taxa that are recorded for the first time in the Pliocene of the TPB or result to be better defined by the Villalvernia material.

Phylum **MOLLUSCA** Cuvier, 1797
Class **GASTROPODA** Cuvier, 1797
Subclass **PROSOBRANCHIA** Milne-Edwards, 1846
Family Trochidae Rafinesque, 1815
Genus *Calliostoma* Swainson, 1840

Type-species: *Trochus zizyphinus* Linnaeus, 1758

Calliostoma cf. *gualterianum* (Philippi in Martini & Chemnitz, 1848)

Fig. 19 a-e, Fig. 20 a, b

cf. 1848 *Trochus Gualterianus* Philippi in Martini & Chemnitz, p. 69, pl. 11, fig. 15.
cf. 2004 *Calliostoma gualterianum* (Philippi, 1848) - Gofas in World Register of Marine Species.
cf. 2005 *Calliostoma gualterianum* (Philippi) - Repetto et al., p. 87, fig. 113.

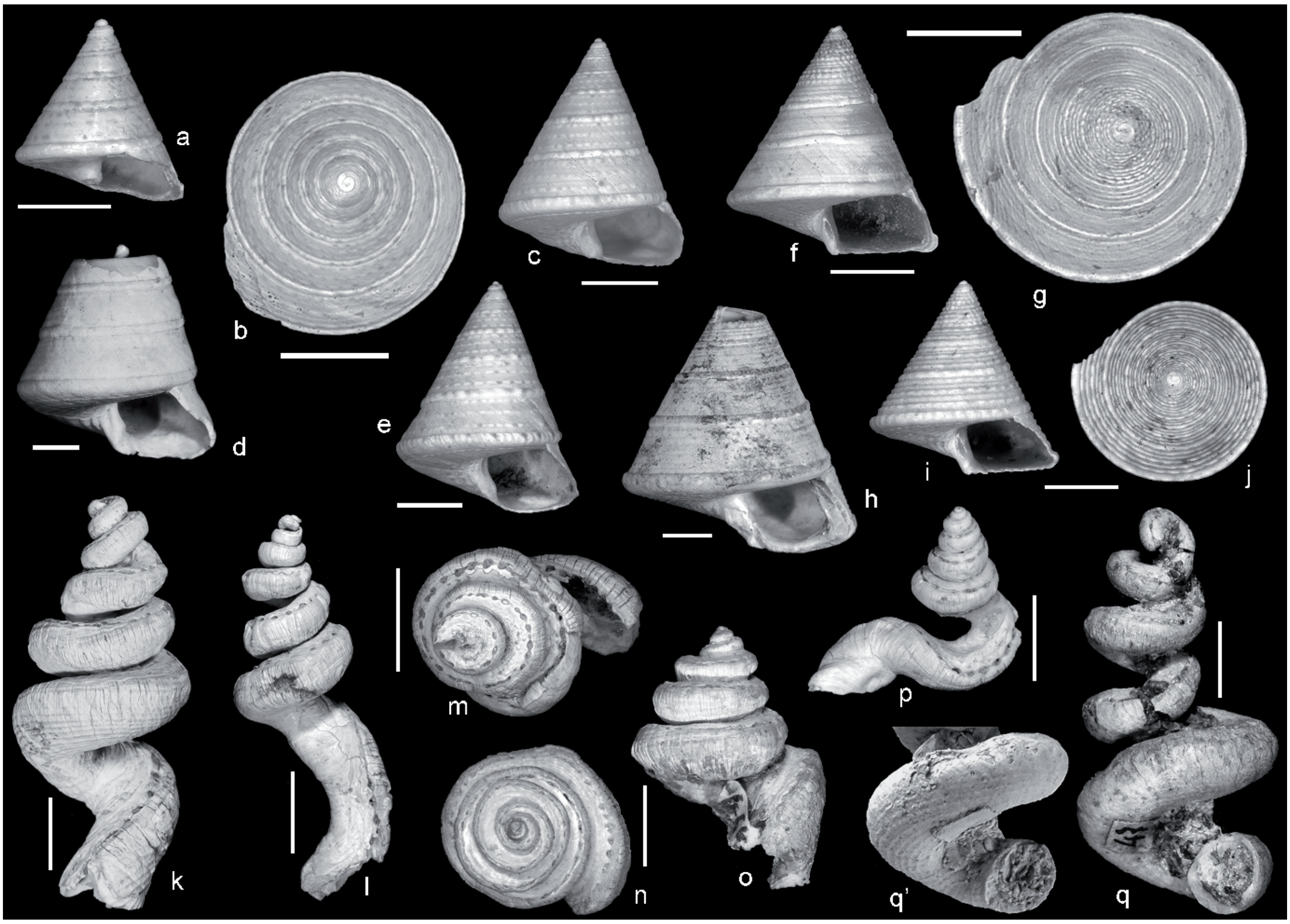

Fig. 19 - [a-e] *Calliostoma* cf. *gualterianum* (Philippi, 1848): (a) MGPT-PU 143181, Rio Vaccaruzza, Bed 9; (b, c) MGPT-PU 143182, Cascina Fiora; (d) MGPT-PU 143183, Rio Vaccaruzza, Bed 9; (e) MGPT-PU 143184, Cascina Fiora. [f-j] *Calliostoma conulus* (Linnaeus, 1758): (f, g) MGPT-PU 143185, Cascina Fiora; (h) MGPT-PU 143186, Rio Vaccaruzza, Bed 9; (i, j) MGPT-PU 143187, Cascina Fiora. [k-p] *Tenagodus ligusticus* (Della Campana, 1890): (k) MGPT-PU 143188, Rio Vaccaruzza, Bed 3; (l) MGPT-PU 143189, Rio Vaccaruzza, Bed 3; (m) MGPT-PU 143190, Rio Vaccaruzza, Bed 3; (n, o) BS.065.01.011, Sant'Agata Fossili (Tortonian); (p) MGPT-PU 143191, San Damiano (Lower Pliocene). [q] *Tenagodus miovermiculatus* (Sacco, 1896), lectotype, BS.065.01.013, Colli Torinesi (Lower Miocene). The image q' shows the last whorl of the lectotype q coated with ammonium chloride to highlight the feeble longitudinal ribbing. Scale bars: 2.50 mm (horizontal) and 5.00 mm (vertical).

Material: 32 specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 110752, MGPT-PU 143181, MGPT-PU 143183). Additional specimens were studied from the Early Pliocene of Monale (Asti) in the locality "Cascina Fiora" (Pavia 1980; see also "le Grottine" in Pedriali & Robba 2005) (MGPT-PU 143182, MGPT-PU 143184, MGPT-PU 110471).

Size: The specimens are mostly juvenile. The biggest one from the Rio Vaccaruzza Bed 9 (MGPT-PU 143183: Fig. 19 d) measures H = ~15.0 mm, W = 10.5 mm, W/H = 0.70; a further specimen (MGPT-PU 143181: Fig. 19 a) has: H = 4.8 mm, W = 4.0 mm, W/H = 0.83. Two specimens from Cascina Fiora measure: H = 9.8 mm, W = 7.0 mm, W/H = 0.71 (MGPT-PU 143182: Fig. 19 b, c) and H = 9.5 mm, W = 7.0 mm, W/H = 0.74 (MGPT-PU 143184: Fig. 19 e).

Description. Conical shell with slightly rounded base, becoming taller with growth (W/H, 0.83 to 0.70). The protoconch is paucispiral (lecitotrophic) with one whorl and a third ornated by a thin hexagonal net (Fig. 20 b). The first 1.5-2 whorls of the teleoconch show slightly oblique and spiral ribs that produces a grid simulating a granulated ornamentation: three spiral ribs, 15 radial ribs in the 1st whorl and 26 in the 2nd whorl. Ornamentation becomes progressively weaker from the middle of the 2nd whorl; the following whorls are nearly smooth with evanescent spiral grooves that occasionally produce weak, discontinuous ribbing. Starting from the beginning of the teleoconch a large abapical cord runs at the side margin and determines the angular shape of the shell; it is granulated by the radial ribs. The base is slightly convex with eight to nine furrows more engraved near the columella. The aperture is rhomboidal with a blunt tooth on the concave columellar edge.

Remarks. The specimens from the Rio Vaccaruzza and Cascina Fiora localities show morphological parameters that recall those of *C. gualterianum*

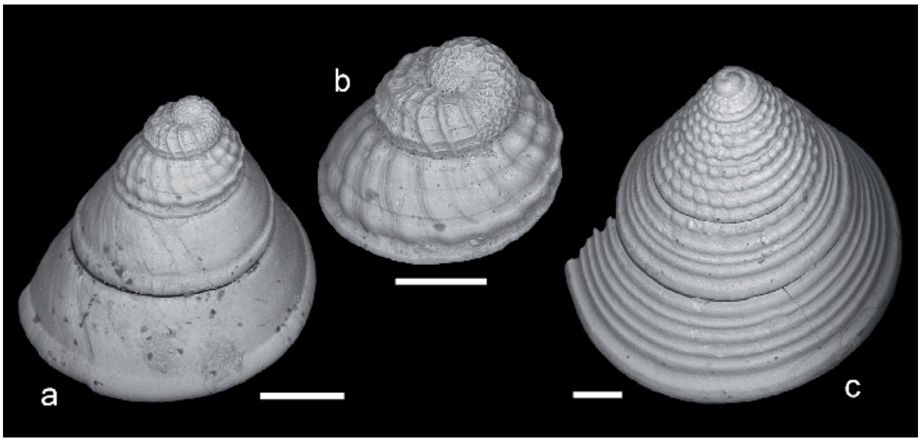

Fig. 20 - [a, b] *Calliostoma* cf. *gualterianum* (Philippi, 1848), MGPT-PU 110471, Rio Vaccaruzza, Bed 9, SEM. [c] *Calliostoma conulus* (Linnaeus, 1758), MGPT-PU 110472, Cascina Fiora, SEM. Scale bars: 0.50 mm.

(Philippi): in this sense, the absence or evanescence of the spiral ornamentation on the teleoconch (Philippi's "testa laevigata") is particularly significative. However, two aspects hinder their assignment to *C. gualterinianum*: (1) the well-marked abapical cord (vs Philippi's "cingulo suturali nullo") and (2) the reticulate ornamentation on the first two whorls of the teleoconch. Nevertheless, with regard to point 2, nothing rules out the possibility that Philippi's assertion "apice haud granulata" meant absence of any kind of granulation towards the upper part of the shell but leave open the possibility that it is present in the first and the second whorl of the teleoconch.

The abapical cord of the described specimens is similar to that of *C. laugeri* (Payraudeau, 1826) that differs for the depressed shape of the shell and the persistence of the granulated stage towards abapical whorls (Giannuzzi-Savelli et al. 1994: 80). A similar extension of the granulated stage (spiral beading) to the 5th whorl characterizes the fossils described as *C. gualterianum* by Landau et al. (2003) from the Pliocene of Estepona, Spain; they likely represent a different taxon comparable to some extant specimens of *C. laugeri* (Payraudeau) figured by Giannuzzi-Savelli et al. (1994: 80).

In conclusion, given these doubts and taking into account Gofas' opinion ("*C. gualterianum* is a bit a mystery, … I fail to recognize a second species in the *C. laugeri* group": pers. comm.), any formal decision cannot be reached at present, and the taxonomic definition of these fossils from Rio Vaccaruzza and Cascina Fiora remains uncertain.

The described specimens show variability in the spiral ribbing up to specimens that might be confused with the coexisting *C. conulus* (Linnaeus, 1758). The latter taxon (Fig. 19 f-j) differs by having squat shells with a flat base (W/H = 0.85-0.95 vs 0.70-0.80), depressed protoconch of one single whorl (Fig. 20 c), a longer granulated juvenile stage (at least four whorls) and more frequent spiral ribs.

Distribution and habitat. In general, all records of *C. gualterinianum* need revision. The oldest record of the species is from the Early Pliocene of the westernmost Mediterranean area (Landau et al. 2003). In the central Mediterranean fossils of *C. gualterinianum* are listed only from the Italian Pleistocene (Malatesta 1960; Ruggeri & Buccheri 1968). Extant specimens are documented all around the Mediterranean (Giannuzzi-Savelli et al. 1994).

Landau et al. (2003) referred this taxon to the AP and HP biocoenoses.

Family Siliquariidae Anton, 1838
Genus *Tenagodus* Guettard, 1770

Type-species: *Serpularia anguina* Linnaeus, 1758

Tenagodus ligusticus (Della Campana, 1890)

Fig. 19 k-p

1890 *Monfortia ligustica* Della Campana, p. 140 (13), pl. 4, fig. 9.
1895 *Monfortia ligustica* Della Campana - Arduini, p. 35.
v 1896 *Tenagodus anguinus* ? var. *ligustica* Della Campana - Sacco 1890-1904, p. 18, pl. 2, fig. 17, 17 b', 17 b".

Diagnosis: Testa tereti, spiraliter involuta, transversim striata, longitudinaliter costulata, fissura foraminibus ellipticis subcontiguis composita (Della Campana, 1890: 140).

Type: Della Campana (1890) based his new taxon on specimens collected from the outcrops of Borzoli (Genova) that have been recently sampled by Brunetti & Sosso (2016). The author mentioned other Ligurian localities such as the marl outcrops around Savona, but he figured a single specimen that could be indicated as the lectotype of *T. ligusticus*. Unfortunately, Della Campana's collection appears to be lost in the Museo Civico di Storia Naturale "Giacomo Doria" of Genova (M. Sosso, pers. comm.). Thus, the species needs a neotype that may derive from the Borzoli outcrops (Brunetti & Sosso

2016) or from the Savona area, or exceptionally from the well-known outcrops of Rio Torsero and Caranchi (Albenga).

Material: Three specimens (MGPT-PU 143188-143190: Fig. 19 k-m) from Bed 3 of the Rio Vaccaruzza section. One isolated specimen and one cluster from the site described by Brambilla (1976) (MGPT-PU 110398). An additional specimen comes from a Lower Pliocene site near San Damiano d'Asti (Pino 2012) (MGPT-PU 143191: Fig. 19 p).

Size: Measures are detectable only for H: extremes 12.4 - 28.1 mm.

Description. Pseudo-turriculate, medium-sized shell with irregular growth and whorls not in contact, except in the initial growth-stage. Protoconch with 2.5-2.7 whorls arranged in a spiral structure that shows a planktotrophic growth: the protoconch 1 is 0.5-0.7 whorl and usually absent due to its fragility; the protoconch 2 consists of two whorls ornated by rows of evanescent pustules and closed by an irregular scar. The teleoconch consists of four or five turriculate whorls followed by a twisted stretch concluding with the circular aperture. A relatively large slit goes along the whole teleoconch in an adapical position at the passage to the whorl flank: it consists of a sequence of "holes" that derive from the presence of irregularly large denticles occluding the slit; denticles do not constitute a continuous bridge, but are just in contact at the centre of the slit. The "holes" are closed by calcareous deposits in the youngest spires. The external side of the whorls is covered by dense radial cracks; feeble spiral sculptures are evident on the final shell stretch.

Remarks. Della Campana (1890) described the taxon as the type-species of his new genus *Montfortia*. Its separated status from *Tenagodus* (accepted synonym of *Siliquaria* Brugnone, 1789, type-species *S. anguina* L. 1758) is based on the shape of the slit denticles, described as absent in *Tenagodus* and continuous both in *Montfortia* and in *Agathirses* Montfort, 1808 (type-species *A. furcellus*). The revision of the genus *Tenagodus* by Schiaparelli (2002) expanded the generic variability that includes both *Agathirses* and *Montfortia* as junior synonyms. The allocation of the taxon *ligusticus* within the genus *Tenagodus* was confirmed by Bieler & Petit (2011: 44).

The differences between *T. ligusticus* and the coexisting *T. obtusus*, at Villalvernia present only in Bed 9, apart from elements not registered such as the operculum and radula, are based on the incomparable dimensions and the morphology of both shell and slit: *T. obtusus* has a larger shell with a flat juvenile stage, an almost regularly spiral middle teleoconch and the absence of clearly defined denticles on both sides of the slit that appear just undulated.

Sacco (1896 in 1890-1904: 19, pl. 2, figs. 18-18c) described the new taxon "*Tenagodes anguinus* var *miovermiculata*" from the Lower Miocene of the Torino Hills, which is closely similar to *T. ligusticus* in size and coiling, but differs for the lower growth rate of the spire and the spaced and narrow slit with small denticles; it is regarded herein as the separated species *Tenagodus miovermiculatus* (Sacco, 1896) with the specimen BS.065.01.013 (Sacco 1896, pl. 2, fig. 18) selected as the lectotype (Fig. 19 q).

Distribution and habitat. *Tenagodes ligusticus* is so far known from the Tortonian layers of the classic locality of Sant'Agata Fossili (BS.065.01.011, Fig. 19 n, o), the Lower Pliocene of Liguria and Piedmont and the Upper Pliocene of the Villalvernia area.

Like the extant *T. obtusus* that lives in Mediterranean in commensalism with the sponge *Holoxea furtiva* Topsent, 1892 (Schiaparelli 2002), a similar mutual relationship may be inferred for *T. ligusticus* with an undefined desmosponge possibly of the family Ancorinidae. This is shown by the cluster of *T. ligusticus* found in Bed 3.

Family Rissoidae Gray ,1847
Genus *Pusillina* Monterosato, 1884

Type-species: *Rissoa pusilla* Philippi, 1836

Pusillina* cf. *nilae Bogi & Chirli, 2004

Fig. 21 e-g

1994 *Pusillina* (*Pusillina*) sp. - Bernasconi & Robba, p. 74, fig. 1, 2.
2004 *Pusillina nilae* Bogi & Chirli, p. 88, fig. 1 d-h.
2011 *Pusillina nilae* Bogi & Chirli - Tabanelli et al., p. 53, fig. 42.

Material: Eight specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 110786, MGPT-PU 143195-143196).

Size: The figured specimen measures: H = 2.5 mm, W = 1.2 mm, W/H = 0.48 (MGPT-PU 143195: Fig. 21 e, g); H = 1.7 mm, W = 0.9 mm, W/H = 0.53 (MGPT-PU 143196: Fig. 21 f).

Remarks. The sample of Rio Vaccaruzza fits both the series-type of *P. nilae* and the specimens described by Tabanelli et al. (2011) in the relatively large planktotrophic protoconch with 2.5 smooth whorls and planar, sinuous scar, the convex whorls separated by sunken sutures, and the absence of ornaments. However, the specimens documented

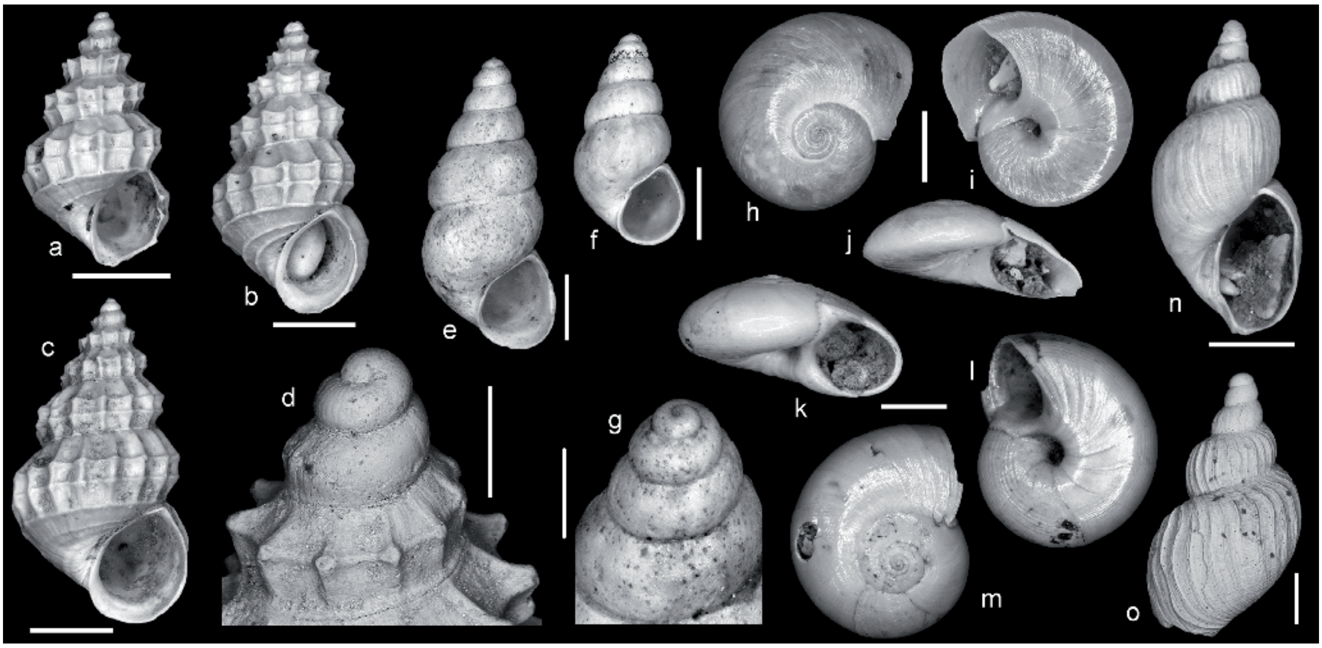

Fig. 21 - [a-d] *Alvania bonellii* Palazzi, 1996, Rio Vaccaruzza, Bed 9: (a) MGPT-PU 143192; (b) MGPT-PU 143193; (c) MGPT-PU 143194; (d) MGPT-PU 143050, SEM. [e-g] *Pusillina* cf. *nilae* Bogi & Chirli, 2004, Rio Vaccaruzza, Bed 9: (e, g) MGPT-PU 143195; (f) MGPT-PU 143196. [h-j] *Teinostoma minutum* (Conti, 1864), MGPT-PU 143197, Rio Vaccaruzza, Bed 3. [k-m] *Teinostoma woodi* (Hoernes, 1856), MGPT-PU 143198, Rio Vaccaruzza, Bed 3. [n-o] *Cymenoritis dellabellai* Sosso et al., 2013, Rio Vaccaruzza, Bed 3, topotypes: (n) MGPT-PU 143205; (o) MGPT-PU 143206, SEM. Scale bars: 0.50 mm (horizontal) and 0.25 mm (vertical).

herein are distinctive by having (1) constancy of the spire angle from the apex to the mouth and consequently a regular spiral growth instead of the coeloconoid shape of the type-series, (2) tighter shells with W/H = 0.40 - 0.48 versus W/H = 0.48 - 0.55 of the type-series, (3) slightly open umbilicus and expanded external lip.

These differences could be regarded as indicative of a placement in a different taxon. Nevertheless, both the measurements reported by Bogi & Chirli (2004) and by Tabanelli et al. (2011) indicated a wide range of the W/H ratio; in this respect, the Rio Vaccaruzza sample can be seen as a morphotype characterized by slender shells within the morphological variability of the species. Nevertheless, for the time being, we prefer to limit the taxonomic definition with a "confer".

Distribution. According to the cited literature, *Pusillina nilae* is known from the Pliocene of Tuscany, Emilia Romagna, Liguria and now Piedmont.

Genus *Alvania* Risso, 1826

Type-species: *Alvania europea* Risso, 1826

Alvania bonellii Palazzi, 1996

Fig. 21 a-d

1827 *Alvania carinata* Bonelli 1824-30, n. 3058 *(*nomen nudum*)*.
1842 *Alvania carinata* Bonelli - Sismonda, p. 30.
1847 *Rissoa Bonellii* Sismonda, p. 53 *(*nomen nudum*)*.
1852 *Rissoa Bonellii* Sismonda - d'Orbigny, p. 166.
1889 *Rissoa Bonellii* Sismonda - Sacco, n. 1986.
v 1895 *Alvinia dictyophora* var. *carinata* (Bon.) - Sacco 1890-1904, p. 29, pl. 1, fig. 71.
v 1984 *Alvinia dictyophora* var. *carinata* Sacco - Ferrero Mortara et al., p. 217, pl. 39, fig. 4-5.
1996 *Alvania bonellii* (Sismonda in Sacco, 1895) - Palazzi, p. 200.
2006 *Alvania dictyophora* var. *carinata* (Sacco, 1895) - Chirli, p. 26.
2012 *Alvania dictyophora* var. *carinata* Sacco, 1895 - Brunetti & Vecchi, p. 44.

Nomenclature: The name to be used for this taxon was discussed by Palazzi (1996) who noted that (1) the binomen used by Bonelli in his unpublished catalogue (*Alvania carinata*) is a nomen nudum that needs to be substituted, (2) the name *A. carinata* Bonelli, 1827 is a secondary homonym preoccupied by *A. carinata* (da Costa, 1778), and (3) for this reason Sismonda (1847) renewed the name as *Rissoa Bonellii* that was accepted by d'Orbigny (1852) and Sacco (1889). Nevertheless, also both the catalogues of Sismonda (1842, 1847) do not fit the ICZN rules and, again, the new name *Bonellii* is a nomen nudum. Therefore, any proposal to maintain the authorship to Sismonda is inconsistent as the ICZN rules state that "a nomen nudum is not an available name …. the same name may be made available later for the same or a different concept; in such case it would take authorship and date from that act of establishment, not from any earlier publication as a nomen nudum". Palazzi

(1996) proposed to title the binomen to Sismonda as it was validated by Sacco in 1889 and confirmed in 1895; this is incongruent because the paper by Sacco (1889) also represents a catalogue without formal elements required to set up a new taxon (ICZN, art 11, 12). On the other hand, if the paper by Sacco (1895) would be the first ICZN correct document to define the taxon, it should not be used because it refers to a different binomen (var. *carinata*) that is invalid due to the mentioned homonymy problems.

This species is so recurring in literature to need a definitive, formal adjustment. On the other hand, the term *bonellii* is available and may be used for "the same or a different concept". Our conclusion is thus to assign the taxon paternity to Palazzi in compliance with ICZN rules concerning priority law, notes and references: *Alvania bonellii* Palazzi, 1996.

Diagnosis: Testa major, basi depressior. Cingula elatiora et cristatiora (Sacco, 1895 in 1890-1904: 29, in comparison with *A. dictyophora*).

Type: The specimen figured by Sacco (1895 in 1890-1904, pl. 1, fig. 71) and by Ferrero Mortara et al. (1984, pl. 9, fig. 4) is the lectotype of *A. bonellii* with the registration number BS.053.14.001 in the BS collection.

Material: 73 specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 110789, MGPT-PU 143192-143194, MGPT-PU 143050). Four additional specimens from the Fontanili site. Further specimens were studied from the Early Pliocene of Monale (Asti) in the locality "Cascina Fiora" (Pavia 1980; see also "le Grottine" in Pedriali & Robba 2005).

Size: Selected adult specimens from Bed 9 measure: H = 3.8 mm, W = 2.0 mm, W/H = 0.53 (MGPT-PU 143192: Fig. 21 a); H = 4.2 mm, W = 2.3 mm, W/H = 0.55 (MGPT-PU 143193: Fig. 21 b); H = 4.5 mm, W = 2.4 mm, W/H = 0.53 (MGPT-PU 143194: Fig. 21 c).

Description. Small conoidal, slender rissoid with large base and stepped profile. High and smooth protoconch constituted by two and a quarter rounded whorl closed by a sinuous scar. The adult teleoconchs are composed of 5-5.2 swollen whorls separated by superficial sutures. The beginning of the teleoconch is marked by an acute spiral rib (keel, "carina") in the middle flanks where the whorl reaches the maximum width. The adapical ramp occupies a half-whorl; the smooth surface is undulated by sharp radial ribs. Starting from the 2nd whorl a second spiral rib lies halfway towards the abapical suture. A third abapical spiral rib runs at the contact of the following whorl, just aligned with the abapical suture. Further spiral riblets (three to four) are present on the basal ramp of the whorl. Radial ornamentation is limited to the exposed area of whorls and the bases show only spiral ribs. Radial ribs are gently proverse and abruptly fade at the whorl-suture; their number varies from 10-14 (respectively, first and last teleoconch whorls) to 12-16. Crossing the spiral ribs, the radial ribs produce squat spines whose sharpness reduces progressively with the shell growth up to a sort of nodes on the last whorl. The umbilicus is reduced to a slit. The aperture is simple without external thickening except occasional approximation of the last two radial ribs.

Remarks. *Alvania bonellii* is so-far known only from the Pliocene of Piedmont (Sacco 1895 in 1890-1904). Similar species are *Alvania maurizioi* Chirli, 2006 from the Pliocene of Tuscany and *Alvania leopardiana* Brunetti & Vecchi, 2012 from the Pleistocene of Emilia-Romagna. Both these taxa share the ornamentation pattern and the slender profile of *A. bonellii* with a high adapical ramp crossed by radial ribs but differing in the granular ornamentation of the protoconch. Moreover, *A. maurizoi* shows a denser spiral ribbing with a couple of ribs at the teleoconch beginning, four spiral ribs on the exposed area of whorls, a sort of thickening of the external lip with internal pre-oral folds. *A. leopardiana* differs for the less stepped profile with rounded whorls, an additional spiral rib on the adapical ramp; the rib intersection is reduced to a small node.

The extant *Alvania dictyophora* (Philippi, 1844) and *Alvania pagodula* (Boucquoy, Dautzenberg & Dollfus, 1884), to which Sacco (1895 in 1890-1904) suspected had a close connection, differ for their reticulate and spaced ornaments (Repetto et al. 2005).

Distribution and habitat. Lower to Upper Pliocene of Piedmont.

No biocoenotic information is available from the literature. Nevertheless, the high frequency of *Alvania bonellii* in the Rio Vaccaruzza Bed 9, and its absence from Bed 3, suggest that it may pertain to a HP biocoenosis. Thus, *A. bonellii* is here regarded as an epiphyte feeding on *Posidonia* leaves like other rissoids such as *Alvania* and *Pusillina* (Relini, 2008) present in the fossil assemblage of Bed 9.

Family Tornidae Sacco, 1896
Genus *Teinostoma* H. Adams & A. Adams, 1853

Type-species: *Teinostoma politum* A. Adams, 1853

Teinostoma minutum (Conti, 1864)

Fig. 21 h-j

1864 *Tornus minutus* Conti, p. 31, 50.
v 1896 *Tinostoma woodi* (Hoernes) var. *parvillima* Sacco 1890-1904, p. 52, pl. 4, fig. 66.
1916 *Tornus minutus* (Conti) - Cerulli Irelli 1907-16, XXII, p. 208, pl. 23, fig. 15-17.
1984 *Tinostoma woodi* var. *parvillima* Sacco - Ferrero Mortara et al., p. 274, pl. 50, fig. 8 a-d.
1992 *Tornus minutus* (Conti) - Ferrero & Merlino, p. 31.
2006 *Teinostoma minutus* (sic) Conti - Chirli, p. 56, pl. 25, fig. 1-7.

Diagnosis: Forma ovata, quasi spirale, leggermente convessa nella parte della spira, composta di tre giri lisci con esili linee di accrescimento. Perimetro trasversale ovoide continuato, acuto; base piana, ultimo anfratto quasi angulato: umbilico spirato ove si vedono i giri interni, base avvolta a guisa di cornetta da caccia (Conti, 1864: 50).

Type: The palaeomalacological collection from the Pleistocene of Monte Mario in Roma, set up by A. Conti in the mid-XIX century, was split in different stocks, one of which merged into the famous Cerulli Irelli collection stored in the Museo di Paleontologia of the La Sapienza University at Roma. At present, the material from Monte Mario is being catalogued in the newly established Earth Science University Museum of Rome (R. Sardella, pers. comm.). As a consequence, no inventory number is currently available for the type of *Teinostoma minutum* (Conti).

Cerulli Irelli (1916) stated that the few specimens at his disposal came only from the Conti collection; therefore, the specimens described by Cerulli Irelli constitute the type-series of *T. minutum*. Among these, the specimen figured by Cerulli Irelli (1916, pl. 23, figs. 15-17) is defined herein as the lectotype of *Teinostoma minutum* (Conti).

Material: 43 specimens from Bed 3 (MGPT-PU 110415, MGPT-PU 143197, MGPT-PU 110593, 110599, 110615, 110712), two specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 110807).

Size: The figured specimen (MGPT-PU 143197: Fig. 21 h-j) measures H = 0.7 mm, W = 1.9 mm, W/H = 2.7 with protoconch D = 0.41 mm. Measurements of further specimens from Bed 3: MGPT-PU 110593: H = 0.6 mm, W = 1.6 mm, W/H = 2.7; MGPT-PU 110599: H = 0.6 mm, W = 1.7 mm, W/H = 2.8; MGPT-PU 110615: H = 0.7 mm, W = 1.7 mm, W/H = 2.4; MGPT-PU 110712: H = 0.7 mm, W = 1.8 mm, W/H = 2.6.

Description. Plane-convex shell with minimal size. The spiral side is regularly convex with embryonal whorls in line with the teleoconch ones; the spiral sutures are well defined although superficial. The base of the last whorl is plano- to depresso-convex, and so flat as to produce a sharp marginal angularity. The umbilicus is open and irregularly surrounded by superficial radial furrows as growth lines. The smooth protoconch counts 2.0-2.2 slightly rounded whorls with sunken sutures; the nucleus is papilliform. The teleoconch consists of at most one and a half whorl; it is ornated by irregularly spaced, feeble spiral ridges mainly visible on the pre-apertural sector of the base. Dense transverse (axial), very fine riblets adorn the shell.

Remarks. The primary synonymy of *Teinostoma minutum* on *T. parvillimum* was formerly provided by Pavia (1976): no difference related to the teleoconch morphology can be found between them. "*Solariorbis*" aff. *minutus* from the Pliocene of Portugal (da Silva 2001) differs from the taxon described by Conti (1864) for its biconvex profile due to a slightly more depressed spire and the convex, not depressed abapical sector; it strictly recalls the specimens of "*Solariorbis*" *parmula* (Moroni, 1981) described from the Pleistocene bathyal clays of Francofonte, Sicily.

A second species of *Teinostoma* is present in both the Villalvernia fossil assemblages; it deals with *T. woodi* (Hoernes, 1856) (Fig. 21 k-m) discussed by Pavia (1976: 126; see also Landau et al., 2013: 89). The differences from the taxon described by Conti (1864) are due to the general rounded axial profile, the pointed protoconch with 2.5 rounded whorls, and the convex teleoconch whorls ornated by dense spiral furrows. A third *Teinostoma* taxon has been described from the Piedmont Pliocene, *T. astense* (Sacco, 1896), which is absent in the Rio Vaccaruzza assemblages; Landau et al. (2004: 59) considered it as a morphotype of *T. woodi*, although its variability is far from being demonstrated to the point of including *T. astense* that, at present, maintains its taxonomic relevance.

Distribution and habitat. *Teinostoma minutum* is presently known only from the Italian Pliocene of Monte Mario, Rome (Cerulli-Irelli, 1916 in 1907-16) and Piedmont (Sacco, 1896 in 1890-1904, and the present work).

No biocoenotic information is available from the literature, and the two fossil assemblages of Rio Vaccaruzza do not allow any inference.

Family Aclididae Sars, 1878
Genus *Aclis* Lovén, 1846

Type-species - *Alvania supranitida* Wood, 1842

Aclis proascaris Sacco, 1891

Fig. 22 a-d

v 1891 *Aclis proascaris* Sacco 1890-1904, p. 95, pl. 2, fig. 105.
v 1984 *Aclis proascaris* Sacco - Ferrero Mortara et al., p. 53, pl. 6, fig. 14.
1997 *Aclis praoscaris* Sacco - Tabanelli, p. 10.
2008 *Aclis penetrans* non Sosso - Tabanelli, p. 51, pl. 2, fig. 7.
2009 *Aclis proascaris* (Sacco) - Chirli, p. 77, pl. 31, fig. 11-15.

Diagnosis: Testa gracilis, parvillima, subulato-turrita, semipellucida, albida, anguste-umbilicata. Anfractus 8-9, convexi, sutura profunda disjuncti; … Costae transverse visibiles in primo anfracto costato 2 ventrales, in mediis 3 vel 4, in ultimo 5; … Apertura rotundata, superne subacuta. Labium externum laevissime extrorsum revolutum, extus pluriplicatum (Sacco, 1891: 95).

Type: The type-series is formed by the two syntypes in the BS Collection inventoried by Ferrero et al. (1984) and coming from Villalvernia. The syntype BS.031.01.001, figured by Sacco (op. cit.) and Ferrero et al. (op. cit.), is regarded herein as the lectotype of *Aclis proascaris* Sacco, 1891.

Material: 17 specimens (topotypes) from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 110819, MGPT-PU 143202-143204).

Size: Selected adult specimens measure: H = 2.8 mm, W = 1.0 mm, W/H = 0.36 (MGPT-PU 143202: Fig. 22 a); H = 2.6 mm, W = 1.0 mm, W/H = 0.38 (MGPT-PU 143203: Fig. 22 b); H = 2.3

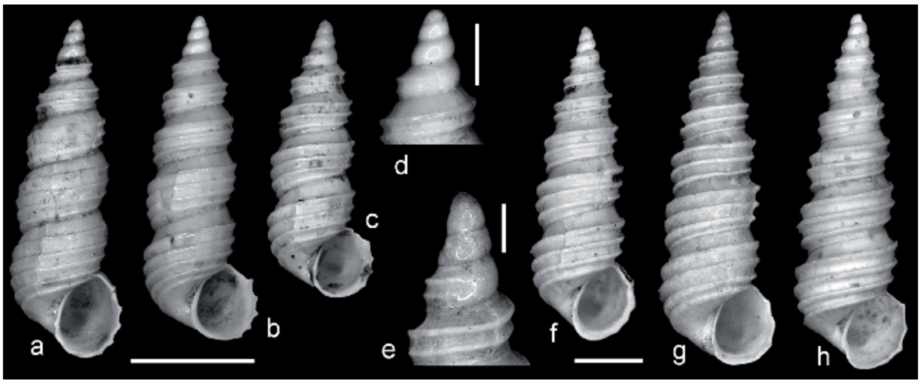

Fig. 22 - [a-d] *Aclis proascaris* Sacco, 1891, Rio Vaccaruzza, Bed 9: (a) MGPT-PU 143202, (b, d) MGPT-PU 143203, (c) MGPT-PU 143204. [e-h] *Aclis cellinii* Chirli 2009, Rio Vaccaruzza, Bed 9: (e-g) MGPT-PU 143200, (f) MGPT-PU 143199, (h) MGPT-PU 143201. Scale bars: 0.50 mm (horizontal) and 0.25 mm (vertical).

mm, W = 0.9 mm, W/H = 0.39 (MGPT-PU 143204: Fig. 22 c, d). The enlargement ratio of the lectotype is: W/H = 0.36.

Description. Minute subulate-turriculate shell with slightly coeloconoid growth of the adapical part of the spire; teleoconch growth slows down and the profile becomes subcylindrical. The protoconch is formed by three smooth whorls with superficial sutures. The teleoconch is formed by 4.5-5.5 rounded whorls with sunken sutures and wide, smooth subsutural band. The aperture is circular and flared with a slightly thickened external lip; the internal lip is laminar, and the umbilicus is a well-defined slit. The ornamentation consists of spiral ribs organized in the following sequence: two ribs in the first whorl, three ribs starting from the second whorl and four ribs in the following abapical sector; the last whorl shows a further rib (the fifth) in perisutural position and is invisible on the preceding whorls. The slope of the shell base bears a light median riblet.

Remarks. Sacco (op. cit.) erected the new species comparing it with the extant *Aclis ascaris* (Turton, 1891) (cf. Gofas et al., 2011, p. 221) that has been recently recorded also from the Pliocene of Emilia Romagna (Bellagamba et al. 2018). According to the diagnosis provided by Sacco (1891), *Aclis proascaris* differs from *A. ascaris* by having a subulate arrangement of the shell and the circular aperture; furthermore, its protoconch is reduced and pointed. A further taxon resembling *A. proascaris* for the spiral ornamentation is *Aclis penetrans* (Sosso, 1999), from the Lower Pliocene of western Liguria, which differs for details of the protoconch and, more importantly, for its larger size and the large number of spires with W/H = 0.15. Due to shell parameters, the specimen reported by Tabanelli (2008) from the Lower Pliocene of Emilia Romagna with a slender protoconch and W/H = 0.28 is attributable to *A. proascaris*.

Distribution and habitat. *Aclis proascaris* is so-far known from the Pliocene of Tuscany (Chirli 2006), Emilia Romagna (Tabanelli 2008) and Piedmont (Sacco 1891 and the present work).

No palaeobiocoenotic information is available from the literature.

Aclis cellinii Chirli, 2009

Fig. 22 e-h

2009 *Aclis cellinii* Chirli, p. 74, pl. 30, fig. 10-15, pl. 31, fig. 1-5 (cum syn.).

Diagnosis: The Author did not provide any diagnosis.

Type: The type-series is formed by six syntypes. The holotype (IGF14639E) and two paratypes are stored in the geo-palaeontological section of the Natural History Museum of the University of Firenze. Three paratypes are stored in the Chirli collection.

Material: 2 specimens from Bed 3 (MGPT-PU 110423), 40 specimens from Bed 9 (MGPT-PU 110818, MGPT-PU 143199-143201) of the Rio Vaccaruzza section.

Size: Selected adult specimens from Bed 9 measure: H = 3.1 mm, W= 1.1 mm, W/H = 0.36 (MGPT-PU 143199: Fig. 22 f); H = 3.3 mm, W = 1.1 mm, W/H = 0.33 (MGPT-PU 143200: Fig. 22 e, g); H = 3.4 mm, W = 1.1 mm, W/H = 0.32 (MGPT-PU 143201: Fig. 22 h).

Description. Minute, turriculate shell with conical-elongated profile. The protoconch is smooth with a papilliform nucleus; it is formed by 3.5-4 high whorls separated by slightly impressed sutures. The teleoconch comprises six or seven rounded whorls with deep spiral sutures. The aperture is rounded, slightly flared in the anterior sector, with a thickened external lip. The umbilicus is a narrow slit. Two spiral ribs adorn the first two whorls of the teleoconch; afterwards a third rib develops and reaches the same relief of the previous two at the beginning of the fourth whorl. A further, feeble rib develops along the suture line and is visible only on the last whorl. The base is smooth.

Remarks. The material from Rio Vaccaruzza fits the morphology of the type-series described by Chirli (2009) except in the slightly inflated shells (W/H = 0.32 - 0.36 vs W/H 0.28 - 0.31 of the type-series) possibly due to the small size of our specimens (ecophenotypes?) whose H values do not exceed 3.5 mm versus 4.5 mm of the holotype.

Distribution and habitat. *Aclis cellinii* is so-far known only from the Italian Pliocene of Toscany (Chirli 2009) and Piedmont (present work). The supposed synonymy (cf. Chirli 2009) of *Aclis verduini* van Aartsen et al., 1984 from the Pliocene of Estepona (Landau et al. 2006) needs confirmation.

No biocoenotic information is available from the literature. Nevertheless, due to the abundance of specimens in the assemblage from Bed 9, it is reasonable to hypothesize the pertinence of the species to the vegetated sectors of the infralittoral bottom.

Family Vanikoridae Gray, 1840

Genus *Cymenorytis* Cossman, 1888

Type-species: *Rissoa fragilis* Lamarck, 1804

Cymenorytis dellabellai Sosso, Dell'Angelo & Bonfitto, 2013

Fig. 21 n-o

2008 *Macromphalus brandenburgi* (non Boettger) - Chirli 2008, p. 13, pl. 2, fig. 7-11.
2013 *Cymenorytis dellabellai* Sosso et al., p. 161, fig. 2 A-T.

Diagnosis: The Authors did not provide any diagnosis.

Type: The type-series is formed by the ten syntypes described by Sosso et al. (2013) from different Italian and Spanish Pliocene sites. The holotype (MZB 49974, stored at the Zoological Museum of the Bologna University) was collected from a currently hidden outcrop of Rio Vaccaruzza, equivalent to our Bed 3 and the section described by Brambilla (1976). The specimens from Bed 3 may be regarded as topotypes.

Material: 7 specimens (topotypes) from Bed 3 of the Rio Vaccaruzza section (MGPT-PU 110432, MGPT-PU 143205-143206).

Size: Two topotypes measure H = 1.35 mm, W = 0.7 mm, W/H = 0.50 (MGPT-PU 143205: Fig. 21 n) and H = 1.05 mm, W = 0.63 mm, W/H = 0.60 (MGPT-PU 143206: Fig. 21 o).

Description. Minute shell with ovoid arrangement and convex whorls separated by deep sutures. The conical protoconch is pointed with respect to subsequent whorls and consists of 2.5 whorls ornated by tiny tubercles concentrated near the abapical suture. The teleoconch of our specimens is formed by a little more than three convex, rounded, slightly canaliculate whorls. Ornaments consist of fine, sinuous, spaced axial ribs that are arched on the adapical shoulder and evanescent in the abapical, periumbilical sector. A very thin and tight spiral ribbing cross both spiral ribs and interspaces. Rounded aperture with thin outer lip, arched columella and close umbilical slit.

Remarks. For details see the typological description by Sosso et al. (2013). The topotypes fit the holotype exactly both in size and morphological features.

The characterization of the Neogene *Cymenorytis* taxa was defined by Sosso et al. (2013: 158; see also Landau et al. 2013) who separated them from the genus *Macromphalus* Wood, 1842, based on the different proto- and teleoconch arrangements. In particular, the Miocene *C. brandenburgi* (Boettger, 1907) differs for the bigger shells (up to 4.5-5 mm height) and the smooth protoconch, whereas the Pliocene *Cymenoritis landaui* Sosso et al. 2013 shows a stocky teleoconch with depressed protoconch completely covered by small tubercles.

Distribution. The Pliocene species *Cymenorytis dellabellai* is largely distributed throughout the western sector of the Mediterranean (Sosso et al. 2013: 163) from Northern Italy (Piedmont, Liguria, Emilia Romagna, Tuscany) to Spain (Huelva basin).

Family Calyptraeidae Lamarck, 1809

Genus *Crepidula* Lamarck, 1799

Type-species - *Patella fornicata* Linnaeus, 1758

Crepidula bellardii n. sp.

Fig. 23 a-g

v 1896 *Crepidula gibbosa* var. *cochlearis* (non Basterot) - Sacco 1890-1904, p. 33 (pars).
v non 1896 *Crepidula gibbosa* var. *cochlearis* (Basterot) - Sacco 1890-1904, p. 33, pl. 4, fig. 17 (= *C. gibbosa*).
v 1984 *Crepidula gibbosa* var. *cochlearis* (non Basterot) - Ferrero et al., p. 249 (pars).

Diagnosis: Thin, subcircular, flat shell with spiral growth, protruding protoconch, adapical margin of the aperture extended to contact the protoconch sector, spiral and undulated inner septum.

Etymology: The species is dedicated to Luigi Bellardi (Genova 1818 - Torino 1889) who described the site Fontanili at Villalvernia where the species is common.

Type: The holotype, MGPT-PU 143210 (Fig. 23 f, g) from Bed 9 of the Rio Vaccaruzza succession. Five paratypes have been selected: MGPT-PU 143207 (Fig. 23 a) from the locality "Cascina Fiora" near Monale; MGPT-PU 143208 (Fig. 23 b, c), MGPT-PU 143209 (Fig. 23 d, e) and MGPT-PU 143211 from Bed 9 of the Rio Vaccaruzza succession; MGPT-PU 143212 from the Fontanili site.

Locus typicus: The right bank of the Rio Vaccaruzza, some 500 m northward of the village of Villalvernia (AL, NW Italy).

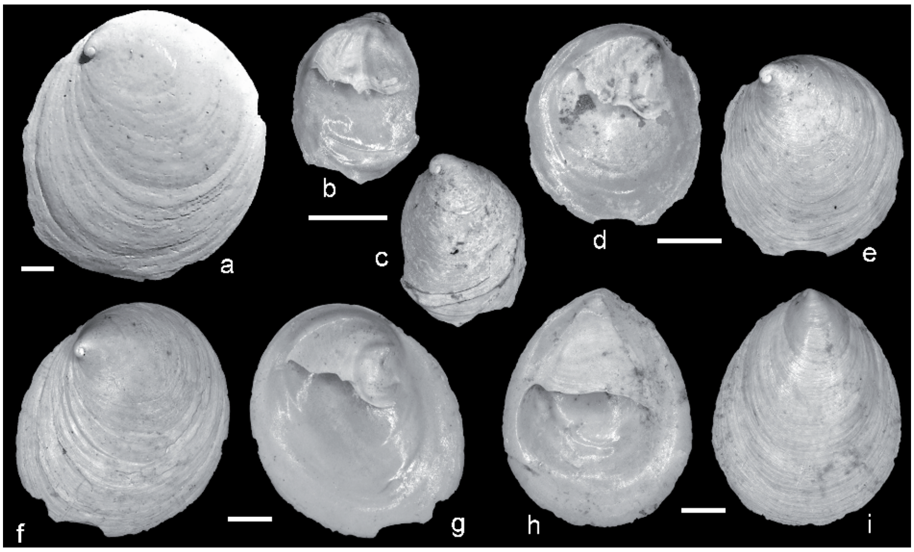

Fig. 23 - [a-g] *Crepidula bellardii* n. sp.: (a) paratype, MGPT-PU 143207, Cascina Fiora; (b, c) paratype, MGPT-PU 143208, Rio Vaccaruzza, Bed 9; (d, e) paratype, MGPT-PU 143209, Rio Vaccaruzza, Bed 9; (f, g) holotype, MGPT-PU 143210, Rio Vaccaruzza, Bed 9. [h-i] *Crepidula gibbosa* Defrance, 1818, MGPT-PU 1432013, Rio Vaccaruzza, Bed 9. Scale bars: 1.00 mm.

Stratum typicum: The Bed 9 of the Rio Vaccaruzza section, Upper Pliocene.

Material: 71 specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 110826, MGPT-PU 143208-143211). One specimen from the Fontanili site (MGPT-PU 143212). Two specimens (MGPT-PU 143207) from the Lower Pliocene of Monale (Asti) at the locality "Cascina Fiora" (Pavia 1980; see also "le Grottine" in Pedriali & Robba 2005).

Further specimens from Villalvernia are present in the BS collection (catalogued by Ferrero et al., 1984 with the stratigraphical acronym "P"); they are mixed with specimens of *Crepidula gibbosa* and need a careful revision.

Size: The holotype MGPT-PU 143210 measures H = 0.8 mm, W = 7.4 mm, W/H = 9.3. The paratypes measure: MGPT-PU 143207, H = 1.0 mm, W = 9.8 mm, W/H = 9.8; MGPT-PU 143208, H = 0.4 mm, W = 3.4 mm, W/H = 8.5; MGPT-PU 143209, H = 0.6 mm, W = 5.0 mm, W/H = 8.3; MGPT-PU 143211, H = 0.7 mm, W = 6.8 mm, W/H = 9.7; MGPT-PU 143212, H = 1.0 mm, W = 9.6 mm, W/H = 9.6.

Description. Little, thin and flat shell. The general outline varies from oval to subcircular in the adult stage with growth progressively twisted clockwise. The general shape is depressed with a mean convexity of 1.05 due to the very short spire axis and the expanded "basal" whorl. The protoconch occupies a marginal position and stands out on the slightly swollen surface of the teleoconch; it is composed of 1.5 smooth, rounded whorls separated by depressed sutures; the terminal scar is planar. The teleoconch consists of little more than one whorl; the adapical sector of the outer lip is close to the protoconch and includes the protoconch sector during ontogeny. The outer surface of the shell is smooth except for irregularly spaced growth-lines. The flared inner surface is polished. The septum, equivalent to the basal sector of the shell, is triangular in shape and occupies the internal third of the aperture; it is spiral and undulated by a central crest that reflects in the sinuous margin; a single bean-shaped muscle scar is present in front to the septum.

Remarks. Sacco (op. cit.) did not distinguish this calyptreid from *C. gibbosa* Defrance, 1818 var. *cochlearis* (Basterot, 1825) which is well known in the Miocene deposits around Europe (e.g. Mikuz & Soster 2014). The morphology "*cochlearis*" characterizes many specimens studied by Sacco (1896 in 1890-1904) from the Miocene and Pliocene of Northern Italy. All authors (op. cit.) recognize that the taxon *cochlearis* falls within the *gibbosa* variability.

C. gibbosa (and its extant equivalent *C. moulinsi* Michaud, 1829 - Gofas et al. 2011: 239; Bellagamba et al. 2018: 80) shows a short spiral protoconch that may recall that of *C. bellardii* n. sp.; however, the protoconch of the former species is depressed, less protruding from the surface of the apical shell. Moreover, substantial differences concern the teleoconch of *C. gibbosa*, whose growth is expanded in opposite direction from apex with a slightly arched arrangement; consequently, the septum regularly extends abapically and is just slightly undulated without evidence of a muscle scar (Fig. 23 h, i).

The specimen figured by Sacco (op. cit., BS.067.02.011) as "var. *cochlearis*" from the Pliocene of Villalvernia falls within the variability of *C. gibbosa* and totally differs from the morphology of *C. bellardii* n. sp. that stand out by the regularly right-handed development of the shell from the protoconch to the adult growth stage.

The BS collection records five additional samples referred to as *C. gibbosa* "var. *cochlearis*" (codes BS.067.02.011/01 to /05). Sample BS.067.02.011/04 contains specimens coming from the Fontanili site in Villalvernia: it consists of two subsamples, the first with ten specimens refers to *C. gibbosa* "var. *cochlearis*", the second (18 small shells in sample "P" of Ferrero et al., 1984) perfectly matches the morphology of *C. bellardii* n. sp.; one of these specimens is selected as the paratype MGPT-PU 143212.

No further report is known from the literature that could be related to *C. bellardii* n. sp.

Distribution and habitat. *Crepidula bellardii* n. sp. is so-far known only from the Lower Pliocene of the Asti Basin and the Upper Pliocene of the Villalvernia area.

The relative abundance of specimens in the assemblage of Bed 9 and its absence in Bed 3 suggest that this species inhabited the vegetated sectors of the infralittoral bottoms, in particular the *Posidonia* meadows biocoenosis (HP). Such a restricted distribution is supported by the palaeoecological information derived from the Cascina Fiora fossil locality whose gastropod assemblage is equivalent to that of Bed 9.

Family Muricidae Rafinesque, 1815
Genus *Coralliophila* H. & A. Adams, 1853

Type-species: *Fusus neritoideus* Lamarck, 1816

Coralliophila* cf. *meyendorffii (Calcara, 1845)

Fig. 24 b-c

cf. 1845 *Murex Meyendorfii* Calcara, p. 38, pl. 4, fig. 22.
cf. 2000 *Coralliophila meyendorffii* (Calcara, 1845) - Chirli, p. 49, pl. 19, fig. 12-16.
cf. 2005 *Coralliophila meyendorffii* (Calcara, 1845) - Repetto et al., p. 181, fig. 673.
cf. 2011 *Coralliophila meyendorffi* (Calcara, 1845) - Gofas et al., p. 285.

Material: One specimen from Bed 3 of the Rio Vaccaruzza section (MGPT-PU 143215).

Size: (MGPT-PU 143215) H = 29.6 mm, W = 17.8 mm, W/H = 0.60.

Description. Stocky shell with globose whorls, pointed apex and short siphon. The multispiral protoconch shows at least 3 convex, slightly abraded whorls. The specimen is an adult individual with a completely formed internal lip. The teleoconch is composed of 4.2 whorls with an asymmetrical profile: the adapical ramp is gently inclined; the middle whorl is globose, regularly rounded towards the abapical sector. The siphonal channel is short, twisted backwards and open in the deep umbilicus. The aperture is pyriform (54 % of the shell height) and converges in the short siphonal channel. The external lip is smooth with indefinite spiral ridges, the columellar one is laminar and a little inverted. The last whorl is ornated by 11 sinuous, strong ribs that are feeble on the adapical ramp and fade on the siphonal channel. Spiral ribs cover all the teleoconch; they are squamose, high and finer on the adapical ramp, and raised at the maximum whorl width. The pagodiform profile of the first two whorls is due to a couple of spiral ribs that mark the maximum whorl width.

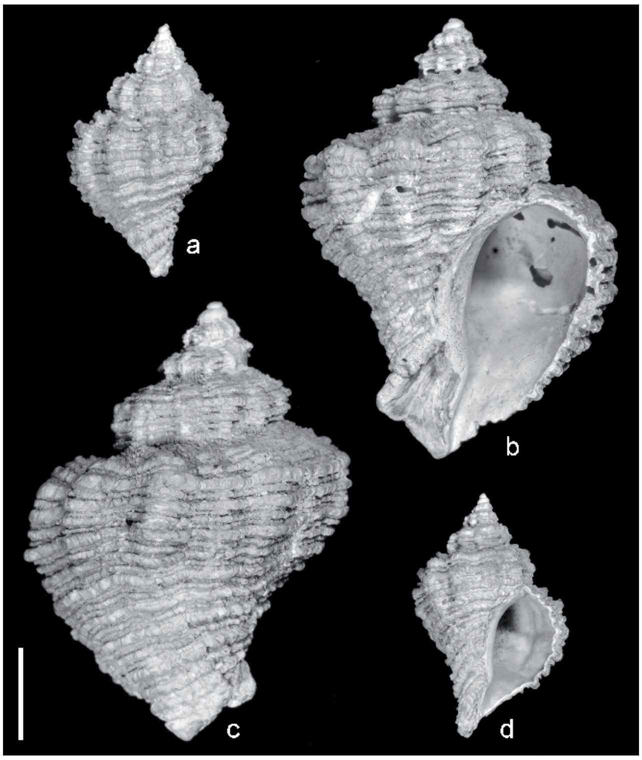

Fig. 24 - [a, d] *Coralliophila* cf. *bracteata* (Brocchi, 1814), MGPT-PU 143214, Rio Vaccaruzza, Bed 3. [b, c] *Coralliophila* cf. *meyendorffi* (Calcara, 1845), MGPT-PU 143215, Rio Vaccaruzza, Bed 3. Scale bar: 5.00 mm.

Remarks. Compared with the specimens of the cited references, the fossil from Villalvernia differs from *C. meyendorffi* in having a more pagodiform profile, a proportionately shorter siphonal channel, a more open umbilicus and the sinuous spiral ribs. *C. bracteata* (Brocchi, 1814) has a longer siphonal channel, a less definite adapical ramp (cf. Fig. 24 a, d) and a distinctive carina with a v-shaped profile. *C. alternata* (Bellardi, 1872) from the Tortonian of western Piedmont shows an ada- to abapical symmetric profile whose angularity becomes more accentuated as

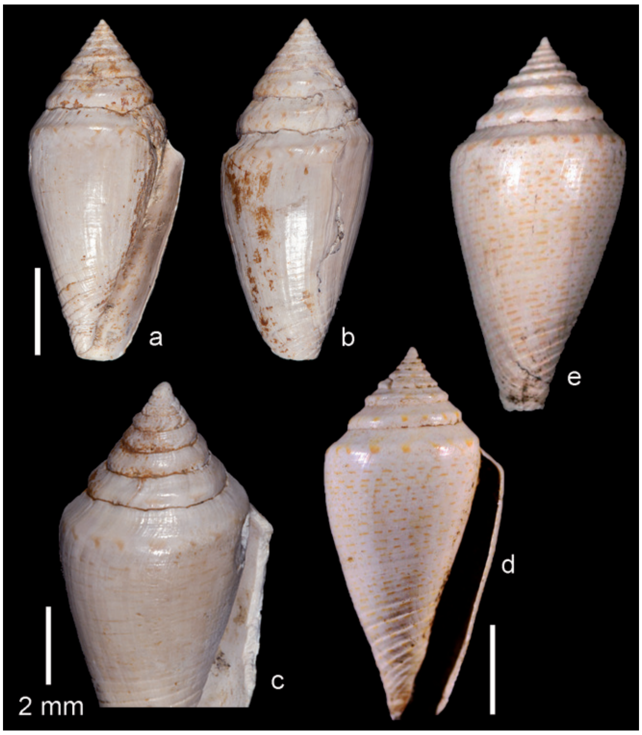

Fig. 25 - *Conus dellabellai* n. sp. (a, b) holotype, MGPT-PU 143224, Rio Vaccaruzza, Bed 9, specimen found by P. Giuntelli; (c) paratype, MGPT-PU 143227, Rio Vaccaruzza, Bed 9; (d, e) paratype, GDB-25001, Poggio alla Staffa, specimen found by G. Della Bella. Note the color patterns, particularly evident on the paratype GDB-25001. Scale bars: 5.00 mm, except for c.

in the conspecific (?) fossil described by Chirli (2000) from the Pliocene of Tuscany.

Family Conidae Rafinesque, 1815
Genus *Conus* Linnaeus, 1758

Type-species: *Conus pulcher* Lightfoot, 1786

Conus dellabellai n. sp.

Fig. 25 a-e, Fig. 26 h-i

1997 *Conus* (*Conolithus*) *canaliculatus* non Brocchi, 1814 - Chirli, p. 12, pl. 3, fig. 9, non pl. 3, fig. 10 (? *C. caroli* Fucini).

Diagnosis: High conical spire, oblique sutural ramp, lecitotrophic protoconch, angular to rounded adapical shoulder, whorl height reducing with growth.

Etymology: Named from Gino Della Bella who helped in the taxonomic definition and provided the paratype of Fig. 25 d, e.

Type: The type-series comes from Bed 9 of the Rio Vaccaruzza site and from the Poggio alla Staffa site (Colle Val d'Elsa, Siena, 43°20'40" N - 11°05'33" E).

The holotype is the MGPT-PU 143224 (Fig. 25 a, b). Four paratypes are selected among the specimens of Bed 9: MGPT-PU 143225 (Fig. 26 i), MGPT-PU 143226 (Fig. 26 h), MGPT-PU 143227 (Fig. 25 c), MGPT-PU 110545. A further paratype is GDB-25001 from Poggio alla Staffa (Fig. 25 d, e).

Locus typicus: The right bank of the Rio Vaccaruzza, some 500 m northward of the village of Villalvernia municipality (AL, NW Italy).

Stratum typicum: The Bed 9 of the Rio Vaccaruzza section, Upper Pliocene.

Material: 2 specimens from Bed 3 (MGPT-PU 110518) and 39 specimens from Bed 9 (MGPT-PU 143004, MGPT-PU 143224-143227, MGPT-PU 143281) of the Rio Vaccaruzza. One specimen from Poggio alla Staffa, Colle Val d'Elsa, Siena, 43°20'40" N - 11°05'33" E.

Size: Due to the decrease of whorl height with growth, the height of the last whorl (H_w) is related to the shell height (H_s).

The holotype MGPT-PU 143224 measures H = 20.1 mm, W = 9.8 mm, W/H = 0.49, $H_w/H_s = 0.64$. The paratypes measure: MGPT-PU 143225, H = 6.6 mm, W = 3.4 mm, W/H = 0.49, $H_w/H_s = 0.73$; MGPT-PU 143226, H = 16.5 mm, W = 8.7 mm, W/H = 0.47, $H_w/H_s = 0.72$; MGPT-PU 143227, H = 11.7 mm, W = 5.7 mm, W/H = 0.49, $H_w/H_s = 0.70$; MGPT-PU 143281, H = 19.1 mm, W = 9.6 mm, W/H = 0.50, $H_w/H_s = 0.69$; GDB-25001, H = 21.0 mm, W = 10.0 mm, W/H = 0.48, $H_w/H_s = 0.73$.

Description. Small-sized shell with biconical shape, regular conical spire, subsutural flexure symmetrically curved and deeper than wide, narrow abapical sector. The lecitothrophic protoconch is composed of 1.5 smooth, rounded whorls (Fig. 25 c and Fig. 26 i): its beginning is globular and uncoassial; the next whorl ends with a planar scar. The teleoconch (8.5 whorls in the holotype) shows an angular to rounded shoulder in the upper part of the whorl that coincides with the maximum shell width. The whorl height decreases with growth and produces a stepped profile of the adult shell. The internal side of the spire is oblique, planar or a bit concave where the shoulder is elevated in a sort of carina, and ornated by discontinuous thin furrows; no trace of beads. The spiral sutures are impressed. The siphonal channel is straight with a laminar external lip; the siphonal fasciole is weakly developed. The abapical half part of the shell shows eight to ten furrows that become evanescent upwards. The color pattern consists of quadrangular red spots on the shoulder and dense red dashes aligned on the whorls.

Remarks. The red spots and dashes are finely recorded on the paratype GDB-25001 (Fig. 25 d, e), whereas the Villalvernia specimens (Fig. 25 a-c) register only red traces on the shoulder (Fig. 25 a, b) and dashes on the whorl (Fig. 25 c). The shells of the new taxon show ontogenetic variability in the spire involution; starting from middle growth (Fig. 25 c, Fig. 26 i), the whorl height drops so that the spire is more and more exposed and shapes a stepped profile (Fig. 25 a, d, Fig. 26 h).

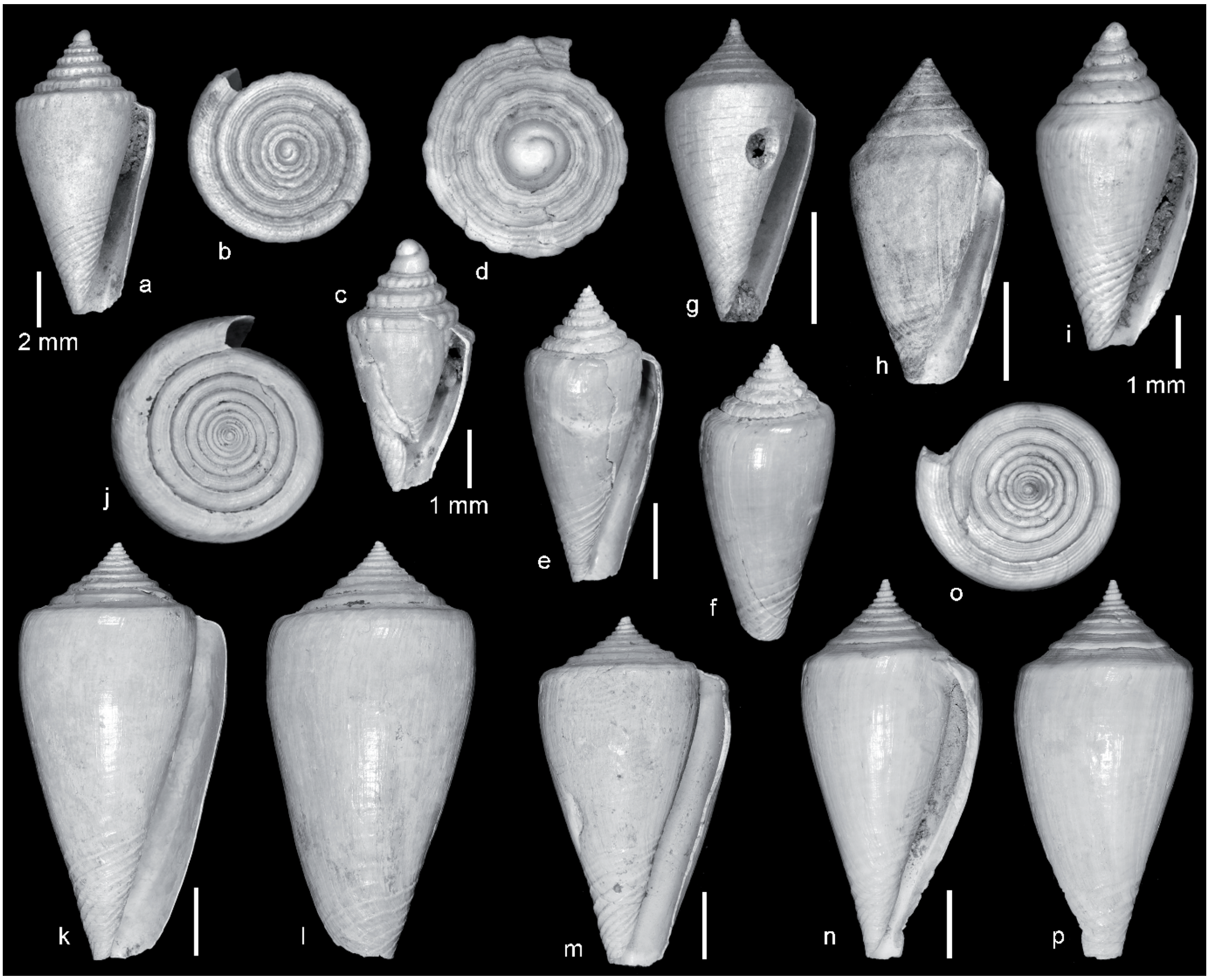

Fig. 26 - [a-f, j-l] *Conus villalvernensis* n. sp., Rio Vaccaruzza, Bed 9: (a, b) paratype, MGPT-PU 143222; (c, d) paratype, MGPT-PU 143223; (e, f) paratype, MGPT-PU 143220; (j-l) holotype, MGPT-PU 143216. [g] *Conus striatulus* (Brocchi, 1814), MGPT-PU 143228, Pliocene of Moncalvo. [h-i] *Conus dellabellai* n. sp., Rio Vaccaruzza, Bed 9: (h) paratype, MGPT-PU 143226; (i) paratype, MGPT-PU 143225. [m] *Conus virginalis* (Brocchi, 1814), BS.038.07.001/02, Lower Pliocene, Zinola. [n-p] *Conus fusuloligusticus* (Sacco, 1893), lectotype, BS.038.07.004, Lower Pliocene, Bordighera. Scale bars: 5.00 mm, except for pictures a, c, i. The picture d is the adapical enlargement of c.

A similar architecture is present in *Conus taurinensis* Bellardi & Michelotti, 1840 that is widespread through the Mediterranean Miocene (Landau et al. 2013: 251) with type-series from the Lower Miocene of the Torino Hills (Sacco 1893 in 1890-1904: 98-99); unfortunately, the shell preservation of neither the syntypes nor the supplementary specimens is sufficient to show the protoconch so that one important parameter of comparison is missing. Nevertheless, *C. taurinensis* definitely differs for the ovoidal architecture of the shell, higher whorls and cyrtoconoid to mammillate spire.

The specimen figured by Chirli (1997, pl. 3, fig. 9) is conspecific because *Conus canaliculatus* differs by having a larger size, as well as a depressed and canaliculate spire with narrow grooves below the shoulder (Landau et al. 2013: 254).

Conus dellabellai n. sp. may be compared with the coeval *C. striatulus* (Brocchi, 1814) for the similar size and the conical spire. *C. striatulus* is common in the Lower Pliocene of the BTP (MGPT-143228, Fig. 26 g); its differences consist of the multispiral, planktotrophic protoconch and the acute shoulder without furrows in the internal side of the spire.

Distribution. *Conus dellabellai* n. sp. is firstly recorded from the Piedmont Pliocene. It is widespread in Toscany and, possibly, in Emilia-Romagna (Della Bella, pers. data).

Conus villalvernensis n. sp.

Fig. 26 a-f, j-l

v 1893 *Lithoconus Mercatii* [sic] var. *Caroli* (non Fuc.) - Sacco 1890-1904, p. 18, pl. 2, fig. 11.

Diagnosis: Coeloconoid stepped spire, lecitothrophic protoconch, subcarinate to rounded adapical shoulder bearing beads up to the middle whorls.

Etymology: Named from the village of Villalvernia.

Type: The type-series comes from Bed 9 of the Rio Vaccaruzza site. The holotype is the MGPT-PU 143216 (Fig. 26 j-l). Six paratypes are selected: MGPT-PU 143217, MGPT-PU 143218, MGPT-PU 143219, MGPT-PU 143220 (Fig. 26 e, f), MGPT-PU 143221, MGPT-PU 143222 (Fig. 26 a, b), MGPT-PU 143223 (Fig. 26 c, d).

Locus typicus: The right bank of the Rio Vaccaruzza, some 500 m northward of the village of Villalvernia municipality (AL, NW Italy).

Stratum typicum: The Bed 9 of the Rio Vaccaruzza section, Upper Pliocene.

Material: Three specimens from Bed 3 (MGPT-PU 110520), 20 specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143007, MGPT-PU 143216-143223).

Size: The holotype MGPT-PU 143216 measures H = 31.8 mm, W = 15.6 mm, W/H = 0.49. The paratypes measure: MGPT-PU 143217, H = 36.8 mm, W = 17.3 mm, W/H = 0.47; MGPT-PU 143218, H = 31.0 mm, W = 14.7 mm, W/H = 0.47; MGPT-PU 143219, H = 25.1 mm, W = 12.2 mm, W/H = 0.49; MGPT-PU 143220, H = 20.3 mm, W = 9.7 mm, W/H = 0.48; MGPT-PU 143221, H = 12.4 mm, W = 5.8 mm, W/H = 0.47; MGPT-PU 143222, H = 10.4 mm, W = 5.3 mm, W/H = 0.51; MGPT-PU 143223, H = 4.3 mm, W = 2.2 mm, W/H = 0.51.

Description. Medium-sized shell with pointed apex, coeloconoid spire, subsutural flexure asymmetrically curved, main body convex, narrow abapical sector. The lecitotrophic protoconch is composed of 1.5 smooth, rounded whorls (Fig. 26 c, d). The beginning is globular and uncoaxial, the subsequent whorl ends with a planar scar. The teleoconch (9.5 whorls in the holotype) shows an elevated, rounded shoulder that causes a stepped profile of the spire. The internal part of the spire is depressed and ornated by three furrows that run constant with growth up to the aperture. In the first four to five whorls the shoulder bears proverse, well-marked beads; on the fifth whorl, there are 25-30 beads, and in the following whorls they weaken up into feeble undulations (ripples). A couple of subtle furrows lies just outside of the shoulder. The upper part of the lateral shell side is little convex and the siphonal channel is straight with a laminar external lip; the siphonal fasciole is poorly developed. The anterior half part of the shell shows 9-11 depressed cords, but in general all the lateral surface is covered by evanescent spiral ribbing.

Remarks. This conoidean was described by Sacco (op. cit.) as *Lithoconus mercati* (Brocchi, 1814) var. *Caroli* (Fucini, 1891) mainly because of the stepped, subcanaliculated spire with furrows and the elevated shoulder. Nevertheless, *C. mercati* has more massive shells and smooth spire without neither beads nor furrows on the shoulder (cf. Landau et al. 2013: 242). The morphology of these conoideans from Villalvernia may be compared with specimens of *Conus caroli* Fucini from the Pliocene of Tuscany (Della Bella's collection); these fossils, topotypical at the basin scale, indicate that *C. caroli* represents a different species due to the higher, not coeloconoid spire without pearling on the shoulder.

The new taxon shows analogies with *Conus virginalis* (Brocchi, 1814) for the stepped spire and the furrows on the internal whorls. Nevertheless, *C. virginalis* shows higher values of the ratio: W/H: 0.62 in the holotype (Rossi Ronchetti 1955) and 0.55 to 0.62 on the specimens described by Sacco (1893 in 1890-1904, see Fig. 26 m) and Chirli (1997); moreover, the protoconch of *C. virginalis* is multispiral and the adapical shoulder of the teleoconch is keeled with spaced undulations that continue up to the adult stage.

The "*Rhizoconus*" *virginalis* var. *fusuloligustica* described by Sacco (op. cit.: 115, pl. 11, fig. 4) from the Lower Pliocene of Bordighera (Liguria) is reminiscent of *C. villalvernensis* n. sp. for the narrow W/H = 0.48. However, Sacco's taxon has a multispiral, planktotrophic protoconch and shows only feeble undulations on the shoulder without any bead; it is here regarded as a separate species (*Conus fusoligusticus* (Sacco, 1893), lectotype here designated at Fig. 26 n-p) that differs from Brocchi's taxon for the architecture with conical spire and oblique internal side.

Distribution. *Conus villalvernensis* n. sp. is so far known from the Lower Pliocene of the Asti area (Sacco 1893 in 1890-1904, BS.038.02.011 and BS.038.02.011/04), the Upper Pliocene of Villalvernia (present work and Sacco 1893 in 1890-1904, BS.038.02.011/02) and the Pliocene of Tuscany (Della Bella, pers. comm.). A careful check of the conoidean assemblages from the Mediterranean Pliocene could expand the geographical distribution of the new species.

Sacco (1893, BS.038.02.011/01) discussed a further specimen coming from the Tortona surroundings (dubitatively Tortonian in age). Its preservation state is not equivalent to what we know for the Upper Miocene records of that region. We think that this specimen is a loose fossil reworked from the Pliocene outcrops of the southern "Tortonese" sector.

Family Mitromorphidae Casey, 1904
Genus *Mitromorpha* Carpenter, 1865

Type-species: *Daphnella filosa* Carpenter, 1864

Mitromorpha columbellaria (Scacchi, 1836)

Fig. 27 a-c

1836 *Mitra columbellaria* Scacchi, p. 10, fig. 12-13.
2007 *Mitromorpha* (*Mitrolumna*) *mediterranea* Misfud, 2001 - Della Bella & Scarponi, p. 48, fig. 96-99 (cum syn.).
2011 *Mitromorpha mediterranea* Misfud, 2001 - Gofas et al., p. 329.
2015 *Mitromorpha* (*Mitrolumna*) *columbellaria* (Scacchi, 1836) - Amati et al., p. 154, fig. 1-7 (cum syn.).

Diagnosis: Testa parva ventrosa, alba, vel fulva; anfractibus sex transvesim striatis, striisque obsoletis per longum dispositis; suturis inconspicuis; primo anfractu rotundato, glabro; columella biplicata; labro acuto interne striato (Scacchi, 1836: 10).

Type: Amati et al. (2015) studied the Mediterranean *Mitromorpha* with revision of the historical taxa and the definition of new ones. In particular, they erected the neotype of *Mitromorpha columbellaria* (Scacchi, 1836) based on a specimen of the Monterosato Collection, stored at the Museo Civico di Zoologia in Roma (inventory code M-21-17319) and coming from the Capri Island.

Material: 72 specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143018, MGPT-PU 143229-143231).

Size: The biggest adult specimen measures: MGPT-PU 143229, H = 7.6 mm, W = 3.6 mm, W/H = 0.47. Selected specimens measure: MGPT-PU 143230, H = 6.0 mm, W = 3.1 mm, W/H = 0.51 (Fig. 27 a, b); MGPT-PU 143231, H = 3.4 mm, W = 1.3 mm, W/H = 0.62 (Fig. 27 c).

Description. Small, fusiform shell whose profile is enlarged in its middle portion, regularly conical in the adapical sector and slightly tapered in the siphonal part. The paucispiral protoconch consists of 1.75 smooth, rounded whorls with impressed sutures (Fig. 27 c). The teleoconch is made up of a maximum of five whorls separated by superficial sutures. The aperture is lanceolate with two columellar folds; the external lip is smooth, laminar and adapically retroflexed by a large, shallow anal sinus. An internal bulge is built up by six teeth in the form of short spiral cords of different relief, the adapical two higher than the others; they are intercalated by smaller denticles. The ornamentation mainly consists of spiral cords, the adapical ones being enlarged and prominent: in all specimens, three cords in the 1st whorl, four cords from the 2nd whorl, and one smaller adapical cord from the penultimate whorl; the rest of the shell is ornamented by 20 cords usually thin except the six ones on the siphonal channel that are a little prominent. Radial ribs intersect the spiral ornamentation in the first two whorls producing a reticulate pattern that vanishes on the penultimate whorl.

Fig. 27 - [a-c] *Mitromorpha columbellaria* (Scacchi, 1836), Rio Vaccaruzza, Bed 9: (a, b) MGPT-PU 143230; (c) MGPT-PU 143231) [d] *Graphis striata* (Philippi, 1884), MGPT-PU 143234, Rio Vaccaruzza, Bed 3. [e, f] *Graphis albida* (Kanmacher, 1798), Rio Vaccaruzza, Bed 9: (e) MGPT-PU 143232, (f) MGPT-PU 143233). Scale bars: 1.00 mm (a, b), 0.50 mm (c), 0.25 mm (d, e, f). The picture c' is the adapical enlargement of c.

Remarks. The Mediterranean Neogene Mitromorphidae species were separated into the genera *Mitromorpha* Carpenter, 1865 and *Mitrolumna* (Bucquoy, Dautzenberg & Dollfus, 1883), the former being differentiated by the presence of radial ribs. However, Bouchet et al. (2011: 279-281, see also Gofas et al. 2011 and Tabanelli 2014) supported the synonymy of the two supraspecific names. The binomen *Mitromorpha columbellaria* (Scacchi, 1836) (= *M. mediterranea* Misfud, 2001) is the most frequent citation reported in the literature (Amati et al. 2015) and this synonymy is accepted herein.

The relief of the spiral ribs varies within the single assemblage and among fossil and extant populations, in general for the rib fading in the middle whorls (Chirli 1997, pl. 7, fig. 9; Amati et al. 2015, fig. 3). In this sense, *M. scarponii* Tabanelli, 2014 differs for the finer and denser spiral ribs that are uniformly distributed on the last whorl, except the adapical strip, as well as for the absence of axial ribbing.

M. olivoidea (Cantraine, 1835) differs from *M. columbellaria* because of its denser (more than 30) spiral ribbing and broader profile as summarized by Amati et al. (2015: 163) who also restricted the former taxon to the Mediterranean rocky bottoms with photophilic algae.

Distribution and habitat. *Mitromorpha columbellaria* is an extant Mediterranean taxon known from the Pliocene and Pleistocene of different Italian localities. This is the first report from the Piedmont Pliocene. It is worth noting the common presence of Mitromorphidae from the Miocene deposit studied by Bellardi (1888 in 1872-1888) with different taxa never confirmed by subsequent literature; these taxa need a comparative revision with the perspective of finding relationships with the more recent taxa.

M. columbellaria populates the rocky bottoms at the transition between the infra- to circalittoral zones with photophylous algae and amid the rhizomes of *Posidonia*. The frequency of specimens in Bed 9 assemblage and its absence in Bed 3 confirm the pertinence of the species to the vegetated sectors of the infralittoral bottoms, in particular the "*Posidonia* meadows" biocoenosis (HP).

Subclass **Heterobranchia** Gray, 1840
Family Cimidae Warén, 1993

The family Cimidae includes tiny gastropods whose taxonomic affinity is strongly debated. Formerly they were assigned to the prosobranch family Aclididae Sars, 1878 because of their right-handed protoconch, but recently they have been transferred to the Heterobranchia as amathinid pyramidelloids (cf. Chirli & Micali 2011: 5) or basal heterobranchs within the family Cimidae (cf. Gofas et al. 2011: 359). We follow Gofas' interpretation based on the anatomical and molecular features and the protoconch arrangement.

Genus *Graphis* Jeffreys, 1867

Type-species: *Turbo albidus* Kanmacher, 1798

Graphis albida (Kanmacher, 1798)

Fig. 27 e-f

1798 *Turbo albidus* Kanmacher, p. 637, pl. XIV, fig. 17.
2001 *Graphis albida* (Kanmacher, 1798) - Buzzurro et al., p. 159, fig. 6, 7.
2005 *Graphis albida* (Kanmacher, 1798) - Repetto et al., p. 161, fig. 554.
2011 *Graphis albida* (Kanmacher, 1798) - Gofas, p. 361.
2013 *Graphis albida* (Kanmacher, 1798) - Chirli, p. 5, pl. 1, fig. 7-12 (cum syn.).

Diagnosis: T. turritus septem anfractibus strigatis apertura ovali. The taper turbo with seven ridged spires and an oval aperture (Kanmacher, 1798, p. 637).

Type: No data are available from the literature.

Material: Two specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143232-143233).

Size: The specimens measure: MGPT-PU 143232, H = 1.6 mm, W = 0.4 mm, W/H = 0.25 (Fig. 27 e); MGPT-PU 143233, H = 1.8 mm, W = 0.5 mm, W/H = 0.20 (Fig. 27 f).

Description. This report is based on the largest available specimen. Minute, slender, turriculate shell with relatively high whorls that are separated by sunken sutures. The protoconch consists of two whorls with depressed nucleus. The shell has 5.5 convex whorls slightly concave adapically. The aperture is oval with laminar columellar lip and the umbilicus is reduced to a slit. The ornamentation consists of 34 sinuous axial ribs on the last whorl; the interspaces are ornamented with 18-20 spiral riblets that do not cross the axial ribs but face each other among contiguous interspaces.

Remarks. The specimens from the Rio Vaccaruzza Bed 9 are consistent with those reported from other localities (e.g., Chirli 2013). The differences with *G. striata* concern the narrow protoconch and the slender shell with shallow sutures.

Distribution. *Graphis albida* is largely distributed in the Mediterranean area since the Pliocene. The presence of this species in the Iberian Miocene (Peñas et al. 2006) needs confirmation. This is the first record of *G. albida* from the Pliocene of Piedmont.

Graphis striata (Jeffreys, 1884)

Fig. 27 d

1884 *Cioniscus striatus* Jeffreys, p. 342, pl. 26, fig. 2.
2001 *Cioniscus striatus* Jeffreys, 1884 - Buzzurro et al., p. 159, fig. 4, 5.
2005 *Graphis striata* (Jeffreys, 1884) - Repetto et al., p. 161, fig. 557.
non 2013 *Graphis striata* (Jeffreys, 1884) - Chirli, p. 6, pl. 1, fig. 13-18.

Diagnosis: The original, detailed description is available on WoRMS at *Cioniscus striatus* (Jeffreys, 1884: 342).

Type: No data are available from the literature, except for the reference by Buzzurro et al. (2001) who figured two syntypes from the Natural History Museum of London.

Material: One specimen from Bed 3 of the Rio Vaccaruzza section (MGPT-PU 143234, Fig. 27 d).

Size: MGPT-PU 143234: H = 1.6 mm, W = 0.5 mm, W/H = 0.31.

Remarks. The pertinence of this taxon either to *Graphis* Jeffreys, 1867 or to *Cioniscus* Jeffreys, 1869 is matter of extensive debate. Buzzurro et al. (2001) specified that the latter genus shows thickset shells, rounded and low whorls, deep sutures, helical arrangement, and a larger size of the protoconch (even more accentuated in *G. gracilis* Monterosato, 1874: Buzzurro et al. 2001, fig. 8 and Gofas et al. 2011: 361). Our specimen fits well with this morphological pattern. Nevertheless, we agree with the conclusion that consider such differences insufficient to support a distinction of these Cimidae at the genus level (cf. Gofas et al. 2011: 361).

The record documented by Chirli (2013) cannot be taken into account as his specimens show an heterostrophic protoconch that brings it close to *Saccoina monterosatoi* (Sacco, 1892) whose characteristics were defined by Bogi & Chirli (2004: 91). It is worth noting that the holotype of "*Spica*" *monterosatoi* was described by Sacco (1892 in 1890-1904: 67) from Villalvernia, most likely from the Fontanili site (cf. Ferrero Mortara et al. 1984: 78, pl. 11, fig. 8); unfortunately, the low amount of fossil shells in the Fontanili material collected by Bellardi (Fig. 10 e) prevents us from finding any topotypes of *S. monterosatoi.*

Distribution. As far as we know, this is the first report of *Graphis striata* in the Worldwide fossil record.

Family Pyramidellidae Gray, 1840
Genus *Odetta* de Folin, 1870

Type-species: *Odetta sulcata* de Folin, 1870

Odetta chirlii n. sp.

Fig. 28 a-g

2011 *Odetta marci* non van Aartsen et al., 1998 - Chirli & Micali, p. 68, pl. 3, fig. 5-15.

Diagnosis: Minute, stocky shell with impressed suture, heterostrophic protoconch type B, teleoconch ornated by spiral sulci irregularly distributed.

Etymology: Species named after Carlo Chirli in recognition of his contributions to the molluscan study of the Italian Pliocene.

Type: The holotype is the MGPT-PU 143235 (Fig. 28 a, b) from Bed 9 of the Rio Vaccaruzza site. Four paratypes are selected from the same site and bed: MGPT-PU 143236 (Fig. 28 c), MGPT-PU 143237 (Fig. 28 d), MGPT-PU 143238 (Fig. 28 e), MGPT-PU 143239 (Fig. 28 f, g).

Locus typicus: The right bank of the Rio Vaccaruzza, some 500 m northward of the village of Villalvernia (AL, NW Italy).

Stratum typicum: The Bed 9 of the Rio Vaccaruzza section, Upper Pliocene.

Material: Two specimens from Bed 3 (MGPT-PU 110572) and 72 specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143049, MGPT-PU 143235-143239).

Size: The holotype MGPT-PU 143235 measures H = 3.7 mm, W = 1.6 mm, W/H = 0.43. The paratypes measure: MGPT-PU 143236, H = 3.0 mm, W = 1.4 mm, W/H = 0.47; MGPT-PU 143237, H = 3.6 mm, W = 1.6 mm, W/H = 0.44; MGPT-PU 143238, H = 2.8 mm, W = 1.4 mm, W/H = 0.50; MGPT-PU 143239, H = 3.8 mm, W = 1.6 mm, W/H = 0.42.

Description. Minute shell with maximum height of 4 mm with six whorls on the holotype. The general outline varies ontogenetically from conical to pupoid. The protoconch type B, just a little submerged, is composed of 2.5 whorls and ends with an oblique scar. The whorls of the teleoconch are planar to slightly convex abapically; they are separated by lightly sunken sutures that generate a stepped profile; the surface is smooth and shiny. The last whorl is a little less than half the shell with an average value of the ratio W/H = 0.44 in adult specimens; in the juveniles the ratio W/H is more than 0.5 reflecting an ontogenetic variation of the shell structure from stocky to slender. The aperture is pyriform; the outer lip is internally notched in the adult specimens; the columellar lip is lightly expanded and bears an acute plica. The umbilicus is a thin crack. Spiral ornamentation: an adapical groove is present in the first one or two whorls; a marked groove lies in the middle of the flank and is often accompanied by one or two a bit lighter grooves; six to eight small, concentric grooves are present on the shell base.

Remarks. The type-series and other specimens of *Odetta chirlii* n. sp. from Villalvernia fit well the morphological features of the material described by Chirli & Micali (2011) from the Pliocene of the Siena area (average W/H = 0.43), although the latter specimens differ in their number of spiral grooves, which can be up to more than 5 per whorl but also 2 or even less. However, these two stocks are regarded as conspecific or at most they could represent two morphotypes possibly separable as allopatric subspecies. The dense ornamentation of the Tuscany specimens resembles the one exhibited by the extant *Odetta marcii* described from the Mauritanian coasts by van Aartsen et al. (1998). Nevertheless, apart from the ornamentation, *O. marcii* shows different structural features, including the pupoid morphology of the shells with a convex whorl and W/H = 0.38.

Odetta sulcata (de Folin, 1870) is a further taxon described from the Pliocene of Tuscany (Bogi & Chirli 2004) and currently living in Senegal (van Aartsen et al. 1998). This species shows a morphological structure comparable with that of *O. chirlii* n. sp., but differs by having a protoconch type A, the regularly conical profile, and sunken sutures.

Distribution and habitat. At present, *Odetta chirlii* n. sp. is so far restricted to the Italian Pliocene, in Piedmont (present work) and Tuscany (Chirli & Micali 2011).

The abundance of specimens in the assemblage of Bed 9 suggests the pertinence of the species with the vegetated sectors of the infralittoral bottoms, in particular in the root apparatus of the "*Posidonia* meadows" biocoenosis (HP).

Genus *Ondina* de Folin, 1870

Type-species: *Ondina semiornata* De Folin, 1872

Sacco (1892 in 1890-1904) assigned some new "pyramidelloids" from the Pliocene of Piedmont to the genera *Ondina* and *Anisocycla*. However, these can be assigned to different genera and families:

- *Ondina imperforata* Sacco (1892: 48, pl. I, fig. 106) and *O. pliobliqua* Sacco (1892: 49, pl. I, fig. 106 bis) were considered by Pavia (1976: 136; see also Chirli 2006: 73) as synonyms, with priority to the former, and transferred to the prosobranch Iravadiidae due to the holostrophic protoconch: *Rhombostoma imperforatum* (Sacco, 1892);
- *Ondina*? *bugellensis* (Sacco 1892: 53, pl. I, fig. 107) is confirmed herein within the Turbonelliidae as *Ondina bugellensis* Sacco, 1892;
- *Anisocycla nitidissima* var. *praecedens* Sacco (1892: 57, pl. II, fig. 25) is transferred herein to the Turbonellidae as *Ondina praecedens* (Sacco, 1892) due to the heterostrophic protoconch of type C;
- *Anisocycla subalpina* Sacco (1892: 49, pl. II, fig. 26) was revised by Pavia (1976: 160; see also Chirli & Micali 2011: 17) and transferred to the Turbonellidae as *Eulimella subalpina* (Sacco, 1892) due to the heterostrophic protoconch of type A.

Ondina diaphana (Jeffreys, 1848)

Fig. 28 h-j

1848 *Odostomia diaphana* Jeffreys, p. 341.
2005 *Ondina diaphana* (Jeffreys, 1848) - Repetto et al., p. 243, fig. 1049.
2011 *Ondina diaphana* (Jeffreys, 1848) - Chirli & Micali, p. 69, pl. 24, fig. 4-8 (cum syn.).
2011 *Ondina diaphana* (Jeffreys, 1848) - Gofas et al., p. 389.

Diagnosis: The original, detailed description is available on WoRMS at *Ondina diaphana*. (Jeffreys, 1848: 341).

Type: No data are available from the literature on the type-material stored at the Natural History Museum of London.

Material: One specimen from Bed 3 (MGPT-PU 110573) and two specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143051, MGPT-PU 143240-143241).

Size: The specimens from Bed 9 measure respectively: MGPT-PU 143240**,** H = 2.2 mm, W = 1.1 mm, W/H = 0.50 **(**Fig. 28 h); MGPT-PU 143241**,** H = 2.4 mm, W = 1.2 mm, W/H = 0.50 **(**Fig. 28 i, j).

Remarks. The specimens from Villalvernia fit well with both the fossil and extant material of *Ondina diaphana* except for their slightly reduced size and the larger profile (0.50 *vs* 0.43-0.39 in Chirli & Micali 2011). The second feature may be related to the usual width reduction with ontogeny of these pyramidellid shells.

Distribution. *Ondina diaphana* currently occurs in the Mediterranean and the eastern Atlantic, as well as in the Pliocene of Tuscany. This is the first record of *O. diaphana* in the Pliocene of Piedmont.

Ondina warreni (Thompson, 1845)

Fig. 28 k-n

1845 *Rissoa warreni* Thompson, p. 315, pl. 19, fig. 4.
1998 *Ondina warreni* (Thompson, 1845) - van Aartsen et al., p. 19.
2001 *Ondina warreni* (Thompson, 1845) - Gofas et al., p. 390.
2005 *Ondina warreni* (Thompson, 1845) - Repetto et al., p. 294, fig. 1055.
2011 *Ondina warreni* (Thompson, 1845) - Chirli & Micali, p. 70, pl. 24, fig. 9-15 (cum syn.).

Diagnosis: The original, detailed description is available on WoRMS at *Ondina warreni*. (W. Thompson, 1845: 315).

Type: No data are available from the literature on the two syntypes recorded by Thompson.

Material: Two specimens from Bed 3 (MGPT-PU 110574) and nine specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143053, MGPT-PU 143242-143243).

Size: Selected specimens of Bed 9 measure: MGPT-PU 143242, H = 1.9 mm, W = 0.9 mm, W/H = 0.49 (Fig. 28 k); MGPT-PU 143243, H = 3.0 mm, W = 1.3 mm, W/H = 0.45 (Fig. 28 l-n).

Remarks. Chirli & Micali (2011) described the shell structure and morphology of the species. Essentially, *O. warreni* differs from *O. diaphana* for the deeper sutures among the swollen whorls and the spiral grooves that characterize the base of the shell and can be extended to the entire whorl.

Distribution. Concerning Italy, *Ondina warreni* is reported from the Pliocene of Tuscany and

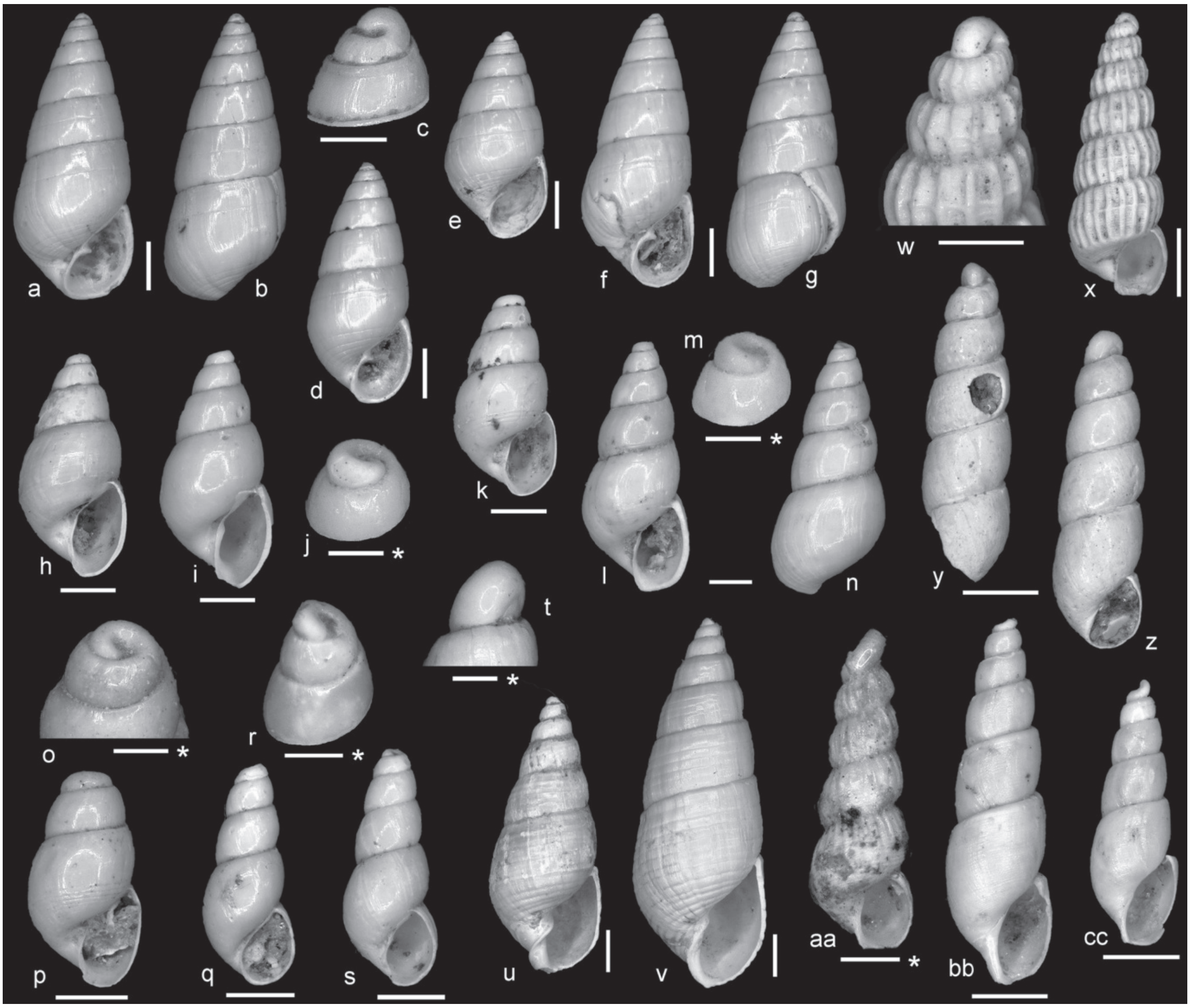

Fig. 28 - [a-g] *Odetta chirlii* n. sp., Rio Vaccaruzza, Bed 9: (a, b) holotype, MGPT-PU 143235; (c) paratype, MGPT-PU 143236; (d) paratype, MGPT-PU 143237; (e) paratype, MGPT-PU 143238; (f, g) paratype, MGPT-PU 143239. [h-j] *Ondina diaphana* (Jeffreys, 1848), Rio Vaccaruzza, Bed 9: (h) MGPT-PU 143240; (i, j) MGPT-PU 143241. [k-n] *Ondina warreni* (Thompson, 1845), Rio Vaccaruzza, Bed 9: (k) MGPT-PU 143242; (l-n) MGPT-PU 143243. [o-p] *Ondina curta* n. sp., Rio Vaccaruzza, Bed 9: (o) paratype, MGPT-PU 143245; (p) holotype, MGPT-PU 1432444. [q-s] *Ondina elongata* n. sp., Rio Vaccaruzza, Bed 3: (q) paratype, MGPT-PU 143247; (r) paratype, MGPT-PU 143248; (s) holotype, MGPT-PU 143249. [t-v] *Ondina pseudovitrea* n. sp, Rio Vaccaruzza, Bed 9: (t) paratype, MGPT-PU 143253; (u) paratype, MGPT-PU 143251; (v) holotype, MGPT-PU 143246. [w, x] *Turbonilla victoriae* (Pantanelli, 1880), MGPT-PU 143254, Rio Vaccaruzza, Bed 9. [y, z] *Anisocycla subcylindrica* n. sp., holotype, MGPT-PU 143259, Rio Vaccaruzza, Bed 3. [aa] *Anisocycla nitidissima* (Jeffreys, 1856), MGPT-PU 143256, Rio Vaccaruzza, Bed 9. [bb, cc] *Anisocycla striatula* (Jeffreys, 1856), Rio Vaccaruzza, Bed 9: (bb) MGPT-PU 143257, (cc) MGPT-PU 143258. Scale bars: 1.00 mm (vertical), 0.50 mm (horizontal), 0.20 mm (asterisk *).

the Pleistocene of Calabria. Extant populations are known along the central and northern Atlantic coasts up to Scandinavia. This is the first record of *O. warreni* from the Pliocene of Piedmont.

Ondina curta n. sp.

Fig. 28 o, p

Diagnosis: Very minute, stout shell with inflated to planar whorls and deep sutures, teleoconch ornated by a few spiral sulci on the whorl base.

Etymology: Short (curtus) shell.

Type: The holotype is the MGPT-PU 143244 (Fig. 28 p) from Bed 9 of the Rio Vaccaruzza site. The paratype MGPT-PU 143245 (Fig. 28 o) derives from the Fontanili site (Bellardi's collection).

Locus typicus: The right bank of the Rio Vaccaruzza, some 500 m northward of the village of Villalvernia (AL, NW Italy).

Stratum typicum: The Bed 9 of the Rio Vaccaruzza section, Upper Pliocene.

Material: One specimen from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143244) and one specimen from the Fontanili site (MGPT-PU 143245).

Size: The holotype MGPT-PU 143244 measures H = 1.6

mm, W = 0.8 mm, W/H = 0.55 with protoconch D = 0.32 mm; the paratype MGPT-PU 143245 has H = 1.7 mm, W = 1.0 mm, W/H = 0.59.

Description. Microscopic shell with truncated outline at the apex. The sunken protoconch type C exposes only the last, smooth whorl; the terminal cicatrix is planar and distinguishable by the change in color compared to the teleoconch possibly due to their different shell microstructures. The teleoconch is composed by 2.5 inflated whorls, planar in the middle side, and separated by deep sutures. The last whorl is higher than the half shell and ornamented by numerous, very light spiral grooves limited to the basal whorl and therefore hidden on the previous whorls. Rounded, subrectangular aperture with laminar outer lip. The thin inner lip shows a weak columellar fold in the middle. The umbilicus forms a relatively open chink.

Remarks. Further material is needed for checking the possible differences in the microstructure of the protoconch and the teleoconch.

Ondina curta n. sp. belongs to the *Ondina* species group characterized by the spiral ornamentation combined with the Pliocene to Recent *O. warreni* (Thompson, 1845) and the extant *Ondina mosti* Aartsen et al. (1998). Nevertheless, those species show slender biconical shells, totally different from the stout profile of the taxon described herein. *O. curta* n. sp. shows analogies with the extant *Ondina crystallina* Locard, 1892 (Mediterranean and eastern Atlantic: W/H = 0.53 in Gofas et al. 2011, p. 389) for size and umbilicus although the latter has a narrow apex. *O. curta* n. sp. differs from *O. bugellensis* (Sacco, 1892) from the Pliocene of Masserano (NW Italy) by having an ovoidal shell ornamented with spiral grooves totally absent in Sacco's species.

Distribution. *Ondina curta* n. sp. is so-far known only from the Upper Pliocene of the Villalvernia area.

Ondina elongata n. sp.

Fig. 28 q-s

Diagnosis: Very minute, slender shell with arched whorls, smooth teleoconch.

Etymology: Elongated (elongatus) shell.

Type: The holotype is the MGPT-PU 143246 (Fig. 28 s) from Bed 3 of the Rio Vaccaruzza site. Two paratypes are selected from the same site and bed: MGPT-PU 146247 (Fig. 28 q), MGPT-PU 146248 (Fig. 28 r).

Locus typicus: The right bank of the Rio Vaccaruzza, some 500 m northward of the village of Villalvernia (AL, NW Italy).

Stratum typicum: The Bed 3 of the Rio Vaccaruzza section, Upper Pliocene.

Material: Seven specimens from Bed 3 of the Rio Vaccaruzza section (MGPT-PU 110575, MGPT-PU 143246-143248).

Size: The holotype MGPT-PU 143246 measures H = 1.8 mm, W = 0.8 mm, W/H = 0.42 with protoconch D = 0.24 mm. The two paratypes measure: MGPT-PU 143247, H = 1.7 mm, W = 0.7 mm, W/H = 0.41; MGPT-PU 143248, H = 1.6 mm, W = 0.7 mm, W/H = 0.40.

Description. Microscopic shell with a high conical outline truncated at the apex. The sunken protoconch type C exposes only the last, slightly convex, smooth whorl; the terminal cicatrix is planar, proverse and distinguishable only where the protoconch is more abraded than the teleoconch due to different shell microstructures. The teleoconch is composed of four slightly convex whorls separated by engraved sutures; they are totally smooth. The last whorl is as high as the half shell. The aperture is oval with the external laminar lip regularly convex and expanded abapically. The columellar lip is small and bears a central, weak columellar fold. The umbilicus is central and reduced in size.

Remarks. Contrary to the shell target of the genus that leads to a W/H reduction with growth, *Ondina elongata* n. sp. develops higher W/H values (0.40 to 0.42) during ontogeny. A similarly high value of W/H is present in *O. curta* n. sp., which differs the larger protoconch, the stouter shell and the fine spiral grooves in the basal portion of the shell. The closest species of *O. elongata* n. sp. with protoconch type C are the extant *O. coarctata* (Sars, 1878) and *O. divisa* (J. Adams, 1797: van Aartsen 1987) that are characterized by subturriculate shells. *O. bugellensis* (Sacco, 1892) from the Pliocene of Masserano shows a stocky shell (W/H = 0.58 vs 0.40-42) and oval aperture, whereas O. *praecedens* (Sacco, 1892) from the Pliocene of the Asti basin is subcylindrical with a larger apex.

Distribution. *Ondina elongata* n. sp. is so-far known only from the Upper Pliocene of the Villalvernia area.

Ondina pseudovitrea n. sp.

Fig. 28 t-v

Diagnosis: Proportionally large shell with minute protoconch type B, dense spiral grooves on the teleoconch.

Etymology: Similar (pseudo) to *O. vitrea*.

Type: The holotype is the MGPT-PU 143249 (Fig. 28 v) from Bed 9 of the Rio Vaccaruzza site. Four paratypes are selected from the same site and bed: MGPT-PU 143250, MGPT-PU 143251 (Fig. 28 u), MGPT-PU 143252, MGPT-PU 143253 (Fig. 28 t).

Locus typicus: The right bank of the Rio Vaccaruzza, some 500 m northward of the village of Villalvernia (AL, NW Italy).

Stratum typicum: The Bed 9 of the Rio Vaccaruzza section, Upper Pliocene.

Material: 36 specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143052, MGPT-PU 143249-143253).

Size: The holotype MGPT-PU 143249 measures H = 9.3 mm, W = 3.4 mm, W/H = 0.37. The four paratypes measure: MGPT-PU 143250, H = 7.1 mm, W = 3.0 mm, W/H = 0.43; MGPT-PU 143251, H = 5.0 mm, W = 2.3 mm, W/H = 0.46; MGPT-PU 143252, H = 3.3 mm, W = 1.6 mm, W/H = 0.49; MGPT-PU 143253, H = 1.8 mm, W = 1.0 mm, W/H = 0.54.

Description. Small, fusiform shell with high conical spire and pointed apex. The holotype is an adult shell with seven whorls, the upper ones slightly convex, and the last two planar with linear sutures; a concave, large band lies close to the adapical suture. The blunt protoconch of type B is planorbid and inclined; it is formed by 1.5 rounded whorls, and the terminal cicatrix is made evident by the reduced size of the teleoconch beginning. The aperture pyriform is elongated with a thin, often broken outer lip; the inner lip without callus is extended, overturned on the shell axis, and bears an acute columellar fold. The umbilicus is nearly closed. The youngest whorls are smooth, just ornamented by irregular axial folds; from the 2.5 whorl the surface is engraved with furrows of irregular width and distance; 13 furrows can be observed on the last whorl of the holotype.

Remarks. The new species, apart for its greater size compared to other known species of the genus *Ondina*, may be compared with the extant *O. vitrea* (Thompson, 1845) for the reduced protoconch of type B, the W/H = 0.39 at the adult stage and the pyriform aperture (Gofas et al. 2011: 390). Nevertheless, *O. pseudovitrea* n. sp. shows planar adult whorls, small umbilicus, less numerous, larger and more engraved grooves. A second extant comparable species is *O. obliqua* (Alder, 1844) with the same W/H = 0.47 at comparable size and the extended inner lip (Repetto et al, 2005, p. 244, n. 1053); this species differs by having a smaller size, higher whorls and denser spiral grooves

Distribution and habitat. *Ondina pseudovitrea* n. sp. is so-far known only from the Upper Pliocene of Villalvernia area.

The relative abundance of specimens in Bed 9 assemblage suggests the pertinence of the species with the vegetated sectors of the infralittoral bottoms, in particular the "*Posidonia* meadows" biocoenosis (HP).

Genus *Turbonilla* Risso, 1826

Type-species: *Turbon costulata* Risso, 1826

Turbonilla victoriae (Pantanelli, 1880)

Fig. 28 w, x

1880 *Pyrgulina Victoriae* sp. n. Pantanelli, p. 275.
1990 *Turbonilla victoriae* (Pantanelli, 1880) - Micali, p. 145, fig. 1.
2011 *Turbonilla victoriae* (Pantanelli, 1880) - Chirli & Micali, p. 107, pl. 38, fig. 13-18.

Diagnosis: Testa elongata, acuta; anfractus valde convexi, carinati, sutura profunda divisi; longitudinaliter costati, costae 16, vix incurvae, in anfractu ultimu prope basim carentes; costellae transversae circiter 20, quarum una maxima in media parte anfractum; basis subplanata; apertura subrhombea (Pantanelli, 1880: 275).

Type: No data are available from the literature on the type-material stored in the palaeontological Museum of the University of Modena.

Material: Five specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143068, MGPT 143254-143255).

Size: The figured specimen (MGPT-PU 143254) measures H = 2.8 mm, W = 1.0 mm, W/H = 0.36.

Remarks. The original diagnosis and the subsequent descriptions (see synonymy) clearly define the morphological characters of this rare species without any possible doubts. Its main diagnostic feature was summarized by Pantanelli himself (1880) as "This very elegant species is distinguished by the median (spiral) rib of the whorls which, raised above the others, makes the whorl keeled". A further peculiar aspect of its ornamentation is represented by the fine spiral riblets visible in the intercostal spaces.

The Rio Vaccaruzza specimens, although smaller, are morphologically similar to those reported by Chirli & Micali (2011) as regards shell shape and ornamentation, but are smaller; for this reason, their W/H ratio is higher: 0.36-0.33 vs 0.32-0.24. On the other hand, the largest specimen described by Chirli & Micali (2011) is approximately equivalent to the lectotype that measures H = 5.0 mm, W = 1.0 mm, W/H = 0.20 (Pantanelli 1880).

Distribution. *Turbonilla victoriae* is currently known only from the Pliocene of Piedmont (present work) and Tuscany.

Family Murchisonellidae Casey, 1904

Genus *Anisocycla* Monterosato, 1880

Type-species: *Aciculina emarginata* Deshayes, 1861

According to van Aartsen (1995), *Ebala* Gray, 1847 must be regarded as a junior synonym of *Turbonilla* Risso, 1826, and the first valid, usable name is *Anisocycla* Monterosato, 1880 (see Landau et al. 2013 for a detailed discussion).

Anisocycla nitidissima (Montagu, 1803)

Fig. 28 aa

1803 *Turbo nitidissimus* Montagu, p. 299, pl. 12, fig. 1.
? 1969 *Anisocycla Nitidissima* (sic) Montagu - Fekih, p. 56, pl. 11, fig. 11.
1994 *Anisocycla nitidissima* (Montagu, 1803) - van Aartsen, p. 93, 94, fig. 14.
2000 *Anisocycla nitidissima* (Montagu, 1803) - van Aartsen et al., p. 16.
2005 *Ebala nitidissima* (Montagu, 1803) - Repetto et al., p. 252, fig. 1101.
2011 *Ebala nitidissima* (Montagu, 1803) - Gofas et al., p. 397.
2013 *Anisocycla nitidissima* (Montagu, 1803) - Landau et al., p. 321, pl. 76, fig. 6-7 (cum syn.).

Diagnosis: The original, detailed description is available on WoRMS at *Anisocycla nitidissima* (Montagu, 1803: 299).

Type: No data available from the literature on the type-material stored at the Natural History Museum of London.

Material: One specimen (MGPT-PU 143256) from Bed 9 of the Rio Vaccaruzza section.

Size: The figured specimen (MGPT-PU 143256) measures H = 1.2 mm, W = 0.4 mm, W/H = 0.33.

Remarks. The specimen from the Rio Vaccaruzza shows a shell structure and ornamentation equivalent to the specimens of *Anisocycla nitidissima* described in the literature (see synonymy list): very minute shell with low growth rate, convex whorls separated by sunken sutures, dense, thin spiral sculpture, and axial riblets on the adapical half of the whorl corresponding to more impressed growth lines. The examined specimen has a greater W/H ratio compared to those listed in synonymy (0.33 *vs* 0.28 in Landau et al. 2013 and 0.24-0.20 in Gofas et al. 2011); this difference is clearly related to the different ontogenetic stage (respectively four, five, six and seven whorls).

The approximate iconography does not define the possible conspecific status of the material from the Pliocene of Tunisia (Fekih 1969), although the absence of axial ornamentation suggests a different taxonomic placement. More generally, all the Murchisonellidae described by Fekih (1969) need attention as these fossils may provide a wider scenario of this family, comprising several new taxa referred to the genus *Saccoina* (type-species *S. monterosatoi* from Villalvernia) never confirmed by the recent literature.

Distribution. Fossils of *Anisocycla nitidissima* are known from the Middle Miocene of eastern Parathethys to the Pliocene of the Mediterranean and Northern Europe (Landau et al. 2013). Today, the species spreads from the Mediterranean to the western Atlantic. This is the first record from the Pliocene of Piedmont.

Anisocycla striatula (Jeffreys, 1856)

Fig. 28 bb, cc

1856 *Eulimella striatula* Jeffreys, p. 186, pl. 2, fig. 14, 15.
1994 *Anisocycla striatula* (Jeffreys, 1856) - van Aartsen, p. 93, 95, fig. 14.
2005 *Ebala striatula* (Jeffreys, 1856) - Repetto et al., p. 252, fig. 1103.
2011 *Ebala striatula* (Jeffreys, 1856) - Gofas et al., p. 398.

Diagnosis: The original, detailed description is available on WoRMS at *Ebala striatula* (Jeffreys, 1856: 186).

Type: No data are available from the literature (van Aartsen, 1994: 95) on the type-material stored at the Natural History Museum of London.

Material: Two specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143257, 143258).

Size: The specimens measure: MGPT-PU 143257, H = 2.4 mm, W = 0.8 mm, W/H = 0.31 (Fig. 28 bb); MGPT-PU 143258, H = 1.8 mm, W = 0.6 mm, W/H = 0.33 (Fig. 28 cc).

Description. The descriptions by van Aartsen (1994) and Gofas et al. (2011) provide a complete overview of the morphological features of this species, just as they can be observed in our specimens.

Minute, subcylindrical shell with flattened whorls and a stepped profile due to a sort of adapical shelf. The nearly planospiral protoconch type B is inclined at 55° and counts two rounded whorls; its last whorl is almost vertical and ends with a proverse cicatrix. The teleoconch of the specimen MGPT-PU 143257 is 5.5 whorls with the last one high as the half shell. The aperture is oval, the external lip is sharp, and the columellar one is slightly reversed without a columellar fold. The umbilicus is closed. The whorl surface is ornamented by a dense grid resulting from spiral striae that produce microscopic knots at the intersection with the sinuous, opisthocline growth lines.

Remarks. The specimen described by Gofas et al. (2011) exhibits seven whorls with W/H = 0.24; its last whorl is 31% of the shell height. The specimen reported by Repetto et al. (2005) counts 4.5 whorls with W/H = 0.33; its last whorl is 53%

of the shell height. The largest specimen examined in this study is in an intermediate position, i.e. the species becomes slenderer during ontogeny.

Distribution. *Anisocycla striatula* is known from the infralittoral bottoms of the western Mediterranean. As far as we know, this is the first fossil documented occurrence of the species in the fossil record.

Anisocycla subcylindrica n. sp.

Fig. 28 y, z

Diagnosis: Subcylindrical spire, large protoconch type B, no ornaments.

Etymology: Quasi-cylindrical whorls.

Type: The holotype is the adult shell MGPT-PU 143259 (Fig. 28 y, z) from Bed 3 of the Rio Vaccaruzza site. One paratype from the same site and bed: the juvenile shell MGPT-PU 143260.

Locus typicus: The right bank of the Rio Vaccaruzza, some 500 m northward of the village of Villalvernia (AL, NW Italy).

Stratum typicum: The Bed 3 of the Rio Vaccaruzza section, Upper Pliocene.

Material: Two specimens from Bed 3 of the Rio Vaccaruzza section (MGPT-PU 143259-143260).

Size: The holotype MGPT-PU 143259 measures: H = 2.6 mm, W = 0.8 mm, W/H = 0.31; the paratype MGPT-PU 143260 is H = 1.5 mm, W = 0.6 mm, W/H = 0.39.

Description. Minute, turriculate shell with conical to subcylindrical shape and large apex. The stocky protoconch type B is planorbid and inclined at 45°; the terminal cicatrix is engraved and proverse. The teleoconch of the holotype is an adult shell with 4.3 whorls. Except for the first convex whorl, the following ones are subplanar with narrow and deep sutures; the last whorl equals 45.3 % of the shell height, whereas in the paratype this value is 51.0 % on 2.5 whorls. The aperture is elliptical with internal lip slightly reversed and bearing a small columellar fold. The umbilicus is closed. The shell is smooth, without ornamentation visible even at high magnification.

Remarks. *Anisocycla subcylindrica* n. sp. differs from A. *subscalarina* (Fekih, 1969, p. 57; see also Chirli & Micali 2011, p. 111) due to its less conical profile, more superficial spiral sutures, higher protoconch, reduced growth rate (W/H = 45.3 vs 60.8 on four whorls in Chirli & Micali 2011), and absence of spiral stripes. The extant *A. trigonostoma* (de Folin, 1870) from the Atlantic and southern Mediterranean coasts (Repetto et al. 2005; Gofas et al. 2011) shows close similarity with *A. subcylindrica* n. sp. in terms of plano-convex whorls, W/H = 0.29 on 4.5 whorls and absence of spiral ornamentation; nevertheless, the new species shows a stouter protoconch, less incised sutures, and elliptical aperture with a small columellar fold.

Distribution. *Anisocycla subcylindrica* n. sp. is so-far known only from the Upper Pliocene of the Villalvernia area.

Family Retusidae Thiele, 1826
Genus *Retusa* Brown, 1827

Type-species: *Bulla obtusa* Montagu, 1803

Retusa mammillata (Philippi, 1836)

Fig. 29 a-b

1836 *Bulla mammillata* mihi Philippi, p. 122, pl. 7, fig. 20.
1910 *Tornatina (Retusa) mammillata* Phil. - Cerulli Irelli 1907-16, XVI, p. 33, pl. 1, fig. 63-65.
1983 *Retusa mammillata* (Philippi, 1836) - Menesini & Ughi, p. 238.
1983 *Retusa truncatula* (non Bruguière, 1792) - Menesini & Ughi, p. 238, pl. 2, fig. 14.
1986 *Mamilloretusa mammillata* (Philippi) - Caldara, p. 140, 143.
2001 *Retusa mamillata* (Philippi, 1836) - Tringali & Oliverio, p. 135, fig. 46, 47.
2005 *Retusa mamillata* (Philippi, 1836) - Repetto et al., p. 256, fig. 1128.
2011 *Retusa mammillata* (Philippi, 1836) - Gofas et al., p. 405.
2018 *Retusa mamillata* (Philippi, 1836) - Ceulemans et al., p. 122.

Diagnosis: Testa minuta, cylindrica, longitudinaliter substriata, vertice truncato, medio papillato, spira conspicua (Philippi, 1836: 122).

Type: No data are available from the literature.

Etymology: The name *mammillata* was clearly referred by Philippi to the small teat-like structure dominating the apex. The Latin spelling of "teat" is "mamilla", whose specific Latin adjectivation would be *mamillata*, consequently there is a formal conflict between the two spellings (see the synonymy list). This situation is ruled by ICZN, Art. 32.5.1.1: in case of an inadvertent error (e.g. lapsus calami) the name must be corrected, but the same paragraph specifies that "incorrect transliteration or latinization … are not to be considered inadvertent errors". In compliance with this statement, the name *Retusa mammillata* may be correctly used.

Material: Two specimens from Bed 3 of the Rio Vaccaruzza section (MGPT-PU 143261-143262).

Size: The specimens measure: (MGPT-PU 143261, Fig. 29 a, b) H = 1.8 mm, W = 1.0 mm, W/H = 0.54; (MGPT-PU 143262) H = 0.7 mm, W = 0.4 mm, W/H = 0.59.

Description. Minute, thin, subcylindrical shell with slight flanks, rounded adapical margin (shoulder) and depressed spiral area. Heterostrophic apex surmounting the shoulder in the form of a spherical protuberance. The aperture is narrow and widens piriformis in the abapical sector; the internal lip is slightly reversed producing a short columellar fold. The surface is engraved by fine spirals and growth lines, the last being more visible on the shoulder.

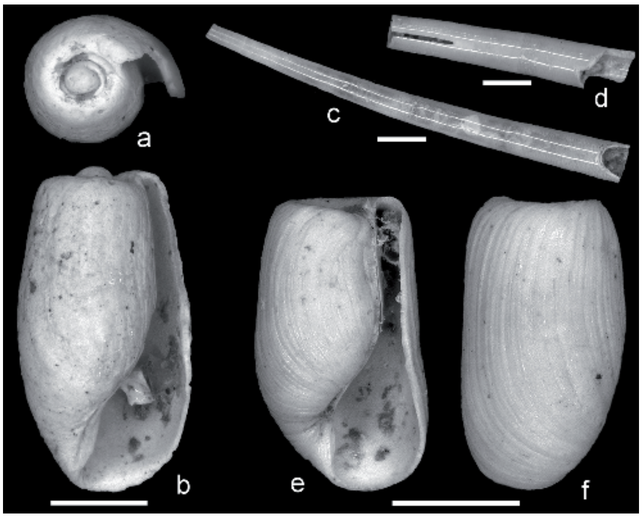

Fig. 29 - [a, b] *Retusa mammillata* (Philippi, 1836), MGPT-PU 261, Rio Vaccaruzza, Bed 9. [c] *Episiphon filum* (Sowerby, 1860), MGPT-PU 143266, Rio Vaccaruzza, Bed 3. [d] *Fustiaria rubescens* (Deshayes, 1826), MGPT-PU 143267, Rio Vaccaruzza, Bed 3. [e, f] *Retusa minutissima* (Monterosato, 1878), MGPT-PU143264, Rio Vaccaruzza, Bed 3. Scale bars: 0.50 mm.

Remarks. The most relevant feature is represented by the surmounting apex that is visible also in the lateral view. The specimens examined for this study are characterized by a medium size, since the species can develop up to 3 mm (Gofas et al. 2011).

Distribution. *R. mammillata* is largely distributed in the Western Atlantic and Mediterranean Sea (Gofas et al. 2011). The fossil record seems to be restricted to the Pleistocene, in particular to the Lower Pleistocene of Tuscany (Menesini & Ughi 1983) and Monte Mario, Rome (Cerulli Irelli 1910 in 1907-1916), and from the Upper Pleistocene of Puglia (Caldara 1986). As far as we know, this is the first record of *Retusa mammillata* for the Italian Pliocene.

Retusa minutissima (Monterosato, 1878)

Fig. 29 e-f

1878 *Utriculus minutissimus* Monterosato (ex H. Martin ms), p. 159.
2001 *Retusa minutissima* (Monterosato, 1878) - Oliverio & Tringali, p. 131-135, fig. 36-38, 40-44, 54-56.
2001 *Retusa minutissima* (Monterosato, 1878) - Baroncelli et al., p. 229, fig. 2-3.
2005 *Retusa minutissima* (Monterosato, 1878) - Repetto et al., p. 257, fig. 1129.
2011 *Retusa minutissima* (Monterosato, 1878) - Gofas et al., p. 404.
2017 *Retusa minutissima* (Monterosato, 1878) - Repetto et al., p. 137, 139, fig. 4.
2018 *Retusa minutissima* (Monterosato, 1878) - Ceulemans et al., p. 122.

Diagnosis: Espèce caractérisée par sa petite taille et par sa contraction médiane (Monterosato, 1878: 159).

Type: The rich material of Monterosato's collection is stored at the Museo Civico di Zoologia in Roma. Olivero & Tringali (2001) confirmed the species validity of *R. minutissima*; they described many syntypes of the species, but no lectotype was defined.

Material: Ten specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143078, MGPT-PU 143263-143265).

Size. Selected specimens measure: MGPT-PU 143263, H = 1.6 mm, W = 0.9 mm, W/H = 0.54; MGPT-PU 143264, H = 1.3 mm, W = 0.7 mm, W/H = 0.56 (Fig. 29 e, f); MGPT-PU 143265, H = 1.2 mm, W = 0.7 mm, W/H = 0.58.

Description. Microscopic shell with subcylindrical profile and truncated apex. A light compression affects the middle to upper part of the whorl being more evident at the aperture. The bulbous, heterostrophic protoconch is sunken and surrounded by the arched adapical edges (high shoulders) of the whorls. The aperture is surmounting on the apex, becomes restricted in the centre and widens piriformis in the abapical sector; the internal lip is slightly reversed and produces a light columellar fold. The surface is engraved by fine growth lines that become deep on the shoulder and produce an ornamentation by proverse, arcuate riblets.

Remarks. Apart from size and sunken apex, differences with the coexisting *R. mammillata* are the slightly sinuous profile with relief of the shoulder, the adapical riblets and the absence of spiral lines (Ceulemans et al. 2018, p. 122). With these characteristics, the specimens described herein fit well the extant forms, like the Pliocene specimen studied by Baroncelli et al. (2001).

Distribution. *R. minutissima* is widely recorded from the Mediterranean coasts (Oliverio & Tringali 2001; Gofas et al. 2011). Fossils of this species are known only from the Pliocene of Piedmont, at Monale (Baroncelli et al. 2001) and Villalvernia (present work). A Pleistocene record from Sicily needs confirmation based on the doubtful report by Oliverio & Tringali (2001, p. 131).

Class **Scaphopoda** Cuvier, 1797
Order **Dentaliida** Da Costa, 1776
Family Gadilinidae Chistikov, 1975
Genus *Episiphon* Pilsbury & Sharp, 1897

Type-species: *Dentalium filum* Sowerby, 1860

Episiphon filum (Sowerby G.B II, 1860)

Fig. 29 c

1860 *Dentalium filum* Sowerby, p. 99, fig. 45.
1872 *Dentalium filum* Sowerby - Monterosato, p. 27.

1979b *Dentalium filum* Sowerby - Di Geronimo, p. 97.
1981 *Dentalium filum* G.B. Sowerby - Gaglini, p. 12-18, fig. 1-4.
1986 *Fustiaria* (*F.*) *filum* (G.B. Sowerby II, 1860) - Gaglini, p. 6, pl. 6, fig. 12.
? 1997 *Episiphon filum* (Sowerby, 1860) - Steiner, p. 102, fig. 2, 4H.
? 2004 *Episiphon filum* ? (Sowerby G.B II, 1860) - Repetto & Lacroce, p. 201, pl. 1, fig. 21.
2005 *Episiphon filum* (Sowerby G.B II, 1860) - Repetto et al., p. 358, fig. 1713.
2009 *Episiphon filum* (Sowerby G.B II, 1860) - Caprotti, p. 33.

Diagnosis: Testa tenui, angustissima, laevi, acuminata, pallide fulva, apice integro (Sowerby, 1860: 99).

Type: No data are available from the literature on the syntypes figured by Sowerby (Gaglini, 1981) stored at the Natural History Museum of London.

Material: One specimen from Bed 3 of the Rio Vaccaruzza section (MGPT-PU 143266: Fig. 29 c).

Size: MGPT-PU 143266, H = 4.8 mm, W = 0.2-0.4 mm, W/H = 0.04-0.08.

Description. Sowerby's supplementary note (They are of thread-like narrowness, smooth, and without fissure) may be detailed as follows: Extremely elongated, slightly curved shell with circular section and very low growth ratio. The shell is transparent, glassy and smooth; no traces of ornaments except ghosts of growth lines at right angle to the shell axis. Both apical and pedal apertures are circular, the former without slit.

Remarks. The family Gadilinidae is represented in Bed 3 by two species that are known from the European Neogene to Present: *Episiphon filum* (Sowerby, 1860) and *Fustiaria rubescens* (Deshayes, 1826). They can be recognized due to the different size: 10-12 mm length of *E. filum* vs 30-35 mm up to 50 mm of *F. rubescens* (Repetto et al. 2005: 358; Gofas et al. 2011: 715); W/H = 0.08 of *E. filum* in Repetto et al. (2005: 358) *vs* W/H = 0.12 of *F. rubescens* in Gofas et al. (2011: 715). For these reasons, the records of *E. filum* reported by Steiner (1997, Recent, Biscay Bay: W/H = 0.12) and Repetto & Lacroce (2004, Pliocene of Piedmont: W/H = 0.13) are to be regarded as doubtful. Moreover, *Fustiaria rubescens* shows a long apical fissure (MGPT-PU 143267, Fig. 29 d; see also Pavia 1991: 128, pl. 6, fig. 11) that is missing in *E. filum*.

Distribution. *Episiphon filum* rarely occurs in the present-day records. Gaglini (1981) listed different localities with *Dentalium gracile* (Jeffreys, 1870) (junior synonym of *D. filum*: Caprotti, 1979, p. 286) from the Bay of Biscay to the entire Mediterranean. A wider distribution outside the Mediterranean Sea (Gaglini 1981; Steiner 1997) cannot be confirmed (Caprotti 2009) especially those from the Western Atlantic. The fossil record is limited to the Upper Pleistocene of Sicily (Monterosato 1872; Di Geronimo 1979b). To the best of our knowledge and taking into account the dubious report of Repetto & Lacroce (2004), this is the first record of *Episiphon filum* from the Pliocene of Italy.

Class **BIVALVIA** Linnaeus, 1758
Infraclass **PTERIOMORPHIA** Beurlen, 1944
Order **Pectinida** Gray, 1854
Family Pectinidae Rafinesque, 1815
Genus *Flexopecten* Sacco, 1897

Type-species - *Ostraea flexuosa* Poli, 1795

Flexopecten hyalinus (Poli, 1795)

Fig. 30 a-j

1795 *Ostrea hyalina* Poli, p. 159, pl. 28, fig. 6.
1989 *Lissopecten hyalinus* (Poli, 1795) - Costa, p. 484.
2005 *Lissopecten hyalinus* (Poli, 1795) - Repetto et al., p. 297, fig. 1350.
2007 *Lissopecten hyalinus* (Poli) - Moissette et al., p. 205.
2011 *Flexopecten hyalinus* (Poli, 1795) - Gofas et al, p. 578.
2019 *Flexopecten hyalinus* (Poli, 1795) - Koskeridou et al., p. 5.

Diagnosis: Concha rotundata, transversim divaricata, depressa, tenuissima, aequivalvis, nitida; radiis circiter decim latiusculis, explanatis, obsoletis; auriculis subaequalibus, cardine recto (Poli, 1795: 159).

Type: No data are available from the literature.

Material: 230 specimens from Bed 9 of the Rio Vaccaruzza section (MGPT-PU 143107, MGPT-PU 143268-143273).

Size: Selected specimens measure respectively for height (H), length (L), hinge (h): [right valves] (MGPT-PU 143268, Fig. 30 i, j) H = 24.1 mm, L = 25.5 mm, h = ~ 14 mm, L/H = 1.06; (MGPT-PU 143269, Fig. 30, d, e) H = 11.9 mm, L = 12.6 mm, h = 9.4 mm, L/H = 1.06; (MGPT-PU 143270, Fig. 30 f) H = 7.8 mm, L = 8.3 mm, h = 6.9 mm, L/H = 1.06; [left valves] (MGPT-PU 143271, Fig. 30 g, h) H = 18.0 mm, L = 19.4 mm, h = 12.1 mm, L/H = 1.08; (MGPT-PU 143272, Fig. 30 a, b) H = 11.2 mm, L = 11.9 mm, h = 9.0 mm, L/H = 1.06; (MGPT-PU 143273, Fig. 30 c) H = 13.9 mm, L = 14.5 mm, h = 10.0 mm, L/H = 1.04.

Description. Small, biconvex, nearly subequilateral and equivalve shells; dorsal to ventral height (H) up to 28 mm and antero-posterior length (L) up to 30 mm. The outline is suboval and the pointed umbo is flanked by large, triangular auricles, of which the anterior ones are more developed. The anterior auricle of the right valve is elongated to protect the byssus; the deep byssate notch points to the umbonal flank and bears three to four small spines that are also present on

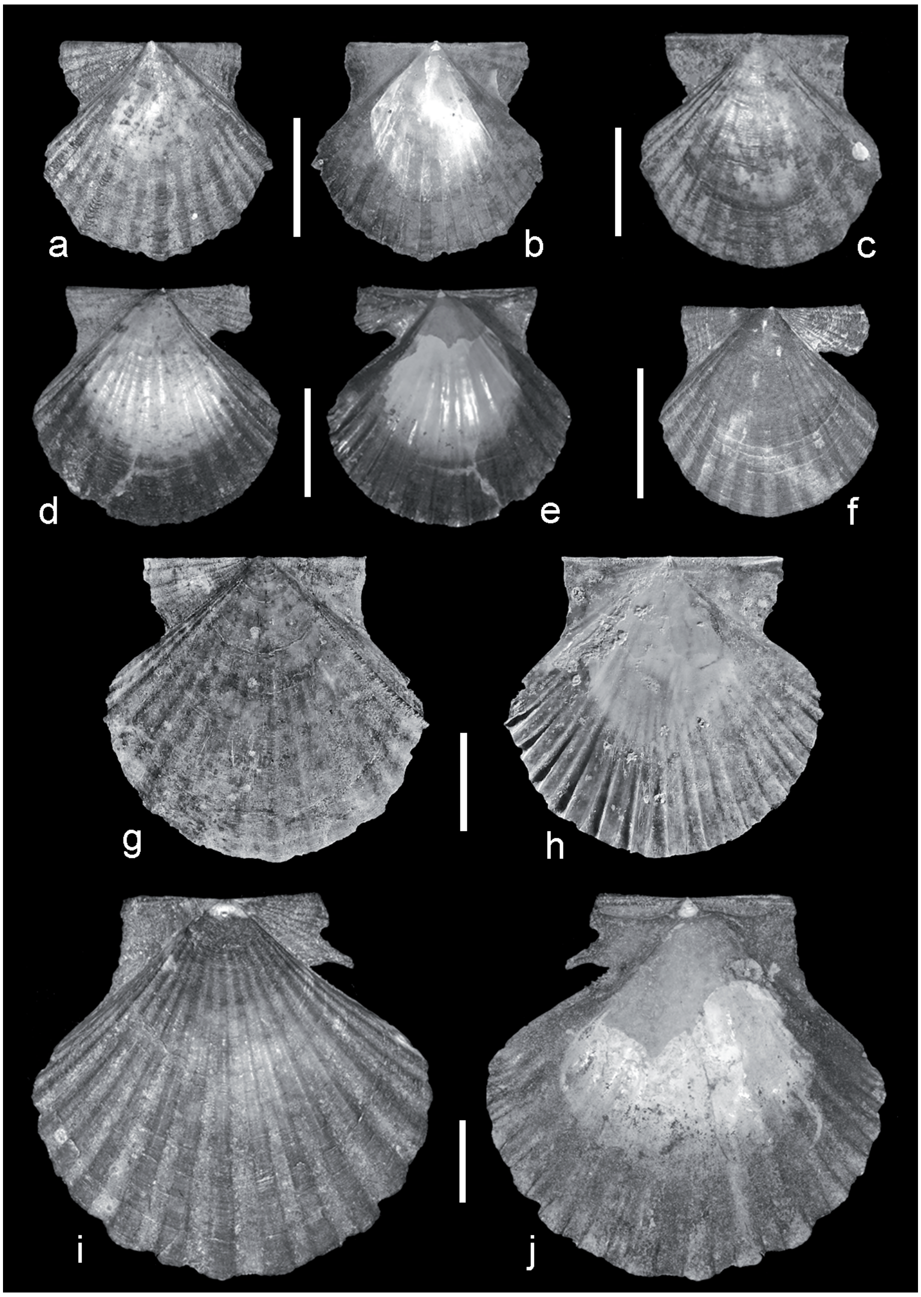

Fig. 30 - [a-j] *Flexopecten hyalinus* (Poli, 1795), Rio Vaccaruzza, Bed 9: (a, b) MGPT-PU 143272, left valve, respectively external and internal views; (c) MGPT-PU 143273, left valve, external view; (d, e) MGPT-PU 143269, right valve, respectively external and internal views; (f) MGPT-PU 143270, right valve, external view; (g, h) MGPT-PU 143271, left valve, respectively external and internal views; (i, j) MGPT-PU 143268, right valve, respectively external and internal views. Scale bars: 5.00 mm.

the left valve in the same position. Seven riblets, made thorny by growth lines, occur on the anterior auricle, whereas the posterior one bears eight to ten less raised riblets. Both valves have 17-19 large radial ribs that are depressed with a subrectangular section around the umbo; they acquire prominence towards the ventral margin. The left valve, less convex, has more prominent marginal riblets which are also crenulated by growth lines.

Distribution and habitat. *Flexopecten hyalinus* occurs in the Mediterranean area since the Pliocene (Monegatti & Raffi 2001: 183). The oldest records date back to the Pliocene of Rhodes (Moissette et al. 2007) and Tuscany (S. Dominici, pers. comm.). In the Pleistocene it has been reported from Rhodes Island (Koskeridou et al. 2019) and Sicily (Ragusa area: Costa 1989). This is the first record from the Pliocene of Piedmont.

F. hyalinus is a typical inhabitant of the *Posidonia* meadows. Our sample includes specimens with a broad size spectrum from 0.2 mm to 30 mm with a sample dominance of 0.20 % (see Table 6). The population datum and its structure confirm the taphonomic analysis that consider the fossil assemblage from Bed 9 as an autochthonous deposit, in which *F. hyalinus* represents the biotic fraction living byssate on the roofs and stems of the *Posidonia* sp. structures.

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APPENDIX

This table lists the 504 molluscs recognized from the fossil assemblages of the Rio Vaccaruzza Bed 3 and Bed 9 with specification of their autoecological parameters and values of Ab (abundance) and D (dominance). The Ab and D values derive only from the bulk-samplings. The taxa collected only by hand-sampling are marked as "n.q." (not quantifiable). In the "Villalvernia collection" supplementary specimens were added after further researches on the outcrop: in the systematic descriptions we take account of this increase. Empty boxes indicate taxa not found in that bed. The asterisk in the column "B & S" refers to the species cited in the monographs of Bellardi (1872-1888), Bellardi & Sacco (1890) and Sacco (1890-1904). The small asterisks preceding selected binomens indicate the taxa recorded for the first time in the Pliocene assemblages of TPB: a single asterisk is used for the taxa already known from Italian Pliocene outcrops, whereas a double asterisk is used for the taxa recorded herein as fossils for the first time, being known only from extant Mediterranean biotopes.

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
	GASTROPODA							
Lottiidae	_Tectura virginea_ (Mueller, 1776)				1	0.01	pref. AP, C	infral.- circal.
Scissurellidae	_Scissurella costata_ d'Orbigny, 1824		n.q.	n.q.	n.q.	n.q.	DC, C	circal.
Haliotidae	_Haliotis tuberculata_ Linnaeus, 1758				9	0.06	pref. AP, HP, C	infral.- circal.
Fissurellidae	_Diodora graeca_ (Linnaeus, 1758)	*	4	0.03	6	0.04	AP, HP, C	infral.- circal.
Trochidae	_Clanculus corallinus_ (Gmelin, 1791)	*			79	0.54	HP, C, M	infral.- circal.
	Gibbula ardens (Salis Marschlins, 1793)		1	0.01			HP	infral.
	Gibbula guttadauri fanuloides (Sacco, 1896)				n.q.	n.q.	HP, SGCF	infral.
	Gibbula magus (Linnaeus, 1758)	*	9	0.08	1	0.01	SGCF, pref. DC	infral.- circal.
	Gibbula seguenzai (De Stefani & Pantanelli, 1878)				49	0.33	(?) AP, HP	infral.- circal.
	Jujubinus montagui (Wood, 1828)				1	0.01	DC, DE, DL	infral.- circal.
	Jujubinus striatus (Linnaeus, 1758)	*			1715	11.7	AP, HP, C	infral.- circal.
	Calliostoma conulus (Linnaeus, 1758)	*			3	0.02	HP, C, M	infral.- circal.
	*_Calliostoma_ cf. _gualterianum_ (Philippi, 1848)				32	0.22	AP, HP, C, M	infral.
Chilodontidae	_Danila sublimbata_ (d'Orbigny, 1852)		n.q.	n.q.			(?) DC	circal.
Turbinidae	_Bolma rugosa_ (Linnaeus, 1767)	*	2	0.02	41	0.28	SGCF, DC, C	infral.- circal.
Skeneidae	*_Skenea bogii_ Chirli, 2004				65	0.44	(?) HP	infral.- circal.
	Dikoleps sp. ind.				1	0.01		
Phasianellidae	_Tricolia pullus_ (Linnaeus, 1758)	*	5	0.04			pref. AP	infral.
	Tricolia tenuis (Michaud, 1829)				340	2.32	AP, HP	infral.
Neritidae	_Nerita zatinii_ Inzani & Bertarelli, 1985		2	0.02				
Cerithiidae	_Cerithium crenatum_ (Brocchi, 1814)	*	15	0.13			AP	infral.
	Cerithium varicosum (Brocchi, 1814)		n.q.	n.q.			SGCF, DC, DE	infral.- circal.
	Cerithium vulgatum Bruguière, 1792	*	3	0.03	102	0.7	HP, SVCM	infral.
	Bittium latreillei (Payraudeau, 1826)	*	23	0.20	1606	10.98	AP, HP, C, M	infral.- circal.
	Bittium reticulatum (da Costa, 1778)	*	23	0.20	467	3.19	AP, HP	infral.
	Cerithidium submammillatum (De Rayn. & Ponzi, 185	*	116	1.00	3	0.02	pref. DC, DE	infral.- circal.
Turritellidae	_Turritella aspera_ Sismonda in Mayer, 1868				1	0.01		
	Archimediella subvaricosa (Sacco, 1895)	*	2	0.02	53	0.36	(?) HP	infral.
	Helminthia vermicularis (Brocchi, 1814)	*	34	0.29	3	0.02	Ire	infral.- circal.
	Turritellinella tricarinata (Brocchi, 1814)		174	1.51			PE, pref. VTC	infral.- circal.
Siliquariidae	_Tenagodus ligusticus_ (Della Campana, 1890)		5	0.04			(?) DC, DE	circal.
	Tenagodus obtusus (Schumacher, 1817)				5	0.03	DC, C	circal.
Triphoridae	_Marshallora adversa_ (Montagu, 1803)		10	0.07	10	0.02	AP, C	infral.- circal.
	Monophorus cristulatus Sacco, 1895		1	0.01	19	0.13		
	Monophorus perversus (Linnaeus, 1758)	*	2	0.02	17	0.12	AP, HP, C	infral.
	Monophorus sp. ind.				8	0.05		
	Strobiligera sp. ind.				2	0.01		
	*_Metaxia metaxa_ (Delle Chiaje, 1828)				3	0.02	AP, HP	infral.
Cerithiopsidae	*_Cerithiopsis jeffreysi_ Watson, 1885				5	0.03		infral.
	*_Cerithiopsis_ cf. _micalii_ (Cecalupo & Villari, 1997)				n.q.	n.q.		infral.
	*_Cerithiopsis scalaris_ Locard, 1891				7	0.05		infral.
	*_Cerithiopsis subulata_ (Montagu, 1808)		2	0.02	4	0.03		infral.
	Cerithjiopsis tubercularis (Montagu, 1803)	*			10	0.07		infral.
	Cerithiopsis sp. ind.				1	0.01		infral.
	*_Costulopsis_ cf. _nana_ (Jeffreys, 1867)				n.q.	n.q.		infral.
	*_Krachia cylindrata_ (Jeffreys, 1885)				n.q.	n.q.		infral.
	Dizonopsis bilineata (Hoernes, 1848)				2	0.01		infral.
Rissoidae	_Rissoa angulatacuta_ (Sacco, 1895)	*			30	0.21	(?) AP, HP	infral.
	Rissoa guerinii Récluz, 1843	*	5	0.04	243	1.66	AP, HP	infral.
	*_Rissoa parva_ (da Costa, 1778)				17	0.12	SVCM, LEE	

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
	Rissoa variabilis (Megerle von Muehlfeld, 1824)				1	0.01	pref. AP, HP	infral.
	Pusillina inconspicua (Alder, 1844)		2	0.02	9	0.06		infral.- circal.
	Pusillina lineolata (Michaud, 1830)	*			51	0.35	HP, SGCF	infral.- circal.
	*_Pusillina_ cf. _nilae_ Bogi & Chirli, 2004				5	0.03		
	Pusillina sulzeriana (Risso, 1826)	*	7	0.06	604	4.13	AP, HP	infral.
	*_Setia turriculata_ Monterosato, 1884				1	0.01	AP, C	
	Alvania bonellii Palazzi, 1996	*			47	0.32	(?) HP	infral.
	Alvania cancellata (da Costa, 1778)	*			26	0.18	Ire	infral.- circal.
	Alvania cimex (Linnaeus, 1758)	*	34	0.29	2031	13.88	HP, C, M	infral.- circal.
	*_Alvania frediani_ Della Bella & Scarponi, 2000				1	0.01		
	Alvania lactea (Michaud, 1830)	*	1	0.01	108	0.74		infral.
	*_Alvania_ cf. _magistriplicata_ Chirli, 2006				n.q.	n.q.		
	Alvania pagodulina (Sacco, 1895)	*	8	0.07	173	1.18	(?) HP	
	Alvania punctura (Montagu, 1803)	*			29	0.20	DC, DE	infral.- circal.
	Alvania thalia De Stefani & Pantanelli, 1888	*	45	0.39	2876	19.66	(?) HP	(?) infral.
	Galeodinopsis tiberiana (Coppi, 1876)				n.q.	n.q.	AP, HP	infral.
	*_Crisilla semistriata_ (Montagu, 1808)		1	0.01	12	0.08	AP, HP	infral.
	Manzonia crassa (Kanmacher, 1798)	*	1	0.01	37	0.25	AP, HP, C, M	infral.- circal.
	Rissoina bruguierei (Payreaudeau, 1826)				52	0.36	AP, HP	infral.
	Rissoina pusilla (Brocchi, 1814)	*	2	0.02	39	0.27	HP	infral.
	Zebinella decussata (Montagu, 1803)				2	0.01		infral.- circal.
Assimineidae	*Melarhaphe neritoides* (Linnaeus, 1758)				1	0.01		
Truncatellidae	*Truncatella subcylindrica* (Linnaeus, 1767)	*			1	0.01	LEE	mesol.
Iravadiidae	*Hyala vitrea* (Montagu, 1803)	*	3	0.03	n.q.	n.q.	pref. VTC	infral.- circal.
	Rhombostoma imperforatum (Sacco, 1892)	*	9	0.08				infral.- circal.
Adeorbidae	*Circulus striatus* (Philippi, 1836)		n.q.	n.q.			C	infral.- circal.
Tornidae	*Teinostoma minutum* (Conti, 1864)		43	0.37	1	0.01	(?) DE	
	Teinostoma woodi (Hoernes, 1858)		8	0.07	1	0.01	(?) DE	
	Tornus excalliferus (Sacco, 1896)	*	2	0.02				infral.
	Tornus pedemontanus Pavia, 1980		3	0.03	n.q.	n.q.		
Vitrillinidae	*Rotellorbis benoisti* Cossman & Peyrot, 1917				3	0.02		
Caecidae	*Caecum auriculatum* de Folin, 1868	*			4	0.03	AP, HP	infral.
	*_Caecum_ cf. _clarkii_ Carpenter, 1859				1	0.01		
	Caecum trachea Montagu, 1803	*	680	5.89	22	0.15	SGCF, DC, C	infral.- circal.
Epitoniidae	*Epitonium clathrus* (Linnaeus, 1758)		n.q.	n.q.	13	0.09		
	Epitonium elegans (Risso, 1826)				1	0.01		
	Epitonium cf. *pedemontanum* (Sacco, 1891)				n.q.	n.q.		
	Epitonium pliosubappenninum (Sacco, 1891)	*			2	0.01		
	Epitonium pulchellum (Bivona, 1832)		n.q.	n.q.				
	Epitonium turtonis (Turton, 1819)	*	6	0.05			pref. SFBC	infral.- circal.
Aclididae	*_Aclis cellinii_ Chirli, 2009		2	0.02	7	0.05		
	Aclis proascaris Sacco, 1891	*			2	0.01		
Eulimidae	*Eulima glabra* (da Costa, 1778)		9	0.08			pref. VTC	infral.- circal.
	Eulima lactea (Grateloup, 1828)	*			2	0.01		
	Melanella bipartita (Moerch, 1859)		2	0.02	10	0.07		
	Melanella pseudoptusa Sacco, 1892				3	0.02		
	Melanella spina (Boettger, 1893)		1	0.01	13	0.09		
	* _Vitreolina philippi_ (de Rayneval & Ponzi, 1854)				6	0.04	AP	infral.
	Niso eburnea Risso, 1826	*	4	0.03				infral.- circal.
Strombidae	*Tetystrombus coronatus* (Defrance, 1827)		2	0.02			AP, HP	infral.
Aporrhaidae	*Aporrhais pespelecani* (Linnaeus, 1758)		30	0.26				infral.- circal.

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
Xenophoridae	*Xenophora crispa* (Koenig, 1825)		9	0.08				circal.
	Xenophora infundibulum (Brocchi, 1814)		1	0.01				
Vanikoridae	*Cymenorytis dellabellai* Sosso et al., 2013		6	0.05				
Calyptraeidae	*Calyptraea chinensis* (Linnaeus, 1758)	*	227	1.96	48	0.33	Ire	infral.- circal.
	Crepidula bellardii n. sp.	*			30	0.21	(?) HP	infral.
	Crepidula gibbosa Defrance, 1818	*	11	0.10	3	0.02	Ire	infral.
	Crepidula unguiformis Lamarck, 1822	*	11	0.10	n.q.	n.q.	pref. SGCF, DC	infral.- circal.
Capulidae	*Capulus ungaricus* (Linnaeus, 1758)		3	0.03			DC, DL, VTC	circal.
	Capulus sinuosus (Brocchi, 1814)		2	0.02				infral.- circal.
Vermetidae	*Petaloconchus deshayesi* (Mayer, 1889)		3	0.03				infral.
	Petaloconchus intortus (Lamarck, 1818)	*	46	0.40	n.q.	n.q.	SFBC, DE	infral.- circal.
	Thylacodes arenarius (Linnaeus, 1758)		6	0.05			AP	infral.
Cypraeidae	*Schilderia flavicula* (Lamarck, 1810)				n.q.	n.q.		
Triviidae	*Trivia arctica* (Pulteney, 1879)				n.q.	n.q.		infral.
	Niveria dimidiata (Bronn, 1831)				n.q.	n.q.		
	Niveria dorsolaevigata (Cocconi, 1873)				1	0.01		
Eratoidae	*Erato pernana (* Sacco, 1894)	*			32	0.22	(?) HP	
	Erato elongata Seguenza, 1880	*			2	0.01		
	Erato voluta (Montagu, 1803)	*			3	0.02	pref. DC, C	circal.
Naticidae	*Natica virguloides* (Sacco, 1891)				3	0.02	(?) HP	
	Cochlis plicatula (Bronn, 1831)		3	0.03			HP, SGCF	infral.- circal.
	Cochlis propinqua (Pecchioli, 1864)	*	63	0.55	n.q.	n.q.	SGCF, VTC	infral.- circal.
	Cochlis pseudoepiglottina (Sacco, 1890)	*	3	0.03			pref. VTC	infral.- circal.
	Cochlis undata (Sasso, 1827)		5	0.04				
	Tectonatica astensis (Sacco, 1890)	*	2	0.02	1	0.01		infral.- circal.
	Tectonatica prietoi (Hidalgo, 1873)				14	0.10	(?) HP	infral.- circal.
	Tectonatica tectula (Sacco, 1890)	*	67	0.58	n.q.	n.q.	DC	infral.- circal.
	Payraudeautia intricata (Donovan, 1804)				3	0.02	HP, C	infral.- circal.
	Euspira helicina (Brocchi, 1814)	*	3	0.03	2	0.01	Ire	infral.- circal.
	Euspira nitida (Risso, 1826)		19	0.16				
	Neverita olla (De Serres, 1829)	*	18	0.16			excl. SFBC	infral.- circal.
	Sinum striatum (de Serres, 1829)	*	3	0.03				infral.- circal.
Tonnidae	*Malea orbiculata* (Brocchi, 1814)		n.q.	n.q.				infral.- circal.
Cassidae	*Cypraeacassis pseudocrumena* (d'Orbigny, 1852)		1	0.01				infral.
	Semicassis laevigata (Defrance, 1817)	*	5	0.04			pref. VTC	circal.- bath.
Ranellidae	*Monoplex distortus* (Brocchi, 1814)	*	2	0.02	1	0.01		infral.- circal.
	Monoplex doderleini (D'Ancona, 1873)				1	0.01		
	Monoplex heptagonus (Brocchi, 1814)				1	0.01		
Bursidae	*Bursa nodosa* (Borson, 1825)				n.q.	n.q.	pref. SGCF, DC	infral.- circal.
Muricidae	*Bolinus brandaris torularius* (Lamarck, 1822)		25	0.22			AP, DE	infral.- circal.
	Heraplex hoernesi (d'Ancona, 1871)		n.q.	n.q.				
	Heraplex tapparonii (Bellardi, 1873)		n.q.	n.q.				
	Purpurellus veranyi (Paolucci, 1886)		3	0.03				
	Favartia absona (de Cristofori & Jan, 1832)		1	0.01				
	Hadriania truncatula (Foresti, 1868)		2	0.02	3	0.02		
	Dermomurex scalaroides (Blainville, 1829)	*			3	0.02	SGCF, C	infral.- circal.
	Ocenebra ariesiana (Fontannes, 1882)		1	0.01				infral.
	Ocenebra erinaceus (Linnaeus, 1758)	*	3	0.03			SFBC, SGCF	infral.- circal.
	* *Ocinebrina aciculata* (Lamarck, 1822)				111	0.76	HP, C	infral.
	* *Ocinebrina imbricata* (Brocchi, 1814)		1	0.01				infral.
	Ocinebrina scalaris (Brocchi, 1814)		2	0.02			pref. SFBC, DC	infral.- circal.

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
	Muricopsis cristata (Brocchi, 1814)		9	0.08				
	Orania turrita (Borson, 1821)		6	0.04	6	0.04		
	Heteropurpura inflexa (Doderlein, 1864)		n.q.	n.q.	n.q.	n.q.		
	Heteropurpura polymorpha (Brocchi, 1814)		43	0.37				infral.- circal.
	Typhinellus labiatus (de Cristofori & Jan, 1832)	*	3	0.03	17	0.12	pref. SVMC, HP	infral.- circal.
	Spinucella monacanthus (Brocchi, 1814)		1	0.01				
	Spinucella praecedens (Bellardi, 1882)		n.q.	n.q.				
	Coralliophila cf. *bracteata* (Brocchi, 1814)		n.q.	n.q.				
	*_Coralliophila_ cf. _meyendorffii_ (Calcara, 1845)		1	0.01			AP	infral.
Fasciolariidae	*Tarantinaea iriae* (Bellardi, 1884)	*	1	0.01	5	0.03		
	Tarantinaea subfimbriata (Bellardi, 1884)	*	1	0.01	6	0.04	(?) HP	infral.
	Fusinus clavatus (Brocchi, 1814)		n.q.	n.q.	n.q.	n.q.		infral.- circal.
	Fusinus longiroster (Brocchi, 1814)		1	0.01				
Buccinidae	*Euthria cornea* (Linnaeus, 1758)		5	0.04	n.q.	n.q.	AP, HP, DC	infral.- circal.
	Aplus ansus (De Gregorio, 1884)	*	3	0.03	117	0.80	(?) HP	infral.
	Aplus nilus (De Gregorio, 1884)	*	2	0.02	34	0.23	(?) AP, HP	infral.
	Chauvetia brunnea (Donovan, 1804)	*	2	0.02	59	0.40	AP, HP	infral.
Nassariidae	*Nassarius andonae* (Bellardi, 1882)	*	n.q.	n.q.				infral.
	Nassarius asperatus (Cocconi, 1873)	*	2	0.02	16	0.11	pref. HP	infral.
	Nassarius bonellii (Bellardi, 1882)		n.q.	n.q.				
	Nassarius bugellensis (Bellardi, 1882)		41	0.36			SGCF	infral.
	Nassarius catulloi (Bellardi, 1882)		n.q.	n.q.				
	Nassarius clathratus (Born, 1778)		23	0.20			pref. SFBC, DC	infral.- circal.
	Nassarius incrassatus (Stroem, 1768)		71	0.61			pref. HP	mesol.- infral.
	Nassarius lima (Dillwyn, 1817)		11	0.10	1	0.01	DE	infral.- circal.
	Nassarius longoastensis (Sacco, 1890)		9	0.08				infral.
	Nassarius macrodon (Bronn, 1831)				2	0.01		
	Nassarius musivus (Brocchi, 1814)	*	14	0.12			SFBC	infral.
	Nassarius productus (Bellardi, 1882)		9	0.08			SGCF	infral.- circal.
	Nassarius semistriatus (Brocchi, 1814)		195	1.69			excl. DE	infral.- circal.
	Nassarius serraticosta (Hoernes, 1852)		6	0.05	36	0.25		infral.- circal.
	Nassarius serratus (Brocchi, 1814)		119	1.03			pref. VTC	infral.- circal.
	Nassarius turgens (Bellardi, 1882)	*			18	0.12	(?) AP, HP	
	*_Nassarius strobilanus (_ Cocconi, 1873)		n.q.	n.q.				
	Cyclope neritea (Linnaeus, 1758)		n.q.	n.q.			LEE, SFBC, SRPV	mesol.- infral.
Columbellidae	*Columbellopsis astensis* (Bellardi, 1890)		n.q.	n.q.				
	Anachis corrugata (Brocchi, 1814)		1	0.01	20	0.14		
	Anachis semicostata (Sacco, 1890)				n.q.	n.q.		
	Mitrella astensis (Bellardi in Sacco, 1890)				79	0.54	SFBC, HP	infral.
	Mitrella minor (Scacchi, 1836)		4	0.03	60	0.41	(?) HP	infral.
	Mitrella scripta (Linnaeus, 1758)	*			30	0.21	AP, HP	infral.- circal.
	Mitrella subulata (Brocchi, 1814)		5	0.04				
	Mitrella villalvernensis (Sacco, 1890)	*			57	0.39	(?) HP	infral.
Mitridae	*Mitra abscissa* Bellardi, 1887	*	5	0.04				
	Mitra astensis Bellardi, 1887				2	0.01		
	Mitra expressa Bellardi, 1887	*			n.q.	n.q.		
	Mitra gemina Bellardi, 1887	*			2	0.01		
	Mitra aff. *imminuta* Bellardi, 1887				1	0.01		
	Mitra inedita Bellardi, 1887		n.q.	n.q.				
	Mitra villalvernensis Bellardi, 1887	*			2	0.01		
	Episcomitra fusiformis (Brocchi, 1814)		1	0.01				

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
	Cancilla alligata (Defrance, 1824)		2	0.02				infral.
	Cancilla bonellii (Bellardi, 1887)		2	0.02				
	Cancilla planicostata (Bellardi, 1887)		5	0.04				
Costellariidae	*Pusia ebenus* (Lamarck, 1811)				15	0.10	AP, HP	infral.- circal.
	Pusia eoebenus (Bellardi, 1887)				2	0.01		infral.- circal.
	Pusia savignyi (Payraudeau, 1826)				31	0.21	AP	infral.
Cancellariidae	*Bivetiella cancellata* (Linnaeus, 1767)	*	18	0.16			AP, DE, C	infral.- circal.
	Tribia uniangulata (Deshayes, 1830)	*	3	0.03				
	Sveltia varicosa (Brocchi, 1814)	*	7	0.06				infral.- circal.
	Trigonostoma parvotriangula Sacco, 1894	*	n.q.	n.q.				
	Trigonostoma umbilicare (Brocchi, 1814)		1	0.01			SFBC	infral.- circal.
Marginellidae	*Granulina clandestina* (Brocchi, 1814)	*	7	0.06	812	5.55	pref. AP, HP, C	infral.- circal.
Cystiscidae	*Gibberula irjae* (Sacco, 1890)	*	1	0.01	213	1.46	AP, HP	infral.
Clathurellidae	*Comarmodia gracilis* (Montagu, 1803)		2	0.02			C	infral.- circal.
	Comarmondia stria (Calcara, 1839)		1	0.01	1	0.01		
Clavatulidae	*Clavatula interrupta* (Brocchi, 1814)	*	2	0.02				infral.
	Clavatula rustica (Brocchi, 1814)	*	28	0.24	19	0.13	(?) AP, HP	infral.
Conidae	*Conus dellabellai* n. sp.		1	0.01	20	0.14	(?) HP	infral.- circal.
	Conus pelagicus (Brocchi, 1814)				n.q.	n.q.		
	Conus pyrula (Brocchi, 1814)		n.q.	n.q.			SFBC, AP	
	Conus villalvernensis n. sp.		2	0.02	8	0.05	(?) AP, HP	infral.
Drilliidae	*Crassopleura incrassata* (Dujardin, 1837)	*			2	0.01	DC, C	infral.- circal.
Pseudomelatonid	*Crassispira brocchii* (Bellardi, 1847)		42	0.36	27	0.18	SGCF, DC	infral.- circal.
Mangeliidae	*Bela nebula* (Montagu, 1803)	*	5	0.04	1	0.01	pref. SFBC, DE	infral.- circal.
	Bela scalariformis (Brugnone, 1862)		3	0.03	n.q.	n.q.		
	Bela submarginata (Bellardi, 1847)	*	6	0.05				infral.
	Bela turgida (Reeve, 1844)	*	4	0.03	n.q.	n.q.		infral.- circal.
	Smithiella ambigua (Brugnone, 1862)		1	0.01				infral.- circal.
	Mangelia attenuata (Montagu, 1803)	*	4	0.03	n.q.	n.q.	pref. SFBC, DE	infral.- circal.
	Mangelia belaeformis (Bellardi, 1877)		3	0.02				
	Mangelia biondii Bellardi, 1877	*			n.q.	n.q.		
	Mangelia clathrata (de Serres, 1829)	*	1	0.01	118	0.81	AP, HP	infral.
	Mangelia frumentum (Brugnone, 1862)		1	0.01				
	Mangelia mitreola Bellardi, 1877	*	9	0.08				infral.
	Mangelia unifasciata (Deshayes, 1835)	*			22	0.15	AP, HP, C	infral.- circal.
	Neoguraleus hispidulus (Jan in Bellardi, 1847)		3	0.03				infral.- circal.
	Neoguraleus vulpeculus (Brocchi, 1814)		1	0.01			pref. SFBC	infral.- circal.
	Pyrgocythara rugosissima (Brugnone, 1862)	*			10	0.07		
	Sorgenfreispira brachystoma (Philippi, 1844)		3	0.03			pref. DC, DE	infral.- circal.
Mitromorphidae	* *Mitromorpha columbellaria* (Scacchi, 1836)				23	0.16	HP, C	infral., circal.
Raphitomidae	*Raphitoma echinata* (Brocchi, 1814)	*	1	0.01	4	0.04	HP, C	infral.- circal.
	Raphitoma histrix (Bellardi, 1847)		1	0.01				infral.- circal.
	Raphitoma michaudi (Bellardi, 1877)				n.q.	n.q.		
	Raphitoma cf. *pupoides* (Monterosato, 1884)				1	0.01		
	Raphitoma philberti (Michaud, 1829)	*			n.q.	n.q.		
	Leufroyia leufroyi (Michaud, 1828)				7	0.05	HP, C	infral.
	Leufroyia raynevali (Bellardi, 1877)				1	0.01		
	Pleurotomoides tumidula (Brugnone, 1875)		n.q.	n.q.				
	Teretia teres (Forbes, 1844)		n.q.	n.q.				
??	*Andonia bonellii* (Bellardi & Michelotti, 1840)		n.q.	n.q.	1	0.01		infral.- circal.
Terebridae	*Hastula costulata* (Borson, 1820)	*	2	0.02				

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
	Hastula farinesi (Fontannes, 1881)	*	2	0.02				infral.- circal.
	Strioreterebrum reticulare Pecchioli in Sacco, 1891	*	32	0.28			pref. SFBC	infral.- circal.
	Subula fuscata (Brocchi, 1814)		11	0.10			pref. SFBC	infral.- circal.
	Terebra acuminata Borson, 1820		6	0.05				infral.- circal.
Architectonicidae	*Psilaxis simplex* (Bronn, 1831)	*			n.q.	n.q.		infral.- circal.
	Pseudotorinia architae (Costa, 1841)				3	0.02		
Mathildidae	*Mathilda quadricarinata* (Brocchi, 1814)				2	0.01	C	infral.- circal.
Omalogyridae	*Omalogyra simplex* (Costa, 1861)				n.q.	n.q.		infral.- circal.
Cimidae	**Graphis albida* (Kanmacher, 1798)				2	0.01	AP	infral.
	***Graphis striata* (Philippi, 1884)		1	0.01				infral.
Pyramidellidae	*Chrysallida curvicostata* (Wood, 1848)		29	0.25				
	**Chrysallida cylindrata* (Cerulli Irelli, 1914)		4	0.03	n.q.	n.q.		
	Chrysallida excavata (Philippi, 1836)		n.q.	n.q.	12	0.08	AP, HP	infral.
	Tragula fenestrata (Jeffreys, 1848)	*	28	0.24	3	0.02	DC, C	infral.- circal.
	Chrysallida fenestratoides (Sacco, 1892)	*	1	0.01				
	Chrysallida holthuisi (van Aartsen et al., 1998)				n.q.	n.q.		
	Chrysallida incerta (Milaschewitsch, 1916)		4	0.03	n.q.	n.q.		
	Parthenina indistincta (Montagu, 1808)		1	0.01	1	0.01	DC	infral.- circal.
	Chrysallida interstincta (Adams, 1797)		6	0.05	3	0.02		infral.- circal.
	**Chrysallida jeffreysi* (Bell, 1872)		1	0.01	n.q.	n.q.		
	Strioturbonilla sigmoidea (Monterosato, 1880)		6	0.05	n.q.	n.q.		infral.
	Strioturbonilla aff. *sigmoidea* (Monterosato, 1880)		1	0.01				
	Pyramidella obtusior (Semper, 1861)	*	1	0.01				
	Pyramidella plicosa Bronn, 1838	*			3	0.02		infral.- circal.
	Eulimella acicula (Philippi, 1836)	*	3	0.03			Ire	infral.- bath.
	Eulimella persuturatoturris Sacco, 1892		4	0.03	n.q.	n.q.		infral.- circal.
	Eulimella scillae (Scacchi, 1835)	*	4	0.03				circal.- bath.
	Eulimella subalpina Sacco, 1892		5	0.04				circal.- bath.
	Eulimella subumbilicatoides Sacco, 1892	*	6	0.05	n.q.	n.q.		
	Eulimella turricompactilis Sacco, 1892		7	0.06				
	Eulimella sp. ind.		1	0.01				
	Odostomia acuta Jeffreys, 1848	*	9	0.08			DC, VTC	circal.-bath.
	Odostomia aperta Pavia, 1976		8	0.07				
	Odostomia aplicangulata (Sacco, 1892)		4	0.03	12	0.08		
	Odostomia conoidosubulina (Sacco, 1892)				2	0.01		
	Odostomia planatina (Sacco, 1892)				1	0.01		
	Odostomia rotundumbilicina (Sacco, 1892)	*	1	0.01	8	0.05		
	Odostomia unidentata (Montagu, 1803)		9	0.08	3	0.02		infral.- circal.
	Odostomia sp. ind.		3	0.03				
	Megastomia conoidea (Brocchi, 1814)	*	71	0.49	71	0.49	Ire	infral.- bath.
	Odetta chirlii n. sp.		2	0.02	28	0.19		
	Ondina curta n. sp.				n.q.	n.q.		
	**Ondina diaphana* (Jeffreys, 1848)		1	0.01	1	0.01		infral.
	Ondina elongata n. sp.		7	0.06	n.q.	n.q.		
	Ondina pseudovitrea n. sp.				25	0.17	(aff.) HP, DC	aff. infral.
	**Ondina warreni* (Thompson, 1845)		2	0.02	4	0.03		infral.
	Pyrgiscus jeffreysii (Jeffreys, 1848)				1	0.01	AP, HP, C	infral.- circal.
	Pyrgiscus rufus (Philippi, 1836)	*	6	0.05	1	0.01	PE	infral.- circal.
	Turbonilla acutissima Monterosato, 1884		2	0.02			GSO	
	Turbonilla amplisuturata (Sacco, 1892)		3	0.03				
	Turbonilla astensidelicata Sacco, 1892	*	26	0.23	11	0.07		

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
	Turbonilla bilineata Seguenza, 1876	*	1	0.01	51	0.35	(?) AP, HP	infral.
	Turbonilla delicata (Monterosato, 1874)	*	6	0.05				
	Turbonilla internodula (Wood, 1848)	*	6	0.05	25	0.17		infral.- circal.
	Turbonilla intuspersulcata Sacco, 1892		5	0.04				infral.- circal.
	Turbonilla lactea (Linnaeus, 1758)	*			2	0.01	SFBC	infral.- circal.
	Turbonilla lacteopusilla Sacco, 1892	*			4	0.03		
	Turbonilla lanceae (Libassi, 1859)		12	0.10				infral.- circal.
	*_Turbonilla plioperstricta_ Chirli, 2011		5	0.04	n.q.	n.q.		
	Turbonilla aff. _plioperstricta_ Chirli, 2011				4	0.03		
	Turbonilla pliopseudogracilis (Sacco, 1892)		n.q.	n.q.				
	Turbonilla pliopupoides (Sacco, 1892)		n.q.	n.q.				
	Turbonilla postacuticostata Sacco, 1892				3	0.02	HP	infral.- circal.
	Turbonilla pseudomarteli Penas & Rolan, 1997		7	0.06				
	*_Turbonilla pumila_ Seguenza, 1876		1	0.01	7	0.05		infral.
	Turbonilla pusilla (Philippi, 1844)	*			3	0.02	HP	infral.
	Turbonilla striatula (Linnaeus, 1758)				3	0.02	HP	infral.- circal.
	Turbonilla turritodelicata Sacco, 1892	*			3	0.02		
	*_Turbonilla victoriae_ (Pantanelli, 1880)				1	0.01		
	Turbonilla sp. ind.		1	0.01	n.q.	n.q.		
Amathinidae	_Carinorbis clathrata_ (Philippi, 1844)	*	9	0.08	1	0.01		infral.
Murchisonellidae	*_Anisocycla nitidissima_ (Montagu, 1803)				1	0.01		infral.- circal.
	*_Anisocycla pointeli_ (de Folin, 1868)		1	0.01				infral.- circal.
	**_Anisocycla striatula_ (Jeffreys, 1856)				1	0.01		infral.
	Anisocycla subcylindrica n. sp.		2	0.02				
Acteonidae	_Acteon semistriatus_ (Basterot, 1825)	*	43	0.37	1	0.01	excl. SFBC	infral.- circal.
	Acteon tornatilis (Linnaeus, 1758)		4	0.03	n.q.	n.q.	SFBC	infral.- circal.
	Rictaxis tornatus (Millet, 1854)		3	0.03	12	0.08		
Ringiculidae	_Ringicula_ gr. _auriculata_ (Ménard de la Groye, 1811)	*	135	1.17	10	0.07	Ire	infral.- circal.
Retusidae	_Retusa decussata_ Sacco, 1897	*	2	0.02	50	0.34	HP	infral.
	*_Retusa mammillata_ (Philippi, 1836)		2	0.02			DC	infral.
	Retusa minutissima (Monterosato, 1878)				3	0.02	AP, HP	infral.
	Retusa pliosimplex Sacco, 1897	*			3	0.02		
	Retusa truncatula (Bruguière, 1792)	*	81	0.70	5	0.03	DE	infral.- circal.
	Retusa umbilicata (Montagu, 1803)		2	0.02				infral.- circal.
Rhizoridae	_Valvulella acuminata_ (Bruguière, 1792)	*	7	0.06	n.q.	n.q.	DE	circal.
Cylichnidae	_Acteocina spirata_ (Brocchi, 1814)		65	0.56	2	0.01		infral.- circal.
	Cylichna cylindracea (Pennant, 1777)		3	0.03			SFBC, AP	infral.- circal.
	Roxania utriculus (Brocchi, 1814)		1	0.01			DE, DC	circal.-bath.
Scaphandridae	_Scaphander lignarius_ (Linnaeus, 1758)		1	0.01			C, VTC	circal.
Bullidae	_Bulla striata_ Bruguière, 1792	*	1	0.01	n.q.	n.q.	AP, HP	infral.
Philinidae	_Philine catena_ (Montagu, 1803)				1	0.01	SFBC, HP, DC	infral.- circal.
Haminoeidae	_Haminoea hydatis_ (Linnaeus, 1758)	*			8	0.05	AP, HP, SGCF	infral.- circal.
	Weinkauffia turgidula (Forbes, 1844)		n.q.	n.q.			AP	infral.
Siphonariidae	_Williamia gussonii_ (Costa, 1829)		1	0.01	7	0.05	HP, C	infral.
Ellobiidae	_Ovatella myotis_ (Brocchi, 1814)				n.q.	n.q.		
	SCAPHOPODA							
Gadilinidae	*_Episiphon filum_ (Sowerby II, 1860)		1	0.01				
	Fustiaria rubescens (Deshayes, 1825)		n.q.	n.q.				
Omnygliptidae	_Omniglypta jani_ (Hoernes, 1856)				n.q.	n.q.		
Dentaliidae	_Dentalium sexangulum_ Gmelin, 1790		7	0.06			pref. SFBC	infral.
	Antalis fossilis (Schroeter, 1784)		28	0.24			SFBC	infral.- circal.

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
	Antalis inaequicostata (Dautzenberg, 1891)	*	3	0.03	14	0.10	HP, DC	infral.- circal.
	Antalis novemcostata (Lamarck, 1818)		5	0.04				infral.- circal.
	Antalis vitrea (Gmelin, 1791)	*	17	0.15				infral.- circal.
Gadilidae	*Dischides politus* (Wood, 1842)		1	0.01				
	BIVALVIA							
Nuculidae	*Nucula jeffreysi* Bellardi, 1875		42	0.36	4	0.03		infral.
	Nucula nitidosa Winckworth, 1930		19	0.16	14	0.10	DC, DE	infral.- circal.
	Nucula nucleus (Linnaeus, 1758)	*	34	0.29	1	0.01	pref. DC, C	infral.- circal.
Nuculanidae	*Jupiteria concava* (Bronn, 1821)				n.q.	n.q.		
	Lembulus pella (Linnaeus, 1767)	*	369	3.20			excl. PE, SFBC	infral.- circal.
	Saccella commutata (Philippi, 1844)		270	2.34	n.q.	n.q.	pref. DC, DE, DL	infral.- circal.
Arcidae	*Arca noae* Linnaeus, 1758		7	0.06	6	0.04	AP, HP	infral.
	Arca tetragona Poli, 1795		2	0.02			SGCF, DC	circal.
	Barbatia barbata (Linnaeus, 1758)		2	0.02	4	0.03	AP, HP	
	Barbatia candida (Helbling, 1779)		78	0.66	31	0.21		infral.
	Barbatia modioloides (Cantraine, 1836)				2	0.01	DC	circal.
	Barbatia mytiloides (Brocchi, 1814)		9	0.08				infral.- circal.
	Anadara diluvii (Lamarck, 1805)	*	32	0.28			DC, DL, VTC	circal.
	Anadara pectinata (Brocchi, 1814)	*	52	0.45	n.q.	n.q.		infral.
	Striarca lactea (Linnaeus, 1758)	*	54	0.47	20	0.14	HP, C	infral.- circal.
Glycymerididae	*Glycymeris bimaculata* (Poli, 1795)		177	1.53	1	0.01	SGCF	infral.- circal.
	Glycymeris glycymeris (Linnaeus, 1758)		6	0.05	n.q.	n.q.	SGCF	infral.
	Glycymeris inflata (Brocchi, 1814)		13	0.11	n.q.	n.q.		infral.- circal.
Mytilidae	*Gibbomodiola adriatica* (Lamarck, 1819)		12	0.10			pref. DC, C	infral.- circal.
	Modiolus sp. ind.				3	0.02		
	Mytilus scaphoides Bronn, 1831		n.q.	n.q.			DE	infral.- circal.
	Gragariella petagnae (Scacchi, 1832)		18	0.16	12	0.08	AP	infral.
	Gregariella semigranata (Reeve, 1858)				1	0.01	pref. C	infral.- circal.
Pteriidae	*Pteria hirundo* (Linnaeus, 1758)	*	8	0.07			VTC, acc. HP	infral.- circal.
Pectinidae	*Pecten flabelliformis* (Brocchi, 1814)		2	0.02			SGCF, DC	infral.- circal.
	Pecten jacobaeus (Linnaeus, 1758)		2	0.02			SGCF, escl. DC	infral.- circal.
	Amusium cristatum (Bronn, 1827)		n.q.	n.q.			VTC	infral.- circal.
	Flexopecten flexuosus (Poli, 1795)	*	2	0.02			SGCF, pref. DC	infral.
	**Flexopecten hyalinus* (Poli, 1795)				29	0.20	excl. HP, C	infral.
	Flexopecten inaequicostalis (Lamarck, 1819)		15	0.13	5	0.03		infral.- circal.
	Mimachlamys varia (Linnaeus, 1758)	*	2	0.02	3	0.02	pref. DC	infral.- circal.
	Talochlamys multistriata (Poli, 1795)		6	0.05	25	0.17	HP, pref. DC	infral.- circal.
	Aequipecten opercularis (Linnaeus, 1758)	*	23	0.20			pref. DC	infral.- circal.
	Aequipecten seniensis (Lamarck, 1819)	*	46	0.40			DC	infral.- circal.
	Lissochlamys excisum (Bronn, 1831)	*	2	0.02			SFBC	infral.- circal.
	Palliolum incomparabile (Risso, 1826)				2	0.01	DC, C	circal.
	Spondylus sp. ind.				n.q.	n.q.		infral.- circal.
Spondylidae	*Plicatula mytilina* Philippi, 1836		6	0.05				infral.
Anomiidae	*Anomia ephippium* (Linnaeus, 1761)	*	9	0.08	1	0.01	Ire	infral.- circal.
	Pododesmus patelliformis (Linnaeus, 1761)				1	0.01	pref. DC, C	infral.- circal.
	Pododesmus striatus (Brocchi, 1814)		1	0.01				
Limidae	*Lima paucicostata* (Sowerby, 1843)				1	0.01		
	Limaria exilis (Wood, 1839)		1	0.01			pref. AP, HP	infral.- circal.
	Limaria hians (Gmelin, 1791)				3	0.02	excl. HP	infral.
	**Limatula gwyni* (Sykes, 1903)		2	0.02			escl. DC	circal.- bath.
	Limea strigilata (Brocchi, 1814)		n.q.	n.q.				

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
Ostreidae	_Cubitostrea frondosa_ (de Serres, 1829)		3	0.03			AP, HP	infral.
	Ostrea edulis Linnaeus, 1758		18	0.16				infral.- circal.
	Ostrea sp. ind.				1	0.01		
Carditidae	_Cardita elongata_ Bronn, 1831	*	5	0.04	39	0.27	AP, HP	infral.
	Cardites antiquatus (Linnaeus, 1758)	*	59	0.51	13	0.09	HP, DC	infral.- circal.
	Glans rudista (Lamarck, 1819)	*	461	4,00	8	0.05	HP, SGCF	infral.- circal.
Lucinidae	_Lucina orbicularis_ Deshayes, 1836	*	13	0.11				infral.
	Codakia leonina (Basterot, 1825)		n.q.	n.q.				
	Lucinoma borealis (Linnaeus, 1758)	*	4	0.03	n.q.	n.q.	PE	infral.- circal.
	Loripinus dentatus (Defrance, 1823)	*	22	0.19	6	0.04		infral.
	Loripinus fragilis (Philippi, 1836)	*	14	0.12	n.q.	n.q.	SFBC, DE	infral.- circal.
	Ctena decussata (Costa, 1829)		8	0.07	139	0.95	SVMC, SGCF	infral.
	Lucinella divaricata (Linnaeus, 1758)	*	44	0.38				infral.
	Myrtea spinifera (Montagu, 1803)		13	0.11			SGCF, pref. DC	infral.- circal.
Ungulinidae	_Diplodonta_ cf. _brocchii_ (Deshayes, 1852)	*			1	0.01	lre	infral.- circal.
	Diplodonta intermedia Biondi-Giunti, 1859		21	0.18	1	0.01	lre	infral.- circal.
	Diplodonta rotundata (Montagu, 1803)	*	5	0.04	1	0.01	lre	infral.- circal.
	Diplodonta trigona Philippi, 1836		1	0.01			excl. SGCF	infral.- circal.
Chamidae	_Chama gryphoides_ Linnaeus, 1758		11	0.10	7	0.05	AP, pref. HP	infral.- circal.
	Chama placentina Defrance, 1817	*	3	0.03	4	0.03		infral.- circal.
	Pseudochama gryphina (Lamarck, 1819)		9	0.08	2	0.01	AP, HP	infral.
Galeommatidae	*? _Galeomma turtoni_ Turton, 1825				n.q.	n.q.	HP, C	infral.
	Spaniorinus reconditus (Fischer, 1872)		2	0.02				infral.- circal.
Lasaeidae	_Bornia geoffroyi_ (Payraudeau, 1826)				1	0.01		infral.
	Bornia sebetia (Costa, 1830)	*	165	1.43	13	0.09	SFHN, acc. HP	infral.
	Kellia suborbicularis (Montagu, 1803)		33	0.29	n.q.	n.q.	pref. DC	infral.- circal.
	Pseudopythina macandrewi (Fischer, 1867)		4	0.03			SFHN	infral.
	Scacchia oblonga (Philippi, 1836)		18	0.16			AP	infral.
	Litigiella glabra (Fischer in de Folin & Périer, 1873)	*	n.q.	n.q.	2	0.01		
	*_Hemilepton nitidum_ (Turton, 1822)		3	0.03	1	0.01	LEE, HP	infral.
	Lepton subtrigonum (Fischer, 1874)		2	0.02				infral.
	Montacuta substriata (Montagu, 1808)		2	0.02			DC, C	circal.
	Mioerycina cf. _compressa_ (Philippi, 1844)		1	0.01				
	*? _Planktomya prima_ (Locard, 1899)				n.q.	n.q.		circal.
	*_Kurtiella bidentata_ (Montagu, 1803)		3	0.03	33	0.23	? VTC	infral.- circal.
Cardiidae	_Procardium indicum_ (Lamarck, 1819)		1	0.01				infral.- circal.
	Acanthocardia echinata (Linnaeus, 1758)	*	8	0.07			pref. DE, DC	infral.- circal.
	Acanthocardia paucicostata (Sowerby II, 1834)		2	0.02			DE, VTC	infral.- circal.
	Acanthocardia spinosa (Lightfoot, 1786)		2	0.02			SFBC, DE	infral.- circal.
	Papillicardium papillosum (Poli, 1791)	*	23	0.20	17	0.12	HP, pref. DC	infral.- circal.
	Plagiocardium hirsutum (Bronn, 1831)				n.q.	n.q.	DC	infral.- circal.
	Parvicardium roseum (Lamarck, 1819)		24	0.21	24	0.16	AP, HP	infral.
	Parvicardium scriptum (Bucquoy, Dautz. & Dollf., 1892)		4	0.03	198	1.35	AP, HP	infral.
	Nemocardium striatulum (Brocchi, 1814)		n.q.	n.q.				infral.- circal.
	Laevicardium crassum (Gmelin, 1791)		7	0.06			pref. SGCF, DC	infral.- circal.
	Discors laevinflatum Sacco, 1899	*	n.q.	n.q.				infral.- circal.
	Discors aff. _laevinflatum_ Sacco, 1899				3	0.02		
	Trachycardium multicostatum (Brocchi, 1814)		2	0.02				infral.- circal.
Mactridae	_Mactra stultorum_ (Linnaeus, 1758)				n.q.	n.q.	excl. SFBC	infral.
	Spisula subtruncata (da Costa, 1778)	*	2450	21.22	1	0.01	excl. SFBC	infral.
	Lutraria oblonga (Gmelin, 1791)		1	0.01	1	0.01	SGCF	infral.

FAMILIES	IDENTIFIED TAXA	B-S	BED 3		BED 9		BIOCOENOSiS	BATHYMETRY
			Ab	D	Ab	D		
Tellinidae	*Oudardia compressa* (Brocchi, 1814)		26	0.23			SFBC, DC	infral.- circal.
	Moerella distorta (Poli, 1791)	*	510	4.42	2	0.01	SFBC, PE	infral.- circal.
	Moerella donacina (Linnaeus, 1758)	*	5	0.04			pref. DC	infral.- circal.
	Peronidia albicans (Gmelin, 1791)		70	0.61			excl. SFBC	infral.- circal.
	Peronaea planata (Linnaeus, 1758)		2	0.02			excl. SFBC	infral.- circal.
	*_Asbjornsenia pygmaea_ (Lovén, 1846)		2	0.02	n.q.	n.q.	HP, SGCF, M	infral.- circal.
	Serratina serrata (Brocchi, 1814)		2	0.02			DE	infral.- circal.
	Gastrana fragilis (Linnaeus, 1758)	*			1	0.01	SVMC, LEE	infral.
	Macoma elliptica (Brocchi, 1814)	*	16	0.14	2	0.01		infral.- circal.
	Arcopagia balaustina (Linnaeus, 1758)	*			3	0.02	lre	infral.-bath.
	Arcopagia corbis Bronn, 1831	*	12	0.10			escl. DC	infral.- circal.
	Arcopagia villalvernenis Sacco, 1901	*	3	0.03	1	0.01		
Donacidae	*Donax venustus* Poli, 1795	*	2	0.02			excl. SFBC	infral.
Semelidae	*Abra alba* (Wood, 1802)	*	135	1.17	6	0.04	lre	infral.- circal.
	Abra prismatica (Montagu, 1808)	*	34	0.29			SGCF, pref. DC	infral.- circal.
	Abra stricta (Brocchi, 1814)		25	0.22			HP	infral.
Psammobiidae	*Gari fervensis* (Gmelin, 1791)		90	0.80			SGCF, escl. DC	infral.- circal.
	Gari uniradiata (Brocchi, 1814)		132	1.14	4	0.03		infral.- circal.
Solecurtidae	*Solecurtus candidus* (Brocchi, 1814)		1	0.01			PE	infral.- circal.
	Solecurtus scopula (Turton, 1822)		n.q.	n.q.				infral.
	Azorinus chamasolen (da Costa, 1778)		23	0.20			pref. DC, DE	infral.- circal.
Veneridae	*Venus nux* Gmelin, 1791		94	0.81			DE, pref. VTC	circal.- bath.
	Venus verrucosa Linnaeus, 1758	*	6	0.05	48	0.33	pref. HP	infral.- circal.
	Circomphalus foliaceolamellosus (Dillwyn, 1817)		21	0.18			pref. SFBC	infral.
	Chamelea gallina (Linnaeus, 1758)	*	76	0.66	1	0-01	pref. SFBC	infral.
	Clausinella amidei (De Stefani, 1874)		7	0.06				
	Clausinella brongniartii (Payraudeau, 1826)		1	0.01	1	0.01	pref. SGCF	infral.- circal.
	Clausinella fasciata (da Costa, 1778)	*	11	0.10	n.q.	n.q.	pref. SGCF, DC	infral.- circal.
	Timoclea ovata (Pennant, 1777)	*	518	4.95	86	0.59	lre	infral.- circal.
	Dosinia lupinus (Linnaeus, 1758)	*	125	1.08	2	0.01	pref. SFBC, DE	infral.- circal.
	Pitar rudis (Poli, 1795)	*	87	0.75	10	0.07	SFBC, pref. DC	infral.- circal.
	Callista chione (Linnaeus, 1758)	*	125	1.08			SFBC, SGCF	infral.- circal.
	Callista italica (Defrance, 1818)	*	2	0.02	n.q.	n.q.	pref. SFBC, DC	infral.- circal.
	Callista puella (Philippi, 1844)	*	73	0.63			excl. SFBC	infral.
	Pelecyora gigas (Lamarck, 1818)		n.q.	n.q.			pref. SFBC	infral.
	Gouldia minima (Montagu, 1803)	*	6	0.05	16	0.11	HP, SGCF, DC	infral.- circal.
	Callistotapes vetula (Basterot, 1825)		3	0.02			SFBC	infral.
	Ruditapes decussatus (Linnaeus, 1758)		n.q.	n.q.			escl. SVMC	infral.
	Venerupsis astensis (Mayer, 1857)		2	0.02				infral.
	Irus irus (Linnaeus, 1758)	*			3	0.02	HP, C, M	
Corbulidae	*Varicorbula gibba* (Olivi, 1792)	*	943	8.17	2	0.01	pref. PE, lre	infral.- circal.
	Corbula revoluta (Brocchi, 1814)	*	3	0.03	7	0.05		infral.- circal.
Gastrochaenidae	*Rocellaria dubia* (Pennant, 1777)	*	19	0.16				infral.- circal.
Hiatellidae	*Hiatella arctica* (Linnaeus, 1767)		58	0.50	1	0.01	SGCF, C	infral.- circal.
	Hiatella rugosa (Linnaeus, 1767)		8	0.07	2	0.01	C	infral.- circal.
Solenidae	*Ensis ensis* (Linnaeus, 1758)		18	0.16			SFBC	infral.
Pandoridae	*Pandora inaequivalvis* (Linnaeus, 1758)		1	0.01			SFBC	infral.
Cuspidariidae	*Cuspidaria cuspidata* (Olivi, 1792)		6	0.05			VTC, DL	circal.