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Paleontologic and stratigraphic data from Quaternary deposits of Leghorn subsoil (Italy)

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ABSTRACT The Authors describe two malacofauna fossils attributable, on biostratigraphic and stratigraphic base, to Pleistocene and Late Pleistocene, observed by a drilling carried out in the east of the city of Leghorn, Italy. The malacological fossil association of Pleistocene was low in number of individuals but well characterized in the number of species; the one attributable to the Upper Pleistocene is related to contemporary associations already known in literature for Leghorn subsoil, and shows two species not previously reported. The malacofauna of the Lower Pleistocene is characteristic of the current coastal muddy debris; Tyrrhenian malacofauna mainly consists of allochthonous elements, from a "*Posidonia* meadows" and the depositional environment is attributable to the Mediterranean current seabeds. The stratigraphy of the subsoil of the area differs from that known in literature, as it shows a single level of "Panchina" that rests directly above clay sediments of the Lower Pleistocene.

KEY WORDS Malacofauna; Stratigraphy; Pleistocene; Leghorn.

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INTRODUCTION

The present study is part of a project examining the malacofauna found in sediments forming the substrate of the city of Leghorn (Italy) which is not always investigable directly. This is mainly because of the closure, at the end of the nineteenth century, of all the quarries, and the rapid development, during the last century, of the city itself, which resulted in the obliteration of the last outcrops. In the second half of 1900 were published a few papers of malacology, including one related to the excavation of the dry dock of the "Torre del Fanale" (Barsotti et al., 1974). Therefore, the study of the malacofauna of Leghorn subsoil can be carried out only by analysing new successions, even within the town limits, to refine the knowledge on biotic fossils and compare them with those already known.

Recently, have been published data on two new sections, one at the immediate northeast outskirts of the town in locality "Vallin Buio" (Ciampalini et al., 2014a), where the Tyrrhenian sediments rest directly on those of the Pliocene, and the other one from an excavation inside the town, near the section studied herein, and called section "via Gramsci" from its location (Ciampalini et al., 2014b), in which is highlighted a malacofauna contained in the top level of the "Panchina" formation.

The present paper describes the discovery of two unpublished fossil malacofauna in deposits attributed to Lower Pleistocene and the Upper Pleistocene.

These deposits were brought to light during the execution of a geological drilling for the geotech-nical characterization of the subsoil and herein named, section “via Manasse” (Figs. 1, 2). Within the sediments, in addition to molluscs, were recovered ostracods and foraminifera, whose study was carried out to assess the chronostratigraphic framework of the sediments and their paleoenvironmental characterization.

Geological framework

In the subsoil of Leghorn, in a modest layer of reddish sands (“Sabbie di Donoratico”), there are up to two calcarenitic sands (Panchina) which, on the basis of stratigraphic and faunal evidence, are generally attributable to the Tyrrhenian (Malatesta, 1942; Barsotti et al., 1974; Ciampalini et al., 2006).

The levels of "Panchina" belong to a morphological element known in the literature as "Terrazzo di Livorno" (Barsotti et al., 1974; Lazzarotto et al., 1990), interpreted as a polycyclic marine terrace (Federici & Mazzanti, 1995) that developed during the stage 5 of the marine isotope stratigraphy ("marine isotope stage 5") (Chen et al., 1991; Antonioli et al., 1999). The substrate of this terrace consists of sediments related to the Lower Pleistocene that, based on fossil remains found on several occasions, were attributed to the “Formazione di Morrona” (Bossio et al., 1981; Dall'Antonia et al., 2004; Boschian et al., 2006).

MATERIAL AND METHODS

The sediments analyzed originate from a drilling, the location of which is shown in figure 1, carried out for the geological and geotechnical assessment of the subsoil (Fig. 2). The fossil shells were collected directly from sediments or after washing them. Considering the small amount of sedimentary material available, it has not been possible to recover a large number of complete specimens of large dimensions.

For measures of shells we used the following abbreviations: d = maximum diameter; l = maximum

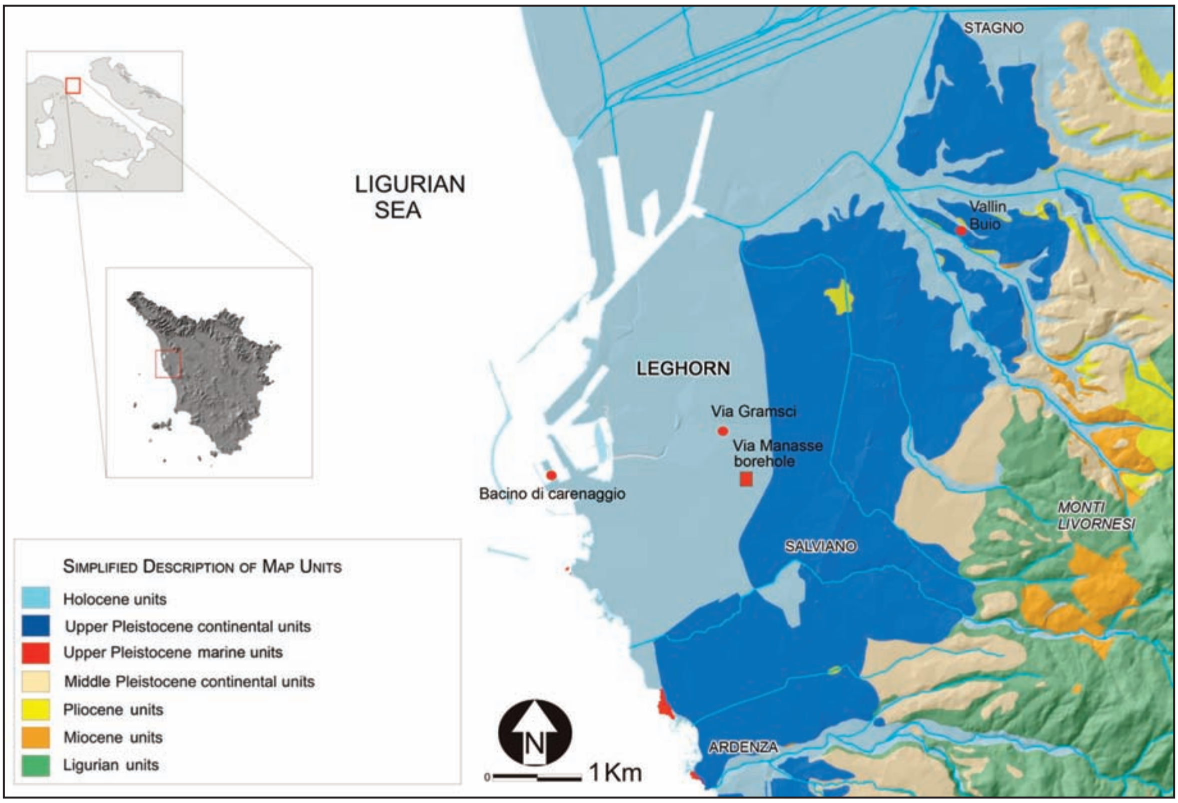


Figure 1. Geological sketch map and location of the investigated borehole from “Via Manasse” (43°33’01” N-10°19’16”E).

width; h = maximum height. The measurements are in millimeters and the specimens figured are numbered in Table 1.

Abbreviations used to indicate the marine biotic communities are according to Pérès & Picard (1964): HP, biocenosis of photophilic algae; SGCF, biocenosis of coarse sands with influence of bottom currents; VTC, biocenosis of coastal terrigenous muds. The list of Tyrrhenian molluscs found in this study, reported in Table 1, is compared with those of other locations recently studied, i.e. "Vallin Buio" and "via Gramsci" (Ciampalini et al., 2014a, 2014b), and with that of the careening basin of the "Torre del Fanale" which is, to date, the largest excavation (Barsotti et al., 1974).

The studied material is deposited, with the catalog number MSNM 827, at the Museum of Natural History of the Mediterranean in Leghorn.

Were weighed 150 g of anhydrous material, employed for the micropalaeontological analysis. The samples were disgregated in water at 100 °C, filtered in sieves with meshes net of 74 µm and then dried in oven at 70 °C. The micropalaeontological analysis was conducted primarily on foraminifera and ostracods. As for the biostratigraphic and palaeoecological appearance of identified taxa, reference is made to the main available papers (Ruggieri, 1973; Dall 'Antonia et al., 2004; Guernet, 2005; Faranda & Gliozzi, 2008).

RESULTS

In the sequence under consideration, starting from ground level, have been recognized seven lithological intervals listed below, from which three samples, indicated with the abbreviations MAN1, MAN2 and MAN3, respectively, were collected, at different elevations (Fig. 3), for micropalaeontological analysis.

Interval 1 (0-0.80 m): dark brown sands, with nodules of Mn. In the first 10-15 cm, dark in color due to the presence of coal, are visible brick fragments that indicate a very recent age;

Interval 2 (0.80-1.10 m): sand with fragments of wood and sand with gravel;

Interval 3 (1.10-3.80 m): ocher sandy silt with Fe-Mn nodules and rare levels of gravel. This level becomes darker in the upper part;

Fig. 2. Core photograph, showing the first 5 meters from ground level; the arrow indicates the portion of the borehole where it was found the Tyrrhenian malacofauna described

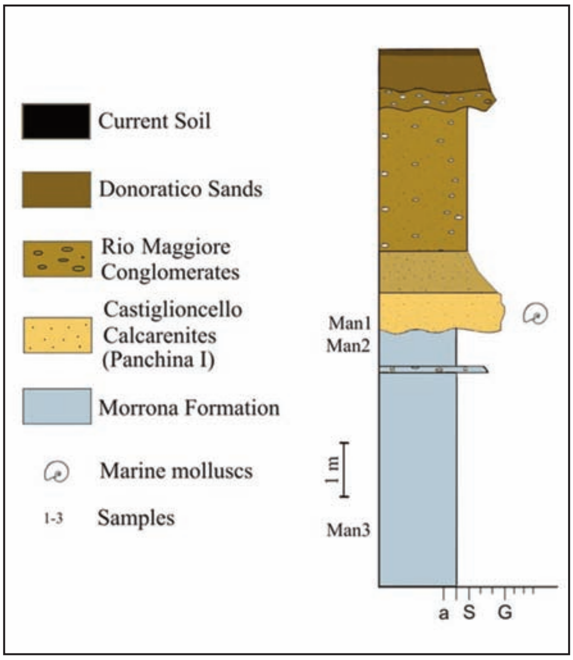


Figure 3. Stratigraphic column of the borehole from "Via Manasse"; sample position is shown; a - Shales, S - Sands, G - Gravels

Interval 4 (3.80-4.50 m): beige calcareous sand, fossiliferous. From this level the sample MAN1 was taken;

Interval 5 (4.5-4.7 m): gray-blue sand. From it the sample MAN2 was taken;

Interval 6 (4.7-10 m): gray blue clayish silt with sandy fossiliferous levels; at 6 m of depth is present a decimeters level of gravel ocher in color. From this range the sample MAN3 was taken;

Interval 7 (10-20 m): gray bluish clay silt with rare fossils.

By micropalaeontological analysis conducted on the sample MAN1, taken within the interval 4, it was observed a malacofauna consisting of few individuals, in good conditions, representing fifteen species of gastropods and four bivalves; the full list is shown in Table 1. By comparison of the species observed with those reported for coeval sections recently described, and those listed for the larger "Bacino di Carenaggio" (see Barsotti et al., 1974; Ciampalini et al. , 2014a, 2014b), it appears the presence of two species not previously reported, i.e. *Gibbula turbinoides* (Deshayes, 1835) and *Fusinus pulchellus* (Philippi, 1844).

Within Foraminifera, the conservation status varies widely, from good to bad; frequently, individuals of *Elphidium crispum* (Linnaeus, 1758) were found associated with common representatives of *Elphidium* spp., *Ammonia parkinsoniana* (d'Orbigny, 1839), *Ammonia beccarii* (Linnaeus, 1758), *Ammonia* spp. The residue of the washing consists of a medium coarse sand, white in color. Granules are formed by lithics, quartz and fossil fragments (molluscs, echinoids, foraminifera) very elaborate, subspherical and with traces of erosion. Noteworthy, part of the components of the sand are cemented forming agglomerates.

The analysis conducted on the sample MAN2, from interval 5, allowed to recognize a rich and diversified association of frequent specimens of *Loxoconcha subrugosa* (Ruggieri, 1977), with specimens of *Aurila lanceaeformis* (Uliczny, 1969), *A. convexa* (Baird, 1850), *Pterigo cythereis*, *Cytheropteron sulcatum* (Bonaduce, Ciampo et Masoli, 1976), *C. latum* (Müller, 1894), *Paracytheridea* cf. *hexalpha* (Doruk, 1980), and representatives of the rare species *Cimbaurila cimbaeformis* (Seguenza, 1883), among the ostracods. Moreover, specimens belonging to the Foraminifera genera *Elphidium*, *Ammonia*, *Dorothia*, *Cassidulina* have been collected. The residue of washing is made up of a sand with a grain size ranging from fine to coarse and gray in color. The granules are complex, mainly made of lithics.

The sample MAN3, from the interval 6, comprises a fossil association rich either in number of specimens or in number of species. Were found numerous specimens of *Loxoconcha subrugosa*, and valves belonging to the genera *Aurila*, *Pterigocythereis*, *Cytheropteron*, *Bosquetina*, *Buntonia* (Ostracoda); specimens belonging to the genera *Elphidium*, *Ammonia*, *Dorothia*, *Cassidulina* and to the species *Hyalinea baltic* (Schroeter, 1783) (Foraminifera) were collected. In addition, frequent remains of echinoids, bryozoans and molluscs were observed. Among these have been identified the species *Turritella tricarinata* (Brocchi, 1814) (Fig. 48), *Nassarius gigantulus* (Bellardi, 1882) (Figs. 49, 50) and *Corbula gibba* (Olivi, 1792) (Figs. 51, 52).

The residue of washing is a gray sand with a particle size ranging from fine to coarse. Sand grains are mainly composed of lithics and fossil remains.

DISCUSSION

The result of the micropalaeontological analysis of the samples MAN2 and MAN3, from the intervals 5 and 6, indicate associations typical of a marine environment of the shallower part of the internal platform. Furthermore, the discovery of significant species as *Aurila lanceaeformis*, *Cimbaurila cimbaeformis*, *Loxoconcha subrugosa*, *Hyalinea baltica* allow to attribute the lower part of the succession to the lower Pleistocene, in particular to the "Calabriano p.p. (Emiliano)", in agreement with the presence of the gastropod *Nassarius gigantulus* that disappears at the top of the "Emiliano" (Ragaini et al., 2007).

In levels 5 and 6 have been identified, as the most significant species, *Turritella tricarinata*, *Nassarius gigantulus* and *Corbula gibba* which form a common association in sediments of the Lower Pleistocene attributable to the VTC biocenosis.

Lithological characteristics and micro- macropaleontologic associations, allow to report the lithological interval 4 to the formation known as "Panchina", widespread in the area, and attributed to the Late Pleistocene (Tyrrhenian). Fossil Mollusca referable to the Tyrrhenian, as *Persististrombus latus* (Gmelin, 1791) and *Conus emineus* (Born, 1778), have been reported by Malatesta (1942) in a sand from the bottom of a well dug in the Hospital of Leghorn, in the vicinity of the succession under study.

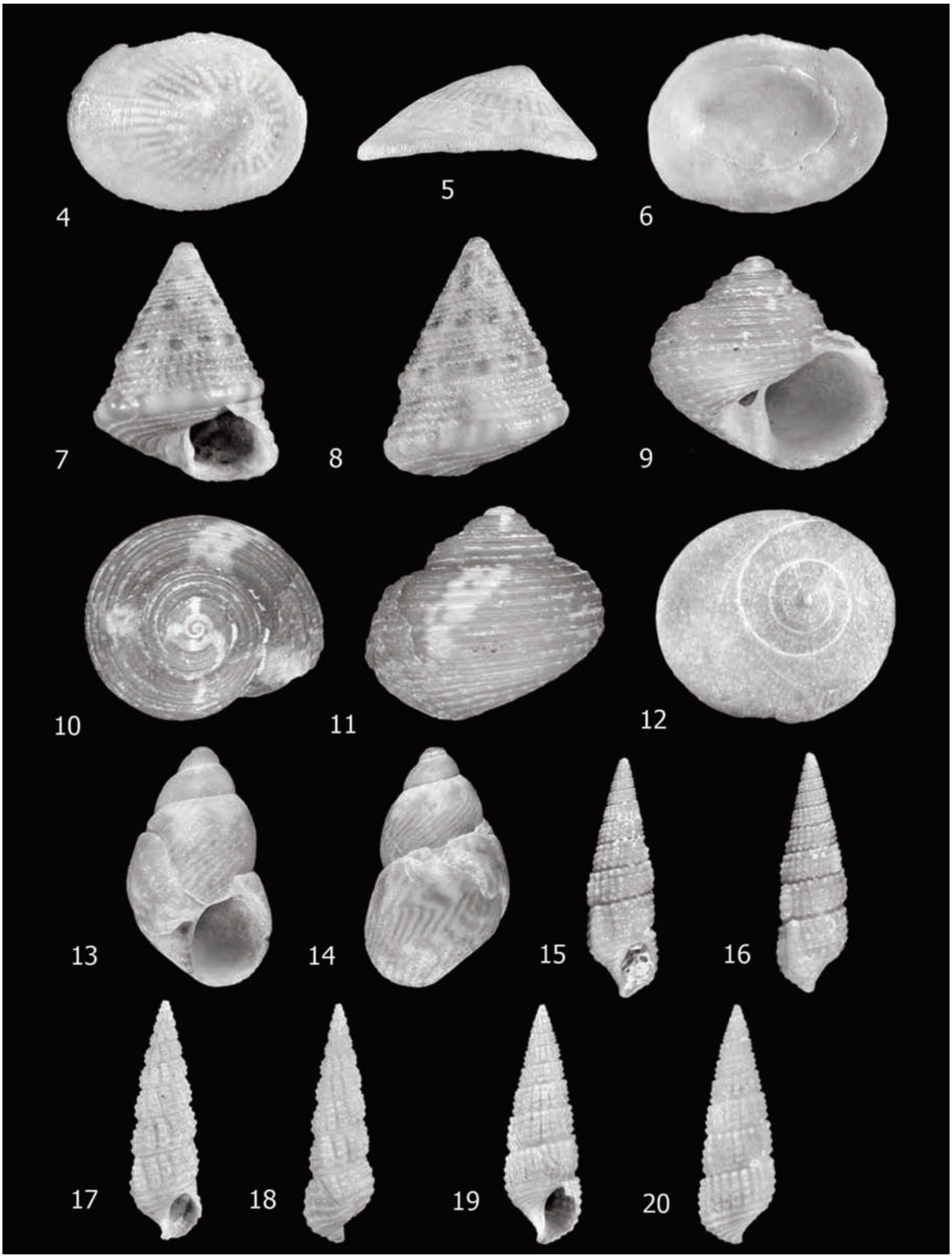
The small number of bivalves (only four species) found in this interval is not significant itself, but, taking into account the fifteen species of gastropods in common with the other sections already known in literature, and considering their sediments, the Tyrrhenian fossil association is

GASTROPODA Cuvier, 1795	**via Manasse**	**via Gramsci** (Ciampalini et al., 2014a)	**Vallin Buio** (Ciampalini et al., 2014a)	**Bacino care-naggio** (Barsotti et al., 1974)	**Figures**
Tectura virginea (O. F. Müller, 1776)	*		*		4–6
Jujubinus exasperatus (Pennant, 1777)	*	*	*	*	7, 8
Gibbula turbinoides (Deshayes, 1832)	*				9–11
Bolma rugosa (Linné, 1767)	*	*	*	*	12
Tricolia tenuis (Michaud, 1829)	*		*	*	13, 14
Bittium reticulatum (Da Costa, 1778)	*	*	*	*	15–18
Bittium latreillii (Payraudeau, 1826)	*	*			19, 20
Cerithium vulgatum Bruguière, 1792	*	*	*	*	
Rissoa variabilis (Von Mühlfeldt, 1824)	*			*	21, 22
Rissoa sp.	*				23
Alvania mamillata Risso, 1826	*	*	*		24, 25
Alvania discors (Allan, 1818)	*	*	*	*	26, 27
Alvania cimex (Linnaeus, 1758)	*			*	28, 29
Rissoina bruguieri (Payraudeau, 1826)	*	*			30, 31
Columbella rustica (Linnaeus, 1758)	*		*	*	32, 33
Fusinus pulchellus (Philippi, 1844)	*				34–36
Vexillum ebenus (Lamarck, 1811)	*			*	37, 38
BIVALVIA Linnaeus, 1758					
Striarca lactea (Linnaeus, 1758)	*	*	*	*	39–42
Glycymeris sp.	*	*	*	*	43, 44
Chama gryphoides (Linnaeus, 1758)	*			*	46, 47
Parvicardium exiguum (Gmelin, 1791)	*	*	*	*	45

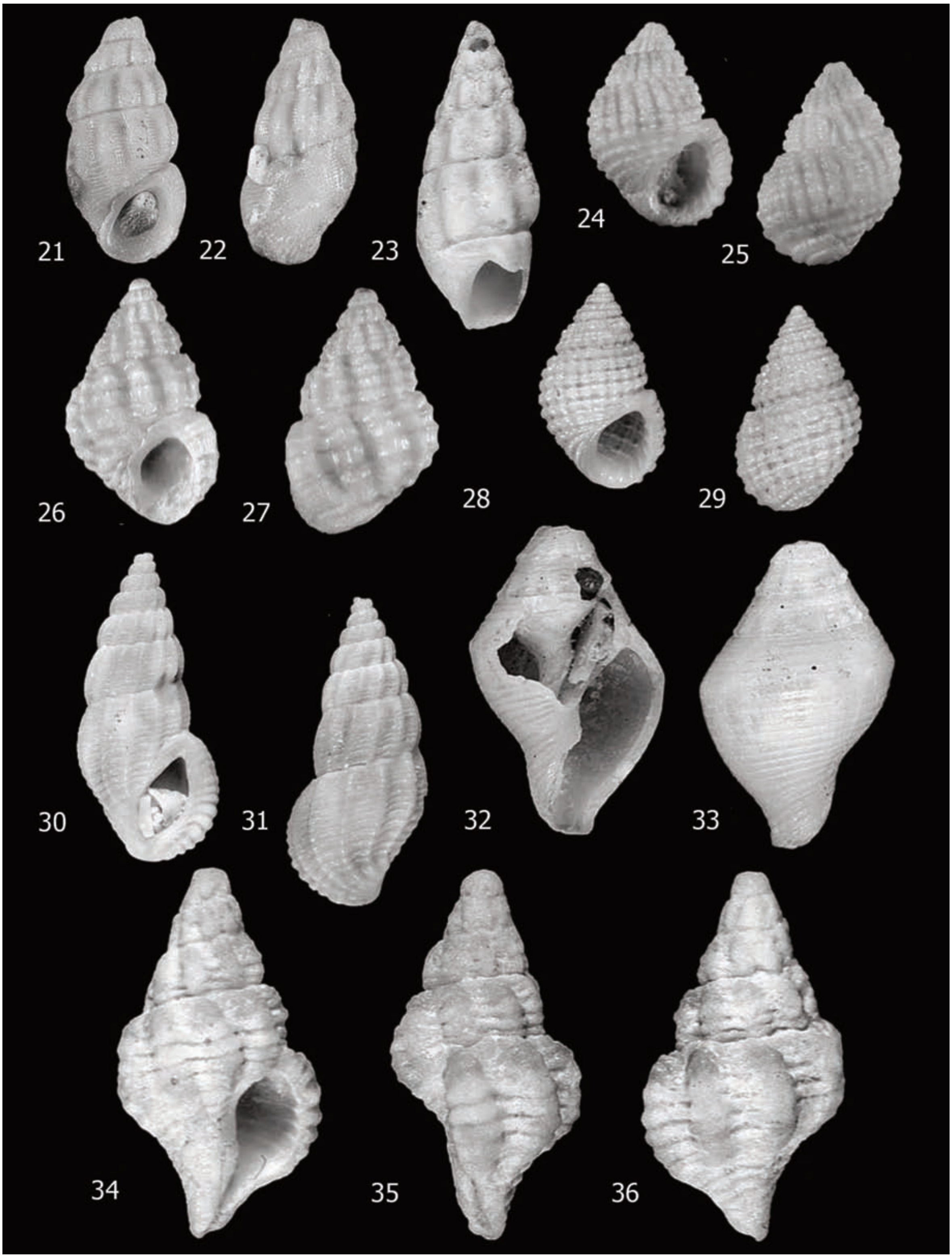
Table 1. List of fossil molluscs from Tyrrhenian found in the survey of “via Manasse”, compared with those found in sections of “via Gramsci”, “Vallin Buio and “Bacino di Carenaggio”.

compatible with a biocenosis of the SGCF type, with specimens from the HP biocenosis. These data confirm those already found in previous studies on similar samples (Barsotti et al., 1974; Ciampalini et al., 2014a; Ciampalini et al. 2014b) and what reported by Corselli (1981) for the current seabed of the Gulf of Baratti (LI).

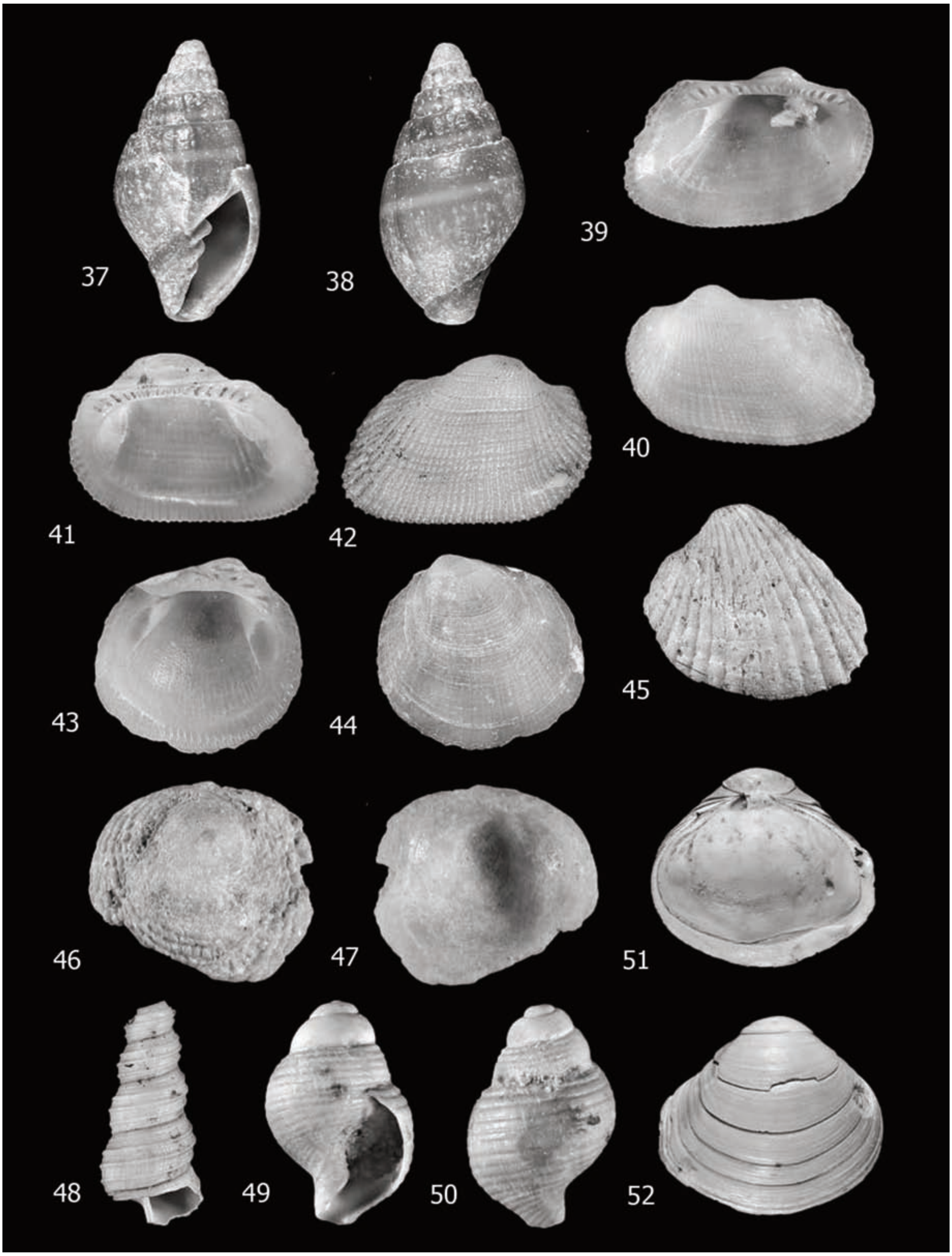
By comparing the lists of molluscs of the Upper Pleistocene, relative to the locations of the territory of Leghorn and reported in the above mentioned papers (Table 1), it can be seen that the species in common are nearly all, with the exception of *Rissoa variabilis* (Von Mühlfeldt , 1824) and *Vexillum ebenus* (Lamarck, 1811), which are absent in the deposits of “ via Gramsci” and “Vallin Buio”, but present at the “Bacino di carenaggio”; *Rissoina bruguieri* (Payraudeau, 1826) present in “via Gramsci”, but absent in “Vallin Buio” and the “Bacino di carenaggio” and, finally, *Gibbula turbinoides* and *Fusinus pulchellus* absent in all other locations. As for the failure of a previous report of *Bittium latreillii* (Payraudeau, 1826), we assumed that the



Figs. 4–6. *Tectura virginea* (O. F. Müller, 1776) d = 3.3, h =1.7. Figs. 7, 8. *Jujubinus exasperatus* (Pennant, 1777) d = 4.8, h = 6.5. Figs. 9–11. *Gibbula turbinoides* (Deshayes, 1835) d = 3.9, h = 3.6. Fig. 12. *Bolma rugosa* (Linnaeus, 1767) operculum d = 6. Figs. 13, 14. *Tricolia tenuis* (Michaud, 1829) d = 4, h =7.1. Figs. 15–18. *Bittium reticulatum* (Da Costa, 1778), Figs. 15, 16: d = 3.2, h =10.8; Figs. 17, 18: d = 2.6, h = 7.3. Figs. 19, 20. *Bittium latreillii* (Payraudeau, 1826) d = 2.4, h = 7.9.



Figs. 21, 22. *Rissoa variabilis* (Von Mühlfeldt, 1824) d = 2, h =3.9. Fig. 23. *Rissoa* sp. d = 1.6, h = 4.2. Figs. 24, 25. *Alvania mamillata* Risso, 1826 d = 3.2, h =5. Figs. 26, 27. *Alvania discors* (Allan, 1818) d = 2.5, h = 4; Figs. 28, 29. *Alvania cimex* (Linnaeus, 1758) d = 2.3, h = 4.4; Figs. 30, 31. *Rissoina bruguieri* (Payraudeau, 1826) d = 2.6, h = 6.8. Figs. 32, 33. *Columbella rustica* (Linnaeus, 1758) d = 3.3, h = 4.9. Figs. 34–36. *Fusinus pulchellus* (Philippi, 1844) d = 2.0 mm, h =5.5 mm.



Figs. 37, 38. *Vexillum ebenus* (Lamarck, 1811) d = 4, h = 8.2. Figs. 39–42 *Striarca lactea* (Linnaeus, 1758), Figs. 39, 40: l = 4.9, h = 3.5; Figs. 41, 42: l = 6.2, h = 3.9. Figs. 43, 44. *Glycymeris* sp. l = 4.1, h = 3.9; Fig. 45. *Parvicardium exiguum* (Gmelin, 1791) l = 7.3, h = 6.3; Figs. 46, 47. *Chama gryphoides* (Linnaeus, 1758) l = 5.3, h = 4.7; Fig. 48. *Turritella tricarinata* (Brocchi, 1814) d = 4.8, h = 11; Figs. 49, 50. *Nassarius gigantulus* (Bellardi, 1882) d = 1.3, h =2.5. Figs. 51, 52. *Corbula gibba* (Olivi, 1792) l = 9.4, h = 8.3.

species may have been confused with *B. reticulatum* (Da Costa, 1778). *Gibbula turbinoides* and *Fusinus pulchellus*, exclusive of the succession of “via Manasse”, are compatible with the habitat of “posidonieto” as one lives at low depth under the rocks and on seagrass, and the other between the *Posidonia oceanica* (L.) Delile rhizomes.

The overall available data and micropalaeontological analysis confirm, for the level of "Panchina", a shallow marine habitat at high energy, with rocky substrates alternating to sandy ones, in proximity of or mixed to seagrass meadows. Even for the micropalaeontological association of the sample collected in the limestone (interval 4), the conservation status of the fossils and the structure of the granules of sand confirm the hypothesis of the occurrence of a marine environment at high energy.

Contrary to other Tyrrhenian fossil malacofauna found in the Leghorn area and at the same stratigraphic level, which are generally poorly preserved (Ciampalini et al., 2014a, 2014b), the association of “via Manasse” is composed of specimens little eroded and often with traces of original coloring. This, combined with the finer grain size of the sediments, although still corroborating the hypothesis of a marine environment at high energy, may indicate a lower transport and consequently a marine environment more stable and little deeper than that assumed for the neighboring area of “via Gramsci”, characterized, instead, by shoals of "Panchina" quite compact.

The lithological study of the drilling revealed peculiar stratigraphic characteristics partly different from those previously reported (Barsotti et al. 1974; Ciampalini et al., 2006; Ciampalini et al., 2014b). The drilling of “via Manasse” shows, in fact, only one level of “Panchina” (lithological interval 4), whereas former studies have often described two levels, separated by a layer of clay and silt of continental environment (Barsotti et al. 1974; Zanchetta et al., 2004; Ciampalini et al., 2006). On the other hand, only one level has been observed in the successions close to the ancient cliffs and at higher altitudes. The presence of the Lower Pleistocene, at the bottom of the drilling, enriches our knowledge on the stratigraphy of the area that, today, is still poorly known. As already reported, in stratigraphic levels below the "Panchina" it is possible to found sediments of both Pliocene and Lower or Middle Pleistocene.

CONCLUSIONS

The lithological study of the drilling revealed seven major lithological intervals. Micropalaeontological and lithostratigraphic analyses allowed to attribute the intervals 7-5 to the Formation of Morrona (Lower Pleistocene, Calabrian) and the lithological interval 4 to the Formation of the “Calcareniti of Castiglioncello” (Upper Pleistocene), also known as "Panchina".

The intervals 3 and 2 are attributed, on the basis of observations on site, to the formation of conglomerates of Rio Maggiore, while interval 1 refers to the “Sabbie di Donoratico”, present throughout the Terrace of Leghorn. On the top of the drilling was identified a soil rich in coal.

In the drilling analysed in this work, was observed only one level of "Panchina" just above the clay sediments of the Lower Pleistocene.

The analysis of malacofauna present in the "Panchina" confirms data already known for an advanced part of the Tyrrhenian cycle. Conversely, no tropical molluscs, typical of the coasts of NW-Centre Africa, and characteristic of the Tyrrhenian baseline (MIS 5e), have been found. Since their discovery was reported by Malatesta (1942) at a depth of about 6 meters (about 12 meters above sea level), in a well near the present hospital and less than one km away from “via Manasse”, this result raises some questions. If for the section of “via Gramsci”, adjacent to the hospital we could hypothesize the failure in finding the African species due to the shallow depth of the drilling, little more than three meters, the same cannot be said for the drilling of ”via Manasse”, up to 20 meters above the ground. At the depth of 6 meters from ground level “via Manasse” sediments and malacofauna are attributable to the Lower Pleistocene, sample MAN3, while in the hospital area both sediments and malacofauna are Tyrrhenian (Malatesta, 1942).

The scantiness of recovered materials due to the nature itself of the sampling carried out, i.e. only a single drilling, could be the cause of the failure in finding or recognizing the Tyrrhenian level MIS 5e. Nevertheless, it is also possible that this level is not always present in the subsoil of Leghorn.

On the other hand, the lack of the second calcarenitic level, probably eroded and replaced by sediments of the river-type (Conglomerates of Rio Maggiore), currently occurring above the fossil level, attests the possibility that important variations in the stratigraphy of the terrace Leghorn have occurred.

In conclusion, it is not easy to find in the subsoil of Leghorn the initial part of the transgressive Tyrrhenian cycle and, consequently, to establish its relationship with the underlying lithological units.

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