MALACOLOGICAL RESPONSE TO PLEISTOCENE SEA-LEVEL CHANGE IN THE NORTHERN PO PLAIN, N. ITALY: DETAILED PALAEOENVIRONMENTAL RECONSTRUCTIONS FROM TWO LOMBARDIAN CORES

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Abstract. The interdisciplinary study of two deep cores drilled in Pleistocene basin fill at Northern margin of Po Plain, has been integrated with qualitative and quantitative malacological analysis. The potential of quantitative malacological analysis, to provide details to the general stratigraphic framework, is here highlighted. The evolution of malacological assemblages has been recorded and correlated to the general regressive trend recognized all over the Po Basin. Lower Pleistocene marine deposits, found at core base (Jaramillo Subchron and older), were gradually replaced by transitional and continental deposits since latest early Pleistocene. Area was eventually covered by continental conglomerate deposits ("Ceppo" facies) during middle-late Pleistocene. Within this general trend, regional significance of a major unconformity ("r" surface), related to onset of Pleistocene glacial cycle, is confirmed. However, as evidenced by malacology, the roughly synchronous onset of coarse clastic progradation did not result in a synchronous shift from marine to transitional and continental settings all over the study area, as an effect of inherited topography and other local factors. During marine sedimentation, fossil record allowed us to recognize a transgressive event, reliably correlated to Marine Isotope Stage 35.

Riassunto. Lo studio interdisciplinare di due sondaggi profondi, perforati nel settore settentrionale del riempimento pleistocenico del bacino Padano, è stato integrato con analisi malacologiche, qualitative e quantitative. In questa sede è stato evidenziato il potenziale dell'analisi malacologica quantitativa, che fornisce dettagli allo schema stratigrafico generale. L'evoluzione delle associazioni malacologiche è stata registrata e correlata con il trend regressivo generale, riconoscibile in tutto il bacino. I depositi marini del Pleistocene inferiore, rinvenuti alla base dei carotaggi (precedentemente al subcrono Jaramillo), sono stati gradualmente sostituiti da depositi transizionali e continentali, a partire dal Pleistocene inferiore terminale. L'area è stata successivamente ricoperta da depositi conglomeratici continentali ("facies di

Ceppo") durante il Pleistocene medio-superiore. All'interno di questo trend generale, è stato possibile confermare la dimensione regionale di una vasta disconformità (superficie "r"), collegata all'inizio del ciclo glaciale pleistocenico. Tuttavia, come evidenziato dalla malacologia, ad un approssimativo sincronismo nell'inizio della sedimentazione ghiaiosa, non coincide un passaggio contemporaneo in tutto il bacino dalla sedimentazione marina a quella continentale, a causa di fattori topografici ed altri fattori locali. Durante la fase di sedimentazione marina, il record fossile ha permesso di riconoscere un evento trasgressivo e correlarlo con lo Stage Isotopico Marino 35.

Introduction

Accurate knowledge on the architecture of complex sedimentary wedge filling Po Basin represents a crucial goal for geological research and, accordingly, an essential precondition for a sustainable exploitation of the subsurface. Stratigraphic evidence stored in the basin fill is essential to understand Earth's surface dynamics at the time of deposition; geometry of buried sedimentary bodies is controlled by evolution of drainage systems and bears direct implications on research of groundwater reservoirs, and on rational strategies aimed at their management.

In 1999, Regione Lombardia undertook a long-term study on subsurface geology of Po Plain in Lombardy in cooperation with ENI E&P (Exploration & Production). Interpretation of some 850 subsurface stratigraphic logs and of over 20,000 km of seismic sections by ENI E&P has led to a sequence-stratigraphic reconstruction of sedimentary succession,

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through recognition of four main sequence boundaries, that can be traced on seismic sections through whole basin (Carcano & Piccin 2002). Local control on depth of sequence boundaries, as well as facies analysis on depositional sequences, has been possible thanks to eleven deep cores drilled by Regione Lombardia. Drillhole cores have been analyzed for stratigraphy, sedimentology, geotechnology, hydrogeology, petrography, palynology, palaeontology and palaeomagnetism. Most results have been published (Carcano & Piccin 2002; Muttoni et al. 2003; Scardia et al. 2006; Cassinis et al. in press).

The present work aims to refine results obtained from interdisciplinary studies, and reconstruct in detail the palaeoenvironmental evolution of central part of Northern margin of Po Plain during early-middle Pleistocene, through faunal description of two deep cores. Cores (RL 5 - Trezzo sull'Adda and RL 7 - Palosco) were studied through malacological analyses (both continental and marine), and their integration with literature data. Malacological studies were carried out on cores RL 1 - 4 by R. Pettinelli (Carcano & Piccin 2002) during a previous phase of the project. Molluscan fossils were not found in cores RL 6 and RL 8 - 11, thus the present work complements and completes the malacological studies on first eleven cores drilled by Regione Lombardia in Po Plain subsurface.

Regional setting

Study area (Fig. 1) is the floodplain bracketed between present rivers Adda and Oglio (Lombardy, Northern Italy). Core RL 5 - Trezzo was drilled 2 km west of the River Adda, on a high plain area where the River Adda passes from a deeply-incised bed (with natural scarps as high as 30 m) to smoother, terraced landforms to the South. Ground surface altitude ranges from 173 to 180 m a.s.l., while Adda bed lies at 135 - 144 m a.s.l. at the same latitude. Core RL 7 - Palosco was drilled on a terraced plain located some 2 km west of the confluence of the River Cherio into the River Oglio; ground surface elevation ranges between 149 and 158 m a.s.l. Surface deposits are related to interacting dynamics of both rivers.

Po Basin is the latest, but probably not the last, foredeep of a continuum of fast-subsiding basins; it is part of a complex larger basin that includes modern Adriatic Sea (Ori 1993). It may be considered as a peri-sutural basin (Bally & Snelson 1980) bounded to the South by uprising Apennines and to the North by Southern Alps. Marine sedimentation started in Po Basin after the Strait of Gibraltar opening, at the beginning of Pliocene (at about 5 Ma).

Filling of marine basin and shift to a continental sedimentation is the combined result of tectono-sedimentary paroxysmal events on Apennine front, separated through time by stages of strong basin subsidence and reduced activity of compressive structures, and by generalised isostatic uplift and erosion of Alps, both enhanced by Pleistocene glacial cycles. Many stratigraphic unconformities, visible on seismic lines, represent discrete steps in the complex basin evolution. Based on these surfaces, biostratigraphically calibrated in the basin, a general stratigraphic framework was defined (Di Dio 1998; Carcano & Piccin 2002). Calibration of surfaces was updated based on magnetostratigraphic and calcareous nannoplankton data by Muttoni et al. (2003) and Scardia et al. (2006).

Complex evolution of the area has been object of several studies during last thirty years (e.g. Corselli et al. 1985; Ori 1993; Pomicino et al. 2001; Bini et al. 2004), aimed to understand stratigraphical relationships among different lithological and hydrological bodies. A correct correlation between subsurface and outcropping Pleistocene successions is rather challenging, because of limited exposures in present-day Po Plain. According to literature (Venzo 1950; Orombelli 1979; Bini et al. 2004; Scardia et al. 2006), a stratigraphic sequence was reconstructed to support interpretation of core RL 5 - Trezzo and western part of study area evolution (Gianolla et al. 2007).

Stratigraphy of core RL 5 - Trezzo, described by Scardia et al. (2006), is here briefly summarized. At the
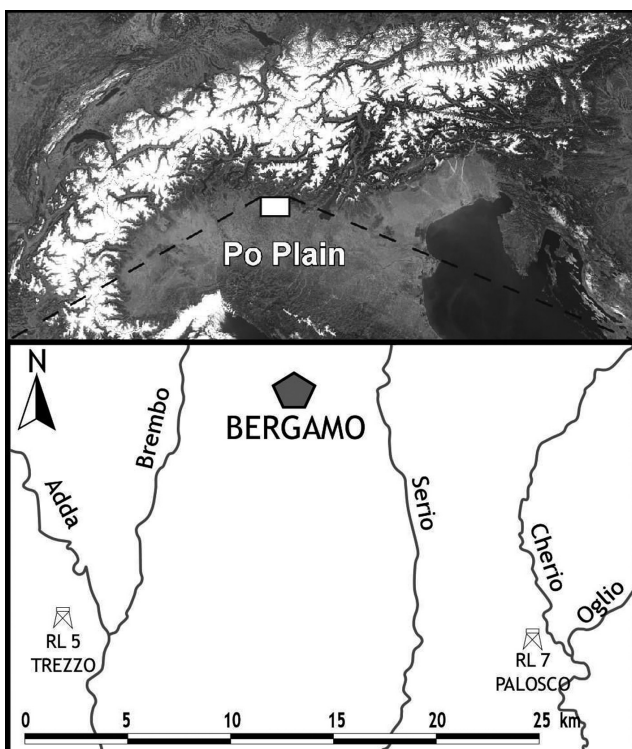

Fig. 1 - Map of the study area.

base of core (150.3 - 149.8 m below ground surface = bgs), a marine clayey interval is overlapped by a thick, regressive fan-delta sequence (depths between 149.8 and about 80 m bgs). This succession, yielding Pleistocene nannofossil *Gephyrocapsa oceanica* Kamptner at depth 110.5 m bgs, was largely deposited during Jaramillo Subchron and upper, post-Jaramillo part of Matuyama Chron. A sandier prograding sequence, seemingly representing an upper delta plain, is topped by continental clays, largely corresponding to upper Villafranchian "Argille sotto il Ceppo" of Venzo (1950) and Pini et al. (2003) (depths between about 80 and 54 m bgs).

Upwards, conglomerates in "Ceppo" facies (Venzo 1950; Orombelli 1979) prevail. Based on petrographic data, this facies in core RL 5 is ascribed to "Ceppo del Brembo", a lithostratigraphic unit of middle Pleistocene age (Bini et al. 2004). In stratigraphic sections exposed in the River Adda canyon, at top of "Ceppo del Brembo", the "Ceppo dell'Adda" unit occurs, but in core RL 5 the latter is absent and replaced by a stratigraphic discontinuity. At the top of core, the Trezzo Formation, corresponding to "Ferretto" after Venzo (1950) and Orombelli (1979), is present.

On the eastern side of studied area, where core RL 7 - Palosco was drilled, a recently-proposed stratigraphic framework, reported by Forcella & Jadoul (2000), ascertained contribution of rivers Cherio and Oglio during Quaternary. In palaeoenvironmental evolution, substantial analogies with RL 5 - Trezzo are observed. In both cores succession starts with clayey marine deposits alternating to silty transitional and sandy-gravelly coastal deposits, arranged in decametre shallowing-upward sequences. They were deposited during a magnetostratigraphic reversal phase, corresponding to middle (pre-Jaramillo) part of Matuyama Chron (Scardia et al. 2006). At the top of interval, a magnetic reversal marks the beginning of normal Jaramillo Subchron.

Continental deposition began, just before the end of subchron (about 1.0 Ma, at around 110 m bgs). Compared to RL 5, in RL 7 the transition between marine and continental deposition is earlier, more abrupt and documented by a much thinner stratal package.

A few metres above base of "Ceppo" deposit (dated at about 0.87 Ma, depth around 55 m bgs) Brunhes/Matuyama magnetic reversal is recorded (Scardia et al. 2006). Middle and Upper Pleistocene are both characterized by deposition of conglomerates with subordinate sandstone, sand and sandy silt, corresponding to the latest progradations of a (fluvio-glacial?) braided-plain system. These sediments have been assigned to a succession of unconformity-bounded stratigraphic units, recognized in outcrop and named, base to top: Valenzano Allogroup, Fantecolo Alloformation, Mon-

tepiane Alloformation, Monterotondo Allogroup (Cassinis et al., in press).

Materials and methods

A total of 47 samples were collected for malacological analyses: 19 from RL 5 - Trezzo core and 28 from RL 7 - Palosco core. RL 5 was sampled in 2006 at warehouse of Regione Lombardia (Milan, Italy) by DG, DS and E. Pisegna Cerone; samples were treated in laboratories of Sapienza University of Rome. RL 7 was sampled at warehouse of Natural History Museum "E. Caffi" in Bergamo by DB, DS and G. Scardia; samples were treated in laboratories of Milano-Bicocca University.

Bulk samples obtained from cores were disaggregated in water (adding hydrogen peroxide when necessary), then washed on a pile of sieves with decreasing mesh (2 and 1 mm for RL 7; 2 and 0.09 mm for RL 5). Recovered fossil material was dried and processed in laboratory, picking out all mollusc shells and fragments suitable for statistical analysis by means of a binocular stereoscope. All visible remains >1 mm were picked up (mainly mollusc shells, but also non-malacological remains). For marine molluscs, Di Geronimo & Robba method (1976) was used.

Molluscs were identified at species level, whenever possible. Marine mollusc nomenclature follows Sabelli et al. (1992). Non-malacological material was identified with the assistance of specialists (I. Soulié-Märsche for Charophyta, C. Emig for Brachiopoda, R. Manni for Echinida, R. Matteucci for ichnofossils of Spongae and Annelida).

Quantitative statistical analyses were performed on species abundance values, normalized to an homogeneous thickness (i.e. volume) of 10 cm. All fossil-bearing samples were retained for analysis. A comprehensive matrix with 126 rows (= taxa; see Tab. 1 for the complete list) and 37 columns (= samples) was then processed by means of Primer software 5.2.8 for Windows (Plymouth Marine Lab.; Field et al. 1982; Warwick & Clarke 1991), obtaining Bray-Curtis similarity matrices of square-root transformed data (Field et al. 1982). These latter provided the base for cluster analysis; represented with single-linked dendrograms and non-metric ordinations (MDS) (Kruskal 1977).

Moreover, a dissimilarity analysis was performed, aiming to define characterizing taxa for each cluster and their individual contribution to total (dis)similarity (Field et al. 1982). Given the heterogeneous nature of data, a multi-step statistical analysis, based on progressive elimination of most dissimilar samples, has been performed. Therefore, first step included all fossil-bearing levels of two cores; second step was performed after elimination of continental levels; third step was performed only on marine levels. Capital letters identify each cluster. A subscript was added to cluster letters in order to identify relevant statistical steps.

For each continental level, only fragments were recorded. Palaeoenvironment was tentatively reconstructed on the basis of richness and ecological significance of molluscs, interpreted through Ložek (1964) ecological marks (Tab. 2) and information furnished by specific guides (see Appendix). For the poorest levels, just a descriptive approach was adopted. Palaeoenvironment of each marine level follows Pérès & Picard (1964, Tab. 3), Picard (1965) and Pérès (1982). Specific comments on application of multivariate statistics and benthic bionomy for palaeoenvironmental interpretation of marine fossil assemblages are discussed by Basso & Corselli (2002).

All reference to depth in core is intended below ground surface, unless differently specified.

Taxon	Ecology	RL 5	RL 7
Nucula nucleus (Linnaeus, 1758)	M	0	10
Nucula sulcata Bronn, 1831	M	6	44
Nucula sp.	M	2	0
Nuculana commutata (Philippi, 1844)	M	3	171
Nuculana illirica Carrozza, 1987	M	0	288
Nuculana pella (Linnaeus, 1767)	M	0	2
Modiolus cf. *barbatus* (Linnaeus, 1758)	M	0	1
Arca tetragona Poli, 1795	M	0	5
Barbatia scabra (Poli, 1795)	M	0	2
Glycymeris sp. (Linnaeus, 1758)	M	0	8
Striarca lactea (Linnaeus, 1758)	M	0	3
Ostreidae ind.	M	1	11
Chlamys varia (Linnaeus, 1758)	M	6	28
Chlamys sp.	M	1	0
Pectinidae ind.	M	3	0
Anomia ephippium Linnaeus, 1758	M	24	185
Chama gryphoides Linnaeus, 1758	M	0	9
Anodontia fragilis (Philippi, 1836)	M	0	0
Lucinella divaricata (Linnaeus, 1758)	M	0	198
Lucinoma boreale (Linnaeus, 1767)	M	0	1
Thyasira cf. *flexuosa* (Montagu, 1803)	M	0	5
Thyasira sp.	M	0	3
Epilepton clarkiae (Clark, 1852)	M	0	4
Hemilepton nitidum (Turton, 1822)	M	2	4
Mysella bidentata (Montagu, 1803)	M	0	5
"Neolepton" obliquatum Chaster, 1897	M	0	1
Galeommatidae ind.	M	1	1
Acanthocardia echinata (Linnaeus, 1758)	M	0	1
Acanthocardia paucicostata (Sowerby, 1841)	M	0	7
Acanthocardia tuberculata (Linnaeus, 1758)	M	0	2
Parvicardium exiguum (Gmelin, 1791)	M	0	37
Parvicardium minimum (Philippi, 1836)	M	0	47
Parvicardium ovale (Sowerby, 1841)	M	0	12
Plagiocardium papillosum (Poli, 1795)	M	20	165
Cerastoderma glaucum (Poiret, 1789)	B	10	0
Spisula subtruncata (da Costa, 1778)	M	0	115
Tellina fabula Gmelin, 1791	M	0	10
Tellina nitida , Poli 1795	M	0	20
Tellina pulchella Lamarck, 1818	M	0	31
Tellina sp.	M	0	3
Abra alba (Wood, 1802)	M	7	3
Abra prismatica (Montagu, 1808)	M	0	17
Abra sp.	M	0	1
Donax semistriatus Poli, 1795	M	0	9
Donax venustus Poli, 1795	M	0	134
Pisidium cf. *pseudosphaerium* Favre, 1927	C	0	1
Venus multilamella (Lamarck, 1818)	M	4	131
Chamelea gallina (Linnaeus, 1758)	M	0	85
Timoclea ovata (Pennant, 1777)	M	11	175
Clausinella brongniartii (Payraudeau, 1826)	M	0	1
Gouldia minima (Montagu, 1803)	M	0	69
Dosinia lupinus (Linnaeus, 1758)	M	0	42
Pitar rudis (Poli, 1795)	M	3	120
Paphia aurea (Gmelin, 1791)	M	0	16
Veneridae ind.	M	1	0
Mya truncata (Linnaeus, 1758)	M	0	1
Corbula gibba (Olivi, 1792)	M	2	650
Lentidium mediterraneum (Costa, 1829)	M	0	25
Hiatella arctica (Linnaeus, 1767)	M	2	83
Dentalium inaequicostatum Dautzenberg, 1891	M	0	17
Acmaea virginea (Mueller, 1776)	M	1	15
Diodora sp.	M	1	1
Gibbula adriatica (Philippi, 1844)	M	0	1

Taxon	Ecology	RL 5	RL 7
Gibbula albida (Gmelin, 1791)	M	0	3
Gibbula pennanti (Philippi, 1846)	M	0	3
Gibbula sp.	M	0	1
Jujubinus striatus (Linnaeus, 1758)	M	0	4
Calliostoma laugieri (Payraudeau, 1826)	M	0	4
Calliostoma zizyphinum (Linnaeus, 1758)	M	0	1
Skeneidae ind.	M	1	0
Xenophora crispa (Koenig, 1825)	M	0	3
Pusillina inconspicua (Alder, 1844)	M	0	1
Pusillina marginata (Michaud, 1832)	M	0	5
Cerithium vulgatum Bruguiere, 1792	M	0	8
Bittium latreillii (Payraudeau, 1826)	M	0	4
Bittium reticulatum (Da Costa, 1778)	M	93	153
Aporrhais serresianus (Michaud, 1828)	M	1	3
Turritella communis Risso, 1826	M	12	550
Cerithidium submamillatum (De Rayneval & Ponzi, 1854)	M	0	106
Hyala vitrea (Montagu, 1803)	M	0	2
Alvania mamillata Risso, 1826	M	0	2
Alvania punctura (Montagu, 1803)	M	4	1
Hydrobia sp.	B	1	4
Bithynia tentaculata (Linnaeus, 1758)	C	13	10
Tornus subcarinatus (Montagu, 1803)	M	0	1
Calyptraea chinensis (Linnaeus, 1758)	M	12	121
Natica hebraea (Martyn, 1784)	M	0	7
Euspira guillemini (Payraudeau, 1826)	M	1	13
Naticidae ind.	M	0	16
Triphoridae ind.	M	0	2
Epitonium tiberii (De Boury, 1890)	M	0	6
Epitonium sp.	M	2	0
Melanella sp.	M	0	1
Nassarius cf. *coralligenus* (Pallary, 1900)	M	0	6
Nassarius pygmaeus (Lamarck, 1822)	M	0	4
Nassarius reticulatus (Linnaeus, 1758)	M	0	25
Nassarius turulosus (Risso, 1826)	M	0	3
Mangelia unifasciata Deshayes, 1835	M	0	14
Mangelia sp.	M	0	2
Bela brachystoma (Philippi, 1844)	M	0	8
Bela nebula (Montagu, 1803)	M	0	1
Mangiliella multilineolata (Deshayes, 1835)	M	4	4
Odostomia conoidea (Brocchi, 1814)	M	0	7
Odostomia plicata (Montagu, 1803)	M	0	1
Odostomia unidentata (Montagu, 1803)	M	0	8
Evalea diaphana (Jeffreys, 1848)	M	0	2
Chrysallida obtusa (Brown, 1827)	M	0	5
Chrysallidinae ind.	M	1	0
Turbonilla acuta (Donovan, 1804)	M	0	3
Turbonilla cf. *fulgidula* (Jeffreys, 1884)	M	2	0
Turbonilla rufa (Philippi, 1836)	M	1	7
Eulimella cf. *praelonga* (Jeffreys, 1884)	M	1	0
Eulimella scillae (Scacchi, 1835)	M	2	2
Eulimella ventricosa (Forbes, 1843)	M	0	2
Pyramidellidae ind.	M	1	0
Valvata cristata Mueller, 1774	C	8	9
Valvata piscinalis (Mueller, 1774)	C	6	38
Retusa truncatula (Bruguiere, 1792) ex sp.	M	5	1
Volvulella acuminata (Bruguiere, 1792)	M	0	1
Planorbidae ind.	C	1	0
Pulmonata juv. ind.	C	0	2
Radix cf. *peregra* (Mueller, 1774)	C	1	0
Gyraulus cf. *laevis* (Alder, 1838)	C	0	1
Pseudofusulus cf. *varians* (Pfeiffer, 1828)	C	0	1
Gastropoda ind.	M	6	0
Ditrupa arietina (Mueller, 1776)	M	0	1

Tab. 1 - Complete list of all malacological taxa recorded in two cores (numbers represent specimens). M = marine, B = brackish, C = continental.

Results

A total of 126 mollusc species was identified; 65 gastropods, 60 bivalves and one scaphopod. Anellid *Di-trupa arietina* (Müller), brachiopod *Megerlia truncata* (Linnaeus), echinid *Arbacina* sp., spongae ichnogenus *Entobia* Bronn and Carophyta *Nitellopsis* cf. *obtusa* (Desvaux in Loiseleur) were also included in the fossil lists.

At Trezzo, recovered faunas from the bottom of section upward to 149.8 m are essentially marine with some brackish element. From 125 m upward to 83 m only scarce and badly preserved remains were recovered (mainly marine with a few continental taxa). Upward

Ecological marks (Ložek 1964)	Significance
10P	species living in marsh waters
10SP	species living in stagnant or marsh waters
10S	species living in stagnant waters
10S(F)	species living preferentially in stagnant waters
10SF	species living in stagnant or current waters
10R	species living in brackish waters
1W	terrestrial species living in woods
?	ecology impossible to infer

Tab. 2 - Ecological marks used for continental molluscs.

Acronyms of biocoenoses (Pérès & Picard 1964)	Significance
VTC	coastal, terrigenous mud
LEE	eurythermal, euryhaline lagoons
SFBC	fine well-sorted sand
SFHN	fine sand in shallow areas
SGCF	coarse sand and fine gravel under bottom currents
SVMC	muddy sand in sheltered areas
AP	photophilous algae
DC	coastal detritic bottom
C	coralligenous
PE	heterogeneous assemblage

Tab. 3 - Marine biocoenoses.

assemblages show strictly continental characteristics (Tab. 1).

At Palosco, from the base of section to 131.35 m-depth only marine assemblages are recognized. Overlying sediments, for a thickness of about 30 m, are barren of fossils. Between 103 m and 96.65 m, sediments yielded mainly continental molluscs along with some marine or brackish species. From 96.65 m to the top of sequence only continental molluscs are recorded (Tab. 1).

After a first, preliminary step of statistical analysis, only two clusters are recognized on MDS ordination and dendrogram, cut at a very low Bray-Courtis similarity (around 5%). They clearly separate frankly continental levels (54.8 - 54.9 m in Trezzo section; 89.6 - 89.72 m, 89.72 - 89.85 m and 96.65 - 96.8 m in Palosco section) from remaining transitional and marine ones.

Continental cluster (Tab. 4) appears to be quite homogeneous. It includes 8 species, all exceeding 1% of mean dominance (MD); dominant elements are *Valvata piscinalis* (Müller) (MD = 50.0%), *Valvata cristata* Müller (MD = 19.3%) and *Bithynia tentaculata* (Linnaeus) (MD = 18.2%), but only the latter occurs in all samples, giving the greatest contribution to total group

similarity (47%). *V. cristata* and *V. piscinalis* account for 29% and 23% of total similarity respectively.

In level 54.8 - 54.9 m (RL 5), 23 fragmentary gastropod specimens (with preserved apex) were recorded and grouped in 6 taxa: *B. tentaculata*, *V. piscinalis*, *Radix* cf. *peregra* (Linnaeus), *V.* cf. *cristata*, *Hydrobia* sp., Planorbidae indet. Species were included in the following ecological marks (Tab. 2): 10SF (for *B. tentaculata* and *V. piscinalis*) represents the larger part of the assemblage (12 specimens = 52.17% of assemblage); 10P (for *V.* cf. *cristata*) is present with 8 specimens (34.78%); the only fragment attributable to family Planorbidae can be tentatively ascribed to *Planorbis* sp., and to the mark 10SP (4.35%). Mark 10S(F) is assigned to *R.* cf. *peregra* (represented by one apex, 4.35%). Also a fragmented specimen of brackish species *Hydrobia* sp. (1 specimen, mark 10R, 4.35%) occurs. In this level, 5 gyrogonites of *N.* cf. *obtusa* (Characeae) occur, together with some other fragments.

In level 71.2 - 71.3 m (RL 5), just 5 opercula of *B. tentaculata* occur. Evidence of brackish waters disappears along with beginning of a frankly continental deposition. The level was not included in MDS analysis because of absence of fossil shells.

In level 89.6 - 89.72 m (RL 7), just 6 apexes occur, almost all belonging to *B. tentaculata* (10SF). A single specimen of *Gyraulus* cf. *laevis* (Alder) can be referred to the mark 10S. In level 89.72 - 89.85 m (RL 7), 2 fragmentary specimens of *B. tentaculata* (10SF) and 9 of *V. cristata* (10P) were recovered.

Level 96.65 - 96.8 m (RL 7) is the richest level for continental malacology: it contains 46 fragmentary specimens, grouped in 4 taxa: *V. piscinalis* and *B. tentaculata* (represented by 41 fragmented specimens and opercula, mark 10SF, 89.13%), *Pisidium* cf. *pseudosphaerium* Favre (1 valve, mark 10P, 2.17%) and brackish *Hydrobia* sp. (4 fragmented specimens, 8.7%).

Other cluster resulting from this elaboration receives the major contributions to total similarity from *Anomia ephippium* Linnaeus (19%), *Turritella communis* Risso (11%) and *Corbula gibba* (Olivi) (8%).

In the second step of analysis, continental levels were removed from the matrix and a new elaboration was then conducted. Results are more complex. At a Bray-Curtis similarity level of about 35.5%, dendrogram delineates 3 clusters (A_2, B_2, C_2) plus 5 isolated levels (Fig. 2). Cluster A_2 and three levels are interpreted as transitional palaeoenvironments, while the others (clusters B_2, C_2 and two isolated levels) refer to marine assemblages which will be better defined in the third step of analysis.

Three transitional samples (i.e. levels), namely 102.2 - 102.4 m, 103.1 - 103.2 m (RL 5 core; no. 3, 4 in Fig. 3) and 102.83 - 103 m (RL 7 core; no. 12 in Fig. 3) are extremely poor in terms of mollusc content (Tab. 5).

Cluster A$_2$ (Tab. 6; Fig. 3), instead, is somewhat richer in molluscs and therefore more significant; it includes Trezzo levels 83.2 - 83.3 m, 97.5 - 97.6 m, 109.5 - 109.7 m, 113.65 - 113.85 m and 125.0 - 125.1 m (no. 1, 2, 5, 6, 7 respectively in Fig. 3). Four identified species count a total of 11 specimens. *A. ephippium* (MD = 45.5%), contributing for 42% to group similarity, is the dominant taxon. The highest contribution to group similarity is due to an undetermined Pectinidae (58%), more regularly distributed in levels.

In level 102.2 - 102.4 m (RL 5; no. 3 in Fig. 3), some reddened internal moulds of gastropods and external imprints of veneroid bivalves, are preserved in a yellowish-reddish sediment.

In level 103.1 - 103.2 m (RL 5; no. 4 in Fig. 3), 2 opercula of *B. tentaculata* (ecological mark 10SF), together with a valve of an undeterminable ostreid, were recorded.

Level 102.83 - 103 m (RL 7; no. 12 in Fig. 3) contains a fragment belonging to family Clausiliidae, unique occurrence of terrestrial molluscs recorded in two cores. Because of some visible internal plies, the specimen can be tentatively attributed to *Pseudofusulus* cf. *varians* (Pfeiffer) (mark 1W). A broken apex, questionably assigned to family Vitrinidae, and an unrecognizable, very small apex occur. A reworked specimen of the marine species *Cerithium vulgatum* Bruguière was also recorded.

In the third step, cluster analysis was performed on marine levels only: at 42.5% of Bray-Curtis similarity, 2 clusters separate in the dendrogram (A$_3$ and B$_3$ in Fig. 4), while 7 levels are isolated (all pertaining to Palosco section).

The first isolated sample corresponds to 151.8 - 152 m level (Tab. 7; no. 12 in Fig. 5). Assemblage com-

Continental cluster	MD	MA	RL5 54.8 - 54.9	RL7 89.6 - 89.72 (1)	RL 7 89.7 - 89.85 (2)	RL7 96.6 - 96.8
Valvata piscinalis	50,0	11,0	6	0	0	38
Valvata cristata	19,3	4,3	8	0	9	0
Bithynia tentaculata	18,2	4,0	6	5	2	3
Hydrobia sp.	5,6	1,3	1	0	0	4
Radix cf. *peregra*	1,1	0,3	1	0	0	0
Gyraulus cf. *laevis*	1,1	0,3	0	1	0	0
Pisidium cf. *pseudosphaerium*	1,1	0,3	0	0	0	1
Planorbidae ind.	1,1	0,3	1	0	0	0

Tab. 4 - Data of the cluster for continental levels. MD = mean dominance, MA = mean abundance.
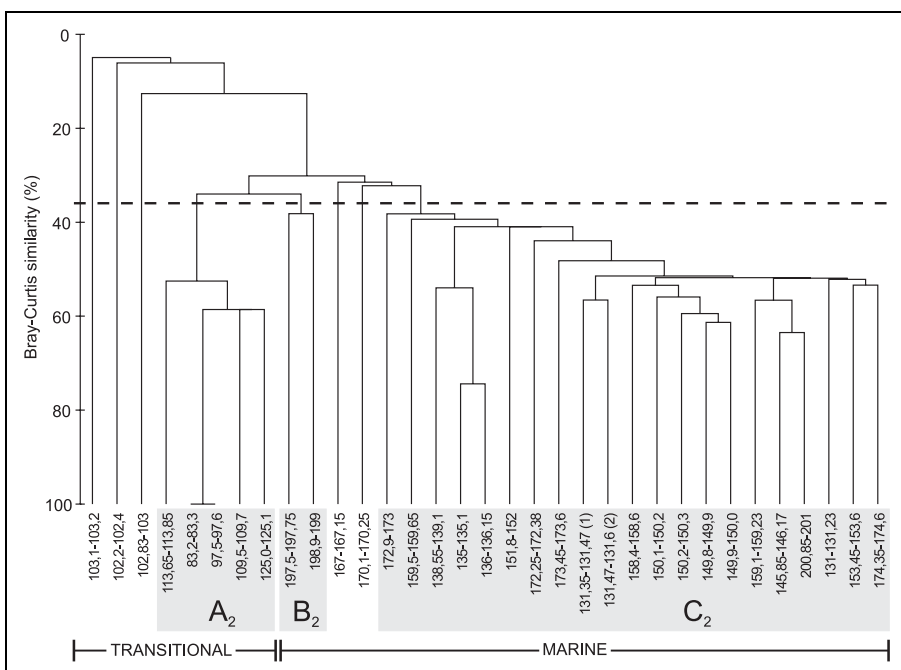

Fig. 2 - Dendrogram considering all non-continental samples, second step (definition of clusters is evidenced by the horizontal line at 35.5% of B-C similarity). See also MDS of Fig. 3.

Transitional levels	D	RL 5 102.2-102.4	RL 5 103.1 - 103.2	RL 7 102.63 - 103
Gastropoda indet.	75.0	3		
Veneridae indet.	25.0	1		
Bithynia tentaculta	66.6		2	
Ostreidae indet.	33.3		1	
Pulmonata juv. indet.	50.0			2
Pseudofusulus cf.*varians*	25.0			1
Cerithium vulgatum	25.0			1

Tab. 5 - Data of the cluster for the isolated transitional levels.

	D	RL7 151.8-152
Turritella communis	25.0	6
Nuculana illirica	20.8	5
Corbula gibba	12.5	3
Cerithium vulgatum	8.3	2
Paphia aurea	8.3	2
Abra prismatica	8.3	2
Nucula sulcata	8.3	2
Odostomia unidentata	4.2	1
Thyasira cf. *flexuosa*	4.2	1

Tab. 7 - Malacofauna of the level 151.8-152 of RL 7 core (no. 12 in Fig. 5).

Cluster A₂	MD	MA	RL 7 83.2 - 83.3	RL 7 97.5-97.6	RL 7 109.5-109.7	RL 7 113.65 -113.85	RL 7 125.0-125.1
Anomia ephippium	45.5	1.0			1	3	1
Pectinidae indet.	27.3	0.6	1	1			1
Epitonium sp.	18.2	0.4				2	
Chlamys varia	9.1	0.2				1	

Tab. 6 - Data of cluster A₂, as in dendrogram of Fig. 2 and MDS of Fig. 3.

prises 9 species and 24 specimens, representing a very disperse and heterogeneous mollusc fauna.

The 159.5 - 159.65 m level (Tab. 8; no. 16 in Fig. 5) is characterized by a rich mollusc fauna, including 19 species and a total of 96 specimens. Assemblage is dominated by *A. ephippium* (D = 22.9%) along with bivalve *Gouldia minima* (Montagu) (D = 16.7%) and wide-

spread gastropod *Bittium reticulatum* (Da Costa) (D = 13.5%).

In 167 - 167.15 m interval, a very scarce fauna was recovered, counting only 5 species, among which *Tellina nitida* Poli, *Chamelea gallina* (Linnaeus) and *Acanthocardia tuberculata* (Linnaeus) (Tab. 9; no. 17 in Fig. 5).

Also 170.1 - 170.25 m sample (Tab. 10; no. 18 in Fig. 5) yielded only seven species with few specimens, among which *Donax venustus* Poli, *Tellina pulchella* Lamarck, *C. gibba*, *Dosinia lupinus* (Linnaeus) and *Turbonilla rufa* (Philippi).

In 172.9 - 173 m level (Tab. 11; no. 20 in Fig. 5) *Tellina fabula* Gmelin, *Spisula subtruncata* (Da Costa), *C. gallina*, and widespread *B. reticulatum* co-occur.

The 197.5 - 197.75 m level assemblage (Tab. 12; no. 23 in Fig. 5), comprising 6 species and 30 specimens,
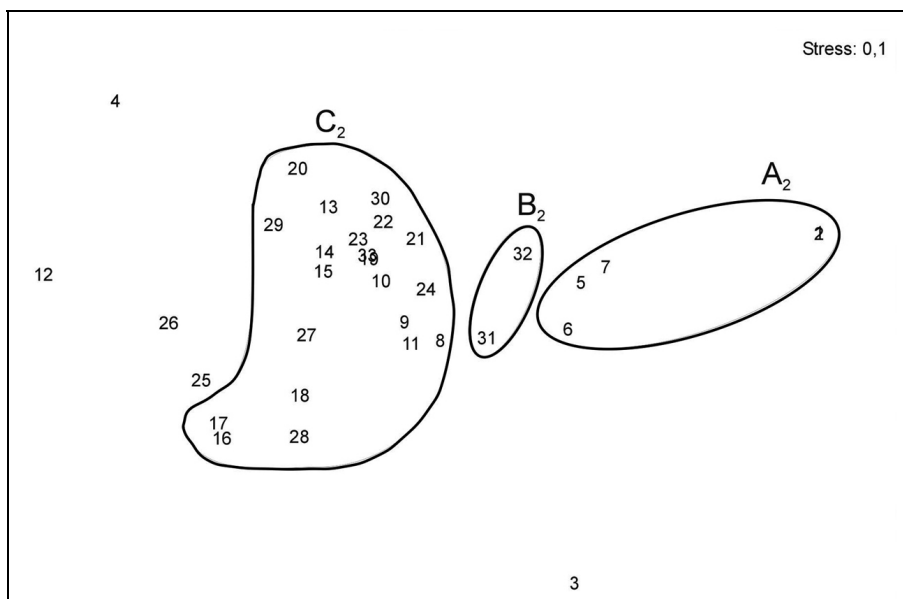

Fig. 3 - MDS Analysis, second step, based on the same similarity matrix of dendrogram in Fig. 2.

is dominated by cardiid *Plagiocardium papillosum* (Poli) with a dominance (D) of 43.3%, followed by *A. ephippium* (D = 30.0%) and *Timoclea ovata* (Pennant) (D = 10.0%).

The 198.9 - 199 m assemblage (Tab. 13; no. 24 in Fig. 5) is somewhat similar to previous one. Here, 29 specimens representing 12 species are counted, dominant role being assumed by *A. ephippium* (D = 41.4%) followed at some distance by *P. papillosum* (D = 20.7%).

Cluster A₃ (Tab. 14; Fig. 5) comprises Palosco samples from 135 - 135.1 m, 136 - 136.15 m and 138.55 - 139.1 m intervals, that are in continuity along the core. Twenty-nine species are recorded by a total of

584 specimens; the lowest level is by far the richest, including all taxa of this cluster, while other samples share with it only a few ones. Eleven species exceed 1% of MD; dominant elements are *Lucinella divaricata* (Linnaeus) (MD = 27.4%) and *D. venustus* (MD = 19.2%), followed by *C. gallina* (MD = 11.6%) and *S. subtruncata* (MD = 10.6%). Major contributions to group similarity are given by *D. venustus* (24%), *L. divaricata* (20%), *C. gallina* (17%) and *D. lupinus* (13%); also *Lentidium mediterraneum* (Costa) and *S. subtruncata* are of some importance in this respect.

Cluster B₃ is by far the largest one (Tab. 15, Fig. 5). It includes 15 remaining samples, 11 of which belonging to Palosco and 4 to Trezzo sections respectively.
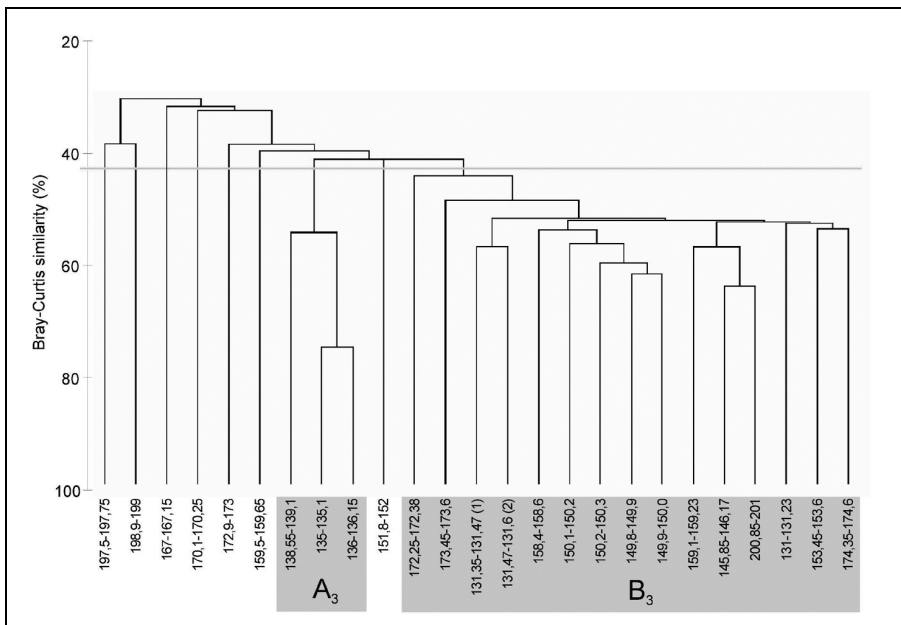

Fig. 4 - Dendrogram considering all marine samples, third step (definition of clusters is evidenced by the horizontal line at 42.5% of B-C similarity). See also MDS of Fig. 5.
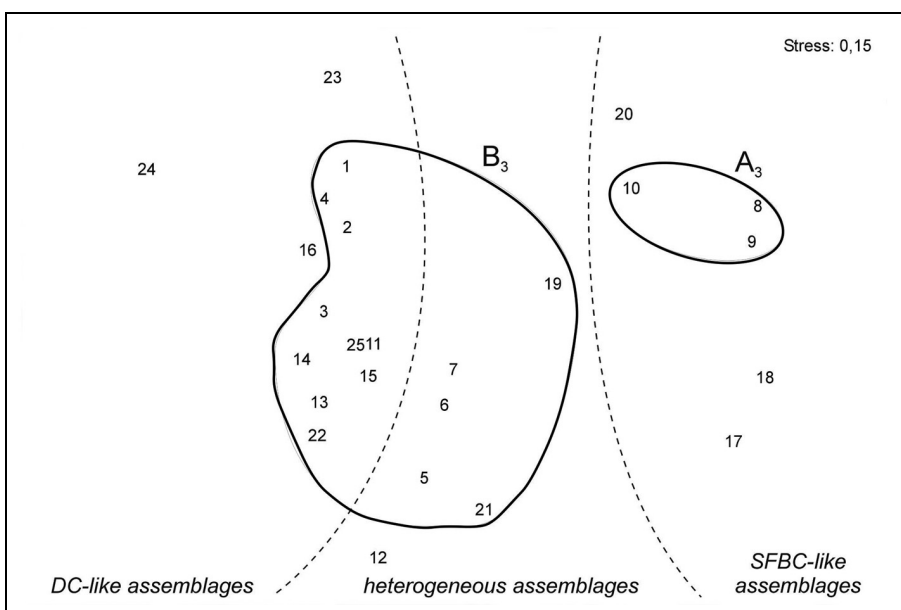

Fig. 5 - MDS Analysis, third step, based on the same similarity matrix of dendrogram in Fig. 4.

	D	RL7 159.5-159.65
Anomia ephippium	22.9	22
Gouldia minima	16.7	16
Bittium reticulatum	13.5	13
Acmaea virginea	9.4	9
Plagiocardium papillosum	5.2	5
Cerithidium submamillatum	5.2	5
Calliostoma laugieri	4.2	4
Calyptraea chinensis	3.1	3
Nassarius pygmaeus	3.1	3
Turritella communis	2.1	2
Corbula gibba	2.1	2
Dentalium inaequicostatum	2.1	2
Nucula nucleus	2.1	2
Pusillina marginata	2.1	2
Nassarius cf. *coralligenus*	2.1	2
Nuculana illirica	1.0	1
Lucinella divaricata	1.0	1
Barbatia scabra	1.0	1
Diodora sp.	1.0	1

Tab. 8 - Malacofauna of the level 159.5-159.65 of RL 7 core (no. 16 in Fig. 5).

	D	RL7 167-167.15
Tellina nitida	42.9	3
Corbula gibba	14.3	1
Lucinella divaricata	14.3	1
Chamelea gallina	14.3	1
Acanthocardia tuberculata	14.3	1

Tab. 9 - Malacofauna of the level 167-167.15 of RL 7 core (no. 17 in Fig. 5).

	D	RL7 170.1-170.25
Corbula gibba	41.7	5
Donax venustus	16.7	2
Dosinia lupinus	8.3	1
Tellina pulchella	8.3	1
Nucula nucleus	8.3	1
"Neolepton" obliquatum	8.3	1
Turbonilla rufa	8.3	1

Tab. 10 - Malacofauna of the level 170.1-170.25 of RL 7 core (no. 18 in Fig. 5).

	D	RL7 172.9-173
Bittium reticulatum	22.6	7
Hiatella arctica	19.4	6
Tellina fabula	12.9	4
Lucinella divaricata	9.7	3
Chamelea gallina	9.7	3
Gibbula pennanti	9.7	3
Cerithium vulgatum	3.2	1
Paphia aurea	3.2	1
Spisula subtruncata	3.2	1
Gibbula albida	3.2	1
Gibbula adriatica	3.2	1

Tab. 11 - Malacofauna of the level 172.9-173 of RL 7 core (no. 20 in Fig. 5).

Cluster A$_2$	D	RL 7 197.5-197.75
Plagiocardium papillosum	43.3	13
Anomia ephippium	30.0	9
Timoclea ovata	10.0	3
Hiatella arctica	6.7	2
Spisula subtruncata	6.7	2
Pusillina inconspicua	3.3	1

Tab. 12 - Malacofauna of the level 197.5-197.75 of RL 7 core (no. 23 in Fig. 5).

The group counts as many as 94 species (3589 specimens), 18 of which bear a MD value greater than 1%. Dominant elements are *C. gibba* (MD = 17.9%) and *T. communis* (MD = 15.4%); this latter gives the greatest contribution to group similarity (18%), followed by *Calyptraea chinensis* (Linnaeus) (12%), *A. ephippium* (9%), *C. gibba* (8%) and *P. papillosum* (6%).

Discussion

On the whole, Palosco marine sequence clearly shows a regressive trend, provisionally interrupted by a short, but abrupt, deepening phase. On the other hand, in Trezzo core, also due to shallower coring depth, only upper part of marine deposition occurs, showing shallow-marine facies. Above marine sediments, transitional conditions are recognized in both sections – yet with

	D	RL7 198.9-199
Anomia ephippium	41.4	12
Plagiocardium papillosum	20.7	6
Epilepton clarkiae	6.9	2
Gouldia minima	3.4	1
Venus multilamella	3.4	1
Nassarius cf. *coralligenus*	3.4	1
Bittium latreillii	3.4	1
Hyala vitrea	3.4	1
Lucinoma boreale	3.4	1
Alvania punctura	3.4	1
Volvulella acuminata	3.4	1
Melanella sp.	3.4	1

Tab. 13   - Malacofauna of the level 198.9-199 of RL 7 core (no. 24 in Fig. 5).

notably different thickness – and pass to overlying continental deposits in "Ceppo" facies.

Palaeoenvironmental evolution along RL- 5 core

At Trezzo, frankly marine levels occur in the deepest part of the core (between 150.3 and 149.8 m). They point to a DC population, although dwelling on a muddy bottom; faunal composition suggests a relatively shallow bathymetric interval, at the top of range commonly assigned to biocoenosis. Assemblages age, as from magnetostratigraphic data, is somehow younger than marine sediments of Palosco, where the youngest marine levels contain faunas comparable to DC, yet very heterogeneous and/or related to unstable environmental conditions (see Chronostratigraphic considerations, p. 92). It appears clear that at Trezzo, both transitional and marine conditions persisted markedly longer than at Palosco, consistent with hypothesis of a relatively deeper setting.

Transitional phase is heterogeneous: it can be placed near low tide mark, reflecting incipient lowering of base level. Above this interval, only scattered mollusc faunas were recognized. Occurrence of calcareous nannofossil *G. oceanica* at 110.5 m (Scardia et al. 2006) indicates a marine environment and a Pleistocene age. Coexistence of continental and marine fossils in the upper level suggests a fan-delta setting, where coarse continental material was transported in a marine depositional environment (data are consistent with geological interpretation of Scardia et al. 2006). Lagoon deposits, with an intense evaporation, occur upward in the core (level 102.2-102.4), suggesting fan-delta progradation and installation of a retro-coastal,

Cluster A$_3$	MD	MA	RL7 135-135.1	RL7 136-136.15	RL7 138.55-139.1
Lucinella divaricata	27.4	53.3	10	20	130
Donax venustus	19.2	37.3	49	39	24
Chamelea gallina	11.6	22.7	33	11	24
Spisula subtruncata	10.6	20.7	6	2	54
Bittium reticulatum	9.9	19.3		1	57
Dosinia lupinus	6.0	11.7	5	8	22
Lentidium mediterraneum	4.3	8.3	18	4	3
Anomia ephippium	1.9	3.7			11
Donax semistriatus	1.5	3.0			9
Plagiocardium papillosum	1.2	2.3			7
Tellina fabula	1.0	2.0	5		1
Abra prismatica	0.7	1.3		1	3
Chama gryphoides	0.5	1.0			3
Cerithium vulgatum	0.3	0.7			2
Tellina sp.	0.3	0.7			2
Ostreidae ind.	0.3	0.7			2
Paphia aurea	0.3	0.7			2
Turbonilla acuta	0.3	0.7			2
Alvania mamillata	0.3	0.7			2
Triphoridae ind.	0.3	0.7			2
Turbonilla rufa	0.3	0.7		1	1
Mangiliella multilineolata	0.2	0.3			1
Jujubinus striatus	0.2	0.3			1
Tornus subcarinatus	0.2	0.3			1
Chrysallida obtusa	0.2	0.3			1
Modiolus cf. *barbatus*	0.2	0.3			1
Mya truncata	0.2	0.3			1
Acanthocardia tuberculata	0.2	0.3			1
Gibbula sp.	0.2	0.3			1

Tab. 14   - Data of cluster A$_3$, as in dendrogram of Fig. 4 and MDS of Fig. 5.

brackish basin. Evidence of progradation persists until about 95 m.

A gradual evolution from transitional to eventual continental deposition can be observed. Upwards in core, frankly continental deposits are present, in which occurrence of whole gyrogonites of *N.* cf. *obtusa* reveals a contribution from cold, relatively deep waters (Soulié-Märsche 1991). Tolerance of this species for occasional oscillations in salinity (Soulié-Märsche 1991; Kipp 2008) is consistent with co-occurrence of *Hydrobia* sp., and suggests proximity of sea, as well as sea influence, even during frankly continental deposition phase. Bad preservation state of mollusc remains suggests mechanical abrasion during transport, indicating a high-energy deposition. It has to be noted that, although fossil sampling was commonly restricted to fine-grained sediments, shift from marine to transitional and continental conditions was characterized by a sudden increase of gravelly and coarse sandy facies above regional unconformity termed "r" surface (Muttoni et al. 2003), irrespective of marine or continental environment in which the unconformity was recorded.

Palaeoenvironmental evolution along RL- 7 core

At Palosco, recognizable trend is similar in general terms, but different in detail. Transition from marine to continental environments is not so gradual as in Trezzo, but shows a more complex development.

Sequence starts with a DC environment, also characterized by several infralittoral taxa and gravel-related elements. Moving towards upper levels, other two DC-related faunas were recovered. However, they appear clearly impoverished, differing one to another for species richness only. Inferred bathymetry relapses in upper circalittoral.

Environment barely changes moving upward, where faunas roughly interpreted as impoverished DC, with an important mud input, are recorded. It is worth noting that in MDS diagram (see Results, p. 82) these levels are placed more rightward, somewhat approaching SFBC samples.

The "shift" toward SFBC-like biocoenoses continues with levels above, changing from a more clearly fine sand-related environment to a heterogeneous SFBC complex, followed upward by two SFBC levels. Bathymetric range of both these faunas is definitely infralittoral. Through malacology, from the core bottom to this point, a regular regressive trend is evidenced.

A distinct change is observed moving toward younger levels, appearing as a step-like return to DC faunas possibly reflecting a sudden relative deepening of sea. The 15 m-thick sequence here represented evidences bathymetries ranging from lower infralittoral to upper circalittoral depths.

A restoration of shallower conditions, with installation of typical SFBC populations, is recorded in overlying deposits. The transition from underlying DC faunas is abrupt, except for the recovering of few gravel-linked taxa in the two oldest SFBC assemblages. A clear regressive trend is evident.

Palosco marine sequence ends with three adjacent levels comprised between 131.6 and 131 m depths, placed by MDS ordination in an indefinite zone, equidistant from DC and SFBC conditions. As a whole, mollusc faunas recovered from this interval have an heterogeneous composition. Markers of sedimentary instability conditions, such as *C. gibba* and *Nuculana pella* (Linnaeus), denoting a terrigenous input from nearby land, here occur. A transitional phase starts, although some levels of marine deposits are still present above these assemblages.

The continental phase is testified by a rich, well preserved fauna, with better taphonomic conditions in respect to Trezzo levels. Moreover, erosion of margin fed deposit with fragments of some reworked terrestrial and marine molluscs (102.83 - 103 m). A contribution from brackish waters during this phase cannot be excluded, based on the occurrence of some brackish-water molluscs. Occurrence of a low percentage of marsh species also suggests the presence of an area characterized by low energy waters. In general, a weak transport is documented by a high percentage of fragments.

Palaeoenvironmental interpretation based on multivariate statistics (2nd and 3rd statistical steps)

Transitional environment is recorded in levels from RL 5 and included in A$_2$ (two isolated levels are also recorded). In particular, level 102.2 - 102.4 m (RL 5) is interpreted as a brackish lagoon environment. Occurrence of reddened moulds suggests shallow waters with intense evaporation. Transitional assemblage of level 103.1 - 103.2 m (RL 5) was probably deposited near a river outlet, that transported continental remains in a shallow marine depositional environment.

Clusters B$_2$ and C$_2$ and levels 167 - 167.15 m and 170.1 - 170.25 m (RL 7) are interpreted as marine environments (Figs. 2, 3), which can be further detailed on the basis of third statistical step (Figs. 4, 5).

Cluster B$_2$ (RL 7) bears malacological elements pointing toward a DC population, yet very impoverished and placed near the upper limit of circalittoral zone (as suggested by presence of *S. subtruncata*). Among recovered species, *P. papillosum* is currently regarded as a preferential element of DC, while *A. ephippium* occurs, along with *Hiatella arctica* (Linnaeus), mainly on small solid substrates, and *T. ovata* spans over various sediment types.

Evolution of cluster C$_2$ (RL 7) is more complex. Between 150 and 160 m, recovered elements suggest a DC biocoenosis. Assemblages are characterized by co-occurrence of species living on DC (*G. minima*, *P. papillosum* and *Acmaea virginea* (Müller)), on small, hard substrates (*A. ephippium*, *C. chinensis*) and on restricted circalittoral depths (*Cerithidium submamillatum* (De Rayneval & Ponzi)). Moreover, the presence of *A. virginea* and peculiar prâlines-like rhodolits delineates "prâlines facies" of DC, and is linked to bottom currents (Pérès & Picard 1964; Basso 1992, 1998). Co-occurrence of *B. reticulatum* and *Calliostoma laugieri* (Payraudeau) can also indicate relative closeness of algae-covered substrates (such as *Posidonia* meadows). Also mud-related taxa (including *Nuculana illirica* Carrozza and dominant *T. communis*) are found, together with PE (*C. gibba*) and SVMC elements (*C. vulgatum*, *Paphia aurea* (Gmelin)).

In deeper levels (RL 7), the scarce fauna is related to SFBC, along with occurrence of some exclusive (*T. fabula*, *S. subtruncata*, *D. venustus* and *T. pulchella*) or preferential (*C. gallina*) SFBC elements, together with widespread *B. reticulatum*. Three species belonging to PE (*C. gibba*, *D. lupinus* and *T. rufa*) seem to evidence substrate instability and water turbidity. Occurrence of

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Cluster B₃	MD	MA	RL5 149.8-149.9	RL5 149.9-150.0	RL5 150.1-150.2	RL5 150.2-150.3	RL7 131-131.23	RL7 131.35-131.47 (1)	RL7 131.47-131.6 (2)	RL7 145.85-146.17	RL7 153.45-153.6	RL7 158.4-158.6	RL7 159.1-159.23	RL7 172.25-172.38	RL7 173.45-173.6	RL7 174.35-174.6	RL7 200.85-201
Corbula gibba	17.9	42.7				2	38	6	30	444	1	3	43	16		2	56
Turritella communis	15.4	36.9		7	4	1	209	55	22	104	22	6	35		12	66	11
Nuculana illirica	7.9	18.8					2	16	5	152	1	5	19			1	81
Timoclea ovata	5.1	12.2		1	3	7			1	66		3				1	101
Nuculana commutata	4.8	11.6		1	1	1				126	2		13		1	5	24
Bittium reticulatum	4.7	11.2	12	36	9	36				4		4	24	40			3
Plagiocardium papillosum	4.3	10.3	2	7	5	6		3	8	89	1	3	1				29
Anomia ephippium	4.2	10.0	11	6		2	17	7	3	37	7		16	31		7	6
Venus multilamella	3.7	8.9		1	2	1				77		8	25		2	11	7
Calyptraea chinensis	3.6	8.7	1	5	3	3	2	17	9	31	1	2	31	5	3	2	15
Pitar rudis	3.4	8.2	3				1		10	68	3		25	7			6
Cerithium submamillatum	2.8	6.7						1	6	69				1			24
Hiatella arctica	2.1	5.1	1	1			1	1	2	46		4	6	4		2	9
Gouldia minima	1.4	3.5							8	2		1	13			1	27
Spisula subtruncata	1.4	3.3						3	5	42							
Nucula sulcata	1.3	3.2	1	2	3					22		3	4			1	12
Parvicardium minimum	1.3	3.1								11		6	17			7	6
Parvicardium exiguum	1.0	2.5								9			25	3			
Lucinella divaricata	0.9	2.2						7	6				1	15	2		2
Chlamys varia	0.9	2.2	1		1	3		1		7	1	3	3				13
Tellina pulchella	0.8	2.0							10				20				
Nassarius reticulatus	0.7	1.7					2	2	8				13				
Donax venustus	0.6	1.3											19	1			
Tellina nitida	0.5	1.1						16		1							
Naticidae ind.	0.4	1.1							1				15				
Dentalium inaequicostatum	0.4	1.0					2	3	4	2			1				3
Mangelia unifasciata	0.4	0.9						1	1	2			10				
Euspira guillemini	0.4	0.9				1								1	3	3	6
Chamelea gallina	0.4	0.9										2	11				
Parvicardium ovale	0.3	0.8											10				2
Paphia aurea	0.3	0.7						2	4				5				
Abra prismatica	0.3	0.7								1		3	3				4
Cerastoderma glaucum	0.3	0.7	3	3		4											
Abra alba	0.3	0.7	3	2	2		2		1								
Ostreidae ind.	0.3	0.6					1	2	1				5				
Bela brachystoma	0.2	0.5					2		1	3			1			1	
Glycymeris sp.	0.2	0.5							7				1				
Odostomia unidentata	0.2	0.5						2				5					
Odostomia conoidea	0.2	0.5					3	3	1								
Acanthocardia paucicostata	0.2	0.5							1			3	3				
Nucula nucleus	0.2	0.5							2	5							
Natica hebraea	0.2	0.5								7							
Acmaea virginea	0.2	0.5		1						2			3				1
Dosinia lupinus	0.2	0.4					4									2	
Chama gryphoides	0.2	0.4							5								1
Epitonium tiberii	0.2	0.4							1	1		1		2	1		
Hemilepton nitidum	0.2	0.4				2				4							
Retusa truncatula	0.2	0.4	1	3		1							1				
Mysella bidentata	0.1	0.3					1						4				
Turbonilla rufa	0.1	0.3				1				1				2			1
Arca tetragona	0.1	0.3															5

Cluster B$_3$	MD	MA	RL5 149.8-149.9	RL5 149.9-150.0	RL5 150.1-150.2	RL5 150.2-150.3	RL7 131-131.23	RL7 131.35-131.47 (1)	RL7 131.47-131.6 (2)	RL7 145.85-146.17	RL7 153.45-153.6	RL7 158.4-158.6	RL7 159.1-159.23	RL7 172.25-172.38	RL7 173.45-173.6	RL7 174.35-174.6	RL7 200.85-201
Chrysallida obtusa	0.1	0.3											4				
Eulimella scillae	0.1	0.3		2								2					
Thyasira cf. *flexuosa*	0.1	0.3											4				
Aporrhais serresianus	0.1	0.3		1									1			2	
Alvania punctura	0.1	0.3	2	1		1											
Mangiliella multilineolata	0.1	0.2						1	1					1			
Jujubinus striatus	0.1	0.2								3							
Xenophora crispa	0.1	0.2								2	1						
Pusillina marginata	0.1	0.2								1				2			
Gastropoda ind.	0.1	0.2	1	2													
Nassarius cf. *coralligenus*	0.1	0.2										1		2			
Bittium latreillii	0.1	0.2											3				
Thyasira sp.	0.1	0.2								1			2				
Nassarius turulosus	0.1	0.2											3				
Striarca lactea	0.1	0.2															3
Cerithium vulgatum	0.1	0.1												1			1
Nuculana pella	0.1	0.1							2								
Nucula sp.	0.1	0.1			1	1											
Galeommatidae ind.	0.1	0.1				1				1							
Eulimella ventricosa	0.1	0.1								2							
Mangelia sp.	0.1	0.1								2							
Turbonilla cf. *fulgidula*	0.1	0.1	1	1													
Gibbula albida	0.1	0.1												2			
Epilepton clarkiae	0.1	0.1														2	
Evalea diaphana	0.1	0.1															2
Tellina sp.	0.0	0.1					1										
Chlamys sp.	0.0	0.1		1													
Barbatia scabra	0.0	0.1						1									
Turbonilla acuta	0.0	0.1								1							
Eulimella cf. *praelonga*	0.0	0.1			1												
Pyramidellidae ind.	0.0	0.1	1														
Skeneidae ind.	0.0	0.1	1														
Chrysallidinae ind.	0.0	0.1		1													
Abra sp.	0.0	0.1								1							
Nassarius pygmaeus	0.0	0.1											1				
Diodora sp.	0.0	0.1				1											
Bela nebula	0.0	0.1												1			
Odostomia plicata	0.0	0.1													1		
Hyala vitrea	0.0	0.1													1		
Acanthocardia echinata	0.0	0.1															1
Ditrupa arietina	0.0	0.1															1
Clausinella brongniartii	0.0	0.1															1
Calliostoma zizyphinum	0.0	0.1															1

Tab. 15 - Data of cluster B$_3$, as in dendrogram of Fig. 4 and MDS of Fig. 5.

H. arctica, usually dwelling on small hard substrates, should denote a somewhat non-homogeneous sediment texture.

Major components of mollusc fauna in Cluster A_3 are exclusive (*D. venustus*, *S. subtruncata*) or preferential (*C. gallina*) SFBC elements. Minority presence of other two SFBC exclusives (*T. fabula* and *A. tuberculata*), confirms placement of the cluster in such biocoenosis. Among other relevant species, *L. mediterraneum* indicates possible deposition in the vicinity of a freshwater input, while *D. lupinus* can denote some sediment dishomogeneity; actually, also species linked to small hard substrates are represented, like *A. ephippium*, *P. papillosum* and *Abra prismatica* (Montagu), well matching with abundance of terrigenous cobbles noted in samples. Species *L. divaricata*, lacks a definite ecological significance. As a whole, data are consistent with mid-lower part of infralittoral zone.

Malacofauna of Cluster B_3 is quite diversified in terms of ecological requirements. As a whole, MDS representation of marine assemblages provides a good subdivision between DC-like (left side of the MDS plot) and SFBC-like palaeoenvironments (right side of the MDS plot). Heterogeneous assemblages, unstable biotopes and variously modified DC and SFBC associations are placed between the two (hatched lines in Fig. 5).

Dominant *C. gibba* is a preferential PE element, being a good indicator of sedimentary and/or trophic supply instability (Di Geronimo & Robba 1989). Some DC preferential or accompanying taxa are represented, such as *P. papillosum*, *Pitar rudis* (Poli) and *G. minima* along with minoritary *A. prismatica* and *A. virginea*, though not exceeding together a 10% MD. *A. ephippium*, *C. chinensis* and *H. arctica* are linked to shell debris or pebbles, while a number of species denotes the presence of muddy bottoms, or muddying in progress (*T. communis*, nuculanids and *Venus multilamella*). Finally, also basically tolerant elements like *T. ovata* and *B. reticulatum* are recorded.

A complex scenario emerges, pointing toward a DC-like biocoenosis installed on a gravelly or shelly bottom undergoing a relevant muddying. A placement in a depth interval comprising circalittoral and the lower infralittoral zones appears plausible. However, this group clearly includes several intermediate situations between coastal detritic, muddy bottoms and also SFBC-similar environments. This appears also on the MDS diagram (Fig. 5), where 5 samples with a typically DC fauna are grouped on the left (11, 13-15, 25 in Fig. 5), 4 Trezzo samples (1 to 4 in Fig. 5) reflect a more surface aspect of DC, while the others represent either impoverished or heterogeneous faunas.

Chronostratigraphic considerations

Malacological record did not yield any biostratigraphic marker: in fact all recorded species were already widely diffused in Plio-Pleistocene Mediterranean Basin (Malatesta 1974), and in Lower-Middle Pleistocene Lombardian basins, such as the Leffe and Piànico-Sèllere Basin (Esu & Gianolla 2009a, b). However, some considerations are possible to argue about evolution of the northern edge of Po Basin in this area, through facies analysis based on a paleoenvironmental interpretation of the molluscan ecological meanings, and its integration with literature data (Fig. 6).
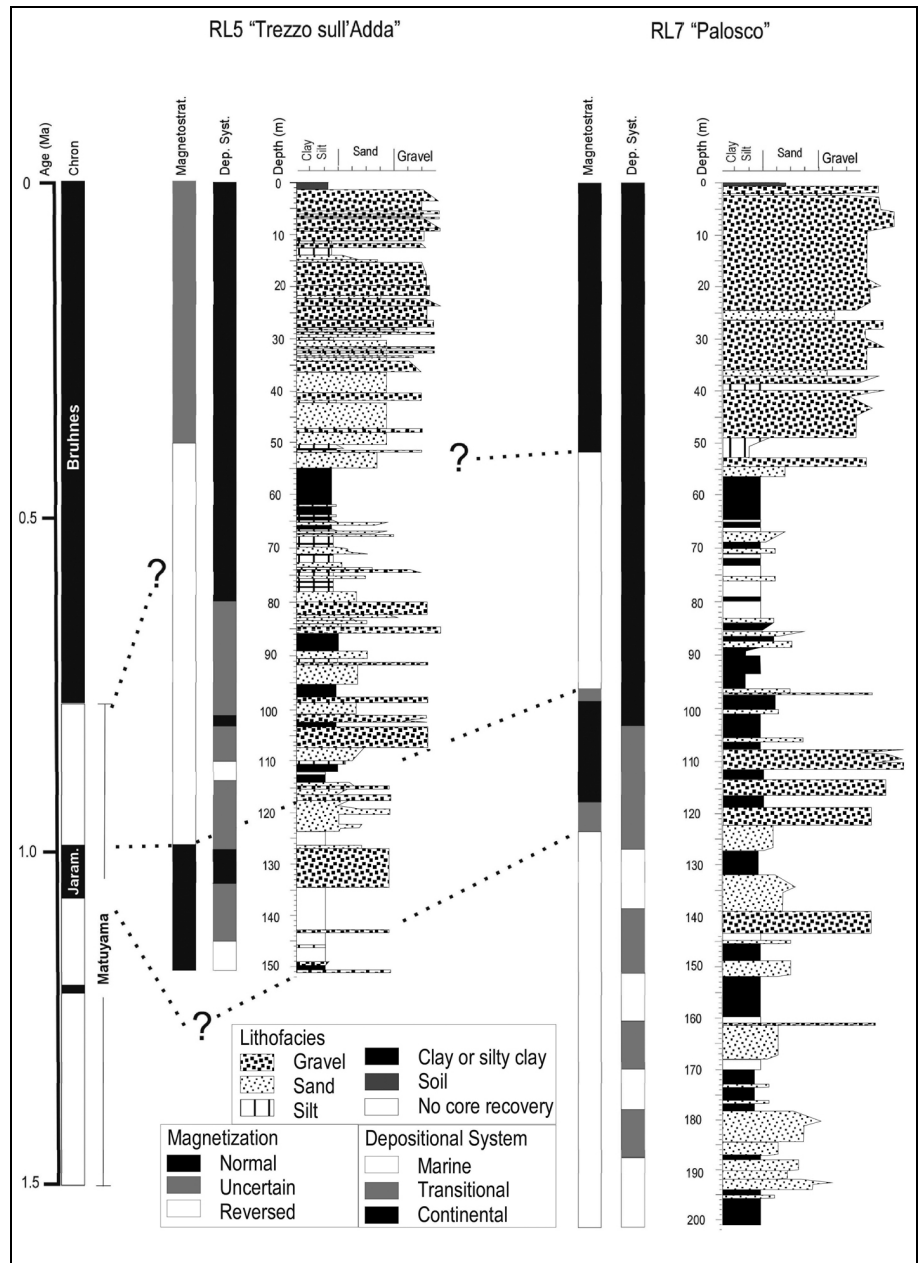
Marine conditions persisted for a considerably longer time in Trezzo than in Palosco area. Related sediments and co-occurring faunas occupy at least lower part of Jaramillo Subchron, thus dating about 1.04 Ma, while at Palosco this latter is entirely included in transitional and beginning of continental phase; marine deposits earlier disappear, at about 1.07 Ma. The delay is maintained and even amplified as regards the transitional phase. In Palosco section it does not encompass top of Jaramillo (thus being older than 1 Ma), while at Trezzo it involves at least half of the last reversal stage of Matuyama Chron, with a younger age of about 0.87 Ma. A delay of about 0.1 Ma persists in continental deposition that, conversely to transitional phase, is shorter at Trezzo than at Palosco. Actually, continental fossiliferous levels of Trezzo core can be tentatively correlated to the last part of Matuyama reversed polarity Chron (between about 0.87 and 0.78 Ma), while transitional levels deposited during terminal part of Jaramillo subchron and immediately subsequent part of Matuyama (about 1.04 - 0.8 Ma).

It appears therefore evident that in Trezzo, sea retreat was definitely delayed in time. This seems to contrast with longitude of two localities in the basin, since regression followed a gross W-E direction. A possible interpretation of this discrepancy implies placement of Trezzo area in a relative low of ancient topography, likely a bay or little gulf (see also Pini 2005): this hypothesis is consistent with recovered fauna, that includes peculiar shallow-water *Cerastoderma glaucum* (Poiret) in a otherwise DC-related assemblage. Moreover, occurrence of mud-related taxa points to an ongoing muddying of pre-existent gravelly/shelly bottom, in agreement with a scenario of incipient bay filling.

Conclusions

Studies on 126 mollusc species from 47 sampled intervals in two continuously-cored drillings allowed to reconstruct in detail the evolution of the central segment of northern Po Plain Basin fill. Such a detail was

Fig. 6 - Synthetic logs of the cores (Modified after Scardia et al. 2006).

possible by integration of palaeoenvironmental data, obtained from molluscs, with independent information available from interpretation of seismic lines and sedimentological analysis of 11 deep cores (gross sequence-stratigraphic architecture), from palaeomagnetic, stratigraphy and calcareous nannoplankton biostratigraphy, from study of palynomorph assemblages, and clastic petrography (drainage shifts).

Vertical distribution of marine, brackish and freshwater molluscan taxa confirms, and refines, the long-term regional regression, already recognized by Pleistocene in the area, from sedimentological analysis and malacological data (Carcano & Piccin 2002; Scardia et al. 2006). In fact, over most of Lombardian Po Plain, Lower Pleistocene sediments deposited in low-energy alluvial plains to deltaic and shelf systems are overlain by higher-energy alluvial "Ceppo" facies. Age of the latter deposits, documenting a stage of enhanced erosional denudation and uplift of Alps (Scardia et al. 2006), spans the latest early Pleistocene to recent.

Shift from marine to transitional and continental environments in northern part of Lombardian segment of Po Plain (Trezzo-Palosco area) was accomplished during a relatively short time span, as evidenced by the rapid-changing in the malacological assemblages. In this gap, a major sequence boundary ("r" surface of Muttoni et al. 2003) was recognizable, that can in turn be interpreted as the onset of Pleistocene glacial cycles, beginning at Marine Isotope Stage 22 at about 0.87 Ma and marking so-called "Mid-Pleistocene Revolution" (Berger & Jansen 1994; Raymo & Huybers 2008 and references therein). Marine intervals underly-

ing the "r" surface record a phase of moderate subsidence, almost keeping pace with sedimentation rates, for much of early Pleistocene. During this relative quiescence stage, sediments recorded a major marine transgression (correlated to Marine Isotope Stage 35 according to Scardia et al. 2006). Its comparatively greater importance has not been detected through sedimentological analysis alone, but clearly evidenced through malacological analyses. Therefore, "r" surface does not coincide in general with a shift from marine/ transitional to continental sedimentation, but rather with the onset of a progradation stage at the base of a stratigraphic sequence ("Acquifer Group B" according to Di Dio 1998; Carcano & Piccin 2002), characterised by a generalised and impressive increase in sediment grain size.

Progradation of continental facies was recorded heterochronously from place to place over study area as a response to local factors (inherited topography, differential uplift vs. sediment compaction rates, etc.). This is evident from detailed chronological correlation of Trezzo and Palosco cores: continental facies became exclusive since Jaramillo Subchron at Palosco, whereas at Trezzo the same environmental shift occurred during following post-Jaramillo, Matuyama Chron. Persistence of shallow-marine and lagoon malacofaunas in Trezzo, longer than in Palosco (against the Po Plain filling trend), is consistent with recent palaeogeographic reconstructions of South-Alpine margin during late early Pleistocene, that postulates the presence of a "Trezzo Gulf" in that area (Pini 2005).

APPENDIX - Remarks on selected species

Phylum **Mollusca**
Class Gastropoda

Turritella communis Risso 1826; Pl. 1., fig. 13.
Ecology (Pérès & Picard 1964; Basso & Corselli 2002): it typically occurs in marine, relatively shallow, muddy bottoms (10-30 m) but occasionally reaches about 200 m depth. This endobiont gastropod can be found in huge numbers, is a preferential characteristic element of coastal terrigenous muds (VTC) biocoenosis, but can also occur in heterogeneous assemblages (PE biocoenosis), undergoing to relevant muddying. It is a slow-moving filter feeder. In loose mud, it can define a markedly oligotypic biofacies.

Recent distribution (Eisenberg 1981, Poppe & Goto 1991): this is a common species ranging from the Northeastern Atlantic (Norway) to the Mediterranean and Southwestern Black Sea.
Fossil records (Papani & Pelosio 1962; Fekih 1975): Pliocene of Tunisia, Pleistocene of Italy.

Bithynia tentaculata (Linnaeus, 1758); Pl. 2, fig. 5
Ecology (Ložek 1964; Girod et al. 1980; Kipp & Benson 2008a): it lives in 25 – 30 cm stagnant waters like lakes, river bends, ditches, marshes, from 0 until about 2000 m a.s.l. It can live in mesohaline waters, with a salinity as low as 12 ‰. Ecological mark: 10SF.
Recent distribution (Esu & Girotti 1974; Girod et al. 1980; Gittenberger et al. 1998; Kipp & Benson 2008a): holarctic.
Fossil record (Esu & Girotti 1974; Gittenberger et al. 1998): Pliocene: Italy, Brasov basin (Romania). During Quaternary it is present in almost all Europe during interglacial and interstadial phases.
Remarks: the species has a typical, well-recognizable operculum. In many deposits, because of transport, opercula are almost unique fossil evidences of this species.

Hydrobia sp.; Pl. 2, fig. 3
Ecology (Esu & Girotti 1974; Torelli 1982): it lives in brackish and marine waters with a salinity range of 1.5 – 33‰, at river outlets, in mud on marine bottom, among Chlorophyta *Ulva* and other seaweeds. Ecological mark: 10R.
Recent distribution (Esu & Girotti 1974; Gittenberger et al. 1998): Western, Northern and Atlantic Europe; Mediterranean coasts; Western Africa; Asia; Northern America.
Fossil record (Esu & Girotti 1974; Gittenberger et al. 1998): Upper Jurassic: Europe, Asia, Africa, Northern America; Paleocene: Europe, Northern Africa; Oligocene-Pliocene: Europe; Pliocene and Quaternary: Europe.
Remarks: because of the preservation state of material, recovered specimens were assigned to *Hydrobia* sp. Within genus *Hydrobia*, species identification requires anatomical comparisons (Torelli 1982).

Valvata cristata Müller, 1774; Pl. 2, fig. 7
Ecology (Ložek 1964; Girod et al. 1980): it lives in stagnant or slowly current water, on muddy, gravel bottom. It is frequent in lakes, ponds, ditches, channel. It occurs in mesohaline waters, with a salinity as low as 12 ‰. Ecological mark: 10P.
Recent distribution (Girod et al. 1980): common in all Europe.
Fossil record (Ložek 1964, Settepassi & Verdel 1965, Gittenberger et al. 1998): Quaternary: Europe, e.g. ex Czechoslovakia, Italy, Netherlands (except in coldest phases).
Remarks: the shell is well-recognizable because of its perfectly rounded aperture. Apex is not easily distinguishable from that of *V. piscinalis*.

Valvata piscinalis (Müller, 1774); Pl. 2, fig. 6.
Ecology (Ložek 1964; Girod et al. 1980; Grigorovich et al. 2005; Kipp & Benson 2008b): it lives in stagnant or slow current waters, down to 50 cm of water depth, but usually is found within 20 cm (lakes, ponds). It generally lives on submerged plants, until 1000 m a.s.l. It is herbivorous, with a strong radula employed to eat periphyton. Ecological marks: 10SF. The species was recognized as particularly well-adapted to colonize extreme environments.
Recent distribution (Esu & Girotti 1974; Grigorovich et al. 2005; Kipp & Benson 2008b): holarctic.
Fossil record (Esu & Girotti 1974; Gittenberger et al. 1998): Upper Miocene: Italy (Pisa, Siena, Volterra) Pliocene: France, Romania, Siberia, Greece; Villafranchian: Italy (Central Italy, Leffe); Pleistocene (interglacials and interstadials): China, Europe.

Radix peregra (Müller, 1774); *R.* cf. *peregra* in Pl. 2, fig. 2.
Ecology (Ložek 1964; Girod et al. 1980): it lives in ponds, ditches, lakes, common in rivers too. It occurs in mesohaline waters,

with a salinity as low as 14‰. Ecological mark: usually 10S(F), but it can vary by morphotype.

Recent distribution (Girod et al. 1980): palearctic.

Fossil record (Ložek 1964; Settepassi & Verdel 1965; Gittenberger et al. 1998): well-known during Quaternary of whole Europe (e.g. ex Czechoslovakia, Italy, Netherlands)

Remarks: the species forms a morphological continuum with species *Radix auricularia* (Linnaeus, 1758) and it is not completely distinguishable through fragments only (Girod et al. 1980).

Gyraulus laevis (Alder, 1837); *G.* cf. *laevis* in Pl. 2, fig. 9.

Ecology (Ložek 1964; Girod et al. 1980; Gittenberger et al. 1998): the species can live in ponds, creeks, channels. It is known at the beginning of lacustrine phases, in pioneer assemblages. Ecological mark: 10S.

Recent distribution (Esu & Girotti 1974; Girod et al. 1980): holarctic.

Fossil record (Esu & Girotti 1974; Gittenberger et al. 1998): Middle Pliocene, France; Pleistocene: broadly widespread in all Europe; Holocene: more widespread than today in Central Europe (especially in Germany, Denmark, Poland, Switzerland, England).

Remarks: the species is not distinguishable from the species *Planorbis moquini* (Requien, 1848) on the basis of the shape of the shell. The two species can be confidently distinguished upon anatomical comparison (Girod et al. 1980).

Pseudofusulus varians (Pfeiffer, 1828); *P.* cf. *varians* in Pl. 2, fig. 11.

Ecology (Ložek1964; Kerney & Cameron 1979; Kerney et al. 1983): moist shaded woodland, under ground litter and stones. Ecological mark: 1W.

Recent distribution (Ložek 1964; Kerney & Cameron 1979; Kerney et al. 1983): discontinuously distributed between the Alpine and the Carpathian area.

Fossil record (Ložek 1964): the genus is known from Pleistocene to recent, in Europe.

Remarks: Recovered material (only an uncomplete last whorl) has been questionably identified as *P.* cf. *varians* on the basis of visible peristome plies.

Class Bivalvia

Anomia ephippium Linnaeus, 1758; Pl. 1, fig. 14,15.

Ecology (Basso & Corselli 2002): it is common from intertidal belt to about 150 m depth. It is a typical member of mollusc assemblages occurring on small hard substrates (living on rocks, boulders, shells and algal holdfasts).

Recent distribution (Tebble 1966, Poppe & Goto 1993): the species ranges from Iceland and Norwegian seas to Mediterranean and Black Sea, and in Atlantic Ocean southward to Ghana and Falkland Islands.

Fossil records (Malatesta 1974; Di Geronimo 1979): Oligocene of France and Germany, Miocene of Atlantic basins (Belgium to Portugal), Mediterranean and Russia, Pliocene and Pleistocene of North Sea basin, Mediterranean and Atlantic Morocco); Holocene of Italy.

Lucinella divaricata (Linnaeus, 1758); Pl. 1, fig. 3, 4.

Ecology (Tebble 1966, Basso & Corselli 2002): occurring on muddy sand and gravel, from lower shore to sublittoral zone. It is a eurythermal, euryhaline, seminfaunal suspension feeder lacking a definite ecological meaning.

Recent distribution (Poppe & Goto 1993): from British waters southward to Mediterranean and Black Sea, Madeira and Canaries.

Fossil records (Malatesta 1974; Di Geronimo 1979; Müllenhoff et al. 2004; Schneider & Hochleitner 2006): Miocene of France, Portugal, Spain and Italy, Pliocene of England, Netherlands, Spain, Italy,

Cyprus, Egypt and Morocco; Pliocene of Aegean area; Holocene of Turkey and Italy.

Plagiocardium papillosum (Poli, 1791); Pl. 1, fig. 7, 8.

Ecology (Pérès & Picard 1964; Basso & Corselli 2002): occurring in the infralittoral and circalittoral zones, down to about 60 m depth. It is a seminfaunal suspension feeder, preferential characteristic of the coastal detritic (DC) biocoenosis.

Recent distribution (Poppe & Goto 1993): from Eastern Atlantic (West Africa coasts) to the Mediterranean and Black Sea, and northward to the British Isles.

Fossil records (Malatesta 1974; Di Geronimo 1979): Miocene of France, North Sea and North Atlantic basins, Italy, Algeria, Egypt, Switzerland and Paratethys basins, Pliocene of North Sea basins, Portugal, Atlantic Morocco and Mediterranean, Pleistocene of Denmark, Atlantic Morocco and Mediterranean; Holocene of Italy.

Spisula subtruncata (Da Costa, 1778); Pl. 1, fig. 11, 12.

Ecology (Pèrés & Picard 1964): dwelling on a variety of substrates, from very fine to coarse sand with a variable proportion of mud; it occurs between intertidal zone down to about 200 m depth. It is preferential characteristic of well sorted fine sand (SFBC) biocoenosis; it is a suspension feeder which can also be found on fine terrigenous sand, where it defines a muddy sand biofacies.

Recent distribution (Barash & Danin 1992): the species spans from Finland to West Africa (Canaries and Senegal), including Mediterranean and Black Sea. It is a Mediterranean migrant into the Suez Canal.

Fossil records (Malatesta 1974): Miocene of North Sea and North Atlantic basins, France, Morocco, Mediterranean and Paratetyhs basins (*S. subtruncata* subspecies), Pliocene of Mediterranean, Portugal and Atlantic Morocco, Pleistocene of Mediterranean and Northern Europe.

Donax venustus Poli, 1795; Pl. 1, fig. 5, 6.

Ecology (Pérès & Picard 1964): dwelling on sandy and gravelly bottoms, from low tide mark down to about 90 m depth. Infaunal suspension feeder, exclusive characteristic species of biocoenosis of well-sorted, fine sand (SFBC).

Recent distribution (Barash & Danin 1992): Mediterranean and Black Sea; sporadically found in Atlantic Ocean. It is a Mediterranean migrant into Suez Canal.

Fossil records (Papani & Pelosio 1962; Ferrero & Merlino 1992): Pliocene and Pleistocene of Italy.

Pisidium pseudosphaerium Favre, 1927; *P.* cf. *pseudosphaerium* in Pl. 2, fig. 10.

Ecology (Ložek 1964; Castagnolo et al. 1980): it lives in marshes, lakes and ponds, in muddy contexts with abundant organic material and vegetation. Shell is usually recovered by algae. Ecological mark: 10P.

Recent distribution (Castagnolo et al. 1980): palearctic.

Fossil record (Ložek 1964, Gittenberger et al. 1998): Upper Pliocene: Turkey; Quaternary: Nederland, ex Czechoslovakia, Germany.

Chamelea gallina (Linnaeus, 1758); Pl. 1, fig. 16, 17.

Ecology (Pérès & Picard 1964): on muddy and sandy bottoms, from lower shore to about 15 m depth and occasionally in circalittoral zone. Seminfaunal suspension feeder occurring as an accompanying element of biocoenosis of well-sorted, fine sand (SFBC); it also occurs in fine superficial sands (SFS) biocoenosis and in fine terrigenous sands, where it defines a pure sand biofacies.

Recent distribution (Barash & Danin 1992): East Atlantic (from Norway to Madeira and Canaries) to Mediterranean and Caspian Sea. It is a Mediterranean migrant into Suez Canal.

Fossil records (Venzo & Pelosio 1973; Malatesta 1974; Di Geronimo 1979): Miocene (?) of Eastern Europe, Pliocene of Netherlands, Atlantic Morocco and Mediterranean, Pleistocene of North Sea basins,

Atlantic Morocco and Mediterranean; Upper Miocene of Italy; Holocene of Italy.

Corbula gibba (Olivi, 1792); Pl. 1, fig. 1, 2.

Ecology (Yonge 1946; Pérès & Picard 1964; Di Geronimo & Robba 1989; Diaz & Rosenberg 1995; Hrs-Brenko 2006): shallow burrower in muddy sand, gravelly and shelly bottoms, where it lives attached by a single byssal thread, occurring from intertidal zone down to about 150 m and occasionally higher depths. Exclusive characteristic species of heterogeneous assemblages (PE). It is a suspension feeder on diatoms, bacteria and organic matter. It is a very tolerant element, able to reach extremely high population densities (over 50,000 specimens for square meter); it withstands low O_2 levels. It is regarded as a good indicator of sediment and/or trophic supply instability.

Recent distribution (Barash & Danin 1992): Atlantic Ocean from Norwegian Sea to Angola, Mediterranean and Black Sea; recently introduced to Australia. It is a Mediterranean migrant into Suez Canal.

Fossil records (Malatesta 1974): Upper Eocene of France, Oligocene of Central, Northern and Eastern Europe, Miocene of Europe, Morocco, Algeria and Tunisia, Pliocene of Europe and Mediterranean, Pleistocene of Atlantic (Sweden to Gabon), Mediterranean and Black Sea.

Lentidium mediterraneum (Costa, 1829); Pl. 1, fig. 9, 10.

Ecology (Pérès & Picard 1964): it is a shallow-water species, occurring on both sandy and muddy bottoms. It appears to prefer sandy estuaries. It is considered as an exclusive characteristic member of fine superficial sands (SFS) biocoenosis.

Recent distribution (Poppe & Goto 1993): from the Atlantic Ocean to Mediterranean and Black Seas.

Fossil records (Martinell & Domènech 1984; Ferrero & Merlino 1992): Pliocene of Spain and Italy.

Phylum **Charophyta**
Class Charophyceae

Nitellopsis obtusa (Desvaux in Loiseleur-Deslongchamps, 1810) J. Groves (1919); *N.* cf. *obtusa* in Pl. 2, fig. 4.

Ecology (Soulié-Märsche 1991; Kipp 2008): the species is typical of permanent, relatively deep (3 – 10 m) cold lakes. The plant can withstand slight salinity intervening after initial growth.

Recent distribution (Soulié-Märsche 1991; Soulié-Märsche et al. 2002; Kipp 2008): it lives from temperate to boreal zones, in Europe, Asia and in Great Lakes of N-America.

Fossil record (Soulié-Märsche 1991; Bhatia et al. 1998; Soulié-Märsche et al. 2002): Early Quaternary to recent, particularly Late Pleistocene and Holocene; recorded in Europe, Asia and North Africa.

Remarks: *N. megarensis* (Plio-Pleistocene) and *N. obtusa* form a continuous ancestor-descendent lineage (Bhatia et al. 1998), but to correctly distinguish the two species at least 100 gyrogonites are necessary (Soulié-Märsche pers. com.): in the analyzed material just five gyrogonites occur, thus allowing a questionable identification as *N.* cf. *obtusa*.

PLATE 1

Scale bars: 2 mm

Fig. 1	- *Corbula gibba* (Olivi, 1792). Right valve. RL 7-Palosco core, level 145.85-146.17 m.
Fig. 2	- *Corbula gibba* (Olivi, 1792). Left valve. RL 7-Palosco core, level 145.85-146.17 m.
Fig. 3	- *Lucinella divaricata* (Linnaeus, 1758). Right valve. RL 7-Palosco core, level 138.55-139.1 m.
Fig. 4	- *Lucinella divaricata* (Linnaeus, 1758). Left valve. RL 7-Palosco core, level 138.55-139.1 m.
Fig. 5	- *Donax venustus* Poli, 1795. Right valve. RL 7-Palosco core, level 135-135.1 m.
Fig. 6	- *Donax venustus* Poli, 1795. Left valve. RL 7-Palosco core, level 135-135.1 m.
Fig. 7	- *Plagiocardium papillosum* (Poli, 1791). Left valve. RL 7-Palosco core, level 145.85-146.17 m.
Fig. 8	- *Plagiocardium papillosum* (Poli, 1791). Right valve. RL 7-Palosco core, level 145.85-146.17 m.
Fig. 9	- *Lentidium mediterraneum* (Costa, 1929). Left valve. RL 7-Palosco core, level 135-135.1 m.
Fig. 10	- *Lentidium mediterraneum* (Costa, 1929). Right valve. RL 7-Palosco core, level 135-135.1 m.
Fig. 11	- *Spisula subtruncata* (Da Costa, 1778). Left valve. RL 7-Palosco core, level 138.55-139.1 m.
Fig. 12	- *Spisula subtruncata* (Da Costa, 1778). Right valve. RL 7-Palosco core, level 138.55-139.1 m.
Fig. 13	- *Turritella communis* Risso, 1826. RL 5-Trezzo core, level 149.9-150.0 m
Fig. 14	- *Anomia ephippium* Linnaeus, 1758. Left valve. RL 7-Palosco core, level 131-131.23 m.
Fig. 15	- *Anomia ephippium* Linnaeus, 1758. Left valve. RL 7-Palosco core, level 131-131.23 m.
Fig. 16	- *Chamelea gallina* (Linnaeus, 1758). Left valve. RL 7-Palosco core, level 135-135.1 m.
Fig. 17	- *Chamelea gallina* (Linnaeus, 1758). Left valve. RL 7-Palosco core, level 135-135.1 m.

PLATE 2

Scale bar: 2 mm

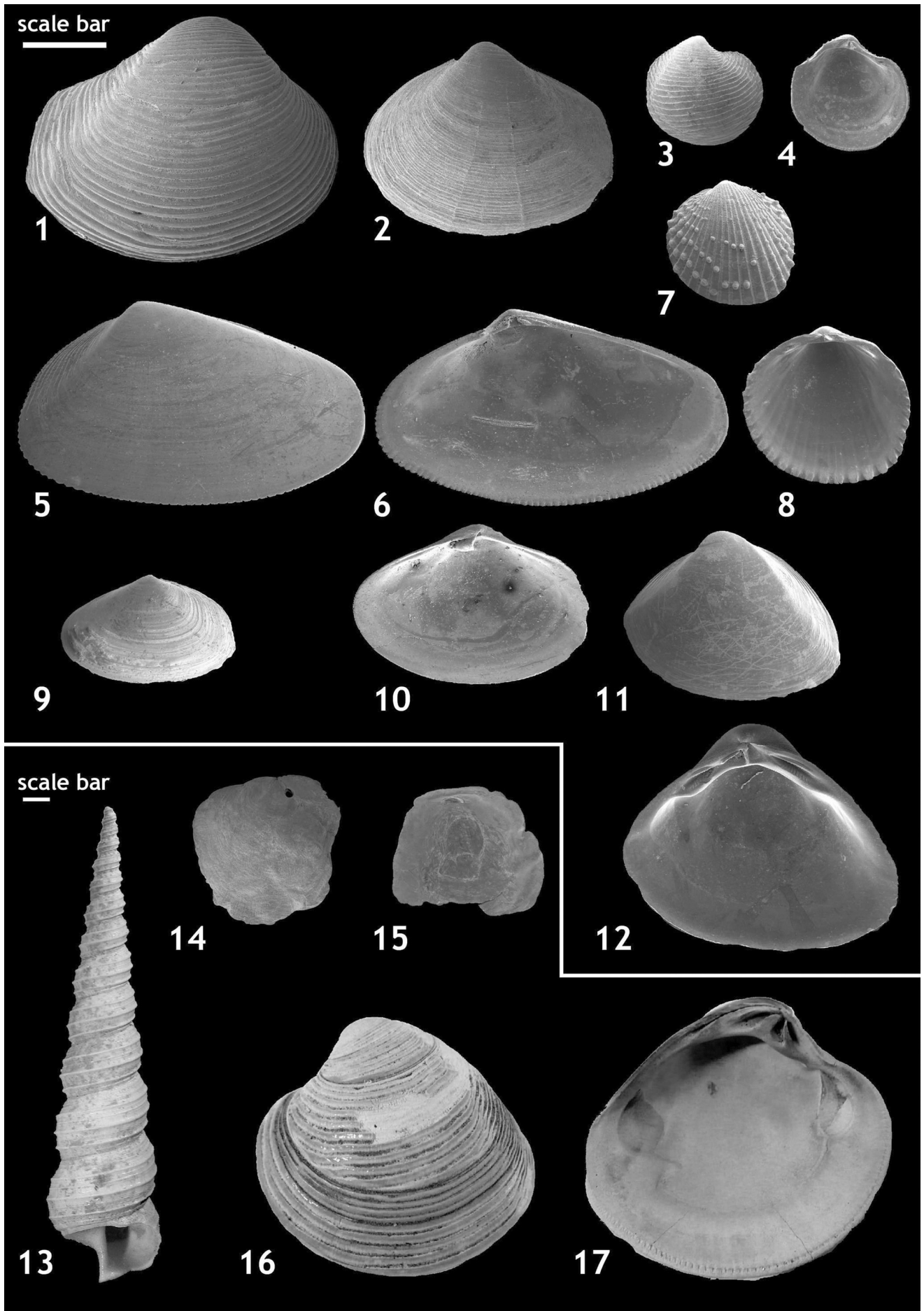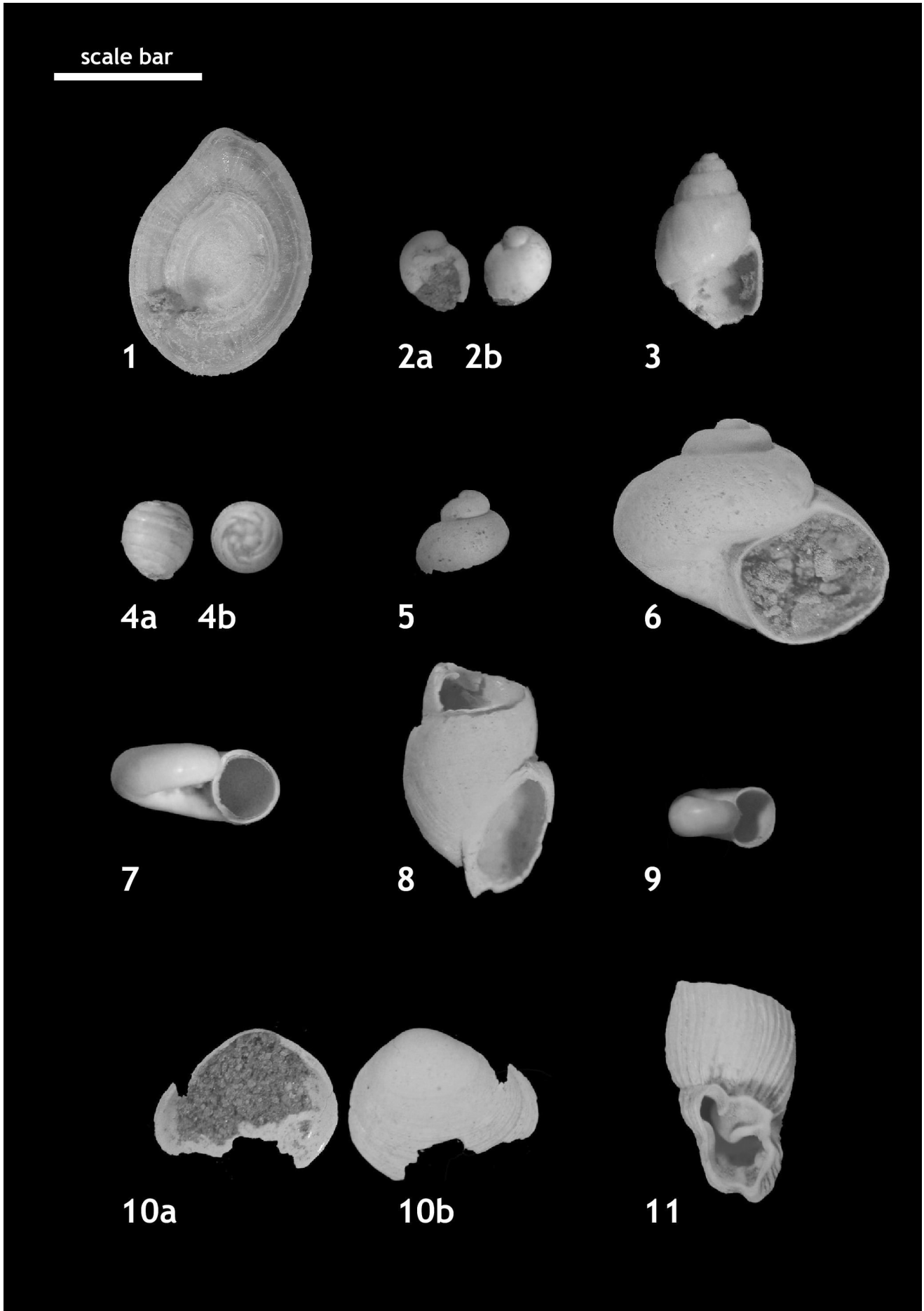| Fig. 1	- *Bithynia tentaculata* (Linnaeus, 1758). Operculum. RL 5-Trezzo core, level 103.1- 103.2 m.
Figs. 2a-b	- *Radix* cf. *R. peregra* (Müller, 1774). RL 5-Trezzo core, level 54.8-54.9 m.
Fig. 3	- *Hydrobia* sp. Apex. RL 5-Trezzo core, level 103.1-103.2 m.
Figs. 4a-b	- *Nitellopsis* cf. *obtusa* (Desvaux in Loiseleur, 1810). RL 5-Trezzo core, level 54.8-54.9 m.
Fig. 5	- *Bithynia tentaculata*. Apex. RL 7-Palosco core, level 96.65-96.80 m.
Fig. 6	- *Valvata piscinalis* (Müller, 1774). RL 7-Palosco core, level 96.65-96.80 m.
Fig. 7	- *Valvata cristata* Müller, 1774. RL 7-Palosco core, level 89.72-89.85 m.
Fig. 8	- *Hydrobia* sp. Aperture. RL 7-Palosco core, level 96.65-96.80 m.
Fig. 9	- *Gyraulus* cf. *laevis* (Alder, 1837). RL 7-Palosco core, level 89.60-89.72 m.
Figs. 10a-b	- *Pisidium* cf. *pseudosphaerium* Favre, 1927. Left valve. RL 7-Palosco core, level 96.65 -96.80 m.
Fig. 11	- *Pseudofusulus* cf. *varians* (Pfeiffer, 1828). RL 7-Palosco core, level 102.83-103.00 m.

PLATE 1

PLATE 2

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