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THE MOLLUSCAN FAUNA FROM THE UPPER PLEISTOCENE VERTEBRATE-BEARING DEPOSITS OF S. TEODORO CAVE (NORTH-EASTERN SICILY)

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Abstract. This paper deals with terrestrial, freshwater and marine molluscs collected in the upper Pleistocene deposits of clay, sands and gravels of S. Teodoro Cave (North-eastern Sicily). Beginning from 1998 two trenches have been excavated (1998 and 2002-2004). A highly diversified assemblage of endemic and not endemic vertebrates (elephant, horse, wild ox, deer, wild boar, hyaena, fox, mouse, ground vole, shrew, hedgehog, bats, birds, reptiles), invertebrates (molluscs) and vegetal remains have been collected from the two trenches. The molluscan fauna is represented by poor to rich-species assemblages of land and freshwater gastropods and bivalves with Mediterranean-European character. Some species have been found for the first time as fossils in Sicily. The land snails prevail in the 1998 trench showing a persistent arid environment during the time of the sediment deposition. The freshwater species, characteristic of slow-running water, point to the presence of a small water body (stream or spring) inside the cave, probably more consistent in the 2002-2004 trench where this fauna prevails. The dispersal of the molluscan fauna of S. Teodoro Cave from the mainland during the low stand sea-level phases of the upper Pleistocene probably belongs to the same dispersal events following the Oxygen Isotope Stage 5e which introduced into the island not endemic faunal elements which are associated with endemic faunal elements in S. Teodoro Cave. Littoral marine reworked molluscs found in the cave deposits probably come from the sedimentary cover of a middle Pleistocene terrace which overlies the roof of the cave.

Riassunto. Viene analizzata la fauna a molluschi continentali e marini proveniente dai depositi argilloso-sabbiosi e ghiaiosi del Pleistocene superiore della Grotta di S. Teodoro (Sicilia nord-orientale), dove, a iniziare dal 1998, sono state scavate due trincee (1998 e 2002-2004). I resti di una associazione molto diversificata di vertebrati endemici e non endemici (elefante, cavallo, uro, cervo, cinghiale, iena, volpe, topo, topo campagnolo, toporagno, riccio, pipistrelli, uccelli, rettili), di invertebrati (molluschi) e di vegetali sono stati raccolti nelle due trincee. I molluschi sono rappresentati da associazioni oligotipiche fino a politipiche di gasteropodi terrestri e di acqua dolce e bivalvi a carattere mediterraneo-europeo. Alcune specie sono segnalate fossili per la prima volta in Sicilia. Le specie terrestri, prevalenti nella trincea 1998, indicano un ambiente arido circostante la grotta. Le specie di acqua dolce, indicative di acque debolmente correnti, come acque di sorgente all'interno della grotta, prevalgono nella trincea 2002-2004. La dispersione dalla penisola italiana dei molluschi continentali rinvenuti nei sedimenti della Grotta di S. Teodoro, durante una delle fasi di basso stazionamento del livello marino del Pleistocene superiore, appartiene probabilmente agli stessi eventi di dispersione posteriori allo stadio isotopico -OIS-5e, che introdussero nell'isola gli elementi faunistici non endemici che si trovano associati a quelli endemici della Grotta di S. Teodoro. I molluschi marini litorali, presenti nei sedimenti della grotta, sono rimaneggiati e derivano probabilmente dalla copertura sedimentaria di un terrazzo marino del Pleistocene medio che sovrasta il tetto della grotta.

Introduction

Fossil records of non-marine molluscs from Sicily are poorly known and S. Teodoro Cave is the only Sicilian cave containing Pleistocene vertebrates from which large mammals, micromammals and molluscs have been collected by systematic excavations. At S. Teodoro Cave (North-eastern Sicily) the Authors distinguished an upper Late Glacial sedimentary unit (unit A, in Bonfiglio et al. 2001) containing humans' feeding remains (mammal bones) associated with late upper Palaeolithic (Epigravettian) stone artifacts, and a lower sedimentary unit (unit B, in Bonfiglio et al. 2001) containing upper Pleistocene endemic mammal remains associated with remains of not endemic mammals (Anca

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1860; Graziosi 1943; Graziosi & Maviglia 1946; Bonfiglio et al. 2001).

During 1998 excavations were carried out and the lower unit (unit B) has been investigated over an area of about 12 m sq. located on the eastern side of the cave at a distance of 8-13 m from the entrance. Only scattered small relics of the upper unit (unit A) were recovered (Bonfiglio et al. 2001) (Figs 1 and 2).

In 2002 a new trench has been located on the inner eastern side of the cave at a distance of 28-34 m from the entrance. It has been digged and enlarged during 2003 and 2004 excavations up to a surface of about 18 m sq. (Mangano et al. 2005; Mangano & Bonfiglio 2005a). During 2004 a new sterile sedimentary unit (unit C) has been detected on the south-eastern side of the trench, probably older than the fossiliferous unit B (Fig. 2) (Mangano & Bonfiglio 2005b).

The investigated unit B is made of clayey sands and gravels which contain a highly diversified assemblage of vertebrates (elephant, horse, wild ox, deer, wild boar, hyaena, fox, mice, ground vole, shrew, hedgehog, bats, birds, reptiles), invertebrates (molluscs) and vegetal remains.

According to previous knowledge, Sicily was thought to have been populated by four vertebrate Faunal Complexes (F.C.) during the Pleistocene. The most recent one (Castello F.C.), Late Glacial in age, includes 'mainland' taxa frequently associated with lithic industries of Epigravettian culture (see Bonfiglio et al. 2000), while the previous complex (*Elephas mnaidriensis* F.C.), late Middle Pleistocene – part of Late Pleistocene in age, includes endemic mammals (Bonfiglio 1991; Bada et al. 1992; Rhodes 1996). In particular, small mammals belonging to this Complex are endemic taxa (*Leithia melitensis*, *Maltamys* cf. *wiedincitensis*, *Crocidura esuae*; Kotsakis 1996; Bonfiglio et al. 1997; Di Maggio et al. 1999) derived from an older fauna characterized by a high degree of endemism (*E. falconeri* F.C., early Middle Pleistocene in age).

The large mammal assemblage from S. Teodoro Cave, which contains elephant (*Elephas mnaidriensis*), wild ox (*Bos primigenius siciliae*), deer (*Cervus elaphus siciliae*), wild boar (*Sus scrofa*), wolf (*Canis lupus*), hyaena (*Crocuta crocuta spelaea*), fox (*Vulpes vulpes*), horse (*Equus hydruntinus*) and the associated small mammal taxa (*Microtus (Terricola)* ex gr. *savii*, *Apodemus* cf. *sylvaticus, Erinaceus* cf. *europaeus* and *Crocidura* cf. *sicula*) have been attributed to a new faunal complex in the Pleistocene of Sicily (Grotta di S. Teodoro – Pianetti F.C.) which includes some endemic taxa surviving from the older *Elephas mnaidriensis* faunal complex associated with not endemic taxa (*Equus hydruntinus*, *Microtus (Terricola)* ex gr. *savii*, *Erinaceus* cf. *europaeus*) (Bonfiglio et al. 2001).

Vertebrate remains are scattered within all the excavated levels. Skeleton remains of large mammals are fragmented and not articulated. The numerous and diverse evidences of cave frequentation by spotted hyaena populations is actually the most prominent taphonomic feature of this deposit. This evidence consists in the occurrence of several *Crocuta* skeletal elements (skull, teeth, limb bones), an impressive quantity of coprolites, and in ubiquitous traces of crushing, gnawing, chewing and digestion that have been detected on almost all the large mammal remains (Bonfiglio et al. 1999). Pollen from coprolites, coming from 1998 trench, depicts a glacial landscape that included steppes of Poaceae, *Artemisia, Ephedra,* Chenopodiaceae, Asteraceae, *Pinus,*

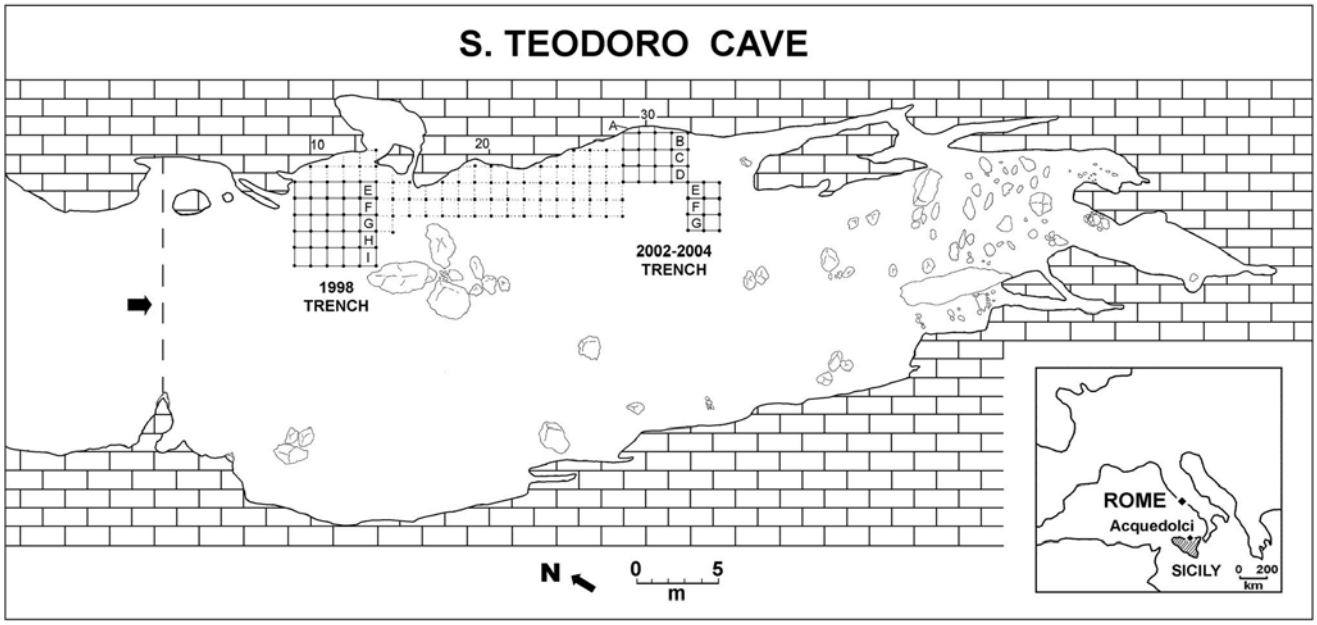


Fig. 1 - Plan of S. Teodoro Cave with location of 1998 trench (squares E-I/9-13) and 2002-2004 trench (squares A-G/29-34). The arrow indicates the entrance of the cave.

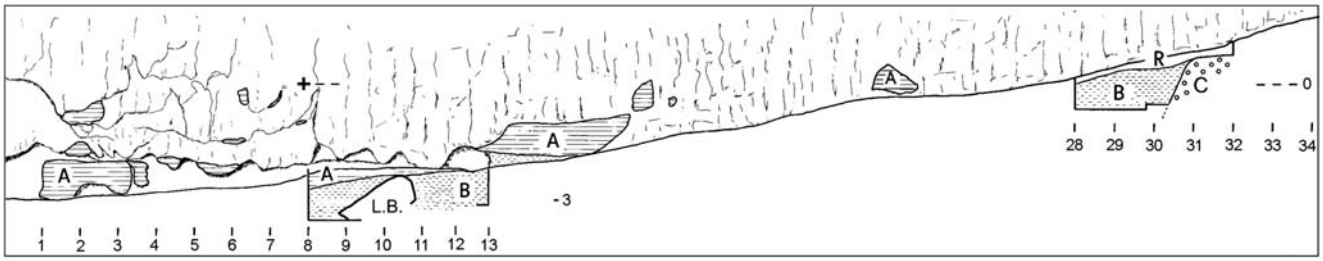


Fig. 2 - Profile of the S. Teodoro Cave floor from the entrance (sq. 1) to the inner of the cave and location of the excavated trenches with correlation of the stratigraphic units. The cross indicates the landmark (quote '0'). The numbers indicate the distance (m) from the entrance. A = unit A; B = unit B; C = unit C; R = recent level; L.B.= Large Boulder.

Cupressaceae. Lower percentages of pollen of mesophilous taxa (*Quercus*, *Betula*, *Abies*, *Alnus*, *Pistacia*, among others) suggest the existence of nearby refugia of temperate and Mediterranean vegetation (Yll et al. 2006).

This paper deals with the molluscan assemblages recovered from 1998 and 2002-2004 excavations of unit B.

Methods

A grid of squares (side = 1 m) identified by surface co-ordinates (numbers and caps letters) have been superposed to the cave floor, starting from the entrance. Square numbers start from the entrance (n. 1) and proceed towards the inner of the cave. Letters start from M, indicating squares immediately eastward of the major axis set at the centre of the cave and N for squares immediately westwards. The excavation trenches have the following co-ordinates: 9 to 13 and E to I (1998 trench) and 29 to 34 and A to G (2002-2004 trench).

The depth co-ordinate, reported for cuts and significant specimens, starts from a landmark (quote '0') marked on eastern side wall of the cave (Fig. 2). Each square has been deepened by cuts having thickness from 7 to 14 cm, resulting from the different size of the skeletal elements scattered within single levels. The cuts have been numbered progressively from the top to the bottom starting from 1. Having the reworked deposits overlying the unit B variable thickness, the sampled deposits start at variable depth in the different squares. The recovered material is therefore identified by surface (square) and depth (cut) co-ordinates. Large sized faunal remains have been collected directly during excavation, while small specimens and molluscs have been recovered by sieving on a 2 mm mesh. The 1998 trench depth is included between – 1.95 and -3.85 m. A large, deeply rooted boulder divides the 1998 trench into two sectors (squares 9, 10 and squares 11, 12, 13) (see Fig. 2) which have been deepened by cuts having different depth.

The 2002-2004 trench depth is included between + 0.51 and – 0.27 m. In the 33/34-FG squares, which have been excavated beginning from 2003, cuts B and A are higher than cut 1 (+ 0.70 and + 0.60 m, respectively).

Lithology and fossil content is fairly uniform all along the investigated trenches. The sediment is prevalently made by grey-green clayey sand. In 2002-2004 trench a diffuse discontinuous concretioning process of the sediment, of the fossil bones and of coprolites occurs, especially in the western squares (C, D).

Molluscs

Detailed sampling for qualitative and quantitative molluscan analyses was carried out on the unit B. Several species of freshwater and terrestrial gastropods and two species of freshwater bivalves (Pl. 1 and 2) were recovered from 90 cave sediment samples. The fossil material is generally in a good state of preservation even if most of the land gastropod shells are affected by various predation marks, such as broken aperture or more or less large holes or breaking on the shell (Pl. 1, Figs 8b, 9, 10 14a, 16b; Pl. 2, Fig. 8), which may have been produced by coleoptera (beetles) or small mammals, such as Soricidae or Insectivora (*Erinaceus europaeus*), rodents, spiders (Opiliones), birds, or by chemical attack by carnivorous land snails (Kerney & Cameron 1979; Falkner 1990). Moreover scarce marine broken shells of gastropods, clearly reworked, are scattered in the cave sediments.

The non-marine molluscs are represented by 23 species belonging to several genera and families of Gastropods (Prosobranchs and Pulmonates) and Bivalves.

Gastropods

Freshwater Prosobranchs

Hydrobiidae: *Mercuria similis* (Draparnaud, 1805), *Pseudamnicola (Pseudamnicola) moussonii* (Calcara, 1841)

Freshwater Pulmonates

Lymnaeidae: *Galba truncatula* (Müller, 1774)

Planorbidae: *Planorbis planorbis* (Linnaeus, 1758)

Ancylidae: *Ancylus fluviatilis* Müller, 1774

Terrestrial Pulmonates

Succineidae: *Oxyloma elegans* (Risso, 1826)

Pyramidulidae: *Pyramidula pusilla* (Vallot, 1801)

Chondrinidae: *Chondrina avenacea* (Bruguière, 1792)

Enidae: *Chondrula (Mastus) pupa* (Linnaeus, 1758)

Daudebardiidae: *Daudebardia (Daudebardia) rufa* (Draparnaud, 1805)

Clausiliidae: *Papillifera papillaris* (Müller, 1774), *Papillifera solida* (Draparnaud, 1805)

Hygromiidae: *Cernuella (Cernuella) cisalpina* (Rossmässler, 1837), *Cernuella (Cernuella) virgata* (Da

Costa, 1778), *Cernuella* sp., *Caracollina (Caracollina) lenticula* (Michaud, 1831), *Trochoidea (Trochoidea) pyramidata* (Draparnaud, 1805), *Monacha (Monacha) cartusiana* (Müller, 1774), *Cochlicella acuta* (Müller, 1774)

Helicidae: *Chilostoma (Campylaea) planospira* (Lamarck, 1822), *Marmorana (Ambigua) fuscolabiata* (Rossmässler, 1842)

Bivalves
Palaeoheterodonts
Unionidae: *Unio* sp.

Heterodonts
Sphaeriidae: *Pisidium casertanum* (Poli, 1791)

Species autoecology and distribution

All the recorded species, except probably for *Papillifera solida,* were already mentioned as living in Sicily by a number of Authors in the 19th century or in the first half of the 20th (Philippi 1836-1844; Calcara 1845; Benoit 1857-1862, 1875, 1882; Monterosato 1892, 1894; De Gregorio 1927), whilst knowledge of their distribution in Cenozoic sediments of Sicily is still limited.

Mercuria similis. A freshwater snail inhabiting running water, mainly springs and streams, on rocky or sandy substrata. Holomediterranean in coastal areas (Giusti et al. 1995). It seems widespread as western European Pleistocene and Holocene fossil (Zilch & Jaeckel 1962; Madurga 1973).

Pseudamnicola (Pseudamnicola) moussonii (*sic*, ICZN 1999, Art. 33.4). A freshwater snail frequently found in association with *Mercuria similis*. It colonizes running water (springs and streams) on rocky and sandy substrata, often on plant debris. Widespread in coastal regions and islands of the western Mediterranean, this species was first described by the author from Sicilian living individuals (Giusti et al. 1995). Common as western Mediterranean Cenozoic fossil (Esu 1986; Giusti et al. 1995). A carinate morphotype (Pl. 1, Fig. 3), very probably belonging to *P. moussonii*, has been recorded from S. Teodoro Cave together with standard specimens of this species, whose shells sometimes show the tendency to form shouldered whorls (Pl. 1, Fig. 2).

Galba truncatula. It is an amphibious freshwater pulmonate found in a variety of aquatic habitats such as small stream, ponds, ditches, marshes, water meadows, open wet woodland, often in ephemeral habitats where there is no permanent water. Holarctic, through Europe to beyond the Arctic circle (Killeen 1992; Kerney 1999). Widespread in warm and cold Pleistocene and Holocene phases (Ložek 1964).

Planorbis planorbis. A very common snail of stagnant or slow-moving well-vegetated freshwaters, but especially characteristic of shallow pools and swampy ditches liable to dry up in the summer. Holopalaearctic (Giusti et al. 1995; Kerney 1999). Widely diffused in warm and cold Pleistocene and Holocene phases (Ložek 1964; Puisségur 1976).

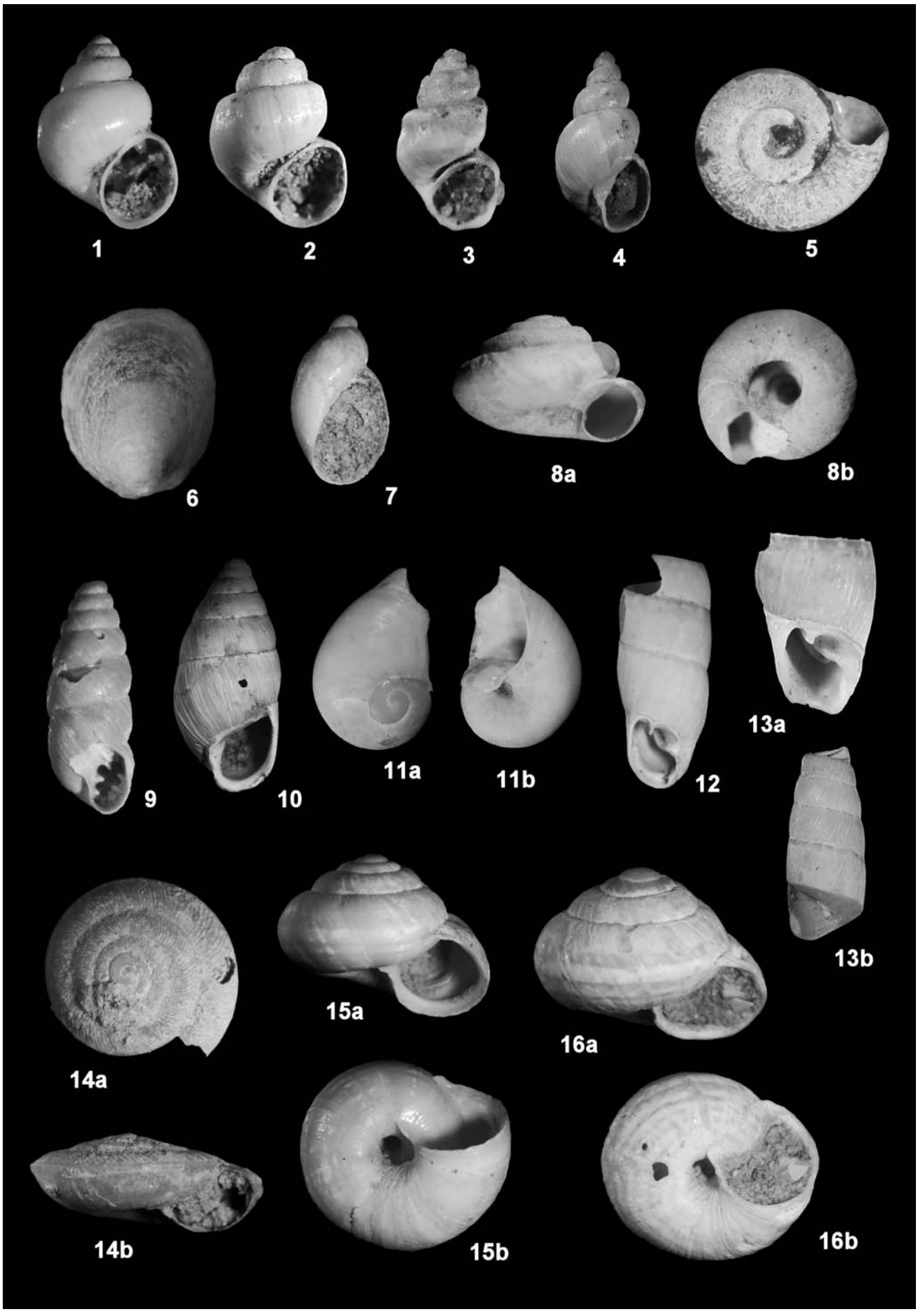
Ancylus fluviatilis. A very common and widely distributed freshwater species. It mainly inhabits running water of streams and rivers particularly those with a stony substrate on which it can adhere. It requires clean water free from suspended matter and avoids muddy substrate. Holopalaearctic (Killeen 1992; Kerney 1999). Widely diffused as late Cenozoic fossil in warm and cold phases (Ložek 1964).

Oxyloma elegans. A highly hygrophilous terrestrial pulmonate living in permanently wet sites such as marshes, fens and river banks. Holarctic (Giusti et al. 1995). Widely diffused as late Cenozoic fossil, especially during warm phases (Ložek 1964).

Pyramidula pusilla. A very small land species inhabitant of limestone rocks. It is widespread in the entire Mediterranean area and western and central Europe (Gittenberger & Bank 1996). Since this species has been generally synonymized with *Pyramidula rupestris* (Draparnaud) it is difficult to know its real stratigraphic distribution; for example, *P. rupestris* figured by Ložek (1964, fig. 38) looks like *P. pusilla*. Taxa named *P. rupestris* are known during Pleistocene interglacial phases in central and western Europe (Ložek 1964; Puisségur 1976).

PLATE 1

Non-marine molluscs from S. Teodoro Cave, Late Pleistocene. Fig. 1 - *Mercuria similis* (Draparnaud) 8x, MPUR-7-3396. Fig. 2 - *Pseudamnicola moussonii* (Calcara) 11.5x, MPUR-7-3440. Fig. 3 - *Pseudamnicola* cf. *P. moussonii* (Calcara) 10.6x, MPUR -7-3441. Fig. 4 - *Galba truncatula* (Müller) 5.8x, MPUR-7-3397. Fig. 5 - *Planorbis planorbis* (Linnaeus) 5.3x, MPUR-7-3398. Fig. 6 - *Ancylus fluviatilis* Müller 12.7x, MPUR-7-3399. Fig. 7 - *Oxyloma elegans* (Risso) 4.7x, MPUR-7-3400. Fig. 8a, b - *Pyramidula pusilla* (Vallot) 15x, MPUR-7-3401. Fig. 9 - *Chondrina avenacea* (Bruguière) 7.5x, MPUR-7-3402. Fig. 10 - *Chondrula (Mastus) pupa* (Linnaeus) 3.7x, MPUR-7-3403. Fig. 11a, b - *Daudebardia (Daudebardia) rufa* (Draparnaud) 9.5x, MPUR-7-3404. Fig. 12 - *Papillifera solida* (Draparnaud) 6x, MPUR-7-3409. Fig. 13a, b - *Papillifera papillaris* (Müller) 7x (a), 5x (b), MPUR-7-3405. Fig. 14a, b - *Caracollina (Caracollina) lenticula* (Michaud) 5.1x (a), 6.2x (b), MPUR-7-3408. Fig. 15a, b - *Cernuella (Cernuella) cisalpina* (Rossmässler) 4.5x, MPUR-7-3406. Fig. 16a, b - *Cernuella* sp. 7.5x, MPUR-7-3410.
All the specimens are stored in coll. Esu-Girotti, MPUR, Palaeontological Museum of University of Rome "La Sapienza".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Chondrina avenacea. It lives in dry open calcareous places, especially characteristic of rocks and walls. West European and Alpine (Kerney & Cameron 1979). Known as rare fossil in Pleistocene and Holocene deposits of western and central Europe (Ložek 1964; Puisségur 1976).

Chondrula (Mastus) pupa. A terrestrial xeroresistant species frequent in open habitats such as stony grassland, garigue, maquis etc. mostly on calcareous substrata. Frequent also in disturbed substrata under stones, near human settlements. Holomediterranean (Giusti 1973; Giusti et al. 1995). It is known as fossil from Pliocene and Pleistocene deposits of Mediterranean Europe, Mediterranean islands and North Africa (Esu 1978; Giusti et al. 1995).

Daudebardia (Daudebardia) rufa. Carnivorous and largely subterranean, it lives in leaf litter and under stones in moist woods (Ložek 1964). In Sicily it is common in wet places (Benoit 1857-1862). Central and southern European (Kerney & Cameron 1979). A subspecies, *D. rufa maravignae* (Pirajno 1840), is described for Sicily (Bodon et al. 1995). The scanty and fragmentary material of this species from S. Teodoro Cave does not permit the identification at subspecific level. The species was recorded in Pleistocene interglacial and Holocene deposits of central Europe and Italy (Ložek 1964; Cinque et al. 1986; Esu & Girotti 1991).

Papillifera papillaris. A terrestrial snail living on all kinds of rocky substrata, also walls covered with lichens, mosses and other vegetation. It is very common in western-central Mediterranean realm. Known as fossil in the Quaternary deposits of the Maltese Islands (Giusti et al. 1995; Hunt 1997).

Papillifera solida. A thermophilous xeroresistant land species living on calcareous rocks along the Italian Tyrrhenian coast and in southern France (Giusti & Castagnolo 1982). It seems unknown in Sicily. Not known as fossil in Italy so far.

Cernuella (Cernuella) cisalpina. It occurs in dry natural and anthropogenic habitats usually under stones or other debris. Holomediterranean. Known as fossil in the Quaternary deposits of Malta (Giusti et al. 1995).

Cernuella (Cernuella) virgata. It lives in moderately dry and open calcareous sites, dunes, grassy habitats and anthropogenic habitats. Western European and Mediterranean, known as fossil in Pleistocene sediments of France, Spanish, and Malta (Madurga 1973; Kerney & Cameron 1979; Dubar & Magnin 1991; Giusti et al. 1995).

Cernuella sp. It is a small globular morphotype belonging to the genus *Cernuella*. Many small living species of *Cernuella* were described by the ancient authors for Sicily, but the lack of material for comparison does not permit a specific identification of this small *Cernuella* at present.

Caracollina (Caracollina) lenticula. A thermophilic and thalassophilic species, very frequent in retrodune habitats or on rocky coasts under stones, wood and plant debris. It also occurs in anthropogenic habitats in coastal sites. Widespread in western Mediterranean area (Giusti et al. 1995). Known in Holocene deposits of Malta (Hunt 1997).

Trochoidea (Trochoidea) pyramidata. A widespread thermophilic and very xeroresistant species living on the coasts and in the internal areas in western Mediterranean (Giusti 1973). Uncertain reports as fossil are known from the Quaternary of the Maltese Islands (Giusti et al. 1995).

Monacha (Monacha) cartusiana. Widespread in open, unshaded places on calcareous soil, grassland, hedges, but it is also found in moister places. Rare above 500 m, it has Mediterranean and south-estern European range; probably introduced to Britain from southern Europe as a "weed" of cultivation by prehistoric farmers (Neolithic?) (Kerney & Cameron 1979; Kerney 1999). Known as fossil in Pleistocene interglacial and Holocene deposits of central and western Europe (Ložek 1964; Puisségur 1976).

Cochlicella acuta. A maritime snail which lives usually in dunes and coastal grassland in large populations, occasionally on calcareous ground inland. Mediterranean and Atlantic (Kerney & Cameron 1979). Known as a common Quaternary fossil (Giusti et al. 1995; Hunt 1997).

Chilostoma (Campylaea) planospira. A south Alpine species living preferably in grassland and open woods. Subspecies are mentioned for Sicily (Bodon et al. 1995). Only fragments have been recorded from S. Teodoro Cave. It is known in Pleistocene and Holocene deposits from Italian Peninsula and from middle Pleistocene bone-bearing breccias of Sicily (Bellini 1902; Esu et al. 1986).

Marmorana (Ambigua) fuscolabiata. The genus *Marmorana* has circum-Tyrrhenian distribution (Giusti et al. 1995). This species is spread in southern Italy and Sicily (Bodon et al. 1995). It is known as fossil in Holocene (under the name of *Iberus surrentina*) and upper Pleistocene deposits of Capri Island (Bellini 1902; Cinque et al. 1986).

Unio sp. Only a shell fragment with beak was recorded. Species belonging to this genus prefer running waters.

Pisidium casertanum. A freshwater small bivalve living in a wide diversity of freshwater habitats such as cold or thermal springs, streams, rivers, lakes. One of the most common and widespread *Pisidium* species, Holarctic (Castagnolo et al. 1980; Kerney 1999). Widespread as Cenozoic fossil, found also in the Maltese Islands (Settepassi & Verdel 1965; Giusti et al. 1995).

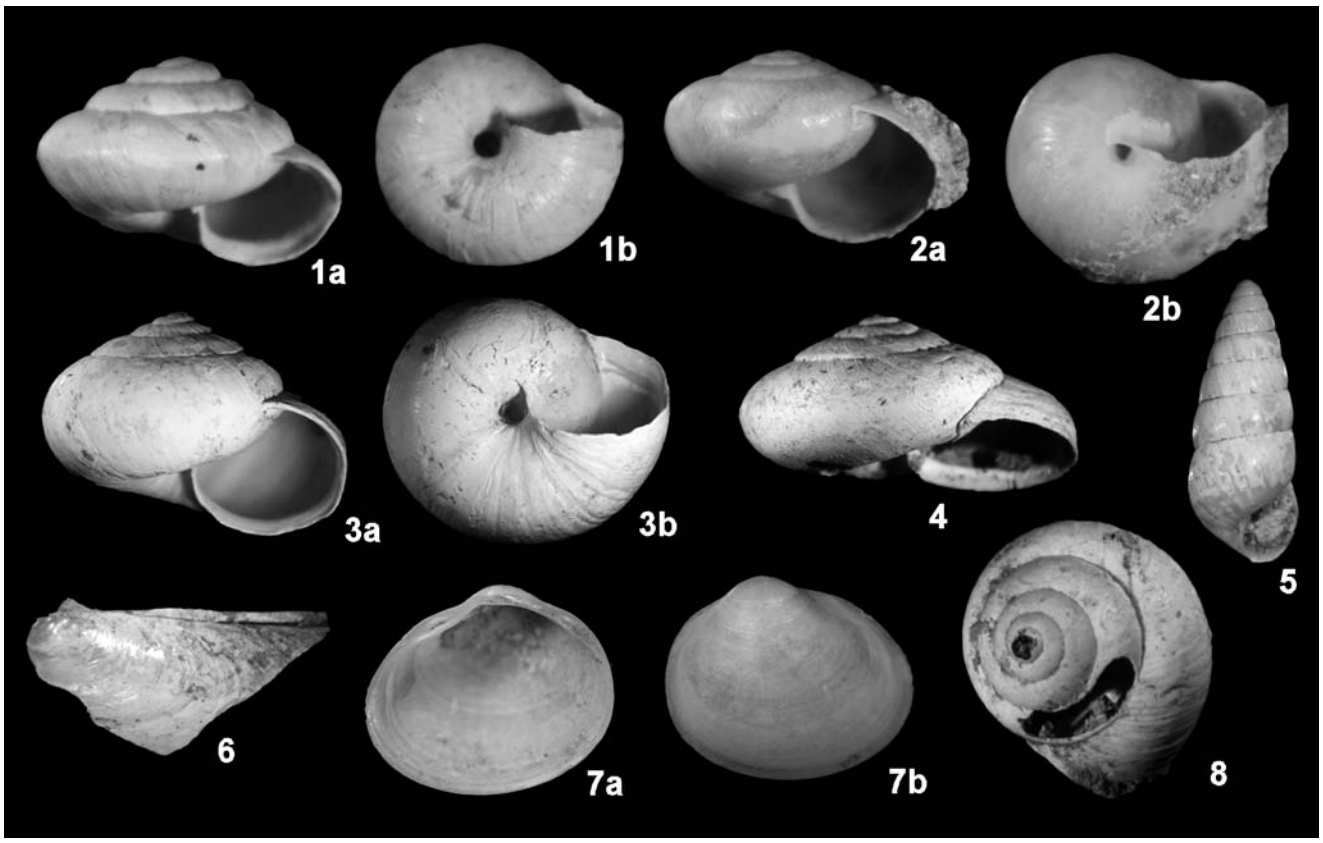

PLATE 2

Non-marine molluscs from S.Teodoro Cave, Late Pleistocene. Fig. 1a, b - *Trochoidea (Trochoidea) pyramidata* (Draparnaud) 8x (a), 6.6x (b), MPUR-7-3411. Fig. 2a, b - *Monacha (Monacha) cartusiana* (Müller) 5.3x, MPUR-7-3412. Fig. 3a, b - *Cernuella (Cernuella) virgata* (Da Costa) 3.7x, MPUR-7-3407. Fig. 4 - *Marmorana (Ambigua) fuscolabiata* (Rossmaessler) 2.3x, MPUR-7-3414. Fig. 5 - *Cochlicella acuta* (Müller) 4.5 x, MPUR-7-3413. Fig. 6 - *Unio* sp. 2.6 x, MPUR-7-3415. Fig. 7a, b - *Pisidium casertanum* (Poli) 8.2x, MPUR-7-3416. Fig. 8 - Large predation mark on *Cernuella* shell 4.5x, MPUR-7-3442.
All the specimens are stored in coll. Esu-Girotti, MPUR, Palaeontological Museum of University of Rome "La Sapienza".

Molluscan analyses

Molluscan analyses were carried out on 53 cuts from 1998 trench and 37 from 2002-2004 trench of unit B. The distribution of the recorded species and specimens throughout the stratigraphic levels (from -3.85 to -2.43 m, -3.17 to -1.95 m and -0.27 up to + 0.70 m) and the total number of freshwater and terrestrial species and specimens is given in Tab. 1 for each trench. The abundance of specimens and the dominance of land or freshwater taxa for each square is shown in Tab. 2. A correlation among the molluscan assemblages from the squares of the three sectors is not possible because of the different depth of the cuts (see methods above). Taking into account this factor each sector is treated separately. The following malacological evidences are underlined:

1998 trench, first sector (square E-G/9-10). Square E, F and G: a very low species diversity of open-land taxa, such as *P. pusilla, C. (M.) pupa, P. papillaris* and *M. (M.) cartusiana*, is detected in the middle and lower cuts of squares F9 and 9G. Cuts devoid of molluscs or with poor fragments of land snails occur in the upper part of this trench. No aquatic species were found.

1998 trench, second sector (squares E-H/11-13). Square E and F: rich-land species assemblages with a high number of specimens are present mostly in the lower levels. Particularly cut 12 of squares 11 and 12E and cut 13 of squares 11 and 12F are the richest layers of the trench displaying 9 to 11 species with 50 to 90 specimens. The assemblages are composed essentially of dry open-land taxa. *C. virgata, T. pyramidata* and *M. cartusiana* are the dominant species. Freshwater species, typical of running water, such as *M. similis* and *P. moussonii*, occur in a very low percentage. Middle and upper levels are devoid of molluscs. Square G: well diversified assemblages of land species occur in the middle part of G13 and G12. The species *C. (C.) cisalpina, C. virgata* and *T. pyramidata* of dry habitat are dominant. Freshwater and hygrophilous elements (*M. similis* and *O. elegans*) display low percentages.

Square H: poor shell fragments are recorded in the middle part of this square, whilst a high species

S. Teodoro Cave		Gastropods																					Bivalves		Total specim.		Total species	
		Freshwater					Terrestrial																Fresh.					
Depth (m)	Cuts	*M. similis*	*P. (P.) moussonii*	*G. truncatula*	*P. planorbis*	*A. fluviatilis*	*O. elegans*	*P. pusilla*	*C. avenacea*	*C.(M.) pupa*	*D.(D.) rufa*	*P. papillaris*	*P. solida*	*C.(C.) cisalpina*	*C.(C.) virgata*	*Cernuella* sp.	*C.(C.) lenticula*	*T.(T.) pyramidata*	*M.(M.) cartusiana*	*C. acuta*	*C.(C.) planospira*	*M.(A.) fuscolabiata*	*Unio* sp.	*P. casertanum*	Freshwater	Terrestrial	Freshwater	Terrestrial
1998/ sq. 9-10																												
-2.43/ -2.50	1																											
-2.50/ -2.57	2																											
-2.57/ -2.64	3													fg												fg		1
-2.64/ -2.73	4																											
-2.73/ -2.85	5						2					fg							3							5		3
-2.85/ -2.96	6														2											2		1
-2.96/ -3.06	7														3		1									4		2
-3.06 -3.15	8							1				1			fg				3							5		4
-3.15/ -3.28	9									1		fg		fg			1		6	2						10		6
-3.28/ -3.33	10											1							1							2		2
-3.39/ -3.50	11									1		fg							1							2		3
-3.50/ -3.64	12																											
-3.64/ -3.85	13									fg		fg							1							1		3
1998/ sq. 11-13																												
-1.95/ -2.03	1																											
-2.03/ -2.11	2																											
-2.11/ -2.24	3													fg				fg	fg							fg		3
-2.24/ -2.31	4													fg					fg							fg		2
-2.31/ -2.38	5	1										1		4	5			5	fg						1	15	1	5
-2.38/ -2.45	6	3										fg		3	28			2	fg	1					3	34	1	6
-2.45/ -2.57	7	4	2	2			2			1		3		4	5		fg	4	8	5					8	32	3	9
-2.57/ -2.67	8	3		1			1		1	1		3		2	15			6	9	2	fg				4	40	2	10
-2.67/ -2.78	9	3	1							4		5		10	14	4		18	2	4					4	61	2	8
-2.78/ -2.92	10									3			4	2	17			7	6	2		1				42		8
-2.92/ -3.01	11	1					1		1	2		2		6	18	3		11	4	5					1	53	1	10
-3.01/ -3.09	12	2							2	3		1	3	8	25	5		33	6	7		2			2	95	1	11
-3.09/ -3.17	13	2		2						1		2		9	12	6		6	16	3		1			4	56	2	9
2002-04/ sq. 29-34																												
0.70	B	fg																fg							fg	fg	1	1
0.60	A	16	5				2											2							21	4	2	2
0.51/ 0.44	1	17	11	2	1	1	2											7	6	2			1		33	17	6	4
0.44/ 0.37	2	13	4	1						1		fg						2	8	5					18	16	3	5
0.37/ 0.30	3	24	9	1		1	2			1					7			2	2	8					35	22	4	6
0.30/ 0.25	4	12	5	1			1			2								7	5	7				1	19	22	4	5
0.25/ 0.15	5	8	7									1						4		7					15	12	2	3
0.15/ 0.06	6	1			1									2						2			1		3	4	3	2
0.06/ 0.00	7	3	1				1								1			2		4					4	8	2	4
0.00/ -0.10	8	15	11			1	1				1			2	1			1	3	1				2	29	10	4	7
-0.10/ -0.19	9	18	7	2	1		2			1		2		2	2			8		3					28	20	4	7
-0.19/ -0.27	10	16	11	1			2		1	2	1	fg		4	5			10	2	1					28	28	3	10

Tab. 1 - Numerical frequency of non-marine mollusc species from S. Teodoro Cave in respect to each stratigraphic level of 1998 and 2002-2004 trenches (unit B).

diversity with a large number of specimens belonging to open-land species occur in the lower cuts of 13H. The upper part is devoid of molluscs.

Several reworked littoral marine molluscs, such as *Gibbula, Tornus, Turritella, Bittium,* are scattered in the lower levels of 1998 trench.

2002-2004 trench (squares A-G/29-34). Squares A and B: a few specimens or fragmentary remains of *M.*

S. Teodoro Cave																										
Cuts	Squares E-H (1998 trench/9-10/11-13)														Squares A-G (2002/04 trench)											
	E	F	G	E			F			G			H		A	B	C		D				E		F	G
	10	9	9	11	12	13	11	12	13	11	12	13	12	13	29	29	29	30	29	30	31	32	33	34	33	33
B																										fg
A																									*	*
1																					°°	°	*	*°	*	*°°
2																					°°				*	*°°
3		fg										fg								°°	°				*°	*°°
4												°								°°°	*°°					
5		°									fg	°°								*°°						
6		°	°							fg		°°°	fg	fg						°						
7		°										°°°								°°	°					
8	fg	°	°					fg				°°°	fg		°			°	*°°	°°	°					
9	fg	fg	°°					fg				°°°	fg	°°°			°	°	*°°	*°	*°°					
10	fg	fg		fg	°			fg	°		°°°			°		°	°	°	*°°	°						
11		fg	°		°°°	°		°						°°												
12				°°°	°°°	°		°	°					°°												
13			°	°	°	°	°°°	°°°																		

Tab. 2 - Non-marine mollusc specimen richness in respect to the squares E-H (1998 trench, first and second sector) and A-G (2002-2004 trench) of unit B from S. Teodoro Cave. fg= fragments; ° = 1 to 5 specimens; °° = 6 to 10 specimens; °°° = more than 10 specimens; * = freshwater taxa dominance.

similis, typical of running water, occur in the lower cuts. Square C: poor-species assemblages, characterised by two to five terrestrial and one freshwater species, are recorded in the lower cuts. Square D: rich-species assemblages dominated by taxa typical of running water or hygrophilous taxa, such as *M. similis, P. moussonii, G. truncatula, A. fluviatilis, O. elegans* and *P. casertanum*, are very well represented in several layers. *P. planorbis*, inhabitant of quite temporary small ponds, occurs for the first time. The open-land taxa display lower percentages. Square E, F and G: well diversified assemblages of freshwater molluscs occur in the upper part of these squares. *M. similis,* accompanied by a quite constant occurrence of *P. moussonii,* displays a large number of specimens. Terrestrial taxa of open-land are present in lower percentage.

Fragmentary reworked marine molluscs (*Potamides, Bittium*) occur only in square D.

Discussion

The recorded land species are indicative of generally dry open, lightly vegetated environment in the surrounding of the cave, such as grassland, Mediterranean maquis, hedges, not far from the coast, in accordance with the pollen analysis from the 1998 trench (Yll et al. 2006). The ecological requirements of the freshwater species, which are dominant in the 2002-2004 trench (Fig. 3), show the presence of slow-running and clean waters, such as spring water, inside the cave.

On the basis of the diverse structure of the recorded molluscan assemblages and their distribution inside the different squares it is possible to outline the palaeoenvironmental character for the deposits of the two trenches.

a) 1998 trench, first sector. Very poor molluscan assemblages exclusively composed of open-land snails, absence of aquatic species (Fig. 3) and layers devoid of molluscs reflect arid climatic conditions.

b) 1998 trench, second sector. Quite rich-species assemblages typified by the prevalence of open-land taxa (Fig. 3) typical of dry habitat and a decrease in total number of species upwards shows a gradual climatic trend from fairly arid to drier conditions. Few freshwater species of running water characterising the lower levels indicate the presence of a poor waterbody (spring or stream) inside the cave.

c) 2002-2004 trench. The scarcity of the terrestrial species occurring in lower number in respect to the second sector of 1998 trench and the increase of freshwater and hygrophilous taxa of slowly current water (Fig. 3) point to more humid conditions of the environment. A probable settlement of shallow pools is inferred by the presence of *P. planorbis* of still hard water and the quite constant presence of the hygrophilous terrestrial species *O. elegans*.

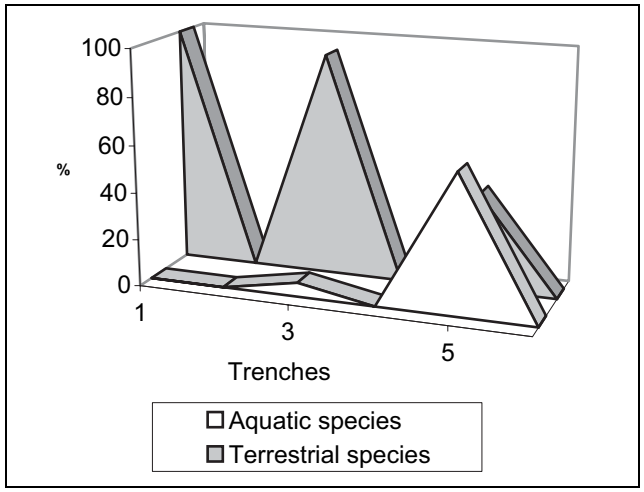

Fig. 3 - Percentage variation of specimens of aquatic and terrestrial species in the excavated trenches. 1 = 1998 (first sector); 3 = 1998 (second sector); 5 = 2002-2004.

Conclusions

The palaeoecological and palaeobiogeographical meaning of the terrestrial and freshwater molluscs collected in the upper Pleistocene deposits of clayey sands and gravels of S. Teodoro Cave permits to infer the following remarks:

1) The structure of the assemblages from the 1998 trench (sq. 11-13), recognised as rather rich-species assemblages characterised by the prevalence of dry-open land taxa and few freshwater species in the lower levels, points to a cool climate evolving into a colder and arid phase as suggested by the poor-species character of the assemblages with scarce or absent freshwater elements from the upper levels of the same unit. The vegetation around the cave ought to be of steppe-like type. The assemblages from the inner and higher 2002-2004 trench, in which a decrease of land taxa and a prevalence of freshwater and hygrophilous elements is registered, show a probable more humid environment in this sector. The wide distribution of freshwater taxa in the sediments points to the presence of a permanent spring or slowly running water inside the cave. Actually the lithology and the structural characters of the deposits in the 2002-2004 trench indicate the presence of gravity flows which were probably located in the areas where concretioning processes and re-crystallized molluscs occur (expecially in D, E, F, G squares of 2002-2004 trench). The different ecological characters provided by freshwater and terrestrial molluscs from 1998 and 2002-2004 trench may otherwise be attributed to different temporal phases of sedimentation. The evidence now available are insufficient in this subject considering the peculiar conditions of sedimentation in a cave environment.

2) It is probable that some terrestrial shells have been transported into the cave by predators, such as coleoptera, small mammals or birds in different times, since most of them from various levels show characteristic predation marks.

3) The present geographic distribution of the recorded non-marine mollusc species shows a strong Holomediterranean component (more than 50%) among the terrestrial taxa, among which only one species (*Cernuella* sp.) is probably restricted to Sicily, and European origin of most freshwater elements. Even if fossil records of non-marine molluscs from Sicily are poorly known a dispersal of the recorded molluscs of S. Teodoro Cave from the mainland during the Pleistocene low stand sea-level phases is inferred. The presence of some of the recorded species in the Pleistocene sediments of Italy and in western Mediterranean islands points to a wider diffusion of these species in the late Cenozoic and to an active dispersion during the Pleistocene low stand sea-level phases.

The combined occurrence in unit B of vertebrate taxa typical, or exclusive, of two contiguous faunal complexes (*Elephas mnaidriensis* and Castello F.C.) has been explained by the occurrence of dispersal events posterior to Oxygen Isotope Stage 5e through a land bridge in the area of the Strait of Messina. The dispersal of the molluscan fauna probably belongs to the same dispersal events which introduced into the island faunal elements from the mainland (*Equus hydruntinus*, *Apodemus* cf. *sylvaticus*, *Microtus* (*Terricola*) ex gr. *savii*, *Crocidura* cf. *sicula*) which dwelled together with some endemic survivors (*Elephas mnaidriensis, Cervus elaphus siciliae, Bos primigenius siciliae*). The molluscan assemblages from 1998 trench depict an arid cold landscape as pollen from coprolites does.

4) The marine molluscs represented by littoral reworked taxa scarcely widespread in the sediments, likely come from the marine sedimentary cover of the middle Pleistocene terrace which overlies the roof of the cave. Actually the mineral particles of sediments in unit B are not calcareous, they are constituted by different lithotypes (arenites, phyllites, etc.) deriving from the substrate of the carbonatic Jurassic massif in which S. Teodoro Cave opens. This substrate provided the boulder and mineral grains which overlie the middle Pleistocene terrace.

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