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THE SMALL MAMMALS (INSECTIVORES, BATS AND RODENTS) FROM THE HOLOCENE ARCHAEOLOGICAL SITE OF VALLONE INFERNO (SCILLATO, LOWER IMERA VALLEY, NORTHWESTERN SICILY)

JUAN MANUEL LÓPEZ-GARCÍA [1], HUGUES-ALEXANDRE BLAIN [2, 3], ENRICO PAGANO [4], ANDREU OLLÉ [2, 3], JOSEP MARIA VERGÈS [2, 3] & VINCENZA FORGIA [4]

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Abstract. The Vallone Inferno rock-shelter is an archeological site located at 770 m a.s.l. in the Madonie massif in Sicily. This massif is modeled into the Triassic and Oligocene sedimentary rocks of the Imerese Basin. The archaeological excavations conducted since 2008 have provided a long prehistoric and historic sequence from the Neolithic to the medieval period. From the four sedimentary complexes identified, only levels 3.4 to 3.1 from complex 3 and 4.2 from complex 4 have yielded small-mammal material. Level 4.2 is poor in remains and as yet without cultural ascription, though it has a radiocarbon age of 9450±50 years BP. Level 3.4 has yielded fragments of ceramic characteristic of the Middle Neolithic-Bronze Age period, with a radiocarbon age between 3948±35 and 3244±42 years BP. Levels 3.3 to 3.1 have provided ceramic fragments ascribed to the Late Roman-Byzantine period, with a radiocarbon age between 1332±26 and 1260±34 years BP. The small-mammal assemblages recovered from the sieving-washing of all the sediment from the excavation campaigns include a total of at least 14 taxa (three insectivores, four chiropterans and seven rodents). The materials from this locality provide the first mention in the fossil record of Sicily for *Suncus etruscus*, *Muscardinus avellanarius*, *Eliomys quercinus* and *Rattus norvegicus*, as well as the last occurrence for *Arvicola amphibius*. The scarcity of the remains recovered from stratigraphic levels 3.1, 3.2, 3.3 and 4.2 makes it difficult to undertake a palaeoenvironmental and palaeoclimatical interpretation of them. However, the richness in small mammal contents from level 3.4 allow us to show that this level is dominated by dry meadows and woodland areas with a temperature and precipitation range that lies within the current values for the surrounding area, coinciding with the dry and temperate phase detected previously by marine surveys and pollen and microcharcoal studies.

Riassunto. Il riparo sottoroccia di Vallone Inferno è un sito archeologico localizzato a 770 m s.l.m. nel massiccio montano delle Madonie, in Sicilia. Questo massiccio è modellato nelle rocce sedimentarie del Triassico e dell'Oligocene del Bacino Imerese. Gli scavi archeologici, condotti dal 2008, hanno fornito una lunga sequenza preistorica e storica dal Neolitico al periodo medievale. Dei quattro complessi sedimentari individuati, solo i livelli 3.4-3.1 dal complesso 3 e 4.2 dal complesso 4 hanno prodotto materiale relativo a micro-mammiferi. Il livello 4.2 è povero di resti e per il momento senza attribuzione culturale, ma con una età al radiocarbonio di 9450±50 anni BP. Il livello di 3.4 ha restituito frammenti di ceramica caratteristica del Neolitico medio – Bronzo, con un'età al radiocarbonio tra 3948±35 e 3244±42 anni BP. I livelli di 3.3-3.1 hanno fornito frammenti ceramici attribuiti al tardo periodo romano-bizantino, con una età al radiocarbonio tra 1332±26 e 1260±34 anni BP. Le associazioni di piccoli mammiferi recuperati tramite il lavaggio e la setacciatura di tutto il sedimento proveniente dalle campagne di scavo comprendono un totale di almeno 14 taxa (tre insettivori, quattro chirotteri e sette roditori). Il materiale di questo sito costituisce il primo ritrovamento in Sicilia di reperti fossili di *Suncus etruscus*, *Muscardinus avellanarius*, *Eliomys quercinus* e *Rattus norvegicus*, così come il più recente ritrovamento di *Arvicola amphibius*. La scarsità dei resti recuperati per i livelli stratigrafici 3.1, 3.2, 3.3 e 4.2 rendono difficile la loro interpretazione paleoambientale e palaeoclimatica. Diversamente, la ricchezza del campione a micromammiferi dal livello 3.4 ci permette di mostrare che questo livello è dominato da prati aridi e da zone boschive con una temperatura e precipitazioni che rientrano nel range degli attuali valori per l'area circostante, che coincide con la fase secca e temperata rilevata in precedenza da indagini marine, analisi polliniche e antracologiche.

1 Gruppo di Ricerca di Paleobiologia e Preistoria, Dipartimento di Studi Umanistici, Università degli Studi di Ferrara, C.so Ercole I d'Este 32, 44121 Ferrara, Italy. E-mail: lpzjmn@unife.it.

2 IPHES, Institut Català de Paleoecologia Humana i Evolució Social, C/ Marcel·lí Domingo s/n (Edifici W3), Campus Sescelades, 43007 Tarragona, Spain. E-mail: hablain@iphes.cat; aolle@iphes.cat; jmverges@iphes.cat.

3 Àrea de Prehistòria, Universitat Rovira i Virgili (URV), Avinguda de Catalunya 35, 43002 Tarragona, Spain.

4 Dipartimenti Beni Culturali Storico-Archeologici, Socio-Antropologici e Geografici. Facoltà di Lettere e Filosofia, Università degli Studi di Palermo, V.le delle Scienze-Ed. 12, 90128 Palermo, Italy. E-mail: enrico.s.pagano@gmail.com; vincenza.forgia@unipa.it.

Introduction

Recent studies of Quaternary vertebrates in Sicily have focused on the palaeoenvironment, the palaeoclimate, taxonomy, evolution and extinctions. Indeed, at least six Pleistocene vertebrate faunal complexes have been recognized in Sicily, ranging from the Early Pleistocene to the Late Pleistocene - Holocene transition (Tagliacozzo 1993; Bonfiglio et al. 2001, 2002; Marra 2005, 2007; Masini et al. 2008 among others). Nevertheless, few studies have been conducted on Holocene small vertebrates. Probably the most significant data from the Holocene come from the Uzzo Cave and Partanna Stretto (Bonfiglio et al. 2000; Masini et al. 2008). By contrast, the environmental and climatic changes undergone by Sicily during the Holocene are well studied on the basis of marine surveys and pollen and microcharcoal analyses (Sadori & Narcisi 2001; Sadori & Giardini 2007; Sadori et al. 2008; Incarbona et al. 2010). These studies indicate that during the Holocene there were significant environmental and climatic fluctuations. The vegetation history shows that the wettest conditions in the Holocene occurred from 9000 to 7200 years BP; a process of aridification started 7200 years BP, with very dry conditions prevailing ca. 3500 years BP; and there has been a clear human impact since 2800 years BP (Sadori & Narcisi 2001; Sadori & Giardini 2007; Sadori et al. 2008). Furthermore, a survey of the southern Tyrrhenian sea indicates that five cooling episodes (called C1 to C5) have occurred during the Holocene in Sicily, producing low sea-surface temperatures (Incarbona et al. 2010).

Against this background, the main aim of this paper is to describe the assemblage of micromammals (insectivores, bats and rodents) from the site of Vallone Inferno. As well as providing a biochronological and palaeobiogeographical interpretation for certain taxa that have not previously been cited in the fossil record of Sicily and others that are not currently represented in the studied zone, the objective is to comment on the changes in fauna and biodiversity in relation to the climate or other causes of change that have taken place during the Holocene, and to produce a palaeoenvironmental and climatic reconstruction of the site on the basis of this small-mammal association. Finally, the environmental and climatic results are compared with previous studies such as marine surveys and pollen and microcharcoal analyses, putting our data into context with the climatic and environmental phases that occurred during the Holocene in Sicily.

Locality

The site named Vallone Inferno is a rock-shelter located at an altitude of ca. 770 m in the municipality of

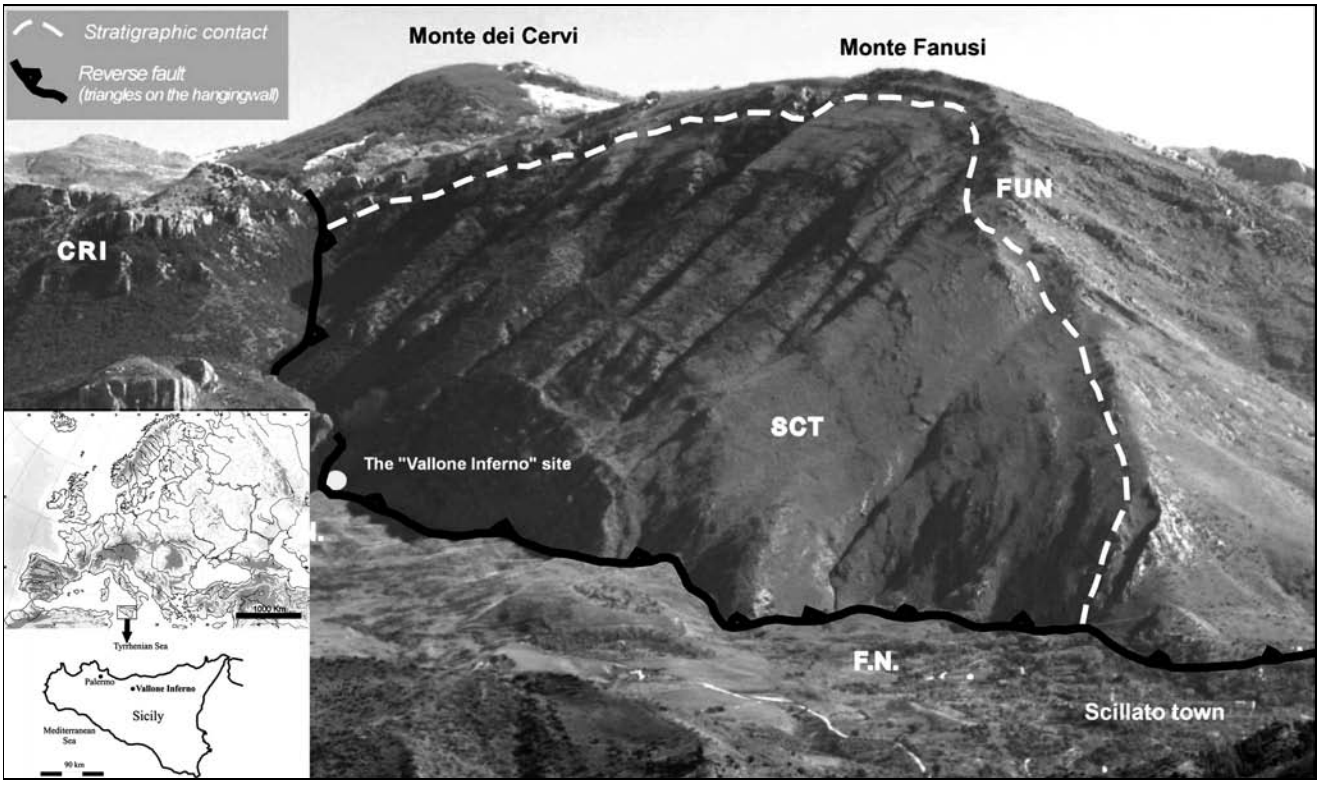


Fig. 1 - Panoramic view and stratigraphic sketch of the Vallone Inferno site in the Madonie area (Palermo, Sicily), Imerese Basin Domain: SCT: calcilutites with chert nodules alternating with radiolarian-bearing marls (Upper Carnian-Reathian); FUN: dolomitic breccias (Lower Liassic); CRI: silicieous shales, radiolarian interbedded with resedimented calcareous megabreccias (Upper Liassic-Upper Cretaceus); Numidian Flysch Basin Domain; F.N.: sandy pelites with interbedded arenaceus layers (Upper Oligocene-Lower Miocene) (from Forgia et al. 2013, modified).

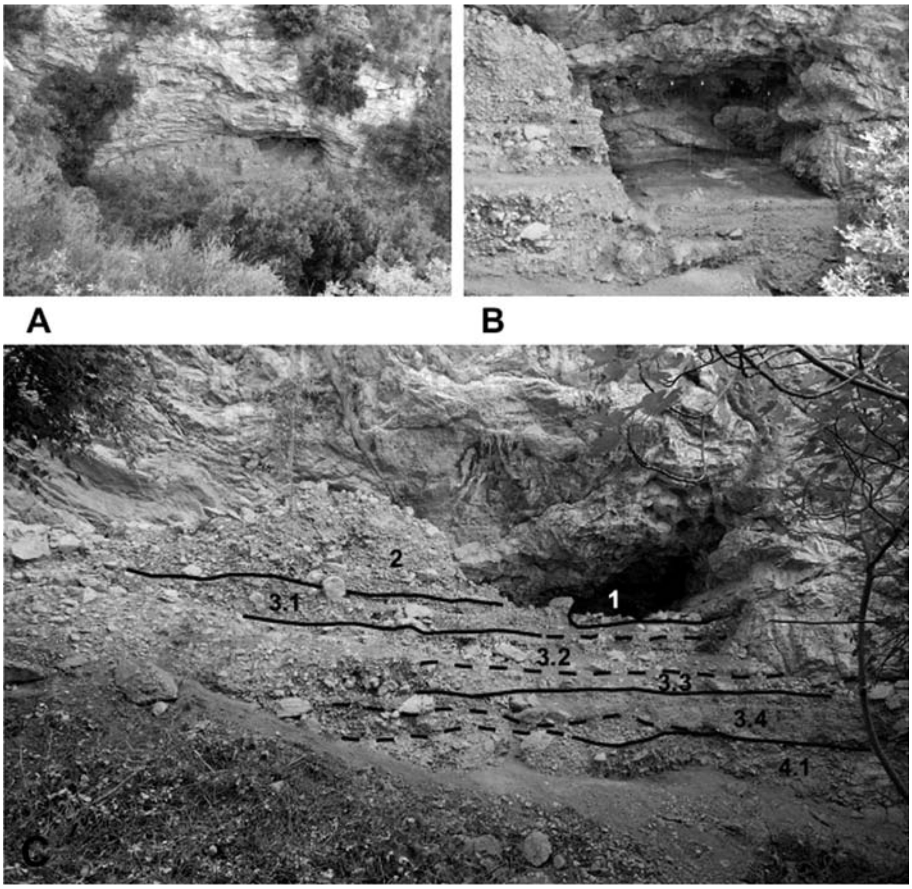


Fig. 2 - A) General view of the Vallone Inferno rock-shelter in 2008, before the excavation; B) The excavated area at the top of unit 3.4.A at the end of the 2011 season; C) Frontal view of the sedimentary succession and initial stratigraphic sketch (2008) (from Forgia et al. 2013, modified).

Scillato, Sicily, Italy; its coordinates are 37° 52' 17.74" N and 13° 55' 58.97" E (Fig. 1).

Vallone Inferno (also known as Fosso Inferno) is a deep gorge, which cuts through the N slope of Monte dei Cervi – Monte Fanusi, a complex fault escarpment at the NW margin of the Madonie massif, which shows evidence of neotectonic activity. In this sector, the massif is modelled into the Triassic to Oligocene sedimentary rocks of the Imerese Basin, in which carbonate, siliceous and terrigenous lithologies (limestone, sometimes cherty, dolomite, marl, clay, radiolarite) alternate with one another (Fig. 1). The origin of the gorge is chiefly fluvio-karstic, though structural and tectonic factors also played a role in its development (Forgia et al. 2013).

The rock-shelter is located at the foot of the left wall of Vallone Inferno, almost at the exit of the escarpment, facing the gentle slope that is found downstream where Cenozoic terrains of Numidian Flysch and slope sediment outcrop.

The formation of the rock-shelter is mainly related to karstic dissolution, which was controlled at the same time by the structural layout of the local bedrock (cherty limestone and dolomitic limestone belonging to the Scillato geological formation).

The archaeological interest of Vallone Inferno was recognized in the context of a major archaeological survey project on the Madonie mountain range (Forgia 2008, 2009). One of the sample areas chosen for the project was an intermediate area lying between local inland uplands (more than 1600 m a.s.l.) and lowlands (around 500 m a.s.l.) near the Imera river valley. The site immediately showed its importance, because a vertical section of the five-metre archaeological deposit was clearly exposed by the Inferno stream.

The archaeological sequence is at present five metres deep in total, and the archaeological investigation covers an area of 30 m^2.

The rock-shelter is more than 10 metres long and 6 metres deep and is oriented to North (Fig. 2). The water stream is close to the shelter, the gorge is narrow, and the visibility from the rock-shelter is reduced to a small portion of the Imera river valley and of the coastal area. At present it is possible to reach the site by ranger footpath, which leads to the mountain.

The Vallone Inferno rock-shelter is almost filled by a thick deposit, within which four main stratigraphic complexes have been identified. From the top to the base these are as follows (Fig. 3A, B) (Forgia et al. 2013):

Complex 1: stone walls and structures dating to the 20th century.

Complex 2: calcareous breccias, ca. 2.5 m thick, which outcrop on the site's magnetic east side and do

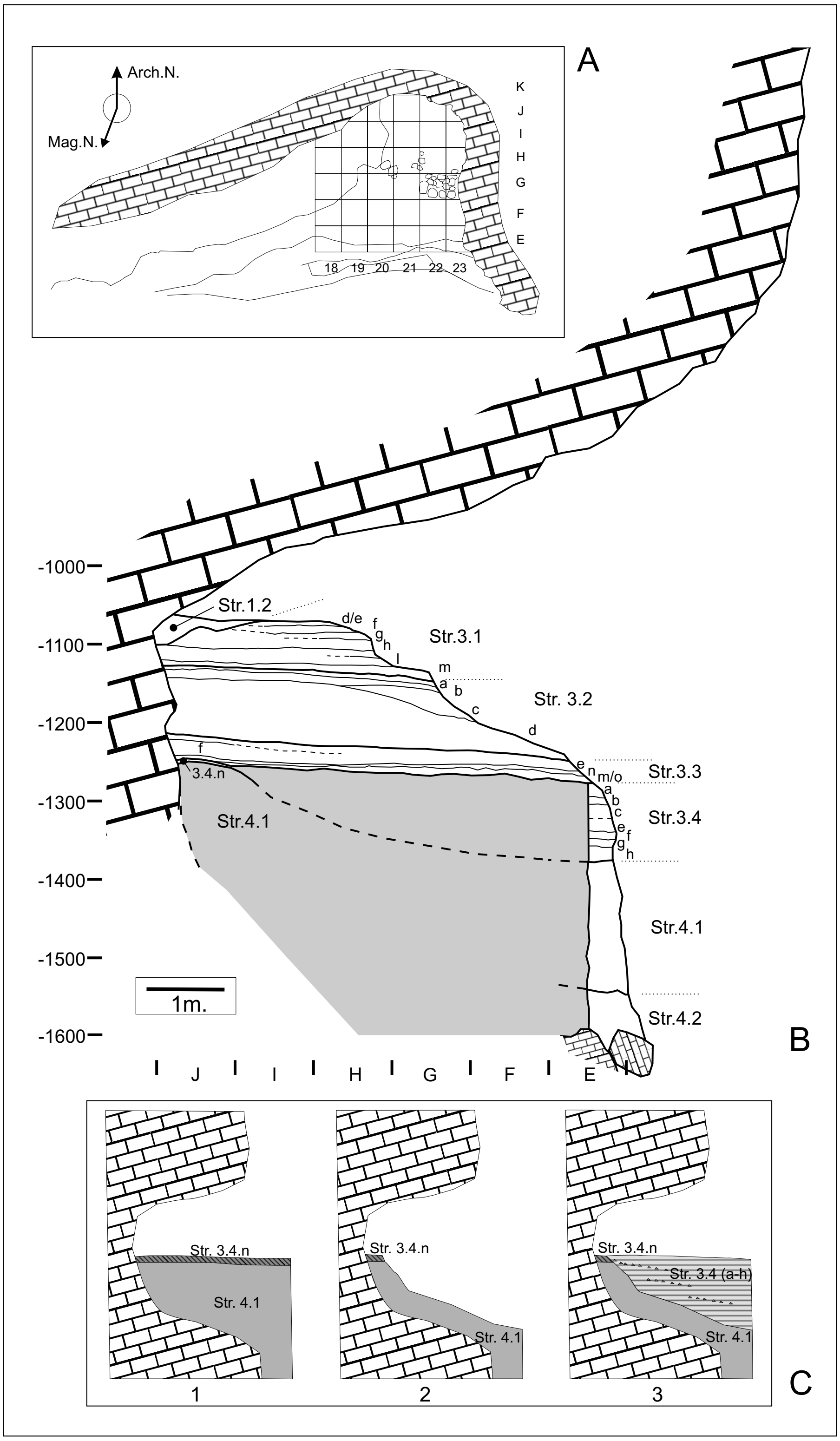


Fig. 3 - A) General plan of the Vallone Inferno archaeological area, before the excavation; B) Synthetic stratigraphic sequence; the cut corresponds to the contact between lines 20 and 21 (although for units 3.1 to 3.3 it corresponds to the 19-20 contact); C) Deposition-erosion-deposition cycle of the Str. 3.4. (from Forgia et al. 2013, modified).

not contain any archaeological evidence. These are made up of massive (top) to poorly-stratified (bottom) clast-supported heterometric angular fragments of limestone with occasional chert elements, with clayey-silt organic fine material filling the space among coarse components. The complex dips W/8°, and a discontinuous layer of laminated silty sand is found at its lower boundary, an erosive (paraconformity) surface.

Complex 3: the archaeological succession, which consists of an alternation of fine-textured archaeological layers and coarser beds. The archaeological succession was split into four subcomplexes, which are as follows, from the top to the base:

subcomplex 3.1: includes ashy and thermoaltered beds alternating with coarse, stony beds with Byzantine-Late Roman archaeological materials;

Lab. code	Archaeological layer	Cultural Attribution	Sample	Conventional Radiocarbon Age (BP)	Calibrated Radiocarbon Age (BP) (2 sigma, 95%)
DSH2816	3.1.1	Byzantine-Late Roman	Vegetal remain	1260±34	1320-1120 calBP
DSH2814	3.2.c	Late Roman	Charcoal	1332±26	1340-1220 calBP
DSH2815	3.4.b	Early Bronce-Middle Neolithic	Seed	3244±42	3600-3360 calBP
DSH1976	3.4.g		Human bone	3948±35	4500-4270 calBP
Beta-314642	4.2		Charcoal	9450 ± 50	10860-10540 calBP

Tab. 1 - Absolute ages of the Vallone Inferno levels.

subcomplex 3.2: is a fining-upward sequence including archaeological materials of a Late Roman date;

subcomplex 3.3: includes organic and thermoaltered beds alternating with coarser beds and contains Late Roman finds;

subcomplex 3.4: is made up of an alternation of coarse and fine layers - the latter often enriched with organic matter and featuring prehistoric assemblages (Early Bronze and Middle Neolithic in age) - which comprise four sedimentary cycles including a complex deposition-erosion-deposition dynamics. The current state of research points to the existence of a first Neolithic occupation of the cave (Str. 3.4.N), a strong erosion that affected most of the level and also the top of the underlying Complex 4, and the subsequent sedimentation of the Bronze Age levels (Fig. 3C).

Complex 4: poorly stratified, partially open work, calcareous breccias, moderately cemented by calcium carbonate. The coarse components are angular to subangular and heterometric, while the fine material is brown silty loam. The complex is ca. 2 m thick, shows local imbrications of coarse components, and contains an intercalation of brown silty sand featuring two thin ash layers at the bottom (subcomplex 4.2). Although microvertebrates and pollen grains have been preliminarily identified in this unit, it has not been excavated and no information other than its dating is offered here.

Five samples have been selected from the sequence for radiocarbon dating by AMS: four come from complex 3 and have been analysed at Circe Innova Lab; the fifth is from subcomplex 4.2 and has been analysed by Beta Analytic Inc. (Tab. 1).

Calibration of all samples has been calculated using the INTCAL09 database (Reimer et al. 2009).

Material and Methods

The small-mammal fossil remains used for this study consist of disarticulated bone fragments collected by water-screening during the 2008 to 2012 excavation campaigns. All the sediment was water-screened using a 0.8 mm mesh screen, and bagged by layer. In subsequent years, the fossils were processed, sorted and classified at the Institut de Paleoecologia Humana i Evolució Social of the University Rovira i Virgili (Tarragona, Spain). The studied levels include a total of 330 fragments, which correspond to a minimum number of 182 small mammals, representing at least 14 taxa, most belonging to level 3.4 (Tab.2; Fig. 4). The small vertebrates have already been published as a faunal list (Forgia et al. 2013). The fragments were identified following the general criteria given by Reumer & Oberli (1988), Vogel et al. (1989), Sarà et al. (1990), Hutterer (1991), Sarà (1995), Sarà & Vitturi (1996), Contoli et al. (2000), Morales & Rofes (2008), Locatelli (2010), and Maul et al. (2011) for insectivores; Felten et al. (1973), Kowalski & Ruprecht (1981), Menu (1985), Sevilla (1988) and Salari (2010) for chiropterans; and Chaline (1972), Pasquier (1974), Damms (1981), Colamussi (2002); Nappi et al. (2005; 2006), Locatelli (2010) and Petruso et al. (2011) for rodents. Specific attribution of this material rests principally on the best diagnostic elements: mandibles and isolated teeth for

	NISP	MNI	%	NISP	MNI	%	NISP	MNI	%	NISP	MNI	%	NISP	MNI	%	OD	OH	W	R	Wa
Taxa/Levels	**3.1**			**3.2**			**3.3**			**3.4**			**4.2**							
Erinaceus europaeus	0	0	0.0	0	0	0.0	1	1	5.0	7	3	2.4	0	0	0.0		0.25	0.75		
Crocidura cf. *C. sicula*	2	2	14.3	0	0	0.0	2	1	5.0	10	6	4.8	12	6	28.6	0.25	0.25	0.5		
Suncus etruscus	0	0	0.0	0	0	0.0	0	0	0.0	1	1	0.8	0	0	0.0	1				
Rhinolophus sp.	0	0	0.0	0	0	0.0	1	1	5.0	0	0	0.0	0	0	0.0			0.75	0.25	
Myotis gr. *myotis-blythii*	0	0	0.0	0	0	0.0	0	0	0.0	2	1	0.8	1	1	4.8			0.5	0.5	
Pipistrellus sp.	0	0	0.0	0	0	0.0	0	0	0.0	1	1	0.8	0	0	0.0			0.75	0.25	
Minopterus schreibersii	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	4	2	9.5			0.25	0.25	0.5
Arvicola cf. *A. amphibius*	0	0	0.0	0	0	0.0	0	0	0.0	3	2	1.6	0	0	0.0					1
Microtus (*Terricola*) *savii*	2	2	14.3	0	0	0.0	8	4	20.0	104	58	46.4	16	8	38.1	0.75		0.25		
Apodemus sylvaticus	5	4	28.6	0	0	0.0	9	5	25.0	57	29	23.2	8	4	19.0			1		
Rattus norvegicus	5	4	28.6	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0		0.5			0.5
Eliomys quercinus	1	1	7.1	0	0	0.0	0	0	0.0	2	1	0.8	0	0	0.0			0.5	0.5	
Glis glis	1	1	7.1	2	2	100	15	7	35.0	42	20	16.0	0	0	0.0			1		
Muscardinus avellanarius	0	0	0.0	0	0	0.0	1	1	5.0	5	3	2.4	0	0	0.0			1		
Total	16	14	100	2	2	100	37	20	100	234	125	100	41	21	100	2	1	7.25	1.75	2

Tab. 2 - The number of identified specimens (NISP), the minimum number of individuals (MNI) and the percentage of the MNI (%) for the small vertebrates from the Vallone Inferno rock-shelter levels (3.1 to 4.2), and the small-vertebrate distribution by habitat. OD: open dry; OH: open humid; Wo: woodland/woodland edge; Ro: Rocky; Wa: water.

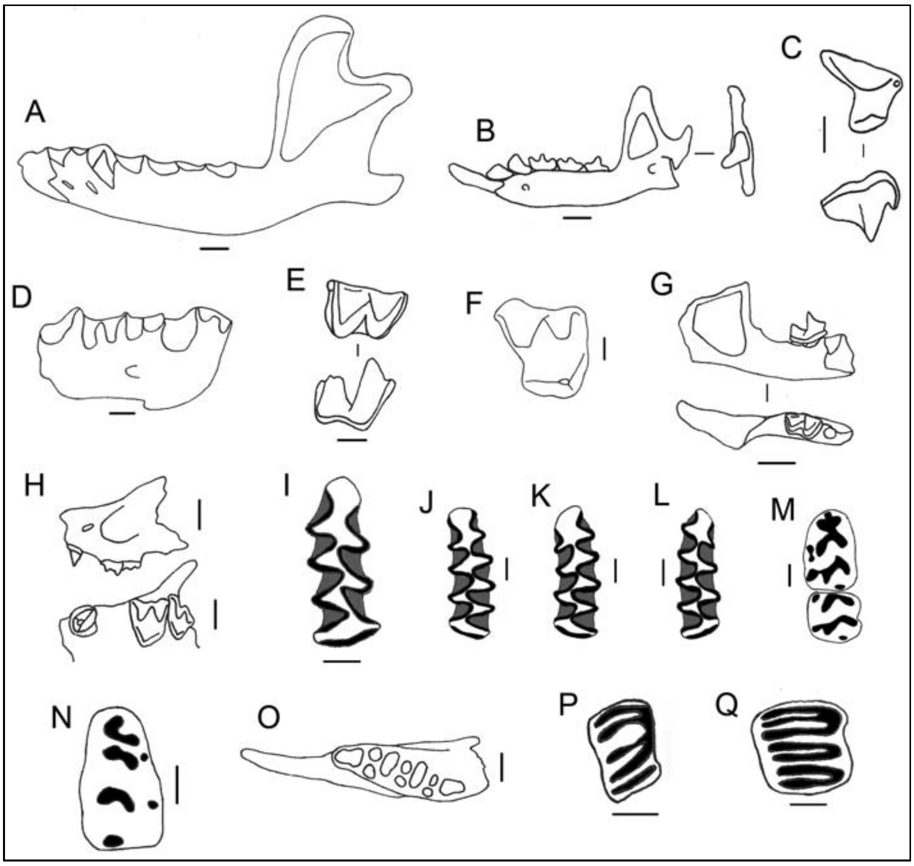


Fig. 4 - Some small mammals from the Vallone Inferno site. A) Left mandible of *Erinaceus europaeus* from level 3.3 (labial view); B) right mandible of *Crocidura sicula* from level 4.2 (lingual and posterior view); C) left fourth upper premolar of *Crocidura sicula* from level 3.4 (occlusal and labial view); D) right fragmented mandible of *Myotis myotis-blythii* from level 3.4 (labial view); E) right second lower molar of *Myotis myotis-blythii*; F) right first upper molar of *Rhinolophus* sp. from level 3.3 (occlusal view); G) right fragmented mandible of *Pipistrellus* sp. from level 3.4 (labial and occlusal view); H) left fragmented maxilla of *Miniopterus schreibersii* from level 4.2 (labial and occlusal view); I) first lower right molar of *Arvicola* cf. *A. amphibius* from level 3.4 (occlusal view); J-L) two first lower left molars and one right molar of *Microtus* (*Terricola) savii* from levels 4.2 and 3.3 (occlusal view); M) first and second lower left molars of *Apodemus sylvaticus* from level 3.4 (occlusal view); N) first lower right molar of *Rattus norvegicus* from level 3.1 (occlusal view); O) right mandible without teeth of *Eliomys quercinus* from level 3.4 (occlusal view); P) first upper left molar of *Muscardinus avellanarius* (occlusal view); Q) second lower right molar of *Glis glis*, (occlusal view). Scale = 1 mm.

insectivores; mandibles and maxillae for bats; first lower molars for the Arvicolinae subfamily; and isolated teeth for the Murinae and Glirinae subfamilies. The abundance of each taxon has been estimated by the minimum-number-of-individuals (MNI) method, by means of which we determined the sample size for each level by counting a diagnostic element, taking into account, whenever possible, laterality. The taxonomic classification for small mammals follows McKenna & Bell (1997), Jaarola et al. (2004) and Wilson & Reeder (2005). Data on the distribution and habitat of extant species are from Spagnesi & De Marinis (2002) and V.V.A.A. (2008).

In order to reconstruct the palaeoenvironment at the Vallone Inferno rock-shelter, we use the method of habitat weightings (see Evans et al. 1981; Andrews 2006), distributing each small-mammal taxon in the habitat(s) where it is possible to find them at present in Sicily. Habitats are divided into five types (in accordance with Cuenca-Bescós et al. 2009; Blain et al. 2008; Rodríguez et al. 2011; López-García et al. 2010; 2011): open land in which dry and wet meadows are distinguished, woodland and woodland-margin areas, rocky areas and areas surrounding water. These types are detailed as follows (Tab. 2): open dry: meadows under seasonal climate change; open humid: evergreen meadows with dense pastures and suitable topsoil; woodland: mature forest including woodland margins and forest patches, with moderate ground cover; water: areas along streams, lakes and ponds; rocky: areas with suitable rocky or stony substratum.

In order to evaluate the palaeoclimatic changes, we use the mutual climatic range method (= MCR) for small mammals. On the basis of the distribution of the extant Sicilian fauna, we identify the climatic range by simply overlaying the geographical regions where all the species present in a given stratigraphical level currently live. Because the atlas we use is based on a 10 x 10 km UTM network (various authors, 2008), the climate data are evaluated for each of these 10 x 10 km squares. Careful attention is paid to ensure that the real current distribution of each species corresponds to the potential ecological/climatic distribution and has not been strongly affected by other limiting or perturbing parameters such as urban development, the human impact on the landscape, predation, competition with other species, etc. Two climatic factors are estimated: the mean annual temperature (MAT) and the mean annual precipitation (MAP). This involves using various climatic maps of Sicily (Drago et al. 2000; Drago 2005) and data provided by the network of Sicilian meteorological research stations over a period of 30 years. From this variably sized region we can estimate the climatic parameters and compare them with the weather station in Petralia Sottana. It has a MAT between 13-17°C (weather station of Petralia Sottana, 930 m a.s.l, 17 km to the south of Vallone Inferno) and a MAP of 600-1000 mm (current data from Drago et al. 2000).

The climatic requirements of the extant representatives of the species may be compared with the climatic values obtained from the whole small-mammal assemblages.

Taxonomy

The small-mammal association from levels 4.2 to 3.1 of Vallone Inferno involves the following taxa (Tab. 2): three insectivores (*Erinaceus europaeus*, *Crocidura* cf. *C. sicula* and *Suncus etruscus*), four bats (*Rhinolophus* sp., *Myotis* gr. *myotis-blythii*, *Pipistrellus* sp. and *Miniopterus schreibersii*) and seven rodents (*Arvicola* cf. *A. amphibius*, *Microtus* (*Terricola*) *savii*, *Apodemus sylvaticus*, *Rattus norvegicus*, *Eliomys quercinus*, *Glis glis* and *Muscardinus avellanarius*.

Class **Mammalia** Linnaeus, 1758
Order **Erinaceomorpha** Gregory, 1910
Family Erinaceidae Bonaparte, 1838
Genus *Erinaceus* Linnaeus, 1758

Erinaceus europaeus Linnaeus, 1758
Fig. 4A

Material: one upper first molar (M1), two fragmented mandibles, one femur, two vertebras and one humerus from level 3.4; one fragmented mandible from level 3.3.

Description and remarks. The material recovered from Vallone Inferno can be ascribed to the species *Erinaceus europaeus* on the basis of the following features: the paraconid in labial view well separated from the protoconid in the fourth lower premolar (p4) and the large paralophid and the thick regular cingulum in the first lower molar (m1).

The genus *Erinaceus* is known in Europe from the Middle Miocene on. In Italy the first mention of the species *Erinaceus europaeus* comes from the Middle Pleistocene period (Masini et al. 2008). In Sicily the species appears during the late Middle Pleistocene, in the *Elephas mnaidriensis* faunal complex (Bonfiglio et al. 2000, 2001, 2003; Masini et al. 2008; Spagnesi & De Marinis 2002, among others). Today's range distribution of the species includes central and western Europe. In Italy it is present throughout the peninsular and insular territory. *Erinaceus europaeus* lives in Sicily in forest or bush areas with low herbaceous and shrub vegetation. It can be found in forest and mountains up to 1800 m, but is usually more abundant in lower and middle mountain regions.

Order **Soricomorpha** Gregory, 1910
Family Soricidae Fisher, 1817
Subfamily Crocidurinae Wagler, 1832
Genus *Suncus* Ehrenberg, 1832

Suncus etruscus (Savi, 1822)

Material: one fragmented mandible from level 3.4.

Description and remarks. Although only one fragmented mandible has been recovered from the Vallone Inferno rock-shelter, the tiny length dimensions of the molar series in the mandible make this record unambiguous.

Suncus etruscus is an ancient Tertiary component of a dry-warm climate, present in various Mediterranean islands having been introduced by humans. At present, there are no data on the fossil record of the species in the whole Mediterranean. The distribution of *Suncus etruscus* in Europe consists basically of the Mediterranean peninsulas (Balkan, Italic and Iberian). In Sicily it is common and well distributed in coastal areas and the inland western and central part. *Suncus etruscus* is a shrew found in a warm and dry climate, with an environmental distribution limited to Mediterranean and sub-Mediterranean vegetation. It is not found at altitudes greater than 1000 metres.

Genus *Crocidura* Wagler, 1832

Crocidura sicula Miller, 1900
Fig. 4B, C

Material: three fragmented maxillae and eight fragmented mandibles from level 4.2; six fragmented mandibles, three fragmented maxillae and one upper fourth premolar (P4) from level 3.4; two fragmented mandibles from level 3.3; two fragmented mandibles from level 3.1.

Description and remarks. The most diagnostic elements recovered from the *Crocidura* specimens of Vallone Inferno are the upper fourth premolars (P4). The teeth in question show a parastyle that is massive and angular like a brick and the dorsal edge of the cingulum undulated, not straight. These characters allow us to ascribe our specimens to the species *Crocidura sicula*.

Crocidura sicula is an endemic Mediterranean element restricted to the Sicilian and Maltese archipelagos. In Sicily the species appears in the early Late Pleistocene in the San Teodoro-Pianetti faunal complex, with an age of ca. 32 ka BP. This species is probably a derivation from a continental *Crocidura* population that dispersed on the island and substituted the larger and endemic Middle Pleistocene species *C. esuae* (Spagnesi & De Marinis 2002; Masini et al. 2008; Bonfiglio et al. 2000, 2002). *Crocidura sicula* is currently widely dispersed in all Sicilian environments from sea level to an altitude of 1600 m. Although it inhabits a great variety of habitats, it prefers shrubs and herbaceous vegetation.

Order **Chiroptera** Blumenbach, 1779
Suborder **Microchiroptera** Dobson, 1875
Family Rhinolophidae Gary, 1866
Genus *Rhinolophus* Lacépède, 1779

Rhinolophus sp.
Fig. 4F

Material: one first upper molar (M1) from level 3.3

Description and remarks. The first upper molar in our specimen is characterized by the presence of a talon without a hypocone, typical of the genus *Rhino-*

lophus. The medium size of the tooth recovered from Vallone Inferno leads us to believe that it could belong either to *Rhinolophus euryale* (the Mediterranean horseshoe bat) or to *Rhinolophus mehelyi* (Mehely's horseshoe bat), but given the clear absence of diagnostic material we have preferred to assign this specimen to *Rhinolophus* sp.

Rhinolophus euryale and *R. mehelyi* are two very similar bat species that probably originated in the Mediterranean Basin. In Italy there are fossil records of the species from the Late Pleistocene of the peninsula (Salari 2010), but there are no data on the fossil record in Sicily. In Sicily these species are currently closely associated with forest environments; they are thermophilous taxa that are rarely found above 800 m.a.s.l.

Family Vespertilionidae Gray, 1821

Genus *Myotis* Kaup, 1829

Myotis gr. **myotis-blythii**

(Borkhausen, 1797/Tomes, 1857)

Fig. 4D, E

Material: one mandible from level 4.2 and two mandibles from level 3.4

Description and remarks. In morphological terms, the material available is characterized by lower molars that are myotodont (with the hypoconulid completely separate from the entoconid), with a reasonably thick cingulum, typical of the genus *Myotis*. The large size of the molars under study leads us to ascribe our material to the group of large-sized mouse-eared bats (*Myotis* gr. *myotis-blythii*), since *M. myotis* and *M. blythii* are the two biggest species of the genus in Europe. These two species are difficult to differentiate from one another on the basis of their dentition alone on account of their great morphological and morphometric similarity (overlapping of size ranges). Given that the shortage of diagnostic material makes it impossible to separate the two species, the fossils from Vallone Inferno have been assigned to *M.* gr. *myotis-blythii*.

Myotis myotis and *Myotis blythii* are two very similar bat species, with a Palearctic European or Asiatic origin. Large-sized fossil bat remains (such as *Myotis*) have been identified in Sicily in the Late Pleistocene of the San Teodoro Cave (ca. 32 ka BP). In Sicily, both species are common in open environments with herbaceous ground cover (Bonfiglio et al. 2000)

Genus *Pipistrellus* Kaup, 1829

Pipistrellus sp.

Fig. 4G

Material: one fragmented mandible from level 3.4.

Description and remarks. The fragmented mandible recovered from level 3.4 is small and preserves the third lower molar (m3). This molar is nyctalodont in form (with the entoconid connected with the hypoconulid), with the labial cingulum more or less thick, characters that allow us to ascribe our specimen to the genus *Pipistrellus*.

Two *Pipistrellus* species are currently recognized in Sicily, *P. pipistrellus* and *P. kuhlii,* but there are no fossil records for these species on the island. Although both species are generalist they are associated with a temperate climate.

Family Miniopteridae Dobson, 1875

Genus *Miniopterus* Bonaparte, 1837

Miniopterus schreibersii (Kuhl, 1817)

Fig. 4H

Material: one fragmented mandible, one fragmented cranium and two humeri from level 4.2.

Description and remarks. The double alveolus in the position of the third lower premolar (p3) in our fragmented mandible indicates a p3 with two roots, characteristic of the genus *Miniopterus*. Further, the fragmented cranium shows a brain case prominently convex in lateral view, the frontal crest poorly developed, not convergent with the sagittal crest to form a Y. Moreover, on its distal epiphysis the humerus is characterized by a long styloid process in the shape of a hook; the epitrochlea is not very wide, and the condyle and epicondyle are separated by a marked constriction. These morphological characteristics make it possible to ascribe the specimens under study to the species *Miniopterus schreibersii*.

Miniopterus schreibersii is a species that is probably tropical in origin. The species is known in the early Middle Pleistocene of Sicily from the "Elephas falconeri" faunal complex (Bonfiglio et al. 2000, 2002; Spagnesi & De Marinis 2002). *Miniopterus schreibersii* is a species that is typically associated with warm climates, often related with water courses, riparian vegetation and forest areas with low cover.

Order **Rodentia** Bowdich, 1821

Family Cricetidae Fischer, 1817

Subfamily Arvicolinae Gray, 1821

Genus *Arvicola* Lacepède, 1799

Arvicola amphibius (Linnaeus, 1758)

Fig. 4I

Material: three lower first molars (m1) from level 3.4

Description and remarks. The specimens recovered from level 3.4 of Vallone Inferno are characterized by their large size and by having five isolated triangles. The anterior loop presents a rounded contour, the enamel is thinner in the trailing edges than the leading edges (positive or *Microtus*-like), and cement is present in all specimens. These morphological characteristics make it possible to ascribe the specimens under study to *A. amphibius*.

Arvicola amphibius is a species that is widely distributed throughout Europe. It appears in Sicily for the first time in the Early Holocene of the Lower Mesolithic levels of the Uzzo Cave (ca. 10 ka BP) and is recorded also at the Neolithic site of Partanna Stretto (ca. 6.6-5.7 ka BP), but it is currently extinct in Sicily (Bonfiglio et al. 2000). *A. terrestris* is a species that is closely linked to the presence of water (Colamussi 2002).

Genus *Microtus* Schrank, 1798

Subgenus *Terricola* Fatio, 1867

Microtus (Terricola) savii (de Sélys-Longchamps, 1838)

Fig. 4J-L

Material: sixteen m1 from level 4.2, one hundred and two m1 from level 3.4, eight m1 from level 3.3, and two m1 from 3.1.

Description and remarks. The specimens recovered from Vallone Inferno are characterized by the posterior lobe T1, T2 and T3 closed. In the anteroconid complex (ACC), T4 and T5 are broadly confluent, forming the so-called "pitymyan rhombus" typical of species of the *Terricola* subgenus. The anterior cup (AC) in the lower first molars is wide and extensive and less constricted, and the ACC is shorter and looks more squat and asymmetric compared with other species of the subgenus *Terricola* (Petruso et al. 2011). These morphological characters allow us to ascribe our material to the species *Microtus* (*Terricola*) *savii*.

Microtus (*Terricola*) *savii* is a species endemic to the Italian peninsula, although it is also found in the south of Switzerland and some areas of France bordering on the western Italian frontier (V.V.A.A. 2008). Dispersals of *M.* (*T.*) *savii* from the mainland to Sicily occurred on two occasions during the Pleistocene. One colonization is recorded at Isolidda 3 from the late Middle Pleistocene, during marine isotope stage 6 (MIS 6), and the other took place during the Late Pleistocene, recorded in San Teodoro Cave ca. 32 ka BP (Bonfiglio et al. 2000; Masini et al. 2008; Petruso et al. 2011). *M.* (*T.*) *savii* is present throughout Sicily and is linked to open-temperate environments extending over arid and subarid steppes.

Family Muridae Illiger, 1811

Subfamily Murinae Illiger, 1811

Genus *Apodemus* Kaup, 1829

Apodemus sylvaticus (Linnaeus, 1758)

Fig. 4M

Material: one m1, five fragmented maxillae and two fragmented mandibles from level 4.2; eight upper first molars (M1), 20 lower first molars (m1), 14 fragmented maxillae and 10 fragmented mandibles from level 3.4; one m1, three fragmented mandibles and five fragmented maxillae from level 3.3; two M1, one m1, one fragmented mandible and one fragmented maxilla from level 3.1.

Description and remarks. The presence in the fossil lower molars (m1) of a low occlusal surface with six main cusps, the anterolingual and anterolabial cusps confluent in an X-shape and separated by a deep, narrow groove, in conjunction with a posterior cusp (cp) that is low, rounded and well developed and the presence of secondary cusps (c) on the labial face of the m1 and of a mesial tubercle (tma) allow us to assign our specimens to the genus *Apodemus*. Further, the confluence of tubercles t4 and t7 in the upper first molars (M1) of our material, together with the development of tubercle t9 in the upper second molar (M2), lead us to ascribe our specimens to the species *A. sylvaticus*.

Apodemus sylvaticus is distributed throughout western Europe, north Africa, Sicily and most of the Mediterranean islands (A.A.V.V. 2008). This species is known in Sicily since the Late Pleistocene from the San Teodoro-Pianetti faunal complex, dated to ca. 32 ka BP (Bonfiglio et al. 2000; Masini et al. 2008). *Apodemus sylvaticus* is a species widely present in Sicily, extended throughout the forest environments and Mediterranean maquis from sea level to an altitude of 1800 m, avoiding arid and dry environments.

Genus *Rattus* Fisher, 1803

Rattus norvegicus Berkenhout, 1769

Fig. 4N

Material: two first lower molars (m1), two second upper molars (M2), one third upper molar (M3), one fragmented mandible from level 3.1.

Description and remarks. The big size and the absence of accessory labial tubercles in the first lower molars (m1) recovered from Vallone Inferno allows us to distinguish our specimens from the species *Rattus rattus* and ascribe our material to the species *Rattus norvegicus*.

Rattus norvegicus is currently a cosmopolitan species. As yet, there are no data on its introduction to

Sicily, but it seems to have been introduced to Italy in the Medieval Period and to have expanded throughout the Italian peninsula during the eighteenth century (Spagnesi & De Marinis 2002; V.V.A.A. 2008). Its probable first appearance data in Italy are from Palazzo Vitelleschi (Tarquinia) in the twelfth to fourteenth centuries (Clarke et al. 1989; Audoin-Rouzeau & Vigne 1994). Although, *Rattus rattus* seems that appears early in some Mediterranean islands, such as Corsica (IV-II centuries BC) (McCormick 2003), in Sicily *R. rattus* is documented for the first time in Castello di Fiumedinsi in the XIV century (Villari 1995; V.V.A.A. 2008). *Rattus norvegicus* is a species that is widely spread across Sicily and seems closely associated with urbanized environments, often linked to water streams. It is present too in rural and humid zones with herbaceous vegetation.

Family Gliridae Thomas, 1897
Subfamily Leithiinae Lydekker, 1896
Genus *Eliomys* Wagler, 1840

Eliomys quercinus (Linnaeus, 1766)
Fig. 4O

Material: two fragmented mandibles from level 3.4, one first upper molar (M1) from level 3.1.

Description and remarks. The mandibles recovered from Vallone Inferno have a wide perforated foramen in the distal part of the mandible. The teeth have a concave occlusal surface with a main crest that is well developed at the lingual and labial ends. These characters allow us to ascribe our specimens to the species *Eliomys quercinus*.

Eliomys quercinus is a species endemic to the west Palearctic region, well represented in continental Europe and north Africa, including the larger Mediterranean islands such as Sicily, Sardinia, Corsica and the Balearics (V.V.A.A. 2008). As yet, there are no data on the fossil record of the species in Sicily. *Eliomys quercinus* is the least arboreal of the glirids and frequents a variety of environments, from open areas where walls are present to dry or rocky environments, from sea level to altitudes of 1600 m. It has an extensive and discontinuous distribution in Sicily in comparison with the other glirid species.

Genus *Muscardinus* Kaup, 1829

Muscardinus avellanarius (Linnaeus, 1758)
Fig. 4P

Material: three fragmented maxillae, one second lower molar (m2) and one second upper molar (M2) from level 3.4; one fragmented maxilla from level 3.3.

Description and remarks. The recovered teeth show a flat occlusal surface. The first upper molar (M1) shows a distal crest that is clearly separated from the posterior four. The other molars, both upper and lower, present six transverse crests. These characters allow us to ascribe our specimens to the species *Muscardinus avellanarius*.

Muscardinus avellanarius is a central European species that is well distributed throughout Europe. In Sicily the species probably appears during the Early Holocene, but as yet there is no fossil record for the species (Petruso et al. 2011). The species *Muscardinus avellanarius* is closely associated with deciduous forest environments, where it can be found at altitudes from 800-1600 m. It is a rare terrestrial mammal, present in Sicily only in the eastern side of the Madonie and Peloritani mountain ranges (V.V.A.A. 2008).

Subfamily Glirinae Thomas, 1897
Genus *Glis* Brison, 1762

Glis glis Linnaeus, 1766
Fig. 4Q

Material: two upper fourth premolars (P4), 32 molars, four fragmented maxillae and three fragmented mandibles from level 3.4, 13 molars and three fragmented mandibles from level 3.3, one M1 and one M2 from level 3.2, one upper first molar (M1) from level 3.1.

Description and remarks. The mandibles recovered are not perforated in the distal part. The teeth are big in comparison with other glirid species. The molars present an occlusal surface that is flat, with three accessory crests interspersed with the four main cusps. These characters allow us to ascribe our specimens to the species *Glis glis*.

Glis glis is a central European species that is well adapted to temperate and continental climates. It is well represented on Mediterranean islands such as Sicily, Sardinia and Corsica, among others (V.V.A.A. 2008). The first record of this species in Sicily comes from the Neolithic levels at Partanna Stretto, dated to around 5.7-6.6 ka BP (Bonfiglio et al. 2000; Masini et al. 2008). In Sicily it is a current species typically associated with mature forests. The distribution of *Glis glis* is principally restricted to the eastern side of the Peloritani and Madonie mountain ranges.

Results and discussion

Biochronological and biogeographical data

As regards the small-vertebrate assemblage, the Vallone Inferno rock-shelter provides the oldest finds known so far in Sicily for the species *Suncus etruscus*, *Muscardinus avellanarius*, *Eliomys quercinus* (level 3.4; 3.2-3.9 ka BP) and *Rattus norvegicus* (level 3.1; ca. 1.2 ka BP), as well as the youngest find of the vole species *Arvicola amphibious* (level 3.4).

From a biochronological point of view, the most important species represented at Vallone Inferno are *Arvicola* cf. *A. amphibius* and *Rattus norvegicus*, the former from the Early Bronze – Middle Neolithic level (3.4) and the latter from the Late Roman – Byzantine level (3.1) (Tab. 2).

Arvicola amphibius is a species that is not currently represented in Sicily (Spagnesi & De Marinis 2002). It seems to be found on the island at the beginning of the Holocene Period, when it is represented in the Lower Mesolithic levels (ca. 10 ka BP) and the Early Neolithic ones of the Uzzo Cave (Tagliacozzo 1993; Bonfiglio et al. 2000, 2002). Previous papers (Bonfiglio et al. 2000, 2002) have suggested that the species may have disappeared from Sicily after the Early Neolithic, where it is still present at Partanna Stretto (ca. 6.6-5.7 ka BP) (Bonfiglio et al. 2000, 2002). Its extinction has been considered as likely related to the climatic deterioration that followed the Holocene climatic optimum (ca. 9-5 ka BP) (Masini et al. 2008) but, taking into account the data obtained from Vallone Inferno, where *A. amphibius* is represented in a well-dated level (ca. 3.2-3.9 ka BP), another plausible explanation for the extinction of the species is the expansion of agriculture on the island during the Greek and Roman dominion (Massa & La Mantia 2007).

On the other hand, *Rattus norvegicus* is a species that was introduced to Italy in the Medieval Period and expanded across the Italian peninsula during the eighteenth century (Spagnesi & De Marinis 2002). Previous studies showed its probable first appearance data (FAD) in Italy to be from Palazzo Vitelleschi (Tarquinia), dating to the twelfth to fourteenth centuries (Clarke et al. 1989: Audoin-Rouzeau & Vigne 1994). Taking into account the data obtained from the Vallone Inferno rock-shelter, the presence of the species in Sicily is earlier than has been documented. The presence of *R. norvegicus* in the Late Roman-Byzantine level 3.1 establishes that the oldest find of the species in insular Italy occurs between the seventh and ninth centuries, based on the absolute dates for this level (669-828 cal. AD) (Tab.1).

With the exception of *Arvicola* cf. *A. amphibius*, which is not currently represented in Sicily, all the other species that occur at Vallone Inferno are well represented on the island. However, there are certain minor differences with respect to the present, such as the occurrence of *Muscardinus avellanarius* in the Neolithic layer (3.4) of Vallone Inferno; this species is not present nowadays in the area surrounding the site. Its distribution is today restricted to the northeast of Sicily, including the eastern slopes of the Madonie mountain range (Sarà & Casamento 1995; Cagnin & Grasso 1999; Spagnesi & De Marinis 2002; V.V.A.A. 2008), where it seems closely associated with beech woods (Cagnin & Grasso 1999). Indeed, there are 12 terrestrial small-mammal species (rodents and insectivores) living today in Sicily (Cagnin & Grasso 1999; V.V.A.A. 2008). Given that nine of these extant species are represented at Vallone Inferno, the small-mammal assemblage from this site represents 75% of the extant micromammal species on the island. Taking into account, that some of the Sicilian extant species were introduced after the Roman period, such as *Myocastor coypus* (Modern epoch) or *Rattus rattus* (XIV century), the small mammal assemblage that appears at Vallone Inferno is representative of the ecosystem in the immediate vicinity of the rock-shelter at the time when the remains were deposited.

Palaeoenvironmental and palaeoclimatic data

Although a complete taphonomic study has not been performed in Vallone Inferno and at present the remains are poor in number, some preliminary remarks can be made. The high bone breakage and the poor representation of small-vertebrate skeleton elements are probably related with post-depositional phenomena. The light to moderate digestion seen in microtine teeth, with rounding of the triangles, indicates that the bones were probably accumulated by an avian predator of category 1 (sensu Andrews 1990), such as the barn owl (*Tyto alba*). Our data coincide with the diet structure of *Tyto alba* in Sicily (Catalisano & Massa 1987). Furthermore, the *Tyto alba* pellets recovered from a fissure above the Vallone Inferno site show a representation of small-mammal specimens that are similar to the Early Bronze - Middle Neolithic level (3.4). The most abundant species represented in the pellets and in level 3.4 are *Microtus* (*Terricola*) *savii* and *Apodemus sylvaticus* and to a lesser extent *Crocidura sicula* and *Suncus etruscus* (Tab. 3).

Due to the scarcity of the remains recovered so far from the Byzantine-Late Roman and Early Holocene levels (3.1, 3.2, 3.3 and 4.2), it is difficult to establish a

	NISP	MNI	%
Crocidura sicula	13	7	13.46
Suncus etruscus	11	6	11.54
Microtus (*Terricola*) *savii*	48	24	46.15
Apodemus sylvaticus	21	11	21.15
Mus musculus	8	4	7.69
Total	111	52	100

Tab. 3 - Number of Identified Specimens (NISP), Minimum Number of Individuals (MNI) and the percentage of the MNI (%) of the pellets recovered in different parts of a fissure (900 m) above Vallone Inferno.

palaeoenvironmental interpretation of the sequence as a whole. However, we have tried to relate our data with the environmental and climatic fluctuations that occurred at the beginning of the Holocene in Sicily, taking into account that the most reliable data are provided by the Early Bronze-Middle Neolithic level 3.4.

From a palaeoenvironmental point of view, the Vallone inferno sequence is dominated by woodland/open woodland landscapes, representing more than 45% of the habitat assemblage in all the studied levels (Fig. 3). The open forest cover is indicated basically by the abundance of the species *Microtus* (*Terricola*) *savii*, *Apodemus sylvaticus*, *Glis glis* and to a lesser degree *Crocidura* cf. *C. sicula*, *Erinaceus europaeus* and bats in general (Tab. 2). Moreover, open dry and open humid meadows are well represented in the studied levels, reaching values between 20% and 33% that fluctuate from level to level (Fig. 5). These are represented by species such as *Erinaceus europaeus*, *Crocidura* cf. *C. sicula* and *Microtus* (*Terricola*) *savii*. There is a progressive decrease in open dry meadows from level 4.2 to level 3.1 and an increase in open humid meadows in level 3.1 (Fig. 5). Such a trend is also visible in the amphibian and reptile assemblages, where taxa with Mediterranean woodland and rocky affinities are more highly represented in level 3.4 (*Lacerta* gr. *L. viridis*, cf. *Podarcis* sp., colubrine snakes and *Vipera* gr. *aspis*) than in subjacent levels. Though very scarce, by contrast, amphibians seem to have been better represented in levels 3.1 and 3.2 (with *Discoglossus* cf. *D. pictus* and *Bufo* cf. *bufo*) than in levels 3.4 and 4.2 (with *Bufo* sp.) (Forgia et al. 2013). The environmental results obtained from the small-vertebrate assemblage are consistent with the pollen and charcoal analyses for the Vallone Inferno sequence (Forgia et al. 2013). These studies show a progressive opening of the landscape through the sequence, probably related with the human impact, and thus coincide with the small-vertebrate studies, given that the lowest values for forest (45.2 %) in the sequence are from level 3.1 (Fig. 5). All these palaeoenvironmental results are in accordance with the previous pollen and charcoal studies conducted by Sadori & Narcisi (2001), Sadori & Giardini (2007) and Sadori et al. (2008) at Lago di Pergusa (Sicily), which indicate a progressive deforestation with an increase in aridification from ca. 7000 years BP, reaching the most arid conditions ca. 3500 years BP. This phenomenon is observed in the Early Bronze – Middle Neolithic level 3.4 of Vallone Inferno, dated to between 3200-3900 years BP, where open dry meadows reach their maximum values (23.6 %) after the Holocene climatic optimum (Fig. 5).

From a palaeoclimatic point of view, the results of the intersection of the small mammals studied from the Vallone Inferno rock-shelter show the values of MAT and MAP for all the analysed levels (Tab. 4) to fall within the current range of MAT (13-17°C) and MAP (600-1000 mm) obtained from the Petralia Sottana meteorological station (Drago et al. 2000). Despite these data, there are differences among the levels analysed. Taking into account the temperature and precipitation data obtained for the Early Bronze – Middle Neolithic level 3.4, which presents the highest degree of reliability, the MAT is high (16.6±0.5 °C) and the MAP is low (863±131 mm) in comparison with the other analysed levels (Tab. 4). An attempted correlation may be performed bearing in mind the studies conducted by In-

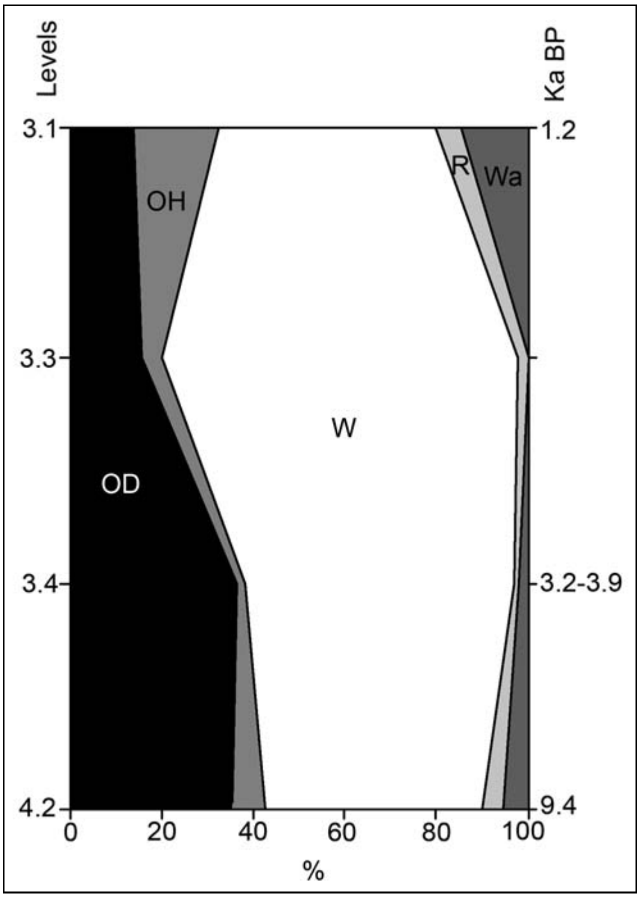
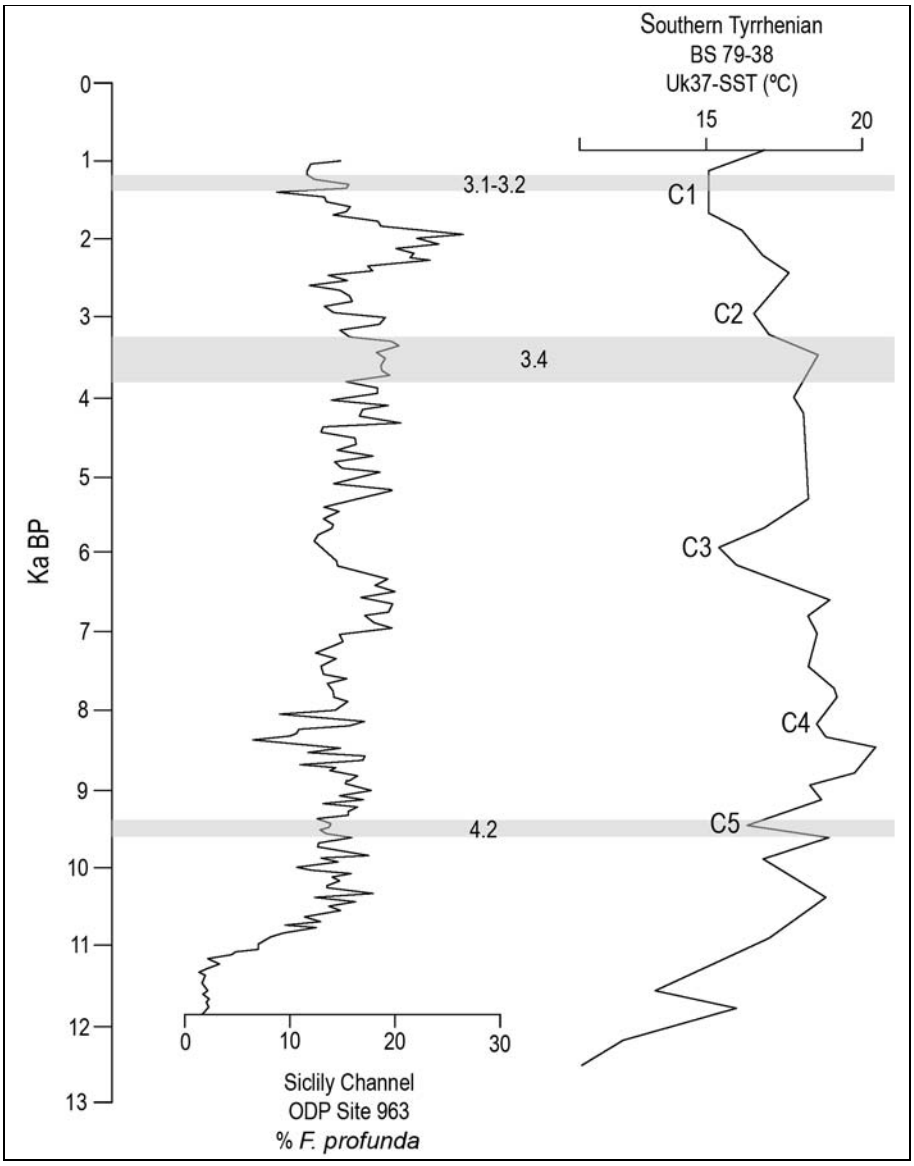


Fig. 5 - Palaeoenvironmental evolution of the Vallone Inferno sequence based on the stratigraphic distribution of the habitat types. OD = open dry meadow; OH = open humid meadow; Wa = woodland/woodland-edge; R = rocky; W = water stream.

		MAT (ºC)				MAP (mm)			
	n	mean	max	min	sd	mean	max	min	sd
3.1	6	15.5	17	12	2.0	900	1300	700	221
3.3	15	14.2	17	11	1.8	893	1300	650	199
3.4	4	16.6	17	16	0.5	863	1000	750	131

Tab. 4 - Relation of temperatures and precipitation for Vallone Inferno. MAT= mean annual temperature; MAP= mean annual precipitation; n= number of intersection points; max= maximum of values obtained; min= minimum of values obtained; SD= standard deviation of values obtained.

Fig. 6 - Proposed correlation of the *F. profunda* curve and the quantitative variation in the annual sea-surface temperatures (Uk37-SST) obtained for the Sicilian Channel and the Tyrrhenian Sea (modified from Incarbona et al. 2010) with the levels (3.1 to 4.2) of the Vallone Inferno rock-shelter. C1-C5 indicate cooling episodes.



carbona et al. (2010) on the percentage representation of the nanofossil *Florisphaera profunda* in the Sicily Channel and the sea-surface temperatures (SST) obtained from the marine survey in the southern Tyrrhenian. The level 3.4 (dated to ca. 3200-3900 years BP) could be related with the increasing of the percentage of *F. profunda* and the SST were increasing just before the cooling episode detected at C2 (Fig. 6), coinciding with the data derived from the Vallone Inferno small vertebrates. In addition, the low MAP obtained could be in relation with the more arid conditions that prevailed ca. 3500 years BP, as detected by Sadori & Narcisi (2001), Sadori & Giardini (2007) and Sadori et al. (2008) for Lago di Pergusa.

Conclusions

The Vallone Inferno rock-shelter provides us with new data that increase our knowledge of the small-mammal faunas of the beginning of the Holocene in Sicily. A total of 330 fragments, mainly from level 3.4, have been analysed. Correspond to a minimum of 182 small-mammal individuals, representing at least 14 taxa, including insectivores, bats and rodents. The presence of taxa such as *Suncus etruscus*, *Muscardinus avellanarius* and *Eliomys quercinus* in the Early Bronze - Middle Neolithic level 3.4, and of *Rattus norvegicus* in the Late Roman - Byzantine level 3.1, provides the earliest known fossil record of these species in Sicily.

Due to the scarcity of the remains recovered from the Byzantine - Late Roman levels (3.1-3.3) and the Early Holocene level (4.2), it is difficult to undertake a palaeoenvironmental and palaeoclimatic interpretation of all the sequence. Taking into account the small-vertebrate assemblage, however, level 3.4 can be seen to have been deposited in open dry forest landscape, coinciding with the increase of aridification that occurred in Sicily after the Holocene climatic optimum. The climate parameters estimated on the basis of the small-vertebrate assemblage for level 3.4 show temperatures and precipitation that fall within the range of current values for the Vallone Inferno area. However, the high MAT and low MAP in comparison with the other levels coincide with conditions that were more temperate and arid than today in Sicily, as represented in the SST of the Tyrrhenian Sea and the nannofossils of the Sicilian Channel between ca. 3200-3900 years BP.

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