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NEW FOSSIL VERTEBRATE REMAINS FROM SAN GIOVANNI DI SINIS (LATE PLEISTOCENE, SARDINIA): THE LAST *MAUREMYS* (REPTILIA, TESTUDINES) IN THE CENTRAL MEDITERRANEAN

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Abstract. New fossil vertebrates from the most representative Upper Pleistocene section (Tyrrhenian, MIS 5e) of the outcrop of San Giovanni di Sinis (Oristano, Sardinia) are here reported and described. The fossils, although scarce and fragmentary, document the occurrence of a terrapin (*Mauremys* sp.) and the endemic Sardinian deer (*Praemegaceros cazioti*). Significant is the occurrence of the terrapin because it is the youngest representative of the genus *Mauremys* in the central Mediterranean area where it is extinct at present. The Late Pleistocene extinction of *Mauremys* in Italy follows the same pattern of other Mediterranean reptiles, in being in some cases delayed on the islands. A comparison of the modern range of *Mauremys* and that of the pond turtle, *Emys*, as well as of their past ranges as evidenced by the fossil record, might suggest that some sort of thermophily (at least during pre-hatching stages) characterized the former taxon and is responsible for its past and present distribution.

Riassunto. Vengono segnalati e descritti nuovi resti fossili di vertebrati provenienti dalla più rappresentativa sezione del Pleistocene superiore (Tirreniano, MIS 5e) dell'affioramento di San Giovanni di Sinis (Oristano, Sardegna). I resti fossili, sebbene pochi e frammentari, documentano la presenza di una testuggine (*Mauremys* sp.) e del cervo endemico quaternario della Sardegna (*Praemegaceros cazioti*). Significativi sono i resti della testuggine, perché costituiscono la più recente testimonianza della presenza del genere *Mauremys* nel Mediterraneo centrale, area in cui è attualmente estinto. L'estinzione di *Mauremys* nel tardo Pleistocene italiano segue il pattern di altri rettili mediterranei: le isole consentono in alcuni casi una sopravvivenza prolungata rispetto al continente. Un confronto tra la distribuzione attuale di *Mauremys* e quella della testuggine palustre, *Emys*, così come un confronto tra i loro areali passati (definiti sulla base della documentazione fossile), indica chiaramente che un certo grado di termofilia (almeno durante gli stadi prenatali) caratterizza *Mauremys* ed è responsabile per la sua distribuzione presente e passata.

Introduction

The first note of findings of continental fossil remains in the Pleistocene succession of San Giovanni di Sinis (Fig. 1) was published by Maxia & Pecorini (1968).

Fig. 1 - Location of the San Giovanni di Sinis Tyrrhenian outcrop.

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The authors indicated the presence of "molars of a small Elephant (*Elephas melitensis*?)" and *Helix* shells in a pre-Tyrrhenian dune "underlying the Tyrrhenian sandstones (Panchina)" attributed to the Riss.

Such fossil remains, in an "inter-Tyrrhenian" layer (sensu inter T1 and T2 of Maxia & Pecorini 1968), have been later studied by Ambrosetti (1972) who, whilst discussing the problems of comparing this Sardinian fauna with Mediterranean assemblages, attributed it to *Elephas lamarmorae.* More recently, the same fossil remains have been interpreted as belonging to a mammuthine representative and referred to *Mammuthus lamarmorae* (Melis et al. 2001).

Other fossil vertebrates from the Upper Pleistocene of San Giovanni di Sinis are known since the description given by Caloi et al. (1981). These Authors reported the presence of indeterminate fishes, two terrapins (*Emys orbicularis* and *Mauremys* cf. *M. caspica*), a colubrid snake (*Coluber* sp.), indeterminate birds, an arvicolid species (*Tyrrhenicola henseli*), an ochotonid (*Prolagus* sp.) and a deer (*Megaceros* sp.). The chronological allocation of the fossiliferous sediments (known as "turtle" level), based on the geometric relationships between the different outcropping sedimentary bodies and the fossil remains, has been considered as Late Pleistocene, intermediate between the Tyrrhenian and the Würmian complexes (Caloi et al. 1981).

The nature of the sediments, as well as the relative abundances of the terrapins, suggest that the depositional environment of the level where the vertebrate fossils are preserved could be represented by a coastal marsh, eventually provided with salty waters (as testified by the absence of amphibian remains).

Current research on the Tyrrhenian event in the Sinis region, as well as western and southern Sardinia, is aiming at a new stratigraphic analysis, with the purpose of identifying the most representative Tyrrhenian sections (MIS 5e) in Sardinia and in the Mediterranean area. This renewed research follows a general discussion occurred within the Italian Committee on Stratigraphy during the Spoleto GeoItalia 2005 Meeting. In the course of further stratigraphic investigations, new fossil remains were recovered in the succession exposed at San Giovanni di Sinis. The origin of the layers bearing such fossils is in good agreement with the depositional and palaeogeographic evolution.

This work represents an update of the knowledge about the palaeontology of San Giovanni di Sinis assemblage, and constitutes a chance to recapitulate the fossil record of the Italian representatives of terrapins belonging to genus *Mauremys*, represented in this locality by the youngest members of the central Mediterranean, area where it is extinct at present.

Geological setting

Several authors described at San Giovanni di Sinis aeolian sandstones and continental complexes correlatable with the Riss glaciation (Maxia & Pecorini 1968), and marine sediments attributed to the Tyrrhenian interglacial ("Riss-Würm" Auct., MIS 5) for their content of "warm fauna" (Vardabasso 1956; Masala 1958; Maxia & Pecorini 1968; Comaschi Caria 1968; Pomesano Cherchi 1968; Marini & Murru 1977).

During the 80s, some studies highlighted the presence of several shore-shoreface stratified units within the entire section outcropping at San Giovanni di Sinis. There Tyrrhenian marine deposits were also recognized (Ulzega & Ozer 1980), and later tentatively compared to similar deposits in the Tunisian coast (Ozer et al. 1980): Rejiche Formation - Cala Mosca Formation (Eutyrrhenian), Chebba Formation - Santa Reparata Formation (Neotyrrhenian).

A first attempt to establish the geochronology of the marine units outcropping at San Giovanni di Sinis employing amino acids racemization (67.5 – 56.0 Ka; Wanet et al. 1982) was later considered unreliable because of the difficulty of interpreting the "interspecific variations in racemization rate" (Ulzega & Hearty 1986) and furthermore because of the discrepancy with successive studies (Carboni & Lecca 1985; Davaud et al. 1991; Kindler et al. 1997).

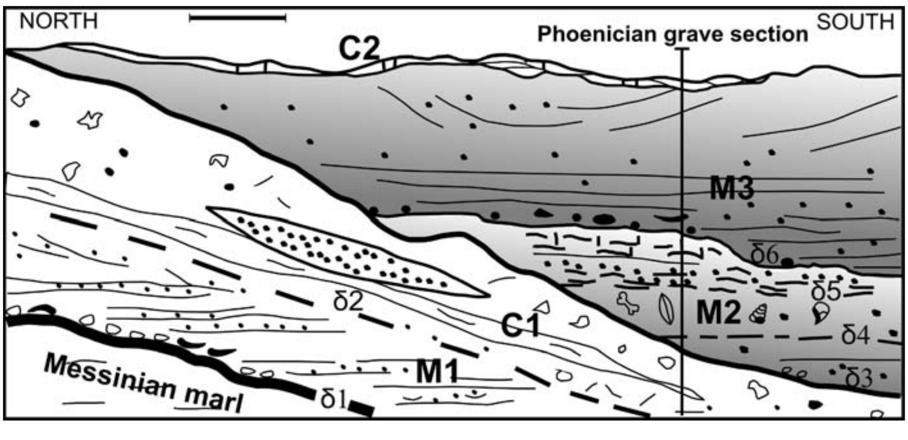

Fig. 2 - Stratigraphic sketch of the shore and continental sequences of the San Giovanni di Sinis Middle – Upper Pleistocene outcrop (modified from Carboni & Lecca 1985). Not to scale.

Carboni & Lecca (1985), studying the Middle-Late Pleistocene outcrops along the Sinis coast, recognized in the San Giovanni di Sinis outcrop three shore-shoreface units in unconformity on the Messinian marls and limestones of the Capo San Marco Formation (Cherchi et al. 1978).

The northern and stratigraphically lowermost part of this outcrop displays a shore unit (M1; Fig. 2) with foreshore facies evolving into a backshore and aeolian dune, covered by a continental sequence (C1) with at least 5 layers of aeolian and colluvial sandstones in alternation. Fossil remains of a proboscidean (*Elephas lamarmorae*) come from a layer of this continental sequence C1 and have been reported by Maxia & Pecorini (1968), Ambrosetti (1972) and Melis et al. (2001). The M1 unit is affected northward by a normal high angle fault, which causes an abrupt interruption and an almost vertical contact with the Messinian marls. Upward, over an erosion surface (δ3) there is a second shore unit (M2; Fig. 2) of temperate sea and low energy transitional-lagoonal environment. Such unit is characterized by several stratigraphic disconformities and arranged in facies of protected shore (M2a, b; Fig. 3), and lagoon (M2c; Fig. 3). The beds M2d, in "Phoenician graves" section (Fig. 3), constituted by fine silty sand, carbonatic silt, carbonatic mud and marly-sandy limestone, testify even episodic emersion phases, and yielded remains of molluscs, mammals and reptiles, also the new remains here described. A third shore unit, evolving in backshore and in aeolian dune (M3a, b, c; Fig. 3), is situated over another erosion surface (δ6), affecting both the top of the continental unit C1 and the transitional unit M2. A second continental unit (C2; Fig. 3) can be broadly observed above the M3 deposits. Without geochronological dating, Carboni & Lecca (1985) attributed, only on the base of the lithostratigraphic and sequential data, the first episode M1 to the "Paleotyrrhenian" ("Mindell-Riss Interglacial" Auct.) and the following episodes M2, M3 to the Eutyrrhenian (MIS 5e highstand).

Ulzega & Hearty (1986) reported U/Th ages of 138 ± 8 ka and of 149 ± 10 ka for two outcrops near the Cagliari area (Fig. 1), at Calamosca (lower unit) e Sa Illetta, respectively. Such work attributed the lower marine unit M1 to the Eutyrrhenian (i.e. MIS 5e) and the highest units M2 and M3 to the Neotyrrhenian (i.e. MIS 5c-5a), with ages between 105 e 75 ka.

Kindler et al. (1997) correlated petrographic and sedimentological data in order to interpret the past climatic conditions and sea level forcing mechanisms. Carried out on different Sardinian Tyrrhenian outcrops, such analysis confirms the chronological attribution of the lower marine unit, which they defined "sequence X" (M1 of Carboni & Lecca 1985), to a pre-Tyrrhenian interglacial ("Mindell-Riss Interglacial" Auct.) and both their "I and II sequences" (M2 and M3 of Carboni & Lecca 1985) to the MIS 5e.

Thus, the literature attributes the first marine unit (M1 of Carboni & Lecca 1985; Sequence X of Kindler et al. 1997) to an interglacial phase of the Middle Pleistocene, and agrees with the presence of other two overlying separate marine units. Contrasting interpretations,

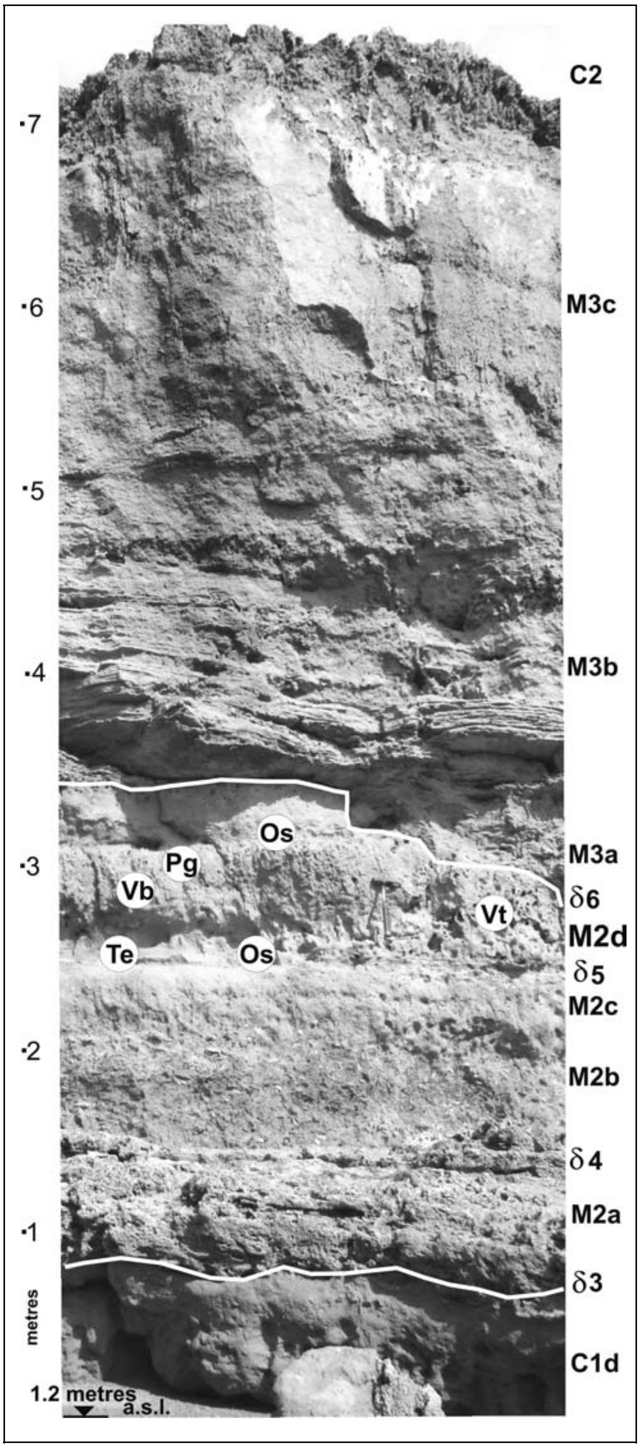

Fig. 3 - "Phoenician graves" section where the vertebrate remains described in this work were found. Key to abbreviations: Os – ostracods, Pg – pulmonate gastropods, Te – terrapins, Vb – vertebrate bones, Vt – vertebrate teeth.

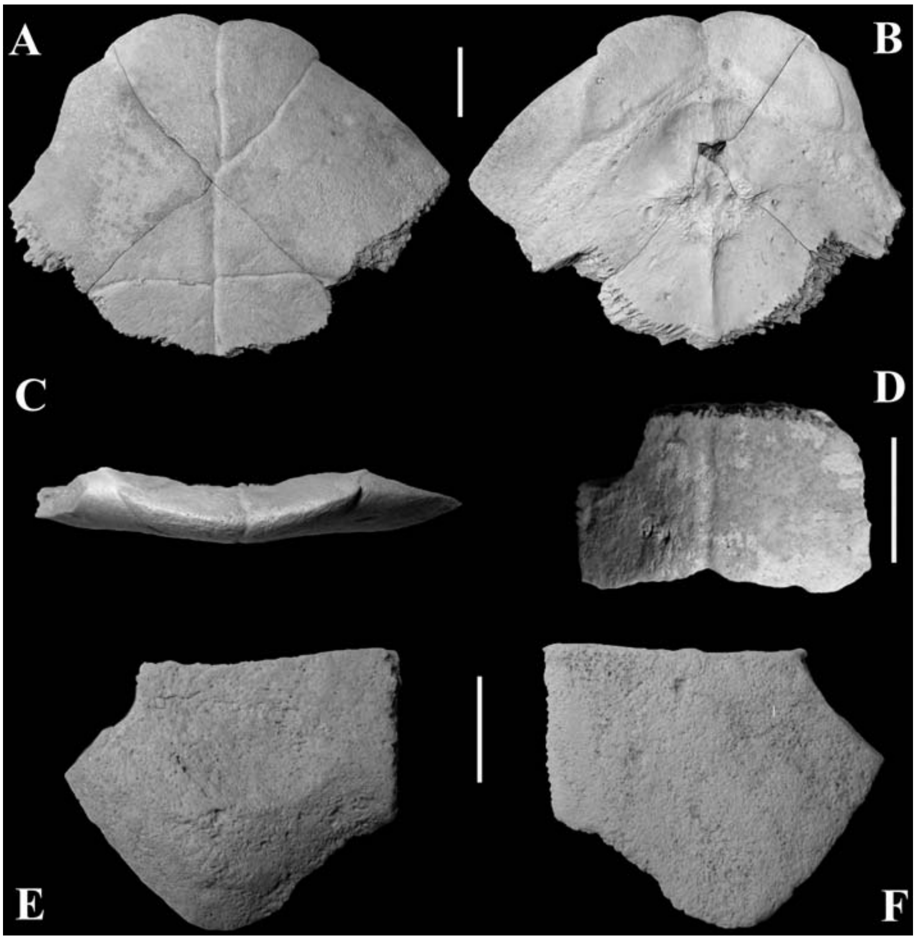

Fig. 4 - *Mauremys* sp. from San Giovanni di Sinis: A-C) fragment of anterior plastral lobe (epiplastra and entoplastron), in ventral (external surface), dorsal (visceral) and anterior view; D) pygal in external view; E, F) fragmentary left xiphiplastron in dorsal and ventral view. The bar is 10 mm long.

however, concern the chronology of these two units within the MIS 5.

Material and methods

The new fossil record, here described, consists of 50 remains, currently stored at the "Università di Cagliari" with the collection number UC 1-50. The taxonomic identification has been based on the comparison of extant and fossil species as well as on the presence of phylogenetically informative characters of bony elements (e.g., for terrapin turtles, Zangerl 1969; Hervet 2000, 2004). Osteological nomenclature of turtle shell elements follows Lapparent (2001). No distinction has been made in the section "Material" between perfectly preserved or fragmentary remains.

Systematic palaeontology

Reptilia Laurenti, 1768

Testudines Batsch, 1788

Geoemydidae Theobald, 1868

Mauremys Gray, 1869

Mauremys sp.

Material. 2 neural plates, 8 pleural plates, 10 peripheral plates, 1 anterior plastral lobe (right and left epiplastra plus entoplastron), 1 right hyoplastron, 2 right xiphiplastra, 3 left xiphiplastra, 1 pygal plate, 13 indeterminate fragments.

Description. UC 1 (Fig. 4 A-C) – Fragmentary anterior lobe of a plastron. Both the epiplastra as well as the entoplastron are present. These elements and their surfaces are perfectly preserved, with the exception of the lateral portion of the right epiplastron. Each element shows spiny edges corresponding to sutures with the missing hyoplastra, but sutural lines between epiplastra and entoplastron are not visible either on the dorsal or the ventral surface. The shape and boundaries of the entoplastron are therefore not perceivable. The humero/pectoral sulcus crosses the entoplastron relatively far from its caudal edge. Since the sutures between the epiplastra and the entoplastron are not visible, it is not possible to directly evaluate if the gular shields covered the entoplastron; however, it is possible to suppose with confidence that they slightly entered it. Epiplastral pads are not developed and the area corresponding to the gular shields forms a distinct dorsal concavity (and a ventral convexity), if seen in anterior view. In ventral view, the area covered by gular shields is vaguely heart-shaped (with a shallow medial notch in the cranial area) and slightly protruding out of the anterior outline of the plastron lobe.

In dorsal (visceral) view, the epiplastral lips are not distinctly cranio-caudally expanded (only slightly cranially). The fragment is 49 mm long and 64 mm wide, the gular shields are 22 mm long and the humeral ones 15 mm.

UC 2 (Fig. 4D) – Pygal plate. The pygal is nearly complete (only a small dorso-lateral portion is broken off). It is relatively short and wide (14 x 24 mm respectively). The ventral (posterior) edge is slightly concave. The external surface shows a sagittal sulcus corresponding to the boundary between the 12th marginals.

UC 3 – Fragmentary right hyoplastron. This fragment is rather thin and belongs to a young specimen. There is no trace of axillary shield. The sulcus between pectoral and abdominal shields reaches the buttress.

UC 4 (Fig. 4E-F) – Fragmentary left xiphiplastron. The fragment consists in the posterior portion of a left xiphiplastron: the cranial edge is fractured, the others are well-preserved. There are no sulci on the external surface. A deep and relatively wide notch is present at the postero-medial corner. The postero-lateral process has a tip slightly bent ventrally and shows a moderate dorsal thickening. The fragment is 25 mm long and 30 mm wide.

UC 5 – Four other xiphiplastral fragments are represented by their anterior portion only. The femoro-anal sulcus is visible in two right elements: it runs nearly perpendicular to the lateral edge of the bone.

Discussion. The remains can be referred with confidence to the terrapins of genus *Mauremys*, because of the combination of the following characters: entoplastron slightly covered by gular shields but extensively covered by pectoral shield; xiphiplastra with femoro-anal sulcus running perpendicularly to the lateral edge of the bone; posterior lobe of plastron with wide anal notch; sulcus between pectoral and abdominal shields reaching the bridge; pygal wider than high, with longitudinal sulcus but without any transversal sign of the boundary between 12th marginals and 5th vertebral (see Hervet 2000, for a description of *Mauremys* shell).

Among the remains associated with the above discussed elements, a small peripheral is morphologically congruent with *Mauremys*, in being characterized by the presence of a sulcus between marginals and costals (therefore it doesn't coincide with the suture between peripherals and pleurals). Neurals, pleurals, peripherals and indeterminate shell fragments are tentatively referred to the same taxon, despite the absence of diagnostic features.

The sample documents the occurrence of at least two individuals, a full grown adult and a juvenile.

Mammalia Linnaeus, 1758

Artiodactyla Owen, 1848

Cervidae Gray, 1821

Praemegaceros cazioti (Depéret, 1897)

1911 *Cervus elaphus corsicanus* Dehaut, p. 54
1926 *Cervus (Polycladus) cazioti* – Joleaud, p. 63
1935 *Cervus cazioti* – Tobien, p. 258
1954 *Cervus elaphus* cf. *corsicanus* – Malatesta & Settepassi, p. 37
1955 *Megaceros (Anoglochis) cretensis* – Comaschi Caria, p. 19, pl. 5
1960 *Cervus cazioti* – Sigogneau, p. 49, pl. 6-8
1968 *Megaceros verticornis* Comaschi Caria, pl. 4
1974 *Megaceros (Nesoleipoceros) cazioti* - Caloi & Malatesta, p. 165

Material. Left I$_1$; right I$_2$; fragmentary root of incisive; right undetermined incisive; right radius lacking epiphyses; left metacarpus lacking caput metacarpale; proximal fragment of left humerus.

Description. UC 6 – Few teeth and some postcranial remains document the occurrence of a cervid taxon among the fossils from San Giovanni di Sinis. The specimens are quite fragmentary and not well preserved.

Dental elements are represented by three incisive fragments. Dental crown of lower incisives appears asymmetric in shape.

Radius and metacarpus belong to the same specimen; the proximal articulation of metacarpus is fairly deep and the distal anterior face of radius shows evident lateral and medial cristae separated by a concave surface; both features are typical of cervid family. These fossils belong to a very young individual as suggested by the absence of both epiphyses in radius, and of the distal one in metacarpus, as well as by their high porosity. On the basis of the available data concerning the timing of ossification in recent taxa, it is possible to refer the remains to a specimen younger than about 6 months. Indeed, the fusion between caput radii and diaphysis occurs after 6-7 months in *Dama dama* (Pohlmeyer 1985) and at about 4 months in *Ovis aries* (cf. Bover & Alcover 1999). As regards the metacarpus, the distal epiphysis joins the diaphysis at about 24 months in *Dama dama* (Pohlmeyer 1985). The fragment of humerus belongs to an adult specimen. Tuberculum majus and minus are incomplete, however their size and proportion agree with a cervid taxon too (e.g. fairly protruding and slender tuberculum majus).

Discussion. Although no element is preserved enough to be measured, by general size, the fossil remains from San Giovanni di Sinis agree with the Sardinian deer *Praemegaceros cazioti* (for the use of the genus name *Praemegaceros* see Abbazzi 2004 and ref. therein).

This is an endemic form of megacerine well known in the Middle and Late Pleistocene of Sardinia

(Comaschi Caria 1955; Caloi & Malatesta 1974; Caloi & Palombo 1991, 1995), within the faunal assemblages referred to the so-called "*Tyrrhenicola-Praemegaceros*" faunal complex (Sondaar & Van der Geer 2002; Abbazzi et al. 2004). The ancestry of this cervid has been identified in the Pleistocene continental species *Praemegaceros verticornis* (Azzaroli 1961; Caloi & Palombo 1995 and references therein) which dispersed towards the Sardinian paleobioprovince close to the Early-Middle Pleistocene boundary.

Though the cervid material here analysed is extremely fragmented, the humerus and incisive size makes highly likely that they belong to this endemic species. As a matter of fact, another middle sized deer is known in Sardinia, the red deer *Cervus elaphus*, however it is documented during the Holocene in archaeological contexts starting from the third millennium B.C. (Cocco & Usai 1988).

Remarks on the evolutionary history and extinction patterns in the Mediterranean area of the extant *Mauremys* species

The occurrence of a terrapin referred to genus *Mauremys* among the vertebrates documented at San Giovanni di Sinis, is of particular relevance because of the present range of the genus, the peculiar phylogenetic relationships among its extant species and their fossil record.

At present, the Palearctic-Oriental genus *Mauremys* shows an east-west doubly disjunct distribution: three species are present in eastern Asia and three species in the Mediterrean region. As for the Mediterranean area: *M. leprosa* inhabits north Africa (from Morocco to west Libya), the Iberian Peninsula and south-west France; *M. rivulata* is widespread in the Balkans and Mediterranean Anatolia; *M. caspica* is present in continental Anatolia and west Asia (Gasc et al. 1997; Hervet 2000; Fritz 2001; Barth et al. 2004). The Italian Peninsula and the French area represent therefore a gap in the northern Mediterranean range of this genus.

These three species were formerly thought to represent the same species, *Mauremys caspica*, but have been recently split on the basis of the results of colour-pattern and molecular studies (Fritz & Wischuf 1997; Barth et al. 2004; Feldman & Parham 2004; Mantziou et al. 2004; Spinks et al. 2004; see literature therein). The phylogenetic relationships among these three species and their position in respect to the east Asian members of the genus are still debated and not completely clear: all mentioned molecular-genetic investigations provided evidence that the genus is probably non-monophyletic. According to Feldman & Parham (2004), mitochondrial DNA indicates that *M. rivulata* is basal to the "clade" containing all the other *Mauremys* species and that *M. leprosa* and *M. caspica* are sister taxa. However, this sister-group relationship is weakly supported. Conversely, on the basis of nuclear and mitochondrial DNA data, Spinks et al. (2004) and Barth et al. (2004) indicated that *M. leprosa* is basal to the "clade" containing all the other *Mauremys* species (as well as also all species of *Chinemys* and *Ocadia* for Barth and co-workers) while *M. caspica* and *M. rivulata* are sister taxa. The latter result is at least congruent with the external morphology of these three species (Busack & Ernst 1980; Fritz & Wischuf 1997) and their taxonomic history (see Discussion in Barth et al. 2004) because, after the attribution of the western *M. caspica* populations to *M. leprosa*, for some years the eastern populations were still grouped under the same name, *M. caspica*, and only recently *M. rivulata* obtained a specific status (Fritz & Wischuf 1997). The phylogenetic models of Spinks et al. (2004) and Barth et al. (2004), suggesting that the eastern Mediterranean species are closer to the derived Asian member of the genus than to the basal *M. leprosa*, conflict with the traditional evolutionary scenario that sees the extant Mediterranean species as a direct product of the recurrent southward withdrawal of their ancestor during the Pleistocene glaciations (among others, Delfino 2002). Honda et al. (2002) proposed that since the broad geographic gap between the Mediterranean-west Asian species and the east Asian ones is represented by arid regions, this disjunction is related to the rising of the Himalayas that caused such aridity. On the same line, Feldman & Parham (2004) reported that the collision of India into Asia may be the vicariant event responsible for the current distribution of *Mauremys* and the separation between western and eastern species assemblages should have occurred earlier than the onset of inhospitable environments. According to Barth et al. (2004), the *Mauremys* "patchy distribution is likely to be the result of several ancient radiation events rather than a recent (Pleistocene) extinction".

Particularly interesting should be therefore the understanding of the relationships of the European Paleogene remains referred to the *Mauremys* stem group by Hervet (2004), since they predate such range disjunction. Moreover, the identification of reliable osteological characters allowing to distinguish the extant species assemblages, and therefore a positive allocation of fossil remains, is crucial in supporting or discarding such evolutionary scenarios; in particular, the allocation at specific rank of the European Pleistocene remains could have a relevant role since most likely they belong to extant species. At present, only few shell characters are available for the identification of the three European species (Roualt & Blanc 1978; Busack & Ernst 1980; Hirayama 1984; Lovich & Ernst 1989; Iverson &

McCord 1994; Fritz & Wischuf 1997). Such characters can be applied only when the fossil record is represented by a complete plastron.

The fossil record testifies for a north-west African origin of *M. leprosa* during the Pliocene (fossils in Algeria, Lapparent 2000) and then supports the molecular data in showing the dispersal into Europe (Fritz et al. 2005, 2006).

Less relevant is the current weight of the fossil record in the knowledge of the evolution of *M. caspica* and *M. rivulata*. The poorly known west Asian fossil record of chelonians hinders any well-grounded consideration concerning the past distribution of *Mauremys*. The revision of fossils from the Quaternary of continental Greece (Pleistocene remains from Megalopolis, Melentis 1966; Vugt et al. in Vugt 2000; subrecent material of the Vraona Cave, Rauscher 1995) and Crete (Pleistocene of Grotta Simonelli, Kotsakis 1977), now simply referred to *M. caspica* s.l., could offer information on the chronology of the presence of *M. rivulata* in the Balkans.

Fig. 5 - Geographic distribution of the *Mauremys* fossil record in Italy: 1) cf. *Mauremys* sp. (*Testudo craverii*); Santa Vittoria d'Alba (CN); Late Miocene; Sturani 1973; Kotsakis & Mori 1981. 2) *Mauremys* sp.; Pian Calcinaio, Scansano (GR); Late Miocene; Delfino 2002. 3) *Mauremys* sp. or Geoemydinei indet.; Fornace R.D.B., Villafranca d'Asti (AT); Middle Pliocene; Ambrosetti et al. in Carraro 1996; Delfino 2002. 4) *Mauremys* sp.; Torre Picchio, Montecastrilli (TR); Girotti et al. 2003. 5) *Mauremys portisi* (*Emys portisi*); Valleandona (AT); Late Pliocene; Sacco 1889; Kotsakis & Mori 1981. 6) *Mauremys gaudryi etrusca* (*Emys etrusca*); Colombaiolo, San Giovanni (AR); Late Pliocene-Early Pleistocene; Portis 1890; Kotsakis 1980. 7) *Mauremys gaudryi etrusca* (*Emys etrusca*); Restoni, Figline (AR); Portis 1890; Kotsakis 1980. 8) *Mauremys* sp.; Cava Pirro/Dell'Erba, Apricena (FG); Early Pleistocene; Delfino & Bailon 2000. 9) *Mauremys* sp. (*Emys aniensis*); Grotta del Monte delle Gioie, Ponte Salario (RM); Middle Pleistocene; Indes 1869; Portis 1896; Delfino 2002. 10) *Mauremys* sp. (*M.* cf. *M. caspica*); San Giovanni di Sinis (OR); Late Pleistocene; Caloi et al. 1981; this paper.

The French and Italian fossil record provides evidence for the presence of the genus in areas in which it is extinct at present. France has nearly no post Neogene *Mauremys* remains being the sole exceptions represented by two Holocene sites in Gard and Languedoc-Roussillon departments (Cheylan 1982; Keller & Busack 2001). Four fragments, coming from the Gard department, referred to *M. leprosa* on a morphological basis by Hervet (2000), could testify for a recent significant shrinkage of *M. leprosa* range (the site is dated to about 2000-3000 years B.C.) but since the remains come from an archaeological context with ceramics, we cannot rule out some kind of long distance transportation operated by man. However, evidence for an autochthonous group of *M. leprosa* is offered by the high number of shell fragments identified among meal leftovers in a settlement near Nissan. On the contrary, the Italian Peninsula hosted *Mauremys* at least from the Late Miocene to the Middle Pleistocene while the remains from San Giovanni di Sinis here described testify its presence in Sardinia during the Late Pleistocene (fig. 5). Fossils are widely distributed on the peninsula but, on the basis of the presently known localities (10 altogether), it seems that only the central and southern regions of the peninsula were inhabited during the Pleistocene. Such prolonged survival in the southern areas and, above all in the islands, parallels that of amphisbaenians (Delfino 1997, 2003) and is in agreement with the well-known peninsular and insular effects (Masini et al. 2002a, b).

Lapparent (2000) referred to the species *Mauremys leprosa* the “small tortoise” from the Pleistocene of Malta represented by shell fragments, femur and humerus, and firstly identified by Leith-Adams (1877) as a member of the species *Lutremys europaea*, a junior synonym of the European pond turtle, *Emys orbicularis*. The original description of the specimens by Leith-Adams (1877) should lead to attribute it to a pond turtle because of the “white specks” visibile on the outer dermal layer, specks that could represent the remnants of the external colour pattern typical of *E. orbicularis*.

Because the identification as *Emys* or *Mauremys* of the Maltese fossils has not been corroborated by a description, the presence of these genera in the Pleistocene of this island is here not taken into consideration, waiting an accurate revision.

Analogously to other reptilian taxa that inhabited Southern Europe and its islands, *Mauremys* probably went extinct in the Italian peninsula because it has been less warm than the neighbouring peninsulas and separated from them by biogeographic barriers that prevented recolonization (Delfino 1997, 2002, 2004). The extinction of *Mauremys* and the survival of *Emys* is rather self explanatory. Both these taxa were present in the Italian peninsula as well as in Sardinia and actually, they were syntopic at some sites like San Giovanni di Sinis or Cava Pirro and Cava Dell'Erba (Delfino & Bailon 2000).

The syntopy of such taxa is not uncommon at present where their ranges overlap (as well as in fossil sites like Megalopolis, Melentis 1966; Vugt et al. in Vugt 2000). It is however curious that even if *Mauremys* is considered to be much less sensitive to environmental factors than *Emys* and, where syntopic the former tends to be more common than the latter (Crucitti et al. 1990), *Mauremys* died out in the central Mediterranean sector before the end of the Pleistocene (as indicated by the remains of San Giovanni di Sinis), while *Emys* survived. Despite the absence of temperature-dependent developmental data concerning the embryos of *Mauremys*, a comparison of its present range with that of *Emys* might suggest that some sort of thermophily (at least during pre-hatching stages) is responsible for the Late Pleistocene extinction and therefore for the present-day distribution.

Conclusion

Field investigations of the San Giovanni di Sinis outcrop led to the finding of continental faunal remains of reptiles and artiodactyls, documenting the slowing down of the Tyrrhenian sea level raise and the start of an emerged marsh environment with episodic fresh waters.

The new fossil vertebrate remains allow to confirm the occurrence of a terrapin (*Mauremys* sp.) and the endemic Sardinian deer (*Praemegaceros cazioti*) in the Tyrrhenian of the area, as reported in previous studies (Caloi et al. 1981). Of particular significance is the occurrence of the terrapin: although not identifiable at specific level (*Mauremys* sp.), it is the last representative of the genus known in the central Mediterranean area and offers the opportunity to discuss the extinction patterns of the genus in the circum-Mediterranean area.

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REFERENCES

Abbazzi L. (2004) - Remarks on the validity of the generic name *Praemegaceros* Portis, 1920 and an overview on *Praemegaceros species* in Italy. *Atti Acc. Naz. dei Lincei*, s. 9, 15:115-132, Roma.

Abbazzi L., Angelone C., Arca M., Barisone G., Bedetti C., Delfino M., Kotsakis T., Marcolini F., Palombo M.R., Pavia M., Piras P., Rook L., Torre D., Tuveri C., Valli A. & Wilkens B. (2004) - Plio-Pleistocene fossil vertebrates of Monte Tuttavista (Orosei, Eastern Sardinia, Italy), an overview. *Riv. It. Paleont. Strat.*, 110 (3): 681-706, Milano.

Ambrosetti P. (1972) - L'elefante fossile della Sardegna. *Boll. Soc. Geol. It.*, 91: 127-131, Roma.

Azzaroli A. (1961) - Il nanismo nei cervi insulari. *Paleont. It.*, 56: 1-32, Pisa.

Barth D., Bernhard D., Fritzsch G. & Fritz U. (2004) - The freshwater turtle genus *Mauremys* (Testudines, Geoemydidae) - a textbook example of an east-west disjunction or a taxonomic misconcept? *Zool. Scr.*, 33(3): 213-221, Stockholm.

Bover P. & Alcover J.A. (1999) - Estimating physical characteristic of neonate *Myotragus balearicus* (Artiodactyla, Caprinae). *Deinsea*, 7: 33-53, Rotterdam.

Busack S.D. & Ernst C.H. (1980) - Variation in the Mediterranean populations of *Mauremys* Gray, 1869 (Reptilia, Testudines, Emydidae). *Ann. Carnegie Mus.*, 49: 251-264, Pittsburgh.

Caloi L., Kotsakis T., Palombo M.R. & Petronio C. (1981) - Il giacimento a vertebrati del Pleistocene superiore di San Giovanni in Sinis (Sardegna occidentale). *Atti Accad. Naz. Lincei, Rend. Cl. Sci. Fis. Mat. Nat.*, 69(3-4): 185-197, Roma.

Caloi L. & Malatesta A. (1974) - Il cervo Pleistocenico di Sardegna. *Mem. Ist. It. Paleont. Um., n.s.*, 2: 163-247, Roma.

Caloi L. & Palombo M.R. (1991) - Morfologia e funzione della mano e del piede del megacerino del Pleistocene superiore di Dragonara (Sardegna, Italia). *Atti Acc. Pel. Peric., Cl. Sci. Fis. Mat. Nat.*, 67 (1989): 319-341, Messina.

Caloi L. & Palombo M.R. (1995) - Functional aspects and ecological implications in Pleistocene endemic cervids of Sardinia, Sicily and Crete. *Geobios*, 28(2): 247-258, Lyon.

Carboni S. & Lecca L. (1985) - Osservazioni sul Pleistocene medio-superiore della Penisola del Sinis (Sardegna occidentale). *Boll. Soc. Geol. It.*, 104: 459-477, Roma.

Carraro F. (1996) - Revisione del Villafranchiano nell'area-tipo di Villafranca d'Asti. *Quaternario*, 9(1): 5-119, Verona.

Cherchi A., Marini A., Murru M. & Robba E. (1978) - Stratigrafia e paleoecologia del Miocene superiore della penisola del Sinis (Sardegna occidentale). *Riv. It. Paleont. Strat.*, 84(4): 973-1036, Milano.

Cheylan M. (1982) - Présence de la Clemmyde Lépreuse dans le Chalcolithique de la Grotte de la Salpetrière (Remoulins, Gard). *Etud. Quat. Languedoc.*, 2: 29-33, Montpellier.

Cocco D. & Usai L. (1988) - Un monumento preistorico nel territorio di Cornus. Ampsicora e il territorio di Cornus. In: AA. VV. (Eds) - Atti del II Convegno sull'Archeologia Romana ed Altomedievale nell'Oristanese, Cuglieri, 22/12/1985. *Scorpione Editrice*: 13-24, Taranto.

Comaschi Caria I. (1955) - Resti di cervidi nel Quaternario di Porto Vesme (Sardegna occidentale). *Riv. It. Paleont. Strat.*, 61: 17-26, Milano.

Comaschi Caria I. (1968) - Fossili marini e continentali del Quaternario della Sardegna: 140-229. Atti del X Congresso Internazionale Studi Sardi, Cagliari.

Crucitti P., Campese A. & Malori M. (1990) - Popolazioni sintopiche di *Emys orbicularis* e *Mauremys caspica* nella Tracia, Grecia Orientale (Reptilia: Testudines: Emydidae). *Boll. Mus. reg. Sci. nat. Torino*, 8(1): 187-196, Torino.

Davaud E., Kindler P., Martini R. & Strasser A. (1991) - Enregistrement des variations eustatiques dans des dépôts littoraux du Pleistocène supérieur de San Giovanni di Sinis (Sardaigne occidentale). *Bull. Soc. Géol. Fr.*, 162: 523-533, Paris.

Dehaut E.G. (1911) - III: Animaux fossiles du Cap Figari. In: Dehaut E.G. (Ed.) - Matériaux pour servir à l'histoire zoologique et paléontologique des iles de Corse et de Sardaigne. *G. Steinheil*: 53-59, Paris.

Delfino M. (1997) - *Blanus* from the Early Pleistocene of Southern Italy: another small tessera from a big mosaic. In: Böhme W., Bischoff W. & Ziegler T. (Eds) - Herpetologia Bonnensis. *SEH*: 89-97, Bonn.

Delfino M. (2002) - Erpetofaune italiane del Neogene e del Quaternario. Tesi di Dottorato in Paleontologia. Università degli Studi di Modena e Reggio Emilia. V. of 382 pp., Modena.

Delfino M. (2003) - A Pleistocene amphisbaenian from Sicily. *Amphibia-Reptilia*, 24(4): 407-414, Leiden.

Delfino M. (2004) - The middle Pleistocene herpetofauna of Valdemino Cave (Liguria, North-Western Italy). *Herp. J.*, 14: 113-128, London.

Delfino M. & Bailon S. (2000) - Early Pleistocene herpetofauna from Cava Dell'Erba and Cava Pirro (Apulia, Southern Italy). *Herp. J.*, 10: 95-110, London.

Feldman C. R. & Parham J.F. (2004) - Molecular systematics of Old World stripe-necked turtles (Testudines: *Mauremys*). *Asiatic Herp. Res.*, 10: 28-37, Berkeley.

Fritz U. (2001) - *Mauremys* Gray, 1870 - Bachschildkröten. In: Fritz U. (Ed.) - Handbuch der Amphibien und Reptilien Europas: Land- und Sumpfschildkröten. *AULA*: 35-42, Wiesbaden.

Fritz U., Barata M., Busack S.D., Fritzsch G. & Castilho R. (2006) - Impact of mountain chains, sea straits and peripheral populations on genetic and taxonomic structure of a freshwater turtle, *Mauremys leprosa* (Reptilia, Testudines, Geoemydidae). *Zool. Scr.*, 35 (1): 97-108, Stockholm.

Fritz U., Fritzsch G., Lehr E., Ducotterd J.-M. & Müller A. (2005) - The Atlas Mountains, not the Strait of Gibraltar, as a biogeographic barrier for *Mauremys leprosa*. *Salamandra*, 41: 97-106, Frankfurt.

Fritz U. & Wischuf T. (1997) - Zur Systematik westasiatisch-südosteuropäischer Bachschildkröten (Gattung *Mauremys*) (Reptilia: Testudines: Bataguridae). *Zool. Abh. Staatl. Mus. Tierk. Dresden*, 49(13): 223-260, Dresden.

Gasc J.-P., Cabela A., Crnobrnja-Isailovic J., Dolmen D., Grossenbacher K., Haffner P., Lescure J., Martens H., Martinez Rica J.P., Maurin H., Oliveira M.E., Sofianidou T.S., Veith M. & Zuiderwijk A. (Eds) (1997) - Atlas of the amphibians and reptiles in Europe. V. of 496 pp. SEH & MNHN, Paris.

Girotti O., Capasso-Barbato L., Esu D., Gliozzi E., Kotsakis T., Martinetto E., Petronio C., Sardella R. & Squazzini E. (2003) - The section of Torre Picchio (Terni, Umbria, Central Italy): a Villafranchian site rich in vertebrate, molluscs ostracods and plants. *Riv. It. Paleont. Strat.*, 109(1): 77-98, Milano.

Hervet S. (2000) - Tortues du Quaternaire de France: critères de détermination, répartitions chronologique et géographique. *Mésogée*, 58: 3-47, Marseille.

Hervet S. (2004) - Systématique du groupe "*Palaeochelys* sensu latu - *Mauremys*" (Chelonii, Testudinoidea) du Tertiaire d'Europe occidentale: principaux résultats. *Ann. Paléontol.*, 90: 13-78, Paris.

Hirayama R. (1984) - Cladistic analysis of batagurine turtles (Batagurinae: Emydidae: Testudinoidea): a preliminary result. *Studia Geol. Salmant.*, vol. espec. 1 (Studia Palaeocheloniologica I): 141-157, Salamanca.

Honda M., Yasukawa Y. & Ota H. (2002) - Phylogeny of the Eurasian freshwater turtles of the genus *Mauremys* Gray, 1869 (Testudines), with special reference to a close affinity of *Mauremys japonica* with *Chinemys reevesii*. *J. Zool. Syst. Evol. Res.*, 40: 195-200, Oxford.

Indes F. (1869) - Sur la formation des tufs des environs de Rome et sur une caverne à ossements au Monte delle Gioie. *Bull. Soc. Géol. Fr.*, 2, 26: 11-28, Paris.

Jouleaud L. (1926) - Les Mammifères. *Bull. Soc. Sc. Hist. Nat. Corse*, 45: 29-107, Bastia.

Iverson J.B. & McCord W.P. (1994) - Variation in East Asian turtles of the genus *Mauremys* (Bataguridae; Testudines). *J. Herp.*, 28(2): 178-187, Athens.

Keller C. & Busack S.D. (2001) - *Mauremys leprosa* (Schweigger, 1812) - Maurische Bachschildkrote. In: Fritz U. (Ed.) - Handbuch der Reptilien und Amphibien Europas. Schildkroten (Testudines) I. *Aula*: 57-88, Wiebelsheim.

Kindler P., Davaud E. & Strasser A. (1997) - Tyrrhenian coastal deposits from Sardinia (Italy): a petrographic record of high sea levels and shifting climate belts during the last interglacial (isotopic stage 5e). *Palaeogeogr., Palaeoclimat., Palaeoecol.*, 133: 1-25, Amsterdam.

Kotsakis T. (1977) - I resti di Anfibi e Rettili pleistocenici della grotta "Bate" (Rethymnon, Creta). *Rend. Accad. Naz. Lincei,* ser. 8, 63(6): 571-582, Roma.

Kotsakis T. (1980) - Révision des tortues (Emydidae, Testudinidae, Trionychidae) du Plio-Pléistocène de Valdarno supérieur (Toscane, Italie). *Quaternaria*, 22: 11-37, Roma.

Kotsakis T. & Mori D. (1981) - Note di paleoerpetologia piemontese. I. I Cheloni del Messiniano superiore di Santa Vittoria d' Alba (Cuneo). *Riv. Piem. St. Nat.*, 2: 89-98, Carmagnola.

Lapparent de Broin F. de (2000) - African chelonians from the Jurassic to the present: phases of development and preliminary catalogue of the fossil record. *Paleont. Afr.*, 36: 43-82, Johannesburg.

Lapparent de Broin F. de (2001) - The European turtle fauna from the Triassic to the present. *Dumerilia*, 4(3): 155-218, Paris.

Leith-Adams A. (1877) - On gigantic land-tortoises and a small freshwater species from the ossiferous caverns of Malta, together with a list of their fossil fauna; and a note on chelonian remains from the rock-cavities of Gibraltar. *Quart. J. Geol. Soc. London*, 33: 177-191, London.

Lovich J.E. & Ernst C.H. (1989) - Variation in the plastral formulae of selected turtles with comments on taxonomic utility. *Copeia*, 1989 (2): 304-318, New York.

Malatesta A. & Settepassi F. (1954) - Fossili delle formazioni continentali quaternarie. *Boll. Serv. Geol. It.*, 76: 33-39, Roma.

Mantziou G., Poulakakis N., Lymberakis P., Valakos E. & Mylonas M. (2004) - The inter- and intraspecific status of Aegean *Mauremys rivulata* (Chelonia, Bataguridae) as inferred by mitochondrial DNA sequences. *Herp. J.*, 14(1): 35-45, London.

Marini A. & Murru M. (1977) - Rilevamento geologico della penisola del Sinis (Sardegna centro-occidentale). *Rend. Sem. Fac. Sc. Univ. Cagliari*, 47(3/4): 459-466, Bologna.

Masala L. (1958) - Nuovi lembi di Tirreniano nella zona di Capo Mannu a nord del Golfo di Oristano (Sardegna centro-occidentale). *Rend. Sem. Fac. Sc. Univ. Cagliari*, 29: 95-108, Bologna.

Masini F., Bonfiglio L., Abbazzi L., Delfino M., Fanfani F., Ferretti M., Kotsakis T., Petruso D., Marra C. & Torre D. (2002a) - Vertebrate assemblages of the central western Mediterranean islands during the Pliocene and Quaternary: reflecting on extinction events. In: Waldren W.H. & Ensenyat J.A. (Eds) - World Islands in Prehistory. International Insular Investigations. V Deia International Conference of Prehistory: 437-444, Mallorca.

Masini F., Bonfiglio L., Petruso D., Marra C., Abbazzi L., Delfino M., Fanfani F. & Torre D. (2002b) - The role of coastal areas in the Neogene-Quaternary mammal island populations of the central Mediterranean. *Biogeographia*, 23: 165-189, Forlì.

Maxia C. & Pecorini G. (1968) - Il Quaternario della Sardegna: 57-84. Atti del X Congresso Internazionale di Studi Sardi, Cagliari.

Melentis J.K. (1966) - Studien über fossile vertebraten Griechenlands. 10. *Clemmys caspica* aus dem Pleistozän des Beckens von Megalopolis im Peloponnes (Griechenland). *Ann. Géol. Pays Helléniques*, 17: 169-181, Athens.

Melis R.T., Palombo M.R. & Mussi M. (2001) - *Mammuthus lamarmorae* (Major, 1883) remains in the pre-Tyrrhenian deposits of San Giovanni di Sinis (Western Sardinia, Italy). The Word of Elephas - International Congress: 481- 485, Rome.

Ozer A., Paskoff R., Sanlaville P. & Ulzega A. (1980) - Essai de correlation du Pléistocène supérieur de la Sardaigne et de la Tunisie. *C. R. Acad. Sc. Paris*, 291: 801-804, Paris.

Pohlmeyer K. (1985) - Zur vergleichenden Anatomie von Damtier (*Dama dama* L., 1758), Schaft (*Ovis aries* L., 1758) und Ziege (*Capra hircus* L., 1758): osteologie und postnatale Ontogenese. V. of 287 pp., Paul Parey, Berlin.

Pomesano Cherchi A. (1968) - Il Quaternario del Golfo di Oristano: 87-89. Atti del X Congresso Internazionale di Studi Sardi, Cagliari.

Portis A. (1890) - I Rettili Pliocenici del Valdarno superiore e di alcune altre località plioceniche di Toscana. V. of 32 pp., Le Monnier, Firenze.

Portis A. (1896) - Contribuzioni alla storia fisica del bacino di Roma e studii sopra l'estensione da darsi al Pliocene superiore. Volume 2° - Parti Quarta e Quinta. V. of 513 pp., Torino.

Rauscher K.L. (1995) - Die herpetofauna der Vraona-Höhle (Attika) in Griechenland. *Ann. Géol. Pays Helléniques*, 36: 39-41, Athens.

Roualt J. & Blanc P. (1978) - Notes sur le Reptiles de Tunisie: V.- Caractéristiques biométriques de *Mauremys caspica leprosa* (Schweigger, 1812) (Reptilia: Emydidae). *Archs. Inst. Pasteur, Tunis*, 55(3): 337-357, Tunis.

Sacco F. (1889) - I Cheloni astiani del Piemonte. *Mem. R. Accad. Sc. Torino*, ser. 2, 39: 427-461, Torino.

Sigogneau D. (1960) - Etude d'un Cervidé pléistocène de Corse. *Ann. Paléontol.*, 46: 49-77, Paris.

Sondaar P.Y. & Van der Geer A. (2002) - Plio-Pleistocene vertebrate faunal evolution on Mediterranean islands, compared to that of the Palearctic mainland. *Ann. Géol. Pays Helléniques*, 39(A): 165-180, Athens.

Spinks P.Q., Shaffer H.B., Iverson J.B. & McCord W.P. (2004) - Phylogenetic hypotheses for the turtle family Geoemydidae. *Mol. Phylogen. Evol.*, 32 (2004): 164-182, San Diego.

Sturani C. (1973) - A fossil eel (*Anguilla* sp.) from the Messinian of Alba (Tertiary Piemontese Basin). Palaeoenvironmental and palaeogeographic implications. In: Drooger C.W. (Ed.) - Messinian events in the Mediterranean. *North-Holland Publishing co.*: 243-255, Amsterdam.

Tobien H. (1935) - Ueber die Pleistozanen *Prolagus*-Formen Korsikas und Sardinies. *Ber. Naturf. Ges. Freiburg*, 34: 253-344, Freiburg.

Ulzega A. & Hearty P.J. (1986) - Geomorphology, stratigraphy and geochronology of Late Quaternary marine deposits in Sardinia. *Z. Geomorphol. Suppl.*, 62: 119-129, Berlin.

Ulzega A. & Ozer A. (1980) - Excursion Table-Ronde Tyrrhénien de Sardaigne (Livret-guide). *INQUA*: 1-88, Cagliari.

Vardabasso S. (1956) - Il Quaternario della Sardegna: 995-1081. Actes IV Congr. Internat. Quaternarie, Rome-Pise.

Vugt N.v. (2000) - Orbital forcing in late Neogene lacustrine basins from the Mediterranean. A magnetostratigraphic and cyclostratigraphic study. *Geologica Ultraiectina*, 189: 1-167, Utrecht.

Wanet P., Leone F., Ozer A. & Ulzega A. (1982) - Tentative de datation par racemization des acides aminés de coquilles provenant du Tyrrhénien de Sardaigne (Livret-guide). *Rend. Sem. Fac. Sci. Univ. Cagliari*, 52(1): 159-167, Bologna.

Zangerl R. (1969) - The turtle shell. In: Gans C., Bellairs A.d'A. & Parson T.S. (Eds) - Biology of the Reptilia, Vol. I, Morphology A. *Academy Press*: 311-339, London & New York.

Note added in proof

Recent examination (Chesi et al. 2007) of the chelonians from the Late Miocene sites of southern Tuscany hosted in the collections of "Museo di Storia Naturale dell'Università di Firenze", "Accademia dei Fisiocritici di Siena" and "Museo di Storia Naturale e del Territorio dell'Università di Pisa" revealed the presence of *Mauremys* remains in the following sites: Casino, Casteani and Montebamboli.

Chesi F., Delfino M. & Rook L. (2007) - Late Miocene chelonians from Tuscany and Sardinia. In: Tintori A. & Boccaletti M. (Eds) - Abstract book "VII Giornate di Paleontologia, Barzio/Pasturo, 6-10 giugno 2007": 20-21, Milano.