

Fossil remains of *Cervus* from the middle Pleistocene-Holocene of the island of Capri (Southern Italy): palaeogeographical implications

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ABSTRACT – Several remains of *Cervus* from Middle Pleistocene to Holocene deposits of the island of Capri are examined. In the upper layers of the Quisisana-Certosa section and at Grotta delle Felci deer remains are referable to the endemic form *Cervus elaphus tyrrenicus* Azzaroli, while at Grotta Vascio 'o funno and Grotta Arcera they are referable to the modern *Cervus elaphus* Erxleben. These two populations, the first with continental characters and the second showing a clear insular endemism, imply a change in the palaeogeographic setting of the Capri-Penisola Sorrentina district. As the geological data shows undoubtedly that Capri was an island since the beginning of Late Pleistocene, the variation of the deer populations can be linked to palaeogeographic variations due only to the Late Pleistocene-Holocene glacio-eustatic oscillations of the sea-level. On the basis of the marine palaeoclimatic curve, on the eustatic curve and on the bathymetry of the area of Bocca Piccola few palaeogeographic charts have been drawn. The Capri Island was connected with the Penisola Sorrentina during Isotopic Stages 6, 4 and 2, was only partially connected during Stage 3 and was completely separated from the mainland during Stage 5 and from 15,000 years B.P. to the present days.

RIASSUNTO – [Resti fossili di *Cervus* del Pleistocene-Olocene dell'isola di Capri (Italia meridionale): implicazioni paleogeografiche] – In questo lavoro vengono esaminati i resti di *Cervus* provenienti da vari depositi del Pleistocene medio-Olocene dell'isola di Capri. Nei depositi superiori della successione di Quisisana-Certosa e nella Grotta delle Felci i resti di cervo sono riferibili alla sottospecie endemica *Cervus elaphus tyrrenicus* Azzaroli, mentre i resti raccolti nel deposito di riempimento delle grotte di Vascio 'o funno e Arcera sono attribuibili alla specie moderna *Cervus elaphus* Erxleben. Questi due diversi popolamenti, il primo a carattere chiaramente continentale ed il secondo di tipo insulare, implicano variazioni dell'assetto paleogeografico del distretto Capri-Penisola Sorrentina. Poiché le evidenze geologiche dimostrano che Capri rappresentava un distretto insulare fin dall'inizio del Pleistocene Superiore, gli avvicendamenti faunistici delle popolazioni cervine possono essere dovuti solo a variazioni paleogeografiche legate alle oscillazioni glacio-eustatiche del livello del mare durante il Pleistocene Superiore-Olocene. Sulla base della curva delle paleotemperature oceaniche, della curva eustatica e della batimetria del fondale di Bocca Piccola sono state disegnate alcune carte paleogeografiche. Queste mostrano che Capri fu connessa alla Penisola Sorrentina durante gli stadi isotopici 6, 4 e 2, fu solo saltuariamente connessa durante lo stadio 3 e fu completamente isolata durante lo stadio 5 e a partire da 15.000 anni B.P.

INTRODUCTION

Fossil remains of cervids of Capri are known from the literature, from the sites of Quisisana-Certosa (lower and upper levels), Grotta delle Felci, Grotta Vascio 'o funno and from Grotta Arcera (Friedlander, 1938; Azzaroli, 1961; C.A.I. 1974-75; Piperno & Segre, 1984; Capasso Barbato & Gliozzi, 1995) (Text-fig. 1). They represent deer populations of different ages, from the late Middle Pleistocene (middle Aurelian Mammal Unit, Gliozzi *et al.*, 1997) to the early Holocene.

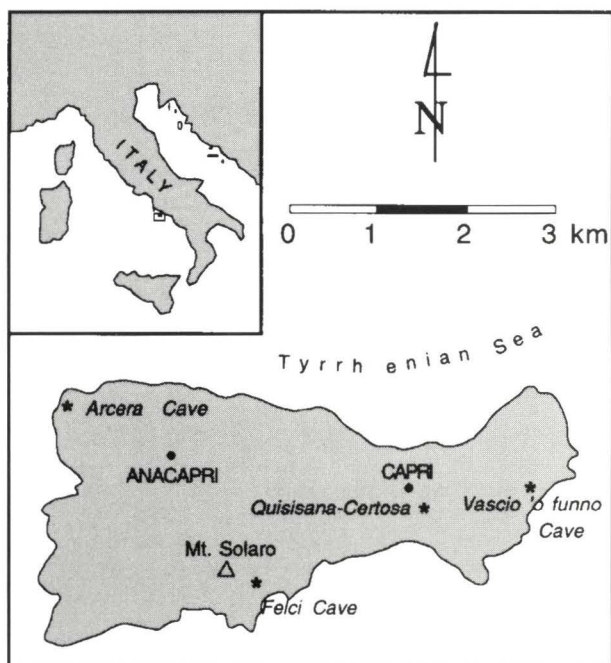
The aim of this work is to identify the hypothetical phylogenetical relationships between these populations in the palaeogeographic frame of the Capri-Penisola Sorrentina district.

ANALYSIS OF THE CERVID REMAINS

QUISISANA-CERTOSA (LOWER LEVELS)

The mammal assemblage collected in the lower levels of Quisisana-Certosa, known from the litera-

ture since 1902 (Bellini *in* Pigorini, 1906), has been recently revised by Capasso Barbato & Gliozzi (1995). On the basis of the presence of *Ursus spelaeus spelaeus* Rosenmüller & Heinroth and *Mammuthus (Mammuthus) chosaricus* Dubrovo, Capasso Barbato & Gliozzi (1995) have referred this assemblage to the late Middle Pleistocene (middle Aurelian Mammal Unit). The assemblage of Quisisana-Certosa lower levels bears two cervid species, *Cervus elaphus* ssp. and *Dama* sp., both represented by scarce and fragmentary remains. In particular, the material referable to *Cervus elaphus* ssp. is represented by two basal portions of antlers, one loose M¹, an incomplete portion of tibia, two astragali and one calcaneum, besides some juvenile bone fragments. The few measurements obtainable from this material fit the variability field of *Cervus elaphus* Erxleben 1777, at present living on the European mainland. The lack of larger antler remains make it impossible to refer these remains to any of the different subspecies recognised in the continent during the Middle Pleistocene (Di Stefano & Petronio, 1997).



Text-fig. 1 - Location map of the study fossiliferous sites.

QUISISANA-CERTOSA (UPPER LEVELS)

Piperno & Segre (1984) quote the presence of *Dama* sp. in the upper portion of the Quisisana-Certosa succession, from the stratified grey cinerite (local facies of "tufo grigio Campano" Auct.) dated with K-Ar around 33,000 years B.P., and of *Cervus tyrrhenicus* remains from the overlying "terre rosse".

In a display-window of the Cerio Museum of Capri, there are preserved remains of a cervid labelled as "*Dama* sp. -6 m in the pozzolana of the Certosa". It is likely that this material corresponds to that quoted by Piperno & Segre (1984). Thank to the courtesy of the Director of the Museum, Mrs. L. Cerio, it was possible to revise this material.

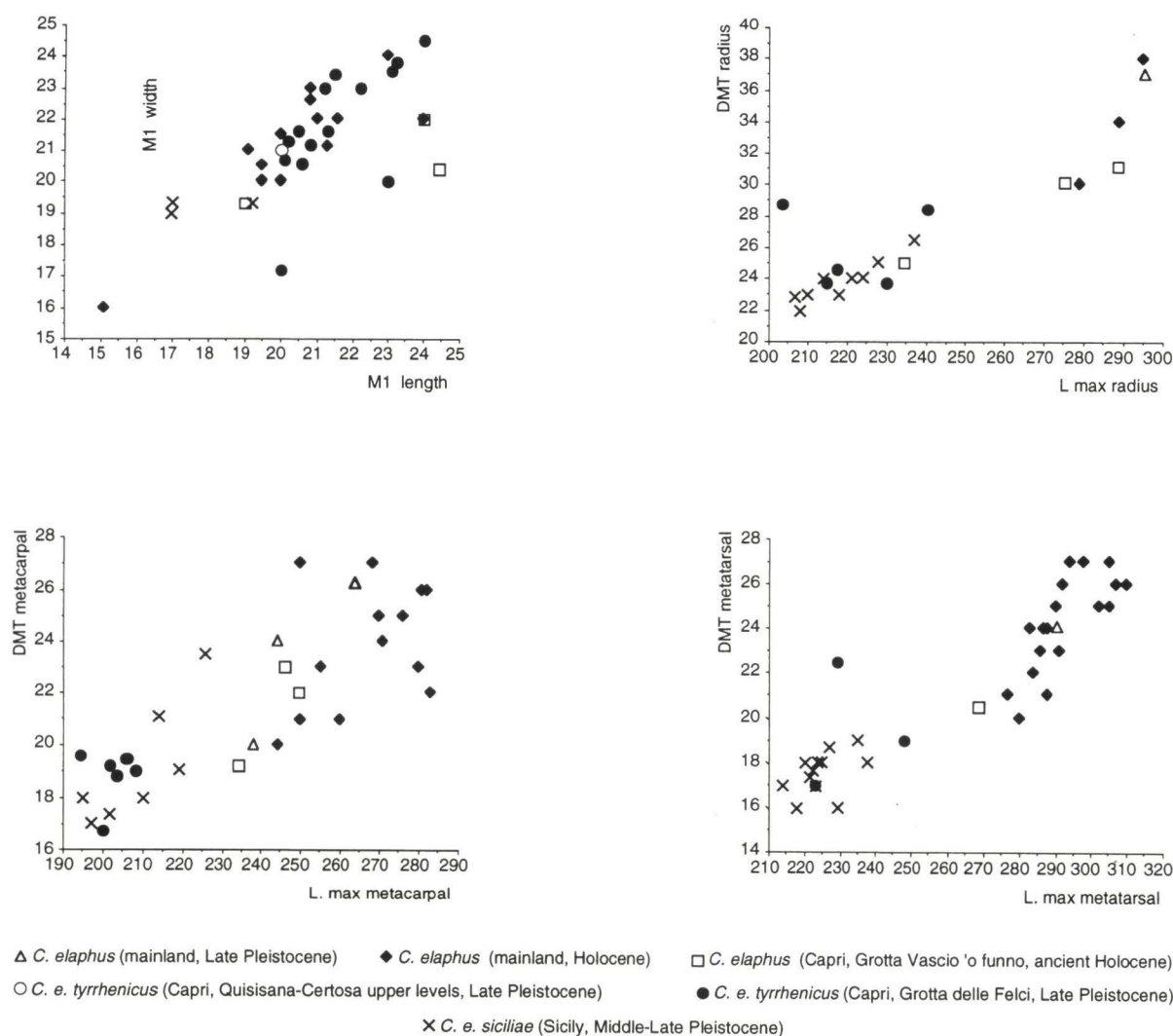
For their morphometrical characters these remains, representing at least three individuals, are referable to a medium-sized cervid slightly larger than the fallow deer. Detailed morphological comparisons with the correspondent bones of *Cervus elaphus* and *Dama dama* led to refer them with certainty to the genus *Cervus* (Di Stefano, 1995). In particular the characters that differentiate the bones from Capri from the fallow deer are: three-rooted P^3 (instead of four roots typical of *Dama*); rounded labial side of the tooth lobes (in *Dama* they are sharper); posterior lobe of P_4 very stout; on the radius the articular surface for the semilunar is continue and not posteriorly bipartite as in *Dama*; in upper view the posterior incision of the metacarpal proximal epiphysis is open and deep while in *Dama* it is shallower and partially closed (Lister, 1990); the anterior surface of the

metacarpal diaphysis is rounded and not sharpened as in *Dama*; on the metatarsal the articular surfaces on the proximal epiphyses are strongly asymmetrical; the *sustentaculum tali* is more developed antero-posteriorly and the articular surface for the malleolar is less deep than in *Dama*; the anterior border of the plantar trochlea of the astragalus is more protruding than the medial one, while in *Dama* they are equally developed. The biometric comparisons both with the continental red deer and with *Cervus elaphus tyrrhenicus* Azzaroli 1961 (Text-fig. 2, M^1 length/ M^1 width), suggest the attribution of the Certosa deer remains to the insular endemic form.

GROTTA DELLE FELCI

The most abundant material of *Cervus elaphus tyrrhenicus* comes from the filling deposits of the Felci cave, in particular from the levels o-g referred by Azzaroli (1961) to the Late Pleistocene on the basis of the abundance of volcanic products in the sediments bearing the bones and of the absence, in the same levels, of Neolithic artifacts. The deer bones were preserved in a succession of sands "stratified under the water", rich in volcanic minerals, with intercalations of levels with prevailing volcanic material ("lapilli") (levels l and q) (Blanc & Cardini, 1959). *C. e. tyrrhenicus* is represented by abundant and very well preserved fossil remains, which were studied in detail by Azzaroli (1961). In comparison with *Cervus elaphus* of the mainland it shows a slight reduction of the size which is realised through some allometries (stout and shortened limbs against a rather normalized skull) (Pl. 1; Text-fig. 2). The dental series are very similar to those of *C. elaphus* except for the proportions of the premolar against the molar series (this character is frequent in the endemic cervids, see Gliozzi *et al.*, 1993; Lister, 1989). The only evident difference in comparison with the mainland deer is the simplification of the antler pattern: besides their generally reduction in size, the antlers of *C. e. tyrrhenicus* show small and few tines (the bez tine is always lacking, the brow tine can be reduced and in some specimens the median tine is absent), the beam shows an irregular trend and the crown is not developed. It is widely discussed in literature the strict correlation between antler growth, hormonal control and environmental stresses and that the environmental stresses cause rapid alteration of the endocrine system (see Bubenik & Bubenik, 1986). By consequence it is not possible to consider the antler modifications as genetical.

Azzaroli (1961) considered the endemic deer of Capri as a distinct species. Taking into account the great variability expressed by the living *Cervus elaphus* and in the light of the modern taxonomy of the red deer forms (both insular and continental ones) we suppose that the endemic deer of Capri could represent only a local subspecies of the mainland deer. The



Text-fig. 2 - Scatter diagrams of some bone measurements of *Cervus elaphus* (mainland, Late Pleistocene), *Cervus elaphus* (mainland, Holocene), *Cervus elaphus* (Capri, Grotta Vascio 'o funno, ancient Holocene), *Cervus elaphus tyrrhenicus* (Capri, Quisisana-Certosa upper levels and Grotta delle Felci, Late Pleistocene) and *Cervus elaphus siciliae* (Sicily, Middle-Late Pleistocene). *Cervus elaphus tyrrhenicus* measurements of limb bones are located near those of *Cervus elaphus siciliae* while the M1 length is included in the dispersal area of the mainland red deer (measurements of *Cervus elaphus* from mainland are taken from Leonardi & Petronio, 1974, while those of *Cervus elaphus siciliae* come from Gliozzi *et al.*, 1993).

morpho-functional modifications in the limb proportions (reduction in size in comparison to the cranial size, slendering of the stylopodium and shortening of the autopodium) is probably due to the necessity of greater stability of the animal induced by a more hard and uneven ground (Caloi & Palombo, 1994).

GROTTA VASCIO 'O FUNNO

Several remains of a cervid have been found inside the calcareous breccias at the top of the thick cave filling deposit of Grotta Vascio 'o funno (Pl. 1) referred to the Late Pleistocene (post Isotopic Stage 5)-Holocene (Cinque *et al.*, 1986). They were collected

by the Club Alpino Italiano (C.A.I.) during 1974 and by the writers in the spring of 1993; the specimens are well preserved but mostly fragmentary. For their morphological and biometrical characters the Vascio 'o funno remains are referable to the normal-sized *Cervus elaphus*. In fact, the measurements obtained by these remains fit the variability field of the mainland *Cervus elaphus* of Late Pleistocene and Holocene, while they are well separated from the measurements pertaining to *C. e. tyrrhenicus*. The diagrams (Text-fig. 2) show the biometric relationships among the mainland *Cervus elaphus* from Late Pleistocene and Holocene deposits, the Capri deer remains of Grotta delle Felci, Quisisana-Certosa (upper levels) and

Grotta Vascio 'o funno and the insular subspecies *Cervus elaphus siciliae* Pohlig from the Late Pleistocene of Sicily. This latter form has been included in the diagrams as an example of insular endemism of cervids. Actually, several important differences may be recognised between *C. e. siciliae* and *C. e. tyrrhenicus*, in the degree of reduction, in the skeletal proportions and in the antler pattern (see Azzaroli, 1961; Gliozzi *et al.*, 1993).

Among the examined material, which is rather homogeneous, there is a fragment of mandible which shows peculiar characteristics: small size, an anomalous thickness of the horizontal ramus, with an accentuated upward curvature which brings the chewing surface of the molars well above the incisors, and an unusual wear of the molar series, which is strongly excavated in its central area. All these characters are probably pathological.

One bone fragment coming from the Vascio 'o funno collection has been dated with ^{14}C (AMS-dating) at the ETH of Zurich and has provided an age of $9,610 \pm 85$ years B.P.

GROTTA ARCERA

Cervid remains of probable Holocene age (Neolithic, Friedlander, 1938) come from a bone-breccia inside the Grotta Arcera (NW area of the island of Capri). This unpublished material is represented by scarce remains generally fragmentary and in a bad state of preservation but some measurements carried on few complete skeletal portions (astragalus, scapho-cuboid) fit the variability field of the continental *Cervus elaphus* and are significantly different from the corresponding measures of *C. e. tyrrhenicus*.

DISCUSSION AND CONCLUSIONS

Taking into account the whole fossil deer remains from the island of Capri, three different populations have been recognised:

late Middle Pleistocene (middle Aurelian Mammal Unit) of Quisisana-Certosa lower levels: normal-sized *Cervus elaphus* ssp.;

Last Glacial-Tardiglacial (late Aurelian Mammal

Unit) of Quisisana-Certosa upper levels and Grotta delle Felci: endemic *Cervus elaphus tyrrhenicus*;

Ancient Holocene of Grotta Vascio 'o funno and Grotta Arcera: modern, normal-sized *Cervus elaphus*.

According to Capasso Barbato & Gliozzi (1995) during the Middle Pleistocene Capri was not an island but represented a seawards extension of the Penisola Sorrentina. Only at the end of the Middle Pleistocene, as a consequence of an extensional tectonic phase, Capri became an insular district. This is evidenced by the notch of a Last Interglacial wave-cut platform (=Eutyrrhenian, corresponding to the high stand of the sea-level during Isotope Substage 5e) that surrounds the island.

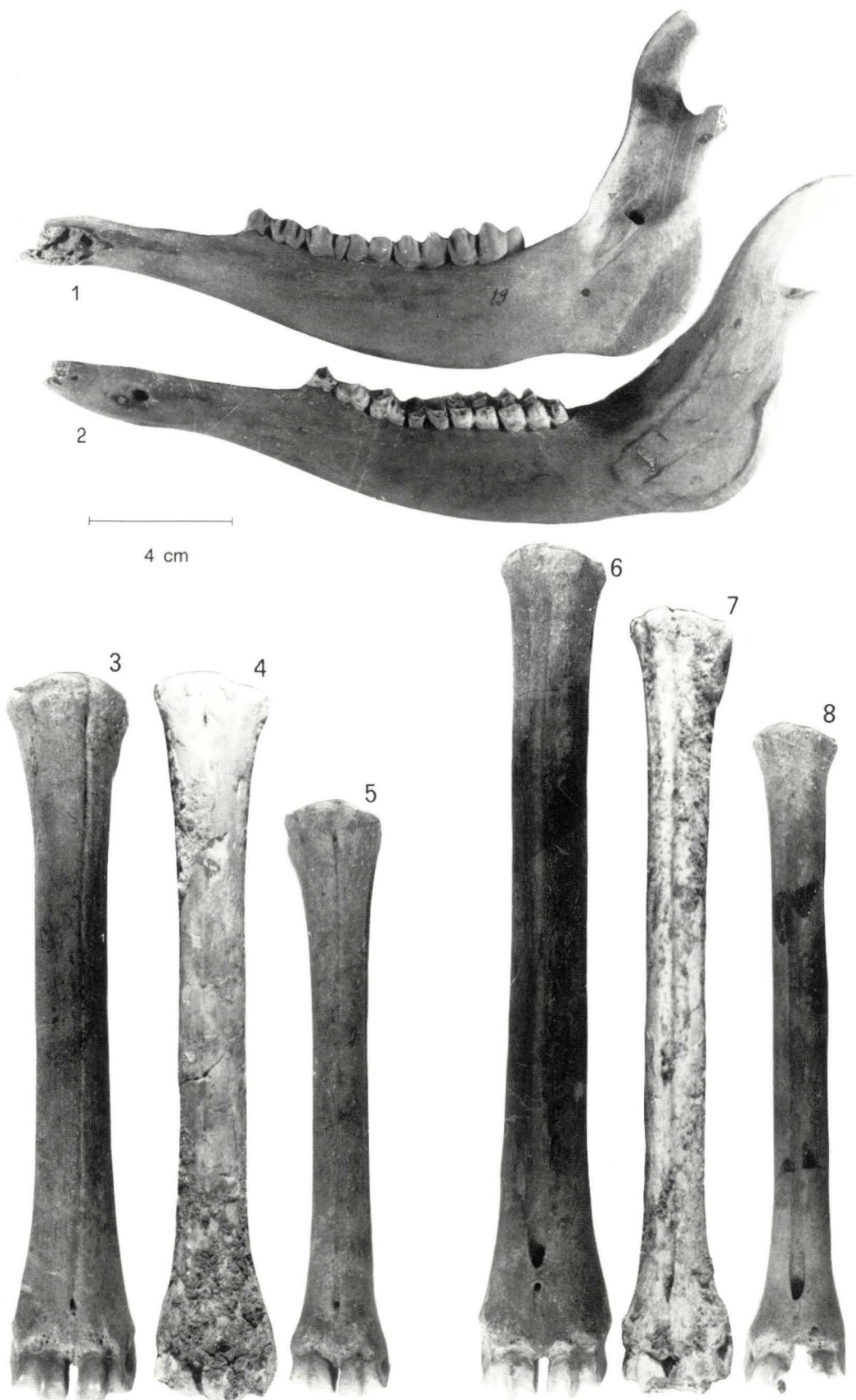
Cervus elaphus ssp. of Quisisana-Certosa lived in the area that became the Capri island during the late Middle Pleistocene together with a rich, well-balanced fauna made of elephants, rhinoceros, hippopotamuses and several carnivores as hyenas, leopards and wolves (Capasso Barbato & Gliozzi, 1995). After the isolation of Capri from the Penisola Sorrentina this fauna disappeared. It is not possible to exclude that only cervids could have survived undergoing a size reduction and giving origin to the endemic *C. e. tyrrhenicus*. Nevertheless in the writers' opinion it is more likely that the ancestor of *C. e. tyrrhenicus* must have entered Capri with a later migration wave.

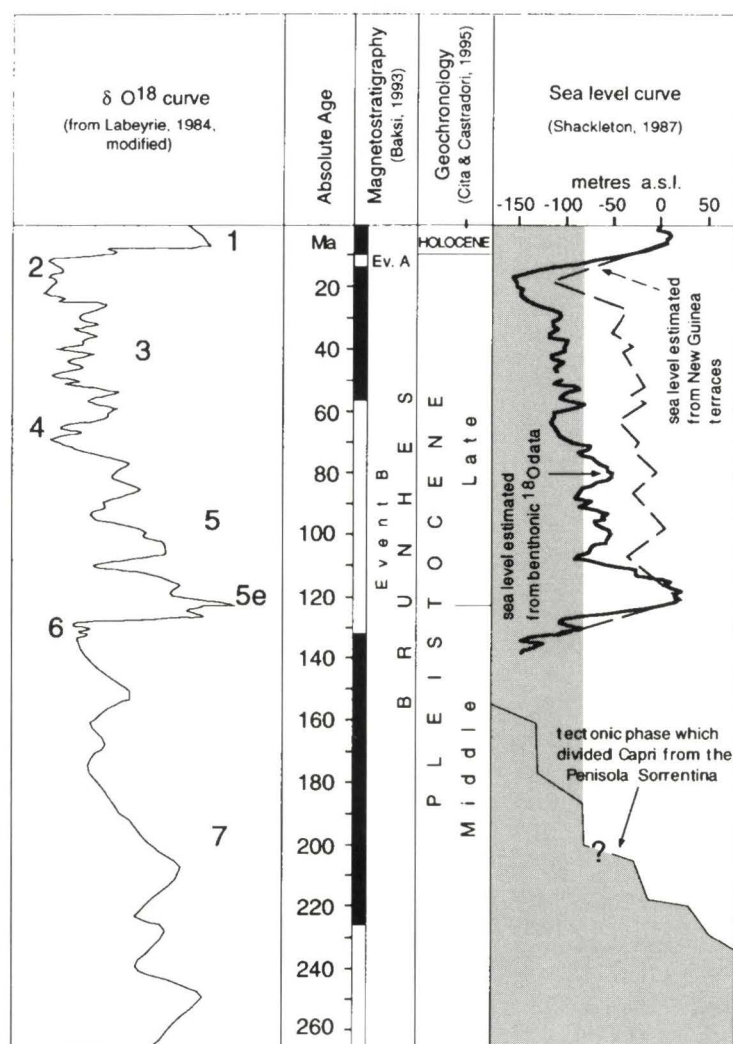
From the end of the Middle Pleistocene, and during the entire Late Pleistocene, Capri was connected with the mainland only sporadically during the sea-level low stands (Text-fig. 3). Taking into account the eustatic values calculated on the basis of the oxygen isotopic ratios, the studies of the Huon Peninsula terraces (New Guinea) (Shackleton, 1987) and the bathymetry of the sea-bottom of the Bocca Piccola area, it is possible to reconstruct the palaeogeographic evolution of the district (Text-fig. 4). The island of Capri was widely linked to the Penisola Sorrentina during the sea-level low stands corresponding to Stages 6 and 2; it was connected with the mainland by a narrow isthmus during Stage 4; it was alternatively isolated and connected by a discontinuous passage during Stage 3 and it was completely isolated during Stage 5 and from 15,000 years B.P to the present days.

EXPLANATION OF PLATE 1

Comparison among some skeletal elements of cervids from Capri and mainland.

- Fig. 1 - right mandible of *Cervus elaphus tyrrhenicus* (Grotta delle Felci);
- Fig. 2 - left mandible of *Cervus elaphus* (mainland);
- Fig. 3 - left metacarpal of *Cervus elaphus* (mainland);
- Fig. 4 - left metacarpal of *Cervus elaphus* (Grotta Vascio 'o funno);
- Fig. 5 - left metacarpal of *Cervus elaphus tyrrhenicus* (Grotta delle Felci);
- Fig. 6 - left metatarsal of *Cervus elaphus* (mainland);
- Fig. 7 - left metatarsal of *Cervus elaphus* (Grotta Vascio 'o funno);
- Fig. 8 - left metatarsal of *Cervus elaphus tyrrhenicus* (Grotta delle Felci).





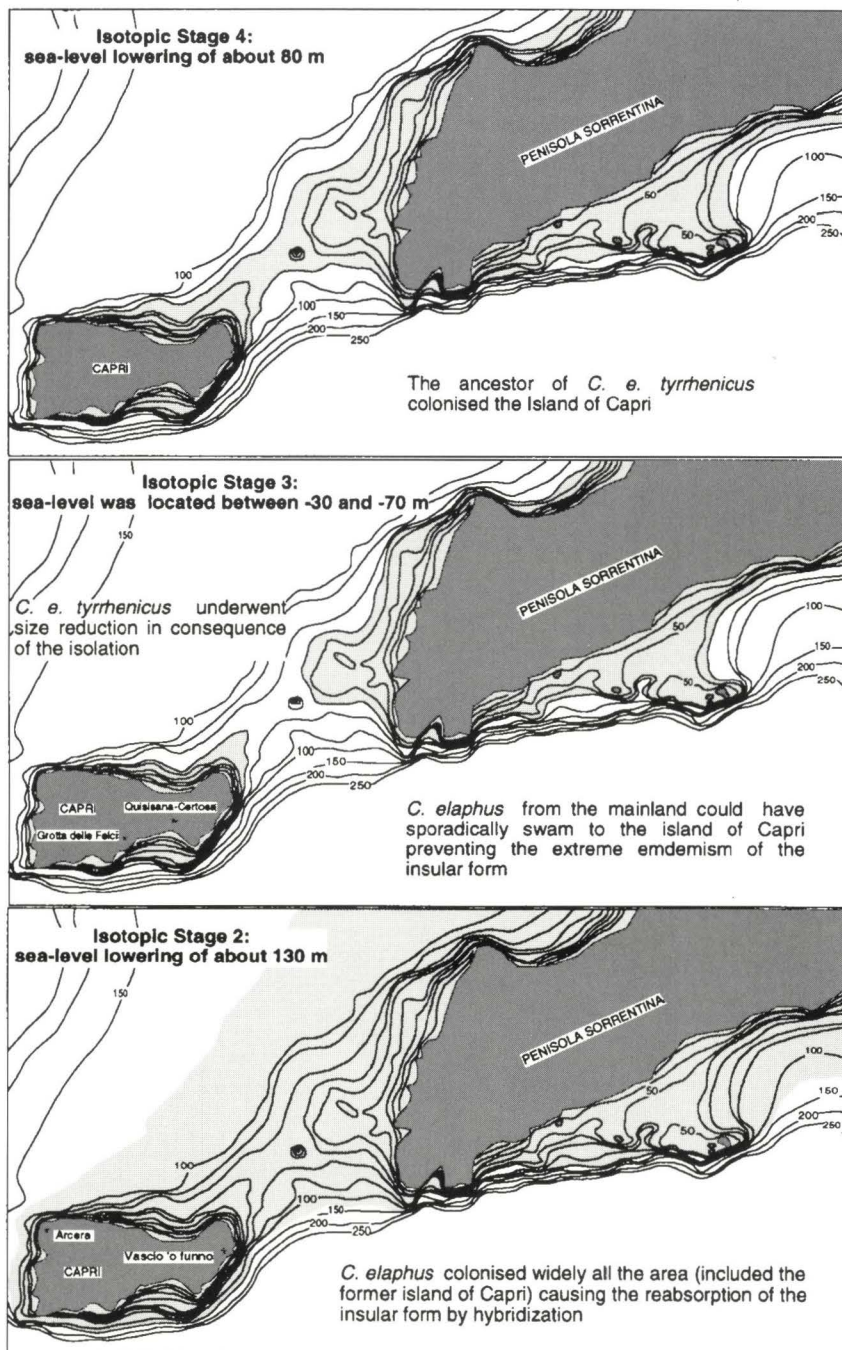
Text-fig. 3 - Chronological sketch of Middle Pleistocene-Holocene with the magnetostratigraphy, the δO^{18} isotopic curve and the eustatic curves. The grey area indicate the sea-level beneath which the island of Capri was surely connected with the mainland. The differences between the two curves cause some difficulties in the interpretation of the island palaeogeography during Stages 3 and 4. In the sketch is also tentatively represented, even if with great chronostratigraphic uncertainty, the extensional tectonic phase which affected the Capri-Penisola Sorrentina district at the end of the Middle Pleistocene, causing for the first time the isolation of the Capri island from the mainland (for more explanations see text).

According to these data and taking into account the ages of about 33,000 years B.P. for *C. e. tyrrhenicus* of Quisisana-Certosa (upper levels) and of 9,600 years B.P. for *C. elaphus* from Grotta Vascio 'o funno respectively, it is possible to hypothesize the following model of populations of the Capri district (Text-figs. 3, 4).

The ancestor of *C. e. tyrrhenicus* could have colonised the island of Capri during the sea-level low stand corresponding to Isotopic Stage 4 (about 70,000 years B.P.). The climatic deterioration of this period induced a lowering of the sea level of about 80 m (Shackleton, 1987) which was enough to link Capri to the Penisola Sorrentina through a narrow isthmus. During Isotopic Stage 3 Capri was probably sporadically linked (directly or through a succession of narrow islets) with the Penisola Sorrentina. Taking into account that deers are good swimmers and that the distance between Capri and the Penisola Sorrentina at that time should have been less than 5

km, it may not be excluded that during this interval the genetic flow with the mainland did not completely interrupted. This fact could explain the low degree of endemism shown by *C. e. tyrrhenicus*, notwithstanding the long period of isolation (about 50,000 years). Lister (1989) demonstrated that the size reduction of about 56% undergone by the Eemian deer of the island of Jersey occurred in a time interval equal or less than 6,000 years.

Normal sized *C. elaphus* of the ancient Holocene (Grotta Vascio 'o funno and Grotta Arcera) probably populated the island of Capri during the low stand of Isotopic Stage 2. During this time-interval Capri was linked to the Penisola Sorrentina by a wide isthmus which lasted about 10,000 years. This new palaeogeographical setting caused the disappearance of *C. e. tyrrhenicus*, probably as a consequence of the increased predatory pressure or, more probably, of the hybridisation with the continental red deer.



Text-fig. 4 - Palaeogeographical maps of the Capri-Penisola Sorrentina district during Isotopic Stages 4, 3 and 2.

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A special thank must be addressed to Prof. A. Azzaroli who helped with useful advice and remembrances during the recovery of the Grotta delle Felci remains of *C. e. tyrrhenicus* dispersed in the several repositories.

Finally, we wish to thank our colleagues and friends Prof. C. Petronio, Dr. G. Di Stefano and Dr. R. Sardella for the stimulating discussions and Mrs. L. Angeloni for the technical support.

APPENDIX:
LIST OF THE REPOSITORIES WHERE THE EXAMINED
MATERIAL IS PRESERVED

- 1) Remains of *Cervus elaphus tyrrhenicus* from the upper level of the Quisisana-Certosa succession: Museo Cerio, Capri. All the examined material is labelled with the inventory number 205.
- 2) Remains of *Cervus elaphus tyrrhenicus* from Grotta delle Felci. The recovery of the original material excavated by the Istituto Italiano di Paleontologia Umana during 1941-42, has been very difficult and has taken almost three years for a partial dismembering of the original collection and for its frequent displacements in several cities (Firenze, Roma, Pisa and Roma again). We think it could be useful to record in this paper the three repositories where we have found the great majority of the fossil remains, hoping that other colleagues could, eventually, notify us the location of the lost part of the collection, in particular the holotype illustrated by Azzaroli (1961), all the cranial portions and the antlers.

Repository of Palombara Sabina (Roma) of the Istituto di Paleontologia Umana. This material, now temporary located in the vertebrate repository of the Museo di Paleontologia, Università degli Studi "La Sapienza" of Rome, is represented by the fossil remains published by Azzaroli (1961) except for the holotype, the cranial and the antler remains which seem to be lost. All the specimens are, in general, very well preserved.

Museo di Paleontologia, Università degli Studi "Federico II" of Naples, Laboratorio Vertebrati (4,2).

Dipartimento di Archeologia, Sezione Antropologia Umana, Università degli Studi di Pisa (inv. 692).

- 3) Material of *Cervus elaphus* from Grotta Vascio 'o funno: Museo sez. C.A.I. Napoli, Castel dell' Ovo.
- 4) Material of *Cervus elaphus* from Grotta Arcera: Museo di Paleontologia, Università di Napoli "Federico II", Laboratorio Vertebrati, 4,2 and 4,6.

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