

A MIOCENE CERVID FROM THE TORRENTE MORRA SEQUENCE (COLLESALVETTI, PISA, ITALY)

GIOVANNI SARTI*, PAUL MAZZA** & MARCO RUSTIONI**

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Riassunto. Una tibia sinistra fossile ben conservata di artiodattilo è stata recentemente rinvenuta lungo il Torrente Morra, nei pressi di Collesalveti (15 Km a sud di Pisa). L'osso è contenuto in sedimenti tardo messiniani depositati in ambiente di delta che affiorano in modo discontinuo nell'area. Il reperto è riferibile ad un cervide primitivo ed ha caratteri morfologici e proporzioni molto vicine a quelle delle tibie dei caprioli attuali. Il ritrovamento è particolarmente significativo perchè mammiferi continentali non sono mai stati segnalati prima nei depositi miocenici di questa area. Un possibile riferimento ad un capriolo primitivo sarebbe in armonia con i dati macrofloristici e palinologici tardo miocenici di quest'area, che testimoniano una transizione da un ambiente forestato di tipo subtropicale ad uno temperato di tipo mediterraneo.

Abstract. A well preserved fossil left tibia of artiodactyl was recently found along Torrente Morra, in the surroundings of Collesalveti (15 Km South of Pisa). The bone is embedded in Upper Messinian deltaic sediments which outcrop patchily in the area. The specimen can be referred to a primitive cervid and shows morphological characters and proportions very close to those of the tibiae of extant roe deer, *Capreolus capreolus*. The find is particularly significant because continental mammals have never been reported before from the Miocene deposits of this area. A possible reference to a primitive roe deer would be consistent with Late Miocene macrofloral and palynological evidence from this area, which attest to a transition from a subtropical forested environment to a temperate Mediterranean one.

Introduction.

A fossil left tibia of artiodactyl was recently found by one of us (G.S.) along the Torrente Morra, in the surroundings of Collesalveti (15 Kms South of Pisa) (Fig. 1). The bone is embedded in Upper Miocene deltaic sediments which outcrop patchily in the area. This makes the find important from the paleontological, stratigraphical and paleogeographical points of view.

The sequence of Torrente Morra is located on the northwestern side of the Fine Valley, about 15 Km South of Pisa. The Fine Valley basin, the easternmost of the Neogene basins of Tuscany, South of the Arno river, is part of the Tyrrhenian extensional margin which was

affected by riftings and by a contemporaneous EW migration of the thrust-belt foredeep system (Elter et al., 1975; Malinverno & Ryan, 1986; Kastens & Mascle., 1990, Patacca et al., 1990) and of the relevant volcanic activity (Barberi et al., 1971). *Half graben* systems generated by the extensional tectonics were progressively infilled with tectonically and eustatically controlled sedimentary sequences.

Sedimentation probably began in the Late Tortonian with the deposition of fluvio-lacustrine sequences. These were followed, during the Messinian, by marine sediments, which in part transgress directly over the substratum. A progressive increase in salinity, which affected the whole Mediterranean area, caused a deterioration of the environmental conditions and led to the deposition of evaporites (salinity crisis, Hsu et al., 1978). Brackish to fresh water terrigenous sediments, containing prevalently reworked evaporites, follow upward in the sequence. These sediments are known as "lago mare" in the literature. Normal marine conditions were re-established rapidly and extensively at the beginning of the Pliocene (McKenzie et al., 1990).

Characters of the sequence (Fig. 2).

The Upper Miocene/Pliocene sequence outcrops rather extensively with an average thickness of about 360 m. For this reason it has been the subject of a number of studies (Giannini 1960; Lazzarotto et al. 1990; Sarti 1995). The sequence, which lays on a substratum of Ligurian units, includes 12 lithostratigraphic units. These are the following, from the base upwards:

Lithostratigraphic 1: Upper Cretaceous Intermediate Ligurian Complex.

Lithostratigraphic 2: matrix- to clast-supported conglomerates, fining and thinning upwards coarse sandsto-

*Department of Earth Science University of Pisa Via S. Maria, 53 56100 Pisa.

**Museum of Geology and Paleontology University of Florence Via La Pira, 4 50121 Florence. e-mail: muspal@cesit1.unifi.it

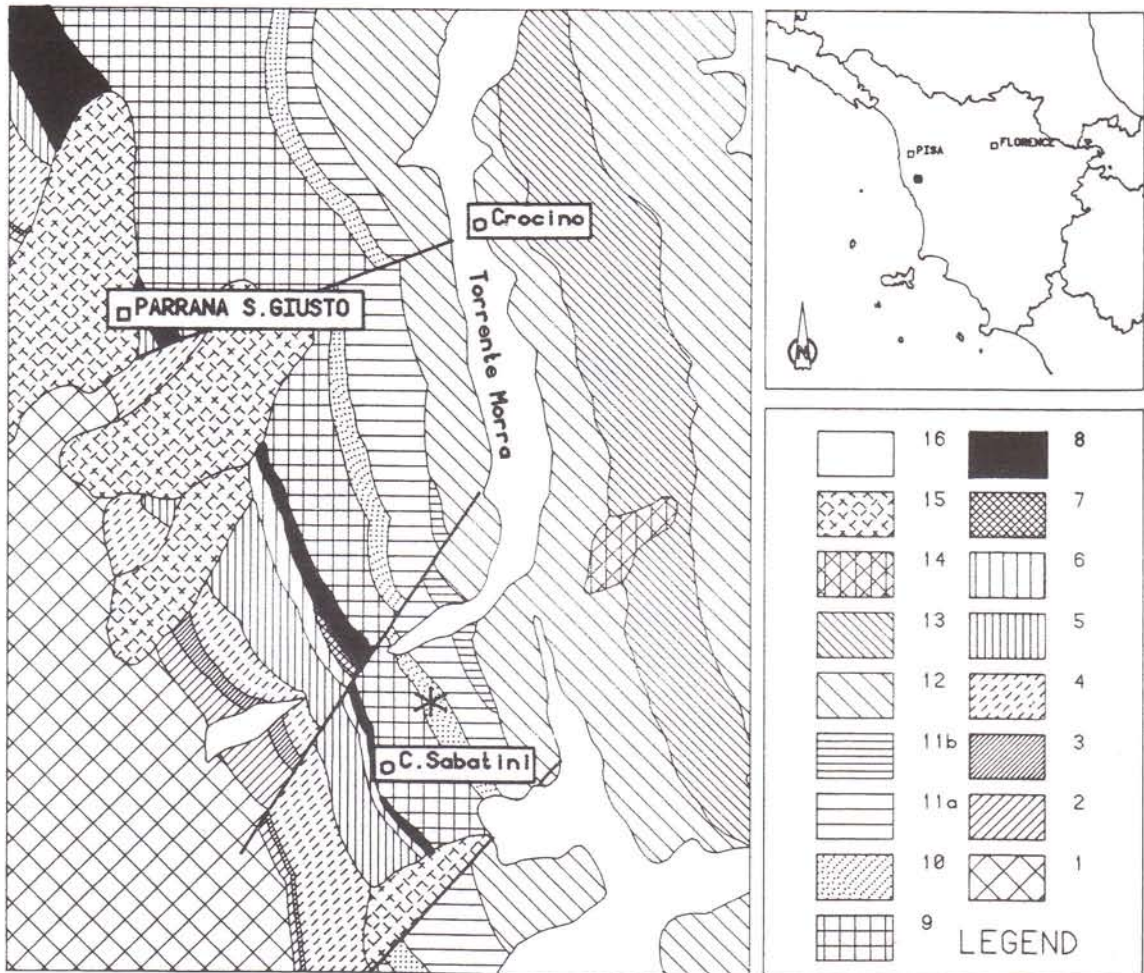


Fig. 1 - Index and geological map of the surroundings of the area of discovery of the fossil tibia (indicated by the asterisk) (1:20.000). Legend: 1) Upper Cretaceous Ligurian substratum; 2) fresh-water fan delta fining e thinning upwards coarse conglomerates; 3) brackish-water deltaic well-sorted fine-grained conglomerates; 4) protected lagoonal fining upwards bioclastic calcarenite; 5) inner platform dolomitic marls; 6) anoxic lagoonal marls and sands with spiculite intercalations; 7) deltaic turbidite-like microconglomerates; 8) evaporitic lagoonal nodular gypsum; 9) low energy brackish lagoonal clayey marls with sandy intercalations; 10) fining upward channelled sands; 11) marls and marly sands of submerged delta plain (11a) characterized, in its upper part, by gypsiferous sandstone lens (11B); 12) Lower Pliocene inner to outer shelf grey massive marls; 13) Pliocene yellow sands; 14) terraced alluvial deposits; 15) talus and colluvium; 16) recent alluvial deposits.

nes and silty clays interpreted like fan-delta deposits retrograding into fresh-water environment.

Lithostratigraphic 3: deltaic clast-supported conglomerates, perhaps of brackish environment by correlation with equivalent sections.

Lithostratigraphic 4: protected lagoonal fining upwards bioclastic calcarenite. Five thin levels of dolomitic mudstones, interbedded with dolomitic marls occur in the upper part of units.

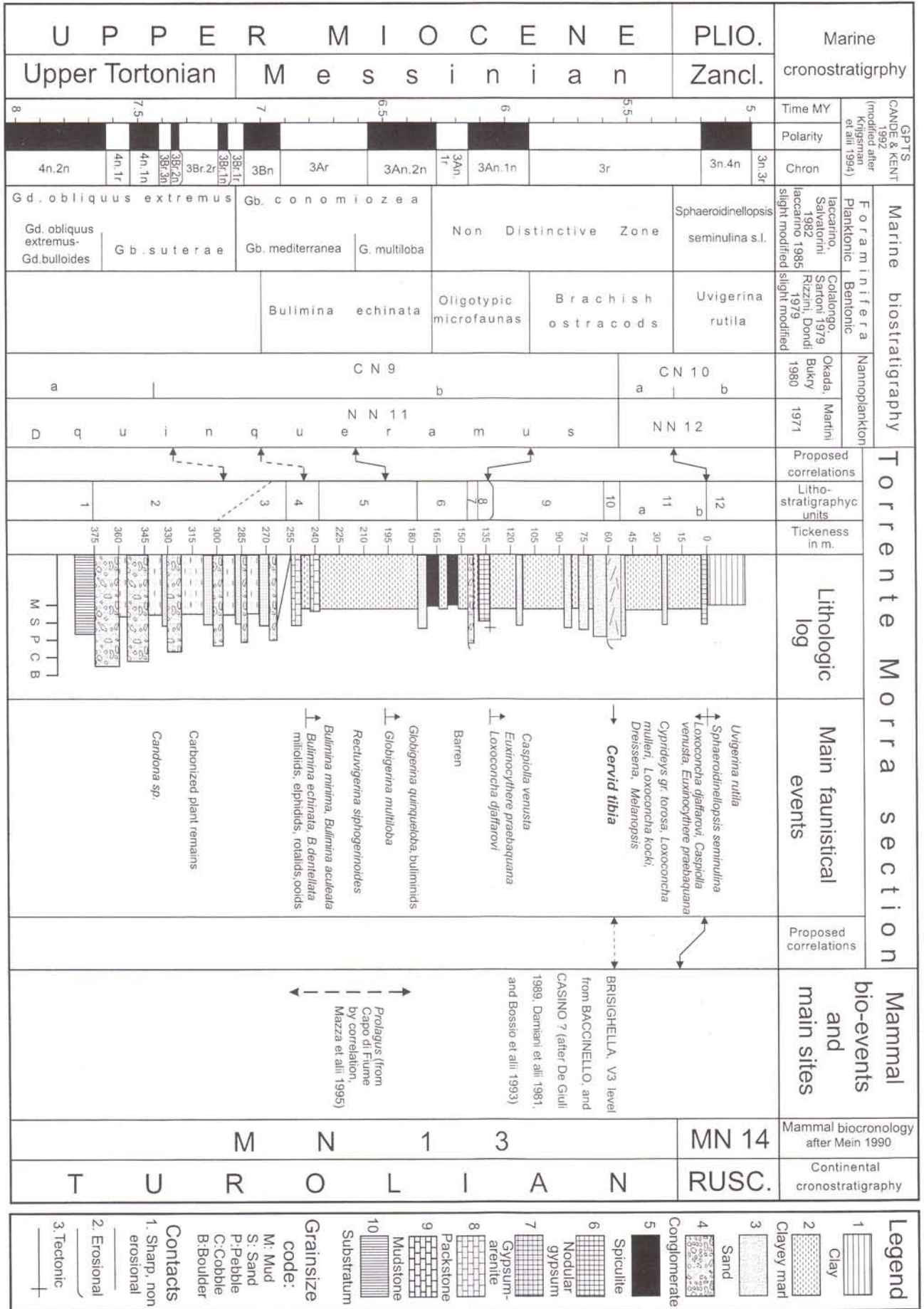
Lithostratigraphic 5: inner platform deepening upward sequence represented by grey dolomitic marls.

Lithostratigraphic 6: anoxic lagoonal marls and laminated sandy marls with intercalation of spiculitic levels. Turbidite episodes (Bouma ta-te intervals) occur in the upper part. Evidence of persistent sinsedimentary tectonics (slump and ball and pillow structures) can be observed in the whole unit.

Lithostratigraphic 7: graded microconglomerates and fine-grained sandstones from gravitative turbidite-like mechanisms (Bouma ta-te intervals) occur in the upper part.

Lithostratigraphic 8: hypersaline lagoonal whitish gypsum.

Fig. 2 - Correlation chart of the main bioevents found in the Torre Motta sequence. The reference magnetostratigraphic scale is that proposed by Krijgsman et al. (1994), who partially modified that proposed by Cande & Kent (1992). The Tortonian-Messinian boundary is placed at 7.1 Ma, again after Krijgsman et al. (1994). The Miocene-Pliocene boundary is placed at 5.32 Ma after Hilgen et al (1993). The calibration of the foram and nannofossil zonations is after Glacon et al. (1990) and Colalongo et al. (1979). Further information is from Patacca et al. (1990), Yong et al. (1994), Rio & Fornaciari (1994), Florindo et al. (1995), Gersonde & Schrader (1984) and Mc Kenzie & Oberhansli (1995).



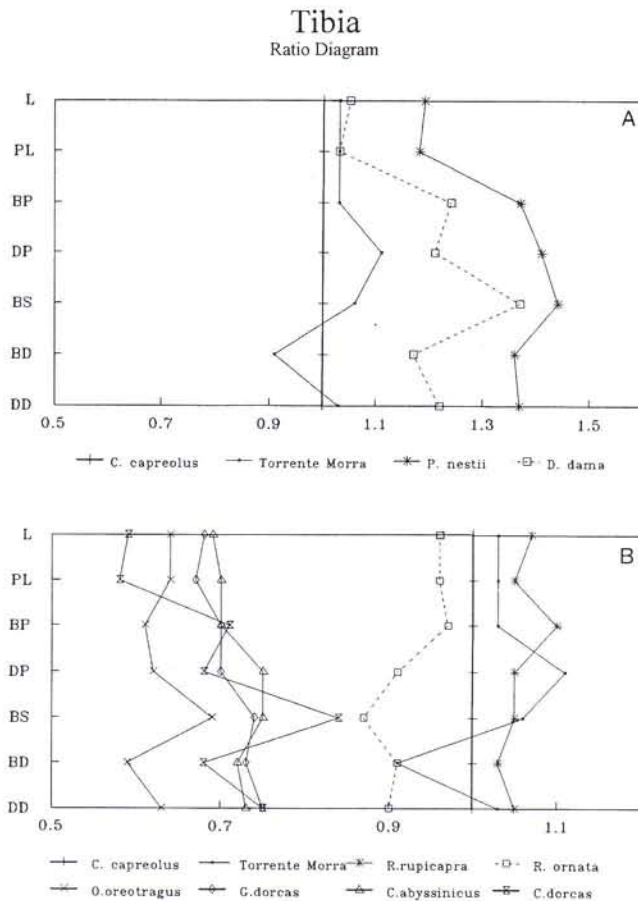


Fig. 3 - A) Ratio diagram showing the comparison of the Torrente Morra specimen with tibiae of present-day and some primitive cervids (*Capreolus capreolus* used as reference). For legend of characters see table 1. B) Ratio diagram showing the comparison of the Torrente Morra specimen with tibiae of some present-day bovids (*Capreolus capreolus* used as reference). For legend of characters see table 1.

Lithostratigraphic 9: brackish, low energy lagoonal dark grey fine-grained sands and massive to laminated clayey marls.

Lithostratigraphic 10: channel infilling sequences represented by light brown, coarse-grained, channelled sands, structured in fining upward sequences about 3-4 m thick. The base is clearly erosive and is marked by a basal lag formed by clasts up to 6 cms large and by oriented flat soft clasts (flat pebble clasts). Low angle planar cross-lamination occurs in the channel. Moving towards the top of the unit, grain size gradually decreases and weavy bedding and climbing ripple levels appear. The fossil tibia studied here was found in this unit; it was found about 100 m south of Torrente Morra. The samples of the embedding sediment are characterized by a high amount of pyrite and pyritized inner molds of gastropods, Charophites oogonia and few specimens of *Loxochoncha mulleri*, *L. kocki*, *Cyprideys* gr. *torosa*. The soft flat pebble clasts attest to a provenance from a nearby intertidal environment and are interpreted as reworked mud crack chips. The channelling suggests peri-

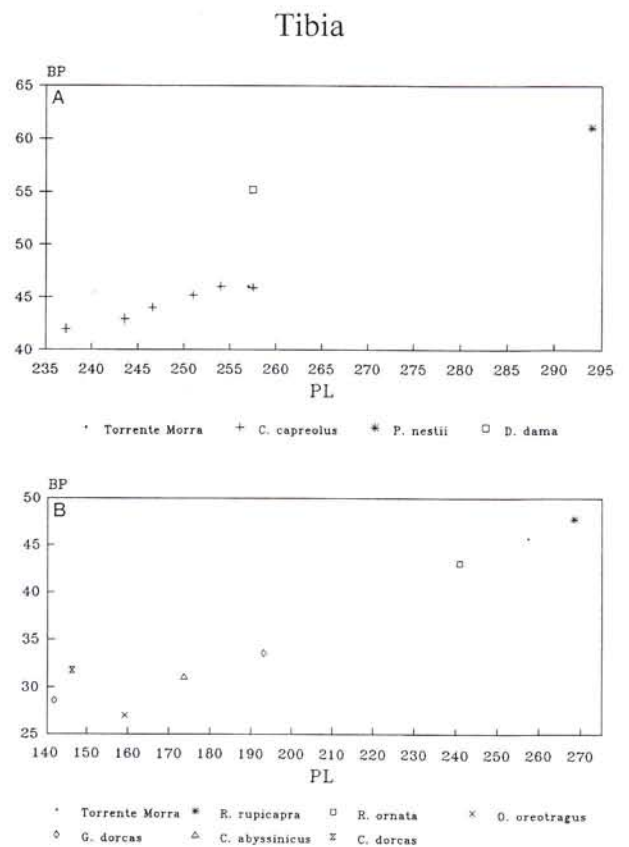


Fig. 4 - A) Physiologic lengths (PL) versus proximal breadths (BP) between the Torrente Morra specimen and cervid tibiae studied here. B) Physiologic lengths (PL) versus proximal breadths (BP) between the Torrente Morra specimen and present-day bovid tibiae studied here.

odical variations of the environmental energy with alternations of traction and settling processes reflecting increased seasonal oscillations.

Lithostratigraphic 11: brackish-water, low energy, submerged inner deltaic plain clayey marls (11a) with *Dreissena* and *Melanopsis* and sandy marls with wavy bedding structures. The unit is characterized, in the upper part, by lens of white to slightly redded gypsiferous sandstones (11b), stratified in centimetric to decimetric amalgamated layers.

Lithostratigraphic 12: inner to outer platform massive grey clayey marls.

Biochronostratigraphic observations (Fig. 2).

The whole sequence described above was entirely deposited during the Messinian, although a possible attribution of the lithostratigraphic units 2 and 3 to the Tortonian cannot be ruled out. The occurrence of *Bulimina echinata* in the upper part of unit 4 is the lowest, most significant biostratigraphic event; it permits to re-

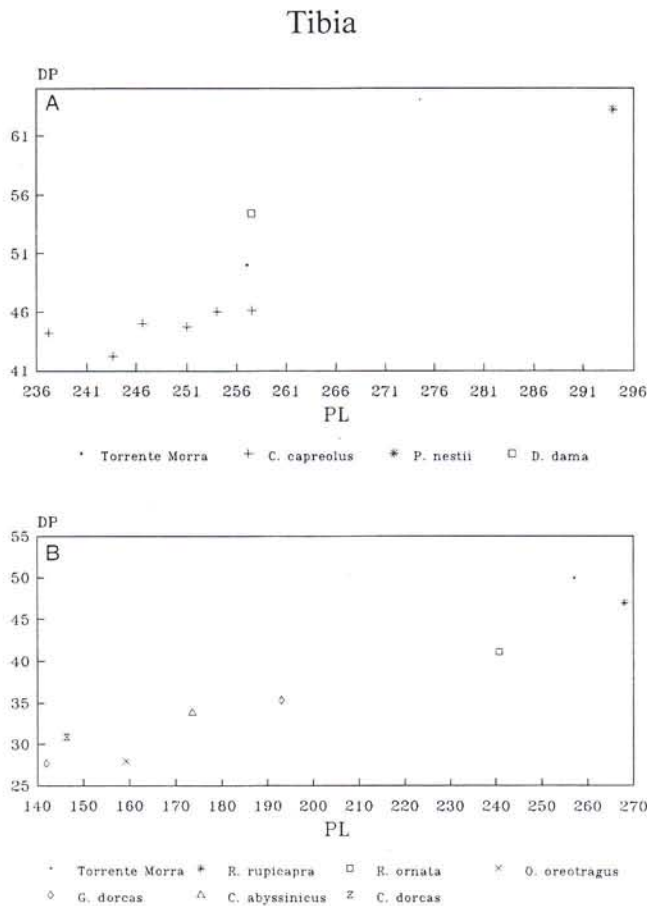


Fig. 5 - A) Physiologic lengths (PL) versus proximal depths (DP) between the Torrente Morra specimen and cervid tibiae here studied. B) Physiologic lengths (PL) versus proximal depths (DP) between the Torrente Morra specimen and present-day bovid tibiae studied here.

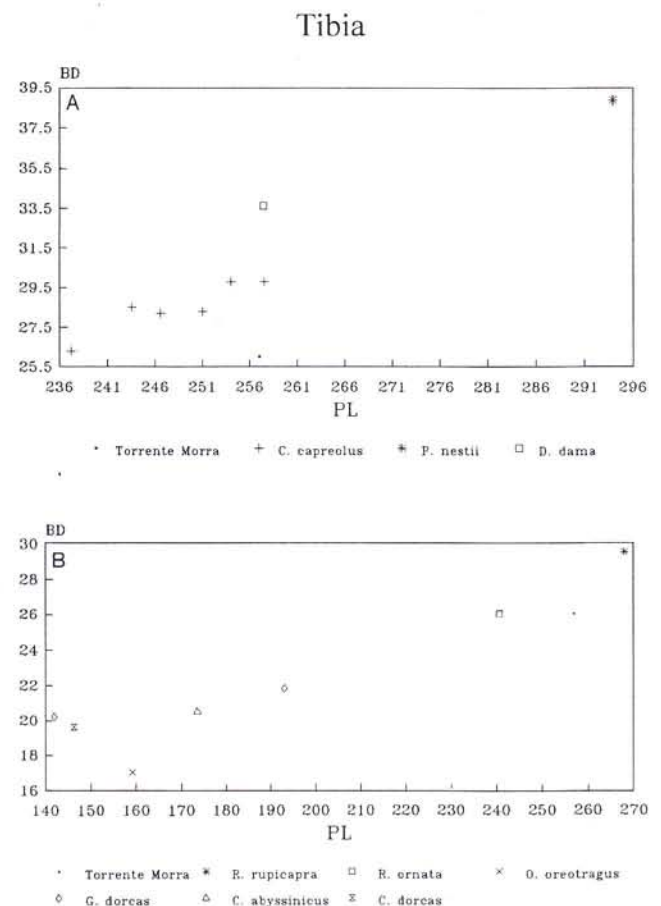


Fig. 6 - A) Physiologic lengths (PL) versus distal breadths (BD) between the Torrente Morra specimen and cervid tibiae here studied. B) Physiologic lengths (PL) versus distal breadths (BD) between the Torrente Morra specimen and present-day bovid tibiae studied here.

fer this unit to the Lower Messinian (Colalongo et al. 1979; Rizzini & Dondi 1979) (Fig. 2). It is worth noting that this of *Bulimina echinata* is a first occurrence (F.O.) and not a first appearance (F.A.), because continental deposits formed at the time of the latter. Thus, the first occurrence of *Bulimina echinata*, actually marks the first Messinian transgression. This datum suggests that the sequence started to accumulate after the F.A. of *Bulimina echinata*. Furthermore, *Globigerina multiloba* appears 45 m above the base of the sequence. Therefore, the upper part of the sequence falls in the *Globigerina multiloba* Zone. Hence, the Lithostratigraphic units 4, 5 and 6 should be referred to a pre-evaporitic Lower Messinian. The rest of the sequence should be referred to the Middle-Late Messinian and is therefore included in Iaccarino & Salvatorini's (1982) Non Distinctive Zone.

Unit 9 and 11 are characterized by a brackish-marine ostracofauna of Pannonic affinity, represented by *Loxococoncha djaffarovi*, *Euxinocythere praeabaquana*, *Casiolla venusta*, typical of the so-called "lago mare" biofacies (Carbonnel 1978). The unit 12 is referable to Iaccarino & Salvatorini's (1982) *Sphaeroidinellopsis seminulina* Zone (Early Pliocene). The fossil tibia comes from the

uppermost levels of the Messinian section, that which overlies the appearance of the ostracofaunas which characterize the "lago mare" biofacies and which slightly antedates the Early Pliocene *Sphaeroidinellopsis seminulina* Zone. The tibia is therefore correlatable with the Late Messinian, more precisely with the highest part of the Non Distinctive Zone of Iaccarino & Salvatorini (1982), which correlates with the brackish marine ostracods of Rizzini & Dondi (1979).

Description of the specimen.

The tibia belongs to an adult individual. It is well preserved and well fossilized and is embedded in a "Lago-Mare" yellowish deltaic sandstone. Only the plantar face of the bone has been developed from the matrix. There is no evidence of transportation, nor of exposure to weathering; only few transversal fractures cut the bone. The specimen is very slender. The diaphysis is sinuous. The proximal articular surface is characterized by prominent lateral intercondylar tubercles, a rather wide fossa for the cranial cruciate ligament and medial and lateral condyles with upcurved borders. In plantar

Tibia

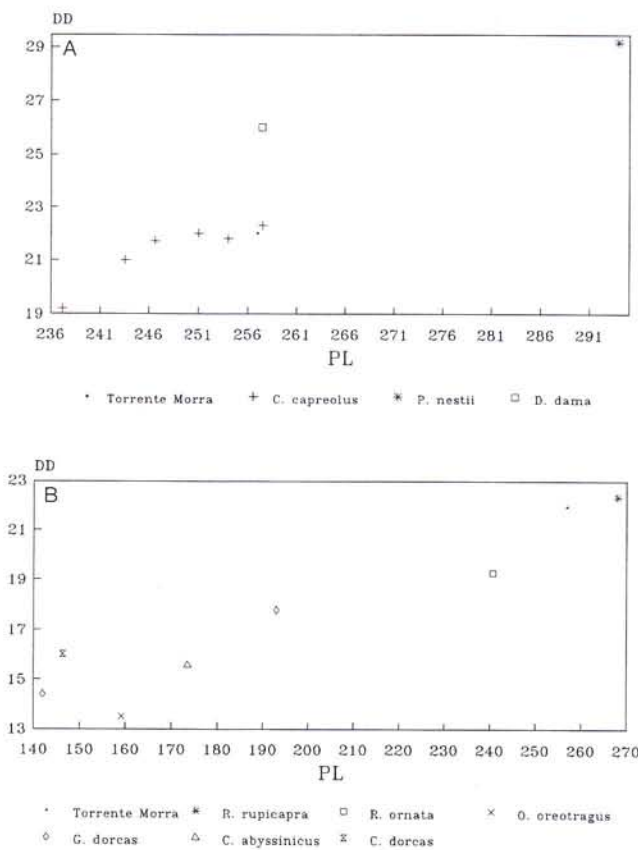


Fig. 7 - A) Physiologic lengths (PL) versus distal depths (DD) between the Torrente Morra specimen and cervid tibiae here studied. B) Physiologic lengths (PL) versus distal depths (DD) between the Torrente Morra specimen and present-day bovid tibiae studied here.

view the bone has a fairly flat face and shows very marked longitudinal digital flexor ridge, located in lateral position. The groove for the lateral digital extensor tendon is narrow and deep. On the other hand, the groove for the medial flexor is wide and shallow and is bordered by prominent ridges which extend quite along the diaphysis. In distal view the dorso-plantar thickness of the medial half of the distal epiphysis exceeds markedly that of the lateral half.

The dimensions of the bone are the following (in mm): greatest length: 267; physiologic length: 257; proximal breadth: 46; proximal depth: 50; breadth of the diaphysis: 17.5; distal breadth: 26; distal depth: 22.

The specimen was compared with some tibiae of approximately comparable size of living and extinct cervids and of living bovids. From the proportional point of view, the specimen from Torrente Morra shows a closer resemblance to the tibiae of *Pseudodama nestii* and *Capreolus capreolus* (Figs. 3-7). In particular, slight differences from the average of the latter species exist only in the dorso-plantar thickness of the proximal epiphysis (Fig. 5) and in the latero-medial breadth of the distal epiphysis (Fig. 6). In morphological terms, unlike the

bovid tibiae, the Torrente Morra specimen shows a flat plantar face and a deep groove for the lateral digital extensor tendon, two features which are present also in the tibiae of *Capreolus capreolus*. At last, in dimensional terms, the tibiae of *Capreolus capreolus* are the closest to that from Torrente Morra. For all these characters the Torrente Morra tibia is attributed here to *Capreolus* sp.

Discussion.

Turolian fossil vertebrate sites are rare in Italy. The most significant are Baccinello, Casteani, Ribolla, Montemassi, Acquanera, Monte Bamboli (Grosseto) (Lorenz, 1968; Engesser, 1989; Hürzeler & Engesser, 1976; Hüermann, 1969; van der Made & Moyá-Solá, 1989; Bernor et al., 1987; Qiu et al., 1987; van der Made, 1989-90; Damiani et al., 1981; Bossio et al., 1993), Casino (Siena) (Bossio et al., 1993), Monticino Quarry (Brisighella, Faenza) (De Giuli, 1989), Gargano (Foggia) (Ballmann, 1976; D'alessandro et al., 1979; De Giuli et al., 1984, 1985a, 1985b, 1985c, 1985d, 1986, 1987; De Giuli & Torre, 1984a, 1984b; Freudenthal, 1971, 1976, 1985; Leinders, 1983; Mazza, 1986a, 1986b, 1987; Valleri, 1984; Willemsen, 1983), Scontrone (L'Aquila) (Rustioni et al., 1992), Capo di Fiume (Maiella Mountains) (Mazza P. et al., 1995) and Gravitelli (Messina) (Seguenza 1902, 1907). Recently, scanty remains of a fauna similar to that from Southern Tuscany was found in Sardinia (Cordy & Ginesu, 1994; Kotsakis, pers. comm., 1993).

The faunas from Southern Tuscany, Casino and Gravitelli are suggestive of a whole paleobioprovince stretched from Northern Africa to Tuscany and Sardinia presumably through the Calabrian Arch. A possible connection with the Iberian peninsula cannot be ruled out. This is consistent with Azzaroli & Guazzone (1980) reconstruction of the paleogeographic setting of the Central Mediterranean during the Messinian.

The Scontrone-Maiella-Gargano fauna is markedly endemic and altogether attests to the occurrence of an isolated, long-lasting, Early Miocene (Late Oligocene?) to Late Miocene, Abruzzo-Apulian paleobioprovince with absolutely no relation with any other contemporaneous paleobioprovince of Italy.

The Monticino Quarry fauna differs considerably from the Sicilian-Tuscan-Sardinian and Abruzzo-Apulian ones. This attests to the existence of a paleobioprovince separated from the Sicilian-Tuscan-Sardinian areas during the Late Miocene and somehow connected, on the other hand, with Eurasia.

From the stratigraphical point of view, part of the faunas from Southern Tuscany, those from Casino and Monticino Quarry and perhaps also those of Gravitelli and the fissure fillings from Gargano possibly correlate with the layer of the Torrente Morra sequence which

provided the fossil roe deer tibia. From the paleogeographic viewpoint, the fossil deer from Torrente Morra is an element of the fauna of the Sicilian-Tuscan-Sardinian paleobioprovince. Paleontological arguments suggest that it may be an immigrant from the Iberian peninsula.

Currently available evidence seems to suggest that primitive roe deer first occurred in Western European continental areas during the Middle Miocene. The oldest known occurrence of *Capreolus* sp. is that from the Vallesian locality of Can Llobateres, northeastern Spain (Mein, 1990). Haupt (1935) considered "*Cervus*" *nanus* from Eppelsheim a possible ancestor of *Capreolus*. On the other hand, Schlosser (1924) considered *Procapreolus* the direct ancestor of *Capreolus* on the basis of the characters of the antlers. However, Zdansky (1927) observed that the teeth of the Chinese representatives of *Procapreolus* recall those of *Cervoceros* and are larger-si-

zed than those of *Capreolus*. The relationship of *Procapreolus* with *Capreolus* is therefore still debated.

Capreolus loczji was reported from the Late Miocene sites of Baltavr and Polgárdi, in Hungary (Kormos 1911, 1913). Another early representative of *Capreolus* is *Capreolus* cf. *cusanus*, from the Lower Villafranchian locality of Las Higuieruelas (Spain) (Alberdi et al. 1984). In Italy, the oldest odocoleine deer is *Capreolus* cf. *cusanus* from Villafranca d'Asti (Italy) (Azzaroli, 1967; De Giuli et al., 1983; Mein, 1990), called *Procapreolus cusanus* by Vislobokova (1992). *Capreolus capreolus* seems to have appeared at the time of the Villafranchian/Galerian faunal turnover (unpubl. data from Pietrafitta, Perugia, Central Italy).

Procapreolus seems to appear for the first time in the Middle Miocene of Eastern Europe, represented by *P. ucrainicus* (Vislobokova, 1992). In Western Europe, the oldest representative of this genus is *Procapreolus*

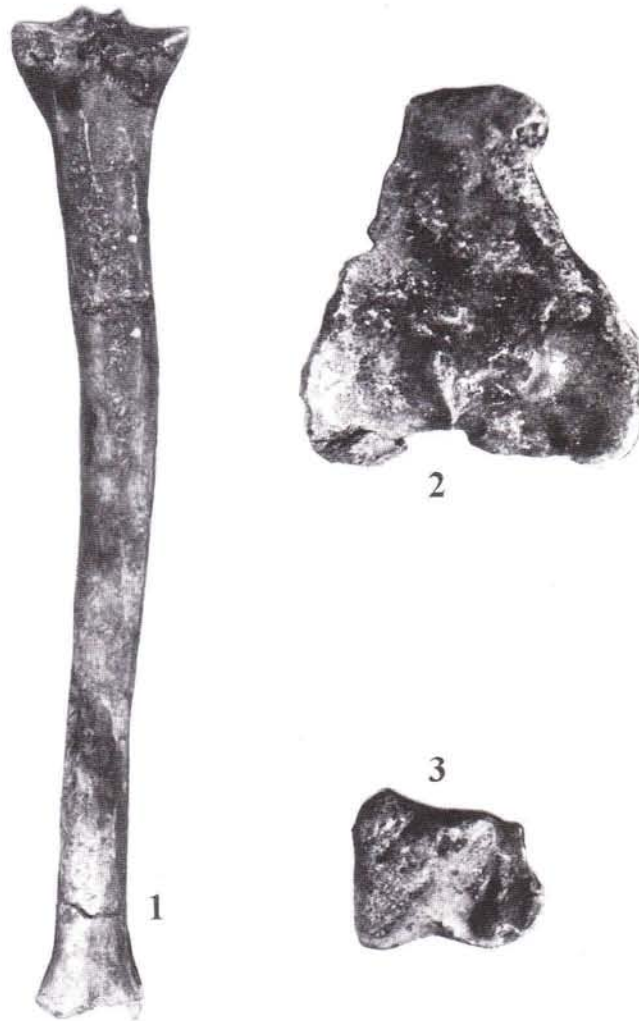


PLATE 1

Cervid. Museum of Natural History of Calci, Pisa, uncatalogued specimen.

- Fig. 1 - plantar view, x 0.5.
 Fig. 2 - proximal view, about nat. size.
 Fig. 3 - distal view, about nat. size.

Table 1a

T. Morra specimen and <i>C. capreolus</i> tibiae	Torrente Morra	1981/1-9817 M left - Camaldoli (Tuscany) MZSF	1967/17- C4166 F right -Unknown locality MZSF	C9876 left - Badia Prataglia (Tuscany) MZSF	Moggiona (Tuscany) right D.R.E.A.M. Poppi (AR)	1981/1-9731 M left Camaldoli (Tuscany) MZSF	M right Avena (Tuscany) D.R.E.A.M. Poppy (AR)
L	267	248.2	253.1	258.2	257.6	265	265.7
PL	257	237.2	243.6	246.6	251	254	257.5
BP	46	42	42.9	44	45.2	46	45.9
DP	50	44.2	42.2	45	44.7	46	46.1
BS	17.5	15.3	14.9	16.4	16.3	18.1	18
BD	26?	26.3	28.5	28.2	28.3	29.8	29.8
DD	22	19.2	21	21.7	22	21.8	22.3

Table 1b

Cervid and bovid Tibiae	Pseudodama nestii IGF 469	Dama dama S. Sidero IGF 833V	Oreotragus oreotragus M4747 C. 800 bis	Rupicapra rupicapra	Rupicapra ornata M4752 C. 12164	Gazella dorcas M4747 C. 1333	Gazella dorcas C. 12246
L	308.6	271.3	166	275.75	249	201.9	148.5
PL	293.9	257.4	159.2	268	240.6	193	142
BP	61.1	55.2	27	48.15	43.3	33.7	28.6
DP	63.3	54.4	27.9	47.05	41.1	35.3	27.6
BS	23.8	22.6	11.4	17.4	14.5	14.3	10.3
BD	38.9	33.6	17	29.5	26	21.8	20.2
DD	29.2	26	13.5	22.35	19.3	17.8	14.4

Tab. 1 - Measurements of the tibia from Torrente Morra (Table a) and of the specimens it was compared with (Table a and b). L) greatest length; PL) physiologic length; BP) breadth of the proximal epiphysis; DP) proximal depth; BS) least breadth of the shaft; BD) breadth of the distal epiphysis; DD) depth of the distal epiphysis.

concludiensis, from the Middle Turolian localities of Conclud and Las Pedrizas (Azanza & Menendez, 1989-90). Later representatives are *Procapreolus* aff. *concludiensis*, from another Spanish Middle Turolian site, Los Mansuetos (Azanza & Menendez, 1989-90), and *Procapreolus wenzensis*, from the Upper Pliocene site of Weze 1 (Poland) (Czyzewska, 1960, 1988).

Two indetermined cervids are reported from Baccinello V3 by Hürzeler & Engesser (1976). Later on, Hürzeler (1987) mentioned again the presence of a cervid from the same assemblage. Rook (1992) claimed the occurrence of ?*Procapreolus* in an updated faunal list drawn from previous studies (Hürzeler & Engesser, 1976; Engesser, 1983, 1989; Hürzeler, 1987; Rook et al., 1991; Rook & Rustioni, 1991) and from unpublished data, but ?*Procapreolus* is never mentioned in the papers indicated by Rook (1992).

In Asia, *Procapreolus latifrons* is known from Upper Miocene deposits of China (Zdansky 1927), while *Capreolus* is a typical element of the Pleistocene and Holocene woodlands of southern Siberia and northern China.

If the tibia from Torrente Morra does actually belong to a primitive roe deer, it would represent the oldest known occurrence in Italy of odocoleine deer. Furthermore, if the ecological preferences of the early representatives of these cervids were like those of extant

forms, the find would testify to the occurrence of woodlands in the immediate surroundings of the area of recovery, given the lack of evidence of transportation on the bone. This would be consistent with macrofloral and palynological observations from the area (Allegranti, unpubl. dissertation, 1989; Falorni, unpubl. dissertation, 1989). Comparative analyses on Miocene plant elements from the surroundings of Gabbro attest to a marked climatic cooling during the Late Messinian. A transition from a warm-temperate, probably double-seasonal, subtropical paleoflora to a cool-temperate one is attested by the replacement of tropical genera by deciduous species of *Quercus*. Such a climatic variation is consistent with the climatic modifications which affected the Mediterranean area during the Messinian.

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