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FIRST OCCURRENCE OF THE GENUS *ARVERNOCEROS* HEINTZ, 1970 FROM THE LATE EARLY PLEISTOCENE OF ITALY

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Abstract. Remains of the large-sized deer *Arvernoceros* from the sites of Madonna della Strada and Selvella (late Early Pleistocene, central Italy) are described. At present, these records represent the first occurrence of this genus in Italy.

These remains show morphological and morphometric characters comparable to the species *Arvernoceros giulii* and quite different from other Early Pleistocene large-sized deer. *A. giulii* was a typical species of a savannah-like environment and it seems to have evolved on the plains of central Asia. The dispersal of the species into Western Eurasia is probably caused by transformations of the eastern Paratethys during the Early Pleistocene and its occurrence in Italy may also have been favoured by climatic changes and by the geographical position of the peninsula.

Riassunto. Vengono descritti resti fossili di un cervo di grande taglia, appartenente al genere *Arvernoceros*, rinvenuti nei siti di Madonna della Strada e Selvella (tardo Pleistocene Inferiore, Italia centrale). Queste due segnalazioni rappresentano al momento la prima presenza certa di questo genere in Italia.

I resti presentano morfologia e dimensioni comparabili con quelle della specie *Arvernoceros giulii* e si discostano dai corrispettivi delle altre specie di cervo di grande taglia del Pleistocene Inferiore. *A. giulii* era una specie tipica di ambiente simil-savana e sembra essersi evoluta nelle pianure dell'Asia centrale. L'evento dispersivo della specie verso l'Eurasia occidentale fu probabilmente causato dalle trasformazioni avvenute nella Paratetide orientale durante il Pleistocene Inferiore e la comparsa della specie in Italia potrebbe essere stata favorita dai cambiamenti climatici e dalla posizione geografica della penisola.

Introduction

Remains of a large-sized deer have been discovered in a Late Villafranchian deposit outcropping in the wide intra-Apennine basin of L'Aquila, near the village of Scoppito, in the locality of Madonna della Strada, and in the deposits of the Chiana river valley at Selvella (late Early Pleistocene, central Italy). The faunal assemblage from Madonna della Strada, which also includes remains of deer, includes an almost complete skeleton of *Mammuthus meridionalis* (Nesti, 1824) (advanced form, *M. m. vestinus* Azzaroli, 1977), *Stephanorhinus etruscus* (Falconer, 1868) and *Hippopotamus antiquus* Desmarest, 1822 (Magri et al. 2010; Pandolfi & Petronio 2011). Based on the mammal assemblage and on stratigraphic analysis, the site is referred to the latest Villafranchian (late Early Pleistocene), about 1.3-1.1 Ma (Magri et al. 2010). The rich faunal deposit from the sandy layers of Selvella belongs to the first fluvio-lacustrine phase of the sedimentary sequence outcropping in the Val di Chiana (central Italy). The large mammal assemblage, including *Canis etruscus* Forsyth Major, 1877, *Lynx issiodorensis* (Croizet & Jobert, 1828), *Mammuthus meridionalis* (Nesti, 1824), *Equus altidens* Reichenau, 1915, *Axis eurygonos* (Azzaroli, 1947) and *Leptobos* ex gr. *L. vallisarni* Merla, 1949, has been referred to the latest Villafranchian (De Giuli 1987; Gliozzi et al. 1997).

In the present paper, morphometrical and morphological characters of the large-sized deer are investigated to distinguish the different genera and to ascribe the remains of Madonna della Strada and Selvella to *Arvernoceros* Heintz, 1970.

Using antler morphology as a basis, Heintz (1970) created the new genus *Arvernoceros*, which included the species *Cervus ardei* Croizet & Jobert (1828) from the Villafranchian site of Perrier-Etouaires (Puy-de-Dôme, Francia). This new genus has later been recorded from different European and Asian localities, thus extending

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its geographic and stratigraphic range (Vislobokova & Changkang 1990; Bajgusheva 1994; David 1992; Kahlke 1997; Stefaniak 1995; Croitor & Kostopoulos 2004; Croitor 2005; Croitor & Stefaniak 2009). The genus *Arvernoceros* includes medium and large-sized species. It is characterized by a rather limited intraspecific variability of antler morphology and by the primitive morphology of the teeth, with simple P/4 and long premolar row (Heintz 1970; Croitor & Kostopoulos 2004).

The systematic position of *Arvernoceros* is still unclear. Heintz (1970) included the genus in the Megacerini, and thus assumed a phylogenetic relationship with *Megaloceros* Blumenbach, 1799. Di Stefano & Petronio (2002) included *Arvernoceros ardei* in the genus *Axis* Gray, 1825, and suggested, on the basis of morphological considerations, that the latter was related to a similar, but more specialized form of *Axis shansius* Teilhard & Trassaert, 1937. Croitor & Stefaniak (2009) noticed close phylogenetic relationships with the modern genus *Rucervus* Hodgson 1838, while Made & Tong (2008) noted similarity with the genus *Sinomegaceros* (Dietrich, 1933).

Before the 1997, two species were ascribed to *Arvernoceros* in Europe: the medium-sized *A. ardei*, occurring in France, Spain and Poland during the Early Villafranchian (Heintz 1970; Croitor & Stefaniak 2009) and the large-sized *A. verestchagini*, described by David (1992) and found only in two localities: Salcia (Moldova) and probably Apollonia (Greece) (David 1992; Croitor & Kostopoulos 2004).

In 1997, Kahlke referred the remains of a large-sized deer from Untermassfeld (Germany; about 1 Ma) to the new species *Eucladoceros giulii*. According to Croitor & Kostopoulos (2004), the hypothetical reconstruction of the antler reported by Kahlke (1997) was based on scant fossil fragments belonging to individuals of different ontogenetic ages. The large-sized deer from Untermassfeld should be ascribed to the genus *Arvernoceros* based on teeth, bones and some antler morphology (Croitor & Kostopoulos 2004). Moreover, Kahlke (1997) and Made (1998, 1999) ascribed to *E. giulii* (= *A. giulii*) also the late Villafranchian large cervids from Venta Micena (Spain), referable to the Italian Pirro Faunal Unit (sensu Gliozzi et al. 1997), Würzburg-Schalksberg (Germany), Atapuerca (Spain), Apollonia (Greece) and Akhalkalaki (Georgia). Croitor & Kostopoulos (2004) referred the remains from Venta Micena to the genus *Praemegaceros* Portis, 1920, those from Akhalkalaki to indeterminate deer, and questioned the determination of remains from Atapuerca.

In Italy the most common large-sized deer of the late Early Pleistocene are *Eucladoceros* Falconer, 1868 and *Praemegaceros* (Azzaroli & Mazza 1992, 1993; Gliozzi et al. 1997; Abbazzi 2004). A limited number of specimens of the genus *Cervalces* Scott, 1885 have also been reported from northern Italy (Ambrosetti & Cremaschi 1975; Azzaroli 1979a; Ravazzi et al. 2005).

Abbreviations: MSG = Museum of San Giuliano; DESSR = Department of Earth Science of University of Rome Sapienza; IGF = Museum of Geology and Paleontology, University of Florence.

Description and comparisons

The remains of large-sized deer considered in this paper are stored in the Department of Earth Science of the University of Rome Sapienza, in the Museum of San Giuliano (L'Aquila) and in the Museum of Geology and Paleontology of Florence. The remains from Madonna della Strada were found in the 1950 and have previously been ascribed to the genera *Eucladoceros* and *Praemegaceros* (labels in the collections; Magri et al. 2010).

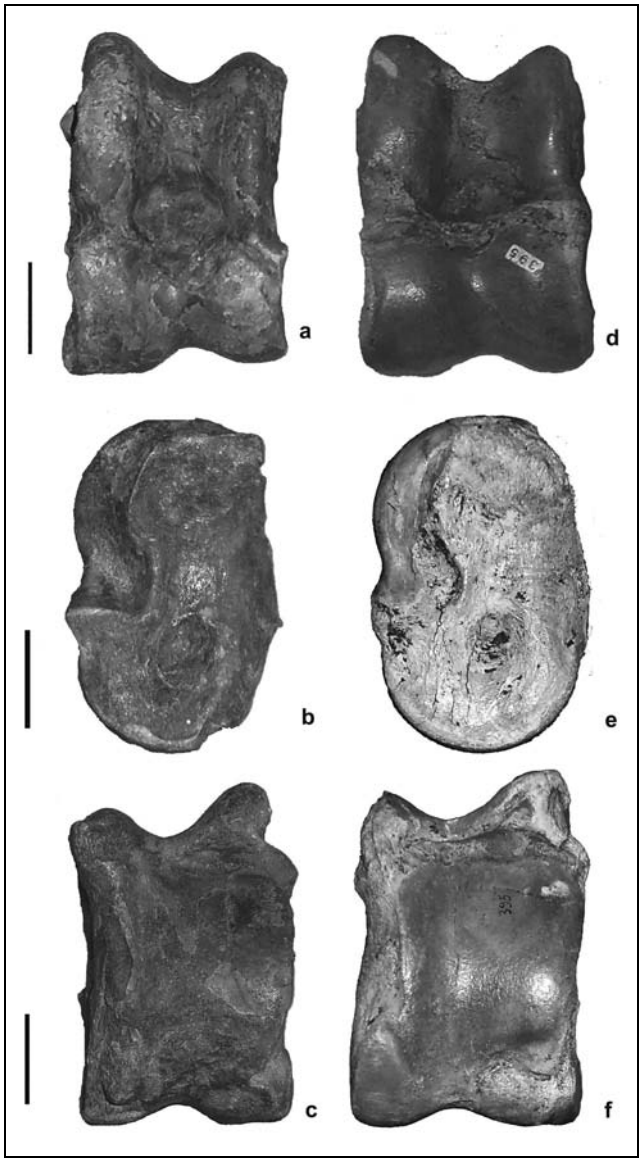

Fig. 1 - Astragali of *A. giulii* from Madonna della Strada (a, b, c = DESSR s.n.; d, e f, = MSG^{no}395). From top to bottom, dorsal view, medial view, posterior view. Scale bar = 2 cm.

They consist of several post-cranial elements, such as femur, scapula, astragali, metatarsus (without the proximal epiphysis) and second phalanx. However, in this paper we carry out a morphometric and morphological analysis of two astragali (MSG^{no}395 and DESSR s.n.) and one metatarsus (DESSR s.n.). The remains from Selvella consist of several post-cranial elements and have previously been referred to the genus *Eucladoceros* (De Giuli 1987). In the present paper we present a detailed analysis only of the astagalus (IGF14158) and metatarsus (IGF14158).

The remains are in various states of preservation and the descriptions of the specimens are compared with the post-cranial bones of the late Early Pleistocene deer *Eucladoceros*, *Praemegaceros* and *Arvernoceros*.

Astragali (MSG^{no}395, DESSR s.n. and IGF14158)

The three astragali are in a good state of preservation and show similar characters. The astragalus stored in MSG (MSG^{no}395) is slightly larger than the others (DESSR s.n. and IGF14158). The astragali from Madonna della Strada belong to two adult individuals, while the astragalus from Selvella probably belongs to a subadult individual. In the astragali of MSG and DESSR (Fig. 1a and d) the distal end of the lateral lip of the proximal trochlea bends inward in anterior view, forming a sort of groove (the specimen from Selvella is damaged in this part). In the same view, the distal end of the medial lip of the proximal trochlea extends medially through a long, oblique and straight edge. In posterior view (Fig. 1c and f), the transverse diameter of the articular surface with the calcaneus is relatively well developed and the sharp tip on the proximal end of the posterolateral surface is prominent. Also, in the astragalus from DESSR, the proximal end of the medial lip of the proximal trochlea in medial view extends posteriorly through a long and straight edge. This feature is not well developed in the specimen from Selvella.

The analyzed specimens have morphological characters comparable with those of the specimens from Untermassfeld. In particular, the groove in the distal end of the lateral lip of the proximal trochlea is seen also in *A. giulii* from Untermassfeld, but is absent or less clear in *Eucladoceros* from the various sites of Upper Valdarno, including the specimens from Poggio Rosso, *P. obscurus* from Pirro Nord and *P. verticornis* from different European sites (Kahlke 1965, 1969, 1971). Furthermore, the long, oblique and straight edge of the distal end of the medial lip of the proximal trochlea is present in *A. giulii* from Untermassfeld. In *Eucladoceros* from Upper Valdarno, *P. obscurus* from Pirro Nord and *P. verticornis* from German sites, however, this feature is less marked or absent. Also, the posterior articular surfaces of the studied astragali are larger than in the genus *Eucladoceros* and the sharp tip on the proximal end of the posterolateral surface is more prominent than in *P. obscurus* from Pirro Nord. Finally, the long and straight edge of the medial lip of the proximal trochlea in medial view, is also seen in *A. giulii* from Untermassfeld, while it extends through a short and curved edge in *Eucladoceros* from Upper Valdarno, *P. obscurus* from Pirro Nord and *P. verticornis* from German sites. In addition, in the specimen from Selvella the proximal end of the medial lip of the proximal trochlea extends more abruptly outward in frontal view than sub-adult individuals of *P. obscurus* from Pirro Nord.

The remains of Madonna della Strada and Selvella are larger than the different species of the genus *Eucladoceros*; they are comparable with *A. giulii* and are smaller than *A.* cf. *verestchagini* from Apollonia-1 (Tab. 1).

Astragali		**L**	**DTD**
Scoppito MSG 395		75	49.5
Scoppito DESSR sn		72	47
Selvella IGF14158		73	44
Arvernoceros Untermassfeld	min.	69.9	43.3
	max.	79.5	49.2
Arvernoceros Apollonia-1		82	52.1
Eucladoceros Upper Valdarno	min.	58.4	36.2
	max.	71	44.6
Praemegaceros Voigtsted		74.3	47.2
Praemegaceros Brasov		64	40
Praemegaceros Süssenborn		80.2	51.5
Praemegaceros Pirro Nord	min.	69	41
	max.	77	48

Tab. 1 - Comparative dimensions of astragali from Madonna della Strada and Selvella, *A. giulii* from Untermassfeld (data from Kahlke 1997), *Eucladoceros* from Upper Valdarno (data from Azzaroli & Mazza 1992), *Praemegaceros obscurus* from Pirro Nord (n = 7), *Praemegaceros verticornis* from different sites (data from Kahlke 1965, 1969, 1971) and *A.* cf. *verestchagini* from Apollonia-1 (data from Croitor & Kostopoulos 2004). L = absolute length, DTD = distal transverse diameter.

Metatarsi (DESSR s.n. and IGF14158)

The metatarsi from Madonna della Strada (DESSR s.n.) and Selvella (IGF14158) (Fig. 2) are slender and the diaphysis relatively small, while the distal epiphysis are relatively large. In proximal view, the metatarsus from Selvella is well developed anteroposteriorly and the medial portion of the epiphysis is more elongated than the lateral portion. Also, the foramen is

Fig. 2 - Metatarsi from Selvella (IGF14158) (a) *Eucladoceros* from Upper Valdarno (b) and Madonna della Strada (DESSR s.n.) (c) in dorsal view. Scale bar = 2 cm.

relatively large and the posterior articular surface with the cubonavicular is elongated and oblique. In the metatarsi from Selvella and Madonna della Strada, the dorsal longitudinal groove seems to be relatively marked in dorsal view, and ends in parallel edges. In the same view, in the distal epiphysis the gap between the trochleae appears relatively enlarged and with parallel edges. The length of the metatarsus from Madonna della Strada, from the distal articular surface to the broken area, is about 295 mm. The broken area is at the beginning of the posterior tuberosity on the medial posterior side of the bone (in correspondence to the beginning of the maximum anteroposterior diameter of the medial side). Morphometric comparison with the metatarsi of *Cervus elaphus elephus* (n = 7) from the Laboratory of Vertebrate Paleontology (DESSR) and *Eucladoceros* (n = 6) from Poggio Rosso (IGF), reveals that the distance from the beginning of the this tuberosity to the proximal end of the bone is at least 60 mm. Even conservatively, we can estimate the length of the metatarsus from Madonna della Strada to about 355 mm.

The analyzed metatarsi appear more slender when compared to the specimens of the genus *Eucladoceros* from different sites of the Upper Valdarno, including those from Poggio Rosso, as well as *P. obscurus* from Pietrafitta. The diaphysis is narrower than the Upper Valdarno specimens, while the distal epiphysis almost overlaps the largest *Eucladoceros*. In proximal view, the proximal epiphysis of the Selvella metatarsus is more developed anteroposteriorly than the specimens of *Eucladoceros*. Also, the gap between the anterior articular surfaces with the cubonavicular and the large cuneiform is wider than in *P. obscurus* and *P. verticornis* (Fig. 3). In the same view, the distance between the articular surfaces with the large and small cuneiforms seems to be greater than in *P. obscurus* and *P. verticornis*. Furthermore, the posterior end of the epiphysis appears more rounded and wider than in *P. obscurus* and *P. verticornis*. The morphological characters of the metatarsus from Selvella are also seen in the specimens from Untermassfeld (Fig. 3). Also, in the metatarsi from Selvella and Madonna della Strada, the dorsal longitudinal groove seems to be deeper in dorsal view than the specimens from the Upper Valdarno. In the latter, it is closed, with curved and narrower edges than the present remains. In the same view the gap between the trochleae of the distal epiphysis of the metatarsi from Selvella and Madonna della Strada appears more enlarged than in the specimens from the Upper Valdarno.

In the scattergrams, the remains from Madonna della Strada and Selvella are comparable to the largest specimens of *Eucladoceros* from Upper Valdarno and the smaller *Arvernoceros* from Untermassfeld (Fig. 4, 5). The remains of *A.* cf. *verestchagini* from Apollonia-1 seem to be larger than the other specimens. In size, the proximal epiphysis of the Selvella specimen overlaps those of *Eucladoceros* and *P. obscurus* and is comparable to those of *P. verticornis* from Tiraspol (see also Azzaroli & Mazza 1992, 1993; Abbazzi et al. 1999). Furthermore, the lateral physiological length of the metatarsus from Selvella (352,8 mm) is greater than in *P. obscurus* from Pietrafitta (340 mm) (see Azzaroli & Mazza 1993). The scattergram of maximal length/transverse distal diameter (Fig. 5) shows a clear distinction between the specimens of *Eucladoceros* from Upper Valdarno, *Praemegaceros* from different sites and *Arvernoceros giulii*. The remains from Madonna della Strada (minimal length estimated) and Selvella are comparable

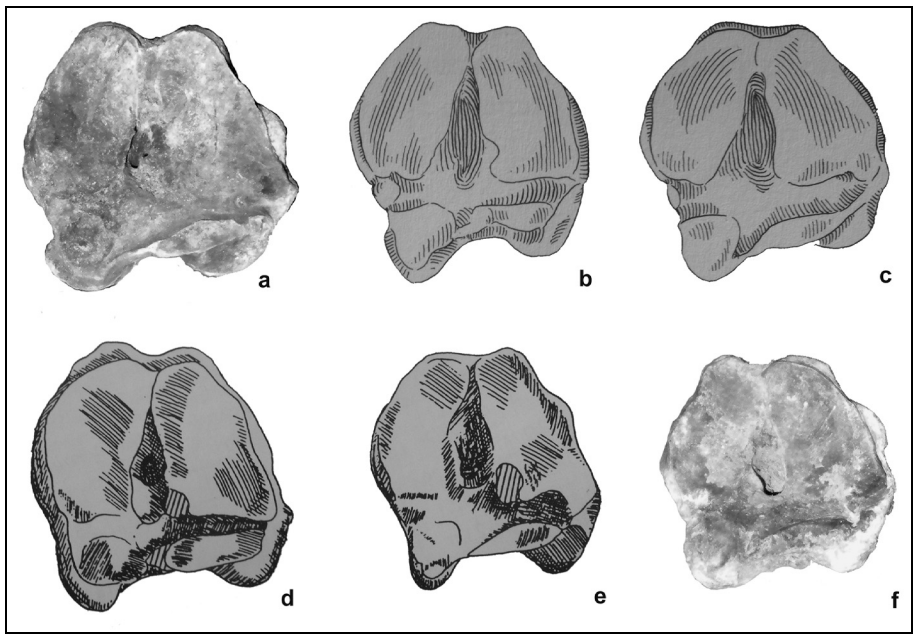

Fig. 3 - Comparison of proximal ends of metatarsi from Selvella (a) (IGF14158), *A. giulii* from Untermassfeld (b, c), (redrawn from Kahlke 1997), *P. obscurus* (d) and *P. verticornis* (e) (redrawn from Abbazzi et al. 1999) and *Eucladoceros* from Upper Valdarno (f = IGF8143v). Not to scale.

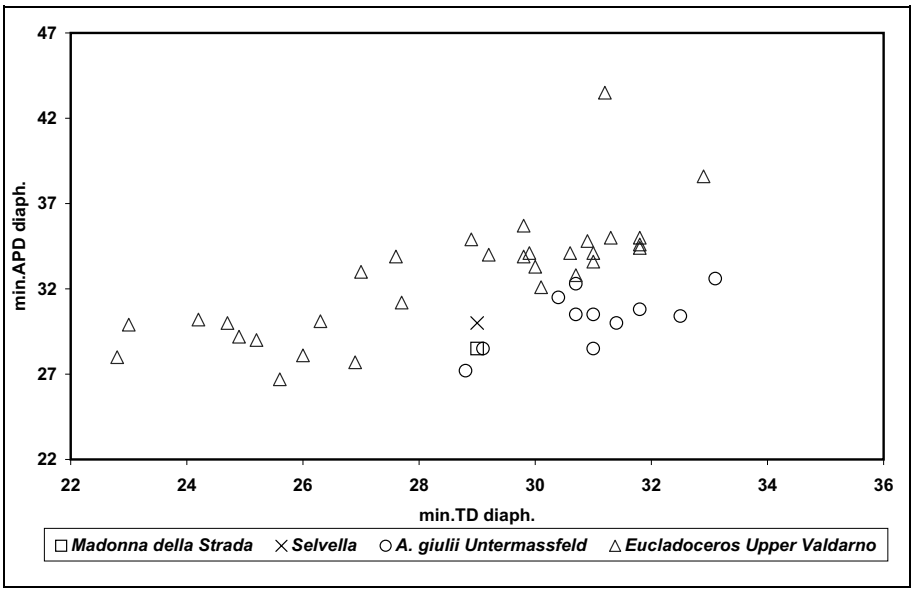

Fig. 4 - Scattergram of metatarsi from Madonna della Strada (minTD diaph. = 29 mm; minAPD diaph. = 28.5 mm) and Selvella (minTD diaph. = 29 mm; minAPD diaph. = 30 mm), *A. giulii* from Untermassfeld (data from Kahlke 1997), *Eucladoceros* from Upper Valdarno (data from Azzaroli & Mazza 1992). minTD diaph. = minimum transverse diameter of diaphysis, minAPD diaph. = minimum antero-posterior diameter of diaphysis.

with the values of the large-sized deer from Untermassfeld and are well separated from the values of the specimens of *Eucladoceros* and *Praemegaceros*.

Discussion and conclusions

The remains of the large-sized deer from Madonna della Strada and Selvella show size and morphological features comparable with *A. giulii* from Untermassfeld, larger than *A. ardei* and smaller than *A.* cf. *verestchagini*. The occurrence of *A. giulii* in the Madonna della Strada and Selvella sites are the first sure records of this mammal in the Pleistocene of Italy. It was an open-landscape, long-legged cursorial form with an estimated body mass of about 400 kg. It was a typical species of a savannah-like environment (Croitor 2005; Croitor & Kostopoulos 2004). Furthermore, *A. giulii* seems to have evolved on the plains of central Asia during the Late Pliocene from *Arvernoceros ubensis* (= *Cervus ubensis* Vislobokova, 1977) and spread into Western Eurasia after the Akchagylian biogeographic obstacle (Paleocaspian water body) disappeared (Croitor 2009). The dispersal of *A. giulii* is probably caused by transformations of the eastern Paratethys during the Early Pleistocene and its occurrence in Italy may also have been favoured by climatic changes, and by the geographical position of the peninsula. In fact, between 1.6 and 1.1 Ma, the local climate in Italy became progressively drier. During this time span, a marked faunal turnover occurred in Italy, with the progressive disappearance of

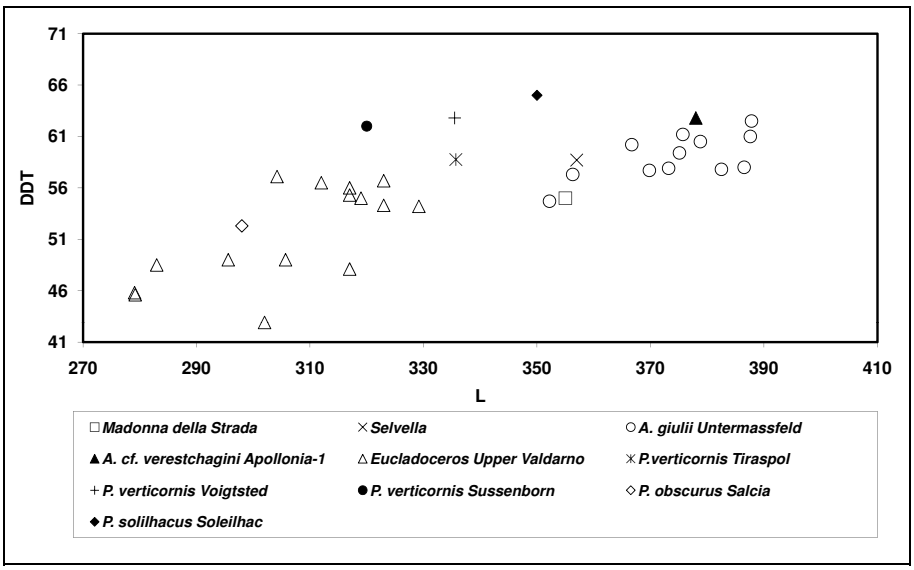

Fig. 5 - Scattergram of metatarsi from Madonna della Strada (L = 355 mm; DTD = 55mm) and Selvella (L = 357; DTD = 58.5 mm), *A. giulii* from Untermassfeld (data from Kahlke 1997), *Eucladoceros* from Upper Valdarno (data from Azzaroli & Mazza 1992), *Praemegaceros* from different sites (data from Azzaroli 1979b; Kahlke 1965, 1969, 1971; Abbazzi 1995) and *A.* cf. *verestchagini* from Apollonia-1 (data from Croitor & Kostopoulos 2004). L = absolute length, DTD = distal transverse diameter.

the Villafranchian species and the gradual arrival of new species that became typical of the Middle Pleistocene (Petronio et al. in press). In the Farneta FU (sensu Gliozzi et al. 1997) (about 1.6 Ma), a primitive form of giant megacerine deer (*P. obscurus*) appeared for the first time in Italy, together with the Villafranchian genus *Leptobos* Rütimeyer, 1877 (medium-large sized bovid) and *Eucladoceros* (Gliozzi et al. 1997; Petronio et al. in press). Among the carnivores, the African saber-tooth cat *Megantereon whitei* (Broom, 1937), the giant hyena *Pachycrocuta brevirostris* Aymard, 1846 and the panther *Panthera gombaszoegensis* (Kretzoi, 1938) were present. In the following Pirro FU (about 1.6-1.3 Ma) (last Villafranchian Faunal Unit), data indicate the prevalence of open landscapes. In fact, a bison, *Bison degiulii* (Masini, 1988), indicating more arid conditions, as well as a medium-sized Equidae, *Equus altidens* Reichenau, 1915, occurred for the first time in Italy. Also, a canid with African hunting dog affinities, *Lycaon lycaonoides* (Kretzoi, 1938), a large porcupine, *Hystrix refossa* Gervais, 1852, and a cercopithecid of African origin, *Theropithecus* Geoffroy, 1843 appear (Petronio et al. in press with references therein). During this time span, the earliest evidence of humans in Italy and in Western Europe was found in the quarries of Pirro Nord, as testified to by about 200 lithic artefacts (Arzarello et al. 2007; 2009). At the same time, the bovids of the genus *Leptobos* and the large-sized deer *Eucladoceros*, typical of more humid conditions, disappeared.

Chronologically correlated with the late Pirro FU are the local faunas of Madonna della Strada and Selvella, in which arid conditions are testified to by the presence of *Mammuthus meridionalis*, *Equus altidens* and *Arvernoceros giulii*.

In the following faunal assemblages (Colle Curti FU) (about 1.1 My), the appearance of *P. verticornis* was first reported in the local fauna of the Colle Curti (Macerata, central Italy) (Gliozzi et al. 1997). During this period, long transitional phases of glaciations were observed in cycles of 100.000 years and the difference in temperatures during glacial and interglacial phases became stronger (Leroy 2007). In the Ranica site in northern Italy, a cold, steppic phase with *Cervalces latifrons* (Johnson, 1874) is well documented (Ravazzi et al. 2005). In central Italy, the pollen diagrams of Colle Curti and Cesi (Terni, Umbria) (Bertini 2000) show high percentages of herbaceous forms. In addition, *Bison schoetensacki* Freudenberg, 1910 and *Sus scrofa priscus* Goldfuss, 1832 occur for the first time.

According to Croitor (2009), the genus *Arvernoceros* became extinct in Europe during the end-Villafranchian faunal turnover when the climate became colder. The species *A. giulii* seems to be present for a well-defined time span, correlated with the Villafranchian-Galerian transition, and in Italy it seems to characterize the latest Villafranchian together with the genus *Praemegaceros*. Furthermore, preliminary analysis of the giant deer from Cava Redicicoli (Rome, central Italy) reveals the probable presence of *Arvernoceros* even at this later site. However, due to the composition of the Redicicoli fauna, Caloi et al. (1979) and Di Stefano et al. (1998) suggest the presence of two different faunal assemblages, which are believed to come from two different levels. The first level is correlated with the Pirro FU and the second with the Isernia FU. Caloi & Palombo (1995, 1997), Palombo et al. (2002) and Milli & Palombo (2005) suggest that the taxa are coeval and that the Redicicoli faunal assemblage should be ascribed to the Colle Curti FU only. Unfortunately, the fossiliferous deposit does not exist anymore and any stratigraphic information can only be derived from the fossil remains.

Finally, the presence of *A. giulii* in the sites of Madonna della Strada and Selvella is the oldest records of this species in Western Europe. However, delayed dispersal events are common in Italy during the Pleistocene, in particular for species that arrive from Asia (for example, *Coelodonta antiquitatis* is not present before MIS 4 and *Praemegaceros solilhacus* is present during the Isernia FU, about 0.600-0.550 My) (Petronio et al. in press). Some African or southeastern European taxa seem instead to be present first in Italy and later in central Europe. This is the case of *Hippopotamus antiquus*, *Dama clactoniana*, *Arvernoceros giulii* and perhaps *Homo* (Petronio et al. in press). The first occurrences in Italy of these taxa can be correlated with Adriatic Sea low stands (its maximum depth in the northern and central areas about 200 m) during the Pleistocene. The presence of a wide "Levantine Corridor" has probably allowed easier access to Italy for taxa present in Eastern Europe as *Arvernoceros*.

However, a more detailed analysis is needed to investigate the probable relationship between the concurrent dispersal events in Italy of the genus *Homo* and *Arvernoceros* and the relationships between the latter and the other giant deer present in the peninsula.

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