

BODY SIZE REDUCTION AND TOOTH AGENESIS IN LATE PLEISTOCENE *MELES MELES* (CARNIVORA, MAMMALIA) FROM INGARANO (SOUTHERN ITALY)

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Abstract. In mammals combined factors such as body size reduction and loss of peripheral teeth are often associated with endemism phenomena. This condition is particularly evident in insular contexts where is a complete geographic isolation. During the Pleistocene there have been several glacial stages, which changed the physiognomy of the Italian peninsula strongly influencing the distribution and morphology of mammalian faunas. Several genetic studies have shown that some Southern Italian areas have particular endemic species of small and medium size mammals. During Pleistocene these areas have been characterized by particular climatic/environmental conditions, and are generally called “glacial refugia”. They represent geographically isolated areas over time, where the origin of faunas with peculiar features is favoured.

In this study, the occurrence of *Meles meles* from the Late Pleistocene site of Ingarano (Apulia, Southern Italy) is documented for the first time. This taxon is represented only by a partial skull (splanchnocranium) that, despite the relative completeness, includes peculiar and well-preserved dental features that could be related to a partial endemic condition. The fossil shows a reduced body size and the agenesis of peripheral teeth, both conditions that are typical of the extant badgers from Crete, Rhodes and Japan. To test this hypothesis, tomographic analysis have been provided to establish the dental agenesis, and, in order to understand the magnitude of the body size reduction, biometric analyses have been carried on. The obtained data have been compared to measures of the extant Eurasian badgers.

Introduction

The Eurasian badgers (*Meles* spp.) are large sized mustelids with a stocky body, short limbs and a short tail. Generally, the body length is 590-900 mm, and tail length is 115-202 mm with a weight between 8-16 kg (Nowak 2005). Nowadays these mustelids have a very wide Palaearctic distribution which includes Europe,

the British Islands and several Mediterranean islands (Aegean Islands, Crete, Rhodes) with the species *Meles meles*, large part of Asia including Palestine, Iran, Tibet, and southern China with the species *Meles leucurus*, and Japan with the species *Meles anakuma* (Corbet 1978; Neal 1986; Abramov & Puzachenko 2004; Nowak 2005). Consequently, Eurasian badgers show high variability in skull and body dimensions, with a clinal variation with Est-West direction, where the specimens from China and Japan show smaller skull size than what observed in the specimens from Europe (Lynch 1994). Moreover a body size variation with North-South direction has been identified in Europe (Neal & Cheeseman 1996), therefore Italian populations of badger show a reduced body size if compared to those of central Europe (Boitani et al. 2003). The palaeontological data of the European fossil badgers show a progressive increase of the skull and teeth dimensions in the last 10.000 years (Kurtén 1965, 1967; Clutton-Brock 1990; Grundbacher et al. 1990). In European continent the fossils remains of *Meles meles* are very abundant with a range from late Early- to Late Pleistocene (Madurell-Malapeira et al. 2011a, b; Petrucci et al. 2013). The occurrence of the Eurasian badger is documented in Italy since the Early Pleistocene (Pirro Nord) (Petrucci et al. 2013), but complete specimens are rare, and the fossil record is represented mainly by fragmentary mandibles and isolated teeth (Fabiani 1922; Graziosi 1928, 1944; Tozzi 1970; Pitti & Tozzi 1971; Radmilli 1974, 1977; Cassoli 1976/1977).

In 2000, during a field survey at the Late Pleistocene site of Ingarano (Apulia, South Italy) (Fig. 1), a research team of the Earth Science Department of Sa-

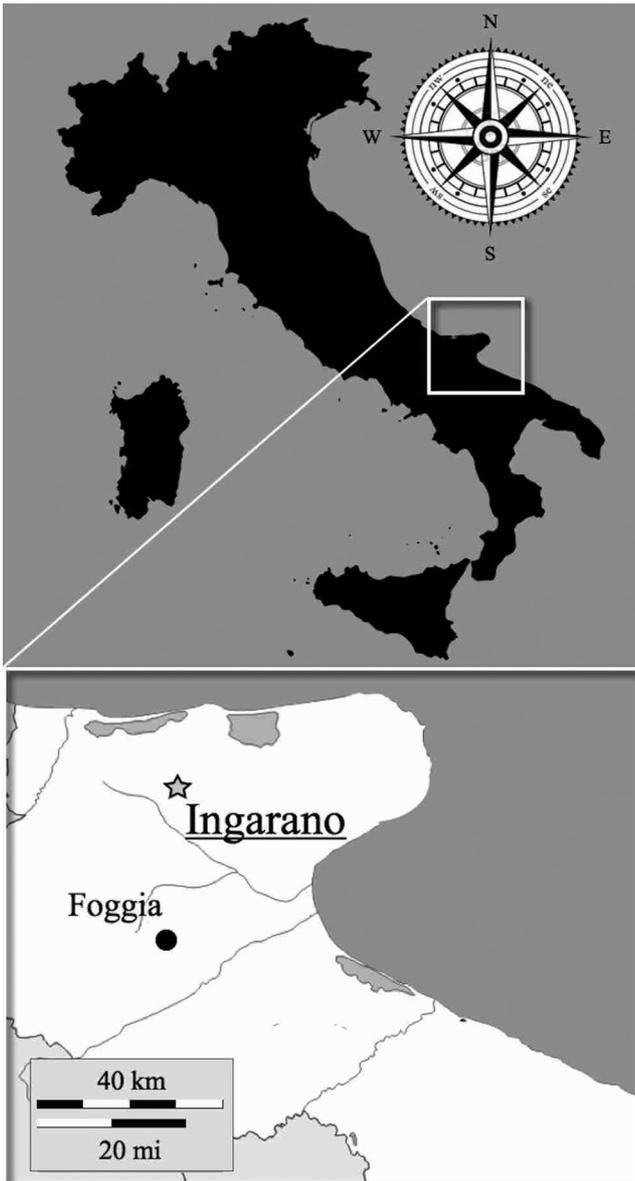


Fig. 1 - Map of Italy with the location of the Ingarano site.

pienza University of Rome collected a rostrum fragment of *Meles meles* (Fig. 2) coming from layer E (see the following stratigraphical description). In 2012, after the restoration of the fragment from the thick encrustations, it was possible to classify the fossil and submit it to tomographic analyses. Despite the wide distribution of *Meles meles* in the Late Pleistocene of Southern Italy, the fossil here described is the first evidence of the species from the Late Pleistocene site of Ingarano. Moreover, despite the relative completeness, includes important and well-preserved peculiar dental features.

The reduction in size shown by some extant populations, involves a reduction in the overall size of the skull, which in turn is directly related with the teeth crowding, including loss of the peripheral teeth of the tooth row (Wolsan 1983). Dental anomalies are largely documented and studied in almost mammalian orders

(Wolsan 1984), including variations in number (extra teeth, missing teeth), morphology (twin and reduced teeth, simplified patterns), position (displaced teeth) and occlusion, in eruption, or in the internal structure (colour changes, hypomineralization or hypoplasia of the enamel) (Hoff & Hoff 1996). Dental anomalies can be related to genetic mechanisms, nutritional and metabolic diseases, and can provide clues to phylogenetic relationships and evolutionary trends.

Loss of premolars and molars has been seen in several insular taxa, such as cervoid (*Hoplitomeryx matthei*), bovids (*Myotragus batei*, *M. balearicus* and *Marmemmia lorenzi*), canids (*Cynotherium sardous*), pigs (*Sus sondaari*) and hippopotamuses (*Phanourios minor*) (Van der Geer et al. 2010). The trend of reduction in size is observed also in a large number of extant mammals of the Italian peninsula. In Eurasian badgers the presence-absence of the first premolars has been described many times (Heptner et al. 1974; Spittler & Jansen 1985; Baryshnikov & Potapova 1990; Lüps 1990; Szuma 1994; Baryshnikov et al. 2003). The variability of the P¹ indicate a distinct clinal variation (Baryshnikov & Potapova 1990; Lüps 1990; Abramov & Puzachenko 2004). Heptner et al. (1974) note that the lowest frequency of P¹ is characteristic of Far East badger populations. Moving from the East towards the West the frequency of the occurrence of P¹ gradually grows (Abramov & Puzachenko 2004; Baryshnikov et al. 2003). In this paper, the specimen from Ingarano is considered to be a case of tooth agenesis in the Late Pleistocene of Southern Italy, possibly related to an endemization process in a peninsular context.

Methods

Tomographic images have been made at “M. G. Vannini” Hospital (Roma) by a Philips Brilliance CT 64-channel scanner. The skull of *M. meles* from Ingarano (ING 2000/12) was scanned in its entirety in the coronal (transverse of some authors) slice plane from front to back. The scanning resulted in 298 slices (images) with dimensions of 768 × 768 pixels. The slices are 0.45 mm thick with an interslice space (the space between consecutive slices) of 0.20 mm. Segmentation and 3D rendering of the rostrum fragment was computed using the Open-Source software Osirix 3.9.4, 32-bit for Mac.

Material. ING 2000/12: Anterior portion of rostrum with right and left I³, right and left C and both P³ broken (Fig. 2).

“ING” refers to Ingarano site. The fossil is housed at the Earth Science Department of Sapienza University of Rome.

Geological setting

The Ingarano site is located near the Apricena town (Foggia, South Italy) at about 270 m.a.s.l (Fig. 1). The fossil deposit is about 12 m thick and was discovered in the 1985, and in 1992 a complete stratigraphy analysis has been provided. The geochemical analysis of

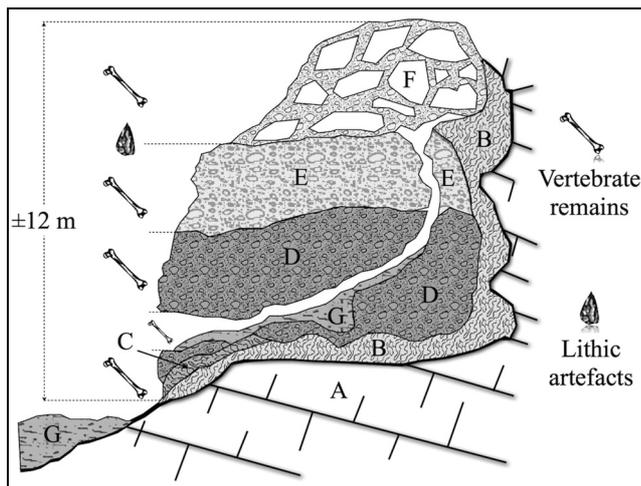


Fig. 2 - Schematic representation of the stratigraphic section of the Late Pleistocene Ingarano succession. For the description of the different layers, see text.

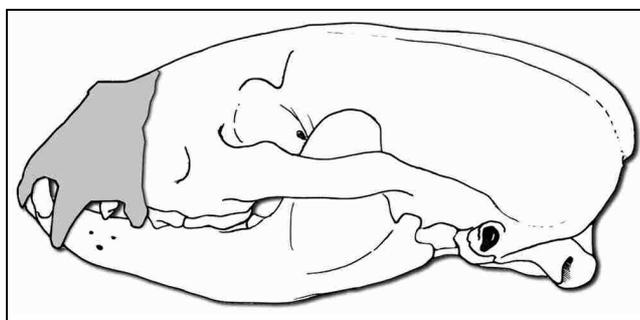


Fig. 3 - Schematic badger skull: In evidence the fragment ING 2000/12 from the Late Pleistocene Ingarano, site (South Italy).

the phosphatic material with the $^{239}\text{Th}/^{234}\text{U}$ method has provided an age of 40.000 ± 2.000 years BP (Capasso Barbato et al. 1992; Bedetti & Pavia 2007). The stratigraphic sequence includes seven layers of different thickness, ranging from a few centimetres to several meters (Fig. 3). The entire stratigraphic sequence stands on Jurassic-Cretaceous limestones of the "Calcare di Sannicandro" Formation indicated as Layer A. The Layer B is represented by Mesozoic limestone (alabastine) and includes some stalagmite and stalactite fragments. The Layer C is a phosphatic encrustation rich in middle- and small-size vertebrate remains. The Layer D, a homogeneous massive conglomerate with flattened calcareous pebbles of small size, overlies these two layers while the silty reddish matrix is locally poorly cemented. The thickness of this layer is variable from one to three metres. A discontinuity surface indicates the passage to another conglomerate two to four metres thick, the Layer E with angular clasts. The Layer F, a two to three m-thick conglomerate with large angular clasts cemented by calcareous matrix (Bedetti & Pavia 2007), closes the Ingarano Pleistocene succession. The Layer G consists of incoherent clayey sediment that fills

small galleries that meander in Layers D and E. At the top of layer E, some Mustertian artefacts were collected (Petronio et al. 1996).

The rich vertebrate fauna from this site, has been studied by several authors (Capasso Barbato et al. 1992; Petronio et al. 1996; Petronio & Sardella 1998; Curcio et al. 2005; Bedetti & Pavia 2007) It includes 41 species, listed below: Amphibians: *Rana* sp.; Reptiles: *Lacerta* sp.; Birds: *Circus* nov sp., *Aquila chrysaetos*, *Falco tinnunculus*, *Falco peregrinus*, *Perdix perdix*, *Columba livia*, *Pyrrhocorax graculus*, *Corvus monedula*, *Corvus corax*; Mammals: *Erinaceus europeus*, *Myothis blythi*, *Oryctolagus cuniculus*, *Lepus europaeus*, *Microtus* sp., *Microtus* gt. *arvalis/agrestis*, *Terricola savii*, *Apodemus sylvaticus*, *Elyomys quercinus*, *Canis lupus*, *Vulpes vulpes*, *Ursus arctos*, *Mustela nivalis*, *Martes* sp., *Gulo gulo*, *Crocuta crocuta*, *Felis silvestris*, *Lynx lynx*, *Panthera pardus*, *Equus hydruntinus*, *Cervus elaphus*, *Dama dama dama*, *Capreolus capreolus*, *Rupicapra* sp., *Bos primigenius* (Bedetti & Pavia 2007). Moreover, remains of *Panthera spelaea*, *Hippopotamus amphibius*, *Coelodonta antiquitatis*, *Stephanorhinus hemitoechus*, and *Elephas (Paleoloxodon) antiquus* have been collected in a sandy-clay level in unclear stratigraphic relationships with the karst succession (Petronio & Sardella 1998).

Description

ING 2000/12 came from Layer E and is represented by the anterior fragment of the rostrum, including the premaxilla, anterior portions of maxilla and the well-preserved anterior portion of the nasal bones (Fig. 4). The remain was enclosed in a hard sediment matrix removed during the preparation phase. The sediment filling the nasal cavities has not been totally removed to prevent damage due to the extreme fragility of the fossil (Fig. 4d). The ING 2000/12 is probably that of an old individual, this would seem evident from the level of wear shown by the teeth, which on their occlusal side have lost much of their enamel. The dentition is not complete and some teeth are partially fragmented. This prevented the study of the teeth morphology and their comparison with other extant specimens. All the incisors are well preserved and moderately worn and their roots are partially exposed (Fig 4c, d, f). The canines are partially damaged, the right one lacking the apex and broken at half-length level, while the left one completely lacks the distal portion (Fig. 4a, b). On the anterior edge of the right canine is clearly evident a wear plane due to friction with the lower canine, probably due to malocclusion (Fig. 4c). The first and second premolars are missing; therefore this specimen shows a large diastema between the canines and third premolars (Fig. 4f).

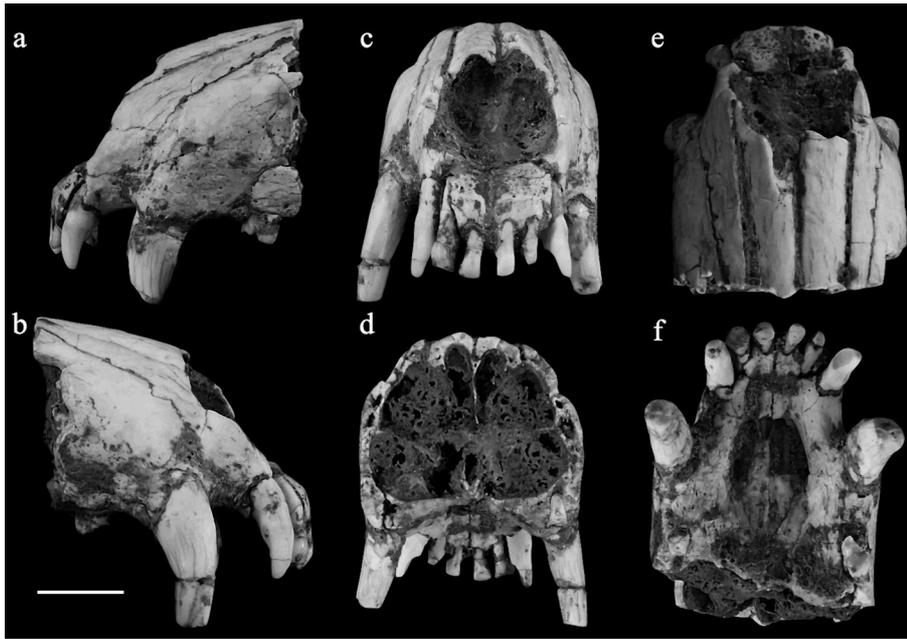


Fig. 4 - Splancnocranium of the Late Pleistocene *Meles meles* (ING 2000/12) from Ingarano (South Italy). a,b) Lateral view; c) frontal view; d) caudal view; e) dorsal view; f) occlusal view. Scale bar = 1 cm.

Locality	<i>Meles meles</i>		<i>Meles leucurus</i>		<i>Meles anakuma</i>	<i>Meles from Ingarano</i>
	European sample	Transcaucasian sample	Siberian sample	Far-Eastern sample	Japan	South Italy
Sex / N Specimens	Male N = 72	Male N = 48	Male N = 111	Male N = 15	Male N = 8	? N = 1
Width of rostrum	32.2 28.5-35.1	29.4 26.0-32.6	29.3 25.0-32.5	27.2 25.0-29.7	24.6 23.2-27.0	25.5
Length of upper Canine	8.6 7.6-9.8	7.6 6.5-9.2	7.7 6.7-9.0	7.1 6.7-8.2	6.5 6.2-7.0	L 6.0 - R 6.0
Width of upper Canine	6.3 5.4-7.3	5.8 5.1-6.7	5.8 5.0-6.8	5.3 4.6-6.0	4.9 4.6-5.2	L 4.8 - R 4.7
Sex / N Specimens	Female N = 59	Female N = 29	Female N = 44	Female N = 7	Female N = 7	? N = 1
Width of rostrum	30.8 27.0-34.4	27.8 25.3-30.6	27.6 24.9-32.1	25.0 24.1-26.4	23.7 22.4-25.9	25.5
Length of upper Canine	7.9 6.7-8.8	6.8 6.0-8.0	7.1 6.1-8.1	6.1 5.8-6.4	5.7 5.1-6.2	L 6.0 - R 6.0
Width of upper Canine	5.9 4.9-7.2	5.2 4.5-6.3	5.2 4.7-6.0	4.5 4.2-5.0	4.2 3.7-4.5	L 4.8 - R 4.7

Tab. 1 - Measurements of the rostrum and canines of the Late Pleistocene *Meles meles* (ING 2000/12) from the Ingarano site (South Italy), compared with those of extant *Meles meles*, *Meles leucurus* and *Meles anakuma* (data from Abramov and Puzachenko 2004).

Both the diastemata show a smooth surface of the bone, without traces of spongy bone tissue, as a result of the alveolar reabsorption. On the left maxilla there is a very small and damaged fragment of P³ while only the anterior root of P³ is visible on the right one. The anterior roots of P³ are morphologically similar to those of the extant specimens as revealed by tomographic analysis.

In lateral view, the fossil shows an evident fracture which breaks the nasal and maxillary bones along a continuous vertical plane (Fig. 4a, b). In frontal view, there is a deep fracture line that affects both premaxillae and has exposed a wide portion of the root of the I³ (Fig. 4c). Sediment fills the nasal cavity, therefore it is not possible to see the turbinate that are very well preserved and visible in caudal view (Fig. 4c, d). In dorsal view the rostral portion of the left nasal is broken and both the premaxillae show a bone porosity probably of pathological origin (osteomyelites) (Iurino et al. 2013a) (Fig. 4e). In ventral view the anterior portion of choanae collapsed, both P¹ and P² are missing and there is no

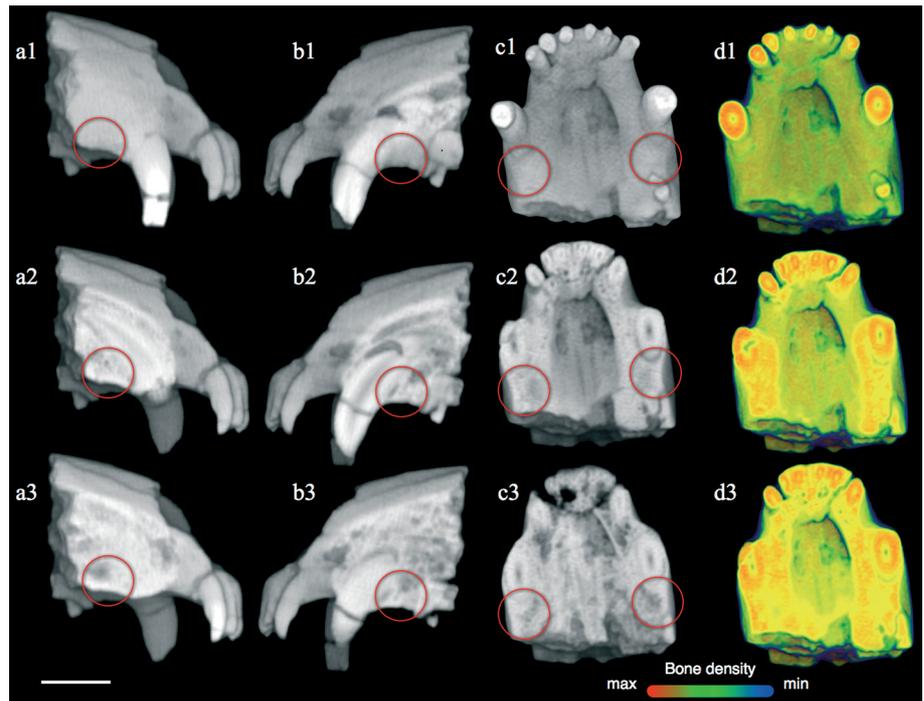
trace of alveolar reabsorption (lack of spongy bone) (Fig. 4f). Compared to the extant badgers the Ingarano specimen shows a very similar morphology of the rostrum but with a smaller size (Tab. 1).

Discussion

The occurrence of *Meles meles* in the fossil deposit of Ingarano, add a new element in the faunal list of the site. European badgers have a great adaptability, thus its occurrence at Ingarano does not provide any significant palaeocological information, but anyway through the analysis of the body size and the presence-absence of teeth and bone abnormalities is possible to infer interesting palaeocological data.

The fossil from Ingarano shows an abnormal dentition, with the first and second upper premolars missing (Fig. 4f). The teeth do not seem to have fallen, smooth morphologically normal bone is present at the

Fig. 5 - Tomographic images of the Late Pleistocene *Meles meles* (ING 2000/12) from Ingarano (South Italy). a1-a3) Sequence of virtual sections of the specimen in lateral view (right side). b1-b3) Sequence of virtual sections of the specimen in lateral view (left side). c1-c3) Sequence of virtual sections of the specimen in occlusal view. d1-d3) Sequence of virtual sections of the specimen in occlusal view with the bone density filter. The image shows a dense bone structure in correspondence of the diastema area. The red circles indicate the absence of first and second premolars. Scale bar = 1 cm. (Electronic version in color).



sites but they never erupted (symmetrical agenesis) and no trace of alveolar reabsorption (lack of spongy bone) can be noticed (Fig. 5). In addition, the inner structure of the fossil has been investigated with a detailed tomographic analysis that confirms the complete absence of P^1 and P^2 roots and the corresponding alveoli. Through the sequential cutting of the fossil, it has been possible to observe the internal structures of the maxilla, in correspondence of the diastema between the canines and third premolars (Fig. 5). The CT images clearly show that in these areas there is no evidence of root fragments of P^1 and P^2 or cavities corresponding to the alveoli. Consequently, the bone tissue is compact and without porosity (Fig. 5). To test this condition, a bone densitometry filter has been applied whose the pattern colour essentially confirms the total absence of both the roots and the alveoli in the surveyed areas (Fig. 5d1-d3). In fact, the bone tissue is presented in orange/yellow colour, in a chromatic scale in which red represents the highest density and blue the least. As seen in the figure 5 the section of the teeth is of red/orange colour, that of the bone tissue in the diastema areas is orange/yellow, while completely missing the patches of green and blue colours (low density), possibly found in the presence of spongy bone tissues (Iurino et al. 2013a, b). The tomographic analysis show how the missing teeth have not been lost during the life of the animal, with subsequent reabsorption of the alveoli, because in this case the colour response would have been significantly different. Therefore, the evidence of the virtual segmentation of the specimen and the densitometric analysis suggest that the first and second premolars of the maxilla never erupted.

The agenesis of upper premolars is reported in a large number of mammals, humans included (Ueberberg 1965; Elzay & Hughes 1969; Kvam 1985; Wederlin 1987; Hancox 1988; Verstraete et al. 1996; Vastardis 2000; Drehmer et al. 2004), and is reported in some Asian badger specimens (Baryshnikov & Potapova 1990; Baryshnikov et al. 2003). Cases of oligodontia and tooth agenesis in mustelids are more often related to the peripheral teeth (premolars and molars) (Ruprecht 1978). According to Hall (1940), variation in tooth pattern in mammals is more often the result of oligodontia/tooth agenesis than polydonta. The tooth pattern variations in Palearctic badgers are of difficult interpretation. Such a condition could be the result and effect of combined action of different mutagenic factors due to climatic, ecological, trophic and genetic variations. The process of shortening of the molarization field of the upper jaw was already observed in other Carnivora, such as foxes and some other canids, and may represent a trend for this group (Szuma 1994). As for these carnivores, in badgers the tooth agenesis can be due to a general trend of teeth reduction. Furthermore is interesting to note that Asiatic badgers, with smaller skull dimensions than those of Europe (Lynch 1994), show a greater tendency in the loss of the first upper premolars (Baryshnikov & Potapova 1990; Szuma 1994; Baryshnikov et al. 2003). In the central Europe the frequency of occurrence of P^1 ranges from 70% to 75% while in the badgers from Kazakhstan the percent of present P^1 approaches 2% and in the Japanese badgers are completely absent (Szuma 1994). The agenesis of the upper second premolars in European badgers are not reported in literature, and the absence of these teeth

is associated only with the loss during the life, due to injuries and pathologies (Hancox 1988). Although ING 2000/12 consists in a reduced portion of the rostrum, some measures relating to the width of the rostrum, the length and width of the upper canines can be taken (Tab. 1). The wear degree of the upper incisors suggests that this specimen was an adult animal. The rostrum and canines dimensions are extremely small if compared with those of *Meles meles* (European badger) and *Meles leucurus* (Asian badger), while it fits well with those of *Meles anakuma* (Japanese badger) (Tab. 1) (Abramov & Puzachenko 2004). Therefore, the Ingarano badger shows the same reduced body-size and P¹ loss of the insular Japanese badgers. This information allows strengthening the considerations reported by Neal and Cheeseman (1996) about the body size variation with north-south direction in extant European *Meles meles*.

According to Baryshnikov et al. (2003) the badgers from Rhodes and Crete may be identified as a small *M. meles*, demonstrating some characters occurring in *M. anakuma* as the absence of first premolars and reduced body-size. Unfortunately, the sample of badgers from these two islands reported by Baryshnikov et al. (2003) is too small to obtain reliable inferences. However, the same features are observed in neighbouring populations from the continental part of Asia. Starting with the assumption that the ancestor of extant European badgers was *Meles thoralis*, that had a Palearctic distribution in Late Pliocene (Madurell-Malapeira et al. 2009), in the Early Pleistocene divergence of marginal populations began, probably because of separation of West European and East Asian parts of the range. This led to formation of two allopatric species in the Middle Pleistocene: *M. meles* in Europe, *M. leucurus* in Central and Eastern Asia (Baryshnikov et al. 2003; Madurell-Malapeira et al. 2011a).

The badger from Ingarano shows some *M. leucurus* and *M. anakuma* features as body-size reduction and P¹ loss. Moreover, this condition is accentuated by the agenesis of the second upper premolars, and suggests a possible phenomenon of adaptive convergence between the islands and peninsulas populations of the Eurasian badgers. Probably the Italian peninsula during the Late Pleistocene was the area in which the body-size reduction of the European badger was highest. Several genetic and paleontological studies indicate the Mediterranean area as a possible refuge during the last glacial periods. In some cases, the geographic isolation has produced characteristic morphological and genetic patterns, especially in small and medium-sized mammals (Bilton et al. 1998; Sommer & Nadachowski 2006).

Among the extant small-size mammals the most interesting cases are represented by: *Lepus corsicanus* (Pierpaoli et al. 1999), *Talpa romana* (Ungaro et al.

2001), *Myodes glareolus* (Amori et al. 2008), *Microtus brachycercus* (Castiglia et al. 2008), *Sciurus vulgaris* (Grill et al. 2009) e *Sorex minutus* (Vega et al. 2010) where South Italian populations show genetic and morphological features slightly different from the other Italian and European populations. A similar condition is also detected in several species of amphibians and reptiles: *Triturus italicus* (Ragghianti & Wake 1986), *Rana (Pelophylax) lessonae* (Santucci et al. 1996; Canestrelli et al. 2008), *Salamandra salamandra* (Steinfartz et al. 2000), *Salamandrina terdigitata* (Mattocchia et al. 2005; Nascetti et al. 2005; Canestrelli et al. 2006a), *Bombina pachypus* (Canestrelli et al. 2006b), *Hyla intermedia* (Canestrelli et al. 2007), *Rana italica* (Canestrelli et al. 2008), *Hierophis viridiflavus* (Nagy et al. 2003), *Podarcis sicula* (Podnar et al. 2005), *Vipera aspis* (Ursenbacher et al. 2006) e *Lacerta bilineata* (Böhme et al. 2007). Medium/large size mammals have greater dispersal ability and, in addition, the original populations of the Italian peninsula have been subject to many reintroductions occurred in historical times. Such conditions, together with strong hunting pressures, caused the local extinction of some endemic populations. These factors have greatly complicated the identification and the genetic and morphological analyses of original populations. Despite this at the moment are reported different subspecies of large mammals from the Italian peninsula: *Canis lupus italicus* (Lucchini et al. 2004; Randi et al. 2000; Stronen et al. 2013), *Ursus arctos marsicanus* (Vigna Taglianti et al. 1984; Boitani et al. 2003), *Lynx lynx alpinus* (Ragni et al. 1993) and *Capreolus capreolus italicus* (Lorenzini et al. 2002) all linked by smaller body-size and by specific genetic and morphological features. The original populations of *Sus scrofa scrofa* present in Italy show body-size reductions if compared with those of Central Europe, although they are not considered as a distinct subspecies (Apollonio et al. 1988). The list of species given above shows that among the extant vertebrates from the Italian peninsula, there is a large number of endemic species.

The paleontological record is much more fragmentary than the zoological one, and to define the presence of endemic species in the Late Pleistocene of Italy is a complicated matter. This is mainly due to the scarcity and fragmented nature of the fossil record that in many cases prevent diagnostics information about the body-size reduction. Therefore, even a general estimation of Italian peninsular endemics during the Pleistocene cannot be depicted in detail, with just few works on this topic.

Some recent case studies could suggest the possible occurrence of endemism among carnivores, especially in the Late Pleistocene of Southern Italy, and the Ingarano fossil record is of particular interest to this purpose. Sardella et al. (in press) show how the Late

Pleistocene wolves (*Canis lupus*) of the Southern Italy, among them nine specimens from Ingarano site (IN604; IN505; IN507; IN517; IN634; IN509; IN635; IN110; IN511), are smaller than those from coeval European sites and generally smaller than the extant Italian wolves. In addition, at Ingarano also *Gulo gulo* (ING 2000/12) occurs (Sardella 2000) and the specimen discovered (a mandible) is substantially smaller than the Late Pleistocene specimens from the North Italy and the Central Europe (Iurino et al., unpublished data).

Therefore endemization processes could affect carnivores in the Late Pleistocene of Southern Italy, thus, the set of characters belonged by *Meles meles* (ING 2000/12), may be related to such a condition. Multiple factor such as the Bergmann's rule, resource limitation, restricted area, intra- and interspecific competition, the composition of peninsular faunas in glacial refugia could cause the body-size reduction in some

peninsular and insular mammals. Endemization process in palaeontological record is not clearly detectable in non-insular contest. Trends in body-size reduction and loss of peripheral teeth reported in fossil mammals are characters suitable for such interpretations, and the Ingarano badger shows both of these characters. Anyway, the scantiness of the sample suggests to consider the hypothesis of an endemization process of this Apulian mustelid with caution, and to address further analyses on the Ingarano vertebrate assemblage to test such hypothesis.

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