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The incisors and premolars of *Ursus* gr. *spelaeus* from Mt. Fenera (Borgosesia-Piedmont, Italy). Could it be *Ursus s. eremus*?

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Ursus gr. *spelaeus* | Mt. Fenera | Zähne | Morphometrie-Morphodynamik | Evolution

Abstract: Mount Fenera arises in NE Piedmont (N. Italy) and its caves are rich in vertebrate fossil remains, mostly cave bear bones. The most well-known cave is surely the Ciota Ciara, but others less known (Riparo Belvedere, Ara, Grotta della Morgana) are abundantly rich in bears bones. For the first time the incisors and the premolars, coming from these caves are morphometrically studied including the elaboration of the morphodynamic analyses. The preliminary results of this study show the possible presence of *Ursus s. eremus* in these caves, whereas *Ursus ingressus* never arrived in this area, to track a possible phyletic relationship with other Italian and foreign cave bear populations.

Kurzfassung: Der Mount Fenera erhebt sich im Nordosten Piemont (Norditalien) und seine Höhlen sind reich an fossilen Überresten von Wirbeltieren, hauptsächlich Knochen von Höhlenbären. Die bekannteste Höhle ist sicherlich die Ciota Ciara, aber auch andere, weniger bekannte Höhlen (Riparo Belvedere, Ara, Grotta della Morgana) sind reich an Bärenknochen. Zum ersten Mal wurden die Schneidezähne und die Prämolaren aus diesen Höhlen morphometrisch untersucht, einschließlich der Ausarbeitung morphodynamischer Analysen. Die vorläufigen Ergebnisse dieser Studie zeigen das mögliche Vorhandensein von *Ursus s. eremus* in diesen Höhlen, während *Ursus ingressus* nie in diesem Gebiet vorkam, und eine mögliche phyletische Beziehung zu anderen italienischen und ausländischen Höhlenbärenpopulationen.

Introduction

Cave bears (*Ursus* gr. *spelaeus*) have been the subject of a lot of studies that embraced different fields of research such as morphometry, climatology, behavioral, genetic, chronological, diet, phylogeny, and so on. Only in the last 20-25 years the Italian cave bear populations have been intensively analyzed mostly morphometrically and morphodynamically, but chronologically and genetically, research are still in an initial phase (Santi & Rossi, 2020). These populations of cave bears come from localities distributed in different regions of North Italy (Piedmont, Liguria, Lombardy, Veneto, Trentino A.A. and Friuli Venezia Giulia), therefore, for some regions (for example Piedmont and Trentino A.A.) researches are still in a preliminary phase. In Piedmont only few populations have been studied (Grotta del Bandito in Cuneo Province, Sambughetto Valstrona in Vercelli Province) and in order to deepen this knowledge, the cave bears from Mount Fenera (Borgosesia, Vercelli and Novara Provinces) (**Fig. 1**) can give an important contribution. In this first study both the incisors and premolars (lower and upper) are morphometrically and morphodynamically analyzed with the aim of trying to individuate a possible taxon and a phyletic relation with other Italian and foreign cave bear populations.

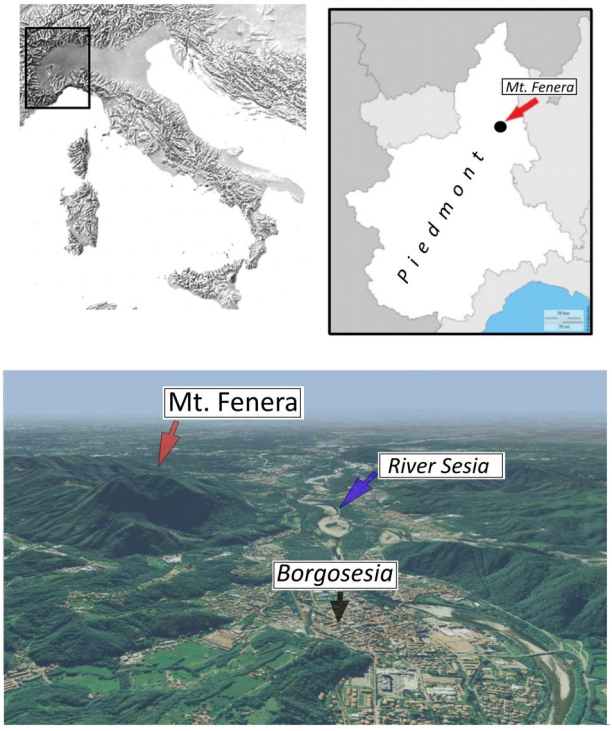


Fig. 1: Geographical position of the Mount Fenera (Piedmont, N. Italy). | **Abb. 1**: Geografische Lage des Mount Fenera (Piemont, Norditalien).

Some notes on the Mount Fenera

Mount Fenera (899 m a.s.l) arises in NE Piedmont (Vercelli and Novara Provinces). Today it is within the natural park »Ente di Gestione delle Aree Protette della Val Sesia«. From the caves of Mt. Fenera, namely the Riparo Belvedere, Ara and Grotta della Morgana and the Ciota Ciara, where in the latter the anthropological excavations have been very extensive, a faunstic assemblage composed of large mammals has been found and collected (Cavicchi, 2018, unpublished). The main component is *Ursus spelaeus*. Two dates have been advanced for the material from Ciota Ciara only; based on the micromammals assemblage the age of both US 13 and US 14 is between 130-80 ky, namely inside the MIS 5 (Berto et al., 2016). Vietti (2016) considered three fossils from the US 14 level (m_3 of *Rupicapra rupicapra*, M^2 of *Cervus elaphus* and a lower molar of *Bos* vel. *Bison*), and using the ESR/U-series method of the Laboratory of the Muséum d'Histoire Naturelle of Paris found these radiometric dating: 310 ± 30 Ky and 281 ± 45 Ky which could insert them within the US 14 level between the end of MIS 9 and the beginning of MIS 8.

Materials and methods

The incisors (i_1, i_2, i_3; I^1, I^2, I^3) and premolars (P^4/p_4) studied come from caves which open within Mt. Fenera; we have also utilized P^4/p_4 data from Ciota Ciara (Cavicchi, 2018, unpublished), considered the most important among them. Globally, the number of the incisors is 102. In **Tab. 1** the global amount of incisors and the different kinds of teeth from both Mt. Fenera and from different caves in North Italy, are reported with the main statistical data. We have measured the incisors and premolars applying the Rabeder (1999), Tsoukala & Grandal d'Anglade (2002) and Baryshnikov et al. (2018) parameters, whereas the P^4/p_4 from the Ciota Ciara have been utilized to elaborate the morphodynamic analysis. The morphodynamic analyses were elaborated utilizing the Rabeder (1999), Baryshnikov et al. (2018), Baryshnikov & Puzachenko (2020) and Gimranov et al. (2021) methods. Using Past 3.2 software (Hammer et al., 2001) a short multivariate analyses was also elaborated.

Results and discussion

Morphometry analysis

Incisors: All types were individuated; generally one of the main problems is to identify the presence of bears like *U. ingressus* in N. Italy and in particular in Piedmont. In this region the presence of oversized cave bears is not documented, but the populations of Grotta del Bandito (Cuneo) and Sambughetto Valstrona (Vercelli) (at present the only populations studied living in Piedmont region) have a size that enters rather well within the statistical mean of the Italian populations, namely a medium size. In fact, the diagram in **Fig. 2** is a proof of this. But, the nearness of Grotta del Bandito to the Basura locality (bears with highest IM of P^4/p_4 = 94.2 std., Quiles, 2004) could suppose the presence of oversized bears; at present a lack of data prevents us from reaching either conclusion. We exclude that oversized bears crossed the Piedmont to colonize the north area of this region (the actual data don't prove this hypothetical passage), but maybe other taxa of bear already occupied this area. This is still an open problem. The data here exposed support the hypothesis that in this region (Piedmont) oversized bears never crossed these territories, and maybe very rarely into W Liguria.

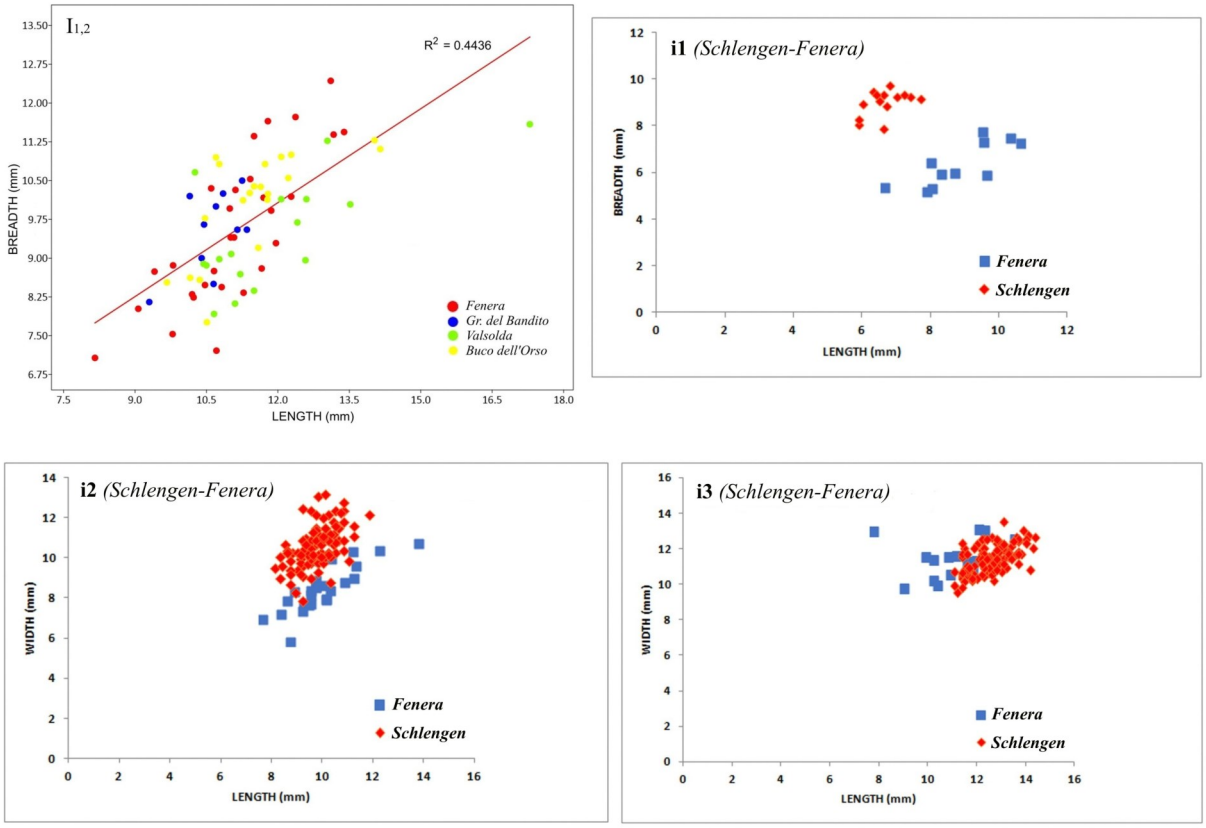


Fig. 2: A-D: Length-Width relationship in upper incisors from Mt. Fenera and some Italian cave bears (A), in i_1, i_2 and i_3 from Mt. Fenera and Schlenkendurchgangshöhle in Bad Vigaun (Austria) | **Abb. 2**: A-D. Längen-Breiten-Verhältnis der oberen Schneidezähne von Mt. Fenera und einigen italienischen Höhlenbären (A), i_1, i_2 and i_3 von Mt. Fenera und Schlenkendurchgangshöhle in Bad Vigaun (Österreich).

A comparison between the size (Length and Width) of lower incisors of the bears from the Schlenkendurchgangshöhle in Bad Vigaun, Austria (in this paper as SDH) belonging to *U. s. eremus* (Knaus et al., 2018) and Mt. Fenera is observable in **Fig. 2**. The size of i_1 and i_2 from Mt. Fenera are clearly smaller than the *U. s. eremus* population of SDH and only i_3 shows a contrary distribution partially linked to that of *U. s. eremus*, and on the basis of these data for the population from Mt. Fenera the presence of bears like *U. s. eremus* cannot be excluded.

Premolars: Morphometrically, the diagrams in **Fig. 3** in which the size of the upper and lower fourth premolars are plotted with the species-types of *U. s. ladinicus* (Conturines), *U. ingressus* (Gamssulzen) and *U. s. eremus* (Ramesch) are very interesting. No differences are observed: the fourth premolars from Mt. Fenera and those of the species-types are very similar. With the use of morphometry only it is very difficult if not impossible to distinguish the different taxa, but considering the conclusions advanced for the incisors we can exclude once again, the presence of *U. ingressus*. A comparison between the P^4 size (Length and Width) of the populations from the different Italian caves (Sambughetto, Valsolda, Grotta del Bandito, Buco del Frate) and Mt. Fenera is shown in **Fig. 3**. Some light differences are individualized probably linked to population variability; consequently, the size of the P^4 for the cave bears that lived in the NW sector of Italy are rather similar and homogeneous.

Morphodynamic analysis

Incisors: i_1: Three different morphotypes (C, C/D and D) (*sensu* Rabeder, 1999) and one with intermediate architecture features (C/D-D) were identified. Following the morphotypes list compiled by Gimranov et al. (2021) three types were identified, namely A1 with the presence of a distoconid, A2 with a distoconid and cingulum around the lingual side, A3 has a smaller mesioconid compared to the distoconid.

i_2: Only the morphotype »s« (acronym of *spelaeus*) was found. The crown is composed of three humps (distoconid, protoconid and mesioconid) with a functional enrichment (Rabeder, 1999). Following the detailed analysis elaborated by Gimranov et al. (2021) we have identified: the types included in the »A-group«, namely A1 with the presence of a distoconid, A2: very large distoconid, A3: presence of mesiocond and a small distoconid, A4: presence of mesioconid and a very large distoconid, A5: presence of a very large mesiocond and distoconid, and the »C-group« morphotypes with C1: presence of distoconid and lingual cusp and C3: presence of mesioconid, lingual cusp and very large distoconid.

i_3: For this kind of tooth the morphotypes are analysed by using the *sulcus mesialis*. Three different morphotypes have been identified: C, B/C and D (Rabeder, 1999). Following the Gimranov et al. (2021) have been individuated: A2 with a small distoconid, A3 with large distoconid and A4 with the presence of a mesioconid.

Locality	i1	i2	i3	I1	I2	I3	Tot.	Locality	I1	I2	I1+I2	I3
Mt. Fenera	12	26	15	9	20	20	102	Mt. Fenera	9	20	29	20
Gr. Bandito		5	8		10	10	33	Gr. Bandito		10	10	10
Sambughetto						3	3	Sambughetto				3
Valsolda		19	7		16	4	46	Valsolda		16	16	4
B. Orso		3	12	3	18	8	44	B. Orso	3	18	21	8
B. d. Piombo			1		4	8	13	B. d. Piombo		4	4	8

Fenera	i1 (n. 11)	i2 (n. 26)	i3 (n. 15)	I1,2 (n. 29)	I3 (n. 20)
Length	Max = 10.63 Min = 6.67 Mean = 8.84 St. dev. = 1.19 *Stand. =* ***134.76***	max = 13.78 min = 7.74 mean = 9.96 St. dev. = 1.27 *Stand. =* ***102.57***	Max = 13.53 Min = 7.78 Mean = 10.90 St. dev. = 1.42 *Stand. =* ***82.58***	Max = 13.39 Min = 8.16 mean =11.09 St. dev. = 1.21 *Stand. =* ***111.12***	Max = 15.49 Min = 9.91 Mean = 12.92 St. dev. = 1.22 *Stand. =* ***68.91***
Width	Max = 7.8 Min = 5.2 Mean = 6.38 St. dev. = 0.95 *Stand.=* ***72.65***	max = 10.75 min = 5.84 mean = 8.49 St. dev. = 1.15 *Stand. =* ***78.24***	Max = 13.11 Min = 9.77 Mean = 11.46 St. dev. = 1.09 *Stand. =* ***92.04***	Max = 12.43 Min = 7.07 Mean = 9.53 St. dev. = 1.45 *Stand. =* ***83.74***	Max = 17.21 Min = 9.62 Mean = 13.93 St. dev. = 1.80 *Stand. =* ***94.37***
Height crown	Max = 12.98 Min = 7.05 Mean = 10.31 St. dev. = 1.99 *Stand. =* ***33.79***	Max = 16.56 Min = 10.02 Mean = 13.06 St. dev. = 1.68 *Stand.=* ***no calcul.***	Max = 15.94 Min = 11.25 Mean = 13.42 St. dev. = 1.27 *Stand. =* ***31.62***	Max = 16.23 Min = 9.11 Mean = 11.88 St. dev. = 2.16 *Stand. =* ***36.39***	Max = 22.48 Min = 14.45 Mean = 19.03 St. dev. = 1.95 *Stand. =* ***38.69***
Height tooth with root	Max = 36.98 Min = 23.67 Mean = 28.13 St. dev. = 4.06	Max = 38.65 Min = 21.07 Mean = 30.19 St. dev. = 4.26	Max = 44.76 Min = 33.03 Mean = 38.28 St. dev. = 4.09	Max = 32.86 Min = 27.28 Mean = 29.47 St. dev. = 4.23	Max = 52.25 Min = 29.85 Mean = 44.09 St. dev. = 6.75

Tab. 1: Main statistical data from the most important parameters in the upper/lower incisors from Mt. Fenera. | **Tab. 1**: Die wichtigsten statistischen Daten der wichtigsten Parameter der oberen/unteren Schneidezähne aus dem Mt. Fenera.

I^1: Four morphotypes were individuated: A1, B1, B2, B3. As Baryshnikov et al. (2018) also indicate, the I^1 morphotypes are characterized by the different development of the cingulum and the variation of the number of cusps (Baryshnikov et al., 2018).

I^2: Four morphotypes have been individuated for this kind of incisor: B2, C1, D1, D2 and most frequently an intermediate morphotype is also individuated (B2/B3). These morphotypes are characterized by the presence of a mesial angle, by degree of the distal cingulun and by their number of cusps (Baryshnikov et al., 2018).

Following Rabeder's morphodynamic development, for both I^1 and I^2 the same morphotypes are valid. For the specimens from Mt. Fenera the following morphotypes were found: d0, p0, p2, s0, s1 and also one intermediate form: s0/s1.

I^3: for this tooth also, four different morphotypes were individuated: A2, A3, A4, B2. They differ from each other by the morphology of the mesial crown (Baryshnikov et al., 2018). According to Rabeder (1999) the morphotypes are individuated using the *kalyx distalis*. For the Mt. Fenera population these are the kinds of morphotypes found: 0, 1, 2, 3 and an intermediate morphotype, 0/1. In **Fig. 4** the percentage of the different morphotypes for the incisors from Mt. Fenera are shown.

The CA analysis (correspondence analysis) is usually utilized when analyzing the frequencies of qualitative features. The relevance of CA is to find a correspondence of the morphotypes of the I^2 and I^3 from cave bears of the Italian populations with those of the Caucasus and Urals (**Fig. 5**). In the diagrams of both I^2 and I^3, cave bears from Caucasus and Urals are grouped along with the Italian ones. In I^2 diagram the Mt. Fenera bears are closer to the *U. kanivetz*, confirming the same observations elaborated with the frequencies of the morphotypes. The CA inherent to I^3 morphotypes shows two clear distributions for the Caucasian and Urals populations and for the Italian populations. In both cases (I^2 and I^3) globally no complete correspondence is observed. Also observing the CA for the i_2 and i_3 we arrive to the same conclusion: the Caucasian and Urals populations do not correspond to the Italian cave bears (**Fig. 5**).

Utilizing Rabeder's morphotypes and considering i_1-i_2, the »C« type is the most abundant in frequency (45%), but together with the »C/D« type the frequencies reach 81%. The morphotype »D« (21% only) is very subordinate. The IM is 236.36 (std = 293.07). When comparing these data with the population from SDH (Bad Vigaun, Austria) belonging to *U. s. eremus* (Knaus et al., 2018), a similarity in the percentage for C and C/D morphotypes is partially identified. In most of the specimens of these two caves (Mt. Fenera and SDH) the C morphotype is mainly individuated, and the biggest difference is found in the greater abundance, from the Austrian site, of the simpler morphotype (A). Unexpectedly the same view, the great presence of A morphotype, can be advanced also for other caves, in particular for the Gamssulzen, the locality-type of *U. ingressus*, but in more caves the same situation is seen, that is, higher frequencies for the lower morphotypes (A, B, C in Rabeder, 1999: 79). With this in mind it seems that i_1 is not an important kind of tooth for phylogenetic discussions or for the identification of taxa.

In i_3 the highest frequency found is the »C« morphotype, while the others individuated (B/C and D have 14% and 21% in frequency, respectively) are much less frequent; globally, the medium-high morphotypes are those mostly identified. This distribution

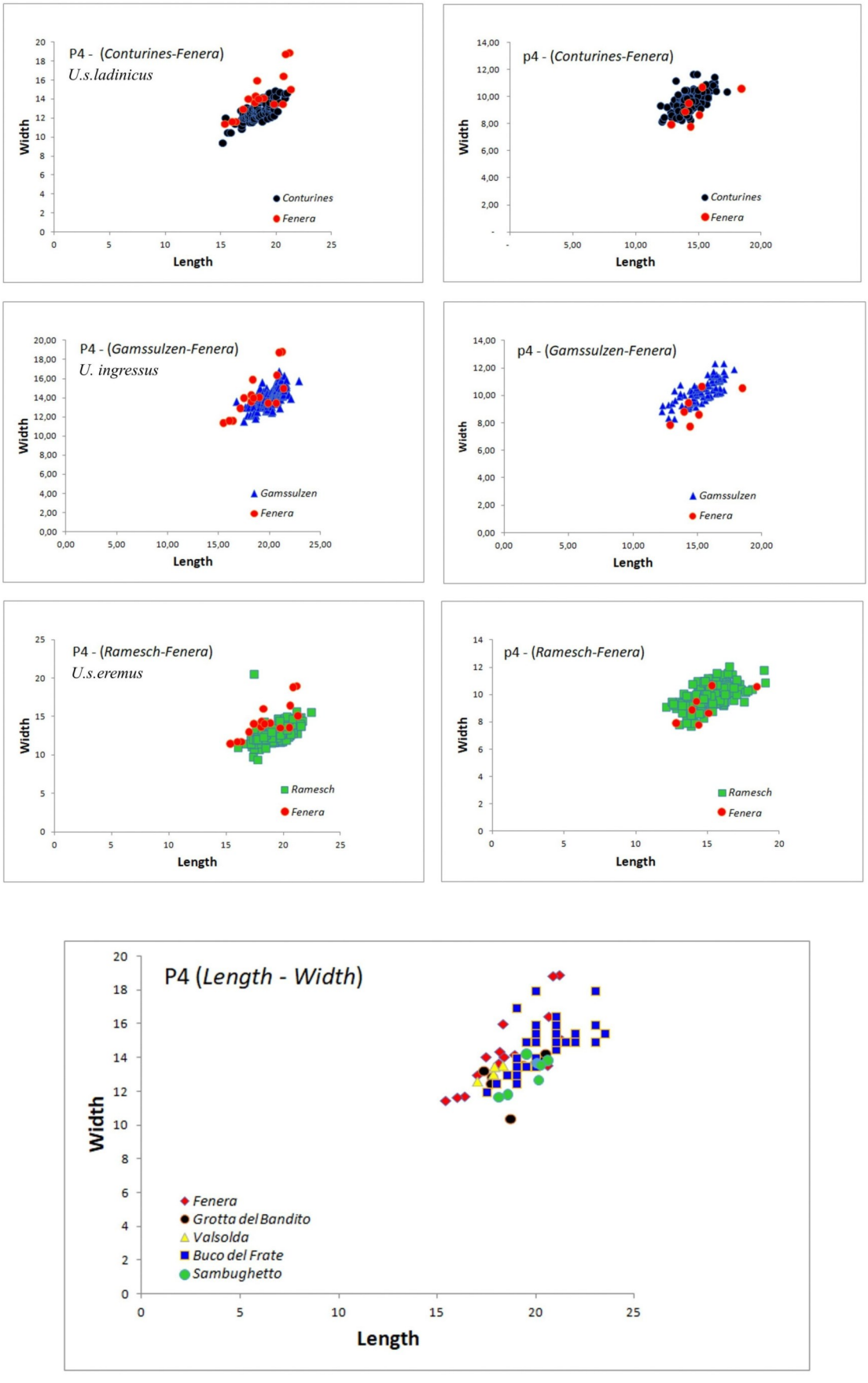


Fig. 3: A-F: Length-Width relationship in P^4/p_4 in bears from Mt. Fenera and Conturines, Ramesch and Gamssulzen. G: Length-width relationship in P^4/p_4 in bears from Mt. Fenera and some Italian cave bears. | **Abb. 3**: A-F: Längen-Breiten-Verhältnis in P^4/p_4 bei Bären aus Mt. Fenera und Conturines, Ramesch und Gamssulzen. G. Längen-Breiten-Verhältnis von P^4/p_4 bei Bären aus Mt. Fenera und einigen italienischen Höhlenbären.

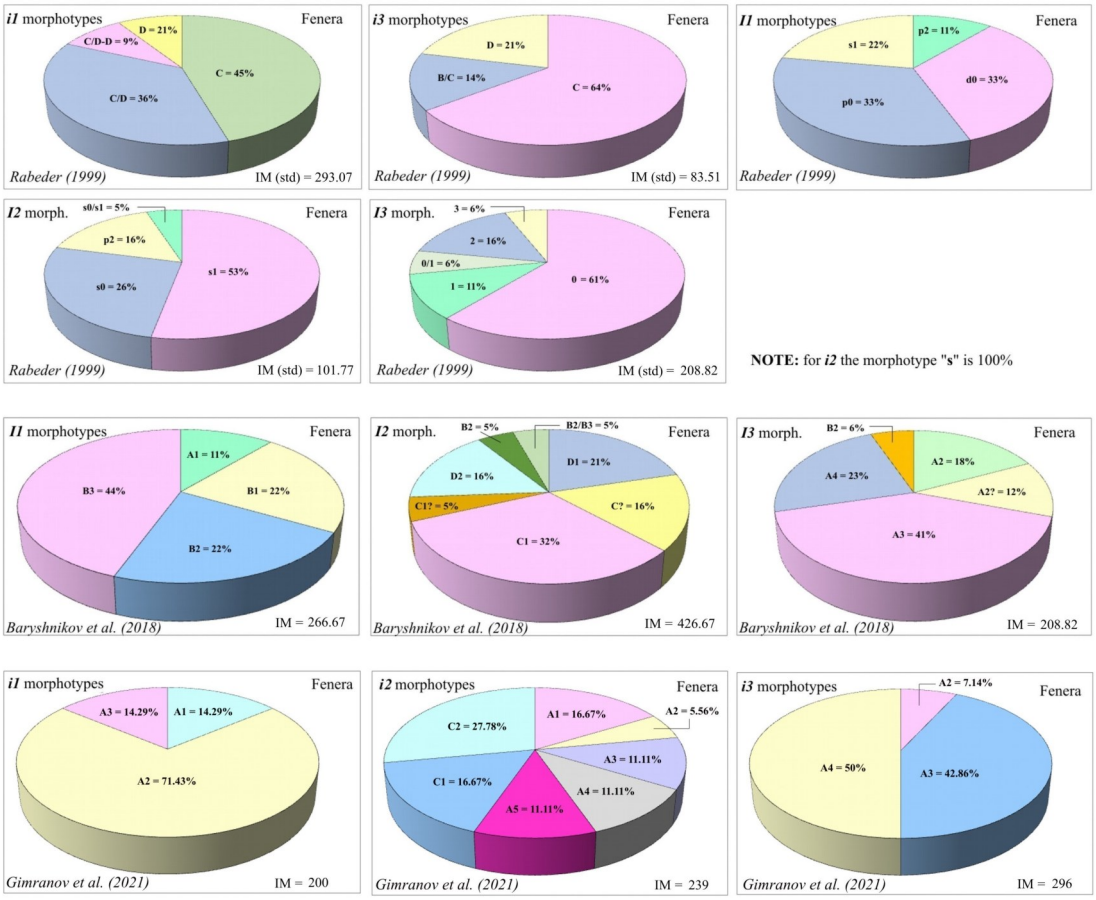


Fig. 4: Frequencies of the morphotypes of the upper/lower incisors from Mt. Fenera. | **Abb. 4**: Häufigkeit der Morphotypen der oberen/unteren Schneidezähne vom Mt. Fenera.

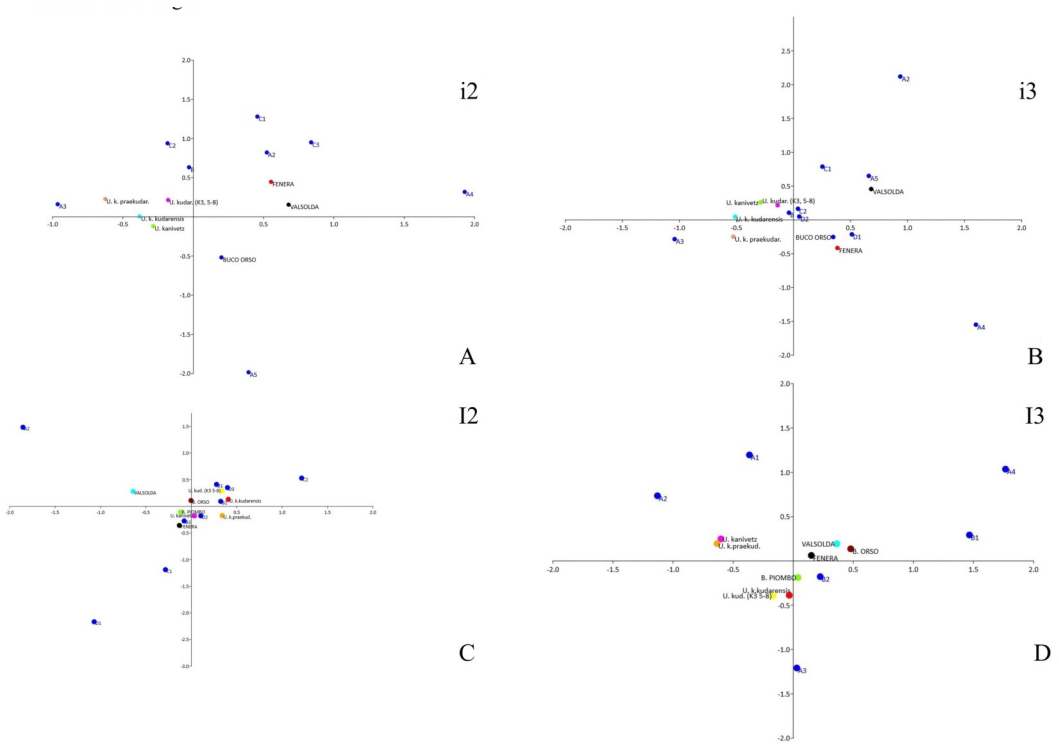
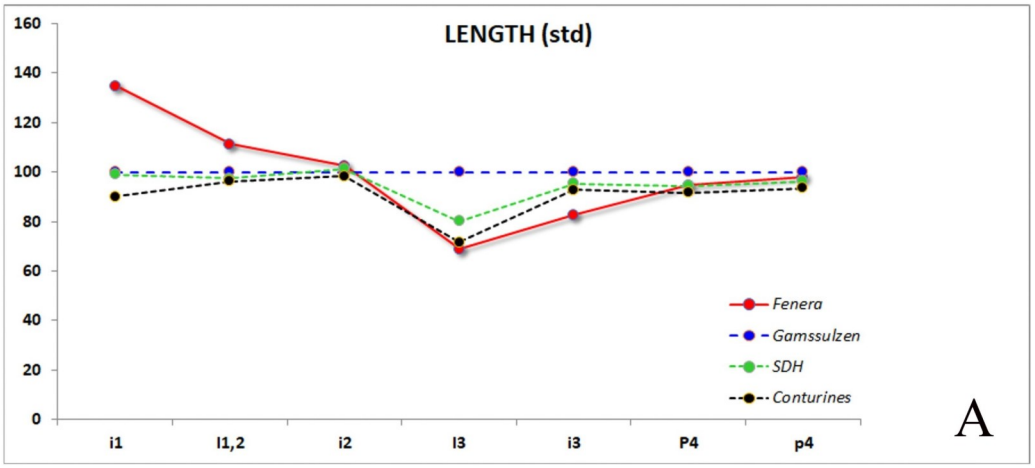
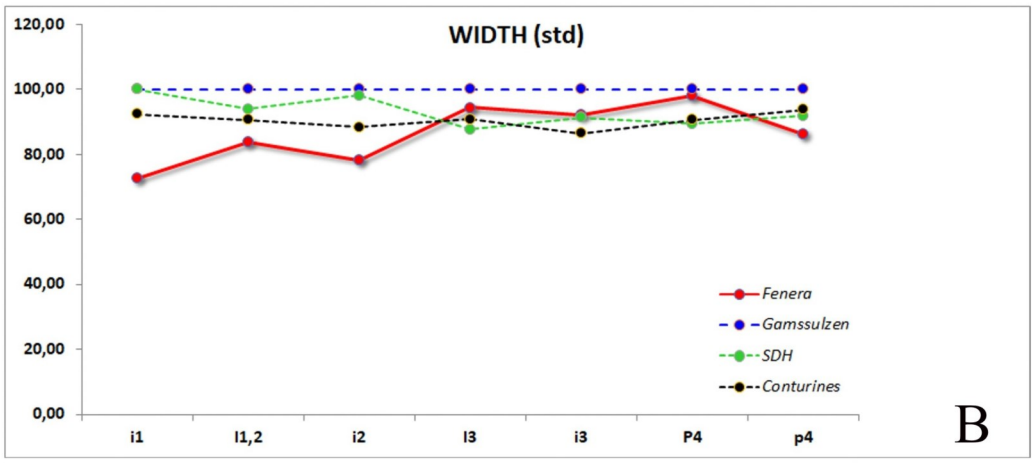


Fig. 5: Correspondence analyses between the incisors from Mt. Fenera and Caucasus-Urals populations | **Abb. 5**: Korrespondenzanalysen zwischen den Schneidezähnen von Mt. Fenera und den Populationen des Kaukasus und des Urals.





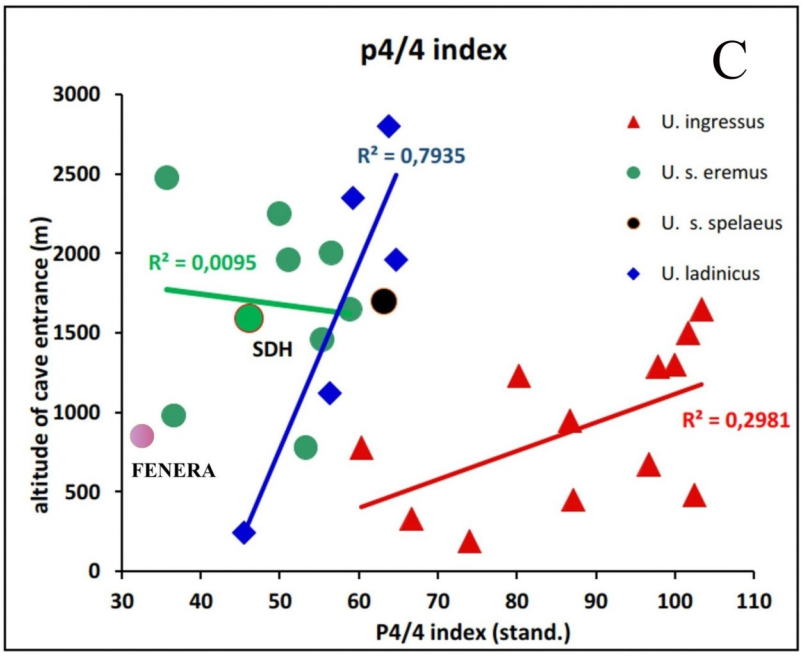


Fig. 6: A: Distribution of the Length (standardized) between the incisors and P^4/p_4 from Mt. Fenera and some European cave bears. B: Distribution of the Width (standardized) between the incisors and P^4/p_4 from Mt. Fenera and some European cave bears. C: Relationship between the P^4/p_4 index (std) and the altitude of the cave entrance in Mt. Fenera and in caves in which lived different taxa of cave bears. | **Abb. 6**: A: Verteilung der Länge (standardisiert) zwischen den Schneidezähnen und P^4/p_4 von Mt. Fenera und einigen europäischen Höhlenbären. B: Verteilung der Breite (standardisiert) zwischen den Schneidezähnen und P^4/p_4 von Mt. Fenera und einigen europäischen Höhlenbären. C: Beziehung zwischen dem P^4/p_4 -Index (std) und der Höhe des Höhleneingangs in Mt. Fenera und in Höhlen, in denen verschiedene Taxa von Höhlenbären lebten.

is not exclusive for the Mt. Fenera population, but seems to be a common fact observed in i_3 of other populations from Europe (see RABEDER, 1999: 73; KNAUS et al., 2018); from a qualitative point of view, these frequencies can be useful to individuate some cave bear taxa (for example *U. ingressus* or more ancient bears such as the Repolust population).

Observing the distribution of the frequencies of the morphotypes in $I^{1,2}$ of the Mt. Fenera population, the group »s« is dominant and the group »p« (p0 and p2) is subordinated. This distribution of the frequencies is a proof that the bears from Fenera are surely speleians, even if a few specimens can be referred to as »d« (acronym of *deningeri*) and »p« (acronym of pre-*spelaeus*) morphotypes. This can be interpreted as an intraspecific variability. As well as observed for other types of incisors (i_3) also for $I^{1,2}$ the main distribution of the frequencies for »p«, »p/s« and »s« morphotypes is global in Europe and like i_3, can be a tool to indirectly define the presence or not of the *spelaeus* group.

Analysing the distribution of the morphotype frequencies in I^3 in **Fig. 4** the »0« morphotype is the most abundant within the population of Mt. Fenera (61%), and the others are subordinated to it. Compared to the other frequencies of distribution of the other European populations we can observe some differences; the percentage of »0« morphotype in the Fenera cave bears is the highest with respect to the other populations, and maybe could be a characteristic of the Fenera bears. At present we haven't enough elements in order to explain this »anomaly« (?), but if we observe the frequencies of the morphotypes in European populations (RABEDER, 1999: 70) the highest frequencies are defined by the »1« morphotype. From this we deduce that the lower morphotypes (»0« or »1«) are rather typical of the speleians in Europe.

Premolars: P^4: For this kind of tooth (n. 51 globally) very different morphotypes were counted: »A« (n. 42), »A/D« (n. 1), »B« (n. 1), »C« (n. 4), »D« (n. 1), »E« (n. 1) and »F« (n. 1) and it is remarkable to note the great abundance of morphotype »A«, the simplest (frequency 82%). Only the morphotype »D/F« is lacking. The Morphodynamic Index (IM) for P^4 is 37.25 (std 14.57).

p_4: Also for this type of tooth (n. 56 globally) the presence of numerous morphotypes was observed, but contrarily to P^4 there is not a great difference among their frequencies. The morphotypes found are: »A« (n. 3), »B1« (n. 10), »B2« (n. 12), »B3« (n. 3), »C1« (n. 11), »C2« (n. 10), »C3« (n. 2), »D1« (n. 2), »D2« (n. 2), »E1« (n. 2). The most complicated p_4 and consequently the highest morphotypes (E2, E3, F2 and F3) are lacking. The main presence is of B1 (17,86%), B2 (21,43%), C1 (19,6%) and C2 (17.86%) and in general the groups »B« and »C« are dominant, while the other morphotypes are subordinated. The Morphodynamic Index (IM) for p_4 is 134.82 (std 68.02); the P^4/p_4 index = 70.87 (std = 31.48).

We have previously proposed the possible presence of *U. s. eremus* within the caves of Mt. Fenera; a probable confirmation could arrive observing the diagrams in **Fig. 6**. In fact the development of the line of the Fenera bears is below that of Gamssulzen (*ingressus*) and similar to those of SDH and Conturines (*ladinicus*). Independently of the fact it that could be *eremus* or *ladinicus* surely it is not an *ingressus* and maybe this taxon never inhabited this area. The same conclusion is confirmed by the observation of the diagram in **Fig. 6C** in which the P^4/p_4 index (std) and the altitude of the caves are plotted, showing that the position of Mt. Fenera is within the distribution of the *U. s. eremus* taxon. If confirmed we have the first evidence of the presence of *U. spelaeus eremus* in North Italy.

Conclusion

The incisors and premolars of *Ursus* gr. *spelaeus* from Mount Fenera (Borgosesia, Piedmont, North Italy) have been the subject of this analysis based on both the morphometry and the morphodynamic methods (RABEDER, 1999; BARYSHNIKOV et al., 2018; GIMRANOV et al., 2021). Comparisons with data from Italian, European and Caucasian-Ural cave bears have also been included. From the morphometry analysis it has been verified that incisors and premolars (P^4/p_4) have a clearly lower size compared to those of the *U. ingressus*, but to identify exactly the taxon in order to classify this population is difficult. Excluding *U. ingressus* as the taxon of appurtenance of the Fenera population, there are not enough decisive elements to indicate one or more taxa (*U. spelaeus spelaeus*, *U. s. eremus*, *U. s. ladinicus*). It is better to group these cave bears in a generic *Ursus.* gr. *spelaeus*. Therefore, the size of some incisors (i_1, i_2 in particular) could confirm the main closeness to *U. s. eremus* rather *U. s. ladinicus* or *U. s. spelaeus*.

The morphodynamic analyses have a focusing role for the population from Mt. Fenera and in this case can be useful to approximate these bears to a more specific taxon. **Fig. 6** explains this possibility well; in fact in this diagram the development of the morphodynamic indices (IM) of the teeth (incisors and premolars) is shown. The present data is unsurprising because of the great similitude between the development of the IM of both Fenera and Schlenkendurchgangshöhle cave bears where the Schlenkendurchgangshöhle population is ascribed to *U. s. eremus*. Can this be the first appearance of *U. s. eremus* in North Italy? In future we hope to have new answers to solve this question.

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Declaration of consent

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence this work. They are not conflicts of interest.

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