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The teeth of cave bears from the Valsolda (Lombardy, N. Italy): An hypothesis on their evolutionary level

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Abstract

In this study, the teeth of cave bears from the Valsolda (Como province, near the boundary with Switzerland) have been morphologically and morphodynamically studied in order to indicate the possible evolutionary level of this population. These bears belong to the *spelaeus* group, and are found within the range of the Italian Alps populations that are generally characterized by medium size, at times higher, but featuring a rather simple dental surface with low or intermediate morphodynamic indices, and consequently a medium or in some case low evolutionary level. With these data only, it is impossible to define the species or subspecies (*ingressus?*, *spelaeus ladinicus?*) for the bears from Valsolda.

Keywords

Ursus, teeth, evolutionary level, Upper Pleistocene, Valsolda.

Résumé

Les dents des ours des cavernes de Valsolda: hypothèse sur leur niveau évolutif.- Dans cette recherche les dents des ours des cavernes de Valsolda (Province de Como, à la frontière avec la Suisse) ont été étudiées sous l'angle morphologique et morphodynamique afin d'identifier le niveau évolutif possible de cette population. Ces ours sont des *spelaeus* et entrent dans le domaine des populations italiennes des Alpes qui sont caractérisées par une taille moyenne, parfois plus élevée, et possédant une surface dentaire très simple avec des indices morphodynamiques bas ou intermédiaires correspondant à un état de niveau évolutif intermédiaire ou dans quelques cas, bas. Les données disponibles ne permettent pas de définir les espèces ou sous-espèce (*ingressus* ?, *spelaeus ladinicus* ?) des ours de Valsolda.

Mots-clés

Ursus, dents, niveau évolutif, Pléistocène supérieur, Valsolda.

1. INTRODUCTION

Valsolda is a locality of the Como province (Lombardy) practically unknown for its fossil records of cave bears. In fact, other caves in Lombardy are surely better known (i.e. Caverna Generosa, Fontana Marella, Buco dell'Orso, Buco del Piombo, Buco del Frate and so on) (Perego *et al*., 2001; Rossi & Santi, 2001, 2013; Santi & Rossi, 2001 Santi *et al*., 2003); despite this, in the past in the Valsolda area several remains of cave bears were gathered and collected. In this first approach we propose an analysis of the teeth coming from this locality which are stored in the Museo Civico di Storia Naturale of Milan (Lombardy). Probably the original cave in which these fossils were gathered, is the so called Buca della Noga (the best known cave of the area). This collection is for the first time studied and at this present day, there are no detailed or general studies concerning the faunal association. The aim of this study is to indicate a preliminary possible evolutionary level of these cave bears within the Italian speleians.

2. SHORT NOTES ON THE BUCA DELLA NOGA

As also indicated by Dal Negro (2014) the Buca della Noga, better known as "Grotta dell'Orso" or "Bus de la Noga" (in local idiom), is the most important cave in Valsolda; it opens at 1310 m a.s.l. inside the Dolomia Principale (Carnian-Norian, 215-204 Myr) and develops

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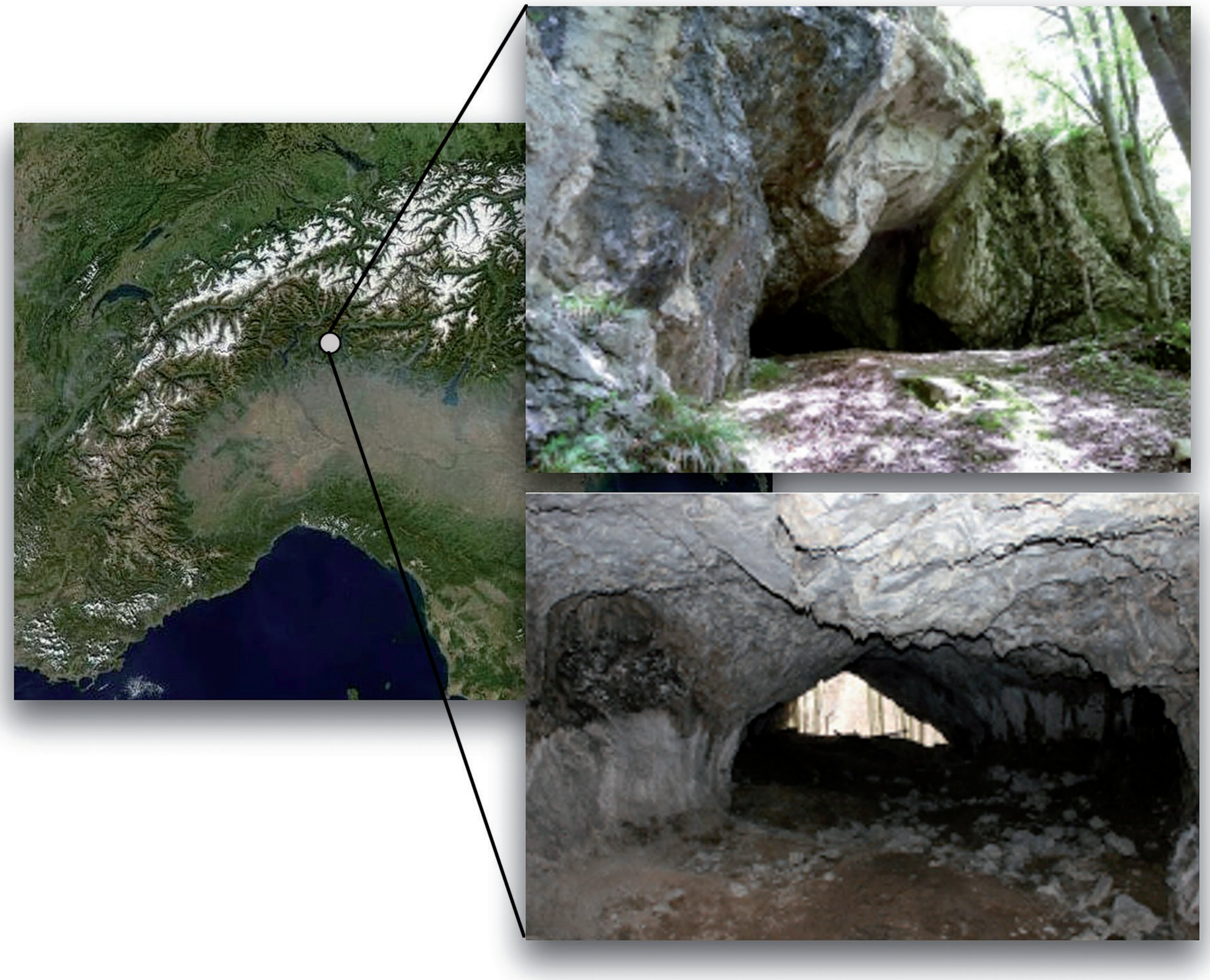


Fig. 1: Geographic position and some details of the Buca della Noga (Valsolda).

for about 50 m (Fig. 1). From its entry, it proceeds downwards for 38 m with 3-4 m in height and 4 m in width; at the bottom, a deep chasm, closed by debris, is present. In the past Prof. Castelfranco gathered inside this cave abundant cave bear remains during the excavations of the year 1883 and, at present, most of them are exposed in the Museo Civico di Storia Naturale of Milan and in the Museo Cantonale di Storia Naturale of Lugano (Switzerland).

3. MATERIAL AND METHODS

This first study analyses 122 teeth including incisors, premolars and molars. Only the $I_{1,2}$ and M_1 are missing from the analysis as well as the canines which are few in number and broken. The very similar conservation of the teeth composing this collection suggests a local origin from the Buca della Noga. These teeth, stored in the Museo Civico di Storia Naturale of Milan, are morphometrically analysed utilizing the parameters codified by Tsoukala & Grandal d'Anglade (2002) and Rabeder (1999), and the morphodynamic studies are also elaborated following Rabeder's indications (1989, 1991, 1999). The morphodynamic analysis was elaborated and initially applied to the fourth premolars only. It was later extended to the other types of teeth. Briefly, this study bases itself on the evaluation of the modifications of the masticatory surfaces, over time (from the less to the more complicated types) correlating them with the cave bears'evolution. It is basically a quantitative method based on a first rough analysis, which can identify the evolutionary degree reached by the bears studied (Rabeder, 1999; Robu, 2016). Recently, this method has been often applied to cave bear studies (i.e. Rabeder & Tsoukala, 1990; Perego *et al*., 2001; Bona, 2004; Quiles, 2004; Argant *et al*., 2012; Frischauf, 2014; Rossi & Santi, 2013, 2015; Rabeder, 2014; Robu, 2016; Santi & Rossi, 2018, 2020 ; Santi *et al.,* 2011 and so on). The diagram in Figure 2 shows the results of the basic schema of the morphodynamic analysis on the $P^4/_4$, whereas in Figure 3 the terminology of the basic components of various types

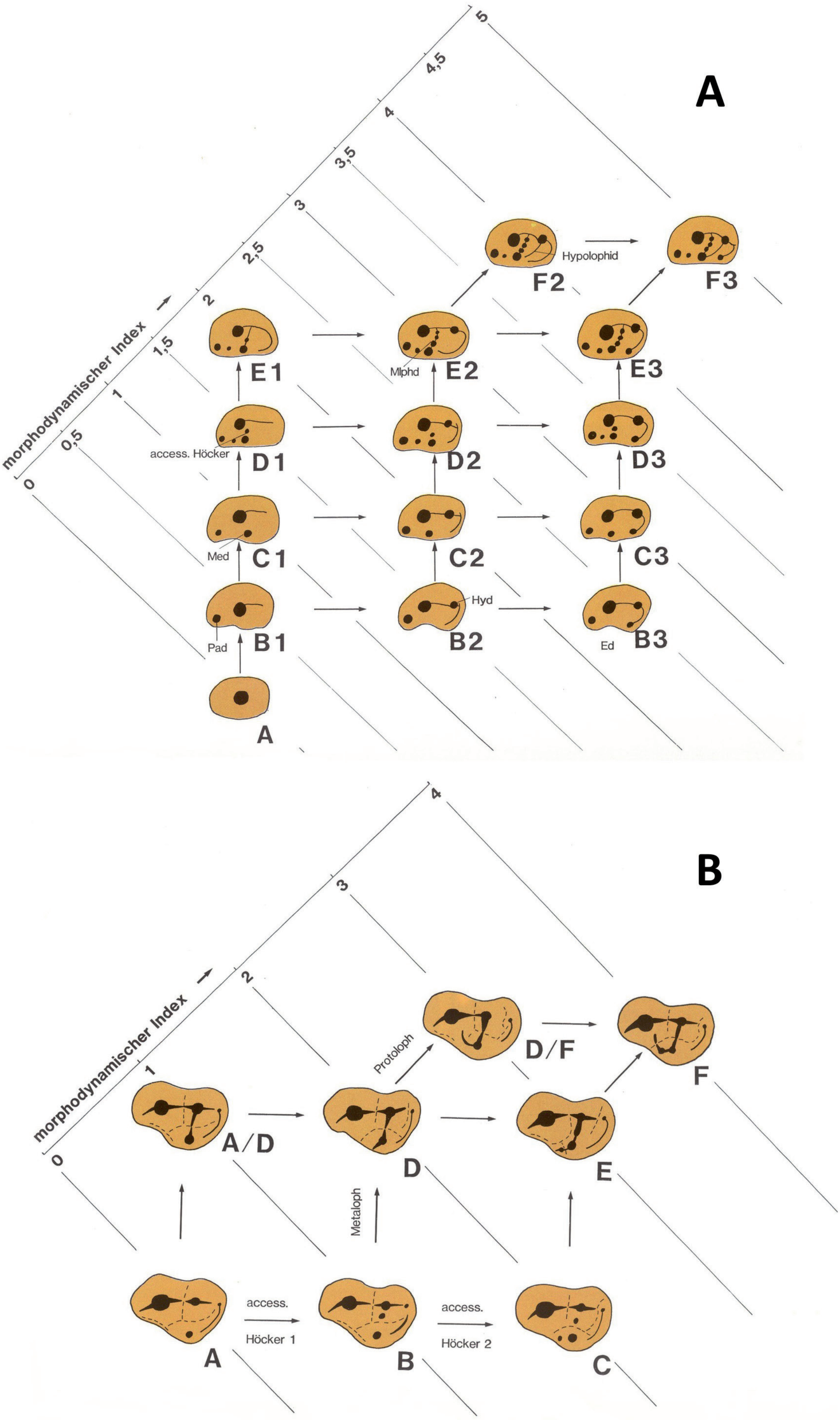


Fig. 2: Morphodynamic indices (IM) of the $P^4/_4$ (from Rabeder, 1991).

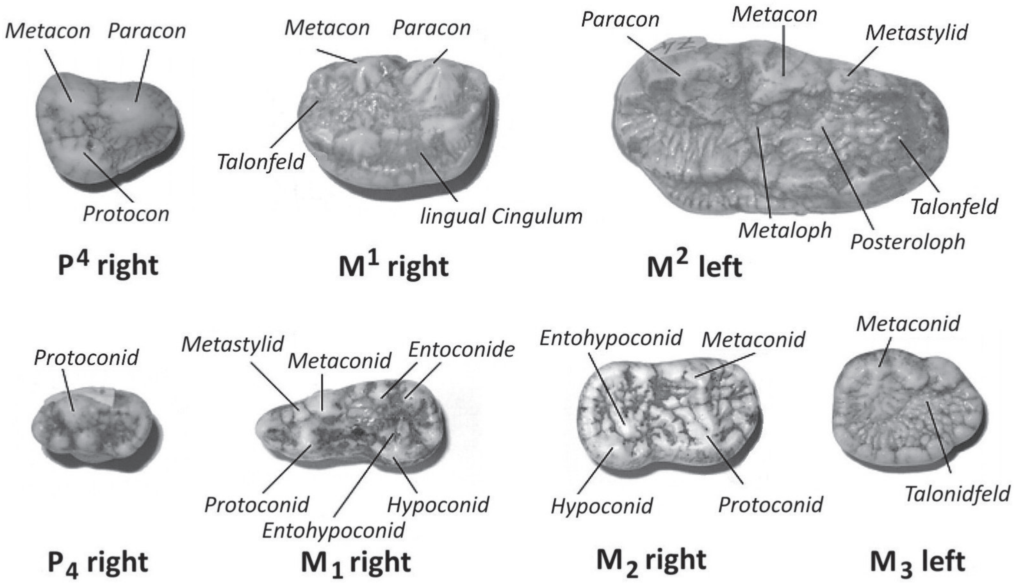


Fig. 3: Nomenclature of the parts composing the different types of teeth (from Hilpert, 2006 unpublished mod.).

of teeth is shown. We compared these data with fossils from other Italian and European caves in order to better understand the differences and the similarities within the evolutionary pattern of cave bears. A part of these data was elaborated using "PAST 3" software (Hammer *et al.*, 2001).

4. MORPHOMETRIC AND MORPHODYNAMIC ANALYSES OF THE TEETH

4.1 Incisors

Morphometry. Morphometry and morphodynamic indices (IM) of the incisors $I_{2,3}$ and $I^{2,3}$ from Valsolda are shown in Table 1. Few studies have analysed this kind of tooth in cave bears (Rabeder, 2011; Frischauf, 2014), especially for those found in North Italy (Santi & Rossi, 2020). Most specimens of I_2 are complete, some of them are lightly worn, or partially broken; the typical morphological features of the speleian are well visible; in fact the distoconid, the mesial and distal border of the cingulum are constantly identifiable. Also the I_3 are complete, some of them have a partial root or incomplete masticatory surface that is much worn; the acceptable state of preservation of these teeth allows us to identify the main features of the speleians such as the *sulcus distalis*, the lingual distal border, the distoconid among others (see Rabeder, 1999: 73). An important observation can be deduced from the diagram of Figure 4, in which the distribution of the dimensions of the Valsolda teeth falls within the lower part of the Gamssulzen cloud (considered the reference cave), with some specimens of I_2 from Valsolda dimensionally similar to I_1 of Gamssulzen. The cave bears from Gamssulzen belong to the *Ursus ingressus* species (Rabeder *et al.*, 2004). In general I_2 of Valsolda are positioned in the lower sector of the distribution of Gamssulzen where the Adjovska specimens are positioned as well. The diagram of Figure 5 is highly significant and shows a comparison of dimensions (means of length and width) of I_3 from different localities in which different species of *Ursus* have been identified. The Valsolda teeth are positioned near the border between the distribution of the *U. ingressus* and *U. spelaeus eremus*. Consequently, using morphometric data only, it becomes difficult to separate the different species of cave bears in this first analysis. This problem is constantly present in the cave bears of other Italian localities (i.e. Grotta del Bandito, Santi & Rossi, 2020) as well.

The other kind of incisors from Valsolda are $I^{2,3}$. As well as for $I_{2,3}$ all the specimens of I^2 are well preserved, although in some of them the root is broken, or is lacking, but typical features of the cave bear can be identified (i.e. the *fossa lunaris*, the distal border of the cingulum, the cusps of the distal cingulum and so on) (Rabeder, 1999: 75). On the contrary, specimens of I^3 are badly preserved, greatly worn or broken and only a few teeth preserve the diagnostic features of the speleians (i.e. *Kalyx distalis*, the lingual border etc.) (Rabeder, 1999: 71). A comparison between $I^{2,3}$ from Valsolda, Buco dell'Orso (Laglio, Lombardy) and Grotta del Bandito (Cuneo, Piedmont) is shown in Figure 6. The distribution is rather homogeneous for I^2 and I^3, and these teeth from these three localities have the same dimensions; at first sight it would seem that no differences in size are present. The same observations found for the $I_{2,3}$ can be made for the upper second and third incisors, i.e. the dimensions are similar to those of the *U. ingressus* from Gamssulzen, Križna jama and Adjovska (Fig. 7A-B).

Table 1: Morphometry and morphodynamic of the incisors from Valsolda.

I_2	Length	Width	Morphotype
VS 86	5.75	7.26	s
VS 87	6.77	10.01	s
VS 88	worn		
VS 89	8.82	10,4	s
VS 90	6.53	8.11	s
VS 91	worn		
VS 92	9,24	11.09	
VS 93	6.54	9.71	s
VS 95	7.1	9.68	s
VS 97	8.74	9.68	s
VS 98	6.72	8.3	s
VS 99	6.89	9.54	s
VS 100	9.72	9.4	s
VS 101	9.88	11.34	s
VS 102	worn		
VS 103	7.1	9.54	s
VS 104	worn		
VS 105	10.56	11.16	s
VS 106	worn		
VS 107	9.51	9.9	s
VS 108	8.56	9.97	s
VS 109	9.79	11.48	s
VS 110	9.66	10.61	s
VS 111	worn		
VS 112	5.8	8.26	s
mean	**8.08**	**9.76**	
Standar.	**74.51**	**100.51**	

I_3	Length	Width	Height	Morphotype
VS 132				D
VS 133	12.97	12.19	16.79	C/D
VS 134	11.57	12.1	15.34	C/D
VS 135	12.36	11.13	14.39	
VS 136				C/D
VS 137	11.56	11.5	15.16	C
VS 138	13.34	12.96	16.62	D
mean	**12.36**	**11.976**	**15.66**	
standard.	**93.64**	**72.85**	**125.78**	
IM				**258.33**
standard.				**100.78**

I^2	Length	Width	Height crown	Morphotype
VS 69	10.14	12.6	14.47	s1
VS 70	8.98	10.77	11.33	p2
VS 71	*cub*			
VS 72	10.14	12.07	13.29	s1
VS 76	11.59	17.29	16.95	p2
VS 77	8.69	11.21	10.42	p2
VS 78	7.92	10.66	11.37	p2
VS 79	10.66	10.26	12.99	s1
VS 80	8.37	11.5	11.92	r0
VS 81	9.69	12.41	11.05	r0
VS 82	9.08	11.02	11.78	p2
VS 83	8.96	12.58	13.08	s1
VS 84	11.27	13.04	15.55	s1
VS 85	8.89	10.44	12.33	p2
mean	**9.4625**	**11.9356**		
Standar.	**83.15**	**119.6**		
IM				**284.61**
IM std				**89,02**

I^3	Length	Width	Mesial Height	Morph. (*Kalyx distalis*)
VS 113	14.72	16.08	22.24	2
VS 114	13.04	13.51	19.67	2
VS 115	12.85	12.18	19.24	2
VS 116	12.81	12.68	17.23	2
mean	**13.355**	**13.6125**	**19.595**	
std	**135.77**	**119.61**		

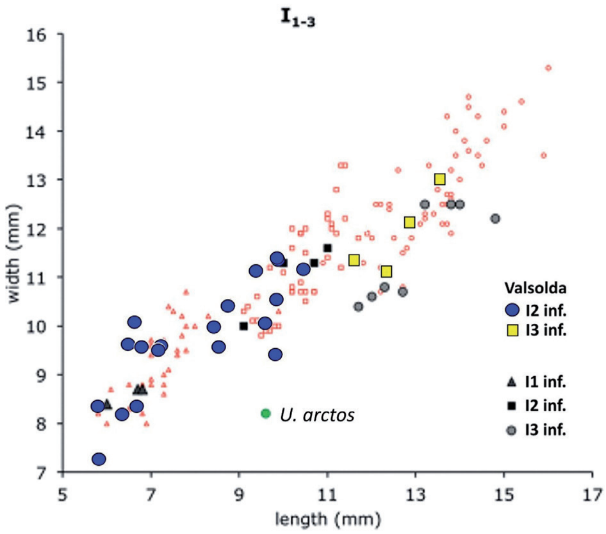


Fig. 4: Length and Width relationship of the incisors from Valsolda and *Ursus* from Adjovska (Slovenia) (black) and Gamssulzen (red) (from Rabeder, 2011, mod.).

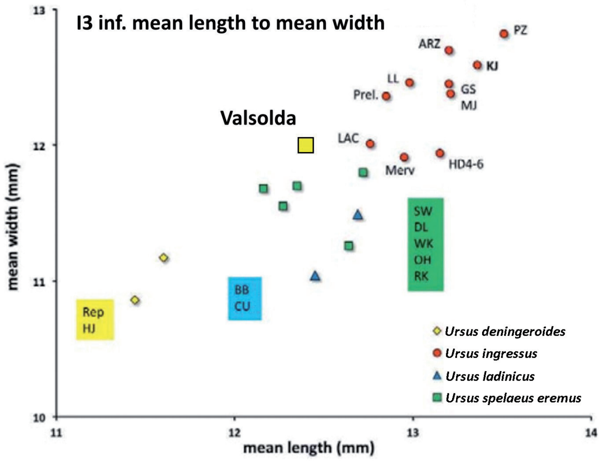


Fig. 5: Means of the Length and Width relationship of the I_3 of the Valsolda bear and alpine and non alpine cave bears faunas (from Frischauf, 2014, mod.).

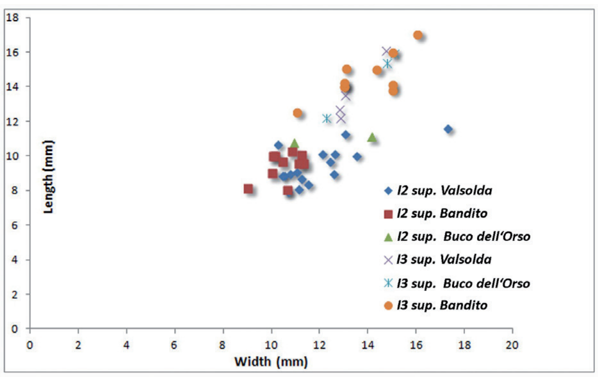


Fig. 6: Length and Width relationship of the I^2 and I^3 from Valsolda, Buco dell'Orso and Badito caves.

Morphodynamic. Following Rabeder's method (1999) and concentrating on I_2, only morphotypes "s", namely *spelaeus*, were identified (index = 100) according to the morphometric and morphologic data, indicating that these specimens surely belong to the *spelaeus* group. Concerning I_3 the morphotypes individuated are C (n. 1) (lower), C/D (n. 3) and D (n. 2) with an IM (morphodynamic Index) = 258.33, standardized to Gamssulzen equals 100.78. The number of available specimens is too low to suggest any conclusive hypotheses. But data I_3 from Valsolda indicate a low evolutionary level. Figure 8, in which the Length x Width (mean) and the Index (std) are plotted, shows the position of Valsolda I_3 within the distribution of the *Ursus s. eremus* and *Ursus s. ladinicus*.

The morphotypes of I^2 are: p2 (n. 6), s0 (n. 2) and s1 (n. 5) with an IM = 284.61, standardized to Gamssulzen

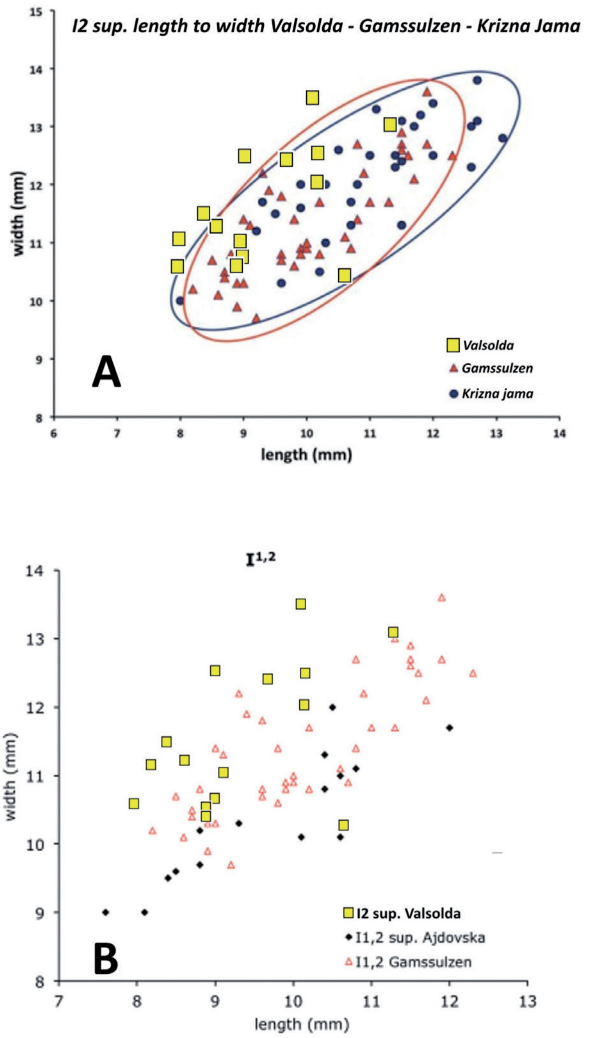


Fig. 7: **A.** Length and Width relationship of the I^2 from Valsolda, Križna jama (Slovenia) and Gamssulzen caves (from Frischauf, 2014, mod.). **B.** Length and Width relationship of the I^{1-2} from Valsolda and *Ursus* from Adjovska (Slovenia) (black) and Gamssulzen (red) (from Rabeder, 2011, mod.).

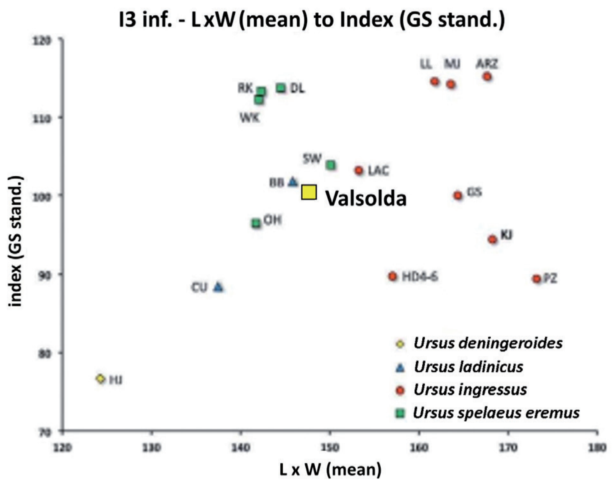


Fig. 8: Length x Width and Index (Gamssulzen std) of I_3 in different cave bears species (from Frischauf, 2014, mod.).

equal 89.03 and equal to the Adjovska specimens (Rabeder, 2011). With the data of this first analysis, the evolutionary level for this kind of tooth is probably low/intermediate and similar to the Adjovska incisors, i.e. "*… quite primitive […] of cave bear line from early Late Pleistocene*" (Rabeder, 2011: 36).

4.2. Premolars

Morphometry. Table 2 shows the morphometry and morphotypes of the premolars. P^4 from Valsolda have a similar size to those of both the Grotta del Bandito and Ruma brickyard (Serbia), in which these specimens compose a different and well separated cloud from that formed by the Adjovska and Schwabenreith bears (Fig. 9). Ruma cave is dated to the Middle Pleistocene (Cvetković & Dimitrijević, 2014), and consequently if we consider only the size of P^4, the bears of the Valsolda and the Grotta del Bandito are closer to the Middle Pleistocene forms and farther from *U. s. eremus* and *U. s. ladinicus*. A first hypothesis could be that the dots from the Grotta del Bandito show sexual dimorphism, whereas those belonging to Valsolda could belong to female only. Curiously, as seen in Figure 10, in which different species of cave bears and recent bears are compared, the distribution of the Valsolda specimens falls within the *deningeri* area (*U. deningeri* from Azé I-1, Einhornhöhle, Bilzingsleben) (Argant, 1991; Musil, 1972, 1991) and near the *Ursus deningeroides* (Azé I-2 and 3) position (Sabol, 2005). A comparison among the P^4 of the Valsolda, Grotta del Bandito, Pocala and Buco del Frate caves, from the Italian Alps, is shown in Figure 11. Four populations of bears, that lived in three different geographical areas (Bandito-western, Valsolda and Buco del Frate-central, and Pocala-eastern), have a size of P^4 that is again very homogeneous at least during the Middle Pleistocene to early (?) Late Pleistocene.

No comparison between P_4 from Valsolda and other caves can be advanced.

Morphodynamic. The small sample size of premolars (four upper and lower) is low and therefore, a rigorous morphodynamic analysis is impossible. The specimens are isolated and well preserved, and only one tooth has worn cusps. P^4 have the following morphotypes: C, A/D and an intermediate D/E morphotype; the specimen of P_4 has a C2 morphotype (Table 2). The low number of specimens however prevents us from advancing any observations on the evolutionary level of these teeth; from this preliminary analysis we can only hypothesize that the bears occupy a possible intermediate evolutionary level.

4.3. Molars

M_2 – The specimens are well preserved, although some of them have a dental surface that is particularly worn or partially broken. One specimen (VS 37) shows a talonid area completely missing, and the crown is also missing; the tooth is deeply worn to the root, with a hole, probably derived from a caries, partially bored into the tooth. Because of the good preservation of the teeth the morphological features of the dental surface are preserved (see Rabeder, 1999: 27).

Morphometry. As for the other kinds of teeth (P^4), the same observations can be advanced for M_2: this kind

Table 2: Morphometry and morphodynamic of the $P^4/_4$ from Valsolda.

P^4	1	2	3	4	5	6	7	8	Morphotype
VS 2	17.79	13.08	11.23	9.22	*8.59*	7.7	9.45	7.15	A/D
VS 3	17	12.65	10.71	8.4	*8.06*	7.73	9.15	7.69	C
VS 4	*18.29*	13.6	10.2	8.44	*8.01*	7.53	9.48	7.81	D/E
VS 5	17.87	13.48					8.73	8.48	
P_4	1	2	3	4	5	6			Morphotype
VS 1	15.32	9,98	10.64	3.83	5.47	8.31			C2

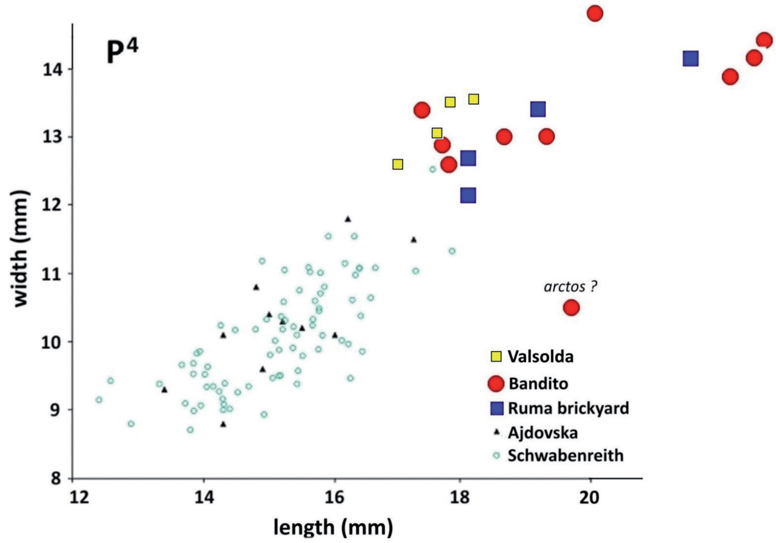


Fig. 9: Length and Width relationship of P^4 from Valsolda, Grotta del Bandito, Ruma, Adjovska and Gamssulzen caves (from Rabeder, 2011, mod.).

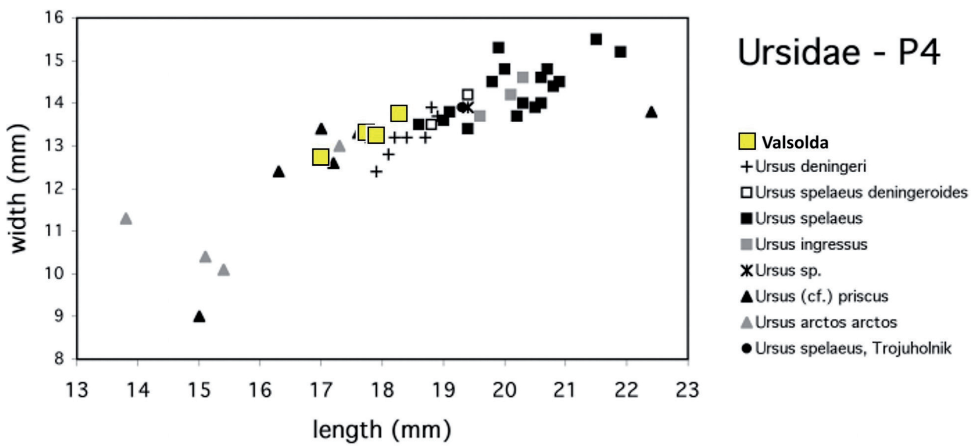


Fig. 10: Length and Width relationship of P^4 from Valsolda and from different species of bears (from Sabol, 2005, mod.).

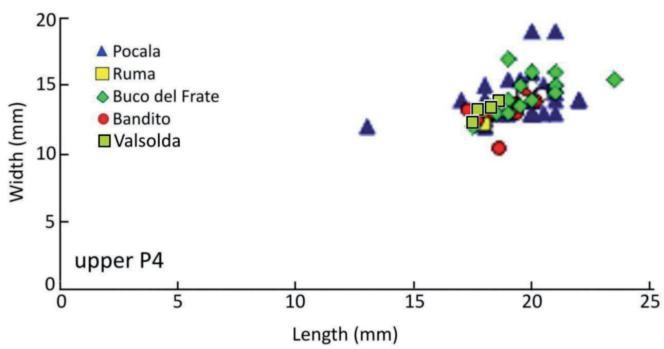
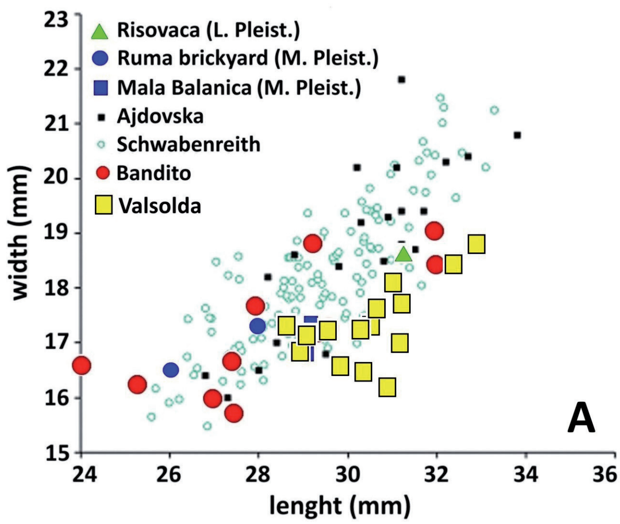


Fig. 11: Length and Width relationship of P^4 from Valsolda and from some caves in N. Italy and Serbia.

of tooth has a size similar to the *deningeri* ones, and no variation in size is observable within the heterogeneity of different species of cave bears (*s. eremus*, *s. ladinicus*, *etruscus*) and in general, within the Middle-to Late Pleistocene populations (Serbia) (Fig. 12 A-B). These M_2 belong surely to the *spelaeus* group, but they are longer and narrower in comparison to the other species of cave bears, and so we can confirm that their sizes are similar to those of *U. deningeri* and *U. deningeroides* (Fig. 12 B).

Morphodynamic. The different components of M_2 have been submitted to morphodynamic analyses (Table 3): the metalophid of morphotype B (with a cusp on the inner side of the protoconid linked to the metaconid with a sharp crest) is present in 46.67%, while the D morphotype (main complex area) in 26.67% of the specimens. The IM (Morphodynamic Index) of the metalophid is 156.67, and 67.68 standardized to the Gamssulzen (the reference cave). For the trigonid area, morphotype 2 (with two cusps and an incomplete "pier") is present within 68.75% of the teeth; the mesolophid complex is characterized by morphotype C (25%) and is the most represented, but a large distribution of morphotypes from A to D is also present and largely fractioned; all the different morphotypes can be identified. The IM for this component is 146.88, and 85.45 standardized to Gamssulzen. Lastly the enthypoconid element within morphotype C (enthypoconid divided in two parts) is present in 73.33% of the teeth analysed. The IM is 186.67 and 100.73 standardized to Gamssulzen. In Italy we do not have many data on the morphodynamic of M_2, and only recently an analysis has been elaborated for the specimens from Grotta del Bandito (Santi & Rossi, 2020). An important comment can be made linked to the different sample sizes in which (Table 3), differences have been noted in data of both the mesolophid and enthypoconid; only data of the metalophid have nearly the same value, except those from the Grotta del Bandito, which were obtained with a higher number of specimens.



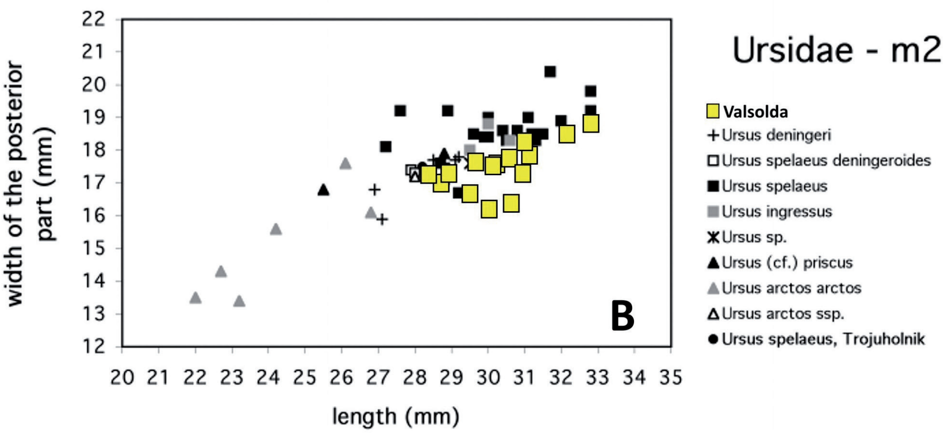


Fig. 12: **A.** Length and Width relationship of M_2 in cave bears from different caves in Europe (from Rabeder, 2011, mod.). **B.** Metric values of M_2 in different species of *Ursus* (from Sabol, 2005, mod.).

Table 3: Morphometry and morphodynamic of the M_2 from Valsolda with a comparison with the main caves in Europe (from Rabeder, 1999, mod.).

M_2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
VS 31	31.35	17.7	18.39	19.05	17.7	17.97	16.65	11.81	9.85	9.19	10.84	12	21.14	18.8	12.03	A	1	B^1	B
VS 33	28.71	16.8	12.52	17.91	17.06	17.37	14.5	10.65	10.76	7.19	9.76	12.74	16.94	20.01	11.9	A	1	A	C?
VS 34	29.65	17.21	16.56	16.98	16.52	17.14	15.08	10		8.99	9.93	10.64	15.7	19.4	11.94	B	2	C	C
VS 35	31.08	18.15	16.27	18.46	17.33	18.39	15.2	10.6	9.87	10.13	11.58	12.34	19.52	18.84	11.88	C/D	2	C/D	C
VS 36	32.9	18.72	18.11	19.7	19	18.43	16.39	11.6	10.77	9.6	11.57	10.51	16.85	20.47	11.86	B	2	B^1	C
VS 38																B	1/2	A	B
VS 39	30.8	16.16	16.08	18.48	16.77	15.51	14.26	10.19	9.37	8.3	10.18	11.61	17.3	18.41	11.53	B	2	B /C	C
VS 40	32.25	18.25	17.06	19.02	18.34	18.54	15.04	11.47	10.21	9	11.29	12.01	17.66	20.51	12.81	D?	3	B	C
VS 41	30.38	17.32	17.43	18.44	17.65	17.7	15.17	10.55	9.4	8.82	10.77	11.68	15.78	20.84	12.47	C	2	B	C
VS 45	30.25	17.36	18.28	18.43	17.43	17.92	15.59	9.65	10.09	9.49	10.41	11.18	16.14	19.3	12.11	D	2	D	B/C
VS 47	29.51	16.64	16.52	18.28	16.84	17.17	13.98	10.83	10.45	8.66	11.64	11.14	16.92	19.19	12.42	B	2	C/D	C
VS 48	30.61	17.64	18.41	19.91	17.62	18.59	16.33	11.53	10.71	8.8	11.02	11.45	17.64	18.69	12.68	D	3	C	C/D
VS 49	28.92	17.07	11.89	17.13	15.78	17.38	12.58	10.05	9.16	8.07	10.39	10.31	16.83	18.85	12.77	B	2	B^1/C	C
VS 50	30.23	16.42	16.44	18.07	16.63	16.52	14.41	10.37	9.43	8.49	10.48	10.11	16.17	19.28	11.71	B	2	A	C
VS 51	31.04	16.92	16.12	18.32	16.74	17.49	15.33	10.97	9.96	8.6	10.66	11.13	17.26	19.73	12.6	D	2	C	C
VS 52	28.53	17.21	16.69	18.35	17.06	17.13	15.65	10.94	9.94	9.04	10.37	11.68	19.04	16.3	10.53	D	2	C	C
mean	**30.414**	**17.3047**	**16.4513**	**18.4353**	**17.2313**	**17.55**	**15.0773**	**10.7473**	**9.9978**	**8.82467**	**10.726**	**11.3687**	**17.3927**	**19.2413**	**12.0827**				

16- Metalophid development; **17** – cusps and pillars of the Trigonid ; **18** – Mesoplophid complex; **19** – Enthypoconid complex

Table 3: Continued

Metalophids Morphotype	A	A/B	B	B/C	C	C/D	D	n	Index	Index std	
Factor	0	0.5	1	1.5	2	2.5	3				
NL+LL	-	-	-	-	12	4	3	19	226.3	97.62	
GS	-	-	1	1	35	12	16	65	231.5	100	
SO	-	-	7	5	19	-	1	32	173.4	74.90	
RK 1-4	-	-	2	7	41	7	3	60	201.7	87.13	
CU	-	-	2	4	17	-	-	23	182.6	78.88	
HD 5-6	-	2	2	3	10	2	1	20	177.5	76.67	
HD 4	-	1	3	7	16	2	-	29	175.9	75.98	
HD 3	-	-	3	1	30	1	-	34	194.1	83.84	
SW	-	-	2	4	31	1	2	40	196.3	84.79	
HD 1-2	-	-	1	8	17	1	-	27	183.1	79.09	
HUN	-	2	6	5	5	-	-	18	136.1	58.79	
BANDITO	3	1	11	1	5	2	3	26	142.31	61.47	
VALSOLDA	**2**	**0**	**7**	**0**	**1**	**1**	**4**	**15**	**156.67**	**67.68**	
Mesolophids Morphotype	A	A/B	B	B’	B/C	C	C/D	D	n	Index	Index std
Factor	0	0.5	1	1.25	1.5	2	2.5	3			
NL+LL	-	1	4	1	11	14	3	-	34	169.9	98.84
GS	1	2	11	7	7	29	3	5	65	171.9	100
SO	-	1	18	1	3	8	-	1	32	135.2	78.65
RK	1	11	13	4	20	11	1	1	62	130.6	75.97
CU	-	3	14	1	13	1	-	1	32	128.9	74.99
HD 5-6	-	1	5	4	2	6	3	-	21	157.1	91.39
HD 4	3	1	5	1	11	8	1	-	30	139.2	80.98
HD 3	2	4	14	5	5	8	-	-	38	120.4	70.04
SW	-	-	21	1	12	4	-	2	40	135.6	78.88
HD 1-2	2	6	7	4	9	4	-	-	32	114.1	66.38
HUN	1	6	7	3	-	1	-	-	18	87.5	50.90
BANDITO	8	1	6	3	0	7	0	0	25	97	56.43
VALSOLDA	**3**	**0**	**2**	**2**	**2**	**4**	**2**	**1**	**16**	**146.88**	**85.45**
Enthypoconid Morphotype	A	A/B	B	B/C	C	C/D	D	n	Index	Index std	
Factor	0	0.5	1	1.5	2	2.5	3				
NL+LL	-	-	5	8	10	6	6	35	200	107.93	
GS	-	-	23	28	41	6	1	119	185.3	100	
SO	-	-	6	5	15	2	4	32	189.1	102.05	
RK 1-4	-	-	12	16	22	8	4	62	210	113.33	
CU	-	-	3	3	11	7	9	31	238.7	128.82	
HD 5-6	-	-	8	1	7	1	4	21	181	97.68	
HD 4	-	-	6	6	11	3	1	27	175.9	94.93	
HD 3	-	1	12	11	7	5	2	38	148.7	80.25	
SW	1	1	8	8	14	3	5	40	177.5	95.79	
HD 1-2	-	1	5	4	12	2	2	30	188.3	101.62	
HUN	-	-	12	2	3	-	-	19	110.5	59.63	
BANDITO	0	3	9	4	9	3	0	28	150	80.95	
VALSOLDA	**0**	**0**	**2**	**1**	**11**	**1**	**0**	**15**	**186.67**	**100.73**	

Consequently in this first analysis, the conclusions proposed for the Grotta del Bandito teeth are validated for those from Valsolda: the medium-low indices characterise the Valsolda M_2 (Rabeder, 1999). Recently Rabeder (2014) calculated a morphodynamic index for the enthypoconid of M_2 (n. 12 specimens) from Križna jama (Slovenia) of 192 (std = 185.3), and also found, for the population from Ajdovska (Slovenia) a very high morphodynamic index for the enthypoconid (std = 166.03) (Rabeder, 2011), while Cvetković & Dimitrijević (2014) for the teeth from Risovaca (Late Pleistocene - Serbia) calculated an index std = 97.8. Finally, also Tsoukala *et al.* (2006) calculated an index of 144.67 (std = 78.08) for the M_2 from Loutrá Aridéas (Greece). Therefore, Rabeder (2011) considers the Adjovska population as belonging to *U. s. ladinicus* Rabeder *et al*., 2004 on the basis of the high morphodynamic index, but it is difficult to indicate which of the species *U. ingressus* and *U. s. ladinicus* is the candidate species for the Valsolda bears.

M_3 – The number of the specimens is low (n. 8), and among these, only 4 teeth were morphometrically studied and their morphotypes defined (Table 4). The other specimens are worn, although complete. The only 4 teeth utilised for this analysis are complete and the morphological components of the surface are well shown (see Rabeder, 1999: 36, Abb. 15).

Morphometry. The analysis is necessarily conditioned by the low number of specimens, but some proposals for future discussions can be raised. For example Figure 13A shows that the M_3 dimensions (Length and Width) of specimens from Valsolda, Buco dell'Orso and Grotta del Bandito are correlated. The specimens from these three caves have the same dimensions (only one fossil has a very large size but, this can be probably linked to the population variability). In this first analysis we deduce that the sizes of the third lower molar of these three populations are homogeneous. Figure 13B shows a relationship between the Length (std) of M_2 (std = 99.29)

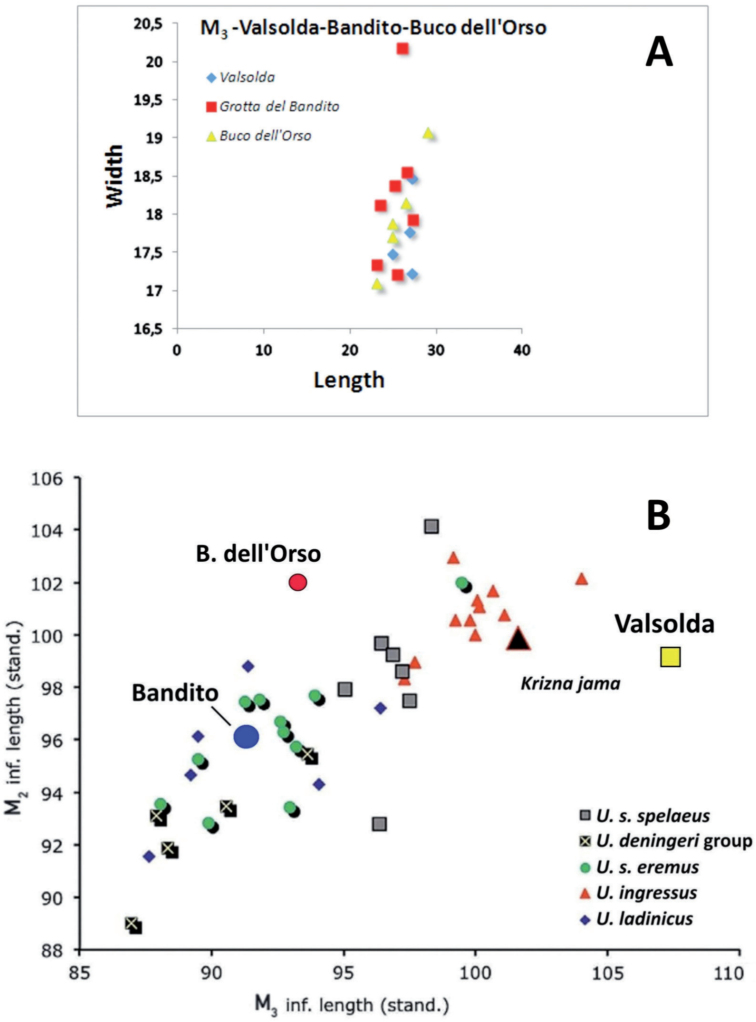


Fig. 13: **A.** Length and Width relationship of M_3 from Valsolda and from some caves in N. Italy (Grotta del Bandito and Buco dell'Orso). **B.** Relationship between the Length (std) and Width (std) in M_3 from Valsolda, Grotta del Bandito, Buco dell'Orso and different species of *Ursus* (from Rabeder, 2014, mod.).

and M_3 (std = 107) for many species of cave bears. In this diagram, in which the position of both the Grotta del Bandito and Buco dell'Orso are also indicated, the Valsolda bears are located at the margin of the diagram; its value in our opinion is not linked to a "true" high value typical of *U. ingressus* (like the Križna jama bears), but is a consequence of the low number of specimens analysed which also prevents a clear association between the Valsolda bears and the *U. ingressus* species. It is surprising that the Grotta del Bandito, Buco dell'Orso and Valsolda dots are positioned at the two extremities of the diagram. In future, if this distribution will be confirmed with more data, this hypothesis will be a matter of discussion. Lastly, in this first analysis and considering the low number of specimens analyzed, the same considerations on the M_2 sizes can be proposed for M_3 (Fig. 14); the teeth are as long as those of the other speleians, but narrower. But as in the case of the other kinds of teeth it is as of yet impossible to define the species.

Morphodynamic. For this kind of tooth also, the low number of specimens prevents a rigorous morphodynamic analysis. A brief summary with comments on the data is exposed here. The morphology of the border is of a D type (with buccal indentation and distal lobe) (Rabeder, 1999: 36), but the development of the protoconid complex shows different typologies: the morphotypes include the A2, C3, D3 and a mix of features characteristic of C3/C4. The low number of specimens also prevents conclusive evolutionary considerations. All of the Rabeder morphotypes (1999) relating to the metaconid development have been individuated (Table 4). In fact, for the hypoconid development, the B1 morphotype (with a simple hypoconid) is prevalent, for the centrolophid complex the distribution of the morphotypes comprises the A, B, D, E types, while the C morphotype is prevalent in the entoconid complex area; and lastly for the talonid complex, the morphotypes individuated are C/D, D and E. Because of this confused presence of different morphotypes (only rarely do we have the prevalence of a single particular morphotype), no reliable considerations on the evolutionary level occupied, are possible.

M^1 - The number of specimens is low; in fact only three specimens were studied and a single specimen is that of a cub (not studied). The three teeth are complete, only one is worn, whereas in the others the typical features of the M^1 were identified (see Rabeder, 1999: 44).

Morphometry. Some few annotations can be proposed. For example, in the diagram in Figure 15, in which the

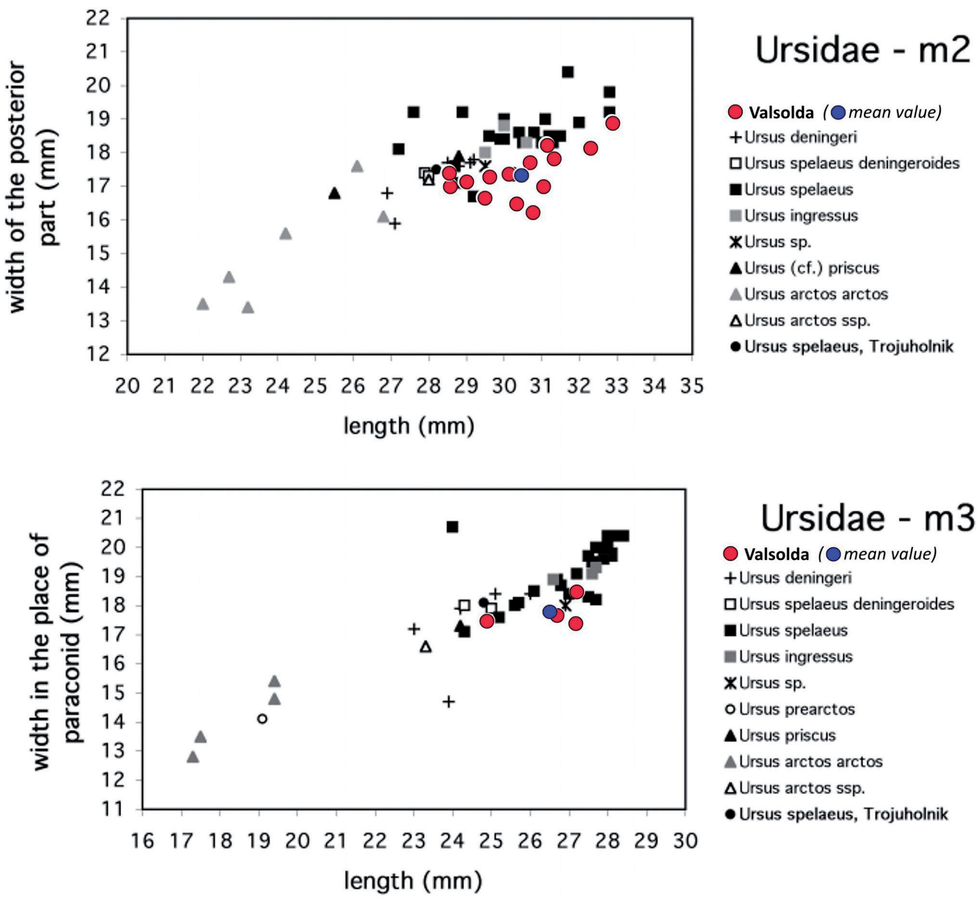


Fig. 14: Length and Width relationship of M_2 and M_3 from Valsolda and from different species of bears (from Sabol, 2005, mod.).

Length and Width of M^1 are plotted, three specimens are located in different parts of the cloud formed by the diverse species of bears. Two specimens are located in the cloud formed by the cave bear species, while the third one is located within the "non speleian" bears. The morphology of the latter is surely speleian, and the tooth probably belongs to a subadult or to a female individual.
Morphodynamic. The specimens are few, but the morphotypes of the different components of the tooth (Table 5) indicate probably, an intermediate evolutionary level for most of the other teeth.

M^2 – Like the other teeth, the specimens are isolated, and are well preserved, mostly complete, with only a few being partially incomplete. Keeping these observations in mind, the features of the masticatory surface typical of the cave bear were studied (Rabeder, 1999: 55 and following).

Morphometry. A brief morphometric analysis is exposed here with few observations; the most important of these is that the higher evolution of the M^2 is confirmed, as seen in Figure 16 in which the M_3/M^2 ratio and M_3/M_1 ratio are plotted.
Morphodynamic. The low number of specimens prevents a complete morphodynamic analysis, therefore on the basis of the few morphotypes individuated some considerations can be proposed. The complexity of the masticatory surface is globally high, and this is in contrast with the observations made on the other teeth. Considering certain features such as the metastyls and posthypocon or the development of the distal cingulum (Table 6) the morphotypes are rather high (Rabeder, 1999). Therefore we suggest that these features are linked to the low number of specimens but do not necessarily reflect the true features of this population. The presence of high morphotypes, if confirmed by other findings, will be matter of future discussion.

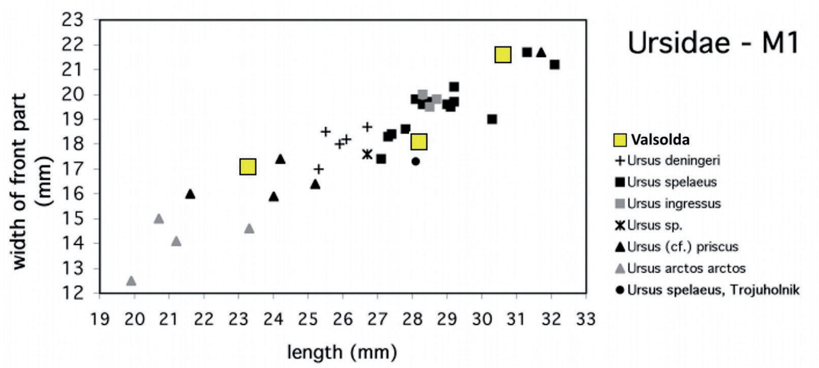


Fig. 15: Length and Width relationship of M^1 from Valsolda and from different species of bears (from Sabol, 2005, mod.).

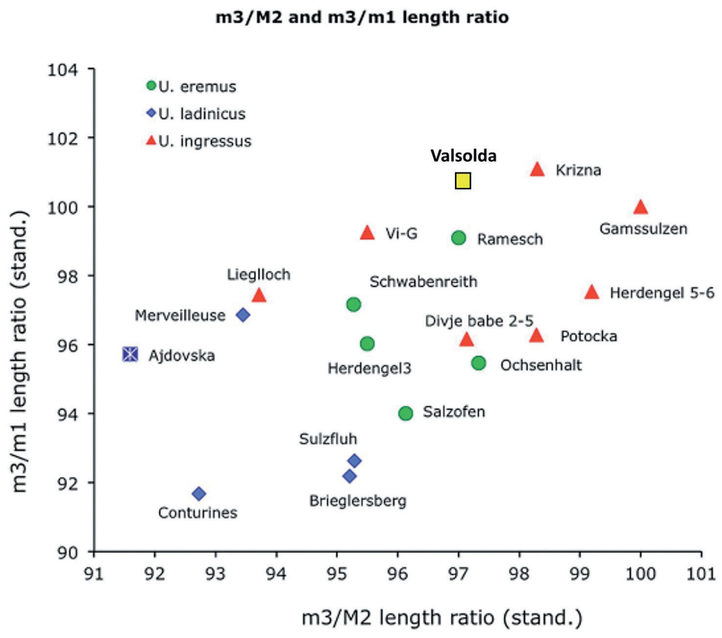


Fig. 16: Relationship between M_3/M^2 and M_3/M_1 length (std to Gamssulzen fauna) (from Rabeder *et al.*, 2011, mod.).

Table 4: Morphometry and morphodynamic of the M_3 from Valsolda.

M_3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
VS 141	27.15	18.49	11.77	18.17	18.25	8.3	8.6	8.28	4.91	14.17	17.41	18.24	9.73	D	C3/C4	D/E	C3	E	C	E
VS 142	24.9	17.49	11.37	17.66	16.2	7.98	7.54	5.89	6.95	13.82	17.39	17.19	11.93	D	C3	A	B1/B2	B	C	C/D
VS 143	27.11	17.23	11.74	17.6	16.39	9.35	7.53	6.21	6.89	13.57	18.19	18.38	12.76	D	A2	B	B1	A	C?	C?
VS 144	26.81	17.78	13.03	18.32	17.45	8.26	8.91	7.45	4.82	13.61	19.62	18.84	12.39	D	D3	C	B1	D	B/C	D
mean	**26.49**	**17.75**	**11.98**	**17.94**	**17.07**	**8.47**	**8.15**	**6.96**	**5.89**	**13.79**	**18.15**	**18.16**	**11.70**							

14 – Morphology of the border; **15 –** Development of the Protoconid-complex; **16 –** Development of the Metaconid; **17 –** Development of the Hypoconids; **18 –** Development of the Centrolophid; **19 –** Development of the Entoconid; **20 –** Development of the Talonid

Table 5: Morphometry and morphodynamic of the M^1 from Valsolda.

M^1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
VS 27	23.2	17.89	11.79	16.18	17.04	17.25	10.12	9.21	9.6	8.74	10.42	18.63	14.51	12.57						
VS 28	28.31	17.93	13.72	17.5	17.98	16.92	10.44	9.96	0.83	9.89	10.9	20.54	15.57	12.3	3/4	2	2	3	C1/C2	C
VS 29	30.65	20.77	14.05	19.22	20.5	18.02	11.44	11.2	10.74	11.35	12.51	20.17	17.37	12.48	4	2	1	3	D2	C

15 - Comparison of different age in the occlusal surface; **16 –** Lingual Paracon wall variability; **17** - Lingual Metacon wall structure; **18 –** lingual Cingulum development; **19 –** Morphodynamic indices of the Mesocon-Protocon inner flank; **20 –** Talon development.

Table 6: Morphometry and morphodynamic of the M² from Valsolda.

M²	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
VS 54															D1	Pl1	D		C	2/2		2.5
VS 55															C3/D3	Pl2 /Pl3	D		C	2/2		
VS 56	41.1	22.07	18.48	21.06	21.09	13.09	10.9	10.4	10.31	14.22	20.34	18.56	13.5	B2	C2	Pl1	C	B/C	A	1/1 2/2	1/2	2.5
VS 57	39.68	19.51	20.27	19.34	19.03	14.35	10.54	11.24	9.86	16.61	23.64	15.38	17.78	B2	D2	Pl3	C	B/C	B/C	2/2	2	2.5
V 58	47.91	23.91	23.81	22.59	21.8	13.32	9.81	11.92	11.58	15.33	22.04	20.1	12.32	B1	D2	Pl2/Pl3	D	B/C	C	2/2	2	3
VS 59	44.71	23.73	22.94	22.12	22.23	12.45	9.57	10.22	10.08	13.42	19.49	17.97	12.62	C1	D1/D2	Pl2/Pl3	D	B/C- C	C	2/2	2	2.5
VS 60	43.14	21.78	20.7	20.77	20.6	12.22	10.1	11.14	10.01	13.83	18.48	15.89	11.18	C1	D2	Pl2/Pl3	B	B/C-C	C	2/2	1/2	3
VS 61	42.47	23.64	23.55	23.41	22.16	12.61	12.08	11.27	10.76	12.68	19.93	18.11	13.17									
VS 62	42.3*	22.38	22.75	22	21.02	12.74	12.14	12.03	11.33	15.9	20.6	18	11.47									
VS 63			21.69	20.77	20.84	13.7	10.34	12.24	11.27	14.31	20.93	17.22	12.7									
VS 65						13.09	9.24			14.78	20.44	17.48	13.33									
VS 66		22.67	21.83	21.67	21.02	14.31	11.09	11.26	10.8	16.01	22.86	16.96	13.06									
VS 67	45.2	23.54	21.54	21.91	20.6	14.23	10	11.62	11.29	15.01	21.07	16.57	12.81									
VS 68	47.18	23.49	23.06	23.2	21.06	14.55	10.93	10.82	10.71	13.45	21.27	17.72	13.88									
mean	**43,957**	**22,67**	**21.87**	**21.71**	**21.04**	**13.39**	**10.56**	**11.29**	**10.73**	**14.63**	**20.92**	**17.50**	**12.99**									

14 – Morphotypes of the parastils complex; **15 –** Morphotypes of the metalophs; **16 –** Morphotypes of the posterolophs; **17 –** Morphotypes of the talons area; **18 –** Morphotypes of the internal wall; **19 –** Development of the distal cingulum; **20 –** Morphotypes of the metastyls and posthypocon; **21 –** Morphotypes of the ribbing of the internal border of the protocongrates; **22 –** Morphotypes of the lingual cingulum.

5. A FIRST ATTEMPT OF A MULTIVARIATE ANALYSIS AND FIRST NOTES OF THE DISTRIBUTION OF CAVES BEARS IN NORTHERN ITALY

Figure 17 represents a dendrogram obtained from the cluster analysis of the sizes of the P^4 from Valsolda, together with other Italian and foreign caves, in particular: the Grotta del Bandito (Cuneo province, Piedmont), the Pocala cave (Trieste province, Friuli Venezia Giulia), Covoli di Velo (Verona province, Veneto region), the Conturines cave (South Tyrol), Buco del Frate cave (Brescia province, Lombardy) and Gamssulzenhöhle (Austria). The choice of these caves for a comparison is based on both chronological and taxonomic reasons, namely a chronological dating that was recently published for Covoli di Velo (29,131±0,9 yr., Rossi *et al*., 2018), the Gamssulzen is the type locality for *U. ingressus* Rabeder *et al*., 2004, whereas Conturines cave is the type locality for *U. spelaeus ladinicus* Rabeder *et al*., 2004. When evaluating this dendrogram it is important to remember that the specimens from Valsolda belong to female individuals, and consequently their closeness to the species *U. spelaeus ladinicus* could be re-evaluated with new data. Figure 17 shows: 1) there are two distinct groups: one of which includes the Gamssulzen population (*U. ingressus*), Buco del Frate, Pocala cave and Covoli di Velo and another that includes the populations from the Conturines cave (*U. s. ladinicus*), the Grotta del Bandito and the Valsolda caves; 2) within the first group, the population from the Buco del Frate resembles the population from Gamssulzen more closely than does the population from Pocala, and the latter resembles more closely the population from Gamssulzen + Buco del Frate with respect to the population from Covoli di Velo; 3) within the second group, the cave bear population from the Grotta del Bandito resembles more closely that from the Conturines cave with to respect to the Valsolda cave; 4) comprehensively, the populations with sizes comparable to those of the species *U. ingressus* and *U. s. ladinicus* seem to spread out throughout the southern Alps without a precise pattern; for example, the presence of *U. ingressus* was recently identified in the Paina and Trene localities (province of Vicenza, Veneto region) (Terlato *et al.,* 2019). The northeastern sector of the Alps and Prealps (namely Veneto and Friuli Venezia Giulia regions) may have been more influenced by the possible, but potentially scarce penetration of the *U. ingressus* than the northwestern sector (Valsolda, Grotta del Bandito). In the latter, the Grotta del Bandito is very particular because the cave bears have the indices of P4/4 (low or intermediate *sensu* Rabeder, 1999)

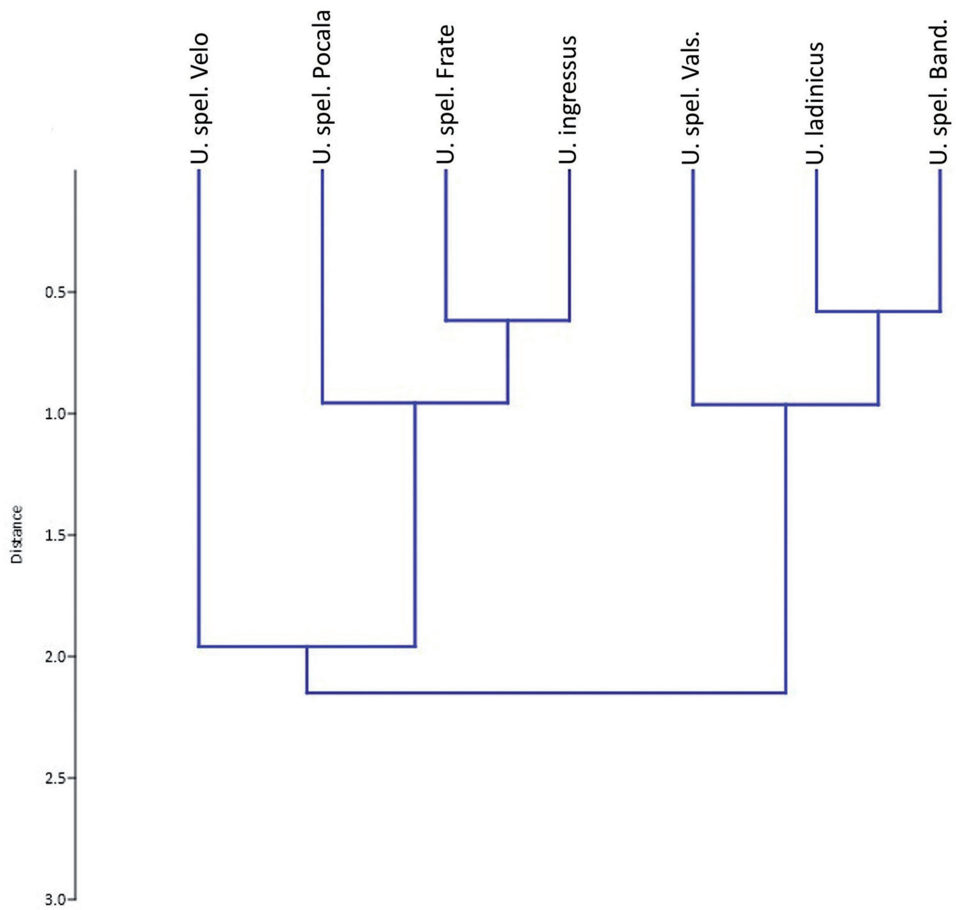


Fig. 17: Dendrogram obtained with the sizes of P^4 from Italian and Gamssulzen caves.

that re-enter within the range of the Italian populations (i.e. Buco dell'Orso, Fontana Marella, Covoli di Velo, Pocala among others), but also others higher indices than the "Italian trend" (Zunino & Pavia, 2005). At this moment we do not have a solution for this distribution, but we hypothesize a possible influence of the Basura population (Liguria), geographically close to the Grotta del Bandito, where the highest indices of the Italian cave bears were calculated (Quiles, 2004); 5) this distribution could be the consequence of local isolation of the cave bear populations, as in the case of *U. s. ladinicus* from the Conturines, especially at higher altitudes, which alternated with penetrations of populations from Western and Eastern Europe, north of the Alps (Argant *et al.*, 2012) .

6. A BRIEF COMPARISON BETWEEN THE *URSUS INGRESSUS* (STEIGELFADBALM - LUZERN) AND *U. SPELAEUS* (VALSOLDA)

In this section we compare the morphometric and morphodynamic data of the teeth of *U. ingressus* (Steigelfadbalm - Luzern) recently studied by Frischauf *et al.* (2017) and *U.* gr. *spelaeus* (Valsolda), keeping in mind that these localities are geographically close, and consequently, *U. ingressus* could possibly reach the Valsolda cave, and then from there reach the lake Maggiore and lake Como areas.

Incisors – The specimens of the incisors analyzed by Frischauf *et al.* (2017) are numerically low, but some considerations and comparisons can be advanced. Among the teeth from Valsolda, the I_1 are missing; the only I_2 studied by Frischauf *et al*. (2017) have a greater size compared to the mean of the I_2 from Valsolda. I_2 from Steigelfadbalm and from Valsolda have the same morphotype index ("s"). Considering that the I_3 from Steigelfadbalm have a higher size compared to those from Valsolda, the morphotypes recognized are C and D, whereas for the teeth from Valsolda the morphotypes are between C/D and D. Also for I^2 of *U. ingressus* (2 specimens only) their sizes are larger than those of the Valsolda and about the same morphodynamic indices for both; the same consideration can be proposed for I^3, but for the teeth of Steigelfadbalm a larger range of values has been recorded.

M_2 – The sizes of M_2 from Steigelfadbalm are substantially higher than those from Valsolda; the morphodynamic index of the enthypoconid is the highest, even greater than that of Gamssulzen (231.5) (Frischauf *et al*., 2017), while for the M_2 from Valsolda the global index is 156.6 (std = 67.68). For the posterolophs index a main diversification of the values is noted inside the M_2 from Steigelfadbalm, but in general the indices for the teeth of the two localities are similar.

M_3 – The same considerations as those advanced for the other kinds of teeth, can be proposed for M_3; those from Steigelfadbalm have a higher size compared to those from Valsolda. These sizes according to Frischauf *et al*. (2017) are typical of the populations living in the middle altitude of the Eastern Alps. No data for a morphodynamic comparison are available.

In general, this comparison shows that the teeth from Steigelfadbalm and Valsolda could be very similar in the morphotypes and that the main difference can be found in their size.

7. CONCLUSIONS

In this analysis 122 teeth of cave bears from the Valsolda (Lombardy, N. Italy) have been morphologically and morphodynamically studied in order to place them within an evolutionary level. The specimens are composed of incisors, premolars and molars with the exception of $I_{1,2}$ and M_1 which are missing. From a general point of view the teeth have a very similar size to those of the other populations from different localities in North Italy and in rest of Europe; they certainly belong to the *spelaeus* group, but it is difficult in this first analysis, to individuate the species (*ingressus*?, *s. ladinicus*?). In some cases, their size is very similar to those of the small cave bears (*deningeri* for example), but the complexities of the dental surface prevents them from being inserted into this species. The identification of smaller sizes not only in the dimensions of the teeth, but also for the skulls, mandibles and metapodia (found in other caves), is a common characteristic of the Italian populations, even if some components of greater size have also been recognized (i.e. in the Pocala cave population, and the Buco dell'Orso phalanges).

For the population from Valsolda, the morphodynamic analyses on the dental surfaces confirm that the evolutionary level of these cave bears is in general medium and in some cases rather low (*sensu* Rabeder, 1999), a typical characteristic of the bears of the early (?) Late Pleistocene. On the contrary, especially for M^2, higher morphodynamic indices have been found, but in few specimens only; this can be probably due to an intraspecific variation and may not reflect the true characteristic of the population.

A first comparison between the size of the teeth of *U. ingressus* from Steigelfadbalm (Luzern) and Valsolda shows that the bears from the cave in Switzerland have a higher dimension of that from Valsolda, but the most important morphodynamic indices are, in general, rather similar. Only in the Buco dell'Orso (Laglio) some remains of cave bears (phalanges) with a large size have been recently studied (Rossi & Santi, 2017); therefore the specimens are still rather too low in number to support a possible penetration of the *U. ingressus* in this area of the

Lombardy, but this issue will surely be a matter of sharp discussion.

With these new data the panorama on the distribution of the cave bear populations in the Italian Alps has been enriched especially for the central sector in which the Buco dell'Orso (Laglio, Como) and Buco del Frate (Brescia) populations are the most studied populations (Rossi & Santi, 2001, 2013, 2017; Santi & Rossi, 2001; Santi *et al*., 2003 among others). From a general point of view in North Italy the populations of speleians are very similar in size (generally medium) and in morphodynamic indices, which consequently indicate a medium evolutionary level with the exceptions of the Basura locality (Liguria Region) and the Cerè cave (Veneto Region). In fact, in the Basura area the cave bears population shows very high morphodynamic indices (the highest of the whole of the populations of North Italy) (Quiles, 2004) while in the Cerè cave remains of the three species of bears have been found: *deningeri*, *spelaeus* and *arctos*, a very rare association (Rossi & Santi, 2005, 2007, 2011; Rossi *et al*., 2006; Santi & Rossi, 2001, 2007, 2008). Overall, for the Basura cave a problem arises: why is then this difference in the morphodynamic indices? At the present we have few data to answer this question, since the chronological and genetic data are missing. In future, with more complete data, this problem will be a deep matter of discussion.

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