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The cave bears (Ursidae, Mammalia) from Steigelfadbalm near Vitznau (Canton of Lucerne, Switzerland)

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Abstract. The fossil vertebrate remains from the "Steigelfadbalm" cave near Vitznau by Lake Lucerne, which are stored in the Cantonal Archaeological Survey of Lucerne, were subject to a scientific analysis at the Institute for Palaeontology at the University of Vienna. The fossils were recovered during excavations which took place between 1913 and 1937, but had not yet been scientifically analysed. The studies about the morphology and dimensions of the teeth and metapodial bones clarified the systematic position of the cave bears. All other remains originate from wild and domestic animals from the Holocene. The basal fossiliferous layers are mixed with younger sediments by bioturbation. One focus of the investigation was the critical evaluation of the bone fragments, including a human manubrium, interpreted by the excavator as Palaeolithic tools.

Key words: Alpine bear cave, *Ursus ingressus*, Middle Wurmian, morphotypes, locomotion versus dietary habits, extinction pattern, "bone-tools".

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I. LOCATION AND GEOLOGY OF THE CA VE (E. NIELSEN)

The Steigelfadbalm cave is located in the steep south-western flank of the Rigi above Lake Lucerne in Central Switzerland, in the municipality Vitznau, Canton of Lucerne (Figs 1-2).

Fig. 1. Geographic position of the cave "Steigelfadbalm" (Canton of Lucerne, Switzerland).

Fig. 2. Position of the cave "Steigelfadbalm" (red point) at the base of a rock wall formed by Miocene conglomerate named "Nagelfluh" (photo: Kantonsarchäologie Lucerne).

The mountain itself has a maximum height of 1,797m above sea-level, and denotes the transition of the Alps and the Molasse-lowland of the Swiss Plateau. The Rigi consists of lose molasses conglomerate (nagelfluh/gompholith) that was shaped by heavy erosion and frequent rock-slides. This brittle rock comprises debris which is kept together by lime and loam. Numerous Sandstone and marl-layers are recognizable in the conglomerate, and the caves of the Rigi emerged by erosion of these layers. The Steigelfadbalm cave is located 960m above sea-level and nowadays about 20m deep and equally wide (Fig. 3). Palaeontological finds recovered by speleologists in the last few decades show that the Central Swiss Alps were mainly ice-free in the Oxygen Isotope Stage 3 (NIELSEN 2013), between 57,000 and 22,000 years ago. During the last glacial maximum about 22,000 years ago, the Reuss-glacier advanced deep into the Swiss Plateau. However, the summit of the Rigi was ice-free and stands as a so-called nunatak amid the glacier. Moraines indicate that the ice reached the level 1,300m above the sea-level. Thus, the Steigelfadbalm cave was overrun by the glacier and heavily eroded. So originally the cave was probably significantly deeper as it is today, but it is not possible to reconstruct the Prehistoric topography more extensively. Due to the fact that the entrance was parallel to the glacier´s flow, the ice didn't penetrate the cave. There are, therefore, still sediments preserved in the cave. A nearby cave is positioned more diagonally and yielded none of such preserved layers. Scratches on the cave roof here, caused by the glacier, indicate that the ice advanced deeply into the cave.

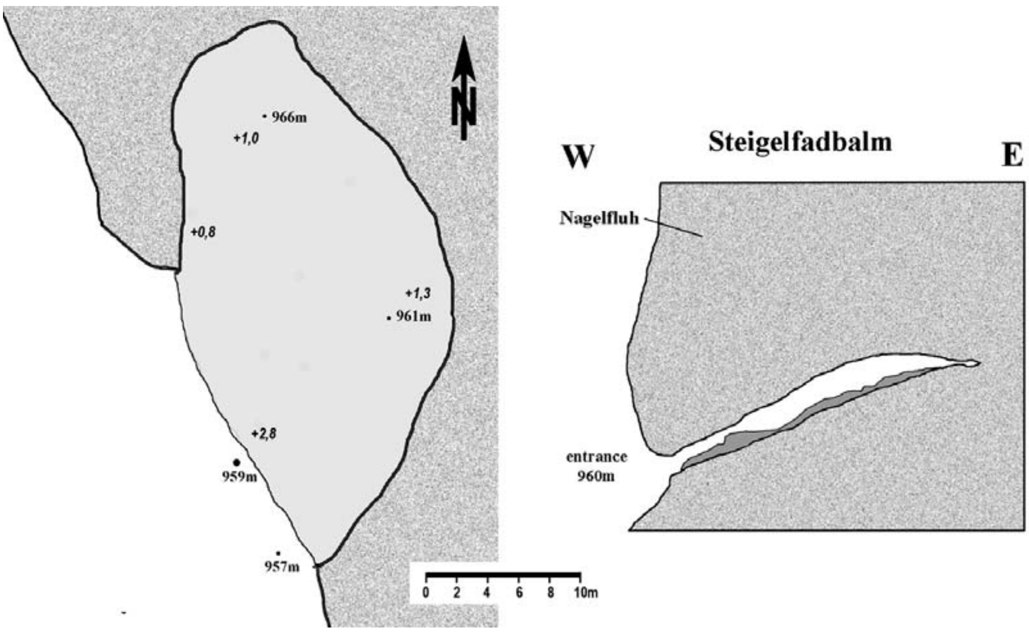

Fig. 3. Ground plan and longitudinal section of Steigelfadbalm (according to AMREIN 1939).

II. HISTORY OF RESEARCH (E. NIELSEN)

The excavations of Wilhelm AMREIN (1913-1937)

During the research of the cave, Wilhelm AMREIN (1913-1937), together with several assistants, impressively and persistently uncovered the hard sediment layers (AMREIN 1939). The excavation was documented according to the standard of that time; unfortunately today, many of the documents and site-plans are presumed lost. Except from a detailed logbook, a few flat glass negatives and plans remain. Several site plans and profile drawings made during the excavation are untraceable today. The loss of this information is extremely regrettable because of the significance of this site. So far, Amrein's results are relatively unknown among scientists. The findings have hardly been acknowledged by the scientific community after AMREIN's death. Firstly they were stored in different institutes, but finally in the Cantonal Archaeological Survey of Lucerne, where they are kept today. AMREIN's results have been barely mentioned in related articles published after his publications. This may be explained by the fact that Amrein interpreted many of the fragments and grinded stones as artefacts, and his working method has therefore been unfairly considered as not serious. Numerous bones, including very small fragments, demonstrate that the excavation was carried out thoroughly. Altogether, AMREIN determined five different layers. Predominant are eolian sands (loess) but also loamy material. Veritable intermediate dung layers prove that wild animals frequently used the cave as a shelter. Occasionally, remains of chamois (*Rupicapra*) which died of natural causes, can still be found in the Steigelfadbalm cave.

In the early 20th century, the archaeology of Alpine caves was of significant interest; not only in caves of the Western Swiss Jura mountains, but also in those of the Eastern Swiss Alps, important results were achieved (LE TENSORER 1998). AMREIN was inspired by this research, and wanted to establish this for the Central Switzerland. In fact, the expected Palaeolithic finds were discovered in the basal layers of the Steigelfadbalm cave, but not as frequently as expected, and predominantly in the form of bones. However, the approximately 3,000 bones and bone fragments confirm the cave as a site of importance - particularly to environmental research. The only radiocarbon analysis to date was induced by the Glacier Garden Museum of Lucerne and yielded a date at approximately 29,000 BP cal. However, archaeological finds indicate that the cave was used by humans already 35,000 BP cal. Consequently, both basal layers must have been deposited during several millennia.

III. ARCHAEOLOGICAL FINDS (E. NIELSEN)

A few stone artefacts out of the "cave bear layers" can be definitely determined as Palaeolithic tools. The most important find is a small point made of rock crystal. This triangular point shows definite traces of retouching. Comparable stone points are characteristic for the middle-Palaeolithic Mousterian culture about 300,000 to 35,000 years ago. Another rock crystal-made artefact is a chisel-like tool, a so-called "splintered piece". Rock crystal deposits are not found in the vicinity of the cave which indicates that it was brought along by the Palaeolithic hunters – for example from the Urner Alps, where the next rock crystal deposits can be found. The crystal point was explicitly mentioned by the excavator and the layer affiliation with find depth was specified. Three other artefacts are made by radiolarite which occurs frequently in the local molasses conglomerate. Two of those artefacts are relatively simple tools, flaked with random retouches, and one small core. How to interpret the apparently proved presence of the Neanderthal men remains open, due to the destruction of major parts of the cave. Most likely, the Palaeolithic inhabitants set up their camp only during the short phases in the snow-free seasons. The excavators reported details about fireplaces on the bottom of the cave. This cannot be confirmed by documentation handed down, and it must therefore be questioned. However, it is important that the presence of the Mousterian culture can be proven for Central Switzerland for the first time.

After the Ice Age

The top layer contained a large blade made of chart which was probably used as a knife. This artefact can only generally be dated into the Neolithic period (5500-2200 BC). From the later Bronze Age, about 1000 BC, a bronze arrowhead was found. It can thus be concluded that the cave was used as a shelter by hunters and shepherds during the late Prehistory. A leaden bullet also documents that in recent times hunters visited the cave. The middle layers are without findings.

Wilhelm AMREIN

The excavator Wilhelm AMREIN (1872-1946) was a remarkable personality. Because he was the son of the couple who founded the Glacier Garden of Lucerne, he became sensitised early on in natural history and archaeological themes. After graduating, he completed financial training, graduated from military academy, and worked for the Swiss costumes (Fig. 4). In 1907, he took over the management of the Glacier Garden Museum and started numerous excavations around Lake Lucerne. His researchers were accompanied by diverse experts including the famous geologist Albert HEIM. AMREIN was a member of various scientific associations, and was awarded an honorary doctorate by the University of Basel. In 1939, AMREIN published his research in the still important book "Urgeschichte des Vierwaldstättersees und der Innerschweiz" ("Prehistory of Lake Lucerne and Central Switzerland").

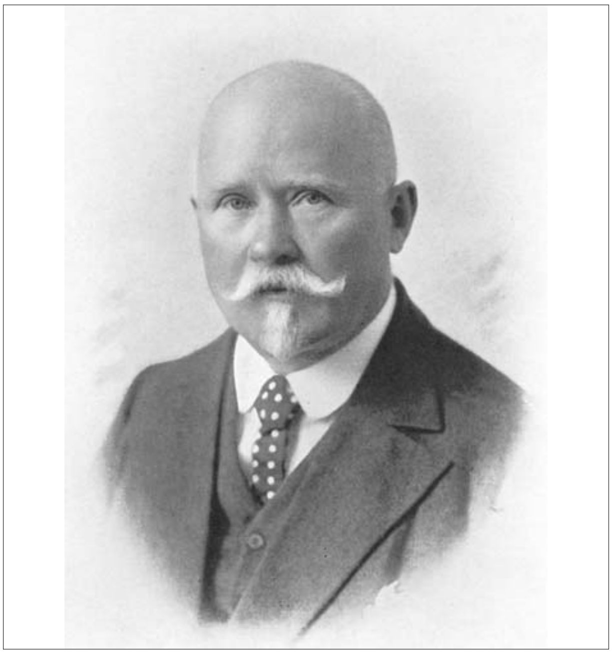

Fig. 4. Wilhelm AMREIN (portrait, Kantonsarchäologie Lucerne).

IV. FOSSIL VERTEBRATE REMAINS FROM THE STEIGELFADBALM
(C. FRISCHAUF & G. RABEDER)

Genus *Ursus* L.

Ursus ingressus RABEDER et al. 2004

Material: around 225 determinable elements.

Deficiency of findings

The number of preserved elements is highly diverse. Resulting from the number of the most frequent element, the 1st lower molar, the MNI (minimal number of individuals) can be concluded. 17 right and 17 left m1 inf. exist so that the MNI is 17.

All other elements are under-represented. This phenomenon, for a number of reasons, is called "deficiency of finding" (RABEDER 2001; FRISCHAUF et al. 2014). Important reasons for this distortion of the preserved remains are: 1. **corrosion** (chemical destruction by acid), 2. **material-separation** and **fragmentation** during the relocation by running water, 3. **selection of the fossils by the excavators** and 4. **bioturbation**. Corrosion and relocation aid the conservation of small compact bones and teeth, whereas long-bones, vertebrae and crania are seldom preserved, and crania, canines and long-bones are preferably selected by the excavators. It can be assumed that the corrosion dissolves the osteolysis more powerfully than the tooth enamel, which leads to the considerable difference between the

Table I

Material overview of determinable cave bear elements from Steigelfadbalm cave: bac – baculum; c1, c2 – os carpale 1,2; fem – femur; fib – fibula; hum – humerus; Mc1 to 5 – metacarpale 1-5; mt 1 to 5 – metatarsale 1-5; phalg. – phalanges; phb – basal phalanx; phm – medial; pht – phalanx terminalis; pisi – os pisiforme; rad – radius; scl – os scapholunatum; t1 – os tarsale 1

Teeth	I1,2	I3	i1	i2	i3	C	Milk teeth	Total
Number	4	3	2	1	2	7	8	27

Cheek teeth	P4	p4	M1	M2	m1	m2	m3	Total
Number	0	7	2	21	34	10	7	81

Limb bones	hum	rad	ulna	fem	tibia	fib	**Total**	varia	bac	v.caud.
number	**3**	**2**	**3**	**3**	**2**	**8**	**21**		**8**	**9**

Autopodials	c1	c2	pisi	scl	t1	Total	phalg.	phb	phm	pht	Total
number	1	1	1	6	1	10		25	1	76	102

Metapodials	Mc1	Mc2	Mc3	Mc4	Mc5	mt1	mt2	mt3	mt4	mt5	Indet	Total
number	0	7	7	2	1	4	7	7	6	6	1	48

frequency of preserved teeth and same-sized bones. According to the notes of the excavator (AMREIN 1939), the fossilised remains of the Steigelfadbalm were heavily affected by bioturbation. The fossil-rich layers are disturbed by foxholes.

The deficiency-index shows the varying frequencies of the preserved bear-elements.

The data illustrated in Table II does not clearly determine the process that led to the deficiency of particular elements. Teeth are more frequent than bones, which indicates factor 1 (corrosion). Big teeth (m1 inf., M2 sup.) were found more frequently than the smaller incisors, which might be a result of the excavation methods. The sediment was obviously not sieved, and the lighting of the site was insufficient - a likely reason why the small incisors might not have been detected. The relatively low number of canines might be due to the fact that these teeth occur heavily fragmented.

The relatively large number (deficiency-index = 100) of bacula (genital bone) is unusual. This bone is statistically the rarest preserved element, as it is found only in adult male bears.

Baculum- and fibula-fragments and partly low-arch-shaped costa-fragments were interpreted as “bone-artefacts” (BÄCHLER 1931). AMREIN (1939) assumed that these stretched bone-fragments, as well as undetermined bone-fragments, are “lacy bone-points” like the find-labels verify. Within the find-units, later assigned with the find-number 236 and 237, such bone-fragments are frequent, so it is to be assumed that the excavators operated selectively.

The low number of autopodial-bones compared with metapodial-bones is also unusual. In the cave-inventory of modern excavations, these small but compact bones are usually more frequent because they are more resistant to corrosion and mechanical stress. Material-separation during water-transportation or bioturbation may be the reason.

In summary, the inventory of the Steigelfadbalm can be seen as “rest-fauna”: the skeletons of the bears that died in the cave are not according to a recognizable pattern, and preserved only selectively.

Table II

Frequency of cave bear bones and teeth in the material from Steigelfadbalm. (*equivalence factor = number of this element in a whole body)

Element	Number of finds	MNI	Equivalence factor*	Debit	Deficience index %
m1 inf.	34	17	2	34	100
baculum	8	17	0.5	8	100
fibula	8	17	2	34	23.53
molars	74	17	20	340	21.76
phalanges	102	17	56	952	10.71
long bones	21	17	12	204	10.29
metapodials	48	17	40	680	7.06
incisors	12	17	12	204	5.88
autopodials	10	17	32	544	1.84

Mandible-remains

Incisors (Table III)

The preservation of the incisors is quite modest. A statistical evaluation of the data is not applicable. The small amount of morphological data indicates a relatively high evolutionary level. The morphotype C of the calyx (significant cusp on the distal-edge of the I3 sup.) only occurs in *Ursus ingressus*. In the material of the Steigelfadbalm there are, out of the four I3 sup, two specimens that represent this morphotype (RABEDER 1999: 70-71).

Table III

Measurements of the incisors of *Ursus* from Steigefadbalm (mm)

Symbol	Objekt number	Fund number	Inventory number	Element	Length	Width	Total height	Morphotype	Side	Notation
Sfb	804 B	**10**	**12**	i1 inf	7.3	9.9	33.1	C	dex	root open
Sdb	804.B	**194**	**II**	i1 inf	6.5	8.4	29.6	worn	dex	root open
Sdb	804.B	**158**	**no nr.**	i2 inf	11.0	11.3	fr	s	dex	root open
Sdb	804.B	**194**	**24 IV 3**	i3 inf	12.9	11.5	fr	C	sin	root open
Sfb	804.B	**228**	**no nr.**	i3 inf	13.1	12.7	fr	D	dex	root open
Sdb	804.B	**12**	**1**	I1,2 sup	10.1	11.0	34.4	worn	dex	root open
Sfb	804 B	**10**	**11**	I1,2 sup	12.1	13.2	31.1	worn	sin	root closed
Sfb	804 B	**10**	**4**	I1,2 sup	fr	fr	ca.34.5	fr	fr	root closed
Sfb	804.B	**121**	**no nr.**	I1,2 sup	11.8	12.3	37.0	s1	dex	root almost closed
Sfb	804 B	**4**	**9**	I3 sup	21.8	17.8	–	0.5	sin	germ
Sfb	804 B	**10**	**3**	I3 sup	fr	fr	fr	fr	fr	root closed
Sfb	804 B	**10**	**6**	I3 sup	worn	worn	–	worn	dex	root closed
Sfb	804 B	**10**	**7**	I3 sup	fr	fr	fr	1.0	dex	germ
Sdb	804.B	**241**	**1**	I3 sup	20.5	16.7	fr	2.0	sin	germ
Sdb	804.B	**241**	**920**	I3 sup	fr	15.2	fr	2.0	sin	germ

Canines (Table IV)

Within the few canines, there were only five pieces whereby it was possible to measure the length and width of the teeth-crowns. In comparison to the canines of the Drachenhöhle of Mixnitz there is only one canine from the Steigelfadbalm which can be classified as a male canine (Fig. 5).

Premolars (Table V)

Within the five lower p4, there is one highly evolved morphotype C3 (with two hypoconid cusps, Fig. 7) which is only known from *Ursus ingressus*. The calculated p4-index (statistically not significant) is 175.0, which comes very close to the p4-index of the type-fauna from the Gamssulzen cave (p4-index=198.2).

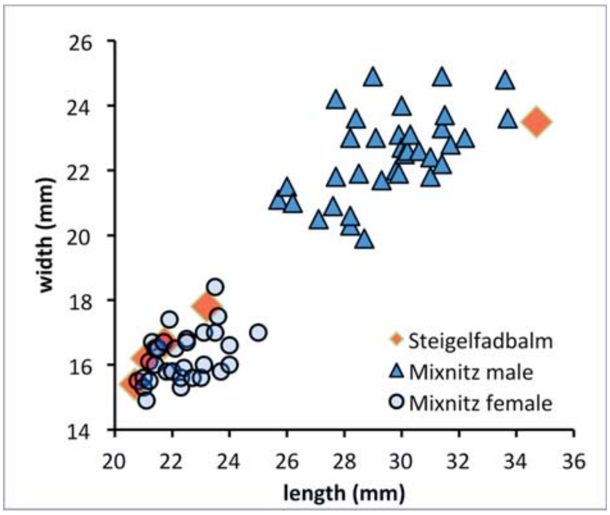

Fig. 5. Scatter diagram of canines from Steigelfadbalm in comparison to teeth from Mixnitz (*Ursus ingressus*).

Table IV

Measurements of the canines of *Ursus* from Steigelfadbalm (mm)

Symbol	Objekt number	Fund number	Element	Inventory number	Length	Width	Sex	notation
Sfb	804.B	**6**	caninus	**28**	21.7	16.7	female	–
Sfb	804 B	**10**	caninus	**10**	fr	fr	indet	splinter
Sfb	804 B	**10**	caninus	**44**	fr	fr	indet	top of crown
Sfb	804 B	**16**	caninus sup	**4**	23.2	17.8	female	–
Sfb	804 B	**16**	caninus sup	**5**	20.7	15.4	female	–
Sdb	804.B	**243**	mandible	**X10**	34.7	23.5	male	mandible sin
Sdb	804.B	**243**	mandible	**1**	21.1	16.2	female	mandible sin

m1 inf (Table VI)

Only from the 1st lower molar is there a statistically significant number of usable teeth. The means of the measurements are very informative for the taxonomic position. Both the mean length and the mean width show higher values than the type-fauna of *Ursus ingressus* (Fig. 7). Similar applies for the enthypoconid-index.

In the scatter diagram of length and width (Fig. 6), a comparison with the m1 inf. of *Ursus ingressus* one find-unit of the “Abelgang”) from the “Drachenhöhle” of Mixnitz is illustrated. It can be assumed that the sex-ratio of the cave bears was not balanced: there are 12 female, m1 inf. and 8 male molars; the sex-index (=n female/n total*100) is 60%. The larger number of female m1 confirms the determined tendency of the canines (Fig. 1).

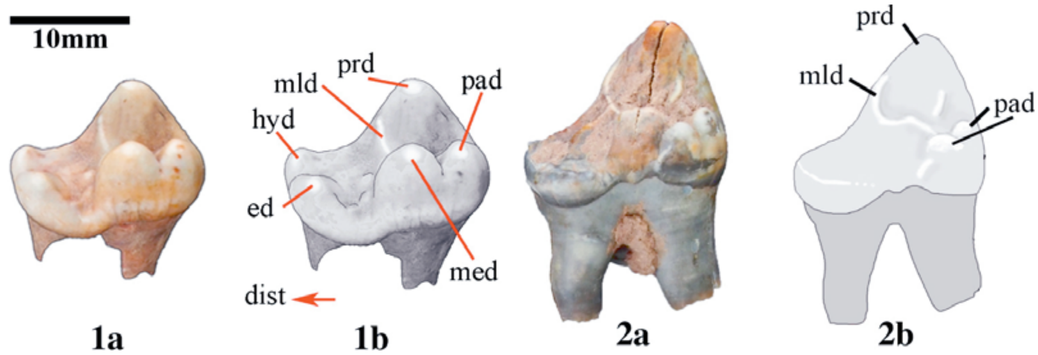

Fig. 6. Two highly developed premolars of lower jaw of cave bear from Steigelfadbalm: 1 – p4 inf. sin Sgf 804-12-2, 2 – p4 inf. dex (invers depicted) Sgf 804-10-49. a – lingual view, b – schem (ed – entoconid, hyd – hypoconid, med – metaconid, mld – metalophid, pad – paraconid, prd – protoconid).

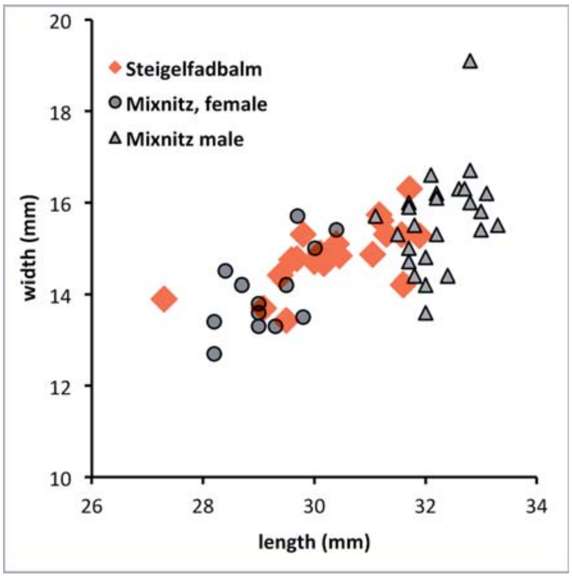

Fig. 7. Scatter diagram of m1 inf from Steigelfadbalm in comparison to teeth from Mixnitz (*Ursus ingressus*).

Table V

Measurements and morphology of the premolars of *Ursus* from Steigelfadbalm

Symbol	Objekt number	Fund number	Inventory number	Element	Length	Width	Morpho-type	Morpho-dyn. factor	Side
Sdb	804.B	**12**	**2**	p4 inf	15.9	10.7	E1	2.0	dex
Sfb	804 B	**10**	**14**	p4 inf	15.7	11.3	C3	3.0	sin
Sfb	804 B	**10**	**59**	p4 inf	14.2	9.8	B1/E1	1.3	sin
Sfb	804 B	**10**	**28a**	p4 inf	13.3	10.5	C1/2	1.5	sin
Sfb	804.B	**201**	**no nr.**	p4 inf	15.1	10.8	C1	1.0	dex
							p4 inf index		**175.00**

Table VI

Measurements and morphology of the first lower molars of *Ursus* from Steigelfadbalm

Symbol	Objekt number	Fund number	Inventory number	Element	Length	Width	Morpho-type	Morpho-dyn. factor	Side
Sfb	804 B	**4**	**1**	m1 inf	fr	14.1	C	2.0	dex
Sfb	804 B	**4**	**2**	m1 inf	fr	fr	fr	–	dex
Sfb	804 B	**4**	**3**	m1 inf	fr	fr	fr	–	dex
Sfb	804 B	**4**	**5**	m1 inf	fr	fr	fr	–	sin
Sfb	804 B	**4**	**7**	m1 inf	31.6	15.3	A/B	0.5	sin
Sfb	804 B	**4**	**8**	m1 inf	31.7	16.3	worn	–	sin
Sfb	804 B	**4**	**10**	m1 inf	30.4	15.1	B/C	1.5	sin
Sfb	804 B	**4**	**12**	m1 inf	30.1	14.9	B	1.0	dex
Sdb	804 B	**4**	**14**	m1 inf	fr	14.4	B	1.0	sin
Sdb	804 B	**4**	**16**	m1 inf	fr	17.5	B	1.0	sin
Sfb	804 B	**4**	**17**	m1 inf	31.6	14.2	C	2.0	dex
Sfb	804 B	**4**	**18**	m1 inf	29.6	14.8	D	3.0	dex
Sfb	804 B	**4**	**19**	m1 inf	31.2	15.7	A	0.0	sin
Sfb	804 B	**4**	**20**	m1 inf	30.2	14.7	B	1.0	dex
Sfb	804 B	**4**	**21**	m1 inf	29.8	15.3	B	1.0	dex
Sfb	804 B	**4**	**22**	m1 inf	31.9	15.3	B	1.0	dex
Sdb	804 B	**4**	**23**	m1 inf	30.5	14.8	B	1.0	dex
Sfb	804 B	**4**	**24**	m1 inf	29.4	14.4	C/D	2.5	dex
Sfb	804 B	**4**	**26**	m1 inf	29.1	13.7	C	2.0	sin
Sfb	804 B	**4**	**28**	m1 inf	29.7	14.8	C	2.0	sin
Sfb	804 B	**4**	**138**	m1 inf	fr	fr	fr	–	dex
Sfb	804 B	**4**	**147**	m1 inf	fr	fr	fr	–	dex
Sfb	804 B	**4**	**340**	m1 inf	29.5	13.4	B	1.0	sin
Sdb	804 B	**10**	**8**	m1 inf	31.1	14.9	B	1.0	sin
Sfb	804 B	**10**	**14**	m1 inf	fr	fr	C	2.0	sin
Sfb	804.B	**20**	**1-3**	m1 or m2 inf.	fr	fr	fr	–	dex
Sfb	804.B	**62**	**no nr.**	m1-fragm	fr	fr	**C**	2.0	sin
Sdb	804.B	**156**	**no nr.**	m1 inf.-fr.	fr	14.2	B	1	sin
Sfb	804.B	**241**	**1**	m1 inf	30.0	14.7	worn	–	sin
Sfb	804.B	**241**	**11**	m1 inf	31.2	15.6	worn	–	sin
Sfb	804.B	**241**	**5**	m1 inf	31.3	15.3	worn	–	sin
Sfb	804.B	**241**	**22**	m1 inf	fr	14.3	B	1.0	dex
Sfb	804.B	**241**	**2**	m1 inf	fr	fr	fr	–	dex
				mean	*30.51*	*14.90*		*138.64*	
				number	19	24		22	
				GS standard	30.22	14.50		131.00	
				mean standardized	**100.96**	**102.74**		**105.83**	

M1 sup (Table VII)

The 1st upper molar is represented by only two exemplars.

Table VII

Measurements of first upper molars of *Ursus* from Steigelfadbalm (mm)

Symbol	Objekt number	Fund number	Inventory number	Element	Length	Width	Side	Notation
Sfb	803B	**10**	1	M1 sup	29.8	21.1	dex	roots open
Sdb	804.B	**156**	**no nr.**	M1 sup.-fr.	fr	fr	dex	germ fragm.

m2 inf (Table VIII)

Out of the 10 preserved 2nd lower molars, there are nine female but only one male m2 inf. according to the scatter diagram (Fig. 3). In the comparative-fauna from the "Drachenhöhle" of Mixnitz, there is not such a clear gender-separation possible, so an overlapping of male and female values are most likely. The means of the teeth-measurements and the enthypoconid-index is higher than the values of the Gamssulzen cave.

Table VIII

Measurements and morphology of the second lower molars of *Ursus* from Steigelfadbalm (mm)

Symbol	Objekt number	Fund number	Inventory number	Element	Length	Width	Morpho-type	Morpho-dyn. factor	Side
Sfb	804 B	**10**	**2**	m2 inf	30.21	18.69	C	2	sin
Sfb	804 B	**16**	**7**	m2 md	32.4	19.2	worn	–	sin
Sfb	804 B	**16**	**8**	m2 md	27.8	17.8	worn	–	dex
Sdb	804.B	**54**	**no nr.**	m2 inf	32.1	19.1	C	2	sin
Sfb	804.B	**201**	**no nr.**	m2 inf	35.1	20.6	C	2	dex
Sdb	804.B	**241**	**23**	m2 inf	28.1	17.6	C	2	sin
Sdb	804.B	**241**	**5**	m2 inf	32.6	19.0	C	2	sin
Sdb	804.B	**241**	**6**	m2 inf	31.2	19.5	B	1	dex
Sdb	804.B	**241**	**1**	m2 inf	33.2	18.5	D	3	dex
Sdb	804.B	**194**	51.5.25	m2 inf	31.38	18.5	B/C	1.5	dex

M2 sup (Table IX)

The large number of M2 sup. germs (Fig. 8) is highly unusual. Out of the 21 preserved exemplars there is only one tooth of an adult bear. All other upper 2nd molars are germs or germ-fragments which originate from juvenile or sub-adult animals. This frequency, especially within the find-number 241, indicates a selective factor, most probably attributed to the excavators. It was not possible to clarify why the excavators might have preferentially collected M2 sup-germs.

Dimensionally, the M2 sup. from the Steigelfadbalm lie within the distribution of the type-fauna *Ursus ingressus* from the Gamssulzen cave, but also within *Ursus spelaeus* from the Schwabenreith cave. The evolutionary level of the metaloph (RABEDER 1999) is high and the frequency of morphotypes with developed metaloph is more than 26%.

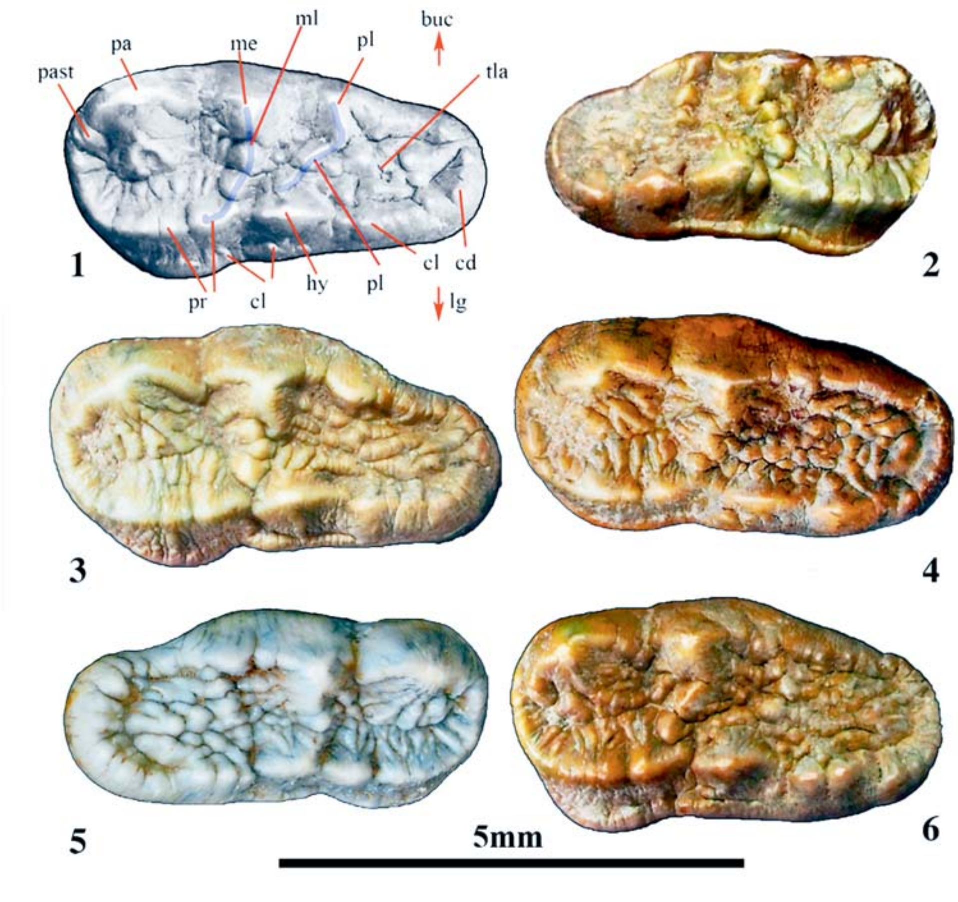

Fig. 8. Six highly developed molars of upper jaw (M2 sup) of cave bear from Steigelfadbalm: 1 – M2 sup sin schema (Sfg 804 B 241-6), 2 – M2 sup sin (Sgb 804 B 241-12), 3 – M2 sup dex (Sgb 804 B 241-4), 4 – M2 sup sin (Sgb 804 B 241-5), 5 – M2 sup dex (Sgb 804 B 241-3), 6 – M2 sup sin (Sgb 804 B 241-13) (buc – buccal, cd – distal cingulum, cl – lingual cingulum, hy – hypocone, lg – lingual, me – metacone, ml – metaloph, pa – paracone, past – parastyl, pl – posteroloph, pr – protocone, tla – talon area).

Table IX

Measurements and morphology of the second upper molars of *Ursus* from Steigelfadbalm (mm)

Symbol	Objekt number	Fund number	Inventory number	Element	Length	Width	Meta-lophid	Postero-loph	side	notation
Sfb	804 B	**10**	**13**	M2 sup	fr	fr	fr	–	indet	germ
Sdb	804.B	**194**	**33.4.25.10**	M2 sup	45	23.27	C3	1	dex	germ
Sfb	804.B	**207**	**1**	M2 sup.	fr	fr	fr	–	dex	germ fr.
Sdb	804.B	**241**	**1**	M2 sup	44.0	22.6	C1	3.0	dex	germ
Sdb	804.B	**241**	**2**	M2 sup	43.7	23.0	D1	2.0	sin	germ
Sdb	804.B	**241**	**3**	M2 sup	45.1	21.8	C/D1	2.0	dex	4 roots
Sdb	804.B	**241**	**4**	M2 sup	41.6	21.3	C3	2.0	dex	germ
Sdb	804.B	**241**	**5**	M2 sup	47.3	24.3	C3	1.0	sin	germ
Sdb	804.B	**241**	**6**	M2 sup	44.8	22.8	D3	3.0	dex	germ
Sdb	804.B	**241**	**7**	M2 sup	44.5	23.1	C1	3.0	dex	germ
Sdb	804.B	**241**	**8**	M2 sup	41.9	21.4	C2	2.0	sin	germ
Sdb	804.B	**241**	**9**	M2 sup	44.2	22.4	B3	3.0	sin	germ
Sdb	804.B	**241**	**10**	M2 sup	43.7	22.0	B3	1.0	dex	germ
Sdb	804.B	**241**	**11**	M2 sup	44.7	23.2	D3	1.0	dex	germ
Sdb	804.B	**241**	**12**	M2 sup	44.4	22.9	B2	2.0	sin	germ
Sdb	804.B	**241**	**13**	M2 sup	47.5	24.0	B3	2.0	sin	germ
Sdb	804.B	**241**	**14**	M2 sup	fr	23.3	B1	2.0	sin	germ
Sdb	804.B	**241**	**15**	M2 sup	48.0	23.2	D1	3.0	dex	germ
Sdb	804.B	**241**	**16**	M2 sup	43.4	21.2	C3	1.0	sin	germ
Sdb	804.B	**241**	**17**	M2 sup	46.4	23.5	A	1.5	dex	germ
Sdb	804.B	**241**	**18**	M2 sup	fr	fr	C2	fr	dex	germ
Sdb	804.B	**241**	**19**	M2 sup	fr	fr	fr	–	sin	germ

m3 inf (Table X)

There are only four isolated lower 3rd molars while the number of isolated M2 sup. is five times higher. The dimensions correspond with cave bears from middle-altitudes of the Eastern Alps ("Drachenhöhle" of Mixnitz, Gamssulzen cave, Schwabenreith cave, etc.).

Table X

Measurements and morphology of the third lower molars of *Ursus* from Steigelfadbalm (mm)

Symbol	Objekt	Fund nr.	Element	**Inv.-Nr**	Length	Width	Side	Notation
Sfb	804 B	**16**	m3 md	**7**	29.0	21.6	sin	in situ
Sfb	804 B	**16**	m3 md	**8**	24.9	18.7	dex	in situ
Sfb	804 B	**10**	m3 inf	**9**	26.9	19.8	dex	worn, 1 root closed
Sfb	804 B	**10**	m3 inf.	**16**	fr	21.1	dex	germ fragm.
Sdb	804.B	**241**	m3 inf	**1**	26.7	20.7	sin	1 root open
Sdb	804.B	**241**	m3 inf	**5**	26.8	19.2	sin	1 root open
Sfb	804 B	**243**	m3 md	**1**	27.7	19.0	sin	in situ

Metapodial bones (Tables XI-XII)

The number of intact and therefore measurable metapodial bones is in comparison to the preserved m1 inf. and M2 sup. low (Table XI).

Table XI

Measurements of metapodial bones of *Ursus ingressus* from Steigelfadbalm (dew – distal epiphyseal width, sdd – smallest depth of diaphysis, sdw – smallest width of diaphysis) (mm)

Symbol	Object	Fund nr.	Inv. nr.	Element	Length	dew	sdw	sdd	Side
Sfb	804 B	**35**	**4**	Mc2	74.77	24.67	16.54	12.02	dex
Sfb	804 B	**218**	**25**	Mc2	84.08	29.45	16.38	11.83	dex
Sfb	804 B	**218**	**23**	Mc2	74.98	24.45	20.88	14.09	sin
Sfb	804 B	**218**	**506**	Mc2	fr	fr	18.22	12.58	sin
Sdb	804.B	**32**	**3**	Mc3	75.06	23.85	15.1	11.4	dex
Sdb	804.B	**32**	**4**	Mc3	88.62	28.97	18.6	16.2	dex
Sdb	804.B	**32**	**5**	Mc3	81.77	27.61	17.7	16.2	dex
Sdb	804.B	**32**	**6**	Mc3	88.81	31.52	20.6	15.7	sin
Sdb	804.B	**32**	**7**	Mc3	83.07	29.18	18.4	14.9	dex
Sdb	804.B	**32**	**8**	Mc3	85.73	22.9	16.2	14.5	sin
Sdb	804.B	**108**	**o.nr.**	Mc3	83.62	28.52	17.5	13.2	sin
Sdb	804.B	**86**	**o.nr.**	Mc4	89.57	28.22	19.32	13.14	sin
Sdb	804.B	**32**	**2**	Mc4	fr	fr	17.7	11.6	dex
Sfb	804 B	**218**	**12**	Mc5	79.54	26.95	16.48	13.32	sin
Sfb	804 B	**218**	**12**	mt1	61.57	21.14	14.48	10.5	dex
Sfb	804 B	**218**	**12**	mt1	61.57	21.14	14.48	10.5	dex
Sfb	804 B	**218**	**17**	mt1	61.6	18.94	13.97	10.83	dex
Sfb	804 B	**218**	**17**	mt1	61.6	18.94	13.97	10.83	dex
Sfb	804 B	**35**	**2**	mt2	71.02	23.90	16.21	12.22	dex
Sdb	804.B	**152**	**1**	mt2	68.05	23.47	15.93	11.84	dex
Sdb	804.B	**152**	**2**	mt2	67.67	23.61	15.37	11.33	dex
Sdb	804.B	**152**	**3**	mt2	69.47	23.35	16.04	12.43	dex
Sfb	804 B	**218**	**12**	mt2	72.94	22.9	15.02	10.21	dex
Sfb	804 B	**218**	**12**	mt2	72.94	22.9	15.02	10.21	dex
Sdb	804.B	**152**	**4**	mt2?	ca. 67.80	24.2	15.36	11.46	sin
Sfb	804 B	**35**	**3**	mt3	81.3	fr	16.96	13.23	dex
Sfb	804 B	**218**	**12**	mt3	83.59	28.62	17.72	14.56	dex
Sfb	804 B	**218**	**12**	mt3	83.59	28.62	17.72	14.56	dex
Sfb	804 B	**218**	**23**	mt3	79.3	25.88	15.86	14.55	dex
Sfb	804 B	**218**	**23**	mt3	79.3	25.88	15.86	14.55	dex
Sfb	804 B	**218**	**30**	mt3	fr	fr	17.33	13.29	dex
Sfb	804 B	**218**	**30**	mt3	fr	fr	17.33	13.29	dex
Sfb	804 B	**218**	**17**	mt4	93.6	28.25	18.56	14.28	dex
Sfb	804 B	**218**	**25**	mt4	83.13	23.61	15.18	12.06	dex
Sfb	804 B	**218**	**25**	mt4	83.13	23.61	15.18	12.06	dex
Sfb	804 B	**218**	**20a**	mt4	93.21	26.08	16.97	15.99	dex
Sfb	804 B	**218**	**20a**	mt4	93.21	26.08	16.97	15.99	dex
Sfb	804 B	**218**	**12**	mt5	81.27	21.57	12.55	12.25	dex
Sfb	804 B	**218**	**12**	mt5	81.27	21.57	12.55	12.25	dex
Sfb	804 B	**218**	**446**	mt5	89.25	28.09	16.14	14.6	dex
Sfb	804 B	**218**	**446**	mt5	89.25	28.09	16.14	14.6	dex
Sfb	804 B	**218**	**448**	mt5	88.45	30.23	18.81	15.12	dex
Sfb	804 B	**218**	**12**	indet	78.89	26.5	16.88	13.07	indet

For the comparison with cave bear remains from other caves, the data of the metapodial bones are standardised. The mean of the cave bears from Gamssulzen cave, the Locus typicus of the highest evolved species *Ursus ingressus* (RABEDER et al. 2004 and see WITHALM 2001), was used as a standard value for the cave bear. For the comparison of the metapodial bones, relevant means from the Gamssulzen cave are are given in Table XII.

The metapodial bones from the Steigelfadbalm lie within the distribution-area of those from the Dragon cave of Mixnitz.

Table XII

Standard values of the metapodial bones of *Ursus ingressus*, Gamssulzen cave (dew – distal epiphyseal width; PI – plumpness index (dew/length*100)) (mm)

Element	Length	dew	PI		Element	Length	dew	PI
mc1	63.5	19.3	30.4		mt1	53.1	17.7	33.3
mc2	73.7	25.3	34.3		mt2	67.3	21.3	31.6
mc3	79.8	26.5	33.2		mt3	77.3	23.4	30.3
mc4	83.6	28	33.5		mt4	84.3	24.5	29.1
mc5	82.5	29.2	35.4		mt5	85.7	24.4	28.5

Locomotion versus dietary habits (LDH-diagram = „run-chew diagram“) (Table XIII)

“The evolutionary lines of the “big bears” (subgenus *Ursus* s. str.) differ in developmental contrary trends (RABEDER et al. 2011): brown bears and polar bears show extended limbs, while the dentition is almost unchanged or even reduced. The dentition of cave bears is augmented whilst the extremities are shorter and thicker. The relation between dentition and limb development can be seen in the so-called “locomotion versus dietary habits diagrams (“run-chew-diagrams”, FRISCHAUF et al. 2014). All the values of a statistically relevant number of teeth and metapodials are standardised (KAVCIK et al. 2016).

The cave bears from the Steigelfadbalm lie within the cluster of *Ursus ingressus* (RABEDER et al. 2004). The taxonomic position therefore cannot be questioned (Fig. 9). These large and relatively plump cave bears together with lions and leopards, immigrated to the Alpine around 50,000 years ago (FASSL & RABEDER 2015).

Chronology

There is one radiometric dating of the cave bears from the Steigelfadbalm. The calibrated radiometric dating is 31,177 years BP (Table XIV). Together with the altitude of 960m, the date integrates well with the elaborated extinction-pattern to date (Fig. 10). The geologically youngest data of cave bears are different for the separate altitudes. However, there is no direct relation within the radiometric dates and the altitude of the cave entrance. The “height dependent extinction line” (HDEL) of cave bears connects all determined radiometric data of the geologically youngest dates pro altitude to date. The course of this line (Fig. 7) is in contrast to the presumption that the extinction of the Alpine cave bears was caused by the temperature drop starting 40,000 ago, which introduced the last ice age (last glacial maximum 25,000 y BP).

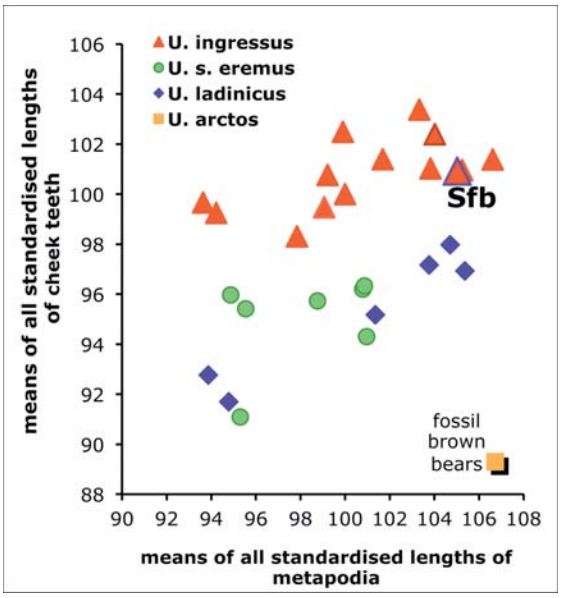

Fig. 9. LDH diagram of Alpine cave bear faunas. The fauna of Steigelfadbalm lies in the cluster of *Ursus ingressus*.

Table XIII

Standard values of the teeth of *Ursus ingressus*, Gamssulzen cave (mm)

Gamssulzen	Length	Width	Md index	Value of index
p4 inf	15.24	10.32	p4 inf	**198.2**
m1 inf	30.22	14.5	enthypoconid	**131**
m2 inf	30.63	18.25	enthypoconid	**185.3**
m3 inf	27.56	19.11	–	–
P4 sup	20.13	14.21	P4 sup	**255.7**
M1 sup	28.73	19.75	–	–
M2 sup	44.4	22.55	metaloph	**375**
P4 + p4	–	–	p4/p4	**225.12**

Table XIV

Radiometric data of cave bear remains from Steigelfadbalm

Lab.nr.	Site	Materia l	**C14 age**	Error +/-	**calBP**	Error +/-	C13	Error +/-	Date
ETH 39620	Steigelfadbalm	bone	**26350**	110	**31177**	342	-22	1.1	16.01.10

Due to this model, the HDEL of 45,000 at 2,800m altitude must gradually decrease to 29,000 years (the extinction of cave bears). The geological dating of the youngest cave bear would therefore be expected by the lowest-situated caves. The recent dates contradict the HDEL passes from the highest-situated cave bear cave at 2,800 m (Conturines cave), the Schreiberwand cave (2,250 m), and the caves around 2,000 m (such as Ramesch-bone-cave), in addition to the caves with the youngest radiometric data in an altitude around 1,650 to 1,750 m.

The further development of the HDEL is a surprise. The youngest AMS-dating is from Alpine caves at an intermediate altitude, but they become older by decreasing altitude. In the range of the bear cave of Winden, the cave bears had already obviously disappeared 43,000 years ago. Climatic changes might be the reason for this peculiar development of the HDEL in the Alpine area. Initially, the gradual cooling reduced the cave bears' diet in high Alpine regions, while in the lower situated areas of the Prealps, the growing steppisation eliminated the essential herbal food. The AMS-dating of the Steigelfadbalm fits into the development of the HDEL (Fig. 10).

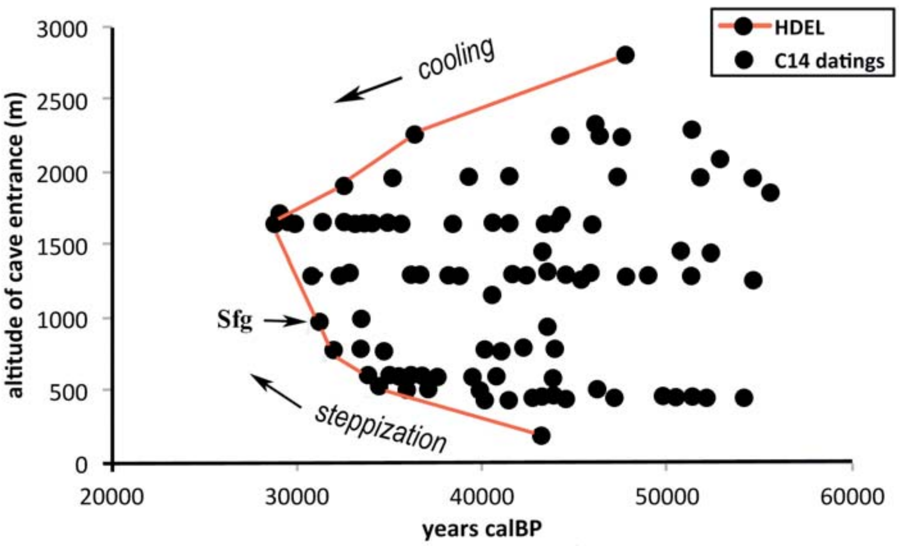

Fig. 10. Radiocarbon data of Alpine cave bears in relation to altitude. The recent age values lie on the HDEL = Hight Dependent Extinction Line which connects the points with the lowest ages per level. Dating according to: HILLE & RABEDER 1986; RABEDER 1995; DÖPPES & RABEDER 1997; PEREGO et al. 2001; ARGANT & ARGANT 2004; BONA et al. 2004; BOLUS & CONARD 2006; CASTEL et al. 2008; PACHER & STUART 2008; BLANT et al. 2009; BOCHERENS et al. 2011; DÖPPES et al. 2011, 2012, 2012, 2016; FRISCHAUF 2011; IMHOF (pers. comm. 2014); SPÖTL et al. 2014; and original).

"Bone-artefacts"

During the research of the Steigelfadbalm after excavations, lectures and publications by Emil BÄCHLER, opinion determined that ice age-men used bones and teeth of cave bears in many ways as tools. Rounded and sharpened bone-fragments were interpreted as "fell-remover, smoother, fell-scraper" (BÄCHLER 1931).

Fig. 11. Label for the "pointed-like bone tools" from the Steigelfadbalm.

Table XV

Pointed-like bone tools out of the fossil-material from the Steigelfadbalm

Fund-nr.	Sub-nr.	Element	Original caption	Remarks
236	1	baculum. proximal fragment	A XIII St 1922 6/X	belonging together with 237-1
236	2	baculum. proximal fragment	St 3/X 23 AXII 15m, 1 m nach unten 20 cm über Steinboden. Sch IV olive	
236	3	baculum. proximal fragment	St12/IX23 11 m 70 20 cm nach Aus?? 25 cm unter dem Humus 15 cm über Felsboden Sch III	
236	4	baculum, middle fr.	A I 18/X 1902 1^{h}10 St	
236	7	canine fragment	824	fragment of the top
236	8	canine fragment	no caption	with grinding mark
236	9	canine fragment	XXXX	with grinding mark
236	11	radius fragment	AXXXVI	with biting marks
236	12	stone splinter	no caption	
237	1	baculum, middle fr.	A VIII St 1922	belonging together with 236-1
237	8	os jugale sin	L	
237	9	sternum distal fragment	XXXXIII	not fossil
238	1	bone fragment: triangular fragment of a big limb bone	K.A VI - 21/X 1922 - G/m 14.35.3 - m 10 u. im G12- 65 cm unt.obere Sch - 25 cm über Fels - Sch IV	
238	13	mandible, ventral fr.	A V St 1922	
238	14	phalanx terminalis	17d	
238	15	phalanx terminalis fr.	1921 17	
238	16	vertebra caudalis term.	AXXXII	

Within the fossil material of the Steigelfadbalm, there are pointed bone- and canine-fragments with the annotation "pointed-like bone tools from the Steigelfadbalm in the Rigi" (Fig. 11). In Table XV, those "artefacts" are presented together. This involves penis-bones (bacula: 5 pieces), 1 os jugale, 3 fragments of canines and many non-determinable bone-fragments. One radius-fragment with a bite mark (most probably caused by *Canis lupus*) and a sharp fracture was described as an artefact (Fig. 12).

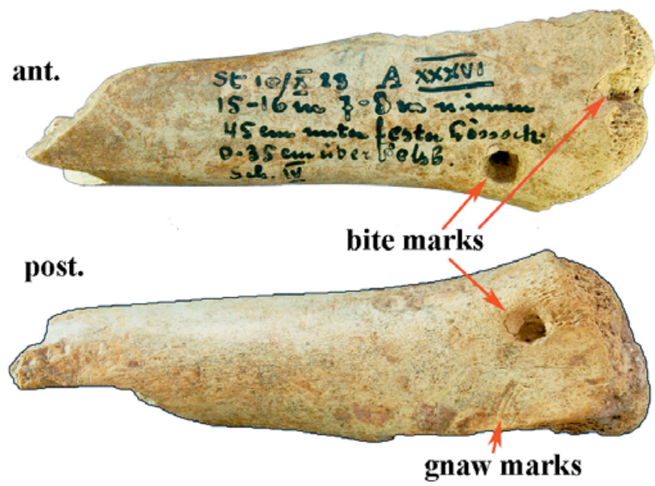

Fig. 12. Fragment of cave bear bone from Steigelfadbalm (Sfb 804 B 236-11) with original fund information. This bone fragment with bite marks and gnaw marks was interpreted as "spitzenartiges Knochenwerkzeug" (pointed-like bone tool) also. This bone fragment bears traces of biting by wolf (?) and gnawing by rodents (ant. – anterior view; post. – posterior view).

One special find was the pointed bone-fragment with the number 237-9 – a human sternum-fragment consisting of the three fused elements: the sternum 3, the sternum 4 and the processus xiphoideus (s. RABEDER et al. 2017). Due to the state of conservation, this fragment is not a fossil. It is specifically light and without signs of fossilisation, and the light grey-brownish colouring indicates a Holocene affiliation.

Two fragments of canines show grinding marks, and smooth polished areas on the enamel and dentine. Teeth with such grinding marks were originally interpreted as artificially modified and were named after a Hungarian cave, "Kiskevélyer knives" (KORMOS 1916). BREUER (1933) followed by FEUSTEL (1969) showed that these grinding marks are not caused by human influence, but by abrasion during the consumption of grass-diet (FRISCHAUF et al. 2016).

Nowadays the interpretation, that those teeth and bone-fragments were artificially modified and used as a tool is critically questioned. The findings from the Steigelfadbalm also show no cutting marks or traces of use. The fractures are not ground or polished, but correlate with a natural fragmented bone.

The large number of bacula within the "pointed-like bone tools from the Steigelfadbalm (Rigi)" (Fig. 13) is noticeable. Obviously, the smooth polished-looking surface and the distal-wards conical run of the contour lines led to the assumption that the ice-age men used the penis-bone as a tool. But the shape of these bone pieces is absolutely natural. Characteristic deepening's in the vertebrate bones interpreted as artificial holes are typical bite traces of carnivores, (see following chapter).

Fig. 13. Pointed-like bone tools (falsely interpreted as artifacts). Typical examples are rib fragments, bacula and tooth fragments. 236-1 to 6: fragment of os penis (baculum), 236-11: radius fragment, 236-7 and 8: fragments of canines.

Genus *Canis* L.

?*Canis lupus* L.

Material: bite marks on six vertebrae, one femur (Sfb 804B.236.AXXXVI) and one calvarium-fragment (Sfb 804.B.22.7) of *Ursus ingressus*.

Round and conical depressions on bones can only be interpreted as bite marks if there are, in addition to these pronounced marks, lower depressions on the opposite side of the bone. This case is a femur-fragment: in addition to the large bite mark on the anterior side, there is a smaller but clearly visible depression on the posterior side. The calvarium-fragment, consisting of the os parietale and the os supraoccipitale, has some deep bite marks on the inner side of the cranium and low counter-marks on the dorsal side.

Wilhelm Amrein imaged 6 vertebrates (AMREIN 1939, Abb. 8) with plenty of round depressions which he interpreted as artificially modified: “Die durchbohrten Wirbel des Höhlenbären...sind nicht als Produkte der Natur oder von Tieren, sondern als menschliche Arbeit und Intention zu werten” (“The perforated vertebrae of the cave bear...cannot be interpreted as a product of nature or animals but of human work and intention”).

An evaluation of these elements confirmed that besides the deep “drill holes”, there are according counter-marks on the opposite side of the vertebrae, and therefore they can be interpreted as bite marks.

Usually bite marks like these are associated with *Canis lupus* (wolf) but also other predators, for example lions produce such traces. The appearance of *Canis lupus* cannot be verified by fossils (bones or teeth) in the Steigelfadbalm.

Genus *Homo* L.

?*Homo sapiens*

Material: 1 sternum-fragment

Within the “pointed-like bone tools of the Steigelfadbalm (Rigi)”, there was one fragment of a human sternum. It consists of three distal-fused sternalia and accords metrically as well as morphologically to recent comparative pieces.

However, the state of conservation is significantly different to the fossil bones of the cave bears. The human sternum-fragments are porous and therefore relatively lightweight. The appearance resembles those of domestic and wild animals associated to the Holocene (RABEDER et al. 2017). Radiometric dating and ancient DNA-analyses may help clarify if there are fossil human remains within the material of the Steigelfadbalm.

V. CONCLUSIONS

All fossil remains of the Steigelfadbalm originate from a large plump cave bear which can be associated with *Ursus ingressus* (RABEDER et al. 2004) due to the high evolutionary extent of the teeth and large body-size.

Therefore, the Steigelfadbalm is the first evidence of *Ursus ingressus* in Switzerland. According to present data, this species developed in the East, immigrated to Middle-Europe 50,000 years ago, and inhabited numerous Alpine caves up to an altitude of almost 1,700 m (Potocka zijalka, Slovenia).

Traces of ice age men are not recognisable on the bones and teeth of cave bears.

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