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ALPINE CAVE BEARS AND CLIMATE IN MARINE ISOTOPE STAGE 3

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Abstract: The Eastern Alps were covered with ice during the last glaciation (Würmian) but glaciers fluctuated and there was no constant ice cover all over the Alpine region. Direct dated cave bear remains document animals within the glaciated area of the Alps during the last glacial cycle. Ice-free conditions are assumed as a prerequisite for a visit of the cave. But no clear succession in time of faunal evidence and climatic conditions has been reconstructed so far. In this study direct dates from cave bears, Greenland Stadials and Interstadials and well defined pollen profiles from south and west of the Alpine arc are compared.

Key words: Alps, cave bear, pollen, climate, Greenland Stadials and Interstadials, ice extent.

INTRODUCTION

Terrestrial information about the Marine Isotope Stage (MIS) 3 is rare because the global Last Glacial Maximum (LGM) during MIS 2 eroded a lot of the evidence from MIS 3. Some pollen sites around the Alpine arc (fig. 1) display long palynological and climatic records covering MIS 3. The interpretation of these continuous pollen profiles offers a possibility to learn more about vegetational and climatic changes in the Alpine area.

Numerous cave fillings in and around the Alpine arc survived the erosion during the LGM as well. Cave bears were the most abundant species in these caves accompanied by a few additional faunal elements, mainly carnivores such as wolves and cave lions. Some of the sites even lie in high alpine areas up to an elevation of 2750 m a.s.l. Direct dates place the remains mainly in MIS 3. Ice-free conditions seem to be a prerequisite for the visit of distinct caves but little is known about the ice extent during MIS 3 (van Husen, 2000). Eleven well dated cave sites (tab. 1) from France, Italy, Slovenia, and Austria are compared to define well continuous pollen sites spanning MIS 4 to MIS 2 in order to understand more about cave bear distribution and climatic conditions during MIS 3.

METHODOLOGY

3-D reconstructions of the LGM ice cover and entrances of the cave sites will act as starting points for modelling of ice fluctuations during the last glacial cycle including MIS 3. For the 3-D reconstruction of the ice cover a triangular irregular network (TIN) data model is created from the digitised point data of the mapped features and digitised contour lines of the map published by van Husen (1987) using the GIS program ArcGIS. The TIN surface model is converted to a grid-based model in order to compare this model with the grid-based digital elevation model (DEM) of the present land topography. Examples of the spatial situation of cave entrances in comparison with the ice are provided in fig. 2 and 3.

Data from several caves were compiled in Tab. 1:

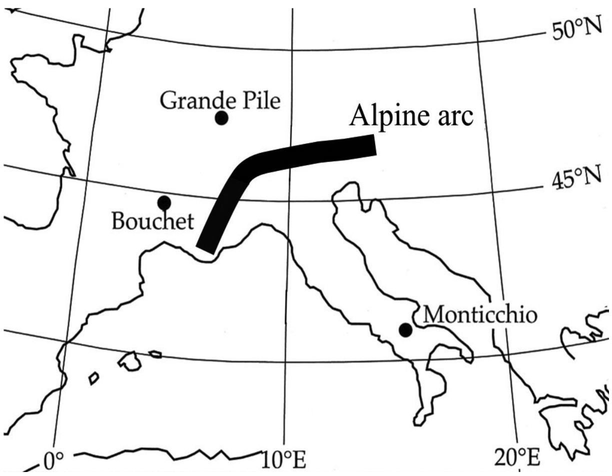

Figure 1. Sites with continuous pollen profiles in the west and south of the Alpine arc (modified after van Andel, 2003:12).

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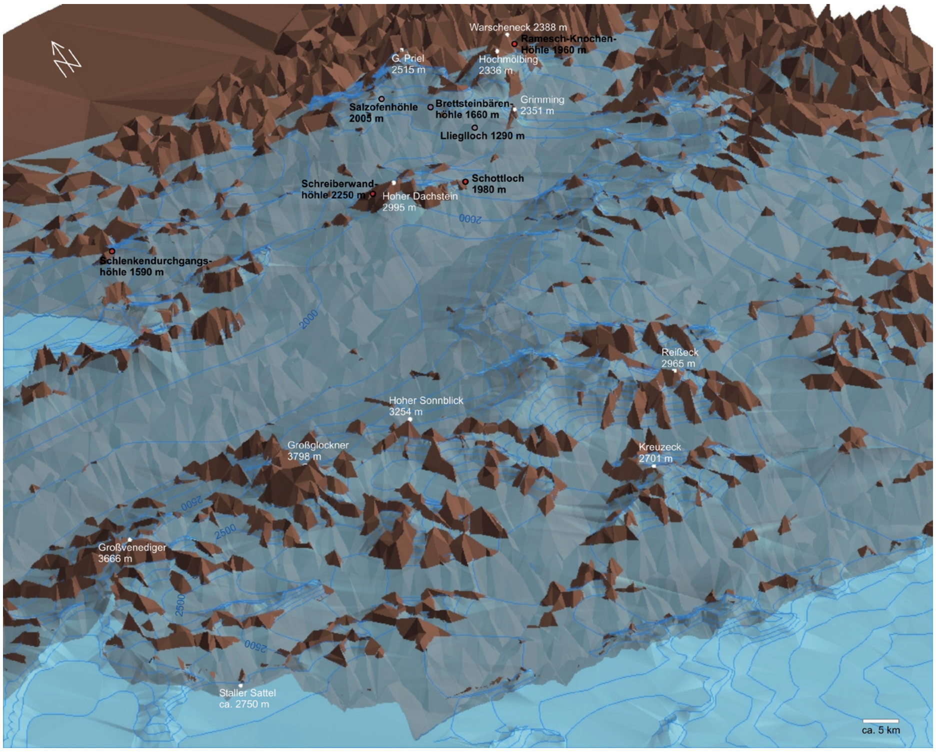

Figure 2. A 3-D reconstruction of the LGM ice elevation in the Eastern Alps and position of selected cave bear sites (digitised after van Husen, 1987). Contour lines of ice elevation have the equidistance of 100 m. The Enns valley is visible in the middle of this illustration (compare fig. 3).

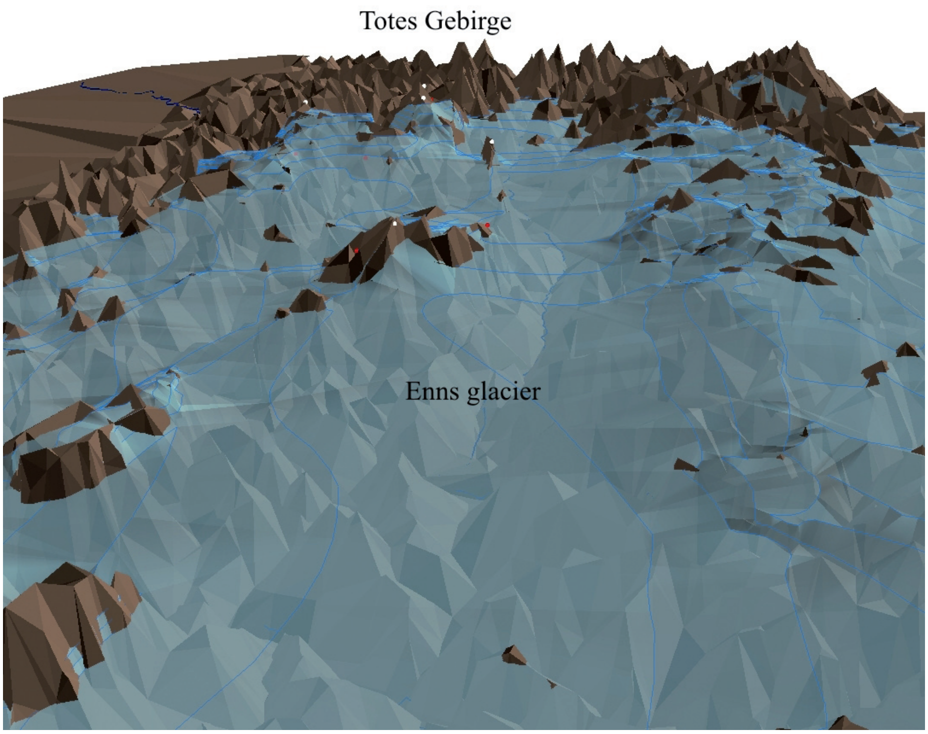

Figure 3. View of the Enns valley towards Totes Gebirge in the north-east of the Alps. The position of most of the caves of Totes Gebirge is very close to the border of the Alpine glaciation during LGM. The nunatak in the middle of the reconstruction is the Hohe Dachstein (2995 m), with the red dots indicating Schottloch and Schreiberwandhöhle (compare fig. 2).

Table 1
Direct radiocarbon dates of cave bear samples from selected cave sites [dates after Blant et al. (2004), Morel *et al.* (1997), Pacher (2003), Philippe (2003), Rabeder *et al.* (2005)]. Palaeoclimate information from Greenland after Rousseau *et al.* (2006) showing the synchronicity of the data to Greenland Stadials (GS) or Greenland Ínterstadials (GIS); in brackets the range of the data considering the period of the error.

	Site	a.s.l.	Lab.no	Dates	CalPal	Palaeoclimate
F	Balme à Collomb	1700	OxA-3946	24160+/-370	29111+/-528	GS4 (GIS4-GS4)
CH	Bärenloch	1645	ETH	26520+/-240	31057+/-169	GS4
A	Lieglloch	1290	VERA-2184	26390+/-110	31017+/-141	GS4
A	Gamssulzen	1300	VRI-1159	25090+/-640	29887+/-675	GS4
A	Gamssulzen	1300	Hv-16893	25965+/-780	30552+/-605	GS4
SI	Potocka zijalka	1700	Beta-143240	26900+110/-100	31257+/-102	GS4
A	Gamssulzen	1300	Hv-16892	27520+/-645	32358+/-897	GIS5 (GS4-GS5)
A	Ochsenhalt	1660	VERA-2191	28370+/-140	32956+/-657	GS5 (GIS5-GIS6)
A	Lieglloch	1290	Ua-15978	28130+/-600	32846+/-979	GS5 (GS4-GS6)
SI	Potocka zijalka	1700	GrN-23501	29130+570/-530	34001+/-922	GS6 (GS5-GIS7)
SI	Potocka zijalka	1700	VERA-0659	29310+750/-250	34083+/-1086	GS6 (GS5-GIS7)
SI	Potocka zijalka	1700	GrN-23500	29600+/-290	34798+/-438	GIS7 (GS6-GIS7)
SI	Potocka zijalka	1700	VERA-0661	29810+/-270	35070+/-372	GIS7 (GS6-GIS7)
SI	Potocka zijalka	1700	VERA-0660	30980+330/-310	36099+/-361	GS7
SI	Potocka zijalka	1700	VERA-2194	31730+210/-200	36692+/-270	GS7
CH	Frueteli	1775	ETH-14476	31740+/-430	36829+/-523	GS7 (GS7-GIS8)
A	Ramesch	1960	Beta-157670	31140+/-310	36320+/-332	GS7
CH	Frueteli	1775	ETH-11357	33140+/-420	38265+/-770	GIS 8 Denekamp (GIS8-GS8)
A	Gamssulzen	1300	VRI-1226	31500+1300/1100	37009+/-1567	GIS8 Denekamp (GIS7-GIS8)
A	Gamssulzen	1300	Beta-157659	32190+/-330	37691+/-853	GIS8 Denekamp (GS7-GIS8)
A	Gamssulzen	1300	Beta-157660	32010+/-320	37408+/-755	GIS8 Denekamp (GS7-GIS8)
A	Gamssulzen	1300	VRI-1228	34300+2400/-1900	39223+/-2243	GS8 (GS7-GIS10)
A	Ramesch	1960	VRI-776	34900+1800/-1500	39762+/-1851	GS8 (GIS8-GIS10)
A	Lieglloch	1290	VERA-2185	33500+/-240	38506+/-888	GS8 (GIS7-GS8)
SI	Potocka zijalka	1700	GrN-22335	35720+650/-600	40996+/-910	GS9 (GS8-GIS10)
A	Ramesch	1960	VRI-792	37200+1900/1600	41760+/-1703	GIS10 (GS8-GIS11)
A	Ochsenhalt	1660	VERA-1601	36240+670/-620	41671+/-503	GIS10 (GS9-GS10)
A	Gamssulzen	1300	VRI-1227	3800+3300/-2300	42163+/-2879	GS10 (GS8-GIS12)
A	Gamssulzen	1300	VRI-1326	3800+2000/-1900	42552+/-1515	GS10 (GS9-GS11)
A	Gamssulzen	1300	Beta-157661	37310+/-580	42380+/-357	GS10
A	Ochsenhalt	1660	VERA-2190	39620+500/-470	43657+/-568	GIS11 (GIS11-GS11)
A	Gamssulzen	1300	Beta-157664	41060+/-920	44715+/-958	GS11 (GIS11-GIS12)
A	Ochsenhalt	1660	KIA-25283	42290+970/-870	45886+/-1198	GIS12 Hengelo (GS11-GIS12)
A	Ramesch	1960	Beta-143242	43610+/-1800	47222+/-2066	GIS12 Hengelo (GIS12-GIS13)
A	Ramesch	1960	Beta-157667	43700+/-1270	47169+/-1771	GIS12 Hengelo (GIS12-GS12)
A	Gamssulzen	1300	KIA-25287	44160+1400/-1190	47547+/-1876	GIS12 Hengelo (GIS12-GIS13)
I	Conturines	2750	Beta-143246	44260+/-900	47532+/-1638	GIS12 Hengelo (GIS12-GS12)
A	Gamssulzen	1300	Beta-157662	44400+/-1380	47742+/-1893	GS12 (GIS12-GIS13)
A	Gamssulzen	1300	Beta-157663	45410+/-1560	48863+/-2285	GS12 (GIS12-GS13)
A	Gamssulzen	1300	Beta-157665	47300+/-1970	50791+/-2685	GS13 (GS12-GS14)
A	Ramesch	1960	Beta-157669	47600+/-2060	51053+/-2696	GS13 (GS12-GIS14)
A	Brieglersberg	1960	VERA-2857	49700+2400/-1800	53069+/-2882	GIS 14 Glinde (GS13-GIS15)
A	Ramesch	1960	Beta-143241	49520+/-1600	52802+/-2207	GIS 14 Glinde (GS13-GIS14)

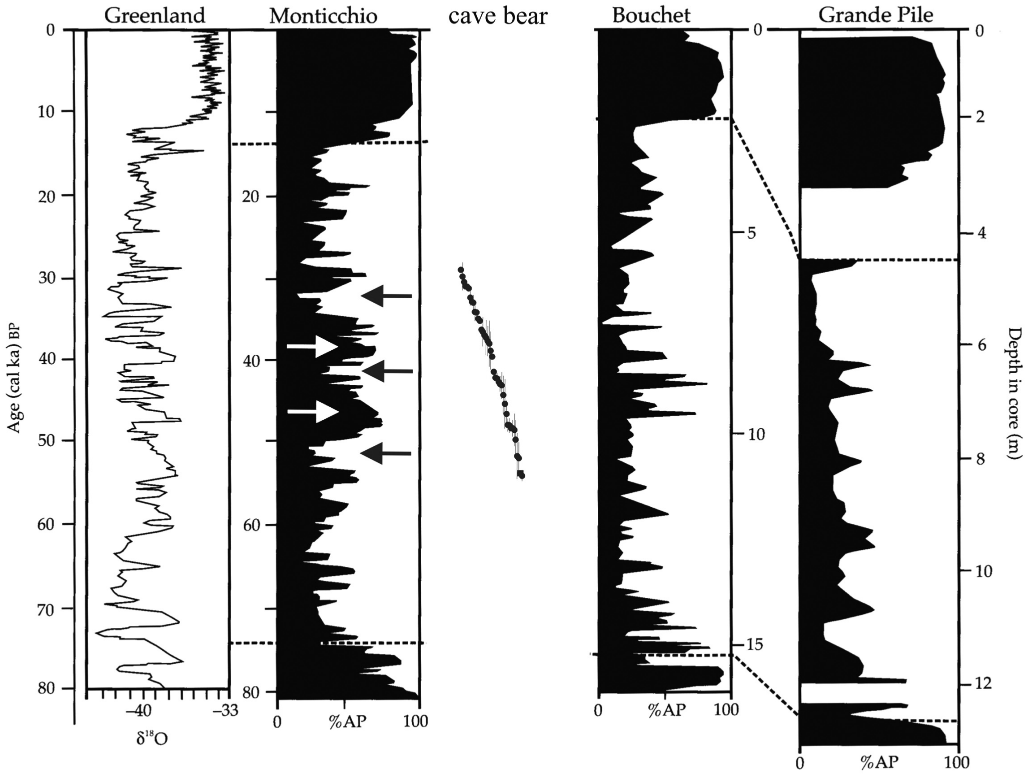

Figure 4. Comparison between calibrated cave bear dates from table 1 and arboreal pollen distribution in the profiles Monticchio, Bouchet and Grande Pile (modified after van ANDEL, 2003:14). Severe changes in the vegetation pattern of Italy (white arrows - increase in arboreal pollen, black arrows - strong decrease) are not reflected in the cave bear occurrence of the Alpine region.

Conturines cave (11°60′/46°63′50′′), Potočka zijalka (14°40'/46°26'), Gamssulzenhöhle (14°17′52′/47°40′56′′), Ramesch-Knochenhöhle (14°15′/47°39′), Ochsenhalt cave (14°10′/47°50′), Brettsteinbärenhöhle (13°59′/47° 37′19"), Brieglersberg (14°03′07′′/47°37′12′′), Liegl-loch (14°/47°34′23′′), Frueteli (8°26′/46°76′), Bärenloch (7°24′ 40′′/46°58′10′′), and Balme à Collomb (5°/45°).

On the base of ROUSSEAU *et al.* (2006) cave bear dates and GRIP events are compared. In addition, the calibrated dates are compared to data from continuous pollen sites south and west of the Alps. Together with considerations of the circulation pattern during the last glacial cycle a picture of the climatic situation during the cave bear occurrence in high Alpine areas is attempted.

RESULTS

The glacier extent as reconstructed by van HUSEN (1987) for the LGM is illustrated in figure 2. Some of the cave sites entrances have been covered by LGM ice, e.g. Brettsteinbärenhöhle, Salzofenhöhle, Lieglloch. Other caves, like Ramesch-Knochenhöhle, were never covered by ice, not even during the high stand of the last glacial cycle, the LGM.

Dates are calibrated using CalPal (http://www.calpal.de), and then sorted according to Greenland Stadials (GS) and Greenland Interstadial (GIS) after ROUSSEAU *et al.* (2006). The ranges of the dates lie between GS 4 to GIS 14. Taking the dates without error 26 samples date into a GS (60,5 %) and 17 samples fall into a GIS (39,5 %). Considering the error range, only 9 samples date completely into a GS while 34 samples are indifferent.

Severe vegetational changes are indicated in the profiles from Monticchio, Bouchet and Grande Pile (fig. 4). Cave bear distribution in the Alpine region does not follow this pattern. Their occurrence seems to be independent of the vegetational and climatic fluctuations indicated in the pollen profiles to the south and in the west of the Alps.

In figure 5 an assumed pattern of winter atmospheric circulation during the LGM is presented. It seems that the transport of moisture towards the Alps comes mainly from the Mediterranean Sea because of a very southern position of the polar front (FLORINETH, 1998). For other

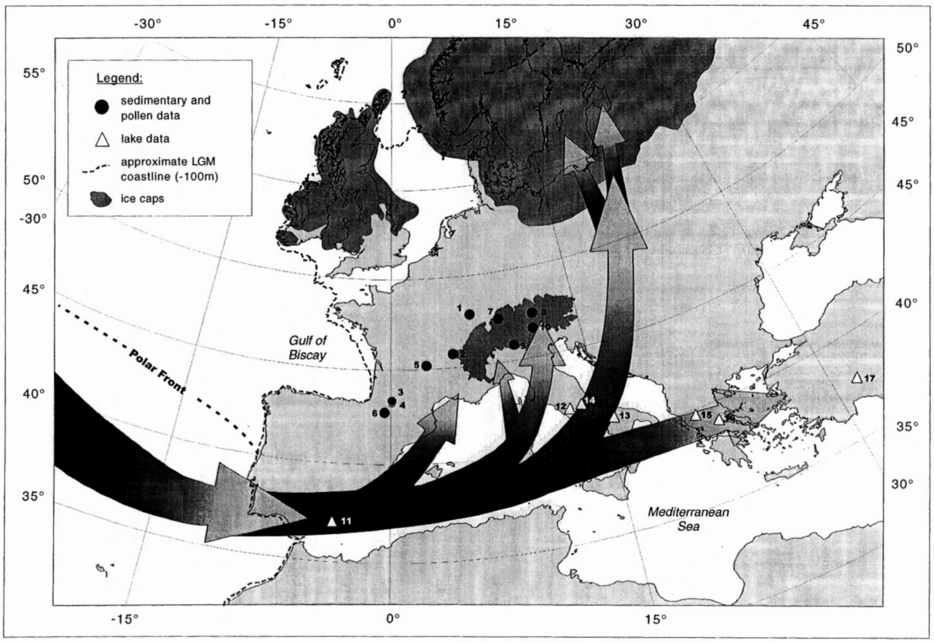

Figure 5. Sketch map of Europe during the LGM with the assumed characteristics of the winter atmospheric circulation pattern. Locality 1 - Grande Pile, locality 13 - Monticchio (from FLORINETH, 1998).

periods of the last glacial cycle, like stage 3 more westerly transport directions can be assumed. The selected pollen profiles to the south and west of the Alps (Grande Pile, Bouchet, Monticchio) are lying in the main transport direction of moisture during stage 3 and 2. Thus, it seems to be unlikely that the high Alpine climate around the cave bear sites was independent of conditions reflected in these pollen profiles.

CONCLUSION

The calibrated dates of the cave bear occurrences point to a more or less even distribution (60% to 40%) over the periods of Greenland Stadials and Interstadials. Considering the whole error ranges of the dates clear statements concerning correlations especially to the very short interstadials are not possible. The comparison of the pollen profiles and the cave bear occurrences seems to confirm the cave bear distribution over stadials and interstadials. There is no correlation between the severe vegetation changes in the profiles of Monticchio, Bouchet and Grande Pile and the occupation of the high Alpine region by cave bears.

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