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LAST GLACIAL (OIS 4, OIS 3 AND OIS 2) PALEOENVIRONMENTAL ANALYSIS FOR WESTERN LOMBARDY (NORTH ITALY) CAVE BEAR SITES

Fabio BONA[1]

Abstract: For the first time we propose a tentative paleoclimatic and paleoenvironmental reconstruction for the Prealps area located in the middle-western Lombardy (North Italy), using the small mammals yielded by the *Ursus spelaeus* fossiliferous levels.
The data set is from two caves studied by the Dipartimento di Scienze della Terra "A. Desio", UNIMI, over the last two decades: 1- Caverna Generosa (Como); 2- Grotta sopra Fontana Marella (Varese) which are less than 30 km from each other.
The long and complete stratigraphical sequences kept in both caves allowed the analysis of a time span covering more or less the last 50 Ky, from more than 50 Ky to Holocene-recent.
Paleontological analysis of the sequences of Caverna Generosa and Grotta sopra Fontana Marella highlights for the Insubrian area (North-western Lombardy - North Italy) a well represented climatic and environmental change in the last 50 Ky. Exactly about 50 Ky the environment was a cold grassland; about 45-46 Ky this situation changed when wooded environment taxa, found in the "Sala Terminale" of Caverna Generosa, became dominant on open habitat taxa. The environmental and climatic situation was probably still favourable until 26 Ky; the Grotta sopra Fontana Marella sequence shows a new climate worsening testified by dominance of cold and grassland species. *Ursus spelaeus* attendance in the Insubrian area is confirmed beginning from more than 50 Ky to at least 25 Ky.

Key words: *Ursus speleaus*, North-Western Lombardy, Italy, small mammals, Late Pleistocene, paleoenvironment.

INTRODUCTION

The aim of this work is to propose, for the first time, a tentative paleoclimatic and paleoenvironmental reconstruction for the Prealps area located in the middle-western Lombardy (North Italy), using the small mammals yielded by the *Ursus spelaeus* fossiliferous levels.

During the last two decades numerous studies on Quaternary fossil mammals from western Lombardy pre-Alps have contributed to the paleoclimatic and paleoenvironmental reconstructions. Fossiliferous cave deposits with *Ursus spelaeus* remains are widespread in the Alps, but today, in Italy, only few caves have been exploited with stratigraphical criteria; in most cases the excavations in cave bear sites have been carried out in the nineteenth century, when the stratigraphical importance of the finds was not clearly known by the majority of researchers.

This study is focused on small mammal remains coming from two cave bear caves well studied, in the last fifteen years, by students of Università degli Studi di Milano: 1- Caverna Generosa (Como) (Bona, 2003; 2004; 2005; Bona *et al.,* in press), 2- Grotta sopra Fontana Marella (Varese) (Zanalda *et al.,* 1997; Perego *et al.,* 2001), which are less than 30 km from each other. For both caves, studies carried out on palaeontological material testify as the most common large mammal was *Ursus spelaeus*. Remains of small mammals (voles, dormouses, mouses, shrews and moles) have also been recovered in the same levels, and they turned out to be essential for this work.

GEOGRAPHICAL SETTING

The Grotta sopra Fontana Marella cave is located in the north-western Lombardy (Northern Italy) (fig. 1), 1040

[1] Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, via Mangiagalli 34, 20133 Milano. fabio.bona@unimi.it

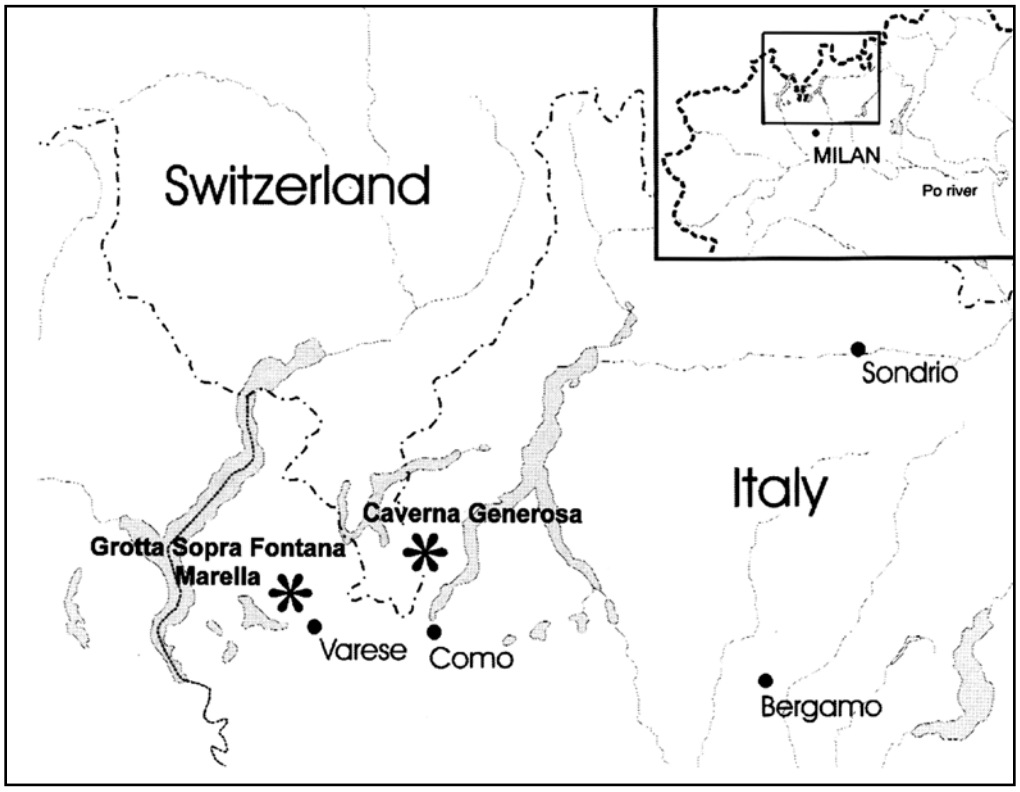

Figure 1. Map of the middle-western Lombardy with the geographical position of Grotta sopra Fontana Marella and Caverna Generosa.

m a.s.l. on the north-eastern slope of the calcareous-dolomitic massif of Monte Campo dei Fiori (maximum elevation 1226 m a.s.l.), Varese province. It is located in Lombardian Pre-Alps facing the Po Plain. It is laterally limited by two deep valleys: Olona Valley and Valcuvia.

Also the Caverna Generosa is situated in the north-western Lombardian Pre-Alps, but a few kilometres East of Grotta sopra Fontana Marella cave, in the Como province. The Caverna Generosa opens at 1450 m a.s.l on the Italian eastern site of Monte Generoso (maximum elevation 1701 m a.s.l.), near the boundary between Italy and Switzerland (fig. 1). The Monte Generoso is a calcareous massif, located between the Lugano and the Como lakes, largely made of Calcare di Moltrasio limestone (Lower Jurassic).

The stratigraphic sequence of Grotta sopra Fontana Marella is about 2 m thick and it has been subdivided in 12 levels. The uppermost four levels have been attributed to Upper Pleistocene according to C14 dating (Zanalda *et al.,* 1997). Its four levels yielding cave bear remains represent a time span not well known for lacking of C14 dates of the lowest level (FM4). Probably FM4 is synchronous with "Sala Terminale" upper levels. Levels FM2 and FM1 have been dated respectively to 26, 266 and 25, 688 years Bp calibrate C14 dating (Perego *et al.,* 2001).

The "Sala Terminale" stratigraphical sequence of Caverna Generosa is about 3 m thick and has been subdivided in 13 levels. The "Sala Terminale" sequence is the most complete and covers the most wide temporal interval. In fact, the uppermost 6 levels have been dated from more than 50 Ky to 38 Ky (Bona *et al.,* in press); the lowermost 7 levels have not been dated because of their old age excess the possibility of C14 method even if, probably, they could reach more than 60 Ky at the bottom.

A new stratigraphical sequence along the shaft, 15 meters from the entrance of the Caverna Generosa has been recently analysed (Cunicolo - MG CUN). So far, no C14 dating are available for this sequence. The presence of a cryoclastic angular limestone deposit at the surface (MG CUN 0 - Holocene-recent) suggests an age close to the last maximum glacial for MG CUN I and MG CUN II (levels with *Ursus spelaeus* dominant). Presence of the Holocene is supported also by the finds of remains of large domestic mammals such as goats and cows (Laurenti, in progress). Probably, according to small mammals frequency, MG CUN IV and MG CUN V could be connected with MG1 and MG2 of "Sala Terminale".

MATERIAL AND METHODS

The paleoenvironmental interpretations suggested in the present paper are based on 665 remains of small mammals (118 from Grotta sopra Fontana Marella, 140 from Caverna Generosa "Sala Terminale" and 407 from Caverna Generosa "Cunicolo"). For the counting of the voles right and left lower first molars have been added. For the other species it has been used the normal counting of MNI using the more represented skeleton portion.

The method used to collect these small remains consists in two phases:

1. The sieving of sediments during field work, with 1 mm mesh sieves, reporting stratigraphical and planimetric indications for each sample;

2. More accurate sieving, in the laboratory of Università degli Studi di Milano, and picking of samples.

The remains found are divided by skeletal constituents using a binocular microscope Wild Heerbrugg M3 with enlargement zoom from 6,4x to 40x and afterwards determined following mainly Chaline *et al.* (1974), Niethammer & Krapp (1978; 1982; 1990).

SMALL MAMMALS DATA

Grotta sopra Fontana Marella (tab. 1)

Concerning the Late Pleistocene levels of Grotta sopra Fontana Marella (Zanalda *et al.,* 1997), in the level FM 4 we have scarce remains: the glirids are the most represented. With some doubts this could be interpreted as a sign of wood extensions and probably small open areas, underlined by a single specimen of vole *Microtus agrestis*.

In the level FM 3 the presence in the same ratio of voles and glirids could testify a mixed wood and grassland environment with scarce *Sorex* sp. and *Arvicola terrestris* attesting the presence of limited humid areas.

During the first field excavation pollen analysis has been carried out. Data collected for levels FM 3-4 of Grotta sopra Fontana Marella (Perego, 1993) shows a large spreading of forest trees, mainly *Betula* and *Pinus*, on the surroundings of Campo dei Fiori slope where Grotta sopra Fontana Marella opens.

With level FM 2 and FM 1 the presence of micromammals typical of cold (*Chionomys nivalis*) and open (*Microtus arvalis* and *Microtus agrestis*) environments, besides the presence of *Marmota marmota* and the com-

Table 1
Grotta sopra Fontana Marella: remains (n) and percentages (%) of small mammals.

FM	Level	1		2		3		4		Tot	
		n	%	n	%	n	%	n	%	n	%
TAXON											
Microtinae											
Arvicola terrestris		6	14	2	20	1	6.7			9	12.5
Chionomys nivalis		7	16.3							7	9.7
Cletrionomys sp.		1	2.3	1	10					2	2.7
Microtus agrestis		7	16.3					1	25	8	11.1
Microtus arvalis		20	46.5	5	50	4	26.5			29	40.3
Muridinae											
Apodemus sp.						1	6.7			1	1.4
Sciuridae											
Marmota marmota		1	2.3							1	1.4
Gliridae											
Muscadinus avellanarius								1	25	1	1.4
Glis glis				1	10	6	40.1	2	50	9	12.5
Leporidae						1	6.7			1	1.4
Insectivora											
Sorex sp.						1	6.7			1	1.4
Talpa cf. *europaea*		1	2.3	1	10	1	6.7			3	4.2

plete absence of wooded taxa from the pollens, could be interpreted as an abrupt transition towards a colder climate, with a sudden decrease of arboreal vegetation and a increase of the soil erosion.

The palynological data for FM1 and FM2 (Perego, 1993) show a floral arrangement typical of grassland and steppe, with the species: *Artemisia* sp., *Ephedra fragilis*, *Centaurea* sp., *Alchemilla* sp., *Poligonum viviparum* and *Echinops* sp.

Caverna Generosa: "Sala Terminale" (tab. 2)

In the "Sala Terminale" of Caverna Generosa levels with the same chronological and sedimentological characteristics have been grouped, owing to the scarcity of remains, in order to obtain significant paleoecological data (Bona, 2006; Bona *et al.,* in press).

Levels MG 10, 11 and 12 (group 4); small mammals are very poorly represented in this group of levels. Only 8 remains have been determined (2 *Arvicola terrestris*; 3 *Terricola* gr. *multiplex-subterraneus*; 3 *Microtus arvalis*) for this time interval, so that it's impossible to make some paleoenvironmental analysis.

Levels MG 5, 6, 8, 9 and III (Group 3) are characterized by an assemblage of *Terricola gr. multiplex-subterraneus* (5,9%), *Chionomys nivalis* (23,5%), *Arvicola terrestris* (29,4%) and *Microtus arvalis* (35,2%). The large presence of *Chionomys nivalis* and *Microtus arvalis*, correlated to a scarcity of wooded taxa allows to suppose that the Monte Generoso area was characterized by open areas with exposed rocks and reduced wooded areas. The climate would have been cold and dry.

For levels MG 3, 4 and II (Group 2) the number of remains is scarce. The best represented taxa are *Terricola* gr. *multiplex-subterraneus* (31,2%) and *Cletrionomys glareolus* (25,0%). Another important taxon is *Apodemus* gr. *sylvaticus/flavicollis* (18,8%). This latter is considered

Table 2
Caverna Generosa "Sala Terminale": remains (n) and percentages (%) of small mammals.

MG "Sala Terminale"	Level	Group 1		Group 2		Group 3		Group 4		Tot	
		n	%	n	%	n	%	n	%	n	%
TAXON											
Microtinae											
Arvicola terrestris		16	20	1	4.8	6	19.3	2	25	25	17.8
Chionomys nivalis		1	1.2			8	25.8			9	6.4
Clethrionomis glareolus		2	2.5	7	33.3					9	6.4
Microtus agrestis											
Microtus arvalis		8	10	1	4.8	11	35.5	3	37.5	23	16.4
Terricola gr. *multiplex-subterraneus*		38	47.6	5	23.8	4	12.9	3	37.5	50	35.7
Terricola cf. *savii*		1	1.2							1	0.7
Muridinae											
Apodemus gr. *silvaticus-flavicollis*		4	5	5	23.8	1	3.2			10	7.1
Gliridae											
Glis glis		3	3.7							3	2.2
Muscradinus avellanarius				1	4.8					1	0.7
Insectivora											
Sorex araneus				1	4.8					1	0.7
Soricidae ind.											
Sorex alpinus		1	1.2							1	0.7
Sorex minutus		1	1.2							1	0.7
Crocidura sp.											
Sorex sp.											
Talpa caeca		2	2.5			1	3.2			3	2.2
Talpa sp.		3	3.7							3	2.2

ubiquitous, so it is not useful for paleoenvironmental considerations. Also *Arvicola terrestris, Microtus arvalis, Sorex araneus* represented each by a single find, are not useful for paleoenvirommetal interpretation.

According to the data above presented it is possible to suppose that the surroundings of Monte Generoso, about 46 Ky ago, were characterized by wide wooded areas with dense underbrush (significant is the presence of *Muscardinus avellanarius*).

Levels MG 0, 1, 2, 2b, A, B and I (Group 1); the collected data underline the presence of wooded conditions in the cave neighbourhood about 38-40 Ky. This interpretation is supported by numerous remains of *Terricola* gr. *multiplex-subterraneus* (49,3 %) and by scarce *Clethrionomys glareolus* (2,7 %) and *Glis glis* (4,1%). It is possible to consider the presence of small open areas alternated by wooded ones owing to the presence of *Microtus arvalis* (11,0%) and of one specimen of *Chionomys nivalis*; the occurrence of *Arvicola terrestris* (16,4%), an animal today living near fresh water like rivers, lakes but also less aquatic habitat, confirms the presence of wet environment, probably nearby the watershed.

Caverna Generosa: Cunicolo, meters 13, 14 and 15 (tab. 3)

At 13m to 15m of Cunicolo of Caverna Generosa the situation is quite different; although we have not C14 dating yet it is possible indicatively to correlate the lower MG CUN V and MG CUN IV with the MG1 and MG2 by using sedimentology and small mammals assemblages. In fact, during the sequence to MG CUN V to MG CUN I it is possible to remark an important climate change.

MG CUN V, MG CUN IV are characterized by mixed wood and open areas, probably with a not so cold a climate.

Table 3
Caverna Generosa "Cunicolo", meters 13, 14 and 15: remains (n) and percentages (%) of small mammals.

MG CUN	Level	0		I		II		III		IV		V		Tot	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%
TAXON															
Microtinae															
Arvicola terrestris		3	1.9	4	9.1	10	23.2	32	22.2	2	11.8			51	12.5
Chionomys nivalis		5	3.2	10	22.7	5	11.6	18	12.5	1	5.9			39	9.6
Clethrionomis glareolus		9	5.8			1	2.3							10	2.5
Microtus agrestis				1	2.3			7	4.9					8	2
Microtus arvalis		15	9.6	14	31.8	17	39.6	47	32.6	4	23.5	1	50	98	24.1
Terricola gr. *multiplex-subterraneus*		76	48.7	8	18.1	7	16.4	31	21.5	8	47	1	50	131	32.2
Muridinae															
Apodemus gr. *silvaticus-flavicollis*		7	4.6			1		1	0.7					9	2.2
Gliridae															
Glis glis		9	5.8	3	6.8	1	2.3							13	3.2
Insectivora															
Sorex araneus		1	0.6	1	2.3	1	2.3	2	1.4					5	1.2
Soricidae indet.		1	0.6											1	0.2
Sorex alpinus		1	0.6											1	0.2
Sorex minutus		1	0.6											1	0.2
Sorex sp.		1	0.6	1	2.3	1		1	0.7					4	1
Crocidura sp.		1	0.6											1	0.2
Talpa caeca		23	14.7	2	4.6	1	2.3	3	2.1	2	11.8			30	7.4
Talpa sp.		2	1.3					2	1.4					4	1
Chiroptera		1	0.6											1	0.2

During deposition of MG CUN III there is an increasing presence of voles typical of open, dry, and probably cold, climate (*Microtus agrestis* is abundant and *Chionomys nivalis* is well represented); some wooded areas however continue to exist (*Arvicola terrestris*).

The dominance of voles typical of open and cold environment (*Microtus arvalis* and *agrestis*, *Chionomys nivalis*), together with the cryoclastic angular limestone blocks deposit at the top of the sequence, testifies for MG CUN II and MG CUN I an age near to the last maximum glacial.

CONCLUSIONS

Data obtained by the study of small mammals, coming from Caverna Generosa and Grotta sopra Fontana Marella, allow to propose the following paleoenvironmental interpretations, mainly for the Insubrian area (Como and Varese provinces, Western Lombardy Prealps), during the last glacial period and Holocene:

- Before 50 Ky the paleoenvironmental situation is not yet clear, owing to the poor amount of remains.
- About 50 Ky (levels MG5-6-8-9 and III), *Chionomys nivalis* and *Microtus arvalis* are dominant, with scarce presence of arboreal species. This suggests that climate was cold and that the area was characterized by an open land with scarce arboreal cover.
- Around 45-46 Ky (levels MG3-4 and II), arboreal species such as *Terricola* gr. *multiplex-subterraneus*, *Clethrionomys glareolus* and *Muscardinus avellanarius* stand out on previous ones. An increase of wooded areas in a milder and wetter climate is suggested by this association of species.
- Levels dated about 40 Ky (Levels MG0-1-2 and probably levels FM3-4) confirm the situation described above. Pollens analysis for levels FM3-4 of Grotta sopra Fontana Marella (Perego, 1993), probably synchronous with MG1 and MG2 (Tintori, pers. com.), shows a large spreading of forest trees, mainly *Betula* and *Pinus*, on the Campo dei Fiori slope where Grotta sopra Fontana Marella opens.
- About 26 Ky (level FM2) *Microtus arvalis* dominance with scarce *Glis glis*, *Cletrionomys glareolus* and *Arvicola terrestris* testifies an important environmental change with wide open land and restricted wooded areas. Near 25 Ky (level FM1) the environment and climate did not change and species typical of cold and open habitats were still dominant. The climatic deterioration is testified by the presence of *Microtus arvalis*, *Microtus agrestis*, *Chionomys nivalis* and *Marmota marmota*. *Cletrionomys glareolus* and subordinate *Arvicola terrestris* prove that small covered areas were still present. FM1 and FM2 palynological data (Perego, 1993) show a floral arrangement typical of grassland and steppe, with the species: *Artemisia* sp., *Ephedra fragilis*, *Centaurea* sp., *Alchemilla* sp., *Poligonum viviparum* and *Echinops* sp.
- Also for MG CUN II and MG CUN I of Caverna Generosa *Microtus arvalis*, *Microtus agrestis* and *Chionomys nivalis* testify an environmental situation similar to that of FM1 e FM2 with grassland and cold climate.
- The Postglacial and Holocene association of MG CUN 0 shows a clear increase of wood with *M. (Terricola)* gr. *multiplex-subterraneus* well represented. Unfortunately at present it is impossible to make more detailed reconstruction for this period.

Paleontological analysis of the sequences of Caverna Generosa and Grotta sopra Fontana Marella highlight for the Insubrian area (North-western Lombardy - North Italy) a well recognizable climatic and environmental change in the last 50 Ky. About 50 Ky the environment was probably represented by a cold grassland; around 45-46 Ky this situation changed when wooded environment taxa became dominant. Environmental and climatic situation was probably still favourable until 26 Ky; the Grotta sopra Fontana Marella sequence shows a new climate worsening testified by dominance of cold and grassland species. *Ursus spelaeus* attendance in the Insubrian area is confirmed at least from 50 Ky to 25 Ky.

Very important for this area is the irregular presence of Neandertal man at 1450 m. a.s.l. in the Caverna Generosa testified by six flint tools (Bona *et al.,* in press). After the last maximum glacial and the disappearance of *Ursus spelaeus* the Insubrian area sees the new spreading of luxuriant wood, modified only recently by human activity (Bona, 2006).

In the sediments of Ciota Ciara cave (Monfenera - Piedmont), a cave characterized by the presence of *Ursus spelaeus* and *Homo neanderthalensis* and located few kilometres West to the Grotta sopra Fontana Marella and the Caverna Generosa, the macromammals remains testified a trend similar to the two caves object of this paper, but the ancient excavation and the incompleteness of the work do not allow an absolute correlation (Fedele, 1968; 1972) within the three stratigraphical sequences presented in this paper.

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