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CLIMATIC FLUCTUATIONS DURING THE LAST GLACIAL IN THE NORTH-WESTERN LOMBARDIAN PREALPS: THE UPPER PLEISTOCENE FAUNAL ASSEMBLAGES OF THE CAVERNA GENEROSA (COMO, ITALY)

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Key words: Upper Pleistocene, Last Glacial, North Italy, small and large mammals, reptiles, amphibians.

Abstract. Since 1991, the Caverna Generosa has been subject of numerous digging campaigns, principally in two areas called "Sala Terminale" and "Cunicolo 13-15". Dating of the first 6 stratigrafical levels of the 13 investigated in the "Sala Terminale" gave an age between 50.000 and 38.000 years BP (^{14}C non calibrated dating). In the area of the "Cunicolo 13-15", between meters 13 and 15 from the entrance, seven stratigrafical levels were excavated, and bones coming from layers from II to V were dated between 37.000 and 31.000 years BP ago (^{14}C non calibrated dating). Microvertebrates remains are used to infer paleoenvironmental and paleoclimatic information. The microfaunal assemblages of "Sala Terminale" testifies for a climatic improvement, during the period between over 50.000 y BP and 40.000 y BP: from a cold climate and an environment characterised by open vegetation to a wooded areas and milder temperature. This climatic improvement is also recorded in the lower level of "Cunicolo 13-15", probably subsequent to the top of the "Sala Terminale". Then, microfaunal associations became typical of cold climate. This climatic worsening had its maximum at the base of lev. Cun 0, during the last Pleniglacial. Therefore, the sediments of "Caverna Generosa" probably testify the climatic and faunal changes of the period between isotopic stage 4 and 1.

Riassunto. Gli scavi presso la Caverna Generosa hanno interessato, dal 1991 ad oggi, principalmente due aree della cavità: la "Sala Terminale" e il "Cunicolo". Nella "Sala Terminale" sono stati indagati ad oggi 13 livelli stratigrafici, i primi sei dei quali datati tra i 50.000 e i 38.000 anni BP (datazione ^{14}C non calibrata). Nel "Cunicolo 13-15" gli scavi sono stati condotti in diversi punti; la trincea oggetto del presente lavoro si estende tra i metri 13 e 15 (distanza dall'ingresso in metri) su 7 livelli stratigrafici. Resti ossei provenienti dai livelli dal II al V sono stati datati tra i 37.000 e i 31.000 anni BP (datazione ^{14}C non calibrata).

L'analisi dei resti recuperati, ed in particolare delle frequenze relative all'interno delle associazioni a micromammiferi, ha permesso di ricavare indicazioni paleoambientali e paleoecologiche.

Le associazioni a micromammiferi della "Sala Terminale" indicano un graduale miglioramento climatico a partire dai livelli più bassi fino alla sommità; di tale miglioramento climatico abbiamo testimonianza anche nei livelli più bassi del "Cunicolo 13-15", molto probabilmente successivi a quelli della "Sala Terminale". Dal LIV III invece la situazione climatica peggiora nuovamente; questo peggioramento raggiunge il suo apice alla base del LIV 0, durante l'ultimo Pleniglaciale. La sommità del LIV 0 è probabilmente di deposizione olocenica. I sedimenti della Caverna Generosa sono perciò molto probabilmente testimonianza del periodo compreso tra lo stage isotopico 4 e lo stage isotopico 1.

Introduction

The evidences of the glaciers presence and development in the area of the Monte Generoso and of the insubrian lakes (Lago Maggiore, Lago di Lugano, Lago di Como) are well known (Bini & Cappa 1975; Bini et al. 1996).

The aim of the present paper is to contribute to the knowledge of climatic, faunal and floristic changes to which the area of Monte Generoso was subject to, using the deposit and palaeontological remains of Caverna Generosa (Bona 2005).

The palaeofaunistic record of the Caverna Generosa includes a large number of mammals taxa, among which *Ursus spelaeus* is widely prevailing (Bona 2004, 2005). Very interesting are the herpetological remains, which are an uniqueness in the Lombardian paleontological record (Bernini et al. 2004). The Caverna Generosa recent field investigations represent the resumption

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of work interrupted, with few exceptions (Vialli 1956, 1957; Perego et al. 2001), more than a century ago (Cornalia 1858-1871).

The excavation revealed two stratigraphical sequences in two different areas of the cave, which covered the time of the isotopic stage 4, 3, 2 and 1. The analysis of the faunal assemblages (large and small mammals, birds, amphibians and reptiles) gave a very detailed reconstruction of the climatic and environmental conditions during the last glacial age for this area, which was not ever covered by glaciers (Bini & Cappa 1975).

Geographical Setting

The Caverna Generosa is located on the Italian side of Monte Generoso (LO CO 2694), in the North-Western Lombardy (Como province), and it opens at an altitude of 1450 m a.s.l. (Fig. 1).

The limestone where the Caverna Generosa opens is named "Calcare di Moltrasio" (Gaetani 1975) or "Lombardische Kieselkalk" (Frauenfelder 1916), and it is characterized by the occurrence of nodules of black cherts. The cave was produced by old karstic processes that probably started in the Oligocene period (Bini & Cappa 1975). The cavity is about 200 meters long but only the first 80 meters are interested by allochtonous sedimentations with faunal remains. In this external area three main parts are recognized: an initial tunnel called "Cunicolo", a little room called "Saletta" and a bigger room called "Sala Terminale".

Stratigraphical Setting

Sala Terminale. Thirteen stratigrafical levels, nearly all fossiliferous, were excavated in the "Sala Terminale". The levels differ mainly for the colour of matrix, the grain size and the structure of the skeleton of the sediment (Fig. 2). Important is also the presence of heavy minerals testifying wind sediments transport (Loess; see Bona et al. 2007).

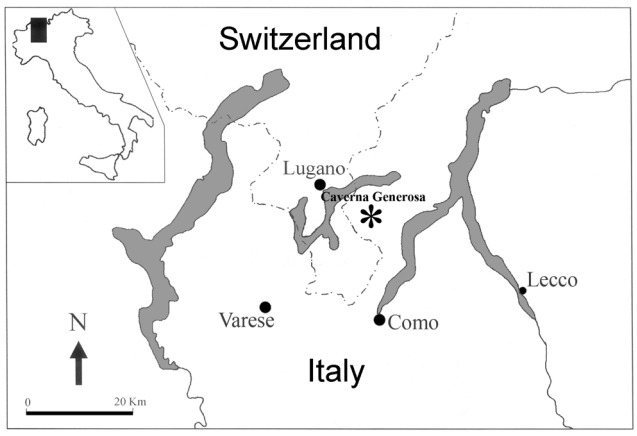

Fig. 1 - Geographical position of the Caverna Generosa.

The stratigraphy of the "Sala Terminale" is very complex with many lateral differentiations. Main macroscopic information of levels are described below, top to bottom (in the brackets coeval lateral levels):

- *Lev. 1 (A, Can, a_o, I):* characterized by the presence of sub-angular limestone blocks (max dimensions 12x5x1 cm); grey silty clay matrix. The thickness is variable from less than 10 cm to 60 cm. The lower boundary is undulated. No fossils found. This level represents the original surface of the cave at moment of the discovery.
- *Lev. 2 (B, 2b, a, a_1):* few sub-angular limestone blocks (max dimensions 5x3x1 cm) are present; grey-yellowish laminated clay matrix. The thickness is about 20 cm. Scarce fossils content.
- *Lev. 3 (b):* yellowish matrix with a silty clay grain size; the skeleton is composed by scarce limestone blocks, with traces of chemical alteration, and residual dark cherts of Calcare di Moltrasio (max size 4-5 cm). Maximum thickness 25 cm. The level closes to north side of the "Sala Terminale". Cave bear bones are common.
- *Lev. 4:* thickness is variable from less than 10 cm to 40 cm; pale red laminated silty matrix with grey-blue clay lenses (max length 25 cm, max thickness 3 cm) probably formed by dissolution of limestone boulders. Few limestone clasts with maximum diameter of 5 cm are present. Fossil bones are common. Gradual boundary to lev. 5.

During the first excavation remains collected from lev. 3 and 4 were ascribed together to lev II.

- *Lev. 5:* thickness is variable from less than 20 cm to 50 cm. Ochre silty matrix. There are big dark lenses probably due to the accumulation of organic matter, the quiescence of which probably underlines an original foot passage of bears. Very rich in fossil bones poorly preserved. Sharp boundary to lev. 6.
- *Lev. 6:* dark red silty clay matrix; common small angular stones. Abundant presence of cave bear remains. The thickness varies from 20 to 40 cm. It's worth to underline the presence of dark laminations that probably testify the surfaces of stamping or the nests of bears. Sharp boundary to lev. 8.

During the first excavation remains collected from lev. 5 and 6 was ascribed together to lev III.

- *Lev. 8:* brown greyish clay matrix; maximum diameter of angular stones is 15 cm, sometimes, in the central portion of "Sala Terminale", they show a vertical position probably due to the presence of collapsed galleries of Alpine marmot. Rich in fossil cave bear bones, not well preserved. The thickness varies from 12 to 20 cm. Clear boundary to lev. 9.

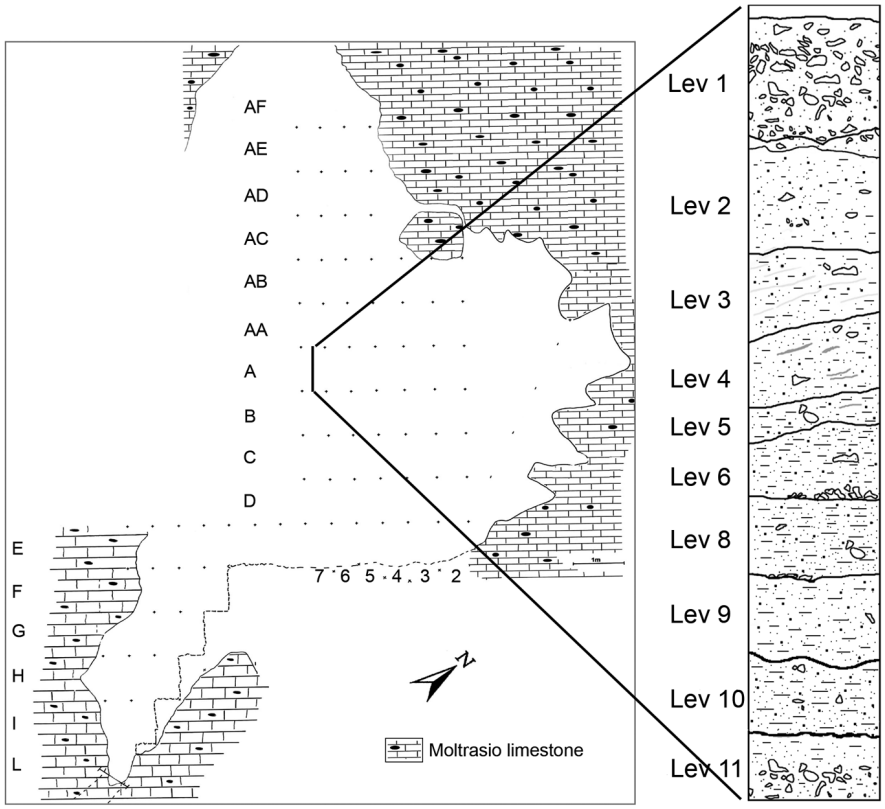

Fig. 2 - Plain and Stratigraphical sequence of "Sala Terminale".

– *Lev. 9:* dark red clay with silt matrix. Common calcareous deeply altered stones of 5-6 cm of maximum length. Cave bear bones are present, but poorly preserved. The thickness varies from 16 to 23 cm. Gradual boundary to lev. 10.
– *Lev. 10:* on the surface, big calcareous angular boulders (up to 25-30 cm) are very common. Dark red, silty clay matrix with yellowish lens. Thickness 12 to 18 cm. Uncommon and usually badly preserved cave bear bones. Sharp boundary to lev. 11.
– *Lev. 11*: greyish clay matrix with millimetric aggregates (maximum size of 3-4 mm). Calcareous angular limestone blocks (max size of 10-12 cm) are very common. In the central portion of "Sala Terminale" the matrix becomes yellowish, less silty and the clasts of Calcare di Moltrasio became smaller and less frequent. Scarce presence of bad preserved bones remains. At the bottom of this level, two Musterian flints have been found during the 2002 and 2004 field excavations (Bona et al. 2007). Sharp boundary to lev. 12.
– *Lev. 12*: dark brown clay silty matrix with small aggregates of 2-3 mm, scarce angular limestone clasts of 2-3 cm (sometimes decimetric blocks are present). Very rare, badly preserved cave bear bones. Thickness about 10-12 cm.
– *Lev. 13:* quite similar to the overlying lev. 12 but with more decimetric clasts. Matrix is very dark brown coloured. At the bottom of the level, few red deer teeth have been found. Thickness about 10 cm.

With the level 13 the sedimentation series of the "Sala Terminale" ends. Below this level there is the limestone floor of the cave.

Cunicolo 13-15. In the "Cunicolo 13-15" six sectors (13 A-B, 14 A-B, 15 A-B), with seven levels each (lev. Cun 0, I, II, III, IV, V, VI), were investigated top to bottom and they are all fossiliferous (Fig. 3).
– *Surface*: boulders (size between 1 dm to1 m) probably collapsed from the ceiling of the cave.
– *Lev. Cun 0*: rich of sub-actual dark brown fossils; characterized by the presence of cryoclastic sub-angular limestone pebbles (max size 10x5x1 cm); scarce grey-yellowish silty clay matrix. The thickness is variable from less than 20 cm to 50 cm. Sharp boundary to lev. Cun I.
– *Lev. Cun I*: yellowish loessic matrix (testifying a change in environmental conditions) with millimetric (less than 5 mm) voids; grey clay covered the wall of these small voids. Well-fossilized brown coloured bones of *Ursus spelaeus* and *Marmota marmota* are common and, on the top, there are some vegetables remains. The thickness varies from 10 to 50 cm. Linear sharp boundary to lev. Cun II.

The lower levels show a dramatic diversity in sedimentation, with abundant clay matrix, and angular pebbles of variable size.
– *Lev. Cun II*: grey yellowish matrix; common prismatic aggregates (less than 5 mm) and millimetric voids. On the top, there are lenses (more than 6-7 cm) of yellowish silt. Calcare di Moltrasio sub-angu-

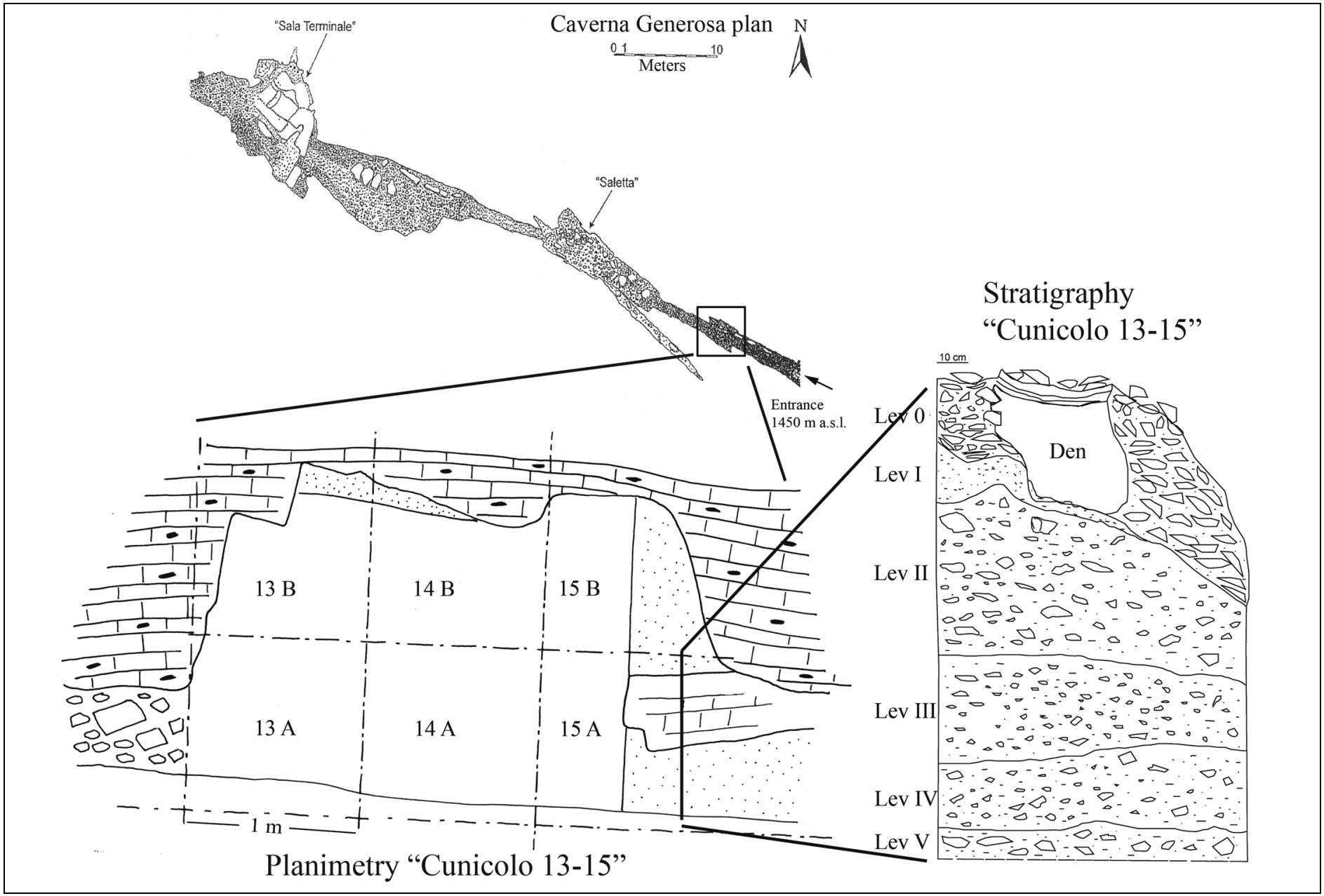

Fig. 3 - Plain and Stratigraphical sequence of the "Cunicolo 13-15".

lar limestone blocks are present, their size decreasing from the top to the bottom (from 20-25 cm to 7-8 cm). Thickness of the level is about 30-35 cm. Gradual boundary to lev. Cun III.

- *Lev. Cun III*: pink-grey matrix with a silty clay grain size; common millimetric prismatic aggregates (4-5 mm), the skeleton is composed by sub-angular limestone blocks and residual dark cherts of Calcare di Moltrasio (max 5-6 cm). Thickness 25-35 cm. Gradual boundary to lev. Cun IV.
- *Lev. Cun IV*: pink-reddish silty clay matrix. Millimetric prismatic aggregates (4-5 mm) are common. Less abundant local sub-angular limestone blocks and black cherts (max size 9-10 cm). Thickness 20-25 cm. Gradual boundary to lev. Cun V.
- *Lev. Cun V*: reddish matrix. Millimetric prismatic aggregates (4-5 mm) are common. Sub-angular Calcare di Moltrasio limestone blocks and black cherts (max size 9-10 cm) are present. Thickness 20 cm. Gradual boundary to lev. Cun VI.
- *Lev. Cun VI*: dark reddish brown matrix. Others components of this level are the same of lev. Cun V.

Lev. Cun II, III, IV, V and VI are very similar, they differ mainly for the colour of the matrix: it is dark brown in the lev. Cun VI and it becomes grey and lighter in the upper levels.

As previously recorded, differences between lev. Cun I and lower levels probably testify to a sedimentation gap or a sudden change in climatic conditions.

Dating

Six bones of cave bear (*Ursus spelaeus*), from "Sala Terminale", have been submitted to ^{14}C dating. The first dating, made by the Geographisches Institut Universität Zürich (UZ 2429/ETH 4249) on an unknown mammal bone (probably cave bear) collected on the surface of "Sala Terminale" in 1988, provided the age of 38.200 +/- 1.400 y BP. Five other cave bear bones, collected in the same area of the cave and belonging to the six upper levels, were dated by Utrecht University laboratory (UtC-10760, UtC-10761, UtC-10762, UtC-10763, UtC-10764). These sediments cover a time span of 12.000 y (between over than 50.000 y to 38.000 y BP), the lower levels fall outside the ^{14}C method limit (Tab. 1).

For the "Cunicolo 13-15" other six cave bear bones have been submitted to ^{14}C dating by CEDAD (Facoltà di Ingegneria Università di Lecce- LTL1775A, LTL1776A, LTL1777A, LTL1778A, LTL1779A, LTL1780A). The samples belong to the levels II, III, and V. The analysis provided an age between 37.000 y and 31.000 y BP (all the datings here reported are not calibrated) (Tab. 1).

Material and Methods

The remains collected in the seven stratigrafical levels of the "Cunicolo 13-15" and in the thirteen levels of the "Sala Terminale" are studied in the present paper.

Macromammal remains were recovered directly in the field during the excavation. Sediments removed from the cave were sieved with a 1 mm mesh sieves, then picked to collect micro vertebrates.

The method used to collect small sized 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 accu-

Tab. 1 - List of the ^{14}C dating of the Caverna Generosa sequence.

Sample name	Sector/level	Analysed fraction	$\delta^{13}C$ (‰)	^{14}C Age (BP)
UtC-10760	MG B6/2	collagene	-23.7	51200 ± 4000
UtC-10761	MG D6/2	collagene	-23.5	39200 ± 1000
UtC-10762	MG AA3/4	collagene	-18.8	46700 ± 2400
UtC-10763	MG AA3/6	collagene	-20.1	47800 ± 2600
UtC-10764	MG AA3/6	collagene	-18.3	50800 ± 5000
UZ 2429/ETH 4249	MG 1/0	collagene	-23.5	38200 ± 1400
LTL1775A	MGCUN 14A/II	collagene	-20.0 ± 0.2	33762 ± 330
LTL1776A	MGCUN 2 14A/II	collagene	-21.0 ± 0.3	36870 ± 400
LTL1777A	MGCUN 13A/II	collagene	-20.0 ± 0.2	37375 ± 1000
LTL1778A	MGCUN 14A/III	collagene	-20.1 ± 0.2	36479 ± 650
LTL1779A	MGCUN 14A/V	collagene	-22.1 ± 0.3	31860 ± 700
LTL1780A	MGCUN 2 14A/V	collagene	-18.1 ± 0.2	35570 ± 460

rate sieving, in the laboratory of Università degli Studi di Milano, and picking of samples.

The small mammal specimens have been identified following mainly Chaline et al. (1974) and Niethammer & Krapp (1978, 1982, 1990). Taxonomic identification of the herpetofauna has been based on the diagnostic characters reported by Estes (1981) and Haller-Probst & Schleich (1994) for caudates, by Bailon (1999) for anurans, by Estes (1983) and Barahona & Barbadillo (1997) for lacertilians, and by Szyndar (1991 a, b) for snakes.

For large mammals the Minimum Number of Individuals (MNI) and for small mammals the Number of Individuals (NI) and the relative frequencies in the stratigraphical sequence have been extimated. For large mammals remains, the MNI for each taxon has been estimated counting of the most frequent bone and considering also: the siding of the same bones (ex: 3 left femurs and 2 right femurs mean the presence of, at least, three different individuals); the level the bone belongs to (considering, for example, a left femur coming from lev. Cun I and an other left femur found in lev. Cun II belonging to two different individuals); the development degree (youngs, sub-adults and adults were distinguished) (Klein & Cruz-Uribe 1984). For the small mammals NI was estimated by adding the number of right and left specimens of the most frequent bone. For voles the most frequent bone is often the first lower molar.

Taphonomy

Large mammals. In the "Sala Terminale", macrofaunal remains consist mainly in *Ursus spelaeus* and *Marmota marmota*. Along the stratigrafical sequence, from the top to the bottom, there is a progressive worsening of bones preservation. The cave bear remains belonging to the upper levels, from lev. 2 to lev. 4, are usually well preserved and complete; they are of a pale yellow colour with few fractures. The remains from lev. 5 to lev. 8 are complete (on the surface of lev. 6 there is a completely articulate cave bear skeleton), but often not well preserved; the bones are fragile and red coloured. The number and the preservation of the cave bear bones decrease in the lev. 9 and lev. 10. In the lower levels, the remains are very infrequent and badly preserved: most of them are complete or fragmented teeth.

Exception made for the almost complete and articulated skeleton found in the lev. 6, the bones are usually scattered in the sediments. This is probably due to the activity of animals (mainly other bears and Alpine marmot) and to the movement of the embedding sediments flowing in the cave.

The remains from the "Cunicolo 13-15" are generally fairly well preserved, although worse than that of the remains coming from "Sala Terminale". Probably this is linked to a different sedimentation, more vigorous in "Cunicolo 13-15" than in the "Sala Terminale". The long bones are infrequent, broken when present, and generally a little rounded by transport. The teeth, vertebrae, metapodials, and toe bones, all of them with evidences of transportation too, constitute the biggest part of the remains.

Of large herbivorous, legs, arms and toe bones have been mainly found. Therefore it is possible that these animals did not enter in the cave by themselves. They should heve been prey of carnivorous, which hunted them outside and entered into the cave/den with selected part of their prey. The outcome of this particular taphonomical process is that a great MNI result from a small number of bones found.

For Alpine marmot (*Marmota marmota*) an high number of skeletal elements represents a relative low MNI. This is due because the Alpine marmot dug their dens in the cave and therefore, after their death, all the bones remained in situ with high chances to be preserved and fossilized.

Small mammals. The micromammal remains are probably the result of the deposition of pellets by birds (owls, barn owls, ecc.) wich used the cave as a shelter; in fact, they are in some cases damaged by digestive processes (See Andrews 1990).

In the "Cunicolo 13-15" lev. Cun 0 is very rich of small faunal remains and, on its surface, it shows the presence of brownish spots even richer of organic matter, with, probably sub-actual, bones and vegetals. It is necessary to underline that, due to the nature of sediments of lev. Cun 0, it is possible that some sub-actual bones coming from the bottom of lev. Cun 0 reached the top of lev. Cun I. These bones are recognizable because of their generally fresh appearance and white colour.

The small mammals bones are less common in lower levels, except for the lev. Cun III, where they are even more frequent than in lev. Cun 0. This is probably due to the presence of a bird nest in this area during the deposition of lev. Cun III.

Amphibians and Reptiles. Most of the remains are relatively well preserved but some are incomplete and show significant breakages or, in few cases, signs of chemical attack that could be related to digestion (as one of the viper vertebrae from 14 B/0), suggesting that the origin of at least a part of the herpetofaunistic assemblage could be connected with the action of a predator.

CUNICOLO Level	0		I		II		III		IV		IV	
TAXON	MNI	%	MNI	%	MNI	%	MNI	%	MNI	%	MNI	%
Artiodactila												
Bovidae												
Bos taurus	1	3,0									1	1,8
Capra hircus	1	3,0									1	1,8
Capra ibex					1	10,0					1	1,8
Capra vel Ovis	1	3,0									1	1,8
Rupicapra rupicapra			1	10,0	1	10,0	1	20,0			3	5,3
Cervidae												
Cervus elaphus					1	10,0					1	1,8
Suidae												
Sus scrofa	1	3,0									1	1,8
Cf. *Sus*	1	3,0									1	1,8
Artidactila ind.	3	9,1	2	20,0	1	10,0	1	20,0			7	12,3
Rodentia												
Sciuridae												
Marmota marmota	3	9,1	3	30,0	3	30,0					9	15,8
Leporidae												
Lepus sp.	2	6,1									2	3,5
Leporidae ind.	1	3,0	1	10,0			1	20,0			3	5,3
Carnivora												
Canidae												
Canis lupus					1	10,0			1	100	2	3,5
Canis sp.	1	3,0									1	1,8
Vulpes vulpes	3	9,1									3	5,3
Cf. *Vulpes*	1	3,0									1	1,8
Felidae												
Felis silvestris	1	3,0									1	1,8
Mustelidae												
Martes foina	2	6,1									2	3,5
Martes sp.	4	12,1									4	7,0
Mustela nivalis	1	3,0									1	1,8
Mustela putorius			1	10,0							1	1,8
Mustelidea ind.	1	3,0									1	1,8
Ursidae												
Ursus arctos	1	3,0	1	10,0	1	10,0	1	20,0			4	7,0
Ursus cf. *arctos*	1	3,0	1	10,0	1	10,0					1	1,8
Carnivora ind.	1	3,0									1	1,8
Aves	2	6,1					1	20,0			3	5,3
TOT	33	100	10	100	10	100	5	100	1	100	57	100

Tab. 2 - List of macrofaunal taxa, different from *Ursus spelaeus*, found in "Cunicolo 13-15".

Faunal remains

Macrofaunal Remains

Sala Terminale. *Ursus spelaeus* remains are the most represented in the abundant mammal record of the "Sala Terminale" (more than 20.000 specimens). Only 106 bones belong to taxa different from *Ursus spelaeus*: 69 of *Marmota marmota*; 25 of *Mustela putorius*; 3 of *Mustela nivalis*; 1 of *Capra ibex*; 2 of *Rupicapra rupicapra*; 6 fragments of teeth of *Cervus elaphus*. These remains come from different levels along the stratigrafical sequence. However, due to their scarcity, it's not possible to infer any palaoenvironmental interpretations.

Cunicolo 13-15. In the "Cunicolo 13-15" *Ursus spelaeus* is the most frequent species. However 257 bones, belonging to 19 species other then cave bear, were also found (Tab. 2).

Most of these remains comes from lev. Cun 0, so probably they are Holocene in age. This interpretation is supported not only by their appearance (the surface of the bones is lightly coloured and fossilisation process is just began) and, above all, by the occurrence of domestic variety of some species, such as *Capra* vel *Ovis*.

Due to the scarcity of macromammal remains in the lower layers we cannot suppose anything sure about the paleoenviroment. The occurrence of ibex (*Capra ibex*), Alpine marmot (*Marmota marmota*) and chamois (*Rupicapra rupicapra*) suggests a cold climate for this faunal assemblage.

Microfaunal Remains

Sala Terminale. In the "Sala Terminale" of Caverna Generosa levels with the same chronological and sedimentological characters have been grouped, owing to the scarcity of remains, in order to obtain significant palaeoecological data (Bona et al. 2007) (Tab. 3). The percentages have been calculated on the bases of the estimated NI.

- *Lev. 10, 11 and 12 (Group 4).* Small mammals are very poorly represented in this group of levels. Only 10 remains have been determined (2 of *Arvicola terrestris*; 4 of *Terricola* gr. *T. multiplex-subterraneus*; 1 of *Chionomys nivalis*; 3 of *Microtus arvalis*) for this time interval. Therefore it is impossible to draw significant paleoenvironmental inferences.
- *Lev. 5, 6, 8, 9 and III (Group 3).* These levels are characterized by an assemblage of *Terricola* gr. *T. multiplex-subterraneus* (10,5%), *Chionomys nivalis* (28,9%), *Arvicola terrestris* (15,8%), *Microtus arvalis* (28,9%) and *Microtus agrestis* (5,3%). The significant 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.
- *Lev. 3, 4, b and II (Group 2).* The best represented taxa are *Arvicola terrestris* (29,7%), *Terricola* gr. *T. multiplex-subterraneus* (18,9%), *Microtus arvalis* (16,2%) and *Clethrionomys glareolus* (10,8%). Another important taxon is *Apodemus* gr. *A. sylvaticus-flavicollis* (10,8%). This latter is considered mainly woodland, hedgerows and field margin, orchards and wooded gardens (Macdonald & Barret 1993). Also present are: *Chionomys nivalis* (2 finds), *Talpa caeca* and *Sorex araneus* represented each by a single finding. According to these data it might be that the surroundings of Monte Generoso, about 46 Ky ago (Tab. 1), were characterized by wide wooded areas with dense underbrush (significant is the presence of *Muscardinus avellanarius*).
- *Lev. 0, 1, 2, 2b, A, B, a, a_0, a_1 and I (Group 1).* The data suggest the presence of wooded conditions in the cave neighborhood about 38-40 Ky (Tab. 1). This interpretation is supported by numerous remains of *Terricola* gr. *T. multiplex-subterraneus* (34,6%) and by scarce *Clethrionomys glareolus* (3,7%), *Glis glis* (1,4%) and *Apodemus* gr. *A. sylvaticus-flavicollis* (2%). It is possible to consider the presence of small open areas alternated by wooded ones owing to the presence of *Microtus arvalis* (15,9%) and of *Chionomys nivalis* (3,7%). The occurrence of *Arvicola terrestris* (16,4%), who is living near fresh water like rivers and lakes but also in less aquatic habitat, confirms the presence of wet environments, probably nearby the watershed.

Cunicolo 13-15. Datings of the materials coming from the "Cunicolo 13-15" are very close and included in a period of time between 32.000 y and 37.000 y BP (Tab. 1). It is quite difficult to clearly distinguish intervals of sedimentation of different levels. Probably they were deposited in a short interval as suggested by the uniformity of their characteristic.

Microfaunal remains consist in more than one thousand specimens identified, belonging to 18 different species (Tab. 4).

According to the ecology of different species occurring in each layer and, above all, to the composition of the faunal associations, it is possible to suggest some hypotheses about climate and landscape around the cave during the period of the sediment deposition.

- *Lev. Cun VI and lev. Cun V.* Due to the scarcity of micromammals remains it is not possible, at present, to make inferences about the climate.
- *Lev. Cun IV.* The most frequent species in the faunal association is *Terricola* gr. *T. multiplex-subterraneus*, with the 46,7% of specimens (NI), which is typical of wooded area. The frequencies of *Microtus arvalis*

Level	Group		*Terricola* gr. *mult.-subt.*	*Terricola savii*	*Chionomys nivalis*	*Clethrionomys glareolus*	*Arvicola terrestris*	*Microtus arvalis*	*Microtus agrestis*	*Microtus* sp.	*Glis glis*	*Apodemus* gr. *sylv.-flav.*	*Sorex minutus*	*Sorex araneus*	*Sorex s/pinus*	*Muscarsinus avellanarius*	*Talpa* cf. *europaea*	*Talpa* cf. *caeca*	Tot
0	1	NI	7				2				1	1	1				1	1	14
		%	50,0				14,29				7,14	7,14	7,14				7,14	7,14	100
1		NI	9		1	1	3	1				2			1				18
		%	50,0		5,6	5,6	16,7	5,6				11,1			5,6				100
2		NI	2				2	1				1					1		7
		%	28,6				28,6	14,3				14,3					14,3		100
2b		NI	2																2
		%	100																100
A		NI	2				1												3
		%	66,7				33												100
B		NI	2				8											1	11
		%	18,2				72,7											9,1	100
Can		NI	2		2	1	9	8				1							23
		%	8,7		8,7	4,3	39,1	34,8				4,3							100
ao		NI	16		5	2	15	9	1			1						4	53
		%	30,2		9,4	3,8	28,3	17,0	1,9			1,9						7,5	100
a		NI	23		16	3	34	14	4	2	2							2	100
		%	23,0		16,0	3,0	34,0	14,0	4,0	2,0	2,0							2,0	100
a1		NI	4			3	3											4	14
		%	28,6			21,4	21,4											28,6	100
I		NI	33	1	6	1	9	14		2	1						2		69
		%	47,8	1,4	8,7	1,4	13,0	20,3		2,9	1,4						2,9		100
3	2	NI						1										1	2
		%						50,0										50,0	100
b		NI			1		7	4											12
		%			8,3		58,3	33,3											100
4		NI	3		1	1	4	1				1							11
		%	27,3		9,1	9,1	36,4	9,1				9,1							100
II		NI	4			3						3		1		1			12
		%	33,3			25,0						25,0		8,3		8,3			100
5	3	NI			1		1		1										3
		%			33,3		33,3		33,3										100
6		NI	2		2		2	3	1										10
		%	20,0		20,0		20,0	30,0	10,0										100
8		NI			3		1	2											6
		%			50		17	33											100
9		NI			4		1	4		1		1						1	12
		%			33,3		8,3	33,3		8,3		8,3						8,3	100
III		NI	2		1	1	1	2											7
		%	28,6		14,3	14,3	14,3	28,6											100
10	4	NI			1			1											2
		%			50			50											100
11		NI	3				1	2										1	7
		%	42,9				14,3	28,6										14,3	100
12		NI	1				1												2
		%	50,0				50,0												100
Tot		NI	117	1	44	16	105	67	7	5	4	11	1	1	1	1	4	15	400
		%	29,3	0,25	11	4	26,3	16,8	1,75	1,25	1	2,75	0,25	0,25	0,25	0,25	1	3,75	100

Tab. 3 - List of taxa of microfauna of "Sala Terminale" from each layer: Number of Individual (NI) and its percentage (NI%).

CUNICOLO Level	0		I		II		III		IV		V		VI		Tot	
TAXON	NI	%	NI	%	NI	%	NI	%	NI	%	NI	%	NI	%	NI	%
Rodentia																
Microtinae																
Arvicola terrestris	14	5,3	6	12,0	21	24,7	36	20,7	3	20,0	1	20,0			80	13,6
Chionomys nivalis	6	2,3	10	20,0	15	17,6	21	12,1	1	6,7					53	9,0
Clethrionomys glareolus	22	8,4			2	2,4									24	4,1
Microtus agrestis	1	0,4	1	2,0	1	1,2	7	4,0							10	1,7
Microtus arvalis	21	8,0	14	28,0	27	31,8	63	36,2	3	20,0	3	60,0			128	21,8
Terricola gr. *multi-sub*	102	38,9	8	16,0	11	12,9	40	23,0	7	46,7	1	20,0	1	100	170	28,9
Muridinae																
Apodemus gr. *sylv-flav*	17	6,5			1	1,2	1	0,6							19	3,2
Gliridae																
Glis glis	19	7,3	5	10,0	2	2,4									26	4,4
Sciuridae																
Sciurus vulgaris	1	0,4													1	0,2
Insectivora																
Sorex araneus	2	0,8	2	4,0	2	2,4	1	0,6							7	1,2
Soricide indet.	1	0,4													1	0,2
Sorex alpinus	1	0,4													1	0,2
Sorex minutus	1	0,4													1	0,2
Sorex sp.	1	0,4	1	2,0	1	1,2	1	0,6							4	0,7
Crocidura sp.	1	0,4													1	0,2
Talpa caeca	49	18,7	3	6,0	2	2,4	3	1,7	1	6,7					58	9,9
Talpa sp.	2	0,8					1	0,6							3	0,5
Chiroptera	1	0,4													1	0,2
TOT	262	100	50	100	85	100	174	100	15	100	5	100	1	100	588	100

Tab. 4 - List of taxa of microfauna of "Cunicolo 13-15" from each layer: Number of Individual (NI) and its percentage (NI%).

(20%) and *Arvicola terrestris* (20%) testify to the presence of open spots and wet areas.

– *Lev. Cun III*. The frequency of *Terricola* gr. *T. multiplex-subterraneus* decreases (22,9%), while the biggest part of remains belongs to *Microtus arvalis* (36%). *Arvicola terrestris*, a species that lives in wet areas, is still present as 20,6% of specimens. The frequency of *Chionomys nivalis*, a typical vole of cold region, increases (12%). Probably climate became colder and landscape less wooded.
– *Lev. Cun II.* The climate remains the same of the previous level. *Microtus arvalis* is still the most frequent species (31,8%) with *Arvicola terrestris* (24,7%). There is a further increase of the NI of *Chionomys nivalis,* which reaches 17,6%.
– *Lev. Cun I*. Typical species of cold climate and open landscape are still predominant in the faunal association: *Microtus arvalis* with 28% and *Chionomys nivalis* with 20% of NI. *Terricola* gr. *T. multiplex-subterraneus* (16%) and *Glis glis* (10%) become more numerous: this occurrence could show a little increase of wooded areas. The frequency of *Arvicola terrestris* decreases to 12%, this is probably linked to more arid conditions.
– *Lev. Cun 0.* This level, under its surface, is made of low matrix content and cryoclastic angular limestone blocks, probably deposited during the last Pleniglacial. Most of the remains found in this level belong to the surface of the deposit and, probably, it is Holocene in age. The predominance of *Terricola* gr. *T. multiplex-subterraneus* (39,1%) and the frequencies of *Clethrionomys glareolus* (8,4%), *Glis glis* (7,3%) and *Apodemus* gr. *A. sylvaticus-flavicollis* (6,5%) are indicative of a wooded landscape with open areas as also indicated by the presence of *Microtus arvalis* (8,0%) and *Chionomys nivalis* (2,3%). Because of the abundance of *Talpa caeca* (18,8%), the soil in the area around the cave is supposed to be soft and deeper than during the time span when the lower levels accumulated. Probably the climate became milder.

Then the sediments of "Cunicolo 13-15" testify for a gradual climatic change: from a cold and open landscape to a wooded one with milder climate.

Herpetofauna. The herpetofauna of the Caverna Generosa is represented by 1321 remains; nearly all the remains (1236 in number; 93.6% of the sample) come from lev. Cun 0. Few remains have been retrieved from lev. Cun I and lev. Cun III but 73 come from lev. Cun II (where *Anguis fragilis* and *Rana temporaria* are nearly equally abundant). No herpetological remains have been collected in lev. Cun IV and just a single Green Lizard element comes from each of the lower stratigraphic layers. The fossils are referred to eight extant taxa (Tab. 5): a caudate of the *Triturus cristatus* group, two anurans, *Bufo bufo* and *Rana temporaria*, two lacertilians, *Anguis fragilis* and *Lacerta* gr. *L. viridis*, and three snakes, *Zamenis* gr. *Z. longissimus*, *Coronella* cf. *C. austriaca*, and *Vipera* gr. *V. aspis*. The remains referred at order level, because poorly preserved or not informative, probably belong to these taxa.

In terms of number of remains (the percentages have been calculated on the bases of the number of specimens, n), the most abundant taxon is *Rana temporaria* (670 remains; 50,7% of the sample), followed by *Anguis fragilis* (28,9%) and then by *Bufo bufo* (10,0%); all the other taxa are represented by few remains (less than 2% each), and *Triturus* gr. *T. cristatus* by a single vertebra only.

From an ecological point of view, the herpetofauna from Caverna Generosa is characterized by taxa that have a wide altitudinal range at present. In Italy, they can be present from approximately sea level to over 2000 m above sea level (see single species entries in Sindaco et al. 2006), with only two exceptions represented by *Triturus carnifex* (the species of the *T. cristatus* group currently inhabiting Italy) and *Zamenis longissimus*, which reach 1980 and 1600 m a.s.l. respectively (but a museum specimen of *Zamenis longissimus* has been collected at 1850 m). Therefore it can be supposed that the amphibians and reptiles found at the Caverna Generosa inhabited the area surrounding the site and that they could reach it also by active dispersal.

As for the palaeoenvironment characteristics, it seems likely the presence of an ecotonal belt between meadows and at least patches of bushes (*Zamenis longissimus* seems to prefer dense bushy vegetations or woods). Nearly all the identified taxa, and the most common taxa -*Rana temporaria* and *Anguis fragilis*- in particular, need a rather high environmental humidity. Still or slowly flowing waters even small in size, relatively shallow, and ephemeral, should have been present within few kilometres for the reproduction of the amphibians.

Conclusions

Data obtained by the study of small mammals, reptiles and amphibians coming from Caverna Generosa, allow to propose the following paleoenvironmental interpretations, mainly for the Insubrian area (Western Lombardy, Prealps) during the last glacial period and Holocene. Dating of lower levels of "Cunicolo 13-15" seems to indicate that they are immediately subsequent to the upper ones of "Sala Terminale". Therefore it is

CUNICOLO Level	**0**		**I**		**II**		**III**		**IV**		**V**		**VI**		**TOT**	
TAXON	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
T. gr. *T. cristatus*	1	0,1													1	0,1
B. bufo	117	9,5	1	16,7	14	19,2									132	10,0
R. temporaria	647	52,3			23	31,5									670	50,7
Anura indet.	75	6,1	1	16,7	7	9,6									83	6,3
A. fragilis	352	28,5	3	50,0	24	32,9	1	25,0			1	100	1	100	382	28,9
L. gr. *L. viridis*	8	0,6													8	0,6
Sauria indet.		0,0	1	16,7											1	0,1
Z. gr. *Z. longissimus*	17	1,4			4	5,5									21	1,6
Coronella sp.	13	1,1			1	1,4									14	1,1
Colubrines indet.	1	0,1													1	0,1
V. cf. *V. aspis*	3	0,2					3	75,0							6	0,5
Serpentes indet.	2	0,2													2	0,2
TOT	1236	100	6	100	73	100	4	100			1	100	1	100	1321	100

Tab. 5 - List of taxa of reptiles and amphibians found in "Cunicolo 13-15" from each layer: number of specimens (n) and its percentage (n%).

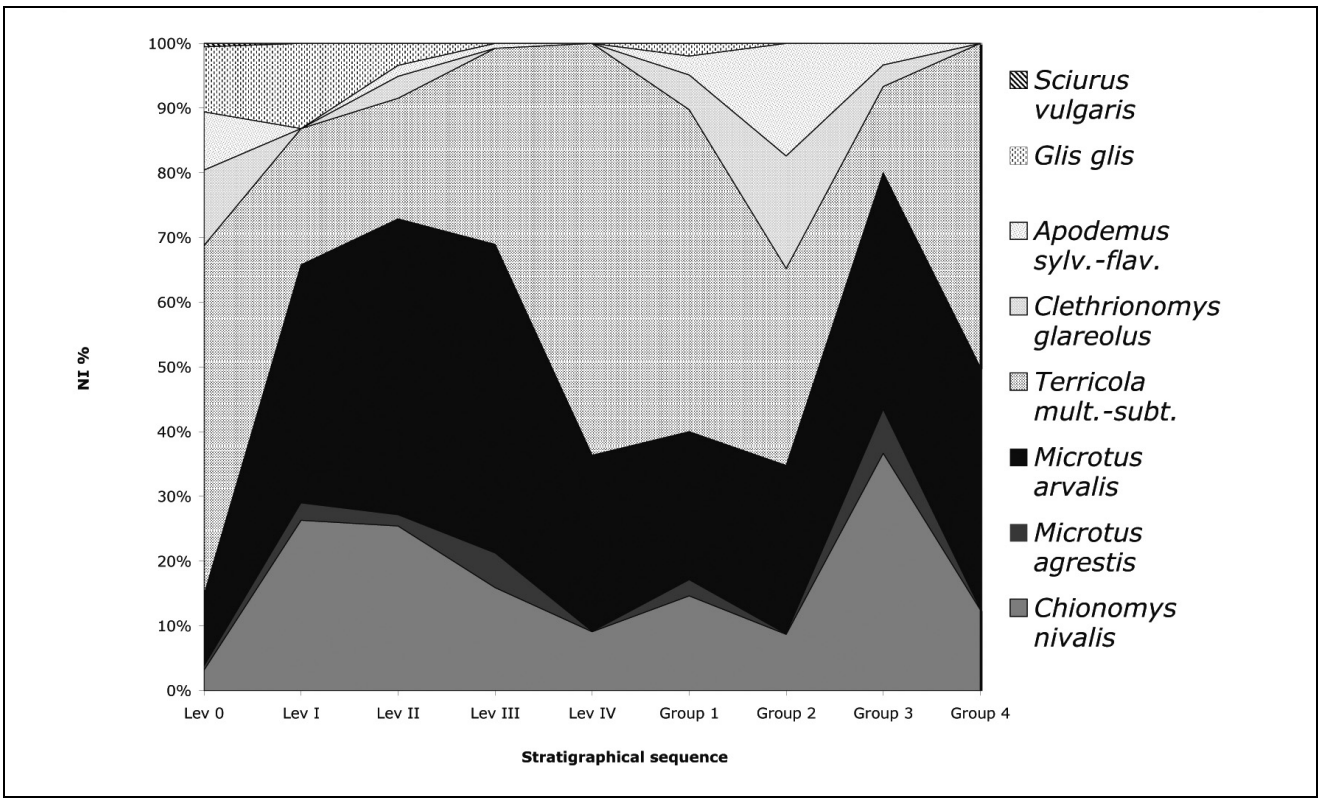

Fig. 4 - Relation between "Bush" taxa (*Apodemus, Terricola, Clethrionomys, Glis* and *Sciurus*) and "Prairie" taxa (*Microtus* and *Chionomys*) from the bottom of "Sala Terminale" sequence (left) and the top of "Cunicolo" one (right)

possible to correlate the two stratigraphical sequences (Fig. 4).

• Before 50.000 y BP (group IV of "Sala Terminale") the paleoenvironmental situation is not clear, owing to the poor amount of remains.

• At about 50.000 y BP (group III of "Sala Terminale"), *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 45.000-46.000 y BP (group II of "Sala Terminale"), arboreal species such as *Terricola* gr. *T. multiplex- subterraneus*, *Clethrionomys glareolus* and *Muscardinus avellanarius* stand out on the previous ones. An increase of wooded areas in a milder and wetter climate is suggested by this association of species.

• Levels dated about 38.000 y BP (group I of "Sala Terminale" and probably lev. Cun VI) confirm the situation described above.

• Between 36.000 to 30.000 y BP (lev. Cun III-II). During the deposition of lev. Cun III and II there was an important climatic deterioration testified by the presence of *Microtus arvalis* (dominant), *Microtus agrestis*, *Chionomys nivalis*. *Terricola* gr. *T. multiplex-subterraneus* is subordinate and *Arvicola terrestris* prove the presence of small and, probably, ephemeral streams.

• Lev. Cun I (no ^{14}C dating available but the presence of abundant Loess allowed to date this level near to the Last Maximum Glacial). The environment and climate did not change and species typical of cold and open habitats were still dominant (*Microtus arvalis*, *Microtus agrestis* and *Chionomys nivalis*).

• The Postglacial and Holocene association of lev. Cun 0 shows a clear increase of wooded areas with *M. (Terricola)* gr. *T. multiplex-subterraneus* well represented. At present it is impossible to make more detailed reconstruction for this period (Fig. 5).

In conclusion, the palaeontological analysis of the sequences of Caverna Generosa highlights the following climatic and environmental changes for the Insubrian area (North-Western Lombardy - North-Western Italy): at about 50.000 y BP the environment was represented by a cold grassland. At around 45.000-46.000 y BP this situation changed when taxa from wooded environment became dominant. Environmental and climatic situation was probably still favorable until 30.000 y BP (lev. Cun IV). After, the sequence of "Cunicolo" shows a new climate deterioration testified by dominance of cold and grassland species. After the Last Glacial Maximum, the Insubrian area records a new spreading of wooded areas; a landscape only recently modified by human activities.

The microfauna collected from the succession is very similar, in taxonomic composition, to the microfauna which lives on the Monte Generoso today. The absence, in the present fauna, of *Arvicola terrestris*,

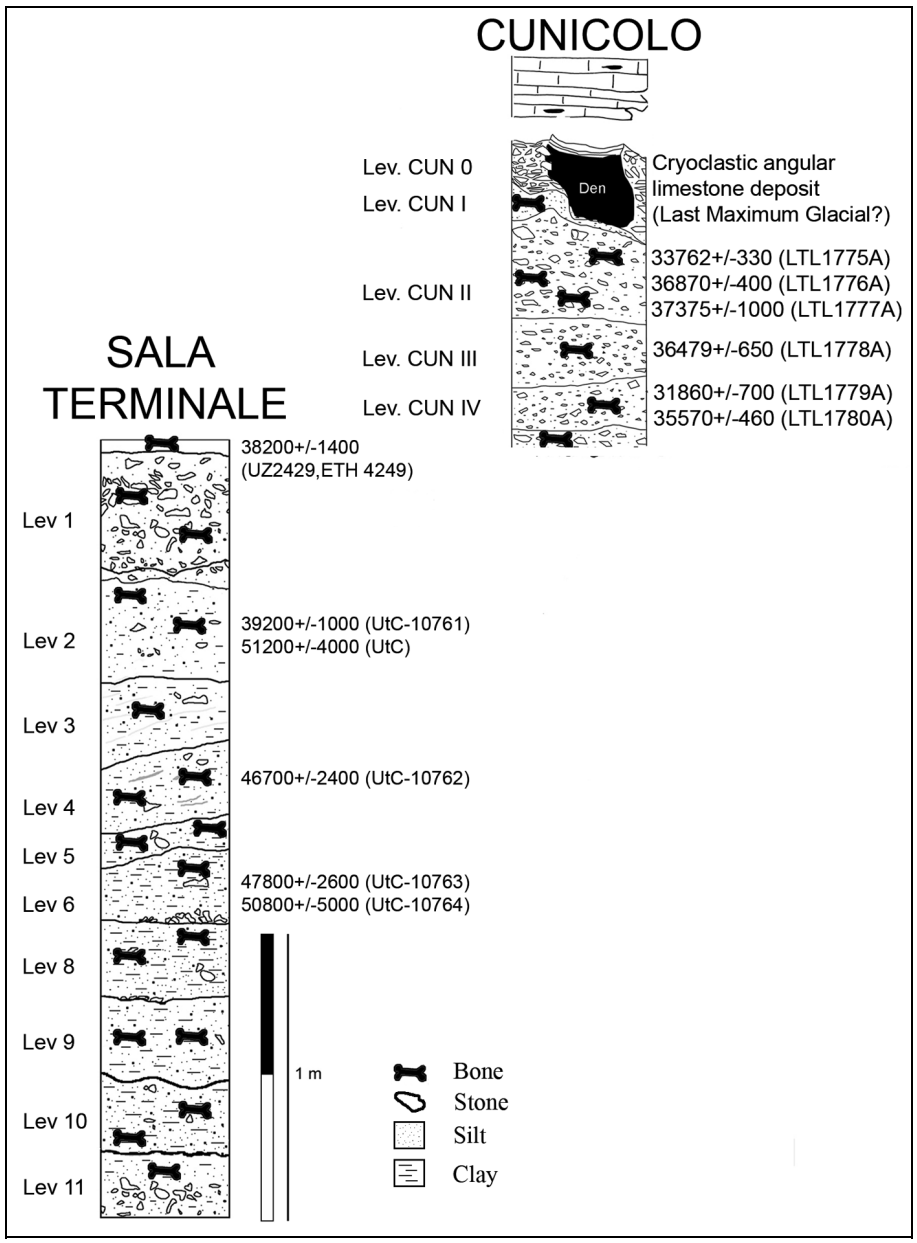

Fig. 5 - Suggested correlation between the stratigraphical sequences of "Sala Terminale" and stratigraphical sequence of "Cunicolo 13-15".

Chionomys nivalis, and *Microtus agrestis* is probably due to the progressive reforestation of the mountain slope which reduced the biotopes inhabited by these species (Salvioni 1987).

It is important to underline that there is only an other site, the Fontana Marella cave (Campo dei Fiori - Va), not far from Monte Generoso, with an Upper Pleistocenic small mammal fauna (Perego et al. 2001). The levels FM1 and FM2 of this deposit, dated about 25-26.000 years ago, show a small mammal distribution very similar to lev. CUN III and II of Caverna Generosa (Bona 2007).

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