Palaeoenvironmental analyses of animal remains from the Kůlna Cave (Moravian Karst, Czech Republic)

Die Paläoumwelt-Analysen von Tierknochen aus der Höhle Kůlna (Mährischer Karst, Tschechische Republik)

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Abstract - The excavations in the Kůlna Cave yielded a quantity of archaeological finds dating from MIS 6 to MIS 2; these represent an extraordinary information potential for the reconstruction of human behaviour in the context of the natural environment from the Middle Pleistocene to the beginning of the Holocene. Apart from the reconstruction of human activities that were under way in the cave, e.g. through GIS applications, the researchers analysed the seasonality and migration of the preserved fauna. Through the study of dental cement increments of selected individuals we tried to ascertain the season when the animals died. The results show that at various periods of time the cave served different purposes; while during the Magdalenian (layer 5) it was occupied in spring, during the Upper Micoquian (layers 6a, 6b) it was a spring and autumn seasonal settlement, and during the Lower Micoquian (layer 7a) it was inhabited from autumn to spring. We propose that the function of the cave gradually changed from an overwintering location in the Lower Micoquian (layer 7a) to a seasonal settlement locality (Upper Micoquian, Magdalenian). Strontium analyses have shown that the majority of the studied animal individuals came from the nearby surrounding area of the cave, most likely the Moravian Karst area, with the exception of two animals with values from beyond the karst region. From this we deduce that not only Neanderthals, but later on also Anatomically Modern Humans took advantage of the location of the cave at the boundary between two different ecosystems, i.e. an open landscape and the karst area, in their hunting strategies. The humans who occupied the cave at different periods made use of different biotopes to provide themselves with supplies. The ratios of C and N isotopes correlate with changes in the character of the natural environment of archaeological layers 7a - 4 and render more precise the information previously acquired by malacological and other faunal analyses.

Zusammenfassung - *Bei der Erforschung der Kůlna-Höhle wurde eine große Menge archäologischer Funde geborgen, die in die Zeitspanne MIS 6 - MIS 2 datiert werden und ein außerordentliches Informationspotential für die Rekonstruktion menschlichen Verhaltens im Kontext der Naturumwelt vom mittleren Pleistozän bis zum Anfang des Holozäns darstellen. Neben der Rekonstruktion menschlicher Aktivitäten in der Höhle, z.B. mittels der GIS-Applikationen, wurde die Saisonalität und Migration der vorhandenen Fauna analysiert. Mittels des Studiums von Zuwächsen des Zahnzements bei ausgewählten Individuen wurde die Jahreszeit ihres Verendens festgestellt. Die Ergebnisse zeigen, dass die Höhle in verschiedenen Perioden verschiedenen Zwecken diente: während sie im Magdalénien (Schicht 5) als Frühlingssiedlung diente, wurde sie im jüngeren Micoquien (Schicht 6a und 6b) als Frühlings- und Herbstsiedlung genutzt; im älteren Micoquien (Schicht 7a) wurde sie vom Herbst bis Frühling bewohnt. Es ist anzunehmen, dass sich die Funktion der Höhle allmählich von der Winterstation im älteren Micoquien (Schicht 7a) zur Saison-siedlung (im jüngeren Micoquien und im Magdalénien) entwickelte. Strontium-Analysen zeigen, dass die meisten untersuchten Individuen aus der nächsten Umgebung der Höhle stammen, wahrscheinlich aus dem Mährischen Karst, bei zwei davon bezeugen die Werte ihre Herkunft außerhalb des Karstgebiets. Daraus lässt sich schließen, dass nicht nur die Neandertaler, sondern später auch die anatomisch modernen Menschen in ihrer Jagdstrategie die Höhle nutzten, die sich an der Grenze zweier verschiedener Ökosysteme befand – der offenen Landschaft und des Karstgebiets. Menschen, die die Höhle in verschiedenen Perioden bewohnten, nutzten bei der Versorgung verschiedene Biotope. Die Proportionen von Kohlenstoff- und Stickstoff-Isotopen bestätigen die Veränderung der Umwelt der archäologischen Schichten 7a – 4 und präzisieren die schon früher durch die malakologischen und faunistischen Analysen gewonnenen Informationen.*

Keywords - Micoquian, Magdalenian, Epi-Magdalenian, $^{13}C/^{12}C$, $^{15}N/^{14}N$ and $^{87}Sr/^{86}Sr$, seasonality analyses
Keilmessergruppen, Magdalénien, Epimagdalénien, $^{13}C/^{12}C$, $^{15}N/^{14}N$ und $^{87}Sr/^{86}Sr$, Saisonalitäts-analyse

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Introduction

Study and reconstruction of the environment of archaeological cultures are carried out within the framework of so-called environmental archaeology, a division of the field that has recently been developing dynamically. The field comprises various disciplines ranging from those most commonly applied (e.g. anthracology, palynology, malacozoology) to relatively new ones which are still poorly acknowledged (e.g. palaeoparasitology). The applicational options of virtually any form of analysis are limited beforehand by the possibility of preservation of the required sample, its state of preservation and, possibly, its representativeness. At the same time, by utilising the widest available options of study of archaeological materials and their interpretation we provide new input to the research and understanding of the human role and impacts on the natural environment and the resulting changes (e.g. Dreslerová 2008: 13). Although cooperation with the natural sciences is a particular feature of the study of the Palaeolithic and it already makes use of the relatively broad potential of a range of analyses, it is possible to apply some new procedures even here. One of those which enhances the fields of archaeozoology or anthropology and provides them with new options for interpreting human and animal behaviour is the study of migrations and seasonality of fauna.

A grant-supported project focused on the chronostratigraphic revision of the Kůlna Cave has been carried out between 2010 and 2013 (Nerudová & Neruda 2011, 2012). One aspect of the project was to verify whether it is possible to carry out palaeo-environmental analyses capable of reconstructing the use of the landscape and the ecosystem at a single site by the bearers of various cultures, i.e. Neanderthals and AMH, over a relatively long time.

One of the most important Middle Palaeolithic sites in Central Europe is the Kůlna Cave in the Moravian Karst, the settlement of which also continued until the end of Pleistocene. It is located in the northern part of the Moravian Karst, in the cadastral area of the village Sloup (Blansko District), 30 km north of Brno, and at 470 metres a.s.l. (Fig. 1). It is a tunnel-like, double S-shaped cavern 87 metres long, 25 m wide and 8 m high. During interdisciplinary research at the cave performed by K. Valoch from 1961-1976 (Valoch 1988) a complex sequence of more than 15 m in depth was documented within which 14 archaeological layers were differentiated. Besides numerous chipped lithic assemblages the excavations yielded a great quantity of osteological material including bones with anthropic modifications (Neruda et al. 2011).

Regarding the exploitability of natural resources, the cave is located at the very boundary of two different ecosystems, an open landscape and a karst territory, and the humans who occupied the cave at various periods of time made a full use of this in their

procurement strategies (Neruda 2005, 2011a: 29). The information potential of the Kůlna Cave is still far from exhausted. Although the archaeological material has been processed from different points of view by various researchers many times (Boëda 1995; Michel et al. 2005, 2006; Moncel 2003, 2004; Nejman et al. 2011; Neruda 2011a; Neruda et al. 2011; Patou-Mathis et al. 2005; Rink et al. 1996; Tostevin 2000; Valoch 1988) palaeoenvironmental analyses have not been performed so far.

Methods

One of the options for the reconstruction of palaeoecology is ascertaining seasonality and migration history of animals. Seasonality establishes the time of the year when an animal died (hunted successfully) and its precise age. The principle of the method lies in the analysis of the microstructure of dental cement increments using thin sections of mammal tooth roots. Although it is theoretically possible to utilise any kind of tooth, a canine tooth (*Dens caninus*), less often the first molar (*Dens molaris*), is usually selected, preferably of a carnivore species. On a tooth the cement layer covering the neck and root is most important since it grows throughout the lifetime of an individual. The cement growth rate depends on the season of the year; during the growing season with plenty of food (April to October) it is very intense, during dormancy (November to March) it is slow. The annual increment comprises the dark winter part, the formation of which starts in November and finishes in April, and a light summer increment that starts to emerge in May. The variations in colours of the increments are caused by differential activity of cementoblasts (the cells participating in the formation of cement; for more details cf. Curci & Tagliacozzo 2000 and Nývltová Fišáková 2007: 13). The total number of yearly increments (annual rings) is counted to establish the age of the specimen, and the thickness of the last increment is measured to ascertain the time of death. From the assessment of the total number of winter and summer increments it is possible to determine the age of the dead animal, while analysis of the last increment enables determination (in terms of months) of the season in which the animal died. In the Czech Republic this method is currently most often used during analyses of the hunted fauna at Gravettian settlements (Nývltová Fišáková 2007, 2013; Nývltová Fišáková et al. 2008).

Geochemical analyses of the ratios of isotopes of strontium, nitrogen, carbon and oxygen found in teeth or long bones establish the proportions and representation of these elements. This information makes it possible to carry out a retrospective reconstruction of the palaeoenvironment (nitrogen), the composition of the animals' palaeo-diet ($^{13}C/^{12}C$) and any migrations carried out by them ($^{87}Sr/^{86}Sr$).

Strontium isotopes get into the biosphere and the food chain through the weathering of crystalline
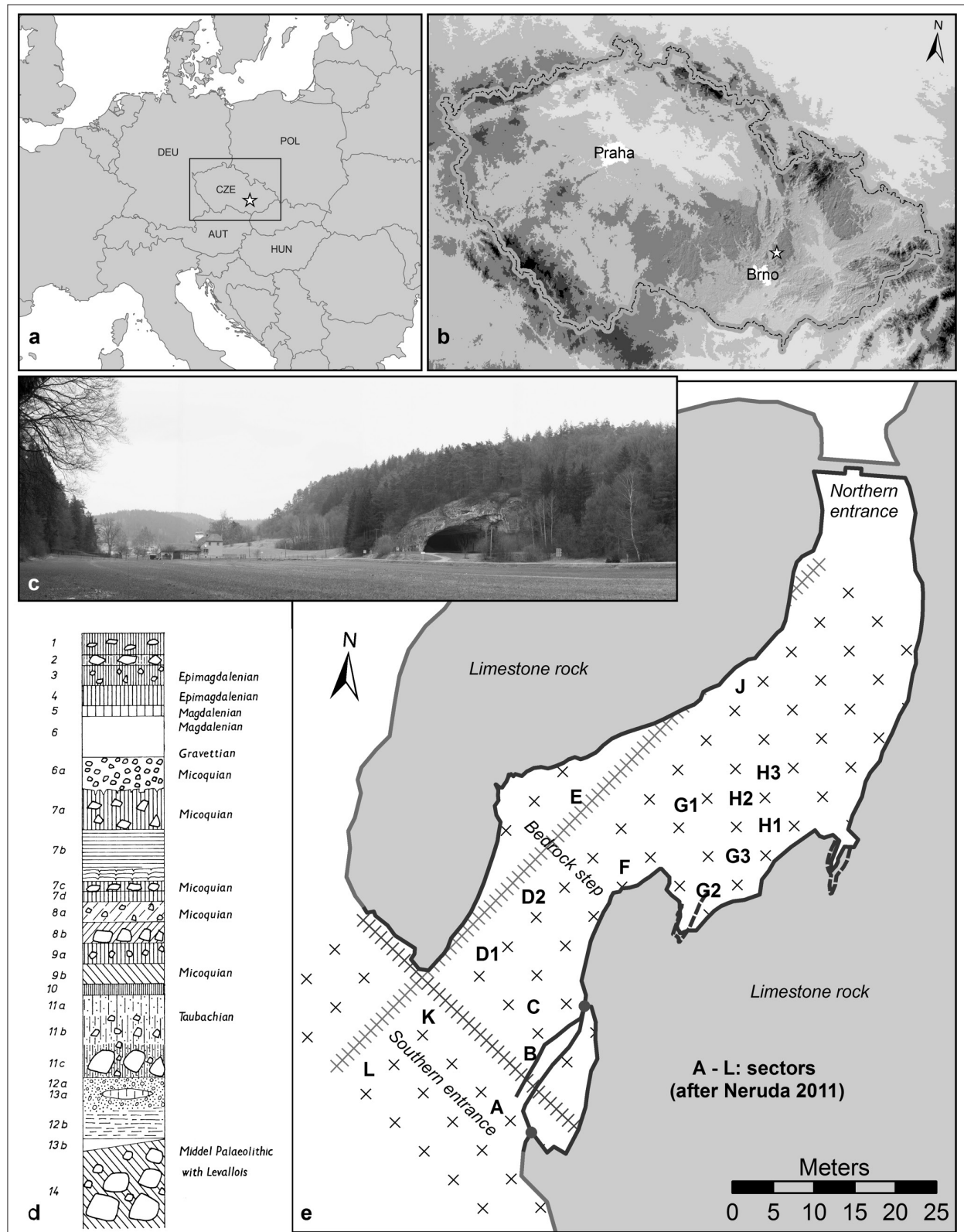
Fig. 1. The Kůlna Cave. a, b – localization of the cave; c – entrance into the cave, the so-called southern entrance; d – schematic profile of the Middle & Upper Palaeolithic layers and the cave area with designated sectors. Digitalized and compiled by P. Neruda.

Abb. 1. *Kůlna-Höhle. a,b – Lokalisierung der Höhle, c – Höhleneingang, sog. Südeingang, d – schematisches Profil der mittel- und jungpaläo-lithischen Schichten und die Fläche der Höhle mit bezeichneten Sektoren. Digitalisierung und Zusammenstellung P. Neruda.*

complex rocks and present a very suitable geochemical indicator, since Sr released during weathering retains the isotopic $^{87}Sr/^{86}Sr$ ratio of the source material and does not become fractionated (transformed in terms of relative abundance of individual isotopes) in the course of biological processes. Because the ^{87}Sr isotope forms by the radioactive decay of ^{87}Rb the specific $^{87}Sr/^{86}Sr$ isotope ratio of all geological materials depends on both their age and primary content of Rb. Strontium passes from the weathered substrate through sediments and the soil layer into water sources in a proportion specific for the given geological substratum and is taken up by plants through their root systems. The isotopes absorbed from ground water through the root systems of plants subsequently pass into the metabolism of herbivores and consequently of carnivores. In animal bones the strontium combines with PO_4^{-} to replace calcium (Ca^{2+}). It is possible to ascertain details of the nutrition of an animal or a human using the ratio of strontium and zinc. A higher proportion of strontium at the expense of zinc is typical for herbivores; this ratio is inverted in carnivores. Since the $^{87}Sr/^{86}Sr$ abundance ratio reflects the specific geological substratum of the ecosystem underlying animal nutrition it can be studied for the reconstruction of animal (and human) migrations. The isotopic composition of the bones and teeth of studied animals and humans make it is possible to identify migrations during their lifetime (Nývltová Fišáková 2007; Smrčka 2005).

Nitrogen is a biogenous element found in important organic compounds and in all living organisms. From the soil it gets into plants and consequently into the entire food chain. Its amount undergoes marked changes depending on the climate and its trophic level in the food pyramid and the $^{15}N/^{14}N$ isotopic ratio provides information on the nutrition of an animal or a human (Bocherens 2003; Bocherens & Drucker 2013; Bocherens et al. 1994, 1996, 2000, 2001; Nelson et al. 1986). The highest ^{15}N isotope values are found in carnivorous animals, the lowest in cereals. The differences in contents are also evident within individual groups. Legumes are richest in ^{15}N isotopes out of plants.

Carbon isotopes help in the determination of the composition of foodstuffs. We differentiate between the so-called C4 and C3 plants, i.e. plants that transform various proportions of ^{13}C and ^{12}C carbon isotopes into complex sugars during photosynthesis. In C3 plants the ^{13}C carbon isotope assay amounts to -22 to -30 ‰ of the PDB standard, in C4 the value is -9 to -16 ‰ of the PDB standard. C3 plants are typically represented by the trees growing in temperate environments (including fruiting trees important for diet) or rice; C4 plants include all cereal plants and grasses (Graminea). According to the proportion of these isotopes ascertained for an animal or human it is possible to find out upon what food types the given individual subsisted (Bocherens 2003; Bocherens &

Drucker 2013; Bocherens et al. 1994, 1996, 2000, 2001; Nelson et al. 1986).

Strontium isotope analysis
Analyses of strontium isotope ratios were carried out in the geochemical laboratories of the CGS - Barrandov branch by Dr. Jitka Míková, and in the Centre for Applied Isotope Studies, University of Georgia, Wisconsin, USA. The samples of bones and shells underwent ultrasonic cleaning in de-ionized water for 15 minutes to remove mechanical impurities, after which samples for decomposition were taken using a dentist's drill. The material acquired by means of this method was ultrasonically cleaned again in de-ionized water and 5 % acetic acid, which is used for removal of the outermost surface layer that might be contaminated by ambient impurities. After this the material was dried in a laminar flow box and combusted at a temperature of 825 °C for 8 hours. The resulting ash was dissolved in concentrated HNO_3, dried, dissolved in 6mol HCl, and again dried. Dissolution in concentrated HNO_3 and a subsequent drying followed. The sample prepared this way was finally dissolved in 2M HNO_3 for separation, which was performed through ion exchange chromatography using selective resin (Míková & Denková 2007). The value of the $^{87}Sr/^{86}Sr$ isotope ratio was determined using a Finnigan MAT 262 mass spectrometer for solid phase ionization in a dynamic mode and double-thread arrangement. Thermal fractioning was corrected by standardisation to the assumed strontium ratio value $^{87}Sr/^{86}Sr$ = 8.375209. Reproducibility of measuring is controlled by measuring the $^{87}Sr/^{86}Sr$ isotope ratio of the NBS 987 standard, the long-term average of which amounts to 0.710248 with 0.000013 standard deviation (23 repetitions; methodology according to Price et al. 2002).

Shells of molluscs found in the Holocene layers during the excavations in the Kůlna Cave were taken for control measuring of background values (Sample 1 – lay. 1, sq. 5, d. 10-20 cm, excavations in 1975; Sample 2 – lay. 3, sq. III/C-G, d. 275-290 cm). Three further control samples of recent shells of *Helix pomatia* were gathered in 2012 at the entrance and from areas in front of the Kůlna Cave (Fig. 5).

Carbon and nitrogen isotope analyses
Analyses of carbon and nitrogen isotopes were performed at the Centre for Applied Isotope Studies, University of Georgia, USA. For the determination of carbon and nitrogen isotope ratios it is important to preserve the original carbon and nitrogen isotope composition of the sample, but to remove foreign and inorganic material. The same methodology used for radiocarbon dating was employed for this investigation (Stafford et al. 1988). Bones were fragmented to sizes smaller than 1 cm and cleaned ultrasonically in distilled water. Subsequently the fragments were dried at 50 °C, and then homogenized to sizes smaller

than 63 µm, and obtained sample was extracted using methanol and distilled water. The remnant of the material was mineralized (to remove carbonate compounds) by 0.5 mol HCl at 4 °C and a constant pH. The samples were rinsed again using distilled water and dried at 50 °C. Alkaline leaching was not employed in order to prevent collagen from being destroyed.

Subsequently the material was burnt and chromatographically separated into nitrogen and CO_2; these gases were subsequently analysed in a MAT 251 mass spectrometer and compared with reference gases of known isotopic composition (the reference material for $\delta^{13}C$ is PDB USA - $\delta^{13}C$ = -29.75 ‰ and for $\delta^{15}N$ IAEA Vienna $\delta^{15}N$ NZ1 = 0 and NZ2 = 20 ‰). The size of the sample is optimized so that the measuring error does not exceed 0.15 ‰.

Isotopes of elements become deposited in the bones and teeth of mammals throughout their lives and the quantities and proportions of the elements deposited in their bodies at any given time depend upon the environment in which the individual exists. Determinations of seasonality by tooth cement analysis help to reconstruct the behaviour of ancient populations in the context of their natural environment, while isotope analyses are helpful in the reconstruction of seasonal and short-term climatic changes and their impact on the ecosystem.

From the methodological point of view it would be appropriate to carry out both seasonality and geochemical analyses using the same samples, however this was impossible because of the state of preservation of some of the teeth, and the destructive character and thus mutual exclusivity of the two methods. However the different geochemical analyses focused on carbon, nitrogen and strontium abundance were mostly conducted on the same samples (see Figs. 5 & 6).

Hitherto a synoptic overview of the complete existing osteological material from the Kůlna Cave has not been published (cf. Valoch et al. 2011: 63). The author of the research (K. Valoch) has sub-divided the collection into an assemblage of more than 3,600 bone specimens bearing traces of human modification, which is integrated into the archaeological collections of the Anthropos Institute (Neruda et al. 2011: 23), and a remaining, more numerous group of finds which form part of an osteological inventory. Material showing clear signs of anthropic impact would be the most suitable for the described analyses. However, this is generally rather fragmentary and difficult to determine taxonomically, not to mention lacking the required type of bones and teeth, and we therefore had to make use of other bones suitable for determination. It must be borne in mind that regardless of the context of this material in a specific archaeological layer its relationship to the respective archaeological situation is not necessarily unambiguous, since bones might represent prey dragged into the cave by carnivores or animals that died of natural causes. Furthermore, for sampling purposes it was necessary to take into consideration the context of the recovered material, both horizontally (to include both entrance and interior areas) and vertically, to include all cave layers of significance in the context of the grant-funded project. Moreover, we have opted only for such items as were precisely recorded.

Despite the large quantity of available preserved material analyses were limited to relatively few samples in view of the mentioned destructive character of the analysis and since this aspect of research has not been the main goal of the project (Neruda & Nerudová 2014), but rather was intended as a test for further options regarding future scientific analyses.

Results

Analysis of seasonality of fauna based on dental cement increments

Altogether we studied 20 thin sections which were viewed with a Nikon polarising microscope at magnifications 2.5, 4, and 10. Except for one sample they were all assigned to the Micoquian period (Fig. 2).

From layer 5 (Upper Magdalenian) it was possible to study one thin section of an arctic fox canine (*Vulpes lagopus*, Fig. 2: sample No.1). The individual shows a finalized winter increment, with the summer increment only just starting to form. This means the fox died during spring, i.e. from April to June.

Altogether, three individuals – two wolves (*Canis lupus*, Fig. 2: samples Nos. 2 & 3) and one cave bear (*Ursus spelaeus*, Fig. 2: sample No. 4) were studied from layer 6a (Upper Micoquian in the entrance part of the cave). Both wolf individuals show a completed winter increment, while the summer increment was only beginning to form. We can therefore infer that these animals died during spring, i.e. from April to June. The bear (a cub) died at the end of summer/beginning of autumn. The sample shows an unfinished summer increment, which on its thickness most likely corresponds to the last third of the "summer season" (Fig. 3), i.e. the individual most probably died in the interval from August to October.

Layer 6b (Upper Micoquian in the interior part of the cave) yielded one sample of cave bear (*Ursus spelaeus*, Fig. 2: sample No. 5) for analysis. Again, the winter increment is finalised and the summer growth just starting to form. The animal died during spring, i.e. from April to June.

A more representative number of samples (14) could be taken from layer 7a (classic Micoquian) and its sub-layers 7a1 and 7a2, which were established by K. Valoch during archaeological excavations in the cave (Valoch 1988). In 6 of 14 individuals (wolf, fox, bear) the season of death was determined to be the winter season from November to January. Winter increments had started to form but were not quite

No. of sample	No. of layer	Layer	Taxon	Square	Depth (cm)	Season of animals´death	Accurate age
1	5	magd.	*Vulpes lagopus*	6-7/S	155-170	IV-VI	6
2	6a	micoq.	*Canis lupus*	6/I-K	180-260	IV-VI	9
3	6a	micoq.	*Canis lupus*	II-III/C-F	370-380	IV-VI	2
4	6a	micoq.	*Ursus spelaeus*	II-III/C-F	370-380	VIII-X	2
5	6b	micoq.	*Ursus spelaeus*	33-35/M-O	175-195	IV-VI	6
6	7a	micoq.	*Vulpes lagopus*	20/A,a	250-275	IV-VI	3
7	7a	micoq.	*Canis lupus*	28-29/b	140-190	XI-I	2
8	7a	micoq.	*Ursus* sp.	12/D-E	230-250	XI-I	7
9	7a	micoq.	*Vulpes* sp.	15-16/E,F	260-290	XI-I	2
10	7a	micoq.	*Vulpes vulpes*	18/K	50	XI-I	5
11	7a1	micoq.	*Canis lupus*	37/O	290-300	VIII-X	6
12	7a1	micoq.	*Canis lupus*	28-30/S-T	240-260	undetermined	undetermined
13	7a1	micoq.	*Ursus spelaeus*	34/M-O	230-240	XI-I	9
14	7a1	micoq.	*Ursus spelaeus*	35/I-O	220-240	IV-VI	11
15	7a1	micoq.	*Ursus spelaeus*	29/K-L	300-320	XI-I	3
16	7a2	micoq.	*Vulpes lagopus*	42/R-U	160-180	VIII-X	2
17	7a2	micoq.	*Vulpes lagopus*	42/R-U	160-180	IV-VI	2
18	7a2	micoq.	*Vulpes* sp.	43/R-T	160-180	IV-VI	2
19	7a	micoq.	*Canis lupus*	16-17/A	220-250	VIII-X	4
20	7c	micoq.	*Canis lupus*	10/L-M	510-520	VIII-X	2

Fig. 2. Seasonality (the interval of survived months is designated with Roman numerals) and ages of the individuals based on the thin sections from teeth radices of mammals from the Kůlna Cave.

Abb. 2. *Saisonalität (Intervall der Lebensmonate ist mit römischen Zahlen bezeichnet) und Alter der Individuen anhand des Schliffs der Zahnwurzeln der Säugetiere aus der Kůlna-Höhle.*

Fig. 3. Bear molar (Fig. 2, sample No. 4). The individual died aged 1.5 years towards the end of summer/ beginning of autumn. It can be seen the molar shows an unfinished summer increment, but its thickness more likely corresponds to the last third of the "summer season". Photo by M. Nývltová Fišáková.

Abb. 3. *Eckzahn eines Bären (Abb. 2, Probe Nr. 4). Das Tier verendete im Alter von 1,5 Jahren Ende Sommer/ Anfang Herbst. Er weist einen unbeendeten Sommerzuwachs auf, aber seine Dichte entspricht eher dem letzten Drittel der „Sommersaison". Foto M. Nývltová Fišáková.*

finalized (Fig. 2: samples Nos. 7-10, 13 & 15). Three foxes (*Vulpes lagopus, Vulpes* sp., Fig. 2: samples Nos. 6, 17 & 18) show completed winter increments, but the summer ones are still at the beginning of their formation, which means the animals were hunted down or died at the same period during spring, i.e. April to June.

Although the summer increment in another wolf individual (Fig. 2, sample No. 19) is not quite completed, its measured thickness corresponds to the last third of the "summer season", i.e. the individual died in the interval from August to October.

Increments were not preserved at all in one wolf individual originating from sub-layer 7a1 (square 28-30/S-T) (Fig. 2: sample No. 12). Another two individual wolves and one fox had unfinished summer increments, but their thicknesses correspond to the last third of the "summer season", i.e. these individuals died in the interval from August to October. One cave bear individual (Fig. 2, sample No. 14), in which the summer increment only just started to form is very interesting. According to the age determination of the tooth this was a rather old specimen (10.5 years) that probably died of exhaustion during the months of spring.

One canine of grey wolf (*Canis lupus*, Fig. 2: sample

No. 20) was studied from Micoquian layer 7c; although it shows an unfinished summer increment, its thickness corresponds to the last third of the "summer season", i.e. the individual died in the interval from August to October.

Geochemical analyses: isotope ratios of carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$) and strontium ($^{87}Sr/^{86}Sr$)
On the grounds of the carbon and nitrogen isotope ratios (Fig. 4) we can describe changes in the climate of the individual periods. In the Epi-Magdalenian (layer 4) individuals existed in a steppe and tundra environment, with isotope values indicative of cold climate without much precipitation (Fig. 4, sample No. C/N_1 & 2). During the Magdalenian (layers 5 & 6) animals lived in a steppe and lichen tundra environment. Moreover, the recorded values indicate great precipitation stress and a colder climate (Fig. 4, samples Nos. C/N_4-6).

In the Upper Micoquian period (layer 6a) the analysed individuals lived in a very variegated environment consisting of stands of light woodland, existing alongside steppe to tundra conditions. Recorded values show a warmer and damper climate (Fig. 4, samples Nos. C/N_7-13) contrasted with the Magdalenian layers, but at the same time a colder

No. of sample	No. of layer	Layer	Square	Depth (cm)	Taxon, bone determination	δ^{13}C	δ^{15}N
C/N_1	4	epimagd	7f	unknown	*Alces alces*, metatarsus dex.	-20	4
C/N_2	4	epimagd	1a	unknown	*Alces alces*, metatarsus sin.	-19	4
C/N_3	5	magd	8e	unknown	*Equus sp.*, tibia dex.	due to low yield	
C/N_4	5	magd	I-II/E-F	210-220	*Equus sp.*, metatarsus - diaphysis, frg.	-17	7
C/N_5	6	magd	I-II/A	250-280	*Rangifer tarandus*, humerus sin.	-17	5
C/N_6	6	magd	III-IV/P-G	240-260	*Equus sp.*, femur sin.,	-19	4
C/N_7	6a	micoq.	31/O	210-230	*Equus sp.*, tibia dex.	-19	3
C/N_8	6a	micoq.	9/H	170-200	*Mammuthus primigenius*, ossa longa frg.	-19	8
C/N_9	6a	micoq.	I-II/B-E	260-270	*Equus sp.*, metatarsus	-19	6
C/N_10	6a	micoq.	I-II/B-E	260-270	*Rangifer tarandus*, metatarsus	-17	3
C/N_11	6a	micoq.	9/G	200-220	*Rangifer tarandus*, tibia dex.	-18	4
C/N_12	6a	micoq.	13-14/C-F	175-200	*Ursus spelaeus*, ulna dex.	-20	4
C/N_13	6a?	micoq.	30-33/b	130-150	*Equus sp.*, femur sin.	-19	4
C/N_14	7a	micoq.	F/34-37	170-190	*Ursus spelaeus*, humerus dex.	-20	3
C/N_15	7a	micoq.	F/34-37	170-190	*Rangifer tarandus*, humerus sin.	-17	3
C/N_16	7a	micoq.	34-37/D	150-160	*Rangifer tarandus*, metatarsus	-17	5
C/N_17	7a	micoq.	F/34-37	120-140	*Ursus spelaeus*, humerus sin.	-20	4
C/N_18	7a	micoq.	E/34-37	150-160	*Rangifer tarandus*, humerus sin.	-19	6

Fig. 4. Geochemical analysis of δ^{13}C and δ^{15}N isotope ratios of selected taxa from the Kůlna Cave.
Abb. 4. *Geochemische Analyse der Proportionen von Isotopen δ^{13}C und δ^{15}N bei ausgewählten Taxa aus der Kůlna-Höhle.*

environment than seen in layer 7a. In the course of the classic Micoquian (layer 7a) animals lived in a very variegated environment, again comprising stands of light woodland, steppe and tundra. The values measured for the time of formation of this layer suggest a colder and drier climate than today (Fig. 4, samples Nos. C/N_14-18; cf. Musil 2010: 132), but warmer than that indicated by the values for the younger layer 6a.

Analyses of strontium ratios (Fig. 5) show that the studied individuals are from animals living in the vicinity of the cave, most probably from the area of the Moravian Karst. This was ascertained for the faunas from both the Epi-Magdalenian layer and the Micoquian layer of the cave settlement. The Sr isotope ratios conform to the interval published for Moravian Karst (Bentley & Knipper 2005: 631; Vašinová Galiová et al. 2013). The bear from layer 6a (Fig. 5, sample No. Sr_8) and the reindeer from layer 7a (Fig. 5, sample No. Sr_9) are the only animal individuals to show isotope values indicative of an origin within a territory beyond the Moravian Karst.

Discussion

The above results are interesting in the context of the analyses of the flaked lithic assemblage and stone raw materials used, from which we are already aware that humans who occupied the cave utilised various ecosystems. However, it would be necessary to analyse a more representative number of individuals capable of providing a statistical assessment in order to allow a valid generalisation of the conclusions arrived at.

Information on the ascertained age and season of death of the analysed fauna appear important in the context of utilisation of the cave for human occupation. In this respect the finds of bear (*Ursus spelaeus*) dated into the months November – January, i.e. during their winter hibernation are of interest. These individuals come from the context of archaeological layers 7a and 7a1. The microstratigraphy of these layers has not been studied, although it would be of key importance for the resolution of the issue of palimpsests (Stiner 1998: 304). It is therefore necessary to consider the mutual relationship of bear presence and human occupation, since coexistence of bears and humans at one and the same place and time appears unthinkable and there is very little direct proof of their interaction (Stiner 1998, 1999: 53). Only two pieces of evidence for an interaction between a bear bone and a stone tool are known from a Middle Palaeolithic archaeological layer in the Kůlna Cave (Stiner 1998: 304). According to the ascertained ages these were a very old individual (10.5 years) and slightly grown cub (1.5 and 2.5 years, see Fig. 2; their sex is unknown) respectively. Young and old individuals of cave bears represent the age spectrum most often found in the Pleistocene fillings of caves (Sabol 2005: 151). A factor that cannot be left aside in the discussion of the human-cave bear relationship is the type of shelter sought by bears for their hibernation. On the grounds of numerous analogies it is generally claimed that bears preferred small natural caves or crevices, in case of nursing females in the vicinity of water (Stiner 1999: 46). However on both its morphology and dimensions the Kůlna Cave does not qualify as a typical bear

No. of sample	No. of layer	Layer	Square	Depth (cm)	Taxon, bone determination	$^{87}Sr/^{86}Sr$	1sigma	2S(M)
Sr_1= C/N_1	4	epimagd	7f	unknown	*Alces alces*, metatarsus dex.	0.710202	0.000039	0.000006
Sr_2 = C/N_4	5	magd	I-II/E-F	210-220	*Equus* sp., metatarsus	0.710187	0.000033	0.000008
Sr_3 = C/N_5	6	magd	I-II/A	250-280	*Rangifer tarandus*, humerus sin.	0.710728	0.000033	0.000008
Sr_4 = C/N_8	6a	micoq.	9/H	170-200	*Mammuthus primigenius*, ossa longa	0.710010	0.000038	0.000005
Sr_5 = C/N_9	6a	micoq.	I-II/B-E	260-270	*Equus* sp., metatarsus, diaph.	0.710486	0.000039	0.000006
Sr_6 = C/N_10	6a	micoq.	I-II/B-E	260-270	*Rangifer tarandus*, metatarsus	0.710142	0.000032	0.000008
Sr_7 = C/N_11	6a	micoq.	9/G	200-220	*Rangifer tarandus*, tibia dex.	0.710594	0.000037	0.000008
Sr_8 = C/N_12	6a	micoq.	13-14/C-F	175-200	*Ursus spelaeus*, ulna dex.	0.709468	0.000045	0.000011
Sr_9 = C/N_16	7a	micoq.	34-37/D	150-160	*Rangifer tarandus*, metatarsus	0.709579	0.000044	0.000010
Sr_10 = C/N_17	7a	micoq.	F/34-37	120-140	*Ursus spelaeus*, humerus sin.	0.710540	0.000037	0.000009
1	surf.	near the southern entrance			*Helix pomatia*, recent shell	**0.709745**	0.000112	0.000016
2	surf.	near the southern entrance			*Helix pomatia*, recent shell	**0.709643**	0.000064	0.000009
3	surf.	near the southern entrance			*Helix pomatia*, recent shell	**0.710598**	0.000069	0.000011

Fig. 5. Geochemical analysis and control values of $^{87}Sr/^{86}Sr$ strontium ratios of selected taxa from the Kůlna Cave, C/N indicates sample in the Figure 4.

Abb. 5. *Geochemische Analyse und Kontrollwerte der Isotopen der Proportionen von Isotopen $^{87}Sr/^{86}Sr$ bei ausgewählten Taxa aus der Kůlna-Höhle, C/N bezeichnen Proben aus Abbildung 4.*

den (unlike e.g. the Pod hradem or Šipka Caves), not even if we assume that in the period when the Micoquian layers were laid down the smaller, northern entrance into the cave might have been partly or totally closed.

The safest time for taking a bear is hunting it during its hibernation period, when even a robust animal is exhausted and weak, or locating a carcass dead of natural causes (Kurtén 1958: 56, 1976: 111; Stiner 1999: 47). The same considerations apply to the cubs ascertained in the Kůlna Cave at a very young age; young individuals with inadequate stored fat also tend to die at the time of their winter sleep.

The possible method of hunting of these large carnivores is also the subject of discussion. Based on the study of muscular attachments of the arm in Neanderthals it is assumed their hunting method involved close and robust contact with the game (Schmitt et al. 2003). This must have been very dangerous, and the decreased activity of carnivores in the winter season might have been advantageous. Unlike with other large animals (e.g. mammoths), the collection of trophies from carcasses is generally not accepted in the case of bears, and some authors are rather sceptical that the hunting of hibernating game

would represent an adequately prestigious activity (Neruda 2011b: 129). Although gnaw- and cut-marks on bears bones are known from the literature, they do not explain the method of hunting (Stiner 1998: 309). Contributions to this discussion may be provided by evidence for bear hunting from the Počka zijalka Cave (pathological changes of vertebra resulting from a contact blow; Withalm 2004) and hunting by means of a spear from the Hohle Fels site (spinal vertebra with an embedded Gravettian stone point; Münzel & Conard 2004). From the point of view of the age structure and season of death of the individuals treated by this study, hunting strategies cannot be unambiguously assessed due to the small number of samples. For instance, according to the ascertained season when the animals died, it seems that game was hunted almost all year round during occupation of layers 7a, 7a1 and 7a2. The age at death of foxes originating from sub-layer 7a2 is of especial interest since all individuals are the same age (1.5 years) and it seems significant that the faunal spectrum comprises fur-bearing mammals. This may indicate that Neanderthals suffered from food stress and made use of all available fat sources for the replenishment of energy (Pryor 2008: 169).
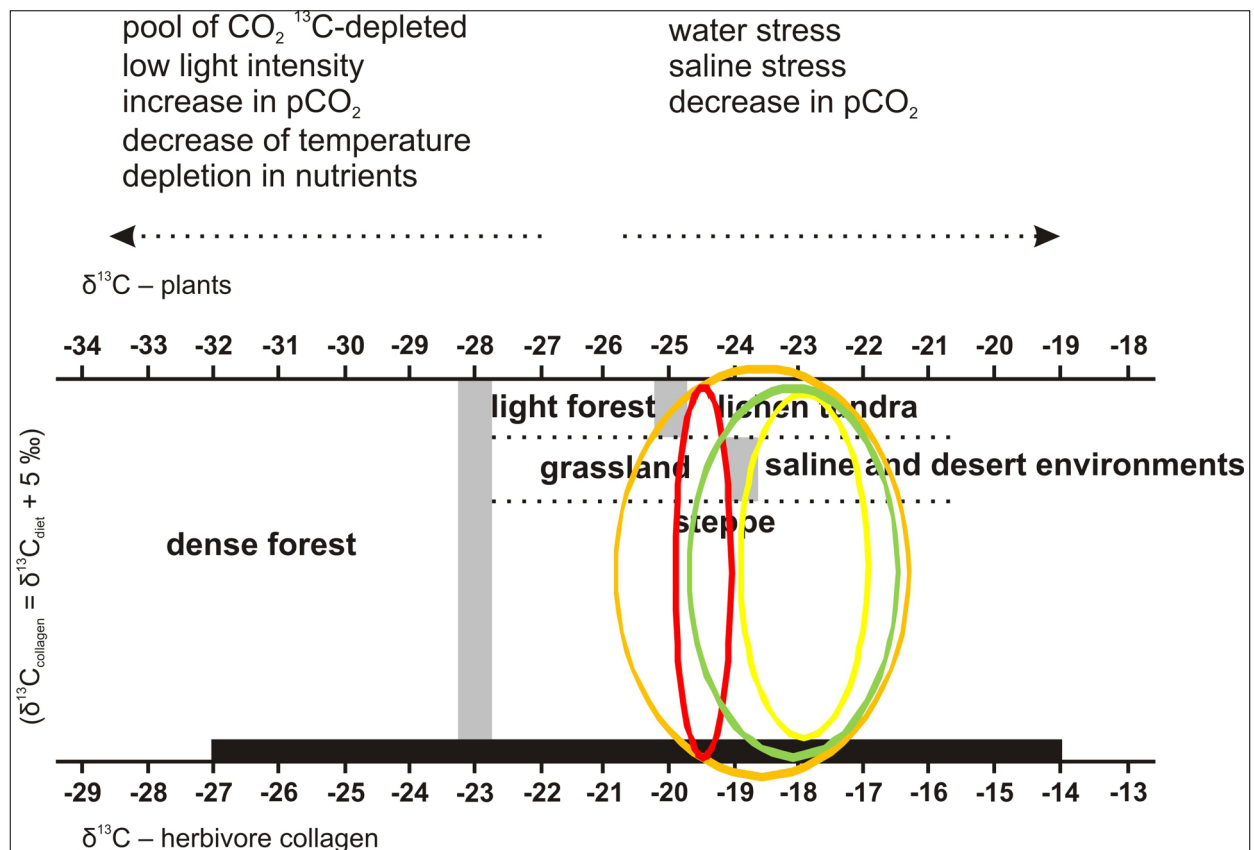

Fig. 6. Carbon isotopes ratio in the bones of animals from the Kůlna Cave. Red – Epimagdalenian; yellow – Magdalenian; orange - 6a; green - 7a. Compiled by M. Nývltová Fišáková based on the data.

Abb. 6. *Proportion der C-Isotopen in Tierknochen aus der Kůlna-Höhle. Rot – Epimagdalenien, gelb – Magdalenien. Orange – Schicht 6a, grün – Schicht 7a. Anhand von Daten von M. Nývltová Fišáková zusammenstellt.*

Conclusion

The described scientific analyses were not designed to exhaust the information potential of the Kůlna Cave osteological material. This was anyway not possible because of its condition and quantity, and due to the demanding character of the analyses themselves. Their primary goal has been to test options for utilising various methods and the application of these to materials coming from cave sediments which tends to have been subjected to post-depositional processes and a specific karst environment. For this reason we need to be careful in our selection of suitable material, since even though we may consider a specific contextual situation in a cave to represent a closed system, we must at the same time take into account potential activities of large carnivores which might have modified or contributed new material to temporarily deserted archaeological layers during interim periods. Nevertheless, the analyses produced interesting results which could provide the basis for further research:

1. The calculated seasons (months) of death (by hunting) of the studied individuals of carnivores suggest that during the period of the classic Micoquian the Kůlna Cave was probably occupied throughout the year, or that humans might have been recurrently coming back to the cave at various seasons over several years. On the grounds of GIS analyses of the structuring of the lithic and bone industries P. Neruda is also inclined to identify a recurrent settlement of the cave (Neruda 2011c: 137).

2. Strontium analyses indicated that the majority of the studied individuals originated from the near vicinity of the cave, most probably from the region of the Moravian Karst. While the values identify an origin beyond the karst region in only two individuals, these do suggest that the Neanderthals were focused on hunting in different biotopes.

3. The C and N isotope ratio analyses revealed that in the Micoquian period (layers 6a & 7a) the climate was warmer and damper than in the Magdalenian and Epi-Magdalenian, and the ecosystem was generally more variegated (Fig. 6). There was also a difference between Micoquian layers 6a & 7a. In the period when layer 7a was laid down the weather was slightly warmer and also with less rain than in the younger layer 6a.

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