

**PALEODIET INFERRED FROM *URSUS SPELAEUS*
ROSENMÜLLER et HEINROTH TOOTH FROM TMAVÁ SKALA CAVE
(SLOVAK REPUBLIC) USING CARBON ISOTOPE ANALYSES**

ODVOZENÍ PALEOPOTRAVY *URSUS SPELAEUS* ROSENMÜLLER et HEINROTH POUŽITÍM ANALÝZ
IZOTOPŮ UHLÍKU ZUBU Z JESKYNĚ TMAVÁ SKALA (SLOVENSKÁ REPUBLIKA)

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Abstract:

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Paleodiet inferred from Ursus spelaeus ROSENMÜLLER et HEINROTH tooth from Tmavá skala cave (Slovak Republic) using carbon isotope analyses

Isotopes of carbon were employed in the study of *Ursus spelaeus* second upper molar M² from Late Würm bear cave Tmavá skala (Little Carpathians, Slovak Republic). Samples of enamel and dentine were used for the analyses. Variations in the carbon isotope ratio (¹³C/¹²C) were used to examine the paleodiet. The δ¹³C of investigated tooth is -11,8 ‰ for dentine and -16 ‰ for enamel. This indicates that the diet of *Ursus spelaeus* was dominated by C3 biomass. These values suggest a forested habitat.

Key words: Carbon Isotopes, Paleodiet, Teeth, *Ursus spelaeus*, Upper Pleistocene.

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Introduction

At present the interest in recording of seasonal and short-term climatic changes and their impact to local ecosystems is increasing. To one of the tools enabling to reconstruct these short-term climatic fluctuations belongs the isotope analysis of biominerals.

After an animal's burial, its unaltered tissue can be studied to gain valuable evidence about its paleo-environment through chemical isotopic analysis.

Teeth and bones both contain biogenic phosphate (i.e., hydroxylapatite), the target substance most readily available for the study. Bone phosphate, however, is highly porous and therefore allows infiltration of water and other impurities. Subsequent alteration leads to difficulties in direct study of such matter. Tooth enamel, on the other hand, is dense and has low porosity. Such properties bolster resistance to change, making tooth enamel a strong candidate for study (KOCH *et al.* 1994).

Reconstructing the diet of extinct species is a fundamental goal in vertebrate paleobiology.

The cave bear (*Ursus spelaeus*) is the macro fauna species that gave rise to the largest amount of fossils at the Pleistocene period in caves. Cave bears have inhabited Europe and the Near East since the Riss glacial period (250 000 years ago, MAZZA and RUSTIONI

1994). Last cave bear population in Slovakia in the area of West Carpathians begun to die out in the time span between 15 000–10 000 BP (SCHMIDT 1970). But it is not excluded, that some parts of Slovakia (Slovak Paradise and Low Tatras) were one of the last refuge of cave bears in Central Europe between the end of Last Glacial and beginning of the Holocene (SABOL 2001).

Cave bear teeth appear to preserve their original isotope composition, they can be dated, and they occur in abundance in many locations of Europe and the Near East. The abundance of the teeth and their large size allows samples used for paleoclimate studies to be restricted to enamel/dentine of one type of tooth. They provide a good potential source of material for detailed investigation of Pleistocene paleo-environment.

Here is assess the bear paleodiet through analyses of the $^{13}\text{C}/^{12}\text{C}$ ratios of tooth enamel and dentine.

Locality

Tmavá skala cave is situated southeastwards of the Plavecký Mikuláš village, in the Plavecký Karst territory in the Malé Karpaty Mountains (Slovak Republic) under the Polámaný hill, 445 m a.s.l (ŠMÍDA 1996) (Fig. 1). The cave is about 50 m long. Maximum width reaches 8.5 m and it is 1.5 to 4 m high. Its opening is oriented to the northwest. Opening to the Tmavá skala cave is in the rocky wall 3–10 m high. The wall is represented by Anisian-Annaberian limestone and underlying Verfenian siliceous sandstone.

The origin of the cave system is related to supposed autochthonous stream (ŠMÍDA 1996). The cave probably represents old occasional rise, which activity was related to the changing of groundwater level, which was connected with climatic changes during Late Pleistocene. Humic soils with pebbles and osteologic material accumulated by fluvial activity of ground stream during interglacial Riss/Würm and intersadials of Würm. The groundwater level decreased during the periods of cold Würm oscillations. In the formation of the cave sediments mainly the eolic activity took part, this created loess series. Occasional rise stopped its function in the consequence of the groundwater decrease after the Late Würm. After this time Holocene sedimentation of humic soil with sharp fragments fallen off from the cave roof (LIŠKA 1973).

Fossil and subfossil fauna of the cave

There was a fossil gastropod and vertebrate fauna discovered in the sedimentary filling. The gastropod fauna (*Helix pomatia*, *Limax* sp., *Macrogastra* cf. *latestriata* (uv.), *Oxychilus depressus*, *O. inopinatus*) represents thermophilous, mostly woodland gastropod fauna from

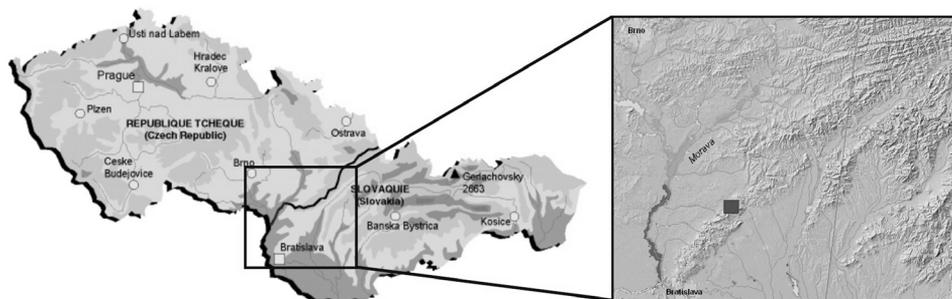


Fig. 1. Tmavá skala cave, Little Carpathians, Slovak Republic (Photo VODIČKA 2003).

Obr. 1. Jeskyně Tmavá skala, Malé Karpaty, Slovenská republika (foto VODIČKA 2003).

Middle to Late Holocene). The vertebrate fauna (Salientia, Reptilia, Insectivora, Chiroptera, Rodentia, Carnivora, Perissodactyla, Artiodactyla) represents mixed elements from the ecological point of view (karst - woodland - open land - mountain areas) and from the stratigraphic point of view (Pleistocene - Holocene - Recent) too (HOLEC *et al.* 1998).

The osteological remains of cave bears represent the largest portion of the fossil material. Due to finding circumstances (secondary redeposition of the original sediments) the age of the fossil remains was dated only as the Late Pleistocene (Riss/Würm interglacial stage - Late Würm glacial stage) The gastropod and other vertebrate fauna, occurring together with the fossil remains of Late Pleistocene cave bears, included mostly indifferent elements, that are characteristic for warm and woodland environment of the Holocene. It demonstrates the secondary redeposition of the original cave sediments too (SABOL 1997).

More concrete paleoclimatic conclusions could not be carried out, as pollen grains of the determined taxa (*Abies*, *Pinus*, *Tsuga*, *Tilia*, *Quercus*) were found in a very small quantity in the samples (HOLEC *et al.* 1998).

Tmavá skala cave is typical bear cave with relatively stable temperature, more spacious subhorizontal space and with sufficient water quantity in the past. Therefore the cave was utilized by tens to hundreds (perhaps) individuals of the species *Ursus spelaeus* for hibernation and birth of cubs during the Late Pleistocene (SABOL 1997).

Material

We analyzed *Ursus spelaeus* second upper molar enamel and dentine from one individual from Tmavá skala cave in Little Carpathians, Slovak Republic (Fig. 2.). On the base of dental cementum analyses we determined the individual age of studied animal. Individual age of animal was about 4.5 years and the season of the death was summer.

Methods

From carbon isotope ratio we can find out the paleodiet - or composition of animal's food. From $^{13}\text{C}/^{12}\text{C}$ ratio it is possible to distinguish between animals which feed on C_3

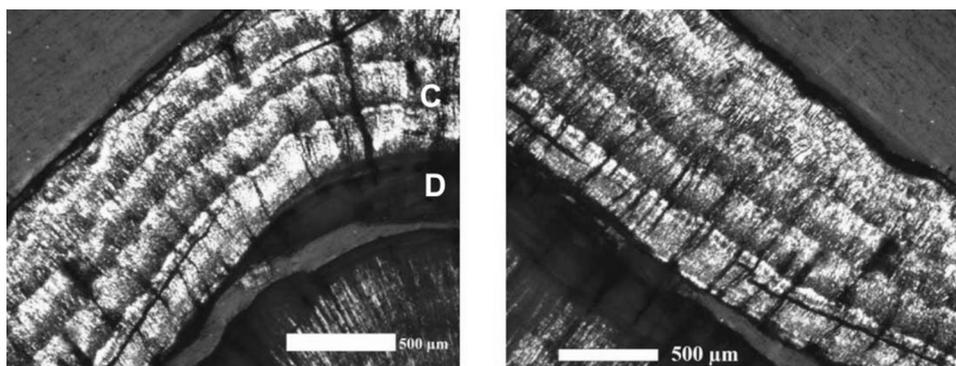


Fig. 2. Transverse cross section of investigated *Ursus spelaeus* tooth (M^2). This tooth was used for isotopic analyses in this study. Photo expose the dentine (D)/cementum (C) junction and annual increments in the cementum. Individual age estimation and season of death on the base of dental cementum analysis: about 4.5 years, death season: summer. (Photo author).

Obr. 2. Pričný prerez studovaným zubem (M^2) druhu *Ursus spelaeus*. Tento zub byl využit pro izotopové studium. Fotografie zobrazuje hranici cement (C)/dentine (D) a roční přírůstky v cementu. Odhad stáří a období uhytní jedince: okolo 4,5 let, období uhytní: léto. (Foto autor).

photosynthetic plants and between those which prefer C_4 plants. This is because the carbon isotopic compositions of the plants they feed on are bimodally distributed. C_3 -photosynthesizing plants (dicotyledonous trees, shrubs, and forbs) have ^{13}C values consistently lower than do C_4 -photosynthesizers (grasses) (CORDON, D. and CORDON, J. 2005).

For determination of $^{13}C/^{12}C$ ratios we used the methodology after MCCREA (1950). The dissociation of the carbonate runs in the vacuum on the powdered sample with the assistance of 100% H_3PO_4 . The samples are equilibrated under the room temperature during 1 day. Then the samples are measured against the international or laboratory standard (Carresian marble) in mass spectrometer MAT 251, mark Finnigan. External precision of determination for $\delta^{13}C$ is better than 0.05 ‰. Internationally recognized standard for carbon is PDB (Pee Dee Belemnite), where $R = 0,0112372$ (EHLERINGER and CERLING, 2002).

Plants using the Calvin cycle, or C_3 plants, include trees (*Picea* sp., *Pinus* sp., *Populus* sp., *Pseudotsuga* sp. ...), shrubs (*Acer* sp., *Alnus* sp., *Betula* sp., *Juniperus* sp., *Salix* sp. ...), and cool-climate grasses (*Agropyron* sp., *Carex* sp., *Calamagrostis* sp., *Eleocharis* sp., *Poa* sp. ...) and have mean $\delta^{13}C$ values of ca. -27.0 ± 3 ‰ (all means reported ± 1 S.D.) with a range of -21 ‰ to -35 ‰. Plants using the Hatch-Slack cycle, or C_4 plants, include sedges, some herbs, rare shrubs, and most temperate and tropical-climate grasses and have average $\delta^{13}C$ values of about -13 ± 2 ‰, with a range of -9 ‰ to -19 ‰ (Fig. 3) (O'LEARY, 1988; TIESZEN and BOUTTON 1989). CAM (crassulacean acid metabolism) plants are not commonly found except in deserts (WANG *et al.* 1993). CAM plants include many succulents such as cactuses and agaves and also some orchids and bromeliads with a range of values between minus 10 and minus 31 ‰ (http://wc.pima.edu/~bfiero/tucsonecology/plants/plants_photosynthesis.htm).

Results

Tab. 1 and provides a summary of results. The $^{13}C/^{12}C$ ratio of *Ursus spelaeus* dentin is -11.8 ‰, $^{13}C/^{12}C$ ratio of enamel is -16 ‰ (tab. 1).

Discussion and conclusion

It was found out that $\delta^{13}C$ of investigated tooth is -11.8 ‰ for dentine

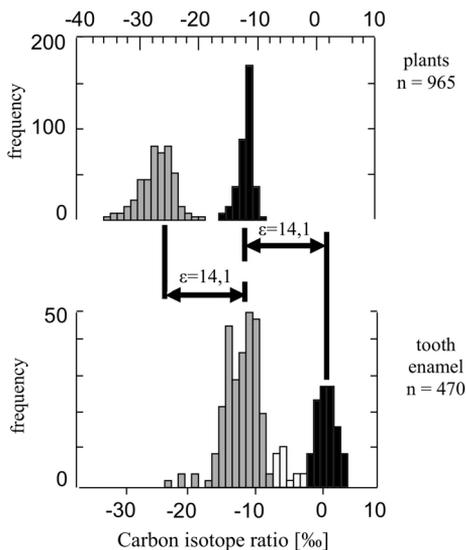


Fig. 3. Isotopic composition of C_3 and C_4 plants, as well as the isotopic composition of the enamel of teeth of animals which eat such plants (<http://ethomas.web.wesleyan.edu/ees123/carboniso.htm>).

Fig. 3. Izotopové složení C_3 a C_4 rostlin a izotopové složení zubní skloviny zvířat, která se živi těmito rostlinami (<http://ethomas.web.wesleyan.edu/ees123/carboniso.htm>).

Table 1. Results of $^{13}C/^{12}C$ ratios of *Ursus spelaeus* dentine and enamel from Tmavá skála cave.

Tabulka 1. Výsledky izotopového poměru $^{13}C/^{12}C$ dentinu a skloviny druhu *Ursus spelaeus* z jeskyně Tmavá skála.

	$\delta^{13}C$ (‰ PDB)
<i>Ursus spelaeus</i> dentin	-11,8
<i>Ursus spelaeus</i> enamel	-16

and -16 ‰ for enamel. This indicates that the diet of *Ursus spelaeus* was dominated by C3 biomass (that means C3 plants or animals, which fed on C3 plant). This values suggest a forested habitat. The isotope record achieves the shift in the animal's food. This indicates that it came to changes in dietary intake in the course of life of studied animal – from C3 plants towards mixed or C4 plants. Isotope record from enamel represent the very short time period during the enamel formation. Dentin is deposited by apposition in the internal side of the tooth during whole life. So dentine thus represents the isotope record from long life period.

Enamel carbonate hydroxylapatite $\delta^{13}\text{C}$ values are low in cave bears (around -14 ‰) when compared to carnivores (around -12 ‰) and herbivores (-10 ‰). This is probably due to lipid use while hibernating during winter. A similar pattern of enamel carbonate hydroxylapatite $\delta^{13}\text{C}$ values differences is found between *Ursus deningeri*, carnivores and herbivores in 200,000 to 600,000 years old cave sediments suggesting a similar physiology for both fossil bear species (BOCHERENS *et al.* 1994).

From viewpoint of environment, the $\delta^{13}\text{C}$ values less than -12‰ represent closed environment and those above -10‰ indicate affinity to opener positions (QUADE and CERLING 1995). Speaking in general, C4 plants are less nutritious and heavier digestible than C3 plants. So changes in relative proportion of these two plant types within ecosystem during the year could be an important ecology component of mammals communities (DEMMENT and VAN SOEST 1985; EHLERINGER and MONSON 1993).

Using the procedure outlined above, the study of samples on a much larger scale could shed some light on the paleodiet of animal's population.

The application of isotope analyses from bear's teeth is efficient from many standpoints:

1. they provide sufficient amount of material
2. they are resistant to alterations
3. they had wide geographical and time extent
4. they are very common and abundant in many locations (mainly in cave sediments)
5. present day bear species provide close analogies to fossil species.

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SOUHRN

Cílem studia byla analýza paleopotravby medvěda druhu *Ursus spelaeus* z lokality Tmavá skála (SR) na základě analýzy izotopového poměru uhlíku ($^{13}\text{C}/^{12}\text{C}$) zubní skloviny a dentinu z druhého horního moláru.

$\delta^{13}\text{C}$ zkoumaného zubu dosahovalo hodnoty -11,8 ‰ pro dentin a -16 ‰ pro sklovinu. Z výsledných hodnot vyplývá, že v potravě studovaného jedince dominovala C3 biomasa. Tyto hodnoty také indikují lesní prostředí. Na základě izotopových výsledků můžeme též konstatovat, že v průběhu života jedince docházelo ke změně potravy – od C3 rostlin směrem ke smíšené potravě nebo C4 rostlinám. Izotopový záznam skloviny představuje krátké období v průběhu formování zubní skloviny. Naproti tomu dentin se usazuje apozičně směrem do centra zubu během celého života jedince, takže představuje záznam delšího životního úseku.

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