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MIGRATION PATTERN INFERRED FROM *URSUS SPELAEUS* ROSENMÜLLER TOOTH FROM TMAVÁ SKALA CAVE (SLOVAK REPUBLIC) USING STRONTIUM ISOTOPE ANALYSES

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Abstract: Isotopes of Sr were employed in the study of *Ursus spelaeus* second upper molar M^2 from Late Weichselian bear cave Tmavá skala (Little Carpathians, Slovak Rebublic). Samples of enamel and dentine were used for the analyses. Variations in the strontium isotope ratio ($^{87}Sr/^{86}Sr$) were used to examine the migration patterns. The $^{87}Sr/^{86}Sr$ ratio of *Ursus spelaeus* dentin is 0.70913, $^{87}Sr/^{86}Sr$ ratio of enamel is 0.70930. Dentine values are close to the enamel values, suggesting little movement or migration during life.

Key words: Strontium Isotopes, Migration, Teeth, *Ursus spelaeus*, Late Pleistocene.

INTRODUCTION

To date the interest in recording seasonal and short-term climatic changes and their impact to local ecosystems has been increasing. One powerful tool enabling the reconstructing of these short-term climatic fluctuations is 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. hydroxyapatite), 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).

An understanding of the migration patterns and home-range sizes of extinct animals is critical for evaluating hypotheses of extinction, speciation, evolutionary change, and paleoclimatic or paleoenvironmental studies based on fossil remains (Hoppe *et al.,* 1999).

During the Pleistocene, bears were important members of mammalian faunas. The last cave bear population of Slovakia in the area of West Carpathians began 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 refugias of relative large 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, can be dated, and 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 we asses the bears movements through analyses of the $\mathbf{^{87}Sr/^{86}Sr}$ ratios of tooth enamel and dentine. The $^{87}Sr/^{86}Sr$ ratio of an animal, and thus its teeth, equals the average $^{87}Sr/^{86}Sr$ ratio of ingested plants (Lenihan *et al.,* 1967; Price *et al.,* 1985). The ratios of plants, in turn, equal the soluble Sr in soils, which is derived from bedrock weathering and atmospheric deposition (e.g., erosols, and precipitation) (Gosz & Moore, 1989; Miller *et al.,* 1993). Environmental $^{87}Sr/^{86}Sr$ ratios thus vary with differences in bedrock age, bedrock composition, and atmospheric input.

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LOCALITY

Tmavá skala cave is situated southeastwards of the Plavecký Mikuláš village, on the Plavecký karst territory in the Malé Karpaty Mountains (Slovak Republic) under the Polámané hill, 445 m above sea level (Šmída, 1996). 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. The 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 a supposed autochtonous stream (Šmída, 1996). The cave probably represents an old occasional rise, activity of which was related with changing of groundwater level, which was connected with climatic changes during Late Pleistocene. Humic soils with pebbles and osteologic material accumulated through fluvial activity of ground stream during interglacial Riss/Würm and interstadials of Würm. The groundwater level decreased during the periods of cold Würmian oscilations. On the formation of the cave sediments mainly the eolic activity took part, which created loess series. Occasional rise stopped its function in the consequence of the groundwater decrease after the Late Würm. After this time, there was Holocene sedimentation of humic soil with sharp fragments falling 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 termophilous, mostly woodland gastropod fauna from 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 stratigrafic 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 ages of the fossil remains were dated only as the Late Pleistocene (Riss/Würm - Late Würm). The gastropod and other vertebrate fauna, occuring 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 polles grains of the determined taxa (*Abies, Pinus, Tsuga, Tilia, Quercus*) were found in very small quantity in the samples (Holec *et al.*, 1998).

Tmavá skala cave is a 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) of 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 of one individual from Tmavá skala cave in Little Carpathians, Slovak Rebublic (fig. 2.). On the base of dental cementum analyses we determined the individual age of the studied animal. The individual age of the animal is about 4,5 years and the season of the death is summer.

Shells of molluscs served for determination of migrations as geological niveau. They were represented by one species i.e. *Helix pomatia* (LINNAEUS, 1758). This species is endemic in the given locality.

Table 1
Ratio results of $^{87}Sr/^{86}Sr$ of *Ursus spelaeus* dentine and enamel and *Helix pomatia* (geological benchmark) from Tmavá skala cave.

	87Sr/86Sr	1 sigma	2S(M)
Ursus spelaeus dentin	0.70913	0.000051	0.000008
Ursus spelaeus enamel	0.70930	0.000063	0.000019
Helix pomatia shell	0.70842	0.000062	0.000013

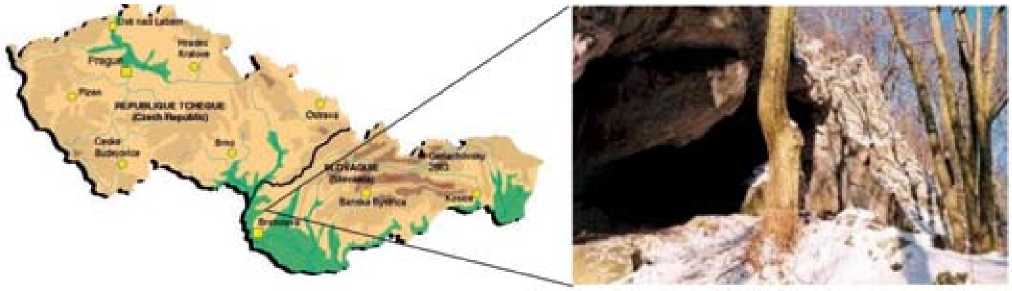

Figure 1. Tmavá skala cave, Little Carpathians, Slovak Rebublic (Photo Vodička, 2003).

METHODS

The method is based on the principle that the ratio of Sr isotopes in the tissues reflects the isotopic ratio in the diet in the time of its origin. If the tooth enamel and the dentine (or compact bone) give different values of the strontium isotopes it can be supposed that the examined animal passed the early years of the life and pre-mortal years in different geochemical kinds of environments (Bentley *et al.,* 2002).

For determination of $^{87}Sr/^{86}Sr$ ratios we used the following methodology. Samples of teeth and shells are cleaned up ultrasonically in distilled water for 15 minutes to remove alien dirts. Then sufficient amount of sample is drilled out with a dental drill. The fragments are cleaned up with ultrasonically in distilled water and in 5% acetic acid. Acetic acid should also secure that the thin surface layer is dissolved (because this layer might be contaminated by the environment in which the sample was found.) After that the fragments were dried in the laminar box. Dry material was burned at 825° for 8 hours. Obtained ash was dissolved at concentrated HNO_3, evaporated to dry, again dissolved at 6M HCl and evaporated to dry. Then follow the last dissolution and evaporating in concentrated $HNO_{3.}$ Vapour was dissolved at 2M $HNO_{3.}$ Separation ran at chromatographical columns with using ionex SR firm Eichron. (Methodology of sample preparing is partially adopted from Price, Manzanilla & Middleton (2000) (with some modifications).

The value of $^{87}Sr/^{86}Sr$ ratio was determined in a mass spectrometer with ionization from the solid phase MAT 262, mark Finnigan, in dynamic mode and in two-fibre arrangement. Thermal fractionalization was corrected by normalization to supposed value of the ratio of $^{88}Sr/^{86}Sr$ = 8,375209.

Reproducibility is checked by measurement of ratio $^{87}Sr/^{86}Sr$ isotopes of the standard NBS 987 whose long-time mean is 0.710248, with standard deviation 0.000013 (at 23 repeating).

RESULTS

Determination of mobility

Tab. 1 and fig. 3 provides a summary of results. The

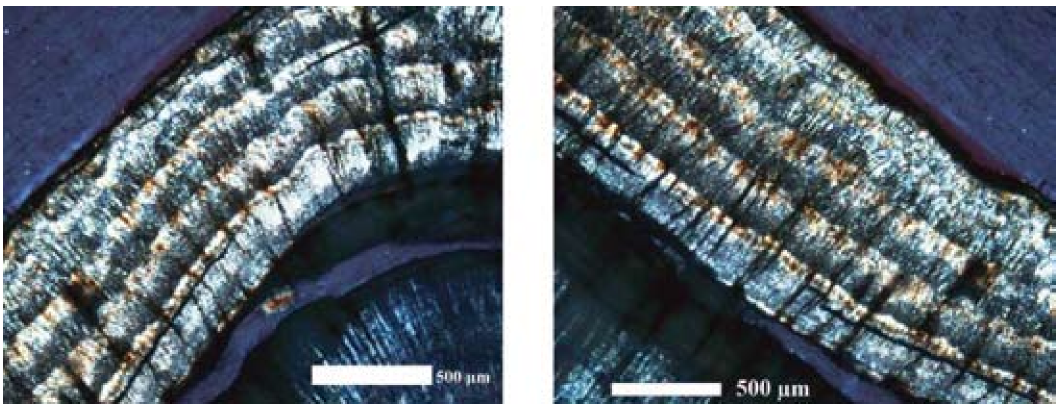

Figure 2. Transverse cross section of investigated *Ursus spelaeus* tooth (M^2) used for isotopic analyses in this study. Photo expose the dentine/cementum junction and annual increments in the cementum. Individual age estimation and season of death on the base of dental cementum analysis: about 4,5 years, death season: summer. (Photo author).

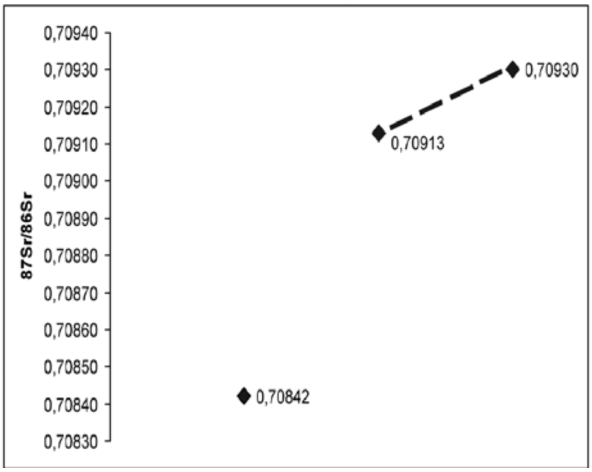

Figure 3. $^{87}Sr/^{86}Sr$ in tooth enamel and dentine of *Ursus spelaeus* from Tmavá skala cave. (*Helix pomatia* is used as a geological benchmark).

$^{87}Sr/^{86}Sr$ ratio is plotted on the y axis and *Ursus spelaeus* dentine and enamel across the x-axis (fig. 3). The $^{87}Sr/^{86}Sr$ ratio of *Ursus spelaeus* dentin is 0.70913, $^{87}Sr/^{86}Sr$ ratio of enamel is 0.70930. The $^{87}Sr/^{86}Sr$ ratio of *Helix pomatia* shell is 0.70842 (tab. 1, fig. 3).

DISCUSSION AND CONCLUSION

When we look at the $^{87}Sr/^{86}Sr$ ratio results of *Ursus spelaeus* enamel (0.70930) and dentin (0,70913) we could tell that the dentine values are close to the enamel values, suggesting little or no movement or migration during life.

Helix pomatia served for determination of migrations as geological niveau. The $^{87}Sr/^{86}Sr$ ratio from his shell (0.70842) is a little bit different from the values of *Ursus spelaeus* enamel and dentine, but this difference is not so great when we take into account the somewhat different life style of the bears and snails.

Using the procedure outlined above, the study of samples on a much larger scale could shed some light on the paleomovements of the animals.

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REFERENCES

BENTLEY, R. A., PRICE, T. D., LÜNGING, J., GRONENBORN, D., WAHL, J. & FULLAGAR, P. D., 2002. Prehistoric migration in Europe: Strontium Isotope Analysis of Early Neolithic Skeletons.- *Curr. Anthrop*. 43, **5**: 799-804.

GOSZ, J. R. & MOORE, D. I., 1989. Strontium isotope studies of atmospheric inputs to forested watersheds in New Mexico. *Biogeochemistry*, **8**: 115-134.

HOLEC, P., SABOL, M., KERNÁTSOVÁ, J. & KOVÁČOVÁ-SLAMKOVÁ, M., 1998. Jaskyňa Tmavá skala. Slovenský kras. Liptovský Mikuláš, **XXXVI**: 141-158.

HOPPE, K. A., KOCH, P. L., CARLSON, R. W. & WEBB, S. D., 1999. Tracking mammoths and mastodons: Reconstruction of migratory behavior using strontium isotope ratios. Geology, 439-442.

KOCH, P. L., FOGEL, M. L. & TUROSS, N., 1994. Tracing the diets of fossil animals using stable isotopes.- In: Stable Isotopes in Ecology and Environmental Science. Blackwell Scientific Publications, 63-92, Oxford.

LENIHAN, J. M. A., LOUTIT, J. F. & MARTIN, J. H., eds. 1967. Strontium metabolism. London, Academic Press, 345 pp.

LIŠKA, M., 1973. Geomorfologické pomery Plaveckého krasu. Manuskript. Achív Katedry geológie a paleontológie UK, Bratislava, 106 pp.

MILLER, E. K., BLUM, J. D. & FRIEDLAND, A. J., 1993. Determination of soil exchange -able - cation loss and weathering rates using Sr isotopes. *Nature*, 362: 438-441.

PRICE, T. D., CONNOR, M. & PARSEN, J. D., 1985. Bone chemistry and the reconstruction of diet: Strontium discrimination in white- tailed deer. *Journal of Archaeological Science*, **12:** 419-442.

PRICE, T. D., MANZANILLA L. & MIDDLETON, W. D., 2000. Immigration and the ancient city of Teotihuacan in Mexico: A study using strontium isotope ratios in human bone and teeth. *Journal of Archeological Science* 7, **10**: 903-913.

SABOL, M., 1997. The cave bear (*Ursus spelaeus* Rosenmüller et Heinroth) from the Tmavá skala cave.- *Mineralia Slovaca*, **30**: 285-308.

SABOL, M., 2001. Fossil brown bears of Slovakia. *Cuadernos do Laboratorio Xeoloxico de Laxe*, **26**: 311-316.

SCHMIDT, Z., 1970. Výskyt a geografické rozšírenie medveďov (Ursinae) na území slovenských Karpát. *Slovenský kras*, **VIII**: 7-20, Liptovský Mikuláš.

ŠMÍDA, B., 1996. Jaskynný georeliéf Plaveckého krasu (Malé Karpaty). Manuskript - archív Katedry geológie a paleontológie PriF UK, Bratislava, 108 pp.

VODIČKA, L., 2003. Paleolit v Malých Karpatoch. Český a slovenský svet./www.svet.czsk.net/sr.html