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ATTEMPT ON THE RECONSTRUCTION OF PALAEOTEMPERATURE AND PALAEOENVIRONMENT IN THE TERRITORY OF SLOVAKIA DURING THE LAST GLACIAL BASED ON OXYGEN AND CARBON ISOTOPES FROM TOOTH ENAMEL AND BONE COLLAGEN OF CAVE BEARS

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M. Ábelová – M. Sabol: Attempt on the reconstruction of palaeotemperature and palaeoenvironment in the territory of Slovakia during the Last Glacial based on oxygen and carbon isotopes from tooth enamel and bone collagen of cave bears

Abstract: A new research of cave bear fossils from four Slovak caves (Medvedia Cave in the Western Tatras Mts., Medvedia Cave in the Slovenský raj Mts., Cave of Izabela Textorisová in the Veľká Fatra Mts., Važecká Cave in the Kozie Chrbty Mts.) yields except of AMS data also palaeoecological ones from $\delta^{13}C$ and $\delta^{18}O$ signatures found in both the teeth enamel and the bone collagen of *Ursus* ex gr. *spelaeus*. Based on the AMS dating of cave bear fossils, the sedimentary filling of sites under study have been deposited during the Last Glacial, probably before the Hengelo Interstadial. Thus, they could be dated to the period from 39 ka BP up to the one before the Glinde Interstadial (51 – 48 ka BP), what corresponds with the OIS3. Preliminary results from carbon isotopes indicate that bears under study feed on plants, which grew in steppe environment, alternating with meadows and light or dense forests at the Western Carpathians area in the time span minimally 40 ka BP and more. It seems that found $\delta^{13}C$ data reflect also changes in climatic conditions. Oxygen isotope values from enamel of bears from the Medvedia Cave in the Western Tatras Mts. indicate that studied animals could live during a mild/warm climatic oscillation within some of OIS3 interstadials.

Key words: Cave bears, Last Glacial, Palaeotemperature, Palaeoenvironment, Isotopic Analysis, Slovakia

INTRODUCTION

Changes in both the continental climate and the paleoecosystem during the Pleistocene, which have so far been studied by using many techniques, are still more discussed question. The response of animals to environmental changes is thus a potential way to decipher these changes provided that a proxy can be found in these animal remains. One of the most direct ways of getting such palaeoenvironmental information is by measuring natural isotopic abundances in fossil tissues.

Carbon stable isotopes are extremely useful tools for reconstruction of animal palaeodiets and their relationship with habitat and ecosystem changes (Ambrose and Norr, 1993; Wang et al., 1993; Bocherens et al., 1994; Bocherens et al., 1995; Koch et al., 1997; Fernández-Mosquera, 1998; Cerling and Harris, 1999; Fernández-Mosquera et al., 2001; Vila-Taboada et al., 2001). It follows the oxygen isotope composition of fossil skeletal material contains information of past atmospheric temperatures in terrestrial environments. It is put more emphasis on study of palaeotemperature based on the oxygen isotopes (D´Angela and Longinelli, 1990; Bocherens et al., 1991; Ayliffe et al., 1992, 1994; Bryant et al., 1996; Genoni et al., 1998; Ábelová, 2007a, 2007b).

The research was aimed at obtaining of palaeoecological data from $\delta^{13}C$ and $\delta^{18}O$ signatures found in both the teeth enamel and the bone collagen of *Ursus* ex gr. *spelaeus* from different Slovak caves. It also proposes a comparison with data from other isotopically well-described and well-documented sites. Using a comparison of data from adult individuals, there was a possibility to reconstruct the palaeoclimatic, palaeodied and palaeoenvironmental conditions during the cave bears life under study.

MATERIAL AND SITES

Within the research, tooth enamel and bones of *Ursus* ex gr. *spelaeus* from the Medvedia Cave in the Western Tatras Mts., the Medvedia Cave from the Slovenský raj Mts. (*U. ingressus* according to preliminary results), Cave of Izabela Textorisová in the Veľká Fatra Mts., and from the Važecká Cave in the Kozie chrbty Mts. (Fig. 1) have been analysed. The analysis of oxygen and carbon isotopes has been realized in laboratories of the Czech Geological Survey in Prague, Czech Republic. The analyses of carbon isotopes from the bone collagen and AMS dating of fossil record under study have been realized in the VERA-Laboratory (Institut für Isotopenforschung und Kernphysik der Universität Wien) in Vienna, Austria.

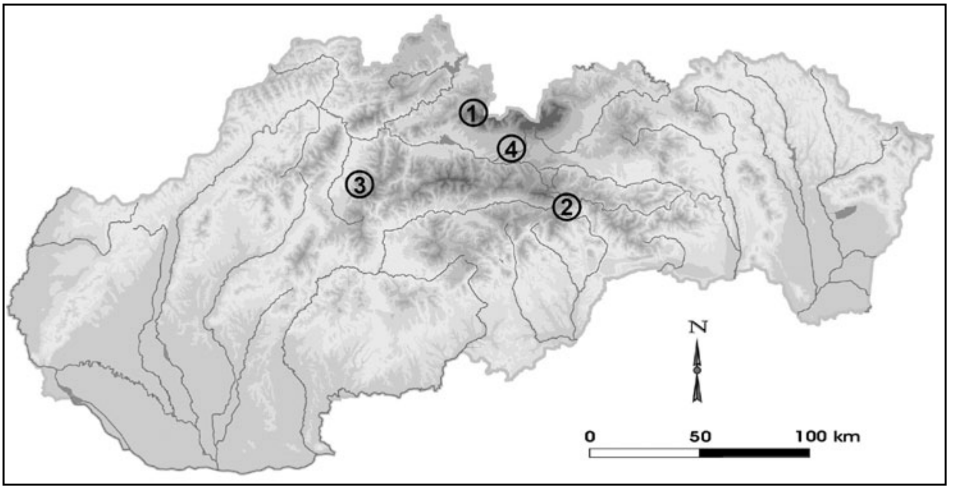

Fig. 1. Location of sites under study. 1 – Medvedia Cave in the Western Tatras Mts., 2 – Medvedia Cave in the Slovenský raj Mts., 3 – Cave of Izabela Textorisová, 4 – Važecká Cave.
Obr. 1. Lokalizácia skúmaných lokalít. 1 – Medvedia jaskyňa v Západných Tatrách, 2 – Medvedia jaskyňa v Slovenskom raji, 3 – Jaskyňa Izabely Textorisovej, 4 – Važecká jaskyňa.

The Medvedia Cave in the Western Tatras Mts., named also as "Cave in Friable Rocks" (Jaskyňa v Sypkých skalách), is situated in northern Slovakia in the Liptovský Mikuláš district with entrance in 1,133 m above the sea level. This fluviokarst-collapsed cave is long more than 150 m (Bella et al., 2007).

The Medvedia Cave in the Slovenský raj Mts., situated in eastern Slovakia in the Spišská Nová Ves district, represents a fluviokarst-corrosional, 497 m long and 30 m deep cave with entrance at altitude 905 m (Bella et al., 2007).

The Cave of Izabela Textorisová, known also as the "Havranová Cave", is 100 m long corrosional-cryogenic cave situated in the Veľká Fatra Mts. (northern Slovakia) near Martin town, with entrance in 754 m above the sea level (Bella et al., 2007).

The entrance of the fluviokarst open **Važecká Cave** is located at altitude 784 m. This 530 m long cave is situated in the eastern part of the north Slovakian district of Liptovský Mikuláš (Bella et al., 2007).

All abovementioned caves are famous by their palaeontological record, mainly represented by cave bears. The fossiliferous sediments have been deposited during the the Last Glacial (see Tab. 1).

METHODS

Carbon stable isotopes within the research yielded data for palaeodiet and palaeoenvironment reconstruction. Oxygen isotopes were used for palaeotemperature estimation.

Carbon isotopic abundances in collagen and carbonate hydroxylapatite are linked to diet, and by the intermediary of the food web, to primary producers, which are photosynthetic plants (Bender, 1968; Smith and Epstein, 1971; Deines, 1980; O'Leary, 1981). The carbon isotope composition ($\delta^{13}C$) of bioapatite reflects the dietary proportions of plants using C_3 (trees, shrubs, cool-climate grasses) and C_4 (warm-climate grasses) photosynthetic pathways, and $\delta^{13}C$ of collagen reflects the C_3:C_4 ratio of dietary protein sources. Plants, which are using the Calvin cycle (or C3 plants), 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, which are using the Hatch–Slack cycle (or C4 plants), include sedges, some herbs, rare shrubs, and most temperate and tropical-climate grasses, having an average $\delta^{13}C$ values of about -13 ± 2 ‰ with a range of -9 ‰ to -19 ‰ (O'Leary, 1988; Tieszen and Boutton, 1989). Based on the modern tropical to temperate distribution of C4 plants, bears populations in Central Europe probably only consumed C3 biomass. Since $\delta^{13}C$ of plants is sensitive to environmental factors such as water and light stress, however, the carbon isotope ratios from bioapatite can still provide insight into animals foraging behaviour. The following comparison between oxygen and carbon isotope ratios in the same samples can constrain palaeoclimatic interpretations (Fox et al., 2003). But metabolism and biomineralisation fractionate accepted carbon with aspect to plant source. Therefore, collagen and carbonate hydroxylapatite are enriched in ^{13}C comparison with composition of received food. In large mammals, collagen is enriched by around 5 ‰ relative to the diet and presumably +4 ‰ relative to the whole body. This enrichment is similar in herbivores and carnivores (Vogel, 1978; Vogel at al., 1990). In carbonate hydroxylapatite, the $\delta^{13}C$ values are enriched by around +10 ‰ in carnivores and +14 ‰ in herbivores relative to the average body (Bocherens and Mariotti, 1992).

The **oxygen** isotope composition of phosphate in mammalian biogenic apatite is linked to that of the body water from which the apatite precipitates at constant body temperature (Longinelli, 1984; Luz et al., 1984). In turn, the isotopic composition of body water reflects that of oxygen inputs to the body, which are sensitive to climate (Luz et al., 1984; Tatner, 1988; Ayliffe and Chivas, 1990; Bryant and Froelich, 1995). Biogenic apatite [generalized as $Ca_{10}(PO_4, CO_3)_6(OH, CO_3)_2$] also contains oxygen in structural carbonate. Variation in the isotopic composition of structural carbonate is also interpreted as a climatic signal (Land et al., 1980; Koch et al., 1989, 1995; Quade et al., 1992). Warmer temperatures and high aridity correspond to higher bioapatite $\delta^{18}O$ values (Fox et al., 2003).

The raw data yielded oxygen ratios in the teeth enamel carbonate relative to the Vienna Pee Dee Belemnite (VPDB). Firstly, this value was converted back to the raw ratio of ^{16}O to ^{18}O:

$$R \text{ sample} = (\delta^{18}O/1000 + 1) \times RVPDB \text{ standard}$$

This raw value was then re-calibrated relative to the VSMOW standard:

$$\delta^{18}O = (R_{sample}/R_{\text{SMOW standard}} - 1) \times 1000 ‰$$

$$^{16}O/^{18}O \text{ VPDB} = 2.00672 \times 10^{-3}$$
$$^{16}O/^{18}O \text{ SMOW} = 2.0052 \times 10^{-3}$$

Isotope data received from the laboratory of Czech Geological Survey represent only results from carbonate part. It was necessary to convert the dentine carbonate values of tooth enamel to phosphate values in order to compare obtained results with results of another researches. The formula according to Iacumin et al. (1996) has been used for this calculation: $\delta^{18}O_p = 0{,}98 \times \delta^{18}O_c - 8{,}5$

For determination of $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios, the methodology according to McCrea (1950) has been used. The dissociation of carbonate ran in the vacuum on the powderized sample with the assistance of 100 % H_3PO_4. The samples have been equilibrated under the room temperature during one day. Then, the samples have been measured against the international or laboratory standard (Carresian marble) in mass spectrometer MAT 251, mark Finnigan. External precision of determination for $\delta^{13}C$ and $\delta^{18}O$ is better than 0,05 ‰.

The results from $\delta^{13}C_{diet}$ isotope analyses and AMS dating are corelated with GISP2 $\delta^{18}O$ record (Fig. 3). The results from $\delta^{13}C_{collagen}$ and $\delta^{18}O$ isotope analyses are compared with isotope analyses of bear samples from Europe and United States of America (Figs. 2 and 4). The $\delta^{18}O$ record from bear samples from ZOO are used only for illustration, although teeth obtained from ZOO have proved to be unsuitable for comparision and palaeoclimatic reconstruction because most ZOO bears were purchased from animal dealers in the 1960's (Reinhard et al., 1996). Records of the place of origin are generally unavailable, and this information is needed to ascertain the $\delta^{18}O$ of drinking water during the time of teeth formation.

RESULTS AND DISCUSSION

Final results of analyses and recalculated values of isotopic relations from both the tooth enamel and the bone collagen of cave bears from the *spelaeus*-group, fossils of which have been found at sites under study, are located in Table 1. The signature of $\delta^{13}C_{collagen}$ varies from -21,8‰ to -16,9‰ and of $\delta^{13}C_{carbonate}$ from -11.8 to -10.1‰.

Unfortunately, the isotope equation for converting $\delta^{18}O_p$ to $\delta^{18}O_w$ for bears does not exist yet. For this reason, it is not possible to translate the phosphate oxygen isotope values in to water values. Because the calibrating of palaeotemperature equation requires species-specific data on the relation between $\delta^{18}O$ of both the animal teeth and the animal bones and that of its environmental water. The extinction of cave bears represents a problem in using of that for the obtaining of data on palaeotemperatures.

Longinelli (1984) suggested that one might calibrate $\delta^{18}O$ values of biogenic phosphate for an extinct species by using oxygen isotope relations of modern species that overlapped its range in space and time. The modern brown bear, *Ursus arctos*, which also lived in Europe at the end of the Pleistocene, is regarded as a descendant of *Ursus etruscus*. Thus, it is

Tab. 1. Data of isotopic analyses and AMS dating of cave bear fossils from the sites under study. The AMS data are not calibrated.
Tab. 1. Výsledky izotopových analýz a AMS datovania nálezov medveďov jaskynných zo skúmaných lokalít. Vekové údaje nie sú kalibrované.

LOCALITY	Altitude (m a.s.l.)	Sample	Material	$\delta^{13}C$ carbonate ‰ PDB	$\delta^{13}C$ collagen ‰ PDB	$\delta^{18}O$ carbonate ‰ SMOW	$\delta^{18}O$ phosphate ‰ SMOW	^{14}C age ka BP	$\delta^{13}C$ food
Medvedia Cave (Western Tatras)	1133	US ZT 1	C dext. (enamel)	-11.8		26.7	17.7		-25.9
Medvedia Cave (Western Tatras)	1133	US ZT 2	C sin. (enamel)	-10.1		27.9	18.9		-24.2
Medvedia Cave (Western Tatras)	1133	US ZT 3	M2 dext. (enamel)	-10.6		27.0	18.0		-24.7
Medvedia Cave (Western Tatras)	1133	VERA-4395	femur sin. (collagen)		-21.8 ± 0.6			>46	-26.8
Medvedia Cave (Western Tatras)	1133	VERA-4396	femur sin. juv. (collagen)		-21.7 ± 0.6			>47.6	-26.7
Medvedia Cave (Western Tatras)	1133	VERA-4810	humerus dext.		-17.6 ± 0.8			>47.5	-22.6
Medvedia Cave (Slovenský raj)	905	VERA-4393 MJ1	bone (collagen)		-22.9			40.8 +1.2/ -1.0	-27.9
Medvedia Cave (Slovenský raj)	905	VERA-4394 MJ2	bone (collagen)		-23.6			49.4 +3.4/ -2.4	-28.6
Medvedia Cave (Slovenský raj)	905	VERA-4394/2 MJ2	bone (collagen)		-16.9			51.1 +4.7/ -2.9	-28.6
Važecká Cave	784	VERA-3740	atlas (collagen)		-20.9			41.9 +1.3/ -1.1	-25.9
Važecká Cave	784	VERA-3755	ulna (collagen)		-21.6			>51	-26.6
Cave of Izabela Textorisová	754	VERA-4041	radius sin. (collagen)		-19.5			>45	-24.5

a good proxy for cave bears. Only relative temperatures, however, could be determined from the fossil teeth until now. From this viewpoint, the part of obtained data has been compared with another results expressed in $\delta^{18}O_{enamel}$ (Fig. 2).

RECONSTRUCTION OF PALAEOENVIRONMENT

$\delta^{13}C$ values of bear teeth enamel and collagen indicate that individuals under study feed on plant food with $\delta^{13}C_{food}$ values from −28.6‰ to −22.6‰. Since C4 plants did not grow in the area of Central Europe during the Last Glacial, calculated values suggest that bears feed on C3 plants. The variability of $\delta^{13}C$ data should be considered as a response to geological time, climatic changes and environmental conditions, since all the data compared belong to adult individuals of the same species. Plants growing at closed environments show considerable negative $\delta^{13}C$ values compared with those from open environments (e.g. Bocherens et al., 1994 or Drucker et al., 2003). Environment where bears under study lived was various in dependence on time period and it is possible to characterize it as steppe, alternating with meadows with presence of light woods, from place to place with dense woods. Isotope results very good correspond with GISP2 $\delta^{18}O$ record and also with Dansgaard-Oeschger and Heinrich events (Fig. 3).

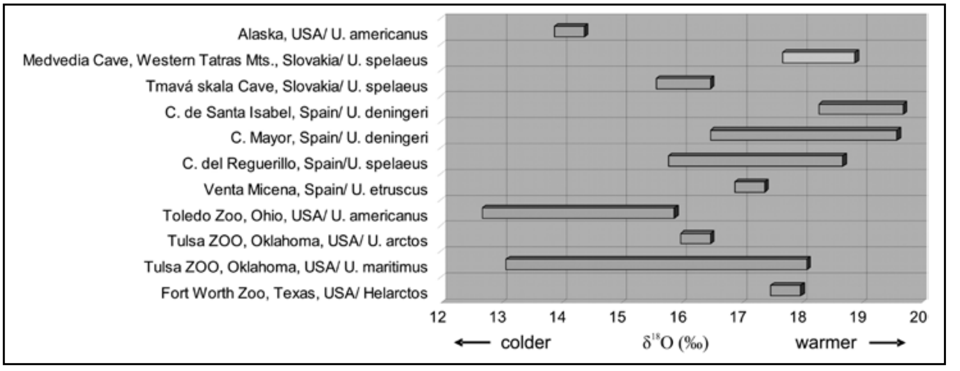

Fig. 2. Comparison of $\delta^{18}O$ from tooth enamel of *Ursus* ex gr. *spelaeus* from the Medvedia Cave in the Western Tatras Mts. with $\delta^{18}O$ from teeth enamel of *Ursus* ex gr. *spelaeus* from the Tmavá skala Cave (500 m a.s.l., Last Glacial, Slovakia) and the Cueva del Reguerillo (820 m a.s.l., 90 – 60 ka BP, Spain), *Ursus deningeri* from the Cueva Mayor (1022 m a.s.l., 350 ka BP, Spain) and the Cueva de Santa Isabel (220 m a.s.l., 350 – 200 ka BP, Spain), *Ursus etruscus* from the Venta Micena (1.0 Ma BP, Spain), *Ursus arctos* and *Ursus maritimus* from the Tusla Zoo, *Ursus americanus* from the Toledo Zoo, and *Helarctos malayanus* from the Fort Worth Zoo (according to Reinhard et al., 1996 and Ábelová, 2008).

Obr. 2. Porovnanie údajov $\delta^{18}O$ zo zubnej skloviny medveďov zo skupiny spelaeus z Medvedej jaskyne v Západných Tatrách s údajmi $\delta^{18}O$ zo zubnej skloviny medveďov zo skupiny *spelaeus* z jaskyne Tmavá skala (500 m n. m., posledné zaľadnenie, Slovensko) a z lokality Cueva del Reguerillo (820 m n. m., 90 – 60 tis. r. BP, Španielsko), druhu *Ursus deningeri* z lokality Cueva Mayor (1022 m n. m.., 350 tis. r. BP, Španielsko) a z lokality Cueva de Santa Isabel (220 m n. m., 350 – 200 tis. r. BP, Španielsko), druhu *Ursus etruscus* z náleziska Venta Micena (1 mil. r. BP, Španielsko), druhu *Ursus arctos* a druhu *Ursus maritimus* zo Zoo v meste Tusla, druhu *Ursus americanus* zo Zoo v meste Toledo, a druhu *Helarctos malayanus* zo Zoo v meste Fort Worth (podľa Reinharda et al., 1996 a Ábelovej, 2008).

Based on the high $\delta^{13}C$ values, the palaeoenvironment is possible to interpret as steppe and meadow, corresponding with cold oscillations. This is the case of **Izabela Textorisová Cave** (place of *Ursus* ex gr. *spelaeus* findings – "Hrobka"; age more than > 45 ka BP). The record is possible to correlate with Heinrich event H5, possibly with preceding cold events. For palaeoenvironmental reconstruction based on palinological analysis, a sample of cave deposits has also been taken away from the site (Vaněková and Bendík, 2008). Found Late Pleistocene to Holocene flora with presence of *Pinus* document a colder time period, whereas the presence of *Alnus* and *Salix* indicate a wet environment. Also, a high portion of deciduous trees has been found within the sample under study. The whole assemblage point out to climatic optimum, which dominated in the cave surroundings during the time when these plants vegetated. The palinological research in the Izabela Textorisová Cave is so far pathbreaking. It could be suitable to check additional samples from another cave parts to obtain exact conclusions about palaeoecology in the cave vicinity.

Some findings from the **Važecká Cave** (with dating around 41 900 +1300/-1100 ka BP) occur also within the colder event H4.

The AMS dating of cave bear fossils from the **Medvedia Cave in the Western Tatras Mts.** determined age more than 46 ka BP. Based on the $\delta^{13}C$ results, it is possible to suggest that individuals of *Ursus* ex gr. *spelaeus* under study come from longer time period, representing both the colder and the warmer events or this bears migrated within environmentally different environments. It is reflected on large range of $\delta^{13}C_{food}$ values. Obtained data allow an assumption of steppe and meadow character with presence of open woods in the vicinity of the cave during colder events, whereas open forest dominated during warmer events.

Analysed samples from the **Medvedia Cave in the Slovenský raj Mts.** point out the warmest climatic oscillations represented by Dansgaard-Oeschger events D-O 12, D-O 14

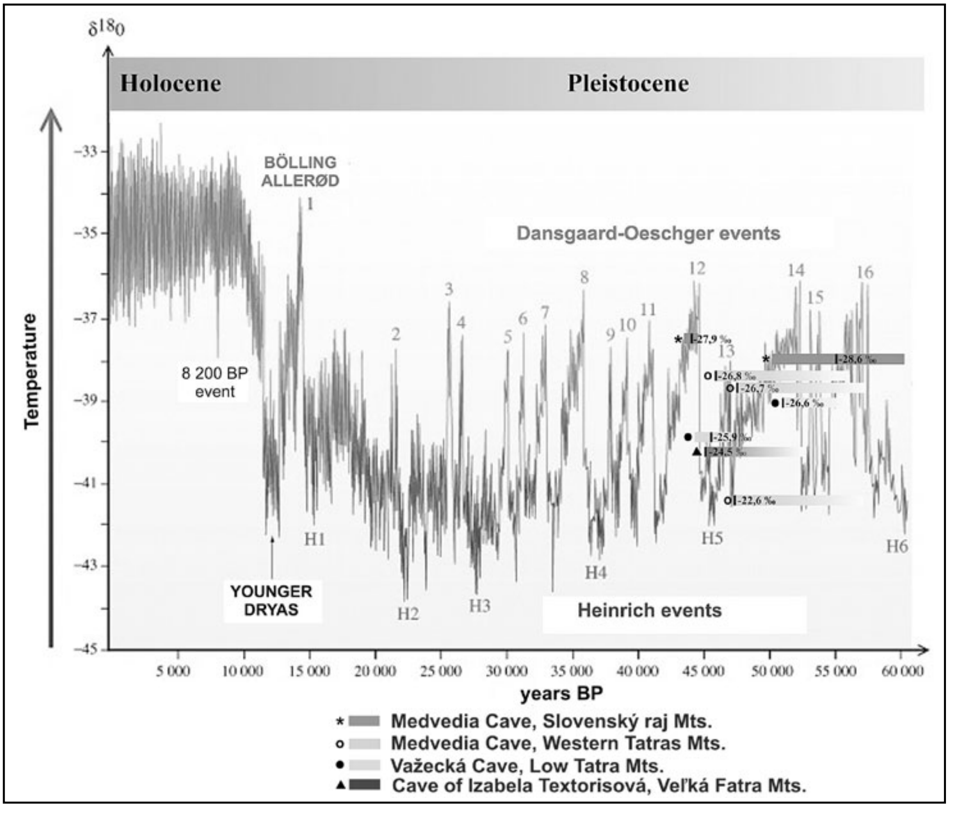

Fig. 3. GISP2 $\delta^{18}O$ record and correlation of results from the isotopic analysis ($\delta^{13}C_{diet}$ ‰) and AMS dating (the data below 50 000 BP were calibrated using CalPal 2007online (Danzeglocke et al., 2007)) of found cave bear fossils from sites under study with data of borehole from the, with marked Dansgaard-Oeschger and Heinrich events (Grootes et al., 1993; Dansgaard et al., 1993; Heinrich, 1988).
Obr. 3. Záznam $\delta^{18}O$ z vrtného jadra GISP2 a porovnanie výsledkov z izotopovej analýzy ($\delta^{13}C_{potrava}$ ‰) a AMS datovania nájdených fosílií medveďov jaskynných zo skúmaných lokalít, s vyznačením Dansgaard-Oeschgerových a Heinrichových eventov (Grootes et al., 1993; Dansgaard et al., 1993; Heinrich, 1988).

to D-O 16. The assumption is confirmed by results of isotope analyses ($\delta^{13}C_{food}$ values reach most negative values) and also by AMS dating of the fossils.

The similar conditions as in the Medvedia Cave in the Slovenský raj Mts. could partly predominate also in the **Važecká Cave** (fossil remains of cave bears dated to time period older than 51 ka BP – although these fossils come from the same layer as abovementioned sample, their different age shows on the possibility of longer time range of the deposition within the fossiliferous sedimentary complex). Cave bears used this cave as a den most likely during the time period, which is possible to correlate with Dansgaard-Oeschger events D-O 14, D-O 15 and D-O 16 (or even older – on account of dating beyond the 14C dating). Character of the palaeoenvironment is possible to interpret as a forest with occurrence of meadows.

Based on the invaluable information about palaeoenvironment character from palinological analyses (Vaněková and Bendík, 2008) it is possible to assume a forest character of the Western Carpathians area during the time period from 52 ka BP until the end of Late Glacial. It depended only on climatic conditions, which determined a predomination of wood composition in vegetation. During the coldest and continental phases, *Larix, Betula, Pinus cembra* with *Pinus sylvestris* and probably also *Pinus mugo* dominated, whereas

Picea, *Alnus* and *Pinus sylvestris* expanded in the Western Carpathians area during the climatically favourable phases when growth of the temperature allowed better hydrologic conditions. *Larix*, *Pinus cembra* and always *Betula nana* presented permanent component of vegetation. The Western Carpathians woods had a character of taiga during the Last Glacial. The nature of vegetation was similar to present-day middle and north Siberian taiga to forest tundra in dependence of climate and vertical zonation (Jankovská 1998, 2002, 2003, 2004; Jankovská et al., 2002).

The Western Carpathians vegetation of taiga character changed to forest-tundra/tundra formations at northern foothills of the area under study. Taiga of southern parts of the Western Carpathians Mts. changed continuously or mosaic to forest steppe. An analogy of such vegetation situation can also be seen in present-day Siberia. Together with woods typical for forests of taiga character, pollens requiring a warmer climate have also been found. The terrain morphology of Slovakia thus could be favourable to refugium of numerous woods (Jankovská, 2004).

Range of established $\delta^{13}C$ isotope values of bears from Slovakia is very wide: from -17.6 ‰ to -23.6 ‰. This range overlaps the values of all compared bear species and areas except of *Ursus arctos* from Alaska, where the $\delta^{13}C$ values are more positive (Fig. 4). Isotope values from individual Slovak caves, however, show mutual differences: 1) $\delta^{13}C_{collagene}$ values of bears from the Medvedia Cave in the Slovenský raj Mts. belong to most negative; 2) $\delta^{13}C_{collagene}$ results from the Važecká Cave and the Cave of Izabela Textorisová show middle values; 3) and $\delta^{13}C_{collagene}$ results from the Medvedia Cave in the Western Tatras Mts. have most positive values, which approximate these values to values from northern parts of Czech Republic, Yukon and Alaska (Fig. 4).

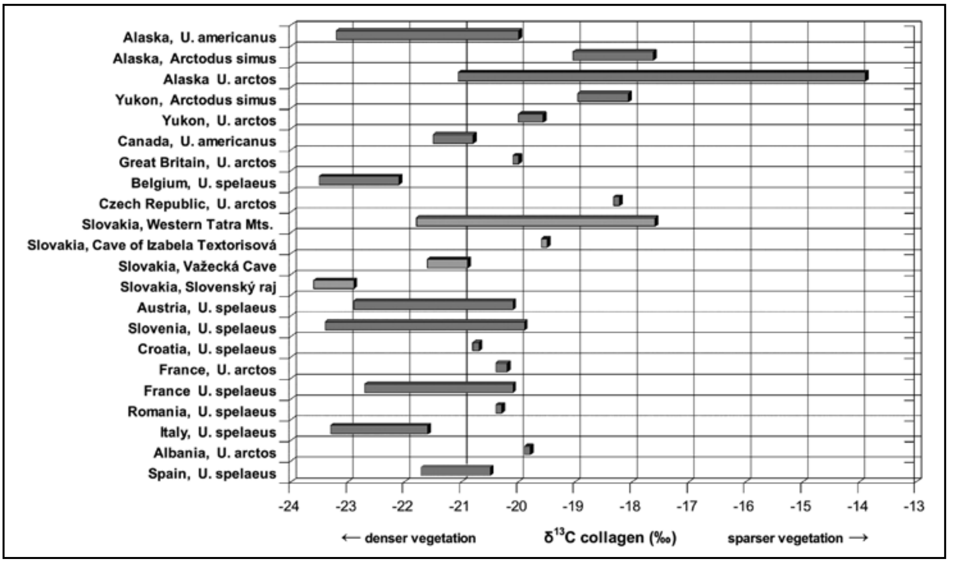

Fig. 4. Stable isotope $\delta^{13}C$ values for bear bone collagen from caves under study and from selected European and North American caves (according to Katzenberg, 1989; Bocherens et al., 1992, 1994, 1997, 1999, 2004, 2006; Matheus, 1995; Fernandez-Mosquera, 1998; Nelson et al., 1998; Vila-Taboada et al., 1999; Bocherens, 2000; Richards et al., 2000, 2008; Fernandez-Mosquera et al., 2001; Baichtal, 2003).
Obr. 4. Hodnoty stabilného izotopu $\delta^{13}C$ z kolagénu kostí medveďov jaskynných zo skúmaných lokalít a z vybraných jaskýň Európy a Severnej Ameriky (podľa Katzenberga, 1989; Bocherensa et al., 1992, 1994, 1997, 1999, 2004, 2006; Matheusa, 1995; Fernandez-Mosquera, 1998; Nelsona et al., 1998; Vila-Taboady et al., 1999; Bocherensa, 2000; Richardsa et al., 2000, 2008; Fernandez-Mosquera et al., 2001; Baichtala, 2003).

Based on the existing results, it is not possible to decide whether individuals under study were exclusively herbivorous or omnivorous and from which specific sources the food comes from. Meat consumption, in particular, varies widely among and within single brown bear populations, due to the availability of ungulate fauna (Jacoby et al., 1999; Gau et al., 2002; MacHutchon and Wellwood, 2003; Mowat and Heard, 2006). Large adult males also appear to be more carnivorous than females or subadult bears (Hildebrand et al., 1999; Jacoby et al., 1999). North American black bears (*U. americanus*) appear to have similar plant/meat dietary proportions as brown bears (Jacoby et al., 1999). Except that the larger brown bears are frequently more carnivorous when the prime meat is maritime (e.g., salmon) (Belant et al., 2006). This ecological flexibility of modern brown bears therefore makes an appropriate model to understand the range of isotopic values now available for European cave bears, both within and between site-specific samples (Richards et al., 2008).

RECONSTRUCTION OF PALAEOTEMPERATURE

Oxygen isotopes $\delta^{18}O_{carbonate}$ have been analysed from three enamel samples of *Ursus* ex gr. *spelaeus* (the Medvedia Cave in the Western Tatras Mts.). $\delta^{18}O_{carbonate}$ values range from 27.9‰ to 26.7‰. The comparison of obtained results with results of another researches displays highest values of data from sites under study (Fig. 2). They are similar mainly to those from Cueva de Santa Isabel, Cueva Mayor or Cueva del Reguerillo from Spain (Reinhard et al., 1996). Based on this comparison and high $\delta^{18}O$ values of obtained results, there is possible to draw that animals under study could live in the territory of the Western Carpathians Mts. during a mild/warm climatic oscillation within some interstadial of OIS3 (Tab. 1, Fig. 3).

This conclusion, however, must remain tentative because of analysis only three teeth and small number of measurements thus could be misleading. A very nice example comes from research of Reinhard et al. (1996). The wide variation in isotopic composition of teeth from Cueva del Reguerillo points to the danger of generalizing from analyses of small number of samples. Having analysed only a few teeth instead of eighteen and more, a conclusion about climatic conditions of the site could be unwarranted and possibly false.

CONCLUSION

Within the scope of this article, only preliminary results are presented. Based on the AMS dating of cave bear fossils, the sedimentary filling of sites under study have been deposited during the Last Glacial, probably before the Hengelo Interstadial. Thus, they could be dated to the period from 39 ka BP up to the one before the Glinde Interstadial (51 – 48 ka BP), what corresponds with the OIS3. This time span includes more climatic oscillations, including warm Dansgaard-Oeschger events D-O 11 to D-O 16 (or even older) and cold Heinrich events H5, H6 (or probably even older).

Preliminary results from carbon isotopes ($\delta^{13}C_{food}$ from -28.6 ‰ to -22.6 ‰) indicate that bears under study feed on plants, which grew in steppe environment alternating with meadows and light or dense forests in the time span minimally 40 ka BP and more in the territory of the Western Carpathians Mts. It also seems that found $\delta^{13}C$ data reflect changes in climatic conditions.

Oxygen isotope values ($\delta^{18}O_{carbonate}$ from 27.9 ‰ to 26.7 ‰) from enamel of cave bear teeth from the Medvedia Cave in the Western Tatras Mts. indicate relatively a mild to warm climatic oscillation during the Last Glacial before minimally 46 ka BP. The comparison of obtained results with results of another researches shows highest values of data from sites under study. They are similar to those from Cueva de Santa Isabel, Cueva Mayor or Cueva del Reguerillo from Spain. Based on that and high $\delta^{18}O$ values of obtained results, it is possible to assumed that animals under study lived in the Slovak territory of the Western Carpathians Mts. during a mild/warm climatic oscillation within some interstadial of OIS3.

The results from palinological researches confirm a forested character of the Western Carpathians area during the whole time span (from the middle part of the Last Glacial to the Late Glacial) in dependence on both the climatic conditions and the vertical zonation. The vegetation can be determined as similar to middle and north Siberia taiga and forest tundra.

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POKUS O REKONŠTRUKCIU PALEOTEPLOTY A PALEOPROSTREDIA NA ÚZEMÍ SLOVENSKA POČAS POSLEDNÉHO ZAĽADNENIA NA ZÁKLADE IZOTOPOV KYSLÍKA A UHLÍKA ZO ZUBNEJ SKLOVINY A KOSTNÉHO KOLAGÉNU MEDVEĎOV JASKYNNÝCH

Zhrnutie

Nový výskum fosílií medveďov jaskynných (*Ursus* ex gr. *spelaeus*) zo štyroch slovenských jaskýň (Medvedia jaskyňa v Západných Tatrách, Medvedia jaskyňa v Slovenskom raji, Jaskyňa Izabely Textorisovej vo Veľkej Fatre a Važecká jaskyňa) priniesol okrem exaktných datovacích údajov aj paleoekologické informácie z analýz $\delta^{13}C$ a $\delta^{18}O$ zubnej skloviny a kostného kolagénu. AMS datovanie poukazuje na možný vek fosílií starší ako 40 000 rokov BP, čo by ich umožnilo datovať do obdobia pred hengelským interštadiálom v rámci posledného zaľadnenia, zodpovedajúceho kyslíkovému izotopovému stupňu OIS 3. Toto časové obdobie zahŕňa viacero klimatických oscilácií, vrátane teplých Dansgaard-Oeschgerových eventov D-O 11 až D-O 16 (prípadne starších, vzhľadom na datovanie za hranice metódy 14C) a studeného Heinrichovho eventu H5 (pravdepodobne tiež H6).

Predbežné výsledky analýz izotopov uhlíka ($\delta^{13}C_{potrava}$ od -28,6 ‰ do -22,6 ‰) preukázali, že skúmané jedince medveďov jaskynných z územia Západných Karpát sa v zistenom období živili rastlinami, ktoré rástli v stepnom prostredí striedajúcom sa s lúkami a svetlými až hustými lesmi. Získané údaje odrážajú zároveň pravdepodobne aj zmeny v klimatických podmienkach. Hodnoty izotopov kyslíka ($\delta^{18}O_{karbonát}$ od 27,9 ‰ do 26,7 ‰) zo zubnej skloviny medveďov z Medvedej jaskyne v Západných Tatrách zároveň poukazujú na pomerne miernu až teplú klimatickú osciláciu počas posledného zaľadnenia minimálne pred 46 000 rokmi BP. Porovnanie získaných výsledkov s údajmi iných autorov ukázalo vyššie hodnoty zo skúmaných jaskýň, podobné údajom z lokalít Cueva de Santa Isabel, Cueva Mayor alebo Cueva del Reguerillo v Španielsku. Na základe toho, ako aj vyšších získaných hodnôt $\delta^{18}O$ je možné predpokladať, že skúmané jedince medveďov jaskynných z územia Západných Karpát mohli žiť počas miernej až teplej klimatickej oscilácie v rámci niektorého z OIS 3 interštadiálov.Výsledky z palynologických výskumov potvrdzujú lesný charakter západokarpatskej oblasti v celom časovom rozsahu (od strednej časti posledného zaľadnenia až do začiatku neskorého glaciálu) v závislosti od klimatických podmienok a vertikálnej zonácie. Vegetačný pokryv je celkovo možné prirovnať k tajge až lesnej tundre dnešnej strednej a severnej Sibíri.