INVESTIGATION OF NATURAL PERENNIAL ICE DEPOSITS OF DURMITOR MTS, MONTENEGRO

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Abstract: We have applied radiochemical methods, namely, γ-spectrometry (^{137}Cs isotope) and β-activity measurements (^{3}H concentration by LSC technique) on two ice cores extracted from two natural ice bodies from Durmitor Mts. Our aim was comparing the mass balance history and ice dynamism of glacier- and cave-ice for the past few decades. We demanded to apply the dated events in the tritium and ^{137}Cs concentration changes of the atmospheric precipitation during the second half of the 20th century. Glacier samples present higher ^{137}Cs concentrations, than the cave ice samples. However, data from the glacier ice show much higher deviations and do not imply any consequent tendency. We think that only a few years could be included into the analysed glacier core that was not sufficient revealing any multi--annual trend.

Tritium concentration data and the stratigraphical feature of the cave ice core suggest that positive net mass balance period followed by a negative net mass balance period and finally positive balance accumulated the uppermost 104 cm thick part of the core.

The negative mass balance period included the 1963 – 1950's epoch or represented such an intensive melting which erased the ice also from this period.

Key words: Balkan Peninsula, ceasium-137, tritium, cave ice mass balance

INTRODUCTION

Durmitor Mts is a prominent range of Dinarides having a very spectacular geomorphologic view owing to the concomitant evolution of karstic and glacial landscape. A special phenomenon of the glacial feature of Durmitor Mts is the synchronic appearance of surface and subterranean glaciations. Debeli Namet (43.12 N, 19.28 E), the southernmost glacier remnant of the Balkan Peninsula and Ledena Pecina (43.14 N, 19.04 E) the ice cave of Durmitor Mts (Fig. 1.).

The Durmitor area is opened towards the Adriatic Sea. So, its climate regime has a maritime character (Ćurić 1996) with two precipitation maxima. The smaller is during April-May and the larger in November (Fig. 2.). The annual precipitation at the region of ridges exceeds 2500 mm (Lješević 1996).

Snow is the dominant part of the precipitation from October to April. These months are the accumulation season, while the ablation season spans from May to end of September.

The aims of this preliminary work were comparison of the glacier- and cave-ice accumulation and dynamism. Also our goal is to set up correspondence of cave and surface archives. We demanded to find the same marker horizon, 1963 characterized by eminent concentration of radioactive isotopes in the above-, and beneath-ground ice deposit.

Tritium (^{3}H) is the radioactive hydrogen isotope with global occurrence and partly natural origin. Tritium is a beta-decay isotope with a half-life of 12.34 years. In the last century nuclear weapon tests were important sources of anthropogenic tritium.

^{137}Cs isotope is not present in the nature. The main sources of ^{137}Cs were the thermonuclear weapon tests and the nuclear plant disasters.

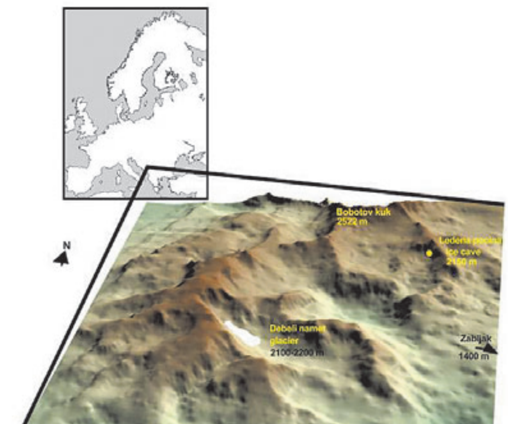

Fig. 1. Location of Durmitor Mountains, and the position of Debeli Namet niche glacier and Ledena Pecina within the mountain range

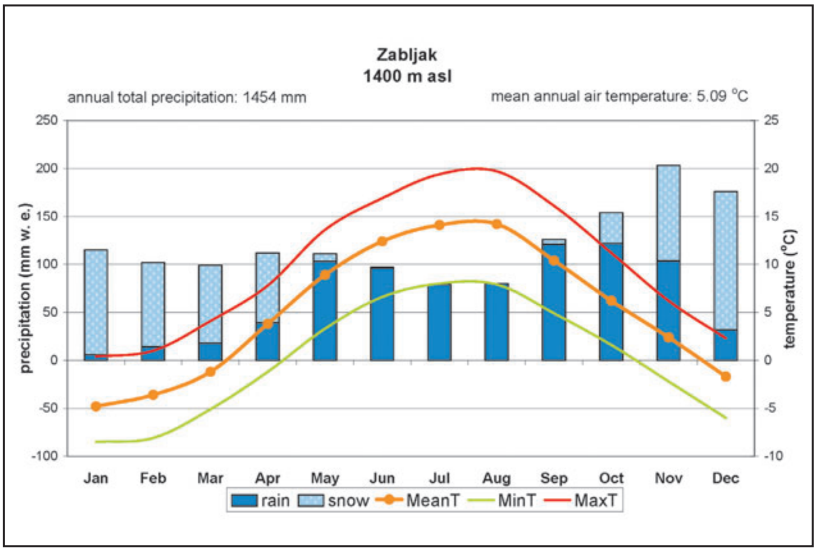

Fig. 2. Zabljak is a significant station on the foothills of Durmitor. Climate data after Ćurić (1996)

The concentration of these isotopes drastically increased in the atmosphere and precipitation after the launch of thermonuclear weapon testing within a couple of years. Following commencement of the Nuclear Test Ban Treaty (so-called "nuclear silence") the above-ground thermonuclear detonations became forbidden. After this event the anthropogenic emission significantly dropped and the tritium and ^{137}Cs level of precipitation is steadily decreased due to dilution and the radioactive decay. The absolute culmination in the tritium concentration in atmospheric precipitation was in 1963 on the Northern Hemisphere and we can contribute the same date to the maximum ^{137}Cs deposition. We decided to apply the anthropogenic concentration peak of tritium and ^{137}Cs isotopes at 1963, coinciding with the so-called "nuclear silence" the cessation of atmospheric thermonuclear weapon tests.

MATERIALS AND METHODS

In order to estimating the age and deposition dynamic of the different type of icy deposits we extracted shallow ice cores from both ice bodies.

The drillings were executed at Debeli Namet on June 17, 2002 and at the ice cave at June 18, 2002. We assessed the upper 220 cm of the Debeli Namet as recent snow deposit from the last accumulation season so we started the drilling process at base of snow layer and the core covered the 2.2 – 3.93 m depth interval, however the ice core from the ice cave penetrated the uppermost 0 – 1.99 m depth interval. We sliced the cores at the spot. The mean segment length was 2.75 cm for glacier core and 2.22 cm for cave ice core.

RADIOCHEMICAL DATING

The tritium activity was successfully applied in dating approach on high-mountain and polar ice cores (ex: Ravoire et al. 1970, Schwikowski et al. 1999, Karlöf et al. 2000) and on ice cave profiles (Horvatinčić 1996, Fórizs et al. 2004, Kern et al. this volume) as well.

^{137}Cs isotope concentration proved to be reliable reference horizon at Svalbarld ice cores (Isaksson et al. 2005). The method was tested at the Calderone Glacier (Gran Sasso, Apennines) (Balerna 2001) but two isolated samples could prove only the presence of ^{137}Cs in the snow layer but were not able to give information on the position of the 1963 concentration peak. In addition, firn and ice core analyses presented from Ellesmere Island (Canadian Arctic) emphasized the potential of parallel application of these two radiochemical methods for ice core dating (Stuart & Sharp, 2003). They have also called the attention of the importance using more geochronological method.

^{137}CS

^{137}Cs isotope concentration of melted samples was measured by gamma spectrometry method (coaxial type HPGe detector shielded by 10 cm thick lead, CANBERRA). The samples were packed in disk shape PP holders and put directly onto the detector. The measuring time varied between one and three days. The spectra were analysed by SAMPO'90 software.

^{3}H

Tritium activities were measured on water melted from the ten samples of the cave ice core using liquid scintillation counting (LSC) technique. Water samples were distilled before LSC measurements to minimize quenching. 10 mL of distillated water sample was mixed with 10 mL of Ultima Gold LLT cocktail in a plastic vial and measured by a Quantulus 1220 (Perkin Elmer) liquid scintillation counter in the lab of Institute of Nuclear Research (ATOMKI).

Measuring time was 1000 minutes per sample, resulting 7.3 TU as detection limit (*tritium unit*, 1 TU is 0.1183 Bq/L) (Curie 1995). Results are published in tritium units, calculated for the date of measurement (5th of April in 2006).

RESULTS AND DISCUSSION

We assessed the incoming signal for ^{137}Cs in the ROI (region of interest) of 659.5 – 663.5 keV. Since the clear peak was hardly detected but we could realize only some enhancement in the ceasium-range. So we have chosen two independent ROIs (653.0 – 657.0 keV and 691.0 – 695.0 keV) where are no any peaks of the natural radioisotopes only the Compton continuum. Then we calculated the average "background" from this two control ROIs and the detected area of 659.5 – 663.5 keV ROI were divided by this averaged background.

A “real” background was measured by 620 000 sec. measuring time. The calculated value of the ratio of the ^{137}Cs ROI and the control ROIs were 0.96 ± 0.05.

Results are displayed as filled squares in Figure 3 and Figure 4. Horizontal error-bars are calculated as two or three samples measured together. Vertical error-bars show the 1σ uncertainty, which corresponds to 68 % probability. Results of the ice cave from Ledena Pecina suggest decreasing concentration of ^{137}Cs isotope towards the deeper part of the cave ice, however the 1-sigma errors suggest high uncertainty. Data from Debeli Namet show much higher deviations and do not imply any consequent tendency. Glacier samples, however, present higher ^{137}Cs concentrations, than the cave samples. This means that the ^{137}Cs deposition is hindered in the cave. Probably a significant part of the ^{137}Cs is absorbed in the organic soil-detritus during the infiltration.

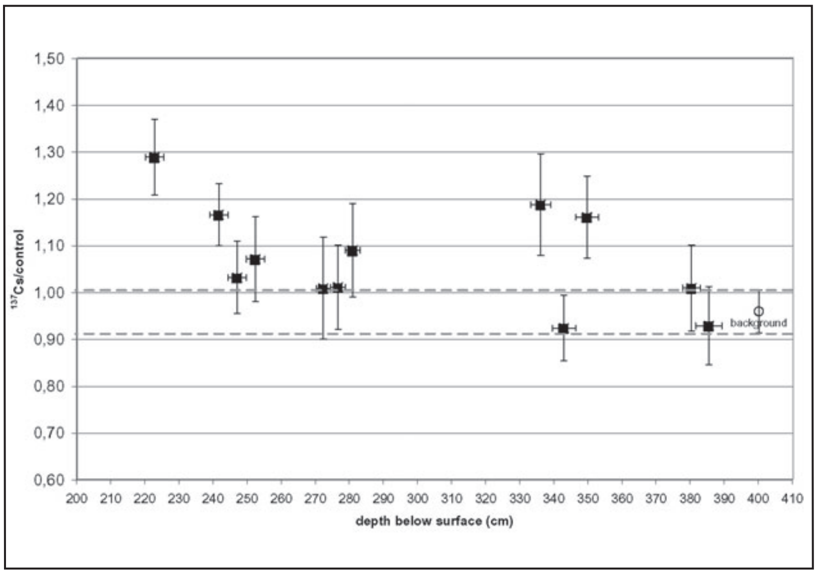

Fig. 3. Results of Debeli Namet. Vertical error-bars represent the 1σ uncertainty. The dashed lines indicate the range of the background

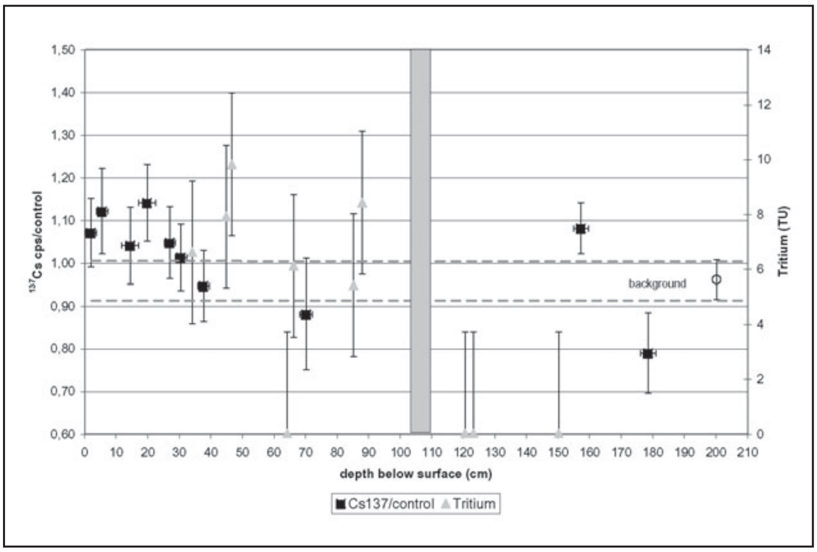

Fig. 4. Results from Ledena Pecina. Vertical error-bars represent the 1σ uncertainty for ^{137}Cs/control ratios and the measurement errors for tritium activities, respectively. The dashed lines indicate the range of the background for ^{137}Cs/control ratio

Considering the tritium values we can find that the elevated concentration for the 1960’s decade are not among the measured samples. In addition there are quite short intervals between the measurements, so we think it is impossible to position the bomb-peak between the measured samples because if it is there we should get higher values for the neighbouring samples. However the results suggest that in the cave ice core above the mud layer we can find modern ice with detectable tritium activity. But it is much more recent than 1963 because the values are quite low.

None of the samples below 1 m depth of the core yielded tritium activity exceeding the detection limit (7.3 TU). We suggest that this part of the cave ice core consist of non-modern ice. It means older than the starting date of the thermonuclear weapon tests (1953). The two segments separated by a massive mud horizon.

According to these results we can reconstruct three periods of the mass balance history of Ledena Pecina.

1. The core segment below 110 cm represents this phase. Positive net mass balance period with ice accumulation before 1950’s, data could not give base for more precise estimation about the age of this ice.

2. The bulky mud layer from 104 – – 110 cm below the ice surface shows this phase. Negative net mass balance period, which included the 1963 – 1950’s epoch or represented such an intensive melting that erased the ice also from this period.

3. The ice down to 104 cm depth below the ice surface demonstrates the last positive net mass balance period. The total length of this segment must deposited after 1963, or even later because the peak of 1963 and the significantly elevated values of the 60’s decade are lacking from the results.

CONCLUSION

Gamma spectrometry did not satisfy the hopes for dating the 1963 AD radiochemical reference horizons from the natural ice bodies of Durmitor Mts. In the case of glacier we think the core was not sufficiently deep. So the desired period was not recovered by the drilling from this ice body. For the next researches drilling down to bedrock is advisable. In the case of cave ice the percept signals were subdued that the applied method was hardly able to detect any. For future research more sensitive method is recommendable to apply.

Tritium measurements helped recognition of three periods with different net mass balance in the history of the Ledena Pecina.

This highlight a distinct difference between the mass balance history of the two prominent ice cave of West Balkan. Ledenica Cave (Horvatinčić 1996) took over the past 60 years with continuously positive but probably highly fluctuating mass balance while ice block of Ledena Pecina survived a negative net mass balance period during the past 50 years. This period included the 1960's and 1950's decades or characterized by such an intensive melting that defeated the ice also from this period.

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