CONTINENTAL ICE BODY IN DOBŠINÁ ICE CAVE (SLOVAKIA) – PART I. – PROJECT AND SAMPLING PHASE OF ISOTOPIC AND CHEMICAL STUDY

Kamil Vrana[1] – James Baker[2] – Henrik Brink Clausen[3] – Steffen Bo Hansen[3] – – Ján Zelinka[4] – Henry Rufli[5] – Ľubomír Očkaik[6] – Juraj Janočko[1]

[1] HYDEKO-KV, Planckova 4, 851 01 Bratislava, Slovakia

[2] $SELOR_{EEIG}$, Saffierstraat 101c, 1074 GP Amsterdam, the Netherlands

[3] Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, DK2100 Copenhagen, Denmark

[4] Slovak Caves Administration, Hodžova 11, 031 01 Liptovský Mikuláš, Slovakia

[5] University of Bern, Bern, Switzerland

[6] Dobšiná Ice Cave, 049 71 Dobšinská ľadová jaskyňa, Slovakia

Abstract: Company HYDEKO-KV Bratislava received licence for drilling and sampling project in the Dobšiná Ice Cave from the Ministry of Environment of the Slovak Republic, Decision No. 5213/967/01-5.1 from 25 January 2002. The initiation and international background of the project was covered by the company $SELOR_{EEIG}$, Amsterdam, The Netherlands as a result of preparation of project proposal for EU funds competition. Technical aspects (drilling, sampling, and isotopic and chemical analyses) were solved mainly in co-operation with University of Copenhagen, Denmark.

So far no special measurements of the ice age were accomplished in the cave, so no representative data on ice age was currently available on the ice. The goal of this project was to analyse climate and environmental changes by detailed study of continental cave ice using isotopic methods and methods of chemical analysis. According to existing knowledge, it could be reasonably supposed that cores of cave ice from Dobšiná could add new information to the Holocene climate record of continental Europe.

The contribution presents details about projecting, sampling, drilling, samples storing and transport of Dobšiná Ice Cave samples, special technical conditions regarding drilling in so called "warm ice", and manipulation with samples before isotopic and chemical analyses. Interpretation of the results is presented in this workshop in the contribution by H. B. Clausen, et al. "Continental ice body in Dobšiná Ice Cave (Slovakia) – Part II. – results of chemical and isotopic study".

Key words: Dobšiná Ice Cave, drilling, sampling, samples transport

INTRODUCTION

The Dobšiná Ice Cave (Slovenský raj Mts., Slovakia) is of the static-dynamic type of cave whose icy masses have been formed and are being supplemented every year through natural cooling of the spaces during the winter season when cold air flowed and still flows through the higher situated opening into to the lower positioned spaces and cools the rocky walls. An average annual air temperature in the Great Hall is –3.9 °C to +0.2 °C and an average air humidity reaches 75 – 90 % (Droppa 1960, Bobro et al. 1994, Bella 2001, 2003).

Recently new evaluations of amount and distribution of ice masses in the Cave have been studied by modern geophysical methods (e.g. GPR-georadar measurements, up-dated morphometric measurements) (Géczy – Kucharič 1995a,b, Tulis – Novotný 1995). In spite of some limitations of interpretation, the thickness of ice from 2.5 to 26.5 m was ascertained. The biggest thickness of ice was found in the Great Hall (26.5 m). 9772 m^2 of total area covered by ice was evaluated. The volume of free space in the Cave was estimated as 33 921 m^3, while the volume of cave ice was 110 132 m^3 (Géczy – Kucharič 1995b). Hydrogeochemical research of the Slovak Caves was realized by Tereková (1990). The same author started to work in 1982 on the methodology of research task "Dating of ice in the Dobšiná Ice Cave", however, this task was not realized at all (V. Tereková, personal communication). Results of studies about ice masses in the Dobšiná Ice Cave, including movement of the ice mass, was published recently by Tulis (1996, 1997), Lalkovič (1995), and Filip (1996). Field investigation proved that general movement of ice body is southward to SE from the cave entrance, the Small Hall and the Great Hall in direction to basement and towards the Ruffiny´s corridor. Lalkovič (1995) found out in the Small Hall of the Cave horizontal movement of ice mass from 10.7 to 14.8 mm per year, and in he Great Hall 5.4 to 18.1 mm per year. Vertical movement reached values 1.5 to 78.5 mm.

The goal of presented work was to analyse climate and environmental changes by detailed study of continental cave ice using isotopic methods and methods of chemical analysis. According to existing knowledge, it could be reasonably supposed that cores of

cave ice from Dobšiná could add new information to the Holocene climate record of continental Europe. Changes of climate are closely related to changes in environment, so project results were supposed to be interesting from ecological point of view, as well.

Climate change studies would contribute to the attaining of commitments made by the EU in international treaties and agreements triggered by global concern about the environment. *"A better formulation of environmental policies"* (Kyoto Protocol 1997) can only be achieved when a better understanding of climate fluctuations, their causes and triggers is known. While an increase in global temperatures of 1 – 3 degrees over the next 80 years is calculated as a result of anthropogenic input, the rise is not higher than natural fluctuations, and so it is not clear if this will have any influence on the occurrence of climate driven abrupt changes. By studying the unique Dobšiná Ice Cave continental ice mass body, which can be calibrated against (sub)recent measurements, it may be possible to gain an insight into the potential effects.

The contribution presents details about projecting, sampling, drilling, samples storing and transport of Dobšiná Ice Cave samples, including specific technical conditions regarding drilling in so called "warm ice", and manipulation with samples before isotopic and chemical analyses.

Interpretation of the results is presented in the related workshop contribution H. B. Clausen, et al. "Continental ice body in Dobšiná Ice Cave (Slovakia) – Part II. – results of chemical and isotopic study".

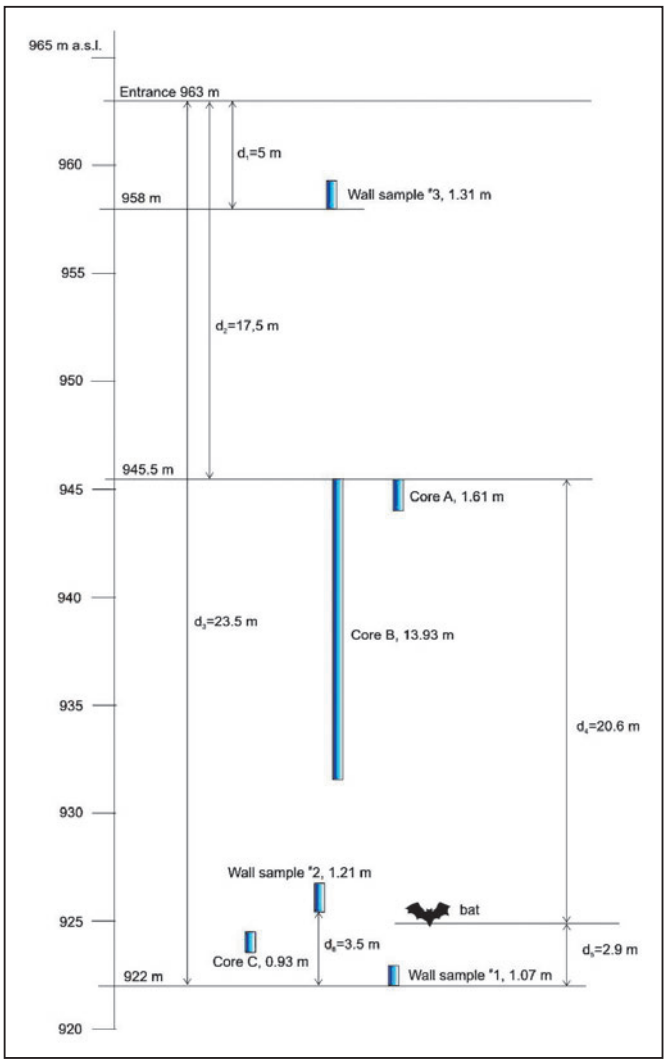

Fig. 1a. Location of sample sites – block scheme

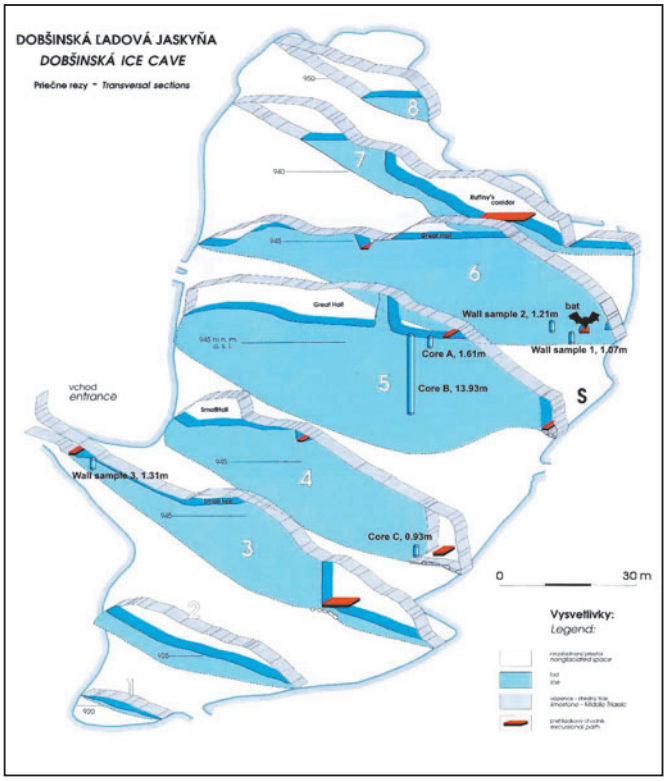

Fig. 1b. Location of sample sites – block diagram

MAIN STEPS OF PROJECT SOLUTION

The main steps of project solution were as follows:

- preliminary sampling and testing analyses, selection of drilling sites
- drilling, sampling, samples storing and transport
- laboratory works and data interpretation.

1. PRELIMINARY SAMPLING AND "TESTING" ANALYSIS, SELECTION OF DRILLING SITES

Field works with the aim to locate sampling places for "testing" samples and examine drilling conditions, to precise drilling sites locations and clarify sampling and samples procedures was accomplished by the "preparatory" working group of experts (J. Baker, S. Bo Hansen, K. Vrana) accompanied by Mr. Ľ. Očkaik, cave manager, Dobšiná Ice Cave, and Mr. M. Peško, hydrogeologist, Slovak Cave Administration, in March 8, 2002.

During the Cave excursion the "preparatory" working group agreed to take three testing samples of relevant volume from the "oldest" and "youngest" part of the continental ice (location in Fig. 1 – "wall samples" denoted as Wall samples 1, 2, 3 and photo

documentation in Fig. 2). Three samples were taken in June 21 – 22, 2002 and analysed for isotopes, chemical elements and constituents in laboratories of the Copenhagen University. Test samples were taken by Prof. Henrik Clausen and Steffen Bo Hansen from Copenhagen University, Kamil Vrana (HYDEKO-KV), Ján Zelinka and Ľubomír Očkaik (SCA).

Fig. 2. Photo documentation from sampling of "wall samples"

Regarding to drilling possibilities the conclusion was that the best place for drilling (to reach the longest possible core profile), is the Great Hall.

2. DRILLING, SAMPLING, SAMPLES STORAGE AND TRANSPORT

The Dobšiná Ice Cave is accessible for a drilling rig. Drilling, sampling, transport and storage of the ice cores were a complex task, which was undertaken by a specialised partner team in the period 8. to 13. December 2002.

The drilling was agreed in the Great Hall of the Cave close to the ice body called the "Well". Two boreholes were realised (see Fig. 1a, b):

- the first one to the depth 1.62 m (stopped by buried wooden pavement) – samples denoted as *Core A*, 5 m SW from the Well (location in S-JTSK: x=1219548.566, y=331837.760 and z=949.004)
- the second one to the depth 13.93 m (stopped by rock - ground?, boulder?) – samples denoted as *Core B*, 3m N of Core A (location in S-JTSK: x=1219551.328, y=331819.191, and z=949.784).

Drilling was accomplished in November 2002 by light drilling rig developed especially for conditions of Dobšiná Ice Cave by Henry Rufli from the University of Bern, Switzerland (Fig. 3). Drilling tower was 3 m high and only electric power was used for coring.

Plastic materials were used and the drillers were aware of the problem of sterility of materials used for direct sampling **(**Fig. 4). All materials used during coring were environmentally friendly. After coring the ice the relevant samples were immediately placed in special cold storage boxes and transported by car to the laboratory of the University of Copenhagen.

After drilling ice core samples in the Great Hall, another two types of samples were collected for chemical and isotopic analysis:

- *core sample* (93 cm, denoted as *Core C*) at the bottom of the Cave (Fig. 1) taken with help of an electrically driven hand drill (see Fig. 5), and
- *sample of bat* cutt off in the Ruffiny´s corridor, nearly at the bottom of the Cave (Fig. 6).

SUMMARY

As denoted above, several samples of ice were taken during the preparatory project phase:

1. PILOT OR "WALL SAMPLES" (21 – 22. 6. 2002) taken from 3 places denoted in Fig 1 as follows:
   - *Wall sample 1*: a bottom part of ice mass at the pavement close to Ruffiny´s Chapel ("the oldest" sample)
   - *Wall sample 2*: the lowest part of ice mass at the tourist pavement ("the oldest" sample – "ground floor" sample), and
   - *Wall sample 3*: a top peak of ice mass at the Cave entrance ("the youngest" sample)

2. ICE CORES DRILLED BY DRILLING RIG
   Core A – the first borehole in the Great Hall close to the "Well" to the depth 1.62 m (stopped by buried wooden pavement)
   Core B – the second borehole in the Great Hall close to the "Well" to the depth 13.93 m (stopped by rock - ground?, boulder?)

3. ICE CORE DRILLED BY HAND DRILL
   Core C – core sample 93 cm, drilled up-ward at the bottom of the Cave – nearly oposit to Core B.

4. SPECIAL SAMPLE: bat bones from the ceiling of Ruffiny´s corridor.

Laboratory testing included:

- physical properties
  (growing of ice crystals)
- chemical analysis
- isotopic analysis

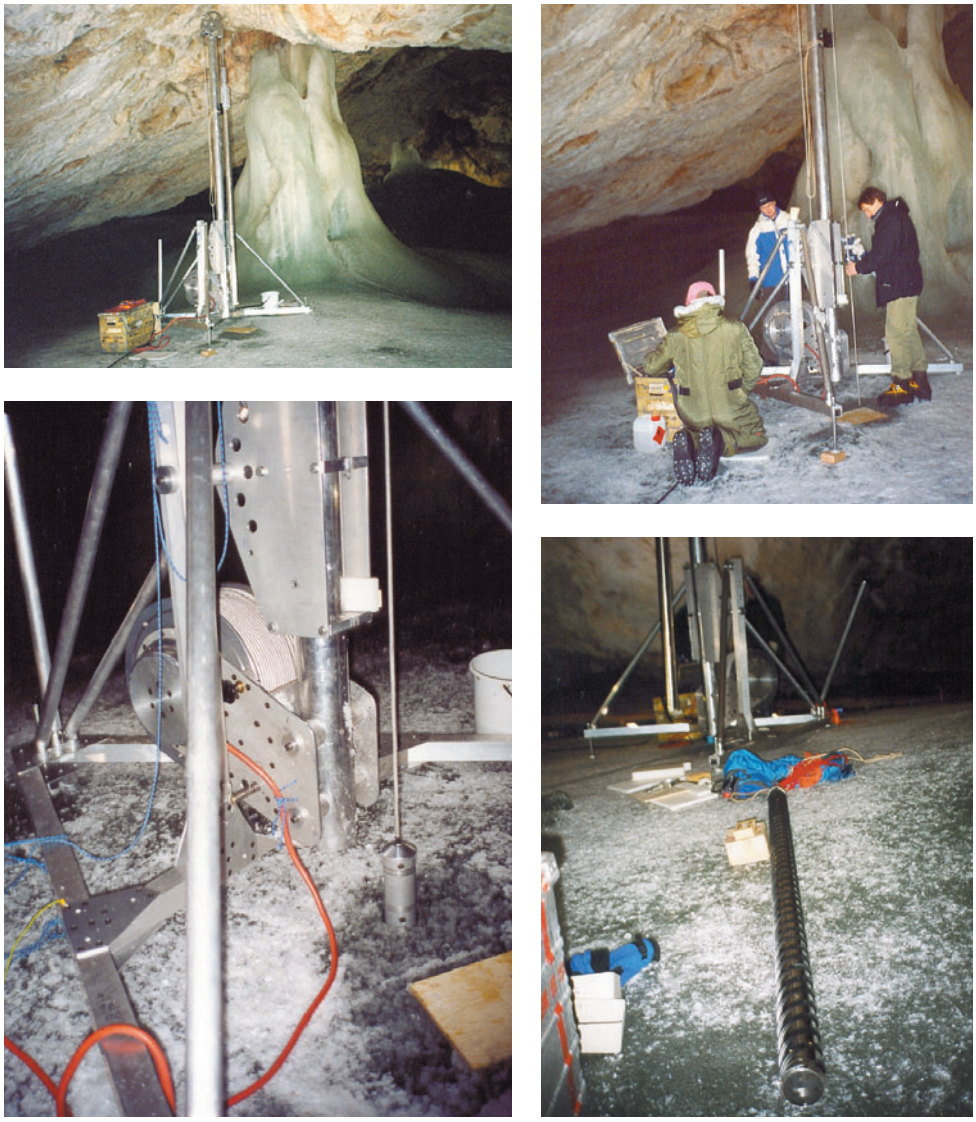

Fig. 3. Drilling rig developed for the Dobšiná Ice Cave by Henry Rufli, University of Bern, Switzerland and details of drilling rig

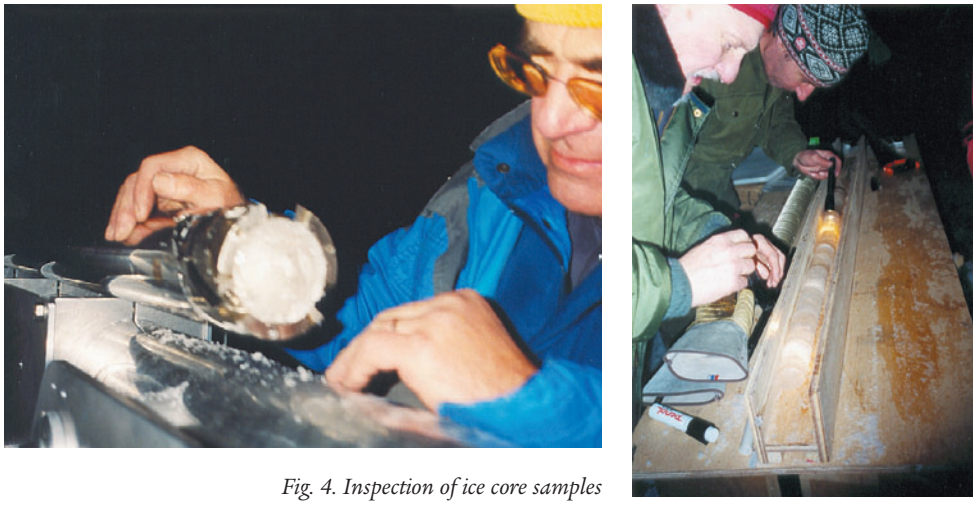

Fig. 4. Inspection of ice core samples

Brief description of procedure used and substantial technical notes:

- collection of ice samples in case of "wall samples" was realized by simple cutting of vertical ice blocks from ice wall by the help of an electrical chain saw – samples were taken by experts of the Copenhagen University in the cross section 5 x 5 cm and splitted into length of 20 cm. Samples were stored in cooled boxes and transported in frozen state by car to Copenhagen
- preliminary results of chemical and stable isotope analysis ($\delta^{18}O$, δD and calculation of d-excess) of pilot samples served for main orientation in analysing and interpreting drilled ice core samples – it had to be taken into account the so called Arnason effect (result of isotopic fractionation due to percolation of melted water through ice masses)
- preliminary results of study of ice crystals growing indicated some differences between "younger" and "older" samples
- the height of the drilling rig was 3.00 m and totally needed height for drilling set was 4.50 m. Drilling was realized by rotation of the core barrel provided with drill bits at the end. The core barrel rotated inside an outer barrel which was provided with an anti torque system to prevent the outer to rotate during drilling. The core barrel was provided with core catchers to prevent loss of the ice core during hoisting up of the drill.
- ice samples were collected and stored from the borehole core according to methodology developed by experts of the Copenhagen University for conditions in continental ice sheet drilling – 2 m core samples were described in detail and photodocumented and then splitted in 0.40 m sections for transport in the frozen state to the laboratory (in the laboratory the resolution of the analysed samples was 2.5 cm)
- samples were stored in special cooled boxes and transported to Copenhagen University for further elaboration

Fig. 5. Sampling with the hand held drill at the bottom of the Cave

Fig. 6. The buried bat cut off the ice in the Ruffiny´s corridor documentation from sampling of "wall samples"

– because the temperature of the ice in the Cave was relatively high (-0.94 °C at the temperature of air in the Great Hall -3.1 °C), rotating of drill head caused melting and refreezing at the drill head. This practically ceased the drilling – for this reason a small amount of 2 % solution of methanol was added to the borehole to enable effective drilling
- stable isotopes analyses ($\delta^{18}O$, δD) of ice samples were performed by Mass Spectrophotometer at the Copenhagen University
- bat bones were examined at the University of Kiel, Germany, for analysis of ^{14}C
- ice samples were analysed by Ion Chromatography at the Copenhagen University for the water soluble compounds: (Li^+, Ca^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+, SO_4^{2-}, NO_3^-, F^-, Cl^-) results apparently exhibit differences between "older" and "younger" samples.

Interpretation of results is presented in the related workshop in the contribution H. B. Clausen, et al. "Continental ice body in Dobšiná Ice Cave (Slovakia) – Part II. – results of chemical and isotopic study".

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