EVIDENCE OF BASAL MELTING OF THE ICE BLOCK FROM SCĂRIŞOARA ICE CAVE

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Abstract

External factors (precipitation and temperature) and internal ones (geothermal flux) are controlling the dynamics of the ice block in Scărişoara Ice Cave. Investigations so far concerned with the dynamics of the ice in relation with meteorological factors, the processes affecting the bottom of the ice being neglected. In this paper, using historical data, we highlight the role played by basal melting in the dynamics of ice in caves, giving also an approximate value for this parameter.

Доказательство донного таяния ледяного массива в пещере Скэришоара

Внешние факторы (атмосферные осадки и температура воздуха) и внутренние (геотермический поток) управляют динамикой ледяного массива в пещере Скэришоара. Исследования, как правило, концентрируются на взаимоотношениях динамики льда и метеорологических факторов, тогда как процессами, воздействующими на лед снизу, пренебрегают. В этой статье, используя исторические данные, мы выдвигаем на первый план роль донного таяния в динамике льда в пещерах, давая также приблизительную оценку этого параметра.

Site description

Scărişoara Ice Cave (46°25′N, 22°52′E, Fig. 1) hosts the second largest underground glacier in Europe – 75.000 m^3 of ice. The entrance of the cave is located on the edge of the Ocoale Plateau (Arieş catchment area, Apuseni Mts.), at 1265 m asl (465 m above Gârda Seacă Valley, the main tributary of Arieş). The cave consists of four main sections: The Great Hall, The Church, The Little and the Great Reserve (Fig. 2).

The ice block is located in the Great Hall, covering a surface of about 3000 m^2. The average thickness is 20 m, the maximum being 22,53 m (Holmlund et al., 2005). Both internal and external controllers are influencing the dynamics of the ice block. Between June and October, due to dripping waters and heat transfer through conduction, a shallow lake develops at the surface of the ice block, generated by the melting of the uppermost layers of ice. The freezing of this lake in late October builds up two distinctive layers: the bottom one containing impurities, and the upper one with clear, bubbly ice. Percolation of water during winter months ads more ice to the upper layer. Thus, the block has a clearly visible horizontal stratified structure, with layers of ice up to 15 cm, in alternation with layers (2 to 7 mm) containing impurities (calcite, dust, pollen, wood remains etc). Cold air, with water vapour content frequently below 90%, enters the cave in the winter months, leading to rapid ablation of the surface of the ice block. On the other hand, this cold air is also responsible for the onset of ice development in late autumn (October–November).

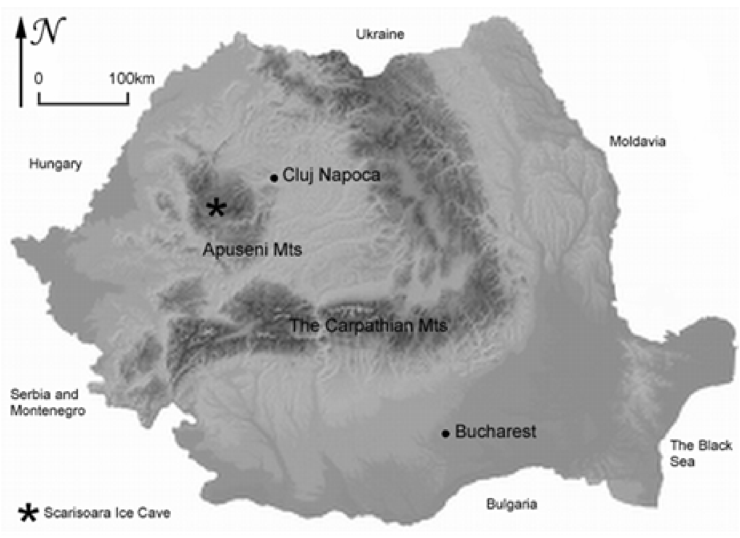

Fig. 1. Location of Scărişoara Ice Cave

At certain distance around the ice block, ice stalagmites have developed. The freezing of dripping waters generates these ice stalagmites. During summer, as there is no cold air input from the outside, the cold wave generated by the ice block partly ceases, so these formations begin to melt, in some years even completely.

The main factor in the dynamics of ice stalagmites in Scărişoara Cave is the dripping water which, depending on temperature, can act as a favourable element for both the growing and melting of ice. Between January and April the ice speleothemes have a growing phase, more important in March and April (as there is an large input of dripping water, generated by melting of snow and precipitation, while inside the cave the temperatures are bellow 0ºC). Starting with May, increase of temperature and also warm percolating water led to a rapid melting of ice.

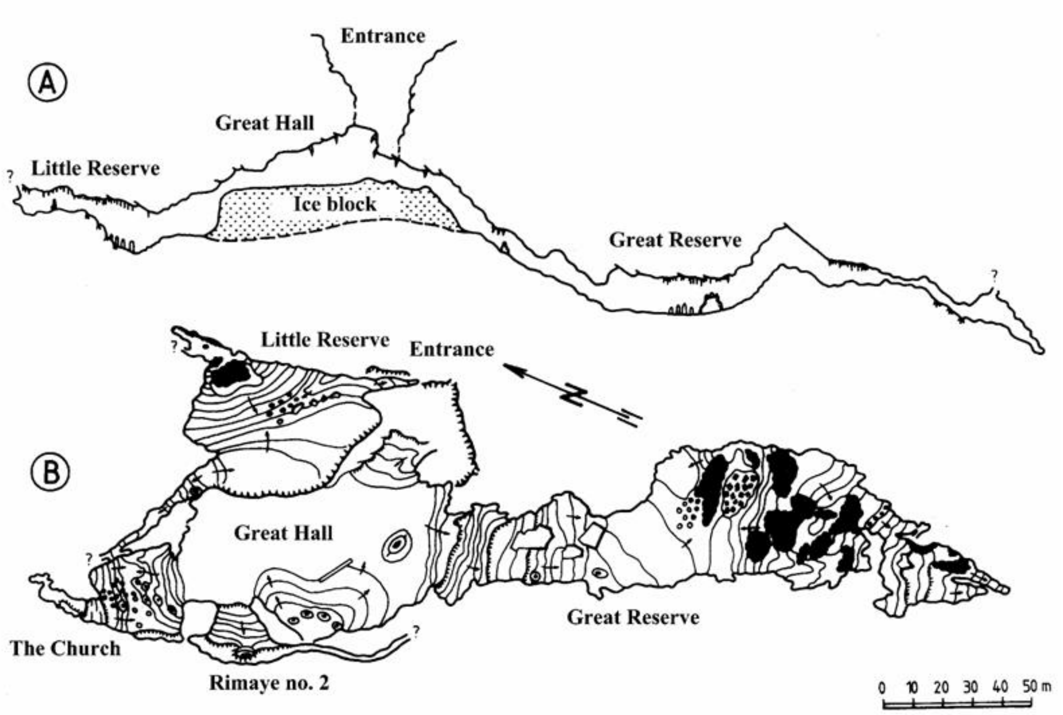

Fig. 2. Map and cross-section of Scărişoara Ice Cave (after Rusu et al., 1970, modif.)

The climate of the cave is a complex one, with four meroclimatic zones (Racoviță, 1984): a transition meroclimate in the entrance shaft, a glacial zone in the vicinity of the ice block (with mainly negative temperatures during the year), a periglacial one at certain distance from the block (with shifts between positive and negative temperatures during one year), and a warm meroclimate in the non-glaciated parts of the cave (positive temperatures all year long). The repartition of these meroclimates is reflected by the thermal pattern of the cave: while in Great Hall the mean annual temperature is around - 0,9ºC, it increases to - 0,2ºC in the Great Reserve and 4,3ºC in the Coman passage.

Air circulation is one of the most important factors for the glacial phenomena in this cave. In winter, airflow is directed from the surface downward into the cave. The cold air replaces the warm air from the cave, which rises and exits the cave along the ceilings. This type of circulation is lasting for approximately 5 months between November and April (Racoviță, Onac, 2000).

In summer, since the cold air in the cave is denser than the external one, there is no air mass exchange between the two environments. Meanwhile, the temperature difference (and thus the density of air) between different parts of the cave led to the establishment of two convective cells, linking the Great Hall and the two reservations. Cold air maintained by the overcooled walls and the ice block, flows down into the reservations replacing the warm air. This warmer air rises and follows the ceiling of the cave, but as it reaches the Great Hall's walls it cools down and descends, thus maintaining the convection. This type of circulation occurs from May until October.

In April and October, rapid changes between summer and winter types of circulation occur, as temperature varies around 0ºC.

Methods

Two data sets are available: one containing the dynamics of the surface of the ice block between 1982 – 1992 (Racoviță, 1994), the second (Racoviță, Crăciun, 1970) recording the vertical descent of the whole ice block (1966 – 1968). Also, present day records were used (2005).

The measurement of the dynamics of the ice block was performed considering the surface of ice in the Great Hall (Fig. 2) at the beginning of the measurement cycle as a reference horizon, and measuring thinning/growth of ice relative to this level (Fig. 3, A). Thus, only dynamics due to external factors was measured. To compensate this, the variations of the ice block were also measured against the rock wall of the cave, both surface and basal dynamics being recorded (Fig. 3, C). The measurements were made with a monthly frequency, the error being less the 0,5 cm.

The total vertical descent of the ices block was measured using the device in Figure 4 (Racoviță, Onac, 2000). In this case, only vertical variations at the bottom of the ice block were recorded. The device was installed in the Rimaye no. 2, at a few meters below the surface of ice. The lowering of the ice block was measured continuously, monthly values being further calculated (with an error less than 2 mm).

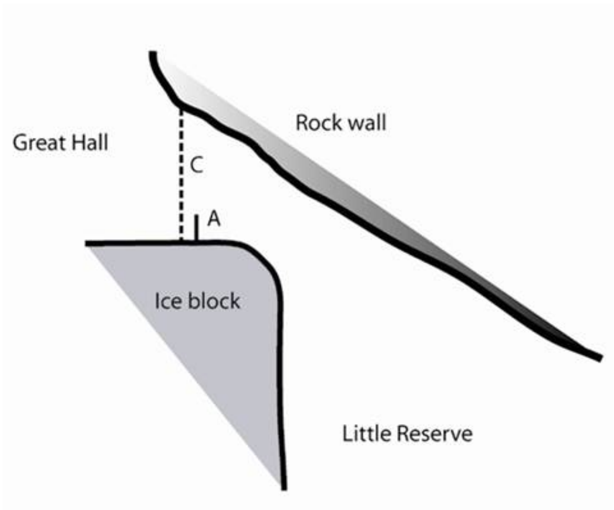

Fig. 3. Measurement station in Great Hall

Results and discussions

Measurements performed in the rimaye show a continuous lowering of the base of the ice block (Fig. 5). On a period of 28 months (January 1966 – April 1968) a total of 43,1 mm of ice has melted at the bottom of the block (Racoviță, Crăciun, 1970), which means 1,54 mm/year. The ablation of the base of the ice block is due to both melting, generated by the geothermal flux and sublimation, due the circulation of cold and dry air under the ice block (Perşoiu, 2004).

The data obtained at the measurement point in the Great Hall is more complex in interpretation. Two different observations were performed. First, it was measured the dynamics of the upper surface of the ice block, relative to the existing level in 1986[1] («A» in Fig. 3). The results (Fig. 6) show a growth of 9,5 cm of the ice level, relative to the surface from 1986, in close relation with meteorological conditions outside the cave - growing periods in spring and melting in summer and autumn (Racoviță, 1984, Racoviță, Onac, 2000). Second, it was measured the distance between the ice block and the rock wall. In April 1986, this distance was 155 cm. Measurements showed a decline of this parameter, of about 2,5 cm by the end of 1992 (the distance between the wall and the surface of ice being 152,5 cm). Comparing these two values (growth of 9,5 cm and lowering of only 2,5) we can concluded that a supplemental 7 cm of ice have melted away, due to basal melting of the ice block. As shown in Fig. 7 some periods of growth are visible. As this is an impossible process, we assume that errors in measurement are responsible[2]. Calculations of yearly basal melting show a value of 1.16 cm/year, which is less than the one recorded in Rimaye no. 2. Data from May 2005 show that the distance between the ice surface and the wall is 155, while at the surface of the ice block an increase of 37cm is recorded. The total mass balance of the ice block is «0» for the interval 1986 – 2005, so the «missing» 37 cm represent the basal melting for the period 1986 – 2005; calculated to have a rate of 1.54 cm/yr (similar to the value recorded in the 1960s).

The data presented here show a clear process of melting, affecting the base of the ice block in Scărişoara Ice Cave. We assume that both geothermal flux, with values of about 70 mW/m^2 (Demetrescu, Andreescu, 1994), and cold air input are responsible for this process. As the melting due to geothermal flux affects the base of the ice block, small openings occur, which allow the penetration of cold and dry air under the ice block in winter (Perşoiu, 2004), leading to an important process of sublimation, and thus enlargement of the initial tunnels. Two evidences support this: scallops on the walls of under glacial tunnels and hoarfrost deposited by warmer air currents exiting these tunnels. As melting due to geothermal flux is constant, we assume that the variations in the intensity of this process are determined by external meteorological conditions (air temperature and relative humidity) influencing the sublimation. New measurements are in course, in order to quantify the influence of these two factors.

Reassessment of historic measurements undertaken in Scărişoara Ice Cave, combined with present day ones, have showed that the base of the ice block hosted by this cave is affected by a continues melting processes, with a mean rate of about 1.54 cm/yr. Both internal (geothermal flux) and external factors (air temperature and relative humidity) govern the intensity of the process.

Conclusions

These findings have an important role in the assessment of the age of the ice block, as the beginning of cave glaciation can be pushed back in time, beyond the calculated age of the ice block: 3500 yr (Pop, Ciobanu, 1950). Also, dynamics of ice in caves meteorological and climatic variations needs to be re-assessed, as so far basal melting was not considered as an important process acting in glaciated caves.

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[1]Measurements of the dynamics of the upper surface of the ice block begun in 1982, but for the purpose of this study we use data only since 1986, as prior to this date, measurements of the total lowering (upper and basal) of the ice block were not performed.

[2]In summer time, a shallow lake, up to 20 cm in depth covers the surface of the ice, so mistakes while measuring could be a reasonable explanation.

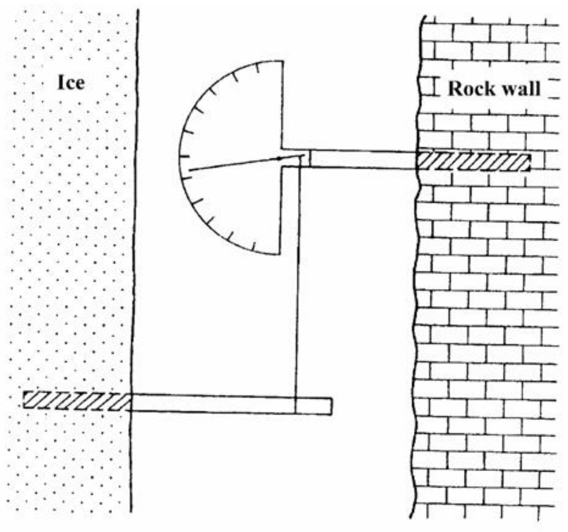

Fig. 4. Measurement device in Rimaye no. 2 (Racoviță, Crăciun, 1970)

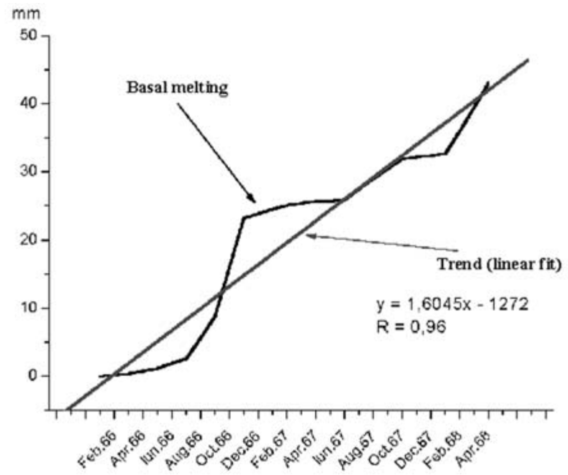

Fig. 5. Basal melting of the ice block recorded in Rimaye no. 2 (1966 – 1968)

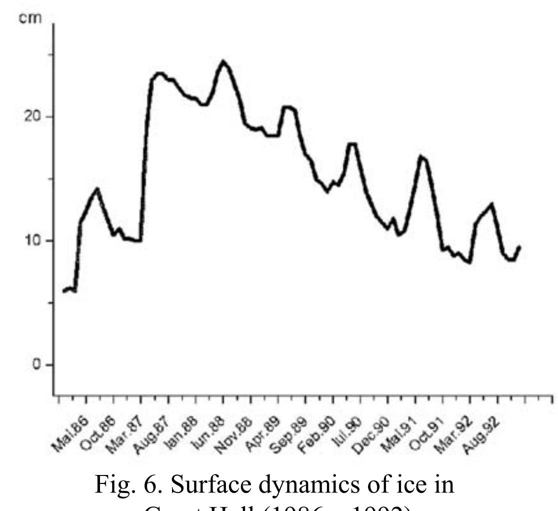

Fig. 6. Surface dynamics of ice in Great Hall (1986 – 1992)

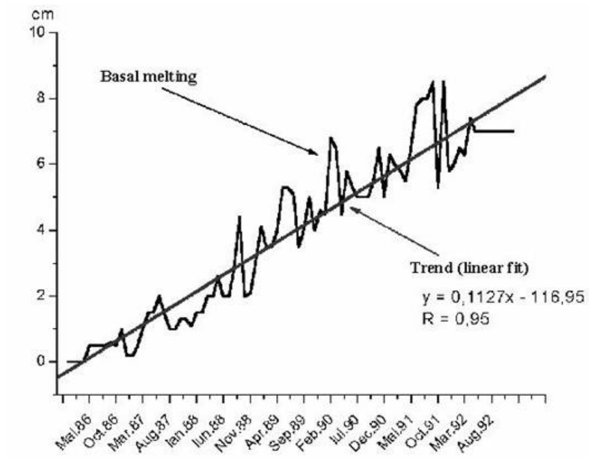

Fig. 7. Basal melting of the ice block (1986 – 1992)

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