# ULTRASONIC INVESTIGATIONS ON THE UNDERGROUND FOSSIL GLACIER IN THE CAVE GHEȚARUL DE LA SCĂRIȘOARA (ROMANIA)

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The intimate structure of an underground fossil glacier provides most important information on cave glaciation and its relation with the overall climate evolution. Ultrasonic probing in one of the most interesting and important cave glaciers — Gheţaul de la Scărişoara — resulted in a surprising image of ice/sediment layering of the 75 000 m³ of ice. A marked melting between 1948 and 1984 is also documented by ultrasonic imagery, as well as the mixing of the upper layers because of annual melting and freeze, which rework sediments in an intricate pattern that very much complicates paleoclimate reconstructions.

## 1. GENERAL DATA

The cave Gheţarul de la Scărişoara is located in the central area of the Bihor Mountains, on the karstic plateau of Scărişoara, within the limits of the village Gîrda, department of Alba.

The cave has a mixed morphology, consisting of a 48 — m — deep, 50 m across entrance shaft, a second, 52 — m — deep lateral shaft, and a large void on their bottom, with two distinctive sections :

— a central hall 108 m long, 78 m wide, which actually includes the Great Hall, the Little Hall, the Church and the Little Reserve.

— a wide passage known as Maxim Pop Passage to SE, issuing into another great hall — the Cathedral. At the far-end of this hall, a narrow passage called Margaret's Window, leads through the Coman Passage to the deepest point of the cave at — 105 m (fig. 1).

The stratified ice block lies in the mid-section of the central hall, its southeastern edge descending about 20 m into the Maxim Pop Passage. Though no drillings have been made so far, by indirect measurings the thickness of ice is estimated to at least 24 m. The glacier consists of probably more than 1, 000 ice layers 0.5 to 15 cm thick, separated by films or even layers of sediments (dust, clay, leaves, erratic breakdown slabs and tree trunks and branches). The relative age of the lowest layer of ice was estimated on pollen grounds to 3.5 Kyr (P o p a n d C i o b a n u, 1950). This estimate is probably the lowest figure, since melting at the bottom of the ice block due to lithostatic pressure removed older layers.

The sides of the ice block are either leaning upon the rock walls or free. The lateral ice/rock contact is possible in the upper parts only, i.e. the areas where cold air-currents overcool rock. In the deeper parts, where ice blocks air-currents, the geothermic flux melts ice, generating so-called "rimayes".

Altogether, the many layers of ice and sediments are an excellent paleoclimate record. Given the extremely reduced technical hardware available to the "Emil Racoviță" Institute's staff, the detailed research of this record has been postponed. However, one of the topics we have been focussing on, is the relief of the bottom of the ice block. Direct investigation is practically impossible, except for a short segment in the Little Reserve, where access beneath the ice block is free for several metres. Thus

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we have attempted some indirect investigation such as ultrasound. By courtesy of Mr. I. Bucur of the Optical Division of Măgurele Scientific Center, we have investigated the ice block with an ultrasonic probe (type INCO DE – 23P), aiming to obtain data on its contact with the breakdown pile supposed to support it. At full power and a frequency of 0.5 MHz, the maximum penetration with visible reflection peaks did not exceed 5 m (Fig. 2 and 3). In compensation, the image provided, is an accurate insight into the detailed structure of the upper layers of ice.

## 2. PREVIOUS DATA ON ICE LAYERS

Şerban et al. (1967) had pointed out the difficulty to establish the time extent corresponding to one layer of ice. The annual sedimentation in actual conditions follows several steps : in summertime, a lake covers important areas of the top of the ice block. The water comes from three different sources : melting of ice, melting of the snow on the bottom of the entrance shaft and seepage water. On the bottom of the lake, directly on ice, a layer of solid residues accumulates, consisting of cryoclastic dust, erratic breakdown slabs, organic matter – mainly of floral origin – and soil. The latter two are more common in the vicinity of the entrance shaft. As Şerban et al. (1967) pointed out, their extent on the ice block is related to outer climate (warm periods would send organic matter to the deeper parts of the cave, colder periods would restrict it to the entrance area). In wintertime, the lake freezes, beginning with the top, then, trapping air-bubbles, down to the bottom. The solid residues are thus delimiting the lower face of an annual layer. All impurities tend to be expelled by crystallization of ice, so a part of the residues must result this way. The next summer interval may (and usually does) melt more than the previous year's layer. Quite often, the sediments corresponding to several years mix, resulting important (thick) sediment deposits. This is why we consider Şerban et al. 's assumptions on the number of years vs. number of ice/sediment layers as strictly informative. On the other hand, Pop&Ciobanu's (1950) estimated age of the entire block of ice – 3–3.5 Kyr – (on pollen association grounds) covers only the existing ice/sediment compounds. One must however take into consideration the melting and elimination of older ice deposits by lithostatic pressure of ice. Thus, the age of cave glaciation i.e. the moment of its engendering, is still a question to be answered.

## 3. ULTRASONIC CROSS-SECTIONS

Two cross-sections have been investigated (Fig. 2 and 3) with probing every second metre. The reflection image (Fig. 4) shows a high resolution for the first 1–2 metres and a fast attenuation with depth. For the interpretation of echoes we considered groups of dense peaks as packs of ice intimately associated with sediments (corresponding to repeated melting/mixing episodes associated to warm spans) and the lack of peaks as widely crystallized ice with little to no sediments (corresponding to colder spans).

*Section A–A'* (Fig. 2). Goes along the long axis of the ice block. Layering is practically horizontal, with several slightly marked "folds". These

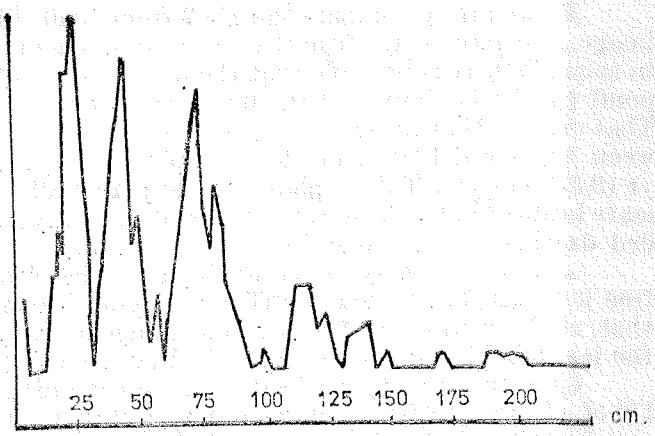


Fig. 4 — Sketch of the ultrasonic image on probe screne corresponding to point 3 in cross section A—A. The numbers represent depth.

are actually areas of a certain ruggedness of the top of the ice block, probably caused by uneven melting and draining of melt water.

The first 0.5 m show little sediment accumulation which advocates for a colder span. The segment between points 4 and 9 is an exception probably due to the vicinity of the entrance shaft.

The following 2 metres reveal a predominance of sediments and probably a warm span, less marked in the northwestern section (deeper in the cave). There are three segments with more sediment between points 1 — 6, 13 — 22 and 25 — 28. They are probably related to the main and second shafts' input of sediments. The last segment shows a relatively constant ice/sediment ratio which suggests more constant conditions (less influence from outside). The remainder has a clear predominance of ice, another cold span which may be the cold interval at the end of the 18th century, if Serban and Racovita's assumptions (1987) are correct.

We must point out the resemblance of the two edges of the cross section i.e. the relative constant ice/sediment ratio. There has also to be mentioned that the northwestern edge shows clear trends of bending (inclining).

*Section B—B'* (Fig. 3). Is perpendicular to section A—A' (Fig. 1). Ice layering is clearly inclined (monocline). The three vertical zones in section A—A' are present, but the sediment layers are less numerous but thicker. The inclined character is related to the overall structure of ice, subject to a previous study (Silvestru, 1989). In this specific case, the cause is the vicinity of the Little Reserve and its 16 m vertical wall of ice.

## 4. CONCLUSIONS

The first (direct) probing of the ice block (at a site close to our cross sections (Fig. 1)) dates back to 1948 (Serban et al.) when a 1.09 m sample of ice (similar to a core) had been extracted. By the time the second sample (42 cm long) was extracted (1960) the authors (Serban et al., 1967) noted that all 1.09 m of ice sampled in 1948 from the top of the ice block, had disappeared (melted).

If we are to compare sample 2 from 1960 (Fig. 2) with the ultrasonic image, we may fairly afirm that the first 0.5 m of the latter cannot be found in sample 2. It is possible that the last 5—6 cm of the sample may correspond to the beginning of the 0.5 m of sediment-free ice in section A—A'. That means that at least 35 cm of the ice block's upper layers melted between 1960 and 1989. Added to sample 1's 1.09 m, that means 1.44 cm/41 yr (3.54 cm/yr). This explains the apparent discordance between the climate indicated by the nature of ice/sediment layering and the climate recorded during the last decade (cold vs. warm).

All of these may be reasonably assumed, provided no new sediment-free ice has formed and lasted since 1960. Various information confirms that, at least until 1984/85 when a change of the general trend (raising) of the ice block's top has been marked (R a c o v i t a et al. 1987).

One thing to be noticed is the great amount of sediments (almost 1/2 of the investigated volume of ice), a rather surprising feature, given the previous image provided by the flanks of the ice block and the sampling performed in 1948 and 1960. It is possible however that not all echoes are coming from layers of sediments. This is why we considered as coming from sediments only the well-marked peaks, the weaker ones being possibly produced by differences in ice structure. Anyway, the amount of sediments is a fact which must be taken into consideration when ice dynamics is investigated. When paleoclimate reconstructions are attempted, thick sediments may be considered marking warm *periods* rather than individual years, since they represent recurrent melting episodes and not necessarily sediment—rich seasons.

The bending at the limits of the ice block in all directions, confirms the supposition that it rests in a conical breakdown pile whose convexity matches the ceiling concavity.

Further investigations are needed, with more efficient equipment which would provide more details on the geometry of the underground glacier and its age/climate record.

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