The Cryosphere Discuss., 4, C1309–C1323, 2010
www.the-cryosphere-discuss.net/4/C1309/2010/

The Cryosphere Discussions

Interactive comment on "Ice genesis and its long-term dynamics in Scărişoara Ice Cave, Romania" *by* A. Perşoiu and A. Pazdur

A. Perşoiu and A. Pazdur

apersoiu@mail.usf.edu

Received and published: 9 December 2010

Response to comments and suggestions by M. Citterio

Comment: 1) the stable isotopes fractionation trends observed in present day ice layers are said to be similar to those found for deeper ice layer dated to the LIA and MWP (p. 1916, l. 26-29): please add the data points for these O and D trends in fig. 3. This is a very nice finding indeed, probably the first time that such a similarity between the isotope signature of observed present-day process and of older ice layers from the same cave ice deposit is published!

Response: isotope data for older ice has been added to fig. 3 (now fig 5)

Comment: 2) multi-annual trends in the mass balance of the ice deposit over the last

60 years are said to follow the pattern of wet/dry cold/warm years of the surface climate (p. 1918, l. 15-18): please add the temperature and precipitation time series in Fig. 2.

Response: There is a complex interplay between precipitation amount, precipitation timing and temperature, on one hand, and ice mass balance, on the other hand, and we don't fully understand it. Moreover, climate-independent processes are also affecting the mass balance of the ice block. RacoviÅčă (1994b, also cited in the manuscript) have shown that generally cold years are associated with ice build-up, while wet and warm ones with ice melting (p 1917, l5-18). However, this dos not clearly show up when the precipitation and temperature plots are viewed, which is the reason for omitting them. We added a plot with precipitation and temperature data from Băişoara station for the 1961-2003 interval. Observations for 2006-2010 are mostly based on discontinuous measurements (data from Băişoara is not available, and the measurements we took couldn't be homogenized we those form Băişoara, as there is no overlapping between the data sets) and personal observations and are not shown.

Comment: Before the "conclusions" section, I miss some more detailed discussion about the possible occurrence and significance of stratigraphic gaps, which can be expected to occur in cave ice deposits forming according to the proposed model, about how to detect them, and about how these may affect the estimated long term accumulation rates and age of this ice deposit. Compounded with the chance of radiocarbon-dating reworked organic matter older than the ice hosting it, stratigraphic gaps may prove a major obstacle in extracting useful/readable pelaoclimate information from this ice. The manuscript only briefly touches the issue by noting that two thick dark layers rich in organic and mineral content likely represent strong melt events affecting several layers (p. 1919 l. 3-8). As it stands now, part of the "conclusions" section is actually a summary, and needs to be improved, especially to the benefit of the wider cryospheric science community. In addition to putting the findings into perspective with regard to the issue of stratigraphic gaps, the age estimate is introduced without adequate discussion, especially considering the described ice deformation and the poorly known

bottom morphology of the ice block, and it reads a bit like an afterthought, not even being mentioned in the abstract. Finally, a note on terminology: within the glaciological community “ice dynamics” normally refers to ice flow, but it is used here mostly as meaning “mass balance fluctuations”. Please replace “ice dynamics” with this or a similar suitable expression throughout the text (specifying surface/bottom/: : : where relevant). This is especially important since ice flow in the cave is also addressed in a section of the manuscript.

Response: The following phrase, addressing the problem of possible stratigraphic gaps has been added in the introduction (Possible gaps and their role in interpreting paleoclimatic data are further discussed in the re-written conclusions): “Moreover, stratigraphic gaps detected in the ice could prove to be difficult to date and thus make the paleoclimatic reconstructions a challenging attempt.” The conclusions have been rewritten, and the age estimate was removed, as we do not have, at this point, enough and reliable data to support it. “Ice dynamics”: we have used the term interchangeably for both “dynamics” and “mass balance/ice level fluctuations”. We have made corrections throughout the text, either by using both terms, or only the relevant one (where appropriate).

Comment: Title: see my remarks about the proper use of the term “dynamics”

Response: We have changed the title to “Ice genesis and its long-term mass balance and dynamics in Scărişoara Ice Cave, Romania”. Like this, it reflects the three main directions of our study.

Comment: p. 1911 l. 4-7: Sentence not very clear, especially for the wider cryosphere audience outside the small cave ice people

Response: the sentence was deleted, as it was redundant (with the text immediately above it).

Comment: l. 20: please also cite the original Romanian names of Biserica, Reservatia

Mare, : : : as this will assist the reader in understanding the wealth of older literature only available in Romanian.

Response: Done. The Romanian names were also added to the map.

Comment: p. 1913 l. 12: “ice dynamics” here and everywhere else in the manuscript: fix inappropriate use of “ice dynamics”

Response: Changed to: “Air circulation is one of the most important factors affecting the mass balance of the ice in the cave.”

Comment: l. 16: “T<-15 C”: is -15 correct?

Response: Yes. However, air quickly warms-up as it penetrates deeper inside the cave.

Comment: l. 23: is this really due to “geothermal heat” or also/mainly the heat capacity of the rockmass?

Response: We have no data to discriminate between the two. For sure, both are influencing the air temperature and the text has been modified accordingly: “under the influence of geothermal heat and the heat capacity of the rock.”

Comment: p. 1914 l. 1-2: move sentence to the end of the “introduction” section

Response: The sentence is redundant, so we have deleted it.

Comment: p. 1915 l. 7: “upper part”: what thickness?

Response: The text was changed: “The upper 9 m of the ice block”

Comment: l. 12: “the preferential: : : isotopes” -> “isotopic fractionation”

Response: The text was changed: “due to isotopic fractionation processes in the forming ice”

Comment: l. 19-20: weight compaction is not the only process to go from snow to ice. Melt, percolation and refreezing may also occur.

Response: Yes. The mentioned mechanism is also ruled out in the next phrases. For clarity, we have modified the paragraph as follows: “Moreover, the reduced thickness of the snow pack allows percolating water (from melting snow and summer rains) to reach the bottom of it quickly, without freezing to further form ice. The freezing of water inside the snow pack is also prevented by the relatively high (between 0 and 0.5°C) air and snow temperatures (RacoviÅčă, 1994a). Most of the snow at the bottom of the shaft melts and drains away through fissures in the underlying limestone, with only occasional inflow towards the ice block.”

Comment: l. 23: what matters for the percolating water to refreeze or not is the snow temperature, not the air temperature

Response: see above.

Comment: l. 25: “impenetrable fissures” are only impenetrable in the caver’s perspective. Here they are effectively open, as they do drain the meltwater.

Response: Indeed. The text has been changed to “drains away through fissures in the underlying limestone”.

Comment: p. 1916, l. 3: “Persoiu 2010” is listed as “in review”. Has it been accepted?

Response: Yes, it is in press now.

Comment: l. 6: “freeze from to bottom” add “surface”

Response: Changed to “freeze from top to bottom”. The word “top” has been omitted in the manuscript due to a typing error.

Comment: l. 9: “over-cooled”? “colder” is better.

Response: Corrected.

Comment: l. 8: “winter, when warmer” -> “winter, when occasional warmer”

Response: Corrected.

Comment: l. 22-26: I think these are the same fractionation trend and interpretation first described for cave lake ice in Citterio M., Turri S., Bini A. & Maggi V. (2004) – Observed trends in the chemical composition, 18O and crystal sizes vs. depth in the first ice core from the “LoLc 1650 Abisso sul Margine dell’Alto Bregai” ice cave (Lecco, Italy). Theoretical and Applied Karstology (Special Issue on Ice Caves) n. 17, 45-50. Consider adding this reference.

Response: Added.

Comment: l. 26-28: as already comented above, this is very interesting, please overlay the relevant data on Fig. 3.

Response: Done.

Comment: p. 1917 “Ice dynamics” -> “mass balance”

Response: The title has been modified to “Ice mass balance fluctuations and dynamics” We have kept the term “dynamics’ as, apart from mass balance fluctuations, we also discuss ice dynamics (i.e., flow).

Comment: l. 9: “trends” -> “fluctuation” ?

Response: Corrected.

Comment: l. 14-17: Please add climate data to the plot as commented above.

Response: Done.

Comment: l. 19: Where is Pojarul Politei with respect to the Scarisoara? Also show on the cave survey where the collapsed connection was in Fig. 4.

Response: The text has been changed to “after the collapse of the passage (in the Little Reservation, see fig. 1), that was linking the cave with Pojarul PoliÅčei Cave” and fig. 1 was modified accordingly.

Comment: l. 21 “overcooling”?

Response: Changed to “cooling.

Comment: l. 23 “descending cave” has been used as synonymous for “cold trap” by cave topoclimatologists for caves with only one endrance and developing toward lower elevations. Here there is talk of caves with more than one entrance

Response: The text has been changed as follows: “as seen in nearby caves with two entrances situated at different altitudes (as Scărişoara Ice Cave must have been at that time)”.

Comment: p. 1918 l. 20: please provide a reference for the regional timing of the LIA

Response: Reference to Popa and Kern (2009) is made.

Comment: l. 21 fix “bellow”

Response: Done.

Comment: p. 1919 l. 3: does any melt take place at the lateral ice/rock contact?

Response: Yes. We have inserted the following phrase: “ Observations over the past 60 years have shown that melting starts at the triple junction between the rock wall, rock floor and ice wall (Fig. 4c), so that the an opening is created at the base of the ice wall while its upper part is still in contact with the rock wall.”

Comment: p. 1920 l. 5: fix “side of the it”, next line: “bellow”

Response: Changed to: “the sides of the block”. Done.

Comment: l. 18: take out “hereafter” and improve the “conclusion” section where it sounds mostly as a summary

Response: Done.

Comment: l. 23- p. 1921 l. 2: this is quite speculative and not fully developed. Either argument it better if there is enough supporting evidence/data or take it out. Also, I can’t see how the basal melt could be stronger at the periphery than at the center

of the ice block, thus helping preserving older ice there, if the mechanism producing subfreezing temperature is the air circulation described above and the rock mass is not in permafrost conditions (and from all evidences it is not, or else you would not have basal melting). This couple of sentences read much like an afterthought and they are not fundamental for the manuscript (no mention of this supposed 5000 years age in the abstract).

Response: We have rewritten the conclusions and removed the estimate for the age of the deepest part of the ice block. The possibility that ice is melting faster on the sides than in the center has been explained in the text (Chapter 4.2.), where the following proposition was inserted: “ Observations over the past 60 years have shown that melting starts at the triple junction between the rock wall, rock floor and ice wall (Fig. 6c), where the amount of heat delivered to the ice block is maximized, so that the an opening is created at the base of the ice wall while its upper part is still in contact with the rock wall.“ Reference to basal melting in the “Conclusions” chapter was, however, removed.

Comment: l. 5: Johnston & al. 2010 is not found in the references list.

Response: it is the 5th reference in the list.

Comment: Table 1: could you turn this table into a plot? Also, the line wrapping of the two rightmost columns is clearly screwed up.

Response: The table has been modified and a depth-age model was introduced as fig. 4. The main text has been modified accordingly.

Comment: Fig. 1: add Romanian names and position of collapsed junction to Pojarul Politei

Response: Done.

Comment: Fig. 2: add temperature and precipitation data

Response: Done

Comment: Fig. 3: add isotopes data for the deeper levels showing the same fractionation trends

Response: Done.

Comment: Fig. 4: explain + and – symbols and the arrows in the caption and possibly the junction toward Pojarul Politei

Response: Done. The former junction with Pojarul PoliÅčei cave was marked on Fig. 1.

The order and numbers of figures has been changed as follows: Fig. 5 was renamed Fig. 3 as it is the next after fig 2 to be cited in the text (following text reorganization). The depth-age model is inserted as Fig. 4. Fig. 3 became Fig. 5. Fig. 4 became Fig. 6.

The radiocarbon ages have been recalibrated using the newer OxCal 4.1 and the INTCAL09 dataset of Reimer et al. (2009).

Interactive comment on The Cryosphere Discuss., 4, 1909, 2010.

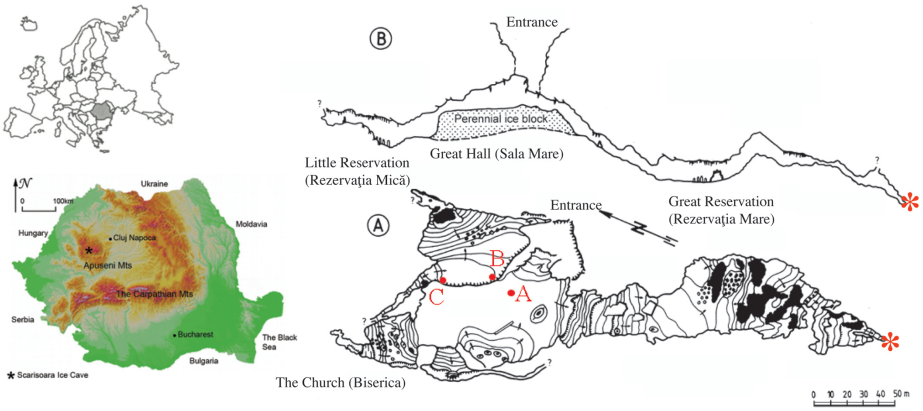

Fig. 1. Fig. 1. Location map, plan view (A) and cross section (B) of Scărişoara Ice Cave (modified from Rusu et al., 1970). See full caption in the final revised manuscript

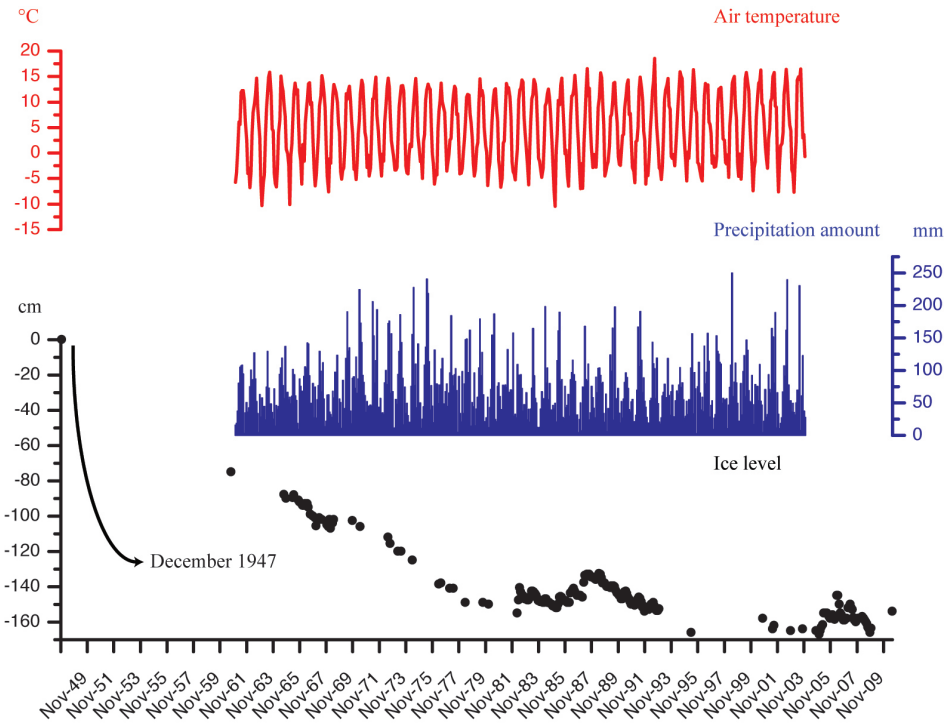

Fig. 2. Fig. 2. Short-term ice level fluctuations in Scărişoara Ice Cave (1947-2010, modified from RacoviÅčă, 1994b) against the air temperature and precipitation amount.

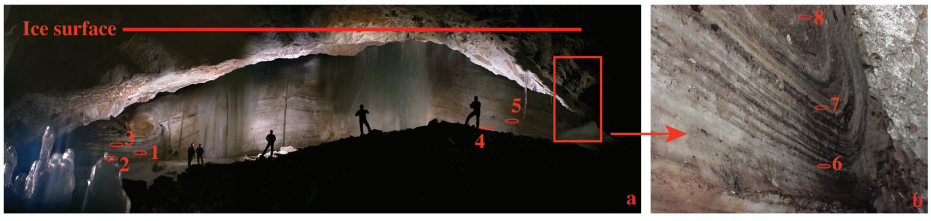

Fig. 3. Fig. 3. The exposed wall of the ice block as seen from the Little Reservation, with the position of radiocarbon ages shown.

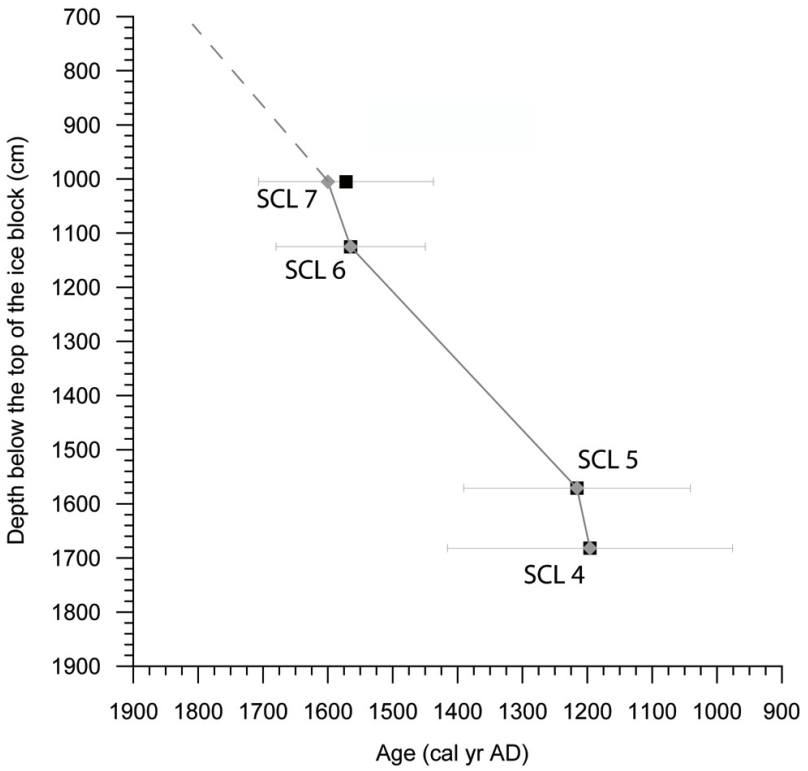

Fig. 4. Fig. 4. Depth-age model of the exposed ice wall in Little Reservation, Scărişoara Ice Cave.

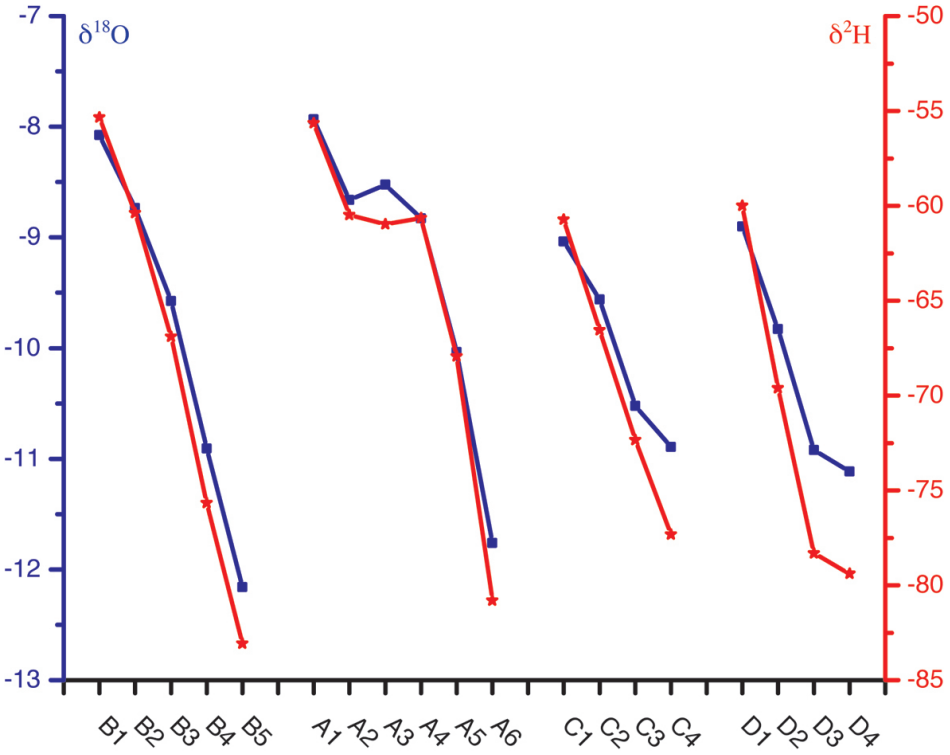

Fig. 5. Fig. 5. δ18O (red line and left axis) and δ2H (blue line and right axis) profiles. See full caption in the final revised manuscript

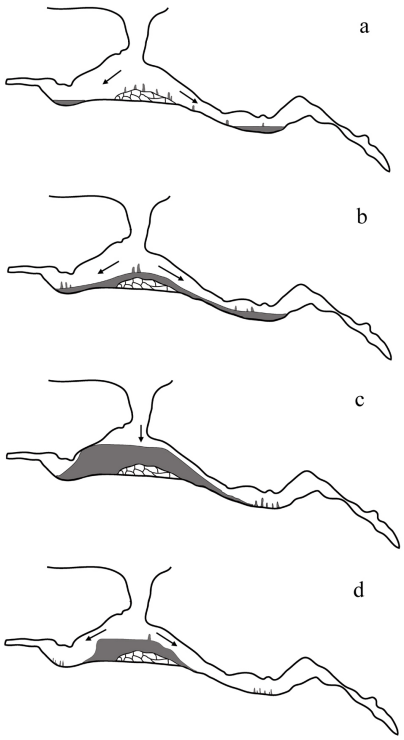

Fig. 6. Fig. 6. A conceptual model of the genesis and long-term volume fluctuations of the ice block from Scărişoara Ice Cave (see main text for details). Arrows indicate the direction of cold air inflow.