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The Cryosphere Discussions

Interactive comment on "Alpine permafrost thawing during the Medieval Warm Period identified from cryogenic cave carbonates" *by* M. Luetscher et al.

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We would like to thank the referee for his or her careful review. Strangely, the reviewer did not access the actual online Discussion paper, but a somewhat older version of the manuscript. The differences being small, many comments remain, however, valid and most of the technical remarks were considered in the final manuscript. Here, we address the main issues only:

1) Generalization of the model of CCC formation

The reviewer underlines the site specificity of the CCCcoarse samples found in Leclanché Cave. In particular, he seems concerned that "the cave differs significantly from many other caves [. . .] and associated CCC (fine or coarse)." We acknowledge that the formation of CCCcoarse is preconditioned by the presence of cave ice, which is possible only under special circumstances (but nonetheless recurrent in periglacial karst environments). This site specificity has already been underlined in the "Discussion" (p. 7, l.26-27). The similarities observed between CCCcoarse from Leclanché Cave and analogue precipitates from central European caves further suggest that CCCcoarse might be more frequent than previously expected. We agree, however, that our understanding of CCCcoarse depositional contexts remains incomplete and that a systematic search for potential sites will provide a more thorough understanding of the processes controlling these deposits. Anyhow, the cryogenic origin of these deposits being demonstrated, our palaeoenvironmental interpretation remains plausible, opening the doors for more detailed studies.

2) Process that precipitates CCCcoarse

The reviewer raises some questions related to the processes leading to the formation of CCCcoarse. Since these precipitates form below the ice surface, they are difficult to document properly under natural conditions and future, process-based studies will require experimental lab work and/or modelling studies. Nonetheless, our conceptual model of CCCcoarse formation, which essentially follows previously published work (e.g. Zak et al., 2004; Richter and Riechelmann, 2008), is detailed more extensively now in the revised manuscript. In particular, we address the question when the water ponds have formed at the top of the ice filling and how to interpret the formation of large prismatic calcite crystals at high freezing rates.

3) Modern analogues

The reviewer underlines that ikaite was claimed to be present in Scarisoara cave but no paper has yet been published on this occurrence. It is therefore difficult to assess the similarities between both study sites. We agree that the microcrystalline material found at the surface of the stalagmites in Scarisoara is likely to be contemporaneous, but it remains to be demonstrated that the larger glendonite crystals are modern indeed. In absence of any U/Th ages we prefer to take this information cautiously. Furthermore, the location and depositional context is hard to derive from the available abstracts. In particular, no information is provided about potential cave ventilation at the time of their formation and thus the possible analogy to Leclanché Cave. Nevertheless, these findings are encouraging and we added a sentence to the revised manuscript referencing Scarisoara cave as a potentially different depositional context.

4) Detailed comments

- Keywords: the keywords have been defined by the editor and we are not sure if we may extend this list. Nonetheless, we followed the reviewer's suggestion and added "cave", "karst", "cryogenic cave calcite" and "permafrost".

- Analytical protocols: the reviewer asked for more details about scientific protocols without specifying which information he would like to see. Since our methodological section follows the standards used in the speleothem palaeoclimate community we decided to not expand it.

- Methods: the reviewer questions the relevance of our mass spectrometer calibration against VSMOW, GISP and SLAP standards as compared to NBS19. The latter are required for water analyses, whereas the former is used for carbonate measurements. The same applies for the reported uncertainties, which refer to water and carbonate data, respectively.

- Abbreviations: we decided to not spell out b2k in the abstract, assuming that this is a well known notation in the palaeoclimate literature. The abbreviation is, however, spelled out in the main text. Finally, we decided to keep the spelling out of CCCcoarse in the figure captions to make sure that the terminology remains properly understood, independently of the main text.

- Permafrozen karst: the reviewer questions the ability of karst systems to drain water under permafrost conditions. We argue that the active layer may drain substantial water fluxes to the epikarst, a process which is even more pronounced in the absence of a soil cover. In presence of large conduits, the water may be drained deeper into the karst system. The absence of surface runoff on Lapi di Bou supports this interpretation, although we agree that the spatial distribution of such drainage patterns is probably heterogeneous.

- is there a particular reason why authors chose Raman instead of XRD?: Raman is a “non destructive” method which was best suited for high-resolution analysis of the inner core of these carbonate aggregates. In contrast, XRD requires the sample to be ground to very fine grain size.

- limit of the permafrost during MWP: we are not aware of any paper documenting the limit of permafrost in the Alpine range during the MWP.

- small depressions in the cave floor could also act as water reservoirs: this is unlikely to be the case in Leclanché Cave as the depressions would still be visible in the cave sediment. Moreover, all the samples we deposited on top of rock fragments strongly suggesting a sedimentary process after melting of the cave ice.

- only 18 values are plotted in Fig. 5: the text refers to the bulk carbonate samples, whereas figure 5 plots transects through individual aggregates.

- there is no data with such value on Fig. 4: the missing data point has been added to Fig. 4.

- actually almost 2.5‰ in Fig. 5 for d18O: No, the maximum amplitude of an individual sample is 1.9‰ i.e. “nearly 2‰ʹ.

- the use of “crystallite” is incorrect as it denotes the initial stage of crystallization of mineral individuals: The term crystallite is commonly used by speleothem petrographers and refers to “the smallest crystal (it can be the size of a unit cell) that forms composite crystals (Kendall and Broughton 1978)” (Frisia et al., 2000).

- it is not clear how the earlier calcite generation was documented: this earlier generation is present in several aggregates and shows a characteristically whitish colour. This information has been included in the revised manuscript.

- Povara, I., Diaconu, G., 1974: We thank the reviewer for making us aware of this paper, which focuses on frost shattering in caves. We did not aim at providing a comprehensive review of subsurface cryogenic processes (which would include a number of other publications as well), but only to refer to some recent, well accessible, literature ("e.g.") summarizing these occurrences.

- Fig. 1 cave length: the figure corresponds to the original survey which yielded a total length of 130 m.

- how these aggregates ended up sitting on top of the cryoclastic breakdown? Settling by gravitation after the ice melted.

5) Additional references cited in this response:

Frisia S., Borsato A., Fairchild I.J., McDermott F.: Calcite fabrics, growth mechanisms, and environments of formation in speleothems from the Italian Alps and southwestern Ireland, J. Sed. Res., 70, 1183-1196, 2000.

Kendall A.C., Broughton, P.L.: Origin of fabric in speleothems of columnar calcite crystals, J. Sed. Petrology, 48, 519-538, 1978.

Interactive comment on The Cryosphere Discuss., 7, 419, 2013.