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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.

M. Luetscher et al.

marc.luetscher@uibk.ac.at

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We thank Karel Zak for his careful review of our above mentioned paper. The reviewer raises three main points we would like to address here:

1) Heat exchanges

The energy balance of an (ice) cave system is complex and the authors are aware of only few studies which have attempted a proper quantification (i.e. Ohata et al. 1994; Luetscher et al. 2008; Obleitner and Spötl, 2011). Such quantifications require the detailed monitoring of air and water fluxes to determine sensible and latent heat exchanges during a full annual cycle. Although very interesting, such a study is outside

the scope of the present article which focuses on the palaeoenvironmental interpretation of the CCCcoarse. Nonetheless, the paper will be completed by a qualitative assessment of the dominant term in the cave energy balance (i.e. conductive heat transfer through the cave host-rock and advection through water inlets). As suggested, the reference to Badino (2010) will also be added.

2) Thermal gradient in the karst system

The temperature gradient in the regional karst system was determined empirically from neighbouring caves. Hourly data recorded since 1998 at 4 different altitudes (i.e. 2376, 2334, 2264 and 2258 m a.s.l.) were compared with sporadic (manual) temperature measurements from surrounding caves. The steeper gradient as compared to the external atmosphere is consistent with exceptionally dry cave conditions reflecting the scarcity of water infiltration into the permafrozen karst system (cf. p. 422 l.27). Yet, we cannot exclude a somewhat higher contribution of the geothermal heat flux due to the lack of water drainage at the base of the karst system. Both processes will potentially shift the temperature gradient closer to the adiabatic lapse rate of dry air (cf. also Luetscher and Jeannin 2004 or Badino 2010 for a discussion on temperature gradients in karst systems). We argue that these empirical data are more likely to represent the regional karst temperature than values extrapolated from distant meteorological stations. The revised article will, however, include an error estimate on the inferred cave temperature in order to account for site-specific effects. It will also be completed with additional details about how the gradient was determined and why it is considered to be representative of the regional karst system.

3) Chemistry of the drip water

The water infiltrating into Leclanché Cave on the day of the visit was limited to seepage flow whose discharge was just about sufficient to sample for stable isotopes. Therefore, only speculations can be made about the carbonate mass balance, essentially relying on chemical analyses of karst waters from analogue settings. Despite the absence of

soil cover in the cave's catchment, we know that some dissolution occurs by the oxidation of pyrite, a sulphide mineral common in the Schrattenkalk Formation (Luetscher et al. in prep.). Here, we assume an alkalinity of 100±50 mgl-1 at 0°C, allowing the precipitation of 80±40 mg of calcite per litre. Having estimated the mass of calcite to ca. 15 g per deposit, we conclude that the latter corresponds to a water volume of between 120 and 370 l, i.e. "in the order of 10-1 m3" (p.427, l.25).

The reviewer's technical comments will all be considered in the final manuscript:

a) Separation method of sub-samples for stable isotope profiling within the aggregate »> by micromilling at 250 μm intervals (cf. p 426 l.3)

b) Structure and structural parameter (200/35) measured on the regional discontinuity »> The cave opens along a regional fault whose dip direction is 200°N and a dip value of 55° (thanks for noticing the typing error).

c) Please specify which standards were used in each case (VSMOW vs VPDB) »> The method section already specifies that the carbonate is reported on the VPDB scale, whereas the water values use VSMOW as a reference (cf. p.424 l.17-21).

d) which of the carbonate-water equations was used for the calculation of water in isotopic equilibrium with the first carbonate formed »> Kim and O'Neil (1997), will be specified explicitly.

e) References »> Clark and Lauriol (1992) will be referred to in the revised article; Kunsky (1939) was published in Slovakian and is not known/accessible to the authors; Spötl (2008) will be replaced by Zak (2008) to avoid any confusion; a reference to Harris et al. (2009) will be added to the introduction; the missing references will be completed.

f) Editing »> editorial changes will be performed according to the reviewer's suggestions (cf. "coarse crystalline"; "Leclanché Cave").

Additional references cited in this response:

Luetscher M., Lismonde B., Jeannin P-Y., 2008, Heat exchanges in the heterothermic zone of a karst system: Monlesi cave, Swiss Jura Mountains. Journal of Geophysical Research, 113, F02025, doi:10.1029/2007JF000892.

Obleitner F., Spötl C., 2011.The mass and energy balance of ice within the Eisriesenwelt cave, Austria. The Cryosphere, 5,245–257.

Ohata T., Furukawa, T., Higuchi K., 1994. Glacioclimatological study of perennial ice in the Fuji ice cave, Japan. Part 1: Seasonal variation and mechanism of maintenance, Arctic Alpine Res., 26, 227-237.F

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