

## ***Interactive comment on “Investigating cold based summit glaciers through direct access to basal ice: A case study constraining the maximum age of Chli Titlis glacier, Switzerland” by Pascal Bohleber et al.***

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### General comments

The paper reports ice temperatures, stable-isotope concentrations and radiocarbon dates from ice located near the base of Chli Titlis, Switzerland. The manuscript reports that the basal ice is cold (and infers that this has been the case for a considerable period of time) and that it has a maximum age of ~5000 years BP. I find the manuscript to be of interest, but also that it still needs fairly substantial revision and improvement

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in a few areas. My main concerns relate to two aspects of the manuscript.

1. The measured ice temperatures at the location are too close to the glacier's surface and/or the access tunnel to be able to ignore these external influences. Seasonal variations in surface temperature typically penetrate 10 to 15 m into the ice. Further, temperature within the tunnel is artificially influenced and, to some extent, controlled (as clear from p. 7 paragraph 1). The reported temperatures are also not substantially below freezing, so error 'estimated at 0.2 degrees C' really needs a more formal quantitative analysis and accompanying statement. I recommend plotting the thermistor time series to reflect ice cooling back down (presumably exponentially) to host temperature following borehole-wall warming by the steam drilling. I believe this aspect of the manuscript needs greater focus and for all the relevant information to be brought into one early section. For example, published temperatures are reported towards the base of page 9 that should really form part of this background material. Temperature control in the tunnel is also mentioned elsewhere later in the manuscript.

2. The manuscript reports on the temperature of basal ice, but presents no formal analysis of the nature that ice. Such an analysis would be useful both for the reader to understand the nature of the environment, and because certain physical basal-ice facies are indicative of certain basal processes and conditions. I recommend the revised manuscript include a formal analysis of the types of ice present at the sample locations (see review by Hubbard and others (2009) in Quaternary Science Reviews and references therein).

Specific comments (page/line):

1/1 "with great success" adds little and is a value judgement; I recommend deletion.

1/3 "... low altitudes may also contain old ice if locally frozen..."

1/5 "However, with recent warming and consequent glacier mass loss,..."

1/6 Delete ", however," and "Since sampling and dating the lowermost ice usually

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requires...”

1/8 “We combine standard glaciological tools...” (and such ‘tools’ should just be specified as the term is rather too open)

1/9 “... physical properties and radiocarbon dating.”

1/11 this “pioneering exploration” needs to be specified for the definite article (“the”) replaced. (Note: I have not gone through the rest of the manuscript in the same detail; the grammar can still be improved)

2/15 These statements make clear the need for a formal analysis of the ice types present and sampled for this study.

2/23 What is “glaciological surveying”?

3/9 “... generally seem to be low” ideally needs some specification and quantification.

3/18 - 21 I recommend combining this material with temperature data from the existing literature in order to present as complete and accurate a situation as possible relating to the thermal history of this site. That this ice is, and has been, cold is central to the manuscript’s message.

5/8-14 I think the manuscript would benefit from a more formal statement of isotopic error here. Currently, some delta D values are issued with caution because of ‘large uncertainty’. I would prefer to see formal error bars added to each data point.

7/25 Tes, there appears to be a pattern here that broadly matches one(s) recorded elsewhere, but such a comparison should include all other profiles (including ice coring literature from Alpine glaciers at least) so the reader is convinced that this particular pattern is significantly over-represented. Also, if it is real, the explanation is a little truncated. Could it be related to the formation of clear facies basal ice by deformation-induced preferential expulsion of light isotopes?

7/33-35 I’d like to see this co-isotopic plot (including error bars). Which of the less

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certain delta D values were used and what is their associated error. If the data are not of sufficient quality to 'interpret in more detail' then they may not be of sufficient quality to present at all; at present, the reader cannot judge this.

8/5-8 Is it possible to illustrate these crystal size differences and the sub-grain boundary and elongation conditions mentioned? The elongated crystals sound like 'interfacial' facies ice, agreeing with the congelation origin advanced in the manuscript. The text states 'grain size' – which is presumably 'ice crystal size'.

9/Fig. 3 These images are not very clear and seem to give no indication of scale

9/2-4 This reference to possible warm temperatures in the past seems at odds with the general thermal interpretation of the site as cold. Perhaps some text could be spent on rationalizing these seemingly contrasting thermal conditions.

10/6 'karst'

10/9-10 More here of relevance to the thermal conditions

10/17 True, but to focus on the future does not address the issue raised by this paragraph – that there may be issues complicating the temperatures reported. . . Surface temperature changes should be accounted for in any interpretation of point temperatures recorded within a thickness of  $\sim 10\text{m}$ . Same for the tunnel, although this zone of influence is likely smaller because the temperature changes in the tunnel will presumably be muted. Are there records of external temperature at the surface (or nearby, to which a lapse rate can be added) and in the tunnel?

11/Fig. 4 Some of the structures here do seem to indicate ice deformation. How does this relate to the interpretation of generally undeformed ice in this location? Maybe these features are not deformation structures, but some analysis and interpretation might help address this possible issue.

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