

Review of Ms tc-2020-82 subglacial carbonate precipitates

Notes

This is a fine paper, clearly presented and well illustrated, but only with skeletal captions that do not do justice to the figures. The paper describes a previously unreported occurrence of subglacial precipitates, and reports considerable data including ages that are much older than expected. The authors appropriately stress the significance of their findings; subglacial precipitates are a novel palaeo-environmental proxy and a research subject well worth further research. Their findings suggest new evidence that highlight the extraordinary nature of the current global warming.

One important improvement would be to add credibility to the ages reported by providing more explicit details about the impact on the calculated age of the initial content of Thorium 230 in the precipitate. One effective way of doing this is in table form much as that shown below from Fitzpatrick, J. J., Muhs, D. R., & Jull, A. J. T. (1990). (Saline minerals in the Lewis Cliff ice tongue, Buckley Island quadrangle, Antarctica. *Contributions to Antarctic Research I*, 50, 57-69). In particular, for 230/232 values of 4, for example, the age could be as much as 40% younger than the age calculated that does not assume there is any 230 initially. Also, the text should reflect as accurately as possible the corresponding large uncertainties.

TABLE 3. Uranium and Thorium Concentrations, Isotopic Activity Ratios, Uranium Series Ages, and Radiocarbon Ages of Antarctic Saline Minerals

Site	Mineralogy	U, ppm	Th, ppm	$^{234}\text{U}/^{238}\text{U}$	$^{230}\text{Th}/^{232}\text{Th}$ Activity Ratios	$^{230}\text{Th}/^{234}\text{U}$	Apparent Age* (ka) Using Correction for Initial $^{230}\text{Th}/^{232}\text{Th}$ Ratios				^{14}C Age, years	
							0	0.5	1.0	1.5		2.0
1	nahcolite	0.73 ± 0.01	0.004 ± 0.001	5.04 ± 0.04	185 ± 25	0.066 ± 0.001	7.4 ± 0.1	NA	NA	NA	NA	24,560 ± 420
2a	nahcolite	0.88 ± 0.01	0.023 ± 0.002	4.19 ± 0.03	28 ± 2	0.055 ± 0.001	6.1 ± 0.1	NA	NA	NA	NA	21,410 ± 315
2b	nahcolite	0.614 ± 0.008	0.122 ± 0.003	3.26 ± 0.03	4.0 ± 1	0.078 ± 0.001	8.8 ± 0.2	7.7	6.6	5.5	4.4	34,470 ± 710
2c	trona	0.299 ± 0.003	0.095 ± 0.002	2.35 ± 0.02	1.30 ± 0.04	0.074 ± 0.002	8.3 ± 0.2	5.2	2.0	0	0	postbomb
2d	nahcolite + borax	0.121 ± 0.003	0.046 ± 0.005	3.24 ± 0.09	14 ± 2	0.55 ± 0.01	78 ± 3	76	75	73	71	9,960 ± 100 (nahcolite only)
2d	nahcolite (matrix)	0.057 ± 0.001	0.020 ± 0.001	3.93 ± 0.07	30 ± 1	0.85 ± 0.01	150 ± 4	NA	NA	NA	NA	37,730 ± 1060

NA, not applicable because measured $^{230}\text{Th}/^{232}\text{Th}$ is ≥ 20 .

*Calculated from corrected $^{230}\text{Th}/^{234}\text{U}$ ratios using the following equation: $^{230}\text{Th}/^{234}\text{U}_{\text{corrected}} = ^{230}\text{Th}/^{234}\text{U}_{\text{measured}} - [^{230}\text{Th}/^{232}\text{Th}_{\text{initial}} (^{232}\text{Th}/^{234}\text{U}_{\text{measured}}) \exp(-\lambda_{230}t)]$, where λ_{230} is the decay constant of ^{230}Th and t is the age of the sample. The equation is solved by successive approximations.

The authors may also wish to consider leveraging the limelight of Ötzi, the Iceage Man, and its climate implications, as referenced by Solomina et al (2015) in their supplementary material.

Specific Comments by line number

29. ...significant volume fraction of what?

41. Also reported from the southern tip of S. America (Tierra del Fuego, Personal communication, Rabassa), New Guinea (Peterson and Moresby, 1979), and from sites where they formed under LGM ice.

56-57. The units, $\text{kg}/\text{m}^2/\text{yr}$, seem unusual. Why not report ice thinning rate in m/yr , or the rate of increase of exposed bedrock, m^2/yr ? This rate must be averaged over a certain area, but what is it? This reference, Gabrovec et al., 2014, does not help; it is incomplete and insufficient.

Fig. 1 caption should be more informative, explaining to unfamiliar readers

- what is what (bedrock vs. precipitate)?
- the orientation of surface imaged relative to horizontal and to the former sliding direction
- the morphology of the precipitates

Fig. 2. What are the pink areas? Replace these terms in legend; in English they are incorrect or awkward.

From:

Relief types

Erosional topography

Depositional topography

Periglacial topography

Relief Shapes

Main ridge

To:

Terrain types

Erosional surfaces

Depositional surfaces

Periglacial terrain

Relief Elements

Topographic divides

60. Replace "...the recently exposed subglacial carbonate deposits due to glacier retreat." by "...the subglacial carbonate deposits recently exposed by glacier retreat."

78. (...targeting carbonate) cement ought to be replaced by the more appropriate word, precipitate

103. Replace "They are fluted and furrowed crust-like deposits characterized by brownish, greyish or yellowish colour." by "The fluted and furrowed crust-like deposits are brownish, greyish or yellowish in colour."

115-6. "Depending on the angle of the lee side of bedrock protuberances, columnar calcite crystals grow either perpendicularly to the host rock (Fig. 5a) or with a lower angle, generally oriented downslope..." Replace "angle" by "inclination" or "slope". It would be good to explain how the crystal orientation varies with bedrock surface inclination less ambiguously. For example, do vertical crystals grow perpendicular to the rock when bedrock surface is near vertical or near horizontal? Is there a relation between the crystal orientation and the former glacier sliding direction?

124. Replace is by are.

127. For the isotopic ratios, the ranges should be included in the text, as well as averages. The reader should not have to look up the supplement for this basic information.

129-134. Briefly explain what ages you expected. Were the “two U-Th ages of stratigraphically younger cement” obtained from the same sample? If any of the thin sections are from this sample, you should mention it in the text, and help understand the stratigraphic setting of these younger deposits. Why would the former glacier be thick, and what do you mean by thick?

147. I'd replace low supersaturated solutions by slightly supersaturated solutions

148-9. Replace “high Mg/Ca ratio in the water partially could be the trigger for the precipitation of aragonite” by “high Mg/Ca ratios in the water partially be responsible for the precipitation of aragonite”.

150-1. Recast sentence to avoid circular logic.

152. I suggest replacing “pose a challenge to determine” by “raise the difficult question of”

159-160. What is it about the moment that matters in the following “... factors such as the percentage of initial aragonite and the moment of the aragonite to calcite transformation...the possible additional redistribution of Th or the degree of opening of the system”? How about this rewording: “... factors such as the initial relative amount of aragonite and the timing of its transformation to calcite ...the possible additional redistribution of Th and the extent of chemical exchange with widespread subglacial meltwater”?

162-4. Suggested edit from:

“Based on the U concentration in samples within this study (in ppm; Supp. Table S2), it is notable that the youngest sample (2ka; T.03_b1) has 1.77 ppm of U concentration, whilst two of the old samples (LGM and YD; T.01_a1 and T.03_a1) have around 0.41 and 0.46 ppm of U concentration, respectively”

To

“It is notable that the U concentration (in ppm; Supp. Table S2) in the youngest sample (2ka; T.03_b1) within this study is 1.77 ppm, whereas it is around 0.41 and 0.46 ppm in two of the old samples, T.01_a1 and T.03_a1, respectively LGM and YD.”

165. Replace contrary by to the contrary

166 & 168. Replace In case of the first possibility...by Assuming the first possibility...The same goes for line 168.

Figure 4:

An informative caption is needed for this important figure. The labels are ambiguous. I assume, but am uncertain, that upper and lower “sides” refers to the surface (facing open air before being collected) and underside of the carbonate samples. In any case, how is depth measured? Is it relative to the surface or to the underside? For T.03, does the “lower side” include limestone bedrock as well as subglacial precipitate? It would be helpful for the reader to indicate clearly in

words or graphics how the ages vary with stratigraphy. Perhaps, this could be done easily by providing the ages that correspond to the depths written on figure. Is this the only sample for which several dates have been obtained?

192. $\delta^{18}\text{O}$ differences of a few per mill in the carbonate precipitate can also arise due to variations in subglacial hydrology shifting from closed to open geochemical systems (see Hanshaw & Hallet)

197. Replace “lighter in deuterium compared to the Triglav...” by “lighter in deuterium than those from Triglav...”

199. The last clause (constraining the implications that the Triglav Glacier was constant during the Holocene.) does not follow logically from the preceding text. Clarify or delete it.

203. I am unsure of your intent with the leading sentence of this section. If it is consistent with the heading, I would suggest this revision: The LGM and YD ages are the first physical evidence that Triglav Glacier persisted through the Holocene to the present day (Solomina et al., 2015). If your intent is different, describe it clearly.

210. I suggest replacing “not being documented in the literature” by “not having been reported in the literature”

214. This paragraph ought to be updated in view of more recent work reporting even slower denudation (e.g. Steinemann et al., 2020), but still supports the contention that the 5mm crust would have weathered off during the HCO if exposed to the elements.

221. Delete the last 3 words because once exposed the subglacial carbonate deposits they cannot be glacially abraded. Moreover, I would not expect them to be abraded even under the glacier because they form in lee positions where I would expect abrasion to vanish as abrading rock fragments diverge from the bed at sites of subglacial precipitation due to regelation ice growth.

228. Delete “assessment of”

240. Replace “quick rate of 21st” by “rapid 21st”

243. Replace “show a lower sensitivity to climate fluctuations” by “are less sensitive to climate fluctuations”

245. This remark about bright limestone substrate reminds me of the photographs, which begs the question: what is responsible for the color difference (greys vs. beige & brown on the more recently exposed bedrock surfaces)?

250. What do you mean here? The preliminary data shows a high possibility that subglacial carbonate deposits may endure unprecedented retreat... Might you mean the following? The preliminary data suggest that subglacial carbonate deposits can archive valuable datable records of glacial retreat, including hints that the current and ongoing retreat is unprecedented.

255. Replace observe by determine.

260. Replace considerably fast by relatively high. This section should also leverage, and be updated by, recent work (Steinemann et al., 2020).

264-5. Replace “particulates on the present remnants of ice (and possible ice cores, if a glacier has not disappeared completely)” by “material on the small remaining ice masses and, if possible, ice cores)

274. The conclusion would be stronger and clearer without the first sentence. I would replace it as follows:

Subglacial carbonate deposits recently exposed by the retreating Triglav Glacier contain the first direct evidence of the existence and extent of Triglav Glacier since the Last Glacial Maximum and Younger Dryas.

The deleted sentences should be incorporated in the previous section and clearly explained: “U-Th ages of subglacial carbonate with the combination of aragonite and calcite are regarded as maximum ages as aragonite-to-calcite transformation, evident in fabrics, might have occurred in calcite crystals that could have been falsely considered as primary.

Missing refs

Hanshaw, B. B. and B. Hallet. 1978. Oxygen isotope composition of subglacially precipitated calcite: possible paleoclimatic implications. *Science*, 200,1267-1270.

Peterson, J. A., and Moresby J.F. 1979 Subglacial travertine and associated deposits in the Carstensz area, Irian Jaya, Republic of Indonesia. *Zeitschrift fur Gletscherkunde und Glazialgeologie*. 15(1), 23-29

Steinemann, O., Ivy-Ochs, S., Grazioli, S., Luetscher, M., Fischer, U. H., Vockenhuber, C., & Synal, H. A. 2020. Quantifying glacial erosion on a limestone bed and the relevance for landscape development in the Alps. *Earth Surface Processes and Landforms*, 45(6), 1401-1417.

Supplementary material

Figure S2:

The caption states “The recently exposed surface with shafts and subglacial carbonate deposits” but does not address the distinct colors, ranging from greys to rusty brown. Do the color boundaries correspond to, or parallel outlines of glacial extent in Figure S4? The figure should also show where the subglacial deposits or shafts are. In fact, what do you mean by shafts?

Figure S8: XRD graphs. A short caption is needed to explain what these samples are, how they differ from one another, and which are bedrock (if any).

Comments and questions in italics. Figure S9: a) Short columnar calcite crystals alternating with brown micritic bands constitute *the first phase of calcite precipitation on the bedrock*. Plane polarised light (PPL); b) columnar calcite crystals predominantly oriented towards the right (downslope) *. [what is the orientation of the thin section relative to the former sliding direction? Same question for Fig S10].* The

growth of the crystal on the center crosscut the direction of growth of previous crystals. [*what is the center crosscut?*] Crossed polarised light (XPL)

Figure S11- caption needs a brief explanation of what the figure shows. What are the various curves?