

Interactive comment on “Origin, burial and preservation of late Pleistocene-age glacier ice in Arctic permafrost (Bylot Island, NU, Canada)” by Stephanie Coulombe et al.

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Comments by the two referees were very enlightening and their suggestions useful; we are grateful for their input. His/her careful reading of the manuscript and his/her good knowledge of the subject-matter allowed providing relevant suggestions and additions to the manuscript. We treat each point raised in detail and with great interest.

Note that the line numbers given in this response refer to the revised version of the manuscript in track changes mode.

Referee #2

C1

General comment

Comment 1:

Referee #2: Provide good arguments why you have measured major cations only and not anions? Both would be necessary to get a comprehensive understanding of the ion composition and water origin. What about standard parameters such as electrical conductivity and pH measurements?

Authors: The origin of the ice has already been established following the analysis of the physical properties (i.e. crystallography), the isotopic composition (dD-18O, D-excess) and the low cation content. We did not need further information to infer its origin. We mainly used the cation content for comparison with glacier ice and other type of ground ice (i.e. interstitial ice, ice wedge). The cation content only showed that the low cation content in the buried massive ice is statistically similar to that of the ice of glacier C93 and had slightly lower cation concentrations than the ice wedge sampled nearby the buried ice exposure. The cation content also allowed showing a strong contrasting profile between the buried ice and the overlying sediment.

We have not measure the conductivity, as it is a proxy for total ion content. We already measured the cation content of the massive ice. As for pH measurement, pH data is meaningless for ground ice samples because of exchange of meltwater with atmospheric CO₂. The only way pH data would represent that of the ice is if the ice is melted in a glove box without a CO₂ atmosphere; hence we would not call this “standard parameters”.

Comment 2:

Referee #2: The results are sometimes written in past tense and sometimes in present tense. Especially in 4.1 they are in past tense throughout and suddenly in 4.2 present tense pops up. Make sure you use one tense throughout. Authors: We agree. This section has been reworked.

C2

Comment 3:

Referee #2: The manuscript is rather short, which I personally like, but it contains more than 100 references although it is clearly not a review paper. The authors should find a way to consolidate and shorten the reference list a bit. Authors: We agree. We shorten the reference list by removing 25 references.

Comment 4:

Referee #2: Sedimentological data is provided in figures 9 and 10. Since Figure 9 already provides information on gravel-sand-mud percentages and on skewness and sorting, Figure 10 does not add a lot of new information and can be removed. This would lead to a better balance of text vs. number of figures/tables. Authors: We agree.

Comment 5:

Referee #2: All the original measurement data on stable isotopes, cation concentration, grain-size properties and crystallographic data as well as the calculated parameters such as slope, D-excess etc. should go into a table into the supplement of the paper or archived in PANGAEA before final publication of the manuscript. Authors: The data is provided on NordicanaD.

Specific comments

Comment 1:

Referee #2: Title- "...Pleistocene-age glacier ice...". It would be easier to read the title (without changing the meaning) when you leave out the -age thing. Authors: We prefer to keep the title as it stands.

Comment 2:

Referee #2: P1L18 - What about anions? Authors: Please see response to comment #1 in Reviewer #2-General comments.

C3

Comment 3:

Referee #2: P1L23 - "As most of the Arctic landscapes..." - Better "some" because several millions of km² (Beringia) in the Arctic have not been glaciated throughout the Quaternary. Authors: We agree and modified for: "As most of the glaciated arctic landscapes [...]"

Comment 4:

Referee #2: P2L1-2 - Please check the references. Apparently, some references are mixed up (i.e. for Antarctica). Authors: Modification made. Problem the reference manager.

Comment 5:

Referee #2: P2L25-27 – Something is wrong with this sentence . Authors: Modification made.

Comment 6:

Referee #2: P3L5 – Suggested revision: "...the mountainous central section of the island forms a striking contrast..." Authors: Suggestion accepted

Comment 7:

Referee #2: P3L19 – Clarification needed: "submerged beneath the sea" Authors: We modified for "Following glacial retreat, the valley became partially submerged [...] as a result of a marine transgression".

Comment 8:

Referee #2: P4L4 – It would be better "Material and Methods" because you are also taking about the studied object and the samples that were taken. Authors: Modification made.

Comment 9:

C4

Referee #2: P4L17 – Clarification needed: “melted” Authors: We modified for “All samples (n=80) were thawed in the field [. . .]”.

Comment 10:

Referee #2: P4L30 – Clarification needed: “describe” Authors: We modified for “[. . .] was conducted to measure their crystal size and shape [. . .]”.

Comment 11:

Referee #2: P5L2-3 – Clarification needed: “Measurements of c-axis orientations of the crystals were not possible since the horizontal orientation of the ice samples could not be ascertained.” Authors: We modified for “C-axis orientations of the crystals have not been measured since the horizontal orientation of the ice samples was not preserved following the sampling.”

Comment 12:

Referee #2: P6L1 – This abbreviation was not mentioned before. Authors: We mentioned the three units (A, B, C) in Section 3 -Material and Methods (lines 13-14). It is mentioned that unit A refers to the massive ice body.

Comment 13:

Referee #2: P6L2 – Clarification needed: “VWC”. Authors: We modified for “With a volumetric ice content [. . .]”.

Comment 14:

Referee #2: P6L10 – Clarification needed: “mm²”. Authors: We modified for “mm”.

Comment 15:

Referee #2: P6L21 – Clarification needed: “The gas bubbles had an average circularity ratio of 0.89 0.18 and a mean surface area of 0.13 0.41 mm² respectively.” Authors: We removed “respectively.”

C5

Comment 16:

Referee #2: P6L23 – Clarification needed: “The dominant cations in the massive ice body were Ca²⁺, Na⁺ Mg²⁺, K⁺ and S; all with low abundances (<1.76mg/L; Fig. 7).” Authors: We modified for “Major cations in the massive ice body (i.e. Ca²⁺, Na⁺ Mg²⁺, K⁺ and S) all occurred in low concentrations (< 1.76 mg/L; Fig. 7).”

Comment 17:

Referee #2: P7L13 – Clarification needed “[. . .] showed a general fining upward trend”. Authors: We modified for “were coarser at the base and finer near the top.”

Comment 18:

Referee #2: P7L17 – Clarification needed: “[. . .] were dated to 786 cal yr BP”. Authors: We modified for “were dated to 885 15 14C yr BP (1164 cal yr BP; 1 range: 1058-1204).”

Comment 19:

Referee #2: P8L1-6 – I suggest to incorporate the sentences of this introductory paragraph in the according sub-chapters 5.1 and 5.2. It looks a bit odd to have such an introductory paragraph in a paper. The first sentence is very similar to the first sentence of 5.1 and could be merged with that. The second sentence can be removed. The third sentence can easily go as first sentence in 5.1. Authors: We agree with this comment. We moved this introductory paragraph to the beginning of section 5.1. The second sentence has been removed.

Comment 20:

Referee #2: P8L6-7 – Clarification needed: “The appearance and structure of buried massive ice are similar to those of englacial ice typically observed at the margin of glaciers, ice caps or ice sheet.” Authors: We modified for “The appearance and structure of the buried massive ice body are similar to those of englacial ice typically ob-

C6

served at the margin of glaciers, ice caps or ice sheet.”

Comment 21:

Referee #2: P9L25 – Suggested revision: “large stagnant ice blocks could have been covered [...]”. Authors: Suggestion accepted.

Comment 22:

Referee #2: P9L25 – Suggested revision: “[...] by glacial sediments accumulations at or near the ice margins [...]”. Authors: Suggestion accepted.

Comment 23:

Referee #2: P9L25-29 – What about burial by supraglacial meltout till? I think this is the most common process of stagnant ice burial. Ice bodies just drown in their own sediment load during melt-out. At some point the sediment thickness exceeds the active layer depth and further melting stops.

Authors: We agree that melt-out of supraglacial till from the ice surface is a common process allowing burial and preservation of the ice. However, production supraglacial melt-out till requires in situ melting of a debris-rich glacier ice, typically basal ice, that will become buried by a thick, stable, insulating cover of sediment. The buried glacier described in this paper has a very low sediment content. In addition, in situ melting of basal ice usually produces a laminated to bedded diamicton consisting mainly of silt. This is not the case here. The sediment covering the ice consist of coarse sand and gravel that we interpreted as glaciofluvial ice-contact sediment. We suggest that the sediment characteristics rather indicates the burial of the ice occurred as meltwater streams deposited sediments in direct contact with glacier ice.

Comment 24:

Referee #2: P10L21 – Suggested revision: “Evidence that support the englacial origin of the massive ice are: [...]”. Authors: Suggestion accepted.

C7

Comment 25:

Referee #2: P10L22 – Clarification needed: “Bubble-rich ice, with small gas inclusions [...]”. Authors: The meaning of “small” refers to the size of the gas inclusions, rather than the abundance.

Comment 26:

Referee #2: P10L27 – Suggested revision: “[...] the buried englacial ice isotopic composition is highly strongly depleted in heavy isotopes [...]”. Authors: Suggestion accepted.

Comment 27:

Referee #2: P10L29 – Suggested revision: “Although stable isotopes cannot yield information [...]”. Authors: Suggestion accepted.

Please also note the supplement to this comment:

<https://www.the-cryosphere-discuss.net/tc-2018-114/tc-2018-114-AC2-supplement.pdf>

Interactive comment on The Cryosphere Discuss., <https://doi.org/10.5194/tc-2018-114>, 2018.

C8