

Clim. Past Discuss., author comment AC1
<https://doi.org/10.5194/cp-2021-132-AC1>, 2022
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Reply on RC1

Tamara Pico et al.

Author comment on "Was there a glacial outburst flood in the Torngat Mountains during Marine Isotope Stage 3?" by Tamara Pico et al., Clim. Past Discuss.,
<https://doi.org/10.5194/cp-2021-132-AC1>, 2022

Reviewer 1

The manuscript by Pico et al. reports evidence of a pre-LGM (Last Glacial Maximum), ice-dammed proglacial lake in the Torngat Mountains in Labrador, with two cosmogenic exposure ages of a wave-cut platform at the lake shoreline. The record, albeit incomplete, provides important evidence of ice-free conditions in the Torngat Mountains during MIS 3, which is contrary to many previous reconstructions of pre-LGM ice sheets and assumptions of the location of ice-sheet inception prior to the LGM. The data are worth publishing as they represent an important limit on ice-sheet extent prior to the LGM. The manuscript is written well, will be of broad interest in the paleoclimate community, and is appropriate for Climate of the Past. The following comments are suggestions for providing more context and perhaps more geologic information regarding the existence of the pre-LGM lake, which would help to motivate future work on the geologic record of the area as the authors repeatedly state is necessary.

We thank the reviewer for these positive comments.

While the geomorphology of the lake shoreline and the cosmogenic ages of the wave-cut platforms are well supported, the evidence of one or more outburst floods from the lake is relatively unclear in the manuscript. Most ice-dammed lakes are unstable and are known to drain and refill, the authors do not report any direct geologic evidence of outburst flooding. This may be a result of the subsequent glaciation in the area and the removal of any geomorphic or sedimentary evidence of outburst floods through lake outlets, which are more abundant (and perhaps better preserved) for ice-dammed lakes that existed in Canada during deglaciation. The authors should provide more geologic evidence for outburst floods from the lake, or a more detailed explanation of the why they believe the lake drained via outburst floods.

We agree with the reviewer that the manuscript should be more specific about outburst flooding evidence to contextualize our findings for the readers.

In response to this comment and similar comments by Reviewer 2 we have revised the text to avoid overextending our data interpretation. We have replaced wording about "glacial outburst flooding" in the title and abstract with "glacial lake", to be specific that our data supports evidence of a glacial lake more strongly than evidence for outburst flooding.

In addition, we have highlighted the evidence for outburst flooding by adding the following sentence:

"Evidence for outburst flooding is based on the rounded, imbricated cobbles in inlet channels. We found these deposits in multiple inlet channels leading to the sample site, which we interpreted as a lake shoreline. We hypothesize that the lake level may have fallen rapidly because there is no evidence for bands of lake shorelines at progressively lower elevations. Nevertheless, future work is required to verify such evidence for glacial outburst flooding"

Finally, the volume of the lake should include some additional considerations of uncertainty given the unclear shape of the damming ice margins during MIS 3. The reported lake volume is based on some detailed consideration of the effects of isostatic rebound, but does not report the uncertainty of the lake volume calculation based on the presumed ice margin positions. This should be taken into account in paragraphs from lines 301-318 to more appropriately limit the potentially contribution to Heinrich Events during MIS 3.

We agree with the reviewer that additional exploration of possible ice margins would contextualize the uncertainty on lake volume estimates for readers. In response to these comments, we performed additional calculations that vary ice margin location to explore the uncertainty on estimated lake volume.

The estimated total lake volume is highly sensitive to our choice of assumed ice margins. We shifted the assumed ice margin boundary northward from 58 N to 58.5 N (~56 km), and found that this reduced the estimated lake volume from $1.14 \times 10^{12} \text{ m}^3$ to $5.42 \times 10^{11} \text{ m}^3$ (reduced by ~50%). Shifting the assumed ice margin boundary northward from 58 N to 58.25 N (~28 km) reduces the estimated lake volume from $1.14 \times 10^{12} \text{ m}^3$ to $7.62 \times 10^{11} \text{ m}^3$ (reduced by ~30%). Shifting the assumed ice margin boundary southward from 58 N to 57.75 N increases the estimated lake volume $1.14 \times 10^{12} \text{ m}^3$ to $1.44 \times 10^{12} \text{ m}^3$.

To address the uncertainty on lake volume resulting from our ice margin assumptions, we will add the following text (line 318):

The total lake volume depends strongly on the assumed ice margin positions that bound the glacial lake. Given the uncertainty on the ice-dammed locations of this lake, we explored three possible scenarios varying the assumed southern position of the ice margin that bound pre-LGM Glacial Lake Koroc. For the intermediate scenario, the southern ice margin boundary is at 58 N, resulting in an estimated lake volume of $1.14 \times 10^{12} \text{ m}^3$. For the smaller lake scenario, we shift the assumed ice margin boundary northward from 58 N to 58.25 N (~28 km), which reduces the estimated lake volume from $1.14 \times 10^{12} \text{ m}^3$ to $7.62 \times 10^{11} \text{ m}^3$ (reduced by ~30%). For the larger lake scenario, shifting the assumed ice margin boundary southward from 58 N to 57.75 N increases the estimated lake volume $1.14 \times 10^{12} \text{ m}^3$ to $1.44 \times 10^{12} \text{ m}^3$ (increased by ~25%).

Line by line comments:

Line 67: reference for the marine oxygen isotope data?

Thank you for catching this. We now reference Channell et al., 2012 here.

Line 82 (and elsewhere): should the names of glacial lakes be capitalized, as in Glacial Lake Koroc? They appear to be considered proper nouns in other literature and are capitalized in the paragraph on lines 180-191.

We have edited the text to read "Glacial Lake Koroc" throughout the manuscript.

Lines 129 and 130: use of "constraints" here and elsewhere. Editors may suggest replacing this with "limits".

Done!

Lines 133: change "previous unpublished" to "new"?

We have left this wording as is since we are reporting legacy data (therefore not new).

Line 134: this is the first appearance of "pre-LGM glacial lake Koroc" (unless my PDF reader is mistaken). Two considerations: (1) add the name of the lake to the abstract, (2) perhaps give the lake a unique name? It appears to be distinct from the younger Glacial Lake Koroc, with a much higher shoreline elevation and presumably much deeper, and perhaps should have a unique name.

We appreciate this suggestion. We have edited the abstract to include the name "pre-LGM Glacial Lake Koroc"

Figure 3 - The caption indicates that the boxed area with a white dashed outline is the assumed area of the lake, but it is unclear what the label "assumed glacial lake boundaries" means.

We have edited this text to read "assumed location of ice margins bounding glacial lake" to clarify that these represent assumed ice margin limits.

Lines 196-200: Is it possible to provide more geologic information about the lake shorelines? If so, considering showing a map with the location of the landforms and sediments representing flow into the lake, or a map that traces out the distribution of shoreline deposits and/or landforms representing the lake. The existence of the lake would be strengthened by more details about its record.

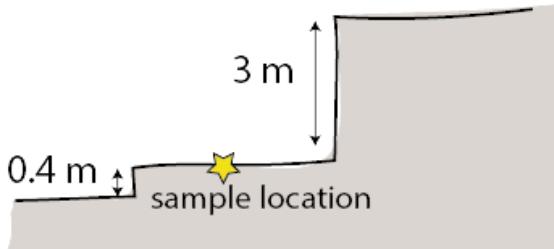
Unfortunately, our study relies on legacy data from a 2003 field expedition, and we do not have data from additional shoreline sites. Attaining such information will be the focus of future field studies.

Lines 203-206: the relative location of the two samples is unclear. This should be explained here. Any photos of the sample sites would be worth including in the paper or in the supplement. The photos in Figure 4 show examples of the wave-cut benches but do not specify the sample locations.

The location of the two samples is at the site marked by the white circle in Figure 3. There is only one location, which is shown in Figure 4b.

We now include a schematic figure in Figure 4 that shows the sample location on this set of wave-cut benches.

We have added text to the manuscript to read "The two samples are at the same location shown in Figure 4C"



Line 205: is the channel in Figure 4A an inlet or outlet channel? If an inlet, the authors should elaborate on how this channel and any associated deposits are indicative of an outburst flood.

The channel in the forefront of Figure 4A on the interpreted wave-cut bench is an inlet channel leading into the glacial lake. The inlet channel would have served as a conduit for water to enter the glacial lake, which can be considered base level for the inlet. Therefore, the inlet channel itself is not indicative of an outburst flood.

We now note in the text:

Evidence for outburst flooding is based on the rounded, imbricated cobbles in inlet channels. We found these deposits in multiple inlet channels leading to the sample site, which we interpreted as a lake shoreline. We hypothesize that the lake level may have fallen rapidly because there is no evidence for bands of lake shorelines at progressively lower elevations. Nevertheless, future work is required to verify such evidence for glacial outburst flooding

Line 220: should the reference be "Willenbring and Staiger, 2005"?

No, the reference is Jane Willenbring's PhD thesis. This is the same person (co-author of study).

Lines 232-234: More information is needed to justify the assumed duration of ice cover. It would be good to include at least a few sentences about the basis of the "apparent exposure age" given on lines 232-234. This is warranted given the potential uncertainty of the duration of ice cover, as it is the only limit on it. Additionally, the preservation of wave-cut platforms suggests cold-based ice at the sample site, but the authors do not explicitly state this. Consider doing this in the Methods paragraphs, as there appears to be sufficient evidence for it and it alleviates at least one concern about the exposure history of the site.

We will add the following text to the Methods section to note the likelihood of cold based ice and a discussion about the assumed duration of ice cover (line 235):

"The sample site was likely covered by cold-based ice for some duration (Staiger et al., 2005)."

Line 260: change "presently" to "at present" or "currently"

Done!

Lines 255-268: Provide some estimate of uncertainty in the lake volume calculation given the unknown ice margin positions.

We have now included a new calculation in response to these comments. We will add the following text:

The total lake volume depends strongly on the assumed ice margin positions that bound the glacial lake. Given the uncertainty on the ice-dammed locations of this lake, we explored three possible scenarios varying the assumed southern position of the ice margin that bound pre-LGM Glacial Lake Koroc. For the intermediate scenario, the southern ice margin boundary is at 58 N, resulting in an estimated lake volume of $1.14 \times 10^{12} \text{ m}^3$. For the smaller lake scenario, we shift the assumed ice margin boundary northward from 58 N to 58.25 N (~28 km), which reduces the estimated lake volume from $1.14 \times 10^{12} \text{ m}^3$ to $7.62 \times 10^{11} \text{ m}^3$ (reduced by ~30%). For the larger lake scenario, shifting the assumed ice margin boundary southward from 58 N to 57.75 N increases the estimated lake volume $1.14 \times 10^{12} \text{ m}^3$ to $1.44 \times 10^{12} \text{ m}^3$ (increased by ~25%).

Line 301: This would be an appropriate place to add some explanation of why the lake drained as outburst floods (see general comment above).

As discussed above, in response to this comment we have added the following text:

Evidence for outburst flooding is based on the rounded, imbricated cobbles in inlet channels. We found these deposits in multiple inlet channels leading to the sample site, which we interpreted as a lake shoreline. We hypothesize that the lake level may have fallen rapidly because there is no evidence for bands of lake shorelines at progressively lower elevations. Nevertheless, future work is required to verify such evidence for glacial outburst flooding

Line 308: would it be possible to add to Figure 3A or 3B the flow direction of water when the lake drained?

Thank you for this suggestion. We will add the potential flow route lines to this figure.

Line 407, 409: it would be more appropriate to state "the first direct on-land evidence for a proglacial lake", because the evidence of an outburst flood not reported in the paper.

Yes, we agree with this suggestion. We will update this wording accordingly.

Line 420: change "tease out" to "resolve"?

Done!