

Geochronology Discuss., referee comment RC3
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Comment on gchron-2022-1

Anonymous Referee #3

Referee comment on "Cosmogenic ^3He paleothermometry on post-LGM glacial bedrock within the central European Alps" by Natacha Gribenski et al., Geochronology Discuss., <https://doi.org/10.5194/gchron-2022-1-RC3>, 2022

Summary: "Diffusion properties of cosmogenic ^3He in quartz can be quantified to reconstruct the evolution of past in-situ temperatures from formerly glaciated areas." For this study, authors apply cosmogenic ^3He palaeothermometry on rock surfaces exposed from the LGM–Holocene from two deglaciation profiles in the European Alps. **Results:** "Lab experiments indicate variability in ^3He diffusion kinetics between the two sites." The authors interpret this as the presence of multiple diffusion domains. "Predictive simulations indicate that ^3He abundance in all the investigated samples should be at equilibrium with present-day temperature conditions - but measured natural ^3He concentrations in samples exposed since before the Holocene indicate a thermal signal colder than today. This cannot be explained by realistic post-LGM mean annual temperature evolution in the Alps. **Hypotheses/interpretations:** One hypothesis is that the diffusion kinetics and MDD model applied may not provide sufficiently accurate paleo-temperature estimates in these samples. Alternatively, the ^3He abundance may reflect complex geomorphic/paleoclimatic evolution with much more recent ground temperature changes associated with the degradation of alpine permafrost."

Overall comments: This is a thorough manuscript and important study that provides detailed information on applying relatively novel methods to deconvolve temperature histories from formerly glaciated areas. The authors do a nice job talking through their interpretations, and all of their interpretations are valid. The amount of data collected and reported is impressive. **My main concern** with this paper is the sheer amount of information that is reported and the delivery of details that make it hard to follow at times. As a result, key takeaways are not obvious, and this diminishes the paper's impact. For example, I noticed throughout the manuscript the author put statements in parentheses within sentences, and I felt this was quite distracting. More work into simplifying those statements and perhaps removing the text within the parentheses will help streamline the paper.

*Most of my comments below are my recommendations for how the authors can better streamline the paper's structure. If a bit of work is put in on improving the structure of this manuscript, it will be much stronger.

Comments by section:

1 INTRODUCTION

General comment: The introduction does a nice job setting up background information for this study.

Line 48: suggestion to change "thanks to" to "due to."

Line 59: I'm a bit confused by the beginning of this sentence, "*the recorded Alpine sequence*" What exactly do you mean by it? Which "recorded Alpine glacial sequence?" Perhaps reword to say: "Alpine glacial history is consistent with polar ice oxygen isotope records."

Line 67: A suggestion to change "inappropriate" to "not viable."

Line 91: Suggestion to change "today" to "presently," and remove "hence." So, it would read: "*Presently, there is a crucial lack of...*"

Line 93: Suggestion to reword to: "*In this study, we attempt to reconstruct paleotemperatures in the high alps during the Late Glacial Period, specifically between the LGM and YD, by...*"

Line 94-95: Perhaps add a brief statement at the end of this sentence for what the benefit of "exploiting the open-system behavior of cosmogenic ^3He in quartz minerals" is? In other words, why is it important to "exploit the open system behavior?" As of now, this statement seems like jargon, and elaborating on your meaning behind this will fix the ambiguity.

Line 95: I think this manuscript would benefit if you briefly describe what you mean by "predictive models."

Line 98: "Leaky" is a bit confusing. For readers that are not experts in ^3He palaeothermometry, what do you mean by "leaky"? Be more specific please. (I think you're referring to open-system behavior? Perhaps just say that instead of leaky if so).

Line 102: I think you need to define "*a priori*," I'm not sure what you mean by this, it feels out of place.

2 STUDY SITES AND SAMPLE MEASUREMENTS

General comment: Permafrost degradation is one of your hypotheses to explain your results, yet there is no mention of permafrost extent in the "settings/study sites" section of your paper. I think you should mention modern and/or past permafrost extent in your study area.

Line 125: Figure 1 is really great! I appreciate the visual.

Line 138: A suggestion for Figure 2 is to add a key box to panels b and d that state " $^3\text{He}/^{10}\text{Be}$ " with a yellow circle symbol. I realize it's in the x-axis label, but consistency with the keys will be more apparent to readers. Also, a suggestion to not use a dash ("-") but instead a comma in your caption because I think of "a-c" as being "a, b, and c..." but you only mean a & c.

Lines 148-150: I like this set up: " *^3He palaeothermometry requires at least two additional pieces of information. **First**, predictive models of thermally-activated ^3He diffusion rely on quartz sample-specific ^3He diffusion kinetics parameters...**Second**, measurement of the total natural cosmogenic ^3He accumulated in the quartz sample permits us to estimate the loss by diffusion...*" I think you should incorporate more summation sentences like this within your manuscript to help streamline the flow.

3 ANALYTICS APPROACH

General comment: As someone who is not an expert on ^3He palaeothermometry, I'm a bit confused of the significance of this section. Why do you need an analytics approach? Is it to perform quality control metrics on your data? Or do you need to run these Matlab codes to actually produce your results? Please start this section with 1-2 sentences briefly explaining why you need to run these Matlab codes. *In the previous section, you just said how you need "*predictive models of thermally-activated ^3He diffusion...*" is this why you're running the Matlab code? If so, a suggestion is to start this section with, "*To determine predictive models of thermally-activated ^3He diffusion, we used Matlab codes...*"

Line 186: This is the first mention of "multi-diffusion domain (MDD)," but there is no explanation for what this is? Please provide a bit of an explanation for what MDD is.

General comment: Once again, I think this section would benefit from an opening sentence briefly stating/reminding the reader of why you need to run these Matlab codes. For example, why do you need to determine ^3He diffusion kinetics, and why do you need to numerically simulate ^3He loss? *I see at **Line 300** you state "*to explore the theoretical sensitivity and potential variability of the MBTP and GELM quartz, we numerically evaluated the time required...*" Is this why you ran the Matlab codes? If so, please clarify this in section 3 above, instead of waiting to the results section to explain this.

Line 199: Please be more specific with what you mean concerning "longer timescales." >1 year? Decadal? *I see at **Line 229** that you define "long-term" as "several years." Please add this clarification to Line 199.

Line 249: You can remove the word "next."

4 RESULTS

General comment: I think this section could be improved if you added an introductory paragraph summarizing all the different results you are going to report. For example, as it is now, you jump right into diffusion kinetics parameters, which is a bit confusing/makes me think these are the most important results, even though you delve into many more below this section.

Line 285: The wording of "*and which in addition predict*" is confusing. Do you mean the range of diffusion kinetics parameters predict the observed natural ^3He concentrations from the Holocene calibration samples? If so, please remove "and which in addition" and replace with "*which predict*" wording only.

Line 315: Figure 4 - a suggestion to make the diamond symbols transparent because the circles are often hidden behind them, and this would show their clear overlap. Also, are there errors of these isoEDT estimates?

5 DISCUSSION

Lines 417-421: These sentences belong in the results section; they distract from your interpretations. A suggestion is to move these statements to the above results section and begin your discussion with interpretations. You could begin the discussion section with **Line 434:** "*We attribute...*"

Line 423: Remove the word "furthermore," and add "set of" after "mean." So, it reads: *"Such large EDT differences would not be supported by any set of mean temperature reconstructions for the..."*

Line 434: Suggestion to reword this sentence to: *"We attribute our results of lower modeled ³He concentrations to observed ³He observations to the dampening effect..."*

Line 435: What do you mean by the "dampening effect?" Perhaps clarify more, I'm not sure how "relatively stable mean temperature conditions similar to present day" relate to this.

Line 436: You can remove "first appears," and just say *"This hypothesis contradicts..."*

Lines 459-464: The parentheses are distracting in the reporting of your interpretation. I think you can reword this paragraph as: *"Even greater EDTs are needed to explain the observed GELM ³He concentrations using either diffusion kinetics approach, including temperature changes from 15-35°C when using Holocene-calibrated diffusion kinetics and >40°C when using laboratory diffusion kinetics."* Then, remove the statements in the parenthesis and make **Line 464** its own sentence as: *"Both cases are clearly incompatible with..."*

Line 466: Suggestion to remove the word "Finally" at the beginning of this sentence.

Line 470: Remove "(i.e., recent)" statement, it is not needed.

Line 479: Suggestion to remove the words "permit to," so it reads: *"For GELM samples, correcting modern/recent EDT does not reproduce the observed ³He concentrations..."*

Line 490: Remove the parentheses in front of "contrary," and reword as two full sentences: *"...during glacier coverage. This is in contrary to ¹⁰Be, which would experience..."*

491: Suggestion to remove the parenthesis and the word "hence" and just reword as: *"This scenario of inheritance and/or complex exposure history would result in..."*. This streamlines your interpretation.

Section 5.3 (Line 538): I'm a bit confused how this discussion differs from Section 5.1. Aren't the ^3He diffusion kinetics and ^3He thermal signal needed to interpret paleo-environmental signals? Why is this discussion lumped in a different section?