

Geochronology Discuss., author comment AC1
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Reply on RC1

Natacha Gribenski et al.

Author 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-AC1>, 2022

Comment on gchron-2022-1
Gribenski et al. (2022)
Geochronology Review

Anonymous Referee #1

In this manuscript, Gribenski et al. detail the methodology of using diffusion kinetics and cosmogenic ^3He measured in quartz crystals to quantify paleo-surface temperatures for two glacial valleys in the European Alps. Description of laboratory methods and diffusion systematics present an argument for how they can be theoretically used to decipher surface temperatures in paleo-environments. However, results from all samples indicate regional temperatures in the pre-Holocene colder than records from other regional proxy studies. Potential influences on this temperature discrepancy could come from issues with helium diffusion kinetics within the measured quartz crystals or geologic/paleoclimatic uncertainty of the sampled glacial surfaces.

This manuscript is very thorough and comprehensive in describing the theory and concept of ^3He diffusion and use as a paleotemperature proxy, testing of results through modeling experiments, while acknowledging areas of misfit and uncertainty. The study presents a novel approach to determining a scientifically relevant problem valuable to the paleoclimate community – what are past surface temperatures? Detailed description of the methods and results allow for reproducibility and illustrate consideration by the authors of multiple variables/influences on the results. While the data presented do not result in a fully-realized and issue-free method of determining EDT, they represent an important step forward in achieving that goal. All interpretations and conclusions are supported by the data. Furthermore, by acknowledging areas of uncertainty and external influences (e.g., permafrost) the authors provide the groundwork for future studies to build off these results.

We thank the reviewer for their overall positive reception of the study and the constructive comments.

While the manuscript is written logically, the overwhelming number of analyses left me lost from time to time. In particular, in the results section, description of the modeling experiments had me revisiting earlier sections to recall why each experiment was being tested. Adding a synoptic sentence or two for each results section will assist the reader in appreciating the robust quality of the experiments within this study.

In order to facilitate the reading of the results section, and in line with another comment from Reviewer 3 (4. Result section, General comment) we will add an introductory paragraph summarizing the different results reported in each following subsections: "First, we examine the characteristics of the ^3He diffusion kinetics parameters we modeled for our quartz samples and explore their sensitivity of the ^3He signal in those samples to Earth surface EDTs. We then present forward model results for the evolution of the cosmogenic ^3He concentrations recorded along each deglaciation profile for two different sets of thermal histories. The first set of thermal histories we investigate assumes a constant EDT since the exposure of the sampled rock surfaces following ice retreat. We then investigate a set of more climatologically-interesting thermal histories, wherein a change in EDT occurs at some point during the exposure time of each sample" (line 319-324).

We will also revise the section headings to delineate which sections are about methods, and add a brief synoptic summary at the beginning of the methods section (section 3) about different methods used. We think this will help clarify the manuscript significantly and make the number of different analyses more digestible.

In addition, we will implement the manuscript following the more specific comments/edits suggested below.

Below are a few minor comments/edits for the manuscript which should otherwise be accepted for publication:

Line 123 – Mention the two interpretations for glacial trimlines: ice-surface vs. thermal boundary. However, this is not mentioned again during the discussion of results, nor is one interpretation suggested over the other. With potential nuclide inheritance discussed later, could coverage by non-erosive, cold-based ice influence the EDT values for a particular site based on the thermal boundary interpretation?

The samples have been all collected below the trimline, implying that during the LGM, they were covered by ice. We do not hypothesize on the ice thickness and thermal state of the ice covering the sampled rock surfaces at this time (i.e., during the LGM) as this is out of the scope of this study.

We are discussing the implications of episodic ice coverage or inheritance due to insufficient erosion (e.g., due to cold-based ice) on the $^3\text{He}/^{10}\text{Be}$ ratio and paleoIsoEDT interpretations in section 5.2 ("Potential geological uncertainties"; that will become section 5.2.2 "Interpretation of cosmogenic nuclide measurements" in the revised manuscript). To make a clearer parallel with possible cold-base ice coverage, and to further illustrate the effect of ice coverage on ^3He evolution we will:

- refer to possible ice coverage by non-erosive cold-based ice: "First, our approach relies on the assumption that [...], without pre-exposure or episodic coverage (i.e., non-erosive cold-based ice)" (line 533-536).
- specify that ^3He will continue to diffuse even at subzero temperatures as expected under ice cover: "While previous bedrock surface exposure would also imply an inherited ^3He concentration, the latter would be subject to diffusion (partial or total) during glacier coverage, even at subzero temperatures and EDTs (Fig. S4)" (line 541-542).
- add a figure in the data supplementary (Figure S4) illustrating the diffusion of ^3He using diffusion kinetics parameters determined for both study sites, for isoEDTs as low as low as -30°C .

Line 170 – Briefly describe the purpose of the tantalum packets for those unfamiliar with the lab methodology.

The use of tantalum packets is not mandatory. What is important is that the samples are packed in some sort of metal packet because metal couples well with diode laser, and because the emissivity of the chosen metal can be calibrated so that we know the temperature that we are heating it to via pyrometer measurements.

In our experiments we were actually using two type of metals: tantalum for bulk degassing experiments and platinum-iridium (PtIr) for stepwise-heating experiments.

We will add this information together with the temperature control systems: “For bulk degassing measurements (Tables S3-S4), the samples were packaged into tantalum packets and heated in two, 15-minute long heating steps at 800 and 1100 °C with a diode laser, with temperature of the tantalum packet measured by pyrometry.” (line 200-202); “For stepwise-heating experiments on proton-irradiated grains, the selected grains were placed in contact with the tip of a bare wire K-type thermocouple inside small platinum-iridium (PtIr) packets. The PtIr packets were heated with a diode laser in a feedback control loop with the thermocouple.” (line 205-207)

Line 176 – Is there a set increment of temperature increase? If so, it might be easier for the reader to interpret those changes rather than the number of increases within a time range.

The increment of temperature change between steps varies; we will simply say this now to avoid confusion about how it is written and refer the reader to the data supplementary table where the holding temperatures are given.

Line 190 – How sensitive are the results for ^{10}Be ages and EDT calculations if a different scaling scheme is used (e.g., time-dependent LSDn)?

Exposure ages calculated using the time-dependent LSDn scaling scheme can be up to 7 % different from those calculated with the time-independent St model, as used in this study.

For such a difference, we estimate that the influence on the EDT calculation (e.g. paleo IsoEDT) remains negligible ($<1^\circ\text{C}$) and within the error margin.

Line 196 – From where are the initial EDT temperatures initially derived and how? A little clarification is helpful.

A full section (3.2; which will become section 3.5 “Effective diffusion Temperature estimates” in the revised manuscript) is dedicated to the description of how the initial (modern) EDT at each sampling site is derived, with an accent on temperature variables used for this calculation. In addition, to further clarify how past EDTs in the case of forward ^3He modelling for varying thermal history) were estimated, we will add at the end of the section: “Past colder EDTs input in forward ^3He modelling for varying thermal history are based on temperature anomalies from modern EDTs.” (line 302-303).

We will also reorganize and edit the Methods section of the paper, with an introductory paragraph at the beginning of the section introducing the EDT concept in the context of our study, which will help clarifying this point.

Line 320 – The thinning data still overlaps within uncertainty and remains stratigraphically consistent. The biggest issue is the disagreement with the ^{10}Be ages.

We will modify this sentence to highlight the point made by Reviewer 1: “¹⁰Be ages show a general decrease with elevation, in agreement with progressive ice thinning along a deglaciation profile in the high Alps during the Late Glacial. This trend is less evident for the apparent ³He ages, which overlap significantly within uncertainties above ~2200 m a.s.l. (Fig. 2).” (line 362-364)

Line 323 – There is a similar pattern of ³He retention for both locations for elevations greater than 2150 m asl. Could it be discussed how this is, or is not, relevant?

We agree that, although significantly overlapping within error, ³He/¹⁰Be age exposure ratios above 2150 m a.s.l. seem to decrease with elevation in both sites. However, because this trend remains within uncertainties, we decide to not further discuss this point.

Line 330 - *these **Corrected**

Line 337 – It might help to clarify that the approximate differences in EDT between high and low-elevation samples are determined from the peak value for each probability distribution.

Following the suggestion of Reviewer 1, we will modify the sentence as follows “[...] they clearly depart from paleoIsoEDTs obtained from the low-elevation/Holocene sample(s), by ~6° (MBTP site) and ~18°C (GELM site) based on the peak values from the obtained bimodal probability distributions (Figs. 5b, e)” (line 379-381).