



EGUsphere, author comment AC1
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Reply on RC1

Jason P. Briner et al.

Author comment on "Drill-site selection for cosmogenic-nuclide exposure dating of the bed of the Greenland Ice Sheet" by Jason P. Briner et al., EGU sphere,
<https://doi.org/10.5194/egusphere-2022-264-AC1>, 2022

We wish to thank this reviewer for their insights, and we very much appreciate their time. Many comments seem to center around requests to further elaborate in certain areas, below you can find our thoughts for doing so. Also, please note that some of our replies to the other referee's comments apply to these comments, so please check out both of our replies. Thanks!

Review 1 comment: I would encourage the authors to elaborate on the possible outcome of this project in relation to what they can say about past GrIS history. You drill at the margin so do you only expect to be able to say something about the marginal ice sheet history or would you expect your results, together with previous studies, can open up for a wider GrIS history interpretation, when it comes to the spatial extent? In the abstract and introduction the is mentioning of studies showing an ice sheet wide history, and it would be good if you in a few lines very clearly could state the outcome of this project.

Our reply: We like the addition of more specific outcomes. Yes we agree that any drill site using the available drills mentioned are by default in the peripheral areas of today's ice sheet. We feel this is still valuable.

Further, using results from ice-margin exposure dates to constrain the size and shape of the Greenland ice sheet using an ensemble of numerical ice-sheet model simulations is the goal of another study, currently in review. We have added a citation to the pre-print of this study where appropriate in order to emphasize this outcome. However, the focus of this study is on integrating multiple forms of data to find the most suitable locations for subglacial access drilling, so the numerical modeling effort is not included directly here.

The abstract end, we would add: "*Results from cosmogenic nuclide analysis in new sub-ice*

bedrock cores from these areas would help to constrain dimensions of the Greenland Ice Sheet in the past."

Review 1 comment: In lines 320-322 you briefly mention the other suitable areas, which meet your criteria, but that were not chosen. Can you elaborate more on why they are not suitable? Maybe give some specific location examples?

Our reply: We explain that we don't emphasize these areas because "most areas are in alpine-style, icefield-type settings, or lie in small areas between outlet glaciers"

The implication is that being smaller target zones to drill into from the ice sheet surface, given existing uncertainties in available datasets (e.g., ice sheet thickness, basal temperature, etc.), they could more easily not pan out than larger patches of the bed that meet drilling requirements. Given the reviewer comment seeking more detail, we would add this statement along those lines: "*In these additional small areas, however, existing uncertainties in available datasets (e.g., ice sheet thickness, basal temperature, etc.) means that drilling there is a bit riskier than in larger patches of the bed that meet drilling requirements.*"

Review 1 comment: Title: This might just be me, but suggesting to change the title to "bed beneath"/"bedrock beneath" instead of "bed of". You also refer to it in this way in lines 33-34; ..."cosmogenic nuclides in bedrock from beneath the Greenland Ice Sheet"....

Our reply: Good idea, will change title to replace "of" with "beneath"

Review 1 comment: Lines 113-115: Can you elaborate "direct constraints" here? I would consider to delete direct and in general maybe elaborate more. The studies I assume you refer to here place constraints, but as far as I remember do not conclude one unique solution/ice sheet burial/exposure history of measured concentrations in sub-ice material?

Our reply: We see a difference between direct/indirect, versus, say, how closely a dataset might constrain ice sheet change. We take indirect data as those such as ice-rafted debris, sediment flux or sediment geochemical records as being indirect on ice sheet size since there are other factors in addition to ice margin position that control their fluctuations. See referee 2's comments on this; they clearly agree. Direct, on the other hand, we take here as cosmogenic nuclide inventory in bedrock, which directly relates to past ice sheet size (presence v absence at a site of data analysis). Cosmogenic nuclide measurements in sediments, which can be transported to a site where today they are measured, may lie somewhere in between (further discussed elsewhere in our reply). All this said, we also agree of course that there are multiple interpretations of sub-ice cosmogenic nuclide

inventories (could be one or many periods of ice-free exposure that result in a particular concentration). There are, however, some conclusions less open to interpretation, such as overall cumulative periods of time that a site has been ice free, or cumulative time that a site has been buried by overlying ice.

We already write on line 99: *"Although alternative histories are possible, the results point to significant ice loss in Greenland within the Quaternary, and likely within the last 1.1 Myr."* {note Referee 2 advises us to remove "likely."}

We would like to clarify that there may not be a single solution, yet there still is an important and direct constraint on cumulative ice sheet presence/absence at a site (compared to most proxies for minimal ice sheet configurations). Based on both referee comments (collectively), we would now write: *"Although alternative histories are possible, the results lead to an important conclusion: an almost entirely absent ice sheet in Greenland within the last 1.1 Myr. Furthermore, these types of data directly constrain past ice-sheet configurations, unlike marine sediment records from adjacent seas that provide indirect evidence."*

Review 1 comment: Lines 340-343: Can you elaborate on how you will look more into/determine if this area has local ice during past interglacials? How would that affect your modeling and interpretation, would you use a different approach than the other areas etc?

Our reply: While we cannot distinguish whether ice covering the Prudhoe Dome site is binned as "local" or "ice sheet" ice, how that ice is categorized is less important than determining if any ice was in these peripheral settings at all during the entire Holocene, or Last Interglacial, and so on. Via use of multiple isotopes, one should be able to simply determine the Holocene history, and likely could explore MIS 5e history versus earlier exposure. Add-on analyses like luminescence methods could help elucidate pre-Holocene exposure timing more finely. Ice sheet models could be paired with cosmogenic nuclide information to help visualize whether or not peripheral high elevation areas persist for long durations after inland ice has receded or not. This is addressed further in our reply to Referee 2.

Review 1 comment: In the conclusion and introduction, you talk about the information retrieved from Camp Century and GISP2 as paradigm shifting and "direct" information, but for me to see they are both "most likely scenario" results, but still with more possible ice sheet histories to fit measured nuclide concentrations? I would consider to make it clearer that there are more than one solutions/result from those studies.

Our reply: This is an important comment, and we are thankful that it has been repeated in comments made by this referee. By now we have addressed this comment since it echoes one made above about "direct constraints." Note that we also discuss added

interpretations of cosmogenic nuclide data in sediments in section 3.5.

Review 1 comment: Minor Comments

You use both "ice sheet" and "ice-sheet" throughout the text, chose one for consistency

Our reply: In English, a compound modifier should be hyphenated if it comes before the word it modifies. When ice sheet is used as an adjective, it is intentionally hyphenated (eg "...ice-sheet model."); and when it is used as a noun ("...under the ice sheet."), it is not hyphenated.

Line 87: Consider to delete "the" before MIS 5e

Our reply: Done.

Line 87: Delete "age"? There is something in the sentence that doesn't make sense

Our reply: Done.

Line 92: "the" sub-ice bedrock exposure age

Our reply: We think it makes more sense to leave "the" out as it refers to not one example site but the bed age more generally.

Line 115: "so far" instead of "thus far"?

Our reply: Subjective.

Line 122: In the abstract you use "<700 m" and here "~700 m", consider to make consistent

Our reply: Done.

Line 158: This is the second section numbered "3.1"

Our reply: Oops. Thank you.

Line 192: Delete space between “warm-” and “and”? As you have it in line 187

Our reply: Actually, it is more correct to add a space on line 187, haha. So now both lines are consistent with each other.

Line 217: This line doesn't read well, do you mean the criterion of being safe, so no air support

is needed or the need of air support for transportation during fieldwork?

Our reply: Done.

Line 248: Consider re-phrasing to “in its south, west and central areas” – it feels like something

is missing when reading the sentence the way it is now.

Our reply: Done.

Line 262: You change between writing “NASA's Operation IceBridge” and “NASA Operation

Ice Bridge” – chose one and make consistent

Our reply: Done.

Line 376: is the “-” after “100” intended?

Our reply: Yes intended.

Lines 282-292: This is up to the authors but it would be great if you could elaborate a bit on

why you want the nuclides to be preserved. You want them for the modelling part, but just to

elaborate a bit on how you can use “inheritance” and different nuclides, with different half lifes

to model past ice sheet extent.

Our reply: We agree that we can clarify that without cosmogenic nuclides preserved in the first place, then one of the main reasons to obtain sub-ice bedrock is already out the window. So, we add to the middle of the paragraph (line 289) the following sentence: “At sites of erosive sub-glacial conditions, cosmogenic nuclides would be largely absent, hence removing one of the main reasons for obtaining sub-ice bedrock samples.”

Line 386: Is a "shows" missing after "sparse radar data that"

Our reply: We agree this is a little unclear, would change "data" to "lines": "The region has relatively sparse radar lines that cross drilling-suitable areas."

Line 405: Consider abbreviating Northeast Greenland Ice Stream since you use the

abbreviation in the caption for figure 8.

Our reply: We favor using acronyms as little as possible. Makes more sense in a figure caption which is a condensed piece of information.

Lines 410-413: Either move to/place instead of lines 403-404 or delete lines 403-404, which

also mentions the sparse radar data

Our reply: Thanks for pointing out the repetition. We would remove "The regional has relatively sparse radar data coverage, suggesting that" from Line 410/4011.

Line 464: Consider to delete "to measure"

Our reply: Agree.

Review 1 comment: Figures

Figures: "A" or "(A)", chose one and be consistent (same in the rest of the figures)

Our reply: Agree.

Figure 1: Suggesting to put the location of NEEM on the map, since it is mentioned several

Times

Our reply: Agree.

Figure 1: Just a suggestion, color either B or C with maybe grey instead of white so they are

not both same color

Figure 1: Consider to add a scale

Our reply: We'd opt to leave scale bars off, and will leave both Fig 1B and Fig 1C white.

Figure 4: Consider to enlarge the figure or maybe just text in the white box, the text is very

small as it is now.

Our reply: Agree.

Figure 8: Is its placement wrong? It should be before section 4.5?

Our reply: Will fix, this would change during type setting anyway.

Figure 8: This is up to the authors, but I would re-arrange this figure, so (A) and (C) would be

in the top panel (with (C) first and then (A)) and (B) would be below in full length.

Our reply: Agree, this makes good sense.

Figure 9: In (B), do you mean "KFJF" and not "KKJF"?

Our reply: Agree, great catch.