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# *Interactive comment on* "Delayed and rapid deglaciation of alpine valleys in the Sawatch Range, southern Rocky Mountains, USA" *by* Joseph P. Tulenko et al.

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## Summary and recommendation

The paper reports a combination of new and previously published geochronological data (10Be ages) in the southern Rocky Mountains, which record glacier retreat following the last glacial maximum. The authors use the data to quantify retreat rates, and then discuss possible drivers of glacier retreat.

Overall, I enjoyed reading the paper, which adds new data and analysis in this region, and which presents interesting questions about possible global, regional and



local drivers of alpine deglaciation. The manuscript is generally well structured, written and illustrated. The methods are all outlined, although more detail could be provided in parts. The results broadly support the conclusions, but more discussion and clarity are required.

I recommend publication in Geochronology following some revision.

There are a few areas where I think the paper could be improved. First, a key component of this work is the quantification of retreat rates, but the authors could better emphasise why knowing the glacier retreat rates is important. Arguably, the discussion about the timing and drivers of deglaciation are supported by the 10Be ages without the need for rates. Second, glacier hypsometry is the only the non-climatic factor that is considered, and this is only briefly discussed. Other non-climatic drivers should be acknowledged and discussed. Third, the comparison to the North Atlantic (Heinrich-Stadial 1/Bolling) climate transition requires either more justification or less weight as a conclusion. The chronology indicates that the glaciers retreated prior to the abrupt warming of the transition, implying that this didn't, at least initially, drive glacier retreat. In summary, this is a nice dataset that, while not conclusive about what drove deglaciation in this region or the extent of possible teleconnections, presents an opportunity to thoroughly discuss possible drivers of glacier retreat.

## Detailed comments

Lines 123-125: It is not clear from this sentence whether the estimate that "glaciers remained at (100%) or near (82-83%) their LGM length until 16-15 ka" is derived by this study or a previous study.

Lines 139-145: Hypsometry is the only named non-climatic factor that is considered. Were these glaciers ever lake-terminating (e.g. Lake Creek)? What role could bed geometry have played?

Line 150: The text refers to a "slightly modified" method. Modified from what – Corbett

et al. (2016)? Modified how?

Line 155-160: What was the ratio/10Be concentration of your procedural lab blank(s)?

Lines 175-179: This isn't the first time that Bayesian age-depth models have been used for transects of 10Be ages. Previous such work (e.g. Jones et al., 2015, Nat. Comms.; Small et al., 2018, GSA Bull.) should be acknowledged. In general, the approach to derive retreat rate estimates needs more detail. What is exactly being modelled here? Is it assuming a linear or non-linear relationship between age and depth/distance? Is the model accounting for age uncertainties? If so, are the age uncertainties included at 1 or 2 standard deviations, weighted or unweighted?

Lines 183-184: Clarify what you mean by "net retreat rates".

Results: You should initially report the results for only the new data (the 12 ages from Clear Creek and Pine Creek), even if only described briefly. After that, you can describe the results in combination with the previously published ages.

Line 190 (and elsewhere): How confident are you in the precision of your distance measurements? Would rounding to the nearest whole percent be more suitable?

Line 214 (and elsewhere): Please clarify here whether the retreat rate result is reported at 68% or 95% confidence. Additionally, the format of reporting is probably not suitable, as the model output distribution is likely non-Gaussian. Such results are therefore typically reported as an uncertainty range, rather than mean with uncertainty.

Lines 233-243: The identification of likely outliers is based on the general stratigraphic relationship of ages within the dataset. These outliers also happen to fall outside of the 95% confidence bounds from the BACON model. But, as far as I can tell, BACON was not used to systemically identify (and remove) outliers. In which case, the estimated retreat rates from BACON will be influenced by these apparent outliers. So, how do the retreat rates differ when these outliers are excluded?

Lines 247-252: More of a discussion point than a criticism: While it seems fairly well



justified to use the Promontory Point calibration site instead of NENA site based on locality and elevation range, it is also worth considering the time period used for the calibration sites. The Promontory Point site is calibrating the production rate at 18.9-18.0 ka, while the NENA site is calibrating for 16.8-13.8 ka. The dataset reported here best correlates to the time period covered by the NENA site, which could be an argument to use this production rate instead of that from Promontory Point.

Lines 266-269: Explain how glacier hypsometry and/or steepness would influence differing glacier behaviour during deglaciation.

Lines 285-288: Glaciers don't respond to CO2, so directly comparing to CO2 seems a little irrelevant. Of course, there is a close relationship between CO2 and temperature, but why not compare your glacier retreat records to proxy global temperature (e.g. Shakun et al., 2012)?

Lines 327-334: The argument that there is similarity between records, and "possible teleconnections", isn't particularly convincing. The majority of the recorded retreat occurred before the North Atlantic climate shift; your ages indicate retreat initiated 1-2 kyr earlier that the climate shift at 14.7 ka. I'd like to see the text rephrased, without mention of teleconnections.

Lines 329-330: What is this period of relative glacier stability based on?

Line 383: "one of two", or both mechanisms, as you state below. Reword this, as these are not mutually exclusive explanations.

Lines 385-386: As mentioned above, it is a difficult to accept that the glaciers "began retreating around the time of abrupt warming" when the data indicate retreat started at least 1-2 kyr before the climate transition. There is only correlation here if you doubt the accuracy (or precision) of the retreat ages, in which case you should discuss more thoroughly.

Lines 387-390: I like the comparison of the rates of glacier and climate change, as it

makes use of your estimated retreat rates and it can be effective if there is any doubt in the absolute timing. However, a number of non-climatic, glaciological processes can also contribute to faster rates, even with a gradual forcing. Such processes also need to be considered.

Line 400: Sorry to be pedantic, but as above, glaciers don't respond to gas concentrations. Refer to global temperature instead.

Table 1: Transact distances are reported to the nearest metre over many thousands of metres. This seems unrealistically precise.

Figure 2: Need to make clear what are the new data and what are previously published data. There are also two references to "n=x", which I presume need values added.

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