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Interactive comment on "Development of a multi-method chronology spanning the Last Glacial Interval from Orakei maar lake, Auckland, New Zealand" *by* Leonie Peti et al.

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We thank Referee #2 for their constructive and helpful review and address the raised points below. RC2 = reviewer comment from reviewer 2. C1-C12 = comments 1 to 12 followed by our response.

General Comments

(RC2-C1) Radiocarbon: I feel that, while not perfect data (e.g., age reversals, unknown reservoir effects), the treatment of the radiocarbon data is fair and the authors are honest about their uncertainties. I would recommend the authors update the calibration

to the SHCal20, now that it is available, and present (and make available) both the SHCal13 and SHCal20 based age models (so that other authors can make direct comparisons to either). Otherwise, the next study that presents Orakei maar lake data on age will need to re-do the age model and this age model will be dated. Response to (RC2-C1): The age model has now been updated to use SHCal20. The difference to the earlier version using SHCal13 is max. 200 yr, usually less than 100 yr. No work from this record using the earlier age model (with SHCal13) has been published yet so that we refrain from a comparison between both age models and urge all co-workers to use the updated age model for future work.

(RC2-C2) Tephra Stratigraphy: Obviously, the author's identification of the "unidentified" basaltic tephra layer T66 is central to the older part of this age model and the only real constraint beyond the RPI correlation (as the uncertainties in the luminescence data prevent those data from providing strong constraint at the temporal resolution of the final age-depth model). The authors propose that this a newly recognized tephra for the AVF, AVFaa, as it cannot be correlated to previously identified tephra layers. They use the Ar/Ar constraints from their proposed eruptive center, Mt. Albert, to assign an age to this layer. I think this assumption is reasonable, and while it is better explained in the appendix, I think it deserves a little more attention in the main text (and perhaps the abstract) because of how important this interpretation/assumption it is to the final age model. This should maybe include the data needed to identify the tephra in the main text, as the authors do for their other tephra in Figure 3. The way the treatment of T66 is presented in the results section 4.1 makes it seem like the age of this tephra layer is well known, the eruptive history of Mt. Albert is well known, and the tephra identification has no ambiguity. This new AVFaa tephra may also be important for future studies. See below, but I also am curious if there is an RPI DTW solution that independently supports this age assignment. Response to (RC2-C2): We have moved the text from the appendix to a new section "4.1.2 Basaltic tephra sample T66" and added a new figure 4 summarising the relevant figures from the appendix (A4-A6). See comment below (RC2-C4) regarding the RPI DTW solution for AVFaa.

(RC2-C3) I am assuming that AVF1 was not used in the age model because it has two possible ages _106 vs _83 ka. It seems like the author's age model, while not using the tephra as a constrain, is more consistent with the older of these two ages. I think it would be worthwhile to add a paragraph in the main text to discuss the AVF1 tephra, how the previously published age constraints were derived and how the new age model compares. Does the new age agree with either of the older ages? Why or why not do you think that is the case? Does it provide an addition independent support for the RPI based correlation? Response (RC2-C3): AVF1 was not used in the age model because it has not been identified via EMPA in the new Orakei 2016 cores that are mostly used in the composite stratigraphy and age model. Its depth is correlated from the core presented in Molloy et al 2009 and could be used but its investigation (along with the same question for all other tephra layers) is part of a separate study in review (with minor revision requested) in New Zealand Journal of Geology and Geophysics. Actually, the updated age model produces an age for AVF1 of ca. 90.4 ka falling somewhat between both ages. As this is discussed in the upcoming NZJGG paper we chose not to discuss it here.

(RC2-C4) Paleomagnetism: I liked the authors use and application of DTW in their correlation of the RPI data. We all know that wiggle stratigraphic correlations can be non-unique, so while not always perfect, at least DTW is objective. However, to get a perfect DTW solution requires perfect data (which is never the case and cannot be expected in paleomagnetism). Thus, the result of the DTW solution when using a general DTW algorithm (like the one used in this study) for geologic data is often a stair-step pattern, implying sediment delivery in pulses separated by periods of no deposition. However, we often assume that sedimentary records like these accumulate gradually over time. The authors in a way deal with this by randomly sampling tuning points from the DTW solution and setting hard start/end tie points. However, this is problem that Hay et al, which the authors cite, also address through their development of a DTW algorithm. In this algorithm, users can work with imperfect data by varying assumptions relevant to geologic data (such as how variable sediment accumulations are) to explore

various possible DTW solutions that can be evaluated against independent constraints and/or expert knowledge. Do the authors think it would be worth trying the Hay et al. DTW approach to explore other possible DTW solutions that may be more reasonable for imperfect geologic data? Why or why not? Can you treat the AVFaa tephra age independent of the RPI DTW solution and find a solution that independently supports the age the authors assign to the AVFaa tephra? Response to (RC2-C4): Obtaining various possible DTW solutions and evaluating them might become an interesting exercise once we have a better understanding of the depositional environment of the sediments. We are expecting ongoing multi-proxy environmental reconstructions and high-resolution micro-facies work to shed light in this matter. A future study may find a better DTW solution but this goes beyond the scope of the current paper. It is true that the alignment path looks very "staircase"-like which is not expected for the mode of sediment delivery (at least on the resolution we can study it here) but is necessary to allow enough stretching and compressing between the PISO and Orakei RPI to happen in the alignment. For this reason, we do not use the alignment path itself as an age model but allow for smoothness again by integrating the tuning points into Bacon.

As for the AVFaa tephra age. We have now updated the DTW procedure (section 3.6) and removed the split at the level of the AVFaa tephra. Thus we're treating the tephra age independently and note that it agrees with the DTW solution within +/- 2 sd.

(RC2-C5) Sedimentation Rates: It makes me nervous when I see a major change in sedimentation rates at a depth where the main chronometer for the age model changes. In the case of this study the authors find a switch from lower to higher sedimentation rates at around the same depth that the age model changes from being primarily constrained by RPI correlation to radiocarbon. I think this observation should be included in the main text. Why should I, the reader, be convinced that this accumulation rate change is the real signal and not an artifact of a non-unique or problematic RPI correlation? It doesn't appear to exactly line up with the facies unit changes or the lithologic log, but maybe there are other data that show a sedimentological change around the same time? Response to (RC2-C5): We have added the following paragraph to section 4.8 “The stepwise increase in sedimentation rate at $\sim$ 45 m nearly coincides with the change in chronometer from RPI tuning points to tephra and 14C ages. Whilst we cannot entirely disprove an influence of the chronometer change on the increase in sedimentation rate, we do note several observations that support this sedimentation rate change to be method-independent: (1) It is a stepwise change not a sudden change at the exact change point in chronometer. (2) In the interval where both chronometers overlap, albeit very short, the Rotoehu tephra and the uppermost RPI running point agree well (Fig. 8). (3) The increase in sedimentation rate does occur at the transition from facies unit 8b to 8a. These sub-facies differ in their colour contrasts between the laminations potentially indicating slightly different chemical composition, thus a slightly different depositional context which may well agree with a different sedimentation rate. (4) Further changes in sedimentation rate, even larger in magnitude than at $\sim$ 45 m occur at other positions in the sediment sequence independent of strong lithological/facies changes (and independent of chronometer changes) such as at $\sim$ 39 m and within facies unit 4 (Fig. 9).”

(RC2-C6) Data Availability: Thanks for posting your data to Pangea. I would also recommend including the actual age-depth relationship with uncertainty as an independent contribution. Response to (RC2-C6): Thank you for this suggestion. We post the updated age-depth relationship (on a cm-resolution) as a supplementary to this publication.

Specific Comments:

(RC2-C7) Line 263: Hay et al. aligned chemostratigraphic data, not paleomagnetic data. Their algorithm was modified to work with paleomagnetic vector data by Hagen at al. But, the Hay et al. algorithm would be the appropriate choice for RPI correlations. Response to (RC2-C7): Corrected the sentence to “Dynamic time warping (DTW) aligns time series datasets through generalized dynamic programming (Hay et al., 2019) and has been adapted for paleomagnetic vector data by Hagen et al. (2020).”

(RC2-C8) Lines 495-515: There is information in this section that seems like it would fit better in the methods section, particularly the choice of DTW algorithm. Response to (RC2-C8): We moved most of section 4.6 into the methods section 3.6 and extended the results section on the aligned curves to better focus on the match between RPI from Orakei and PISO-1500.

(RC2-C9) Figure 2: Would it be helpful to indicate the stratigraphic position/labels of the tephra layers? Response to (RC2-C9): We have added the tephra layers to this figure.

(RC2-C10) Figure 6: It is difficult to read the small text in this figure. Please make the text larger. Response to (RC2-C10): We have made the text larger (now Fig. 8).

(RC2-C11) Figure 7: It might help the clarity of the figure to decrease the symbol size so that it is easier to see how the age control points compare to each other. Response to (RC2-C11): We have decreased the symbol size (now Fig. 9).

(RC2-C12) Figures B1-B2, B4, C4: All of these figures would benefit from increasing the font size of the smaller fonts to make them more legible. Response to (RC2-C12): We have increased the font size in all mentioned figures.

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