

## **General comments**

This paper brings together three independent dating techniques to improve age model reliability for a lake record in Alaska. Davies et al. help to advance two areas; firstly, to expand the tephrostratigraphic record for North America and, secondly, provide a working example of how useful tephrochronology is in validating other independent dating techniques with the use Bayesian statistics.

The paper itself is clearly written and provides an example for using multiple chronometers in a lake record setting. The introduction sets out the problems of obtaining accurate and precise ages using radiocarbon dating, particularly in high latitude lakes, and how these could be resolved with the use of combining other dating techniques such as palaeomagnetism and tephrochronology with the appropriate methods of Bayesian statistics. The methods conducted by the authors is definitive though additional detail could be added to some sections to allow clear reproduction of certain processes and provide additional information as to why a certain process were chosen. The step-by-step assessment of which radiocarbon dates were appropriate for the overall age model was useful to see. The tephra correlations made by the authors look robust and clear. I agree with the comments made by RC1 for this part of the paper. There are a few additional comments made on the attached document around the presentation of data to justify primary deposition. The justification for including/excluding certain ages in the Bayesian age model were made clear and the age model results were repeatable. The discussion section brings together all the important points in a concise format. Additional information and references would provide further context for the reader to understand the points made. Though these are very minor. The figures are beautifully presented with clear and detailed captions explaining everything well. The supplementary files are very useful, particularly the publication of the OxCal coding for the final age model.

Overall, the authors of this paper have done a lot of work to produce valuable results and should be commended. This paper will provide a useful example for the scientific community to work from when conducting research with multiple chronometers as well as providing additional geochemical data for future tephra correlations in North America records.

## **Comments**

Line 90 - A reference to Figure 1 would be useful here to add context to the location of these volcanoes mentioned in this section Alaska and the lake.

Figure 1 - This figure is very clear. Just a short addition of naming the Kamchatka-Kurile volcanic and Alaskan-Aleutian arc regions would help the reader with location of the lake in relation to these volcanic areas mentioned in the text.

## **Section 2.3**

Line 170 - Additional information on the sieve mesh size used would be useful here. Especially as many researchers change between 10 and 25micron yet still follow Blockley et al., 2005.

Line 175 - How were the glass shards mounted for geochemistry? Were they hand-picked using a micromanipulator (using Lane et al., 2014 reference) or another technique due to how little number of shards there were? This information would be useful here for potential replication.

Line 178 - I would suggest saying 'single glass shards were analysed on a JEOL...' to further emphasis single analysis.

Line 181 - What were the peak count times for the individual elements? Did you use a PAP absorption correction method to quantify the geochemical results? A quick sentence and reference to these would be adequate.

Line 191 - Data filtering - what was the limit % of analytical total used to remove non-glass analyses? 93%? 95%? Please state here. What was the justification for this %?

## **Section 2.4**

Line 202 – 'This is more effective than using statistical techniques...' - What statistical techniques are these? Is there a reference for this statistical bias? I think a bit more detail and evidence here would help the reader understand why you decide to use the visual technique to detect offsets.

Line 206 - What calibration curve was used? Please state here. This is especially needed as Steen et al. reference IntCal13 in their radiocarbon calibration from the paper I could find on GChron.

Line 210 - Adapt reference 'Bronk Ramsey, 2013' to 'Bronk Ramsey and Lee, 2013' and correct in the reference section.

Line 211 - Additional reference to Bronk Ramsey (2009) needs to be made here in reference to the Outlier model - Bronk Ramsey, 2009. Dealing with outliers and offsets in radiocarbon dating, Radiocarbon 51(3) 1023-1045

Line 213 – After reading the whole paper, I believe additional information is needed on the use of 'combine' the different PSV models in the OxCal model. This is particularly important as reference is made to 'combine' in section 4 and in File S1.

## **Section 3**

Line 216 - What was the total number of tephra samples examined? A quick reference to the number in the brackets.

Figure 2 – The figures throughout this paper are very clear, useful and appropriate for showing the necessary data. The figure captions explain the data presented in the figure very nicely. Just a quick change of 'filled grey triangles' to 'filled red triangles'.

### **Section 3.1**

Line 237 - I see 36 in the table not 38. Please adjust if necessary.

Line 238 - Yes, homogenous geochemical results can indicate a primary deposition. However, I would like to see additional evidence provided about the glass shards sizes and morphologies in each tephra layer. I believe that this type of information would have been recorded at the same time as the shard count. Were the shards of similar sizes and morphologies within each sample? A quick sentence saying this here would further justify your comment on primary deposition.

Table 3 - caption I don't understand this (#.##) and it is not in the table. Possibly a formatting problem? I believe just refer to 'S.D.' instead in the table and in the caption. Also say if it is 1S.D. or 2S.D? Please make this clear in the caption too.

I believe 'Analytical total' should be displayed here rather than 'normalised total' as current. Using normalised total makes this column obsolete as 100% is repeated, though you can work out the analytical total from the remainder of the information. Many other tephra papers present analytical totals in tables in the main paper.

Table caption should mention 'normalised major element...' to re-emphasise that the data displayed in the table is normalised.

Table 4 caption – 'Age estimates... from Steen et al...' Steen et al. used IntCal13 in their paper to calibrate the radiocarbon dates. This is from the paper I could have access through on Geochronology using your reference (though Steen et al.'s paper title was different to the reference list). Are the ages for these tephra's present here also using IntCal13? If so, they should be updated to IntCal20 to make a similar comparison to the other ages presented here. However, I may be wrong in the paper I could have accessed. Either way, it should be made clear what calibration curve was used for the radiocarbon dates of Cascade Lake in the table caption.

For each cryptotephra layer discussed in the remainder of this section - It would be advantageous to include additional information on glass shard morphology and size for every tephra cryptotephra layer discussed in this section. This has been done for CL-74. This would further emphasise the point that these peaks are homogenous and are primary (if being similar in size and morphology) as well as help with the correlation to which eruption. This might provide further evidence for why CL-105 has two populations due to Na loss but are possibly from the same eruption.

Generally, I would suggest following a similar style to what has been written for CL-74 for each of the cryptotephra layers. Information presented on the most distinguishable geochemistry that makes it clear which eruption it is correlated to, along with the glass shard morphology and size.

Line 271 – 'Chronologically, Aniakchak CFE II has been dated...' Sentence needs re-wording as there are too many and's.

Line 274 – 'The latter is supported using geochemically...' This sentence is confusing. How it is worded currently gives the impression that the ice cores also have tree rings. Please re-word, e.g. "... sulphate peaks. Additional evidence is also provided by tree rings..."

Line 280 - highlight if error  $\pm$  1sd or 2sd for NGRIP age

Line 282 - Reference needed here for the Tau\_Boundary, Bronk Ramsey (2009)

Line 385 - I also think that how the shard concentration graph presented indicates a possibility of problems with taphonomy such as bioturbation or secondary inwash. This is not mentioned in this paragraph when it is an important point to make. This side of the argument I believe should be mentioned in a sentence at the end of this section as further discussion is made in section 5.1.

#### **Section 4**

Line 403 - Please refer to why the potential reason for Steen et al. concluding that these ages were too old. Problems with hard-water effects? Not enough carbon to provide an accurate date? A little more detail will be provided further insight for the reader reading this paper.

Line 410 – ‘...therefore also removed as outliers.’ Again, what is the possible reason that these are outliers? Just a sentence as Steen et al. does explain it in detail. This will help emphasises why this paper only focused on the Holocene tephra record rather than the whole core.

Figure 5 - This is a very clear figure. Very nicely presented and the caption is very detailed

#### **Section 5.1**

Line 450 – ‘... ultra-distal...’ Can you provide a distance in km to further emphasis this point?

Line 471 – ‘... deposition of shard before the reach the northern slops.’ Additional references need to be made here to provide evidence for rain of shards due to a topographic barrier. E.g. Watt et al. 2015 or Stevenson et al., 2013.

Line 471 – ‘Other factors may include...’ Example references need to be made here. E.g. Pyne-O’Donnell, 2011.

Line 475 - This paragraph needs a concluding remark, e.g. that topography primarily influenced shard concentration at Cascade Lake and not lake characteristics.

Line 476 - Closely space eruptions are not the only reason for this type of shard concentration profile. The possibility of taphonomic processes e.g. reworking, bioturbation are also a possibility. This needs to be emphasised here in a short sentence before the detailed discussion in the next session.

Is there any additional proxy information that could help with providing evidence (proxies?) against or for this taphonomic argument from the core? If so, please use this here.

Line 501 – ‘... fallout on snow, sediment accumulation, hydrology...’ References to appropriate papers are needed here.

The remainder of the discussion is very good with arguments for each section presented clearly and supported by further evidence, maintaining a balanced view whilst strengthening this research's conclusions. Shortcomings of the research are also mentioned, providing a basis to advance further research in the areas of tephrochronology and using multiple chronometers in future investigations.

### **Supplementary information**

- File S1 – there is an additional '.' in "Curve("Bomb13NH1","Bomb13NH1.14c"); C\_Date("2.25-3",1901,4.)" that causes the OxCal model not to run. It needs to be simply removed.
- Please create a figure caption for each supplementary figure. Though the figures referred to are in the main paper, further detail could be provided with a simple caption describing what each figure is and any other information you believed to be important to understand the results. This is particularly for Figure S3.
- Table S1 and S2 would be better as an excel file to allow other researchers to quickly compare their own data to yours. It is also typical within tephra papers that geochemical data is presented as normalised within the main paper and non-normalised within supplementary material. I would recommend non-normalised data to be presented here. A table caption should also make it clear it is non-normalised.