Report #1

Submitted on 03 Jun 2024
Anonymous referee #3

Anonymous during peer-review: **Yes** No
Anonymous in acknowledgements of published article: **Yes** No

Checklist for reviewers

1) Scientific significance Does the manuscript represent a substantial contribution to the understanding of natural hazards and their consequences (new concepts, ideas, methods, or data)?	Excellent **Good** Fair Poor
2) Scientific quality Are the scientific and/or technical approaches and the applied methods valid? Are the results discussed in an appropriate and balanced way (clarity of concepts and discussion, consideration of related work, including appropriate references)?	Excellent Good **Fair** Poor
3) Presentation quality Are the scientific data, results and conclusions presented in a clear, concise, and well-structured way (number and quality of figures/tables, appropriate use of technical and English language, simplicity of the language)?	Excellent Good **Fair** Poor

For final publication, the manuscript should be

accepted as is.

accepted subject to **technical corrections**.

accepted subject to minor revisions.

reconsidered after **major revisions**:

rejected.

Were a revised manuscript to be sent for another round of reviews:

I would be willing to review the revised manuscript.

I would not be willing to review the revised manuscript.

Suggestions for revision or reasons for rejection

(visible to the public if the article is accepted and published)

The authors develop an original technique of evaluating the XRF data of the event deposits in scatter plots and look for distinct patterns that help understanding the depositional processes and source regions of the event deposits. This scatter-plot technique is commonly applied for grain size data on event deposits, but using this approach on XRF data is a first time and bears a great potential in other studies as well. The authors make an extensive argumentation that they use the raw XRF data and not the log-ratio transformation of the data (a transformation suggested by the reviewer and which is common practice in sediment geochemistry. As raw counts is not geochemistry data, but rather a mixture of density, grain size and element abundance, interpretation is becoming more difficult. I suggest the authors to re-consider the usage of the CLR approach. Using the Centre-log-ratio (CLR) is important to decrease the effect of grain-size and density and get geochemical robust data from XRF scans. The authors mention that the CLR approach can produce more "noise", which is true. Therefore, it is crucial to select only elements with high signal-to-noise ratio for the calculation of the geometric mean, and to remove any 0 or negative values. So, I suggest the authors to re-consider the usage of the CLR approach on a selected suite of high-quality elements and evaluate the quality of the results. Of course, the final decision is up to the authors on what they consider the most meaningful.

AUTHOR RESPONSE: Yes, the XRF data is a mixture of density, grain size and elemental abundance. The use of the raw (not transformed) XRF data is important because grain size, porosity, and density are implicit variables in addition to the elemental abundance and elemental patterns with grading only show up when viewing the raw data. In otherwords, we are not strictly evaluating geochemistry, but rather the approximate geochemistry with variables that change along with grading (porosity, grain size, density, etc.). This is what allows for the geochemistry to be evaluated as loops (which reflect deposit grading). This cannot be seen in the CLR data because the influence of the other variables has been removed. This is an essential component of this study. Because of the use of the variables in this way we were able to infer processes not as apparent from the log-ratioed XRF. Although both K and Ca have high signal-to-noise ratios, we are limited to these variables as they represent the two endmember sources. If we wanted to get true geochemistry data from XRF, we would use the CLR method, but we are interested in getting the combination of approximate geochemistry and grainsize/density through these graded deposits.

NOTE: The reviewers state the novel approach of this method has value when they state that "but using this approach on XRF data is a first time and bears a great potential in other studies as well"

In any case (raw counts or CLR transformed data), the data presented in Fig. 19 B (K/Si x Density) and interpretation is not acceptable to me. I do not understand the scientific meaning of this procedure. If radiodensity is inherently part of the raw XRF counts, I suppose you just increase this effect by multiplying XRF data with CT density? The resulting quantity is in HU, what would be the physical meaning of this value? Please elaborate it properly and make this more convincing in the article, or alternatively, delete this part.

AUTHOR RESPONSE: This was an attempt to show that the XRF loops are the result of the combination of geochemistry and the other implicit variables (such as radiodensity). Yes, the ratioed data (K/Si) times density was displayed simply to demonstrated that radiodensity is inherently part of the raw XRF counts. There is no meaning to the units, they are simply a way to scale to show how Log-ratio data for the two endmember variables (K, Ca) are influenced by other variables (in part, sediment density) during grading.

For the loops in the XRF scatter plots: the authors rely on the assumption that the background sediment before and after the event is exactly the same, and based on this try to identify the base and top of the event deposit (see event J: Fig. 20). This assumes that earthquakes do not produce any long-term catchment response and no other paleo-environmental changes (human influences in the catchment, climate changes, etc) occurred in the specific timeframes as this would lead to background sediments with different values. This assumption should be evaluated and clearly stated in the manuscript.

AUTHOR RESPONSE: We do not "rely" on the assumption that background sediment before and after the event is exactly the same, but suggest this as a potential explanation, which is supported by changes in sediment density. Since an earthquake does not last very long, it is reasonable to assume that there would be little change in the relationship between raw K and Ca relationships just after earthquakes, especially since any watershed influence would occur some time (weeks to months?) after the earthquake. This interpretation that the start and end close the grading loop is supported by the fact that the identification of these starting and ending points coincide with other variables that also signify the beginning and end of the deposits, including changes in radiodensity, and biogenic composition.

I agree with one of the previous reviewers that the authors invoke several new mechanisms (which have not been documented elsewhere) to explain observations that can be more easily explained by widely recognized processes (e.g. delta failure). I am not going to summarize these (this was done by the previous reviewer). This extra process complexity is not necessary in my opinion, but accept it to be the choice of the authors to put forward these ideas and hypotheses. What matters most for good science is to present robust data in the best way possible, whereas interpretations may change over time. The authors discuss their interpretations in an extensive way, which is required to for the readership to follow the logic argumentation.

AUTHOR RESPONSE: The delta failure mechanism cannot explain the large addition of Ca that produces the subduction earthquake deposits and therefore a new mechanism (liquefaction) was required. Likewise, the change in water column biogenic components can be explained by flocculation which removes primary producers and other components from the water column. Note that we describe the interpretations extensively.

Several figures need to be improved (see list below).

Overall, I recommend moderate revisions.

Detailed comments:

Abstract:
I suggest to write "Cascadia megathrust earthquakes", not just "Cascadia earthquakes".
DONE

Methods: you write that mineralogy was spot-checked using the CSD desktop scanning electron microscope. Where do you show data for this? Also, in the results you mention: "Inspection by Energy-dispersive x-ray spectroscopy (Bruker Quantax 50 EDS; CSD Facility) showed that some mica flakes from the Condrey Mountain Schist surrounding the lake contain a large amount of carbon (as much as 77%) and scanning-electron-microscopic analysis shows the presence of pyrite." You do not show that data. Please add this data to the supplement.
AUTHOR RESPONSE: We do not show data because there isn't any. We just periodically took samples and used the SEM to check what we were seeing. We have some SEM images, but do not have all the minerals in them identified. We were looking for micas, specifically, and a few other minerals to confirm what we were seeing. Our sampling was very inconsistent. Maybe we should remove this statement as a result. The Bruker Quantax data is similar in that we were simply looking at samples and noticed in one sample that 77% was carbon.

Discussion:
L404: please update "Only one study (Van Daele et al., 2019) has successfully discriminated between intraplate and megathrust earthquakes using lake sediments." See e.g. Praet et al., 2022 https://onlinelibrary.wiley.com/doi/abs/10.1111/sed.12986
DONE
L405-410: this explanation is partly correct. The intraslab events in that study also produce thin coseismic turbidites in that lake, AND are followed by catchment response.
DONE
L465: I suggest to also refer to the review paper of Bertrand et al., 2024 which is discussing all these issues. https://www.sciencedirect.com/science/article/pii/S0012825223003288
DONE
L472: "When scaled by radiodensity (Figure 19b)," I do not understand the scientific meaning of this calculation. If radiodensity is inherently part of the raw XRF counts, I suppose you just increase this effect by multiplying XRF data with CT density. What would be the purpose of this? Please elaborate and make this more convincing in the article, or alternatively, delete this part.
DONE. What we have attempted to do is remove the influence of artifacts (including density) by normalizing, then show that scaling by radiodensity reproduces the patterns in the xy plots of the raw data. The purpose was to demonstrate that sediment density is likely an implicit variable in the raw data.
L619: Is SQB5 really located on a ~45° slope? I would not expect any sediment accumulation on slopes steeper than 25°, so that seems strange. Please verify the slope angle calculation you did.
REMOVED THIS ANGLE. THE DATA ARE NOT DETAILED ENOUGH TO

CALCULATE ACCURATELY.
To me, the “summary of interpretations” and “conclusions” contain to much repetition. I suggest to keep the conclusions short and focus on the implications of your study rather than explaining the nature of each event deposit again.
AUTHOR COMMENTS: The summary of interpretations contains repetition because the discussion of the deposits was very long and complex. It seems important to follow with a simplified summary of the interpretations. We agree that this, then, does not need to be repeated in the conclusions.

Clearness and structure of the figures (also in the supplement):

In general, I think that the figure captions are often too large. They should help the reader to understand the figure, but do should not go into the interpretation of the data. This is done in the main text of the article. I suggest to shorten the figure captions to avoid repetition. E.g. a discussion sentence “could this be the result of a post-subduction earthquake aftershock, another subduction earthquake, a large crustal or intraplate earthquake?” should not be in a figure caption (Fig. 20). FIXED FIG. 20 CAPTION. SHORTENED MANY CAPTIONS.

Labeling and units: many figures are missing key elements such as labels and units for the axes. Also, several cores and core plots (such as CT density) are missing a depth scale! (e.g. fig. 21). FIXED.

Fig. 1: what are the blue lines? Are these the faults from the simplified Cascadia forearc fault model? YES. NOW IN CAPTION.
Fig. 3: How is this “spike” in conductivity obtained and why is it not part of the grey curve? In which month is the data measured (important for the development of a thermocline)? THIS VALUE WAS UNSTABLE AND THEREFORE WAS NOT CONNECTED TO THE GREY CURVE. THIS WAS THE MAXIMUM IT FLUCTUATED AT THAT DEPTH. Now indicated in caption.
Fig. 4: many cores were taken on slopes, which can make the record more complicated. As seen in e.g. Molenaar et al.,2021 (https://onlinelibrary.wiley.com/doi/full/10.1111/sed.12856) a slope angle of a few degrees can be enough to have stratigraphic gaps caused by surficial remobilization (due to earthquakes) and to develop in-situ soft sediment deformation structures. It would be good for the reader to get information about the coring strategy. DONE. This was a problem during coring. The lake is very narrow and prevailing winds made it very difficult to stay on location to core the lake’s depocenter (which was the intent).
Fig. 5: The legend shows many lithology symbols, but none of them are used in the figure. FIXED
Fig.5 and 6: It would be useful to indicate the top and bottom of each event deposit. In this way, it is much easier for the reader to see how the event deposits and the background sediments change throughout the lake basin. CAN’T DO THAT BECAUSE WE USED XRF LOOPS TO DETERMINE THE BASE AND TOP OF THE DEPOSITS, AND THAT ISN’T DONE UNTIL FURTHER INTO THE DOCUMENT.
Fig. 7: typo in legend “vivianiate” FIXED
Fig. 10: there is way too much text next to the smear slides FIXED

Fig. 11: At the bottom left there are some plots which are illegible. REMOVED
Fig. 12: The age model is illegible FIXED
Fig. 18: A) Please provide an arrow so we see the direction of the "loops" DONE
Also, why do you use the sequence number as X-axis in Fig. C? It would be easier for the audience if you just plot sediment depth. Same for Fig. 19 DONE
Fig. 19: The colors related to some event deposits have changed compared to Fig. 18. This makes comparison a tedious task. E.g. deposit I is purple (Fig. 18) or red (Fig. 19)… FIXED
Fig. 20: the legend states "confidence intervals in orange". However, I do not see any orange in the plots. IT IS THERE, NEAR THE TOP OF THE XY PLOT.
Fig. 22 (and others): "Note that the horizontal axis for the cartoon of the deposit sequence (bottom right) represents sediment radiodensity." Good that you mention this, but it should be mentioned for all figures that show such a cartoon (e.g. Fig. 10). Otherwise, any sedimentologist in this world would think that the horizontal axis in these cartoons represent grain size and not radiodensity. DONE
Fig. 23: This caption needs more explanation: which deposit are you using as representative of "flood" and of "earthquake"? Also indicate the arrow on the XRF data loops. DONE

Supplement:

2a: XRD figures: screenshots: data and scales are illegible. Can't fix because screenshots were all that were available.
2B: XRD data: the plot axes have no units. Also, the core has no depth scale. FIXED
3. I do not see any "red fault lines "on the map. I guess you refer to the black lines? As these are based on tracing lineaments on topographic data, the map would be more convincing if it would include topography information (i.e. DEM of the region). Yes, black lines. FIXED.
4. The table headers need units. DONE