Reviewer comment – EGUsphere Open Review

Manuscript: Sedimentary insights into organic matter alteration in Arctic Alaska's saline permafrost

General assessment

This manuscript presents valuable data on organic matter (OM) alteration processes in saline permafrost sediments from Arctic Alaska. The topic is highly relevant to understanding carbon cycling and permafrost-climate feedbacks in rapidly warming Arctic systems. However, the current version would benefit from clarification of sampling strategy, clearer data grouping logic, and an expanded discussion on the broader implications of saline permafrost thaw. Figures and tables could also be improved for interpretability.

Author's response (AR): Thank you for your time spending reviewing our manuscript and all your valuable feedback. These will substantially improve the manuscript. Please find below our specific replies to your comments.

Overall, the study has great potential, but the manuscript would be strengthened by addressing the following minor points.

Comments

(Lines 35–45)

Expand the discussion of how increased salinity can enhance ground warming, potentially accelerating carbon degradation. Clarifying this physical–biogeochemical linkage would strengthen the introduction.

AR: Thank you for pointing out, that this linkage should be explained early on in the paper. The paragraph has now been extended to demonstrate the critical role of salts in permafrost carbon dynamics (line 42-50).

(Section 2.21, Line 145)

It is not clear at this part whether only surface sediments or deeper permafrost cores were analysed. This is important, as surface layers are likely subject to strong mixing due to seasonal freeze–thaw dynamics. Please provide sampling intervals, total number of samples per core, and core depths. Without this, the representativeness of the dataset cannot be evaluated. Consider whether surface scouring or removal by groundfast ice might have influenced surface sediment preservation, as this could bias near-surface data (see Table S1).

AR: Thank you for stressing these points. We changed this accordingly: In the method sections 2.2.1 and 2.2.2 details are added now. Fieldwork aimed at sampling near-surface and deep (> 1 m) sediments, which was reached with the exception of coring at West Twin Lake (0.23 m) and the semi-open lagoon (0.46 m). The sampling interval was roughly 5 cm. Total sample numbers were added to Table S1, which also lists core depths. With the exception of East Twin Lake, no artificial disturbances of the cores were observed.

Figure 1: Consider enlarging or dividing into two panels (e.g., adding a panel showing core depths) to improve readability and convey stratigraphic context. The current layout is difficult to read. Either enlarge the figure or add a second panel showing core depths to improve interpretability.

AR: Indeed, this is a large figure and it needs to be printed large on the page in the final manuscript. We hope that this will happen with copy-editing the paper in the final stage. We kindly disagree with dividing the figure into 2 panels, as this visualization in one panel is the only way to compare parameters and individual cores as easy as possible. The core depths can be read on the y-axes and the units were added to improve readability. The figure will be slightly edited for better readability and the caption has now been adjusted by adding the maximum core depth for each core.

Table 3: The rationale for grouping samples after individual core analyses remains unclear. Please clarify the purpose and implications of this grouping, particularly why some groups were excluded from the PERMANOVA due to small sample sizes ($n < 5$). The statistical framework appears rigorous and well executed, but it becomes somewhat detached from the broader scientific narrative. Consider linking these statistical groupings more clearly to the ecological and biogeochemical processes discussed elsewhere in the paper to ensure that the results contribute directly to understanding the mechanisms of organic matter alteration under different thermal and saline regimes.

AR: Thank you very much. As we think thermal and salinity stages are worth being considered individually concerning their influence on organic carbon characteristics, the combined impact is also the most closes to natural reality, and thus valuable to investigate. Especially, as both categories relate to another (i.e., unfrozen sediments tend to have higher salinities). You are absolutely right; the focus of the paper may appear a bit diluted with these detailed analyses. However, the combination of both factors is important as seen by the statistical results which revealed that statistically significant differences exist between groups. These results are therefore also further discussed in sections 4.1.3 and 4.2. For these reasons we would like to keep the combined PERMANOVA in the manuscript.
Including your valuable feedback, we did the following revision: In section 3.2.3 an argumentation on the importance of this analyses is included now and Table 3 has been adjusted for better readability. If any group had low sample counts ($n < 5$), these were generally excluded from the statistics for valid representativeness. This is now stressed in section 3.2.3.

(Lines ~535–580)

The discussion could be expanded to better situate the findings within the broader permafrost–climate context. At present, there is no information provided on lake surface areas or volumes, which would help to contextualize how these systems influence thermal forcing and potential greenhouse gas emissions. Including even basic estimates or references for lake morphology would strengthen the discussion.

AR: Thank you for these valuable comments. The specific impacts on the waterbodies and for the study region will be further discussed. For that, chosen lake morphometrics will be provided in section 2.1 (Study area). Further information can be found in Table S1. The lakes cover ca. 1.3 km^2 each and are about 2 m deep, which lies within the range of typical lakes in the region (Arp et al., 2011). Their impact on landscape evolution is great, since a trend from bedfast to floating ice conditions, such as observed for East Twin Lake (Jones et al., 2023) amplifies permafrost (carbon) degradation. We now mention the role of thermokarst lakes more explicit in line 574-576.

Moreover, while the manuscript effectively documents organic matter alteration across thermal and saline regimes, it stops short of linking these findings to methane production or carbon loss processes in saline permafrost environments. A qualitative discussion of how organic matter degradation under saline, unfrozen conditions may contribute to methane or CO_2 release would significantly enhance the manuscript's broader relevance.

AR: This is a very important point, you are right. We included potential greenhouse gas production thin in the submitted version already (lines 555-599), but it seemed to be too hidden. Therefore, we now try to put more spotlight on this point by adjusting the paragraph in line 578-582: "From a microbiological point of view, this can be explained by microbial communities that are likely dominated by methanogens (CH_4 producers) in West Twin Lake while in East Twin Lake sulfate-reducing microbes (CO_2 producers) probably established additionally due to the saline deposits. A potential co-existence of these microbial communities may lead to enhanced greenhouse gas production (Jenrich et al., 2024; Yang et al., 2023)." Specific conditions and processes however cannot be assessed in this paper and is subject to future research.

In addition, the term "availability" (around line 570) could be replaced with a more precise descriptor such as "degradation potential" or "reactivity" to better reflect the geochemical processes described.

AR: We changed the term "availability to "reactivity".

Finally, a clearer statement on why saline permafrost thaw is globally significant would be valuable—ideally supported by literature estimates of the spatial extent and carbon pool size of saline permafrost deposits. These additions would help connect the strong sedimentary and statistical analyses to the larger climatic implications of thawing saline permafrost.

AR: The distribution and (carbon) properties of saline permafrost is generally not well studied. Our study contributes at filling this gap, but large-scale studies are currently lacking. We added this discussion point now in line 602-605: "Overall, observed carbon and landscape dynamics can be expected to play a major role across the wider saline permafrost region. Brouchkov (2003) published an estimated map of the saline permafrost zone, however large-scale quantifications of the saline permafrost distribution and its properties, including organic carbon stocks, are currently lacking. This calls for future study efforts, which would constitute important steps forward in understanding the role of salt in Arctic permafrost."

Overall recommendation

This study presents a strong and well-structured dataset with great potential to advance understanding of organic matter alteration in saline permafrost systems. The manuscript would benefit from greater methodological transparency and clearer contextual framing to fully highlight its scientific importance. I recommend a minor revision focusing on the following key aspects:

AR: Thank you very much for your support.

Clarify the sampling design and rationale for data grouping, particularly in Table 3, to ensure the statistical analyses are clearly linked to the environmental processes being studied.

AR: Changed accordingly. We are happy to send a revised version with track changes as soon as possible.

Improve figure readability and presentation (especially Figure 1) to better convey stratigraphic and spatial relationships.

AR: Please see our comment from above. Enlarging the figure in the final manuscript with a revised caption explaining e.g. the core depth more would be our preferred revision.

Expand the discussion to more explicitly address the broader climatic implications of saline permafrost thaw, including its potential influence on methane production, carbon degradation, and Arctic greenhouse gas feedbacks.

AR: Changes accordingly applied in the section 4.3 of the revised document.

Addressing these points would substantially improve the manuscript's clarity, coherence, and overall impact within the context of Arctic carbon cycle research.

AR: Thank you very much for your very constructive feedback.