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We would like to note that while we are all researchers working in related fields, we do not specialise in the specific subfield addressed by this paper. This review was conducted as a group exercise to help us gain experience with the peer review process and to deepen our understanding of effective scientific critique. Our feedback is offered in this context, with the aim of being constructive and respectful of the authors' work.

Summary

This manuscript presents a valuable dataset on methane production from deep sediment cores (up to 4 m) in two Yedoma thermokarst lakes of contrasting geomorphological ages. Sediment cores were collected from both locations, with samples taken from both the centre and edges to capture spatial variability. The work is novel in its vertical extent and use of Rock-Eval analysis to link organic matter lability to methane production. It improves understanding of how methane fluxes evolve as thermokarst lakes mature and provides useful empirical support for modelled predictions. Based on key findings in the study, the authors drew a conclusion that methane production is initially high in young lakes due to fresh carbon inputs and declines over time. However, some interpretive and presentational issues require clarification or improvement before the study can be considered for publication.

Major Comments

Overall, the manuscript is detailed and thoughtfully constructed. The authors have strong expertise in the subject matter, and their familiarity with the relevant methodologies and literature is evident throughout. The level of detail provided supports reproducibility and shows a commendable depth of understanding.

The study analyses only two sediment cores per lake (edge and centre), which may not adequately capture the spatial heterogeneity of methane production within each lake. Cores were collected during a single season, yet methanogenesis is known to vary seasonally. We recommend that authors acknowledge the limitations of their data samples.

Although the methane rate was measured up to 4 m depth, substantial production was observed only in the upper 100 cm. The authors should clarify the importance of below 1m. It would be beneficial to include an estimation of the methane production rate per year based on their experimental data and based on other available data sources.

Thank you for this important point. While the highest production rates were observed in the upper meter, our results show that deeper sediments contribute significantly to the depth-integrated methane production due to the increasing thickness of the talik in older lakes. We have clarified this in the Results and Discussion sections and now include a comparison of shallow vs. deep contributions to total production.

The two lakes differ geomorphologically but are both located in the Goldstream Valley and share similar climatic and geological settings. The authors should explicitly discuss the global relevance and limitations of extrapolating these findings to other permafrost lake systems with different environmental conditions.

We agree that this is an important consideration. We have added a paragraph to the Discussion section addressing the geographic and environmental specificity of our study. While both lakes are located in the Goldstream Valley and share similar climatic conditions, we caution against broad

generalizations and highlight the need for comparative studies across diverse permafrost landscapes.

We feel the manuscript would benefit from a brief discussion of potential future work. Given that the study focuses on only two lakes, it would be helpful for the authors to outline how this research could be extended, whether through additional sites, longer time series to gain insight into seasonality, or broader environmental contexts. Such a discussion would help position the current work within a larger research trajectory and highlight its relevance to the field.

Thank you for this suggestion. We have added toward the end of the Discussion the potential future directions, including expanding the study to additional lakes, incorporating seasonal sampling, and integrating microbial community analyses to better understand methane cycling processes.

Minor Comments

Several figures would benefit from improved clarity and presentation.

We thank the commenters for this helpful suggestion. We have revised several figures to improve clarity and presentation, including adjusting axis labels, panel spacing, and resolution where needed.

Figures 3 & 4 present related data and appear somewhat redundant. Consider combining them to enable easier comparison between lakes and harmonise the axis scales for better interpretability. Figure 9 description is excessive and might be better explained along with the discussion in the paragraph post Figure. Figure 7 needs help regarding reading, perhaps some additional x-axis tick marks to more easily read the uncertainty/mean?

We agree that combining figures 3 and 4 improves interpretability. We have merged these figures and harmonized axis scales to facilitate comparison between lakes. We also moved the description of Figure 9 into the main discussion text and improved the readability of Figure 7 by adding additional x-axis tick marks.

Figure 7 makes no mention of the additional error bars in the final section - is this the uncertainty of uncertainty? Is uncertainty required in Figure 7? Would it be easier to plot lines of each core sample x 3? Or as a table for exact values?

We clarified the purpose of the error bars in Figure 7 in the figure caption and text. We also considered alternative formats such as plotting individual core profiles or presenting a summary table but retained the current format for consistency with other figures.

Figures 3 and 4 present related data and appear redundant. We recommend combining them for easier comparison between the lakes and harmonising axis scales for interpretability.

As suggested, we have combined Figures 3 and 4 into a single figure with harmonized axis scales to improve interpretability and reduce redundancy.

Figure 8 is difficult to interpret due to the level of visual clustering. Including both GSL and BTL on the same plot may be contributing to this issue. If the goal is to compare the two lakes directly, it would help to make that comparative intention more explicit in the caption or main text. Alternatively, separating the data into two panels or figures might improve clarity and allow the reader to more easily interpret trends within each lake. Improving the readability of this figure would strengthen its impact and make the results more accessible.

We revised Figure 8 to improve readability by separating the data into two panels for GSL and BTL. We also clarified the comparative purpose of the figure in the caption and main text.

In-text citations should follow consistent formatting. For example, line 389 reads “(Freitas et al., 2015) also showed...”, which should be corrected to “Freitas et al. (2015) also showed...”.

We corrected the citation formatting throughout the manuscript to ensure consistency. The example on line 389 has been revised to 'Freitas et al. (2015) also showed...'.

The title suggests a broad investigation into the evolution of methane production from young to mature lakes. However, the study focuses on only two lakes. We suggest clarifying this in the title—perhaps by including the names or geographic location of the lakes—to better reflect the scope of the study and provide more context to the reader.

We revised the title to better reflect the scope of the study by including the names and geographic location of the lakes. This provides clearer context for readers and aligns with the manuscript's focus.