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Interactive comment on "Organic matter quality of deep permafrost carbon – a study from Arctic Siberia" *by* J. Strauss et al.

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Comments by Anonymous Referee #3

Referee #3: *General comments:*
This manuscript presents a detailed analysis of cores sampled in the Buor Khaya Peninsula, for both Yedoma and thermokarst locations. As stated in the abstract, the study objective is to develop a stratigraphic classified OM quality characterization. The authors also want to investigate Holocene degradation of OM in thermokarst. The method includes an original combination of indicators, including sedimentological and geochemical analysis and lipid biomarkers, and provides a novel OM characterization in this area.

Response: Thank you for this evaluation and the helpful comments.

Referee #3: *The results show no significant (although no statistical tests are applied) differences, based on the chosen analysis, between the two deposits.*

Response: This significance statement was not meant on the proxy level, but on the direction the data is pointing to (better quality for further decomposition: C/N, δ13C, HPFA: thermokarst; CPI: Yedoma). As stated below, we clarified this potential misunderstanding.

Referee #3: *Although, the authors argue that a slightly better quality for the thermokarsts deposit is possible. The authors's conclusions about these results need to be clarified.*

Response: Changed accordingly. ("'We interpret this to indicate a comparable magnitude of organic matter quality in both kinds of deposits, but with a likely better thermokarst organic matter quality for further degradation."')

Referee #3: *As a whole, the authors should strengthen their statistical analysis, perform statistical tests to look for significant differences*

Response: By implementing statistical significance testing (section 2.4.1 and 3.3.1), we adapted the manuscript accordingly. Because the majority of the data is not-normally distributed, we preferred a using the Mann-Whitney-Wilcoxon test (U-test) for comparing the two groups Yedoma and thermokarst. The Kruskal-Wallis rank sum test is applied for comparing all 5 profiles.

Referee #3: *and modify the boxplot presentation (see detailed comments).*

Response: Changed accordingly. We modified the Boxplot (Fig. 7) by merging the 5 profiles to 2 groups, Yedoma and thermokarst.

Referee #3: *The author's should also precise their hypotheses on why Yedoma and thermokarsts deposit should be different. It should be emphasize that both different*

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transformation processes and different OM origin are expected

Response: Changed accordingly. We added "'We hypothesize increased organic matter degradation during thermokarst processes, but also increased organic matter input during climatically favourable Holocene times."' to the end of the introduction chapter. Moreover, we added following paragraph to the discussion: "'We interpret this as following: Compared to unaltered Yedoma deposits, degradation during thermokarst processes, but also heightened amounts of OC input during climatically more favorable Holocene times, are balancing each other concerning the organic matter quality for future degradation. Nevertheless, as there is more carbon stored in the thermokarst basins (Strauss *et al.* 2013), thermokarst deposits imply a higher intrinsic potential to contribute greenhouse gases in a warmer future. This is supported by the acetate data indicating a higher mean content for the thermokarst deposits. Acetate is an excellent substrate for microbial turnover e.g. acetoclastic methanogenesis (Kotsyurbenko *et al.*, 2004)."'

Referee #3: *Detailed comments:*
Abstract:
- P15946, l16. Please define what a good (and therefore better) quality is. This is true for the whole manuscript.

Response: Thank you for this comment. For carbon quality, we added a definition to the abstract: "'To give an idea of how Yedoma region permafrost could respond under future climatic warming, we conducted a study to quantify the organic matter quality (here defined as the intrinsic potential to be further transformed, decomposed, and mineralized) of late Pleistocene (Yedoma) and Holocene (thermokarst) deposits on the Buor Khaya Peninsula, northeast Siberia."' With this definition, 'better quality' is meant as a 'better future decomposability' of one deposit compared to the other one. To underline this, we added "'Relatively"' to the sentence addressed by the reviewer and added "'for further decomposition"' after 'quality' statements.

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Referee #3: *- P15946, l19-20. Are the analyses in the two deposits different or not? The authors should chose based on statistical evidence.*

Response: Changed accordingly. We included statistical significance testing (Mann-Whitney U test).

Referee #3: *- P15946, l25. Are different origins also an hypothesis*

Response: No, we assume a comparable OM origin of both deposit types. A schematic showing different chain lengths in different organisms is given in Fig. S4. The higher C3 land plants are expected to have an ACL of 28-29, which is the case for Yedoma and thermokarst deposits

Referee #3: *Introduction*
- P159448,l1. 83 +61/-57 is confusing

Response: Changed to ± including one mean uncertainty estimation

Referee #3: *Material and methods*
- P15950. Please comment on why different core depths were sampled. What about the active layer depth in the area?

Response: We were not using cores, but samples from exposures. This is shown in the pictures added to Fig 1. As cited, detailed schemes on the exposures are published in Strauss and Schirrmeister (2011). The different depths are related to the possibility to take undisturbed samples. Concerning the active layer: As stated in the title, the aim of this study is a first-time quality characterization of the deep permafrost carbon. The active layer is not part of the permafrost. But repeated measurements on Samoylov Island show summer active layer depth up to 60 cm, which was also found at the study sites (Strauss and Schirrmeister, 2011)

Referee #3: *- P15958. L5. How was the 1mg/l limit defined for acetate?*

Response: Thank you for this question. This threshold value was defined basin on

our measurement experience. Since data can be extremely variable between different habitats, we decided to remove this threshold from the manuscript and use acetate concentrations as a parameter to assess the quality of the organic matter in the different deposits with respect to future microbial degradation. We changed the respective sentence in section 2.3.6. ("'We use the acetate pore water concentrations in the different deposits as a parameter to assess the quality of the organic matter and to compare the potential of the different deposits for future microbial degradation."')

Referee #3: *L10. Please justify the log transformation of some of the data and the square root transformation of others.*

Response: Changes accordingly. Both transformations were applied to reduce right skewness and to put the parameters on the same scale. In detail, we used the LOG10(X+1) transformation for all concentration data to make these rightly skewed positive dataset more normally distributed and to stabilize the variances. As the square root transformation is commonly applied to counted data, especially if the values are mostly rather small, we decided to use this weaker (compared to logarithm) transformation for the TOC data.

Referee #3: *Results*
- P15960. L6-7 "'Every radiocarbon-dated sample and additional samples were used for biomarkers analysis. In total 25 biomarker samples were analyzed."' This sentence should be moved to the M&M section.

Response: Moved accordingly.

Referee #3: *Additionally, the authors should provide some details on how they chose the sampled to be analyzed for biomarkers.*

Response: We added the sentence "'Independent from TOC wt%, the sample selection for biomarkers was based on stratigraphic position with the aim to cover the maximum time period."' to the methods section

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Referee #3: *- P15963.l9. "‘ is quite stable, between 0.1 and 4.9 μg/g TOC wt%"'. This sentence is surprising. It would be more convincing to include mean and sdt.*

Response: Thank you for this suggestion, we changed to this sentence to a range statement ("‘the hop-17(21)-ene concentration at Buo-05 varies between 0.1 and 4.9 μg/g TOC wt%"').

Referee #3: *- P15963.l25-27. The authors should comment the fact that only the peat samples (3-A-03, 2-D-20, 1-A-02) align with axis 1. Indeed, these samples present the high TOC, low δ13C, high C/N values. It would be interesting to perform this analysis without these 'special' samples.*

Response: We agree with the reviewer, this is an interesting point, but there are more peat and paleosol samples not clustering in this area of the ordination plot, e.g. Buo-02-A-06, Buo-02-B-12 and Buo-05-A-04.
Thus, we would like to keep the clustering 3 peat samples in the ordination plot and the PCA analyses.

Referee #3: *Do these samples represent the untransformed OM state and could be used for reference?*

Response: Thank you for this comment. We do not think that these three samples are untransformed. Especially the thermokarst deposits are a mixture of preserved Yedoma OM and Holocene input.

Referee #3: *Discussion*
- P15966.L7. The Holocene OC input in the thermokarst deposit should be discussed. Possible origin? Influence on biomarkers analysis, radiocarbon dating.

Response: The hypothesis is the following. The more favourable Holocene climate increases the plant OM production, but also the OM degradation. Thus, the influence of the biomarker 'qualities' is balanced. Nevertheless, shown by e.g. the higher TOC there has been Holocene OM enrichment. In their recent study, Walter Anthony *et*

al. (2014) also suggested the thermokarst basins have been a carbon sink during the Holocene. The influence on biomarker is a net better quality for further degradation. Thus, we clarified the discussion by adding: "'We interpret this as following: Compared to unaltered Yedoma deposits, degradation during thermokarst processes, but also heightened amounts of OC input during climatically more favorable Holocene times, are balancing each other concerning the organic matter quality for future degradation. Nevertheless, as there is more carbon stored in the thermokarst basins (Strauss *et al.* 2013), thermokarst deposits imply a higher intrinsic potential to contribute greenhouse gases in a warmer future. This is supported by the acetate data indicating a higher mean content for the thermokarst deposits. Acetate is an excellent substrate for microbial turnover e.g. acetoclastic methanogenesis (Kotsyurbenko *et al.*, 2004)."'

Referee #3: - *P15966.L19-20. Which signal? CPI, δ13C or both?*

Response: We added C/N to the sentence.

Referee #3: - *P15968.L28. Figure 7 should be greatly modified. The authors present boxplot with very limited data set (for biomarkers, n=2, 3, 4). A boxplot is designed to provide a synthetic 5-value-indicator for a population. A boxplot cannot be generated with less than 5 samples. I strongly suggest that the authors pool the yedoma and thermokarst data before presenting the boxplots. Please refer to this publication:*

Response: Thank you for this reference. As suggested by the reviewer and the reference, we merged the Yedoma and thermokarst data for the boxplot visualization to reach a sample size of n $>$5. Moreover, we added notches to the boxplots to illustrate the 95% confidence intervals of the median.

Referee #3: - *The authors should relate more clearly the potential fate of OM (what they call 'good quality', and seem to be bioavailability and the biomarkers analysis they have chosen.*

Response: Thank you for this comment. First, we added a definition for the 'quality'

to the abstract: "'To give an idea of how Yedoma region permafrost could respond under future climatic warming, we conducted a study to quantify the organic matter quality (intrinsic potential to be further transformed, decomposed, and mineralized) of late Pleistocene (Yedoma) and Holocene (thermokarst) deposits on the Buor Khaya Peninsula, northeast Siberia."' With this definition, 'better quality' is meant as a 'better future decomposability' of one deposit compared to the other one. In the discussion, we have an section called "'4.3 Fate of organic matter"', were we discussed the acetate as being used as energy source by e.g. Achaea. What happens to the biomarker is explained in the methods section.

Referee #3: *Conclusion*
- P15972.L28. The authors should be more specific in the conclusion. Do not leave vague evaluation: 'perhaps', better ...

Response: Changed accordingly. We clarified ("'We interpret this to indicate a comparable magnitude of organic matter quality in both kinds of deposits, but with a likely better thermokarst organic matter quality for further degradation."') and shortened the conclusion.

Referee #3: *Figures:*
- 3 & 4: the quality should be improved for clarity

Response: Changed accordingly. The diagrams for radiocarbon age, grain size, Oleanen ratio and acetate are now included in the supplement.

Referee #3: *- 5. The relationships should be tested without the 'peat' samples. Please provide significance levels for correlations.*

Response: We added the significant levels to the plot; all linear regressions are statistically significant. The peat samples are an essential part of Yedoma and thermokarst deposits. Moreover, there are more peat and paleosol samples not clustering in this area of the ordination plot (Buo-02-A-06, Buo-02-B-12, Buo-05-A-04). Thus, we would

like to keep the clustering 3 peat samples in the scatterplots (fig 5) ordination plots (fig 6) of the PCA analyses.

Referee #3: - *6. Same for figure 6 + improve clarity*

Response: We improved the clarity.

Referee #3: - *7. See detailed comments on box plots.*

Response: Changed accordingly.