

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

J. Strauss et al.

jens.strauss@awi.de

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Comments by Anonymous Referee #1

Referee #1: *Fate of permafrost soil organic matter and its response to warming process have attracted increased attentions from the community of geosciences. This paper is focused on the difference in the property of soil organic matter in Yedoma and thermokarst region, to illustrate the impact of Holocene degradation on the soil organic matter composition and properties. They have done extensive characterizations for two deposits and found there is no significant difference between Yedoma and thermokarst deposits. Such result is interesting, while partial explanation needs clarification.*

Response: Thank you for this evaluation. Unfortunately, using the term "significant"

C8734

was misleading here. Thus, we included statistical significance testing. Except for the hope, there are significant differences in the Yedoma and thermokarst data, but the parameters are pointing in different directions.

Referee #1: *The extensive characterizations for two deposits request a better integration and overall discussion. In the abstract, the response of Yedoma permafrost soil to global warming is discussed, but the implication of soil characteristics on the response of permafrost soil to warming process is unclear. This reviewer suggests focusing the discussion on the fate of soil organic matter during the Holocene degradation.*

Response: Thank you for this suggestion. We think that the Holocene degradation is already a topic of the discussion. With the study and sampling design it is not possible to identify distinct degradation processes, but the state of degradation as a hint for potential future degradation. Thus, we would like to keep our focus on this comparison of degradation state of Pleistocene vs. Holocene deposits.

Referee #1: *The authors need to generate clearer conclusive statement.*

Response: Thank you for this suggestion, we clarified and shortened the conclusive statement.

Referee #1: *For instance, the results probably can lead to conclusion about whether there is geochemical preference for organic matter degradation during the thermokarst processes.*

Response: Unfortunately, our study design does not allow an identification of a detailed preference. This could be identified by incubation experiments, measuring Yedoma biomarkers before and after a long-term incubation. This was not realized in the present study. Nevertheless, the newly introduced HPFA index is based on a geochemical preference of microorganisms to degrade n-fatty acids faster than n-alkanes. This is described in the method section.

Referee #1: *P15946 L16 What is a better quality? Please give a brief definition.*

C8735

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.

Referee #1: *P15946 L26-28 Can authors be more specific? What kind of degradation steps? How did data support such degradation reactions?*

Response: As stated above, our study design is not designed to identify the degradation preference of specific compounds in detail. Thus, it is not possible to name the specific degradation steps and states. This sentence ("it was possible to show that permafrost organic matter degradation likely occurs via a combination of (uncompleted) degradation cycles or a cascade of degradation steps") is included to emphasize that potential future degradability is not "a linear function of age or sediment facies", as expected e.g. in unfrozen soils.

Referee #1: *P15947 L16 What does that mean by "recent atmosphere"?*

Response: Recent atmosphere is the atmosphere in its today's composition. Changed to "modern".

Referee #1: *P15948 L3-5 It seems there is large uncertainty in estimation for Yedoma OC amount. How about the uncertainty compared to OC in other regions? Can the current study contribute to the reduction in such uncertainty?*

Response: Thank you for this comment. Yes, it is quite a large uncertainty range, but this study could not contribute to an OC uncertainty reduction. But a work bas-

C8736

ing on Strauss *et al.* (2013), Hugelius *et al.* (2014) further improved the calculation approach and thus we were able to reduce the uncertainty ranges to 83 ± 12 Gt for late Pleistocene Yedoma deposits and 130 ± 29 Gt for thermokarst deposits. These uncertainties are now included in the manuscript.

Referee #1: *P15958 L5 Any reference to support this statement?*

Response: This threshold value was defined basing 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.

Referee #1: *P15959 L11-15 Is there relationship between the particle size and availability/degradation of organic matter?*

Response: We did not separate the grain size fractions by e.g. density fractionation or by sieving. Thus, we have no data on particle-size specific availability/degradation of organic matter. The particle size was included to this study to distinguish the transportation and depositional regimes of the deposits.

Referee #1: *P15960 L8 Any explanation for odd preference?*

Response: Long chain n-alkanes with a strong odd-over even carbon number predominance are a typical signal for terrestrial organic matter, whereas the n-alkanes derive from leaf material of land plants (cuticular waxes). Fatty acids in the waxes are synthesized via acetyl-coenzyme A which is a C_2 unit. Thus, fatty acids show an even over odd carbon number predominance. The n-alkanes derive from fatty acids via decarboxylation (minus the one carbon in CO_2) and are, therefore, predominantly odd (Eglinton and Hamilton, 1963, 1967).

Referee #1: *P15961 L1 Probably to make this statement more accurately. What is the standard for higher hop-17(21)-ene concentration*

C8737

Response: In the method section we described the standard for the hopene: "Other triterpenoids like [...] hopene were quantified using the m/z 191 mass trace relative to the peak area of the β,β -diploptene (in the m/z 191 mass trace), the concentration of which was calculated in the total ion current chromatogram relative to the internal standard (5 α -androstane)." Moreover, there is no empirical standard for a higher (or lower) concentration. Our interpretation is meant in a relative manner by comparing the measured data. To clarify the sentence, we change the sentence to "Relatively higher hop-17(21)-ene concentrations are used as an indicator for lower organic matter degradation state".

Referee #1: *P15966 L18-20 If taking the standard deviation into consideration, does this mean anything significantly? The authors may want to do statistical analysis (t-test).*

Response: Thank you for this suggestion. 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 (also known as U-test) instead of the suggested t-test for comparing the two groups Yedoma and thermokarst. The Kruskal-Wallis rank sum test is applied for comparing all 5 profiles. This shows, that higher hop-17(21)-ene concentrations from Yedoma and thermokarst show no significant differences. We added "For hop-17(21)-ene, we do not see significant differences." to the manuscript.

Referee #1: *P15967 L15 What does the "relative state of degradation" mean?*

Response: Thank you for this suggestion. As you mentioned before, classifying the C quality in good and better could be misinterpreted in an absolute way. This study compares the C quality/degradability of 2 kinds of deposits and the $\delta^{13}\text{C}$ allows a comparison of the 2 deposits. This is meant with relative state of degradation.

Referee #1: *P15966 L20-22 What is the variance in N content of these soils? If N does not change substantially, this relationship will be self-correlation between TOC and C.*

C8738

Response: The following table shows the N values including the variance (std and range). The TN values change substantially. TOC and the C in the C/N ratio are identical.

mean Yedoma: 0.22, median Yedoma: 0.16, std: 0.16, min Yedoma: 0.10, max Yedoma: 0.87

mean thermokarst: 0.31, median thermokarst: 0.18, std: 0.36, min thermokarst: 0.11, max thermokarst: 1.54

Referee #1: *P15970 L8-12 This is interesting. Why does freezing protect the further decomposition of acetate compared to the degradation of soil organic matter to acetate?*

Response: Freezing is protecting both, acetate and other organic matter. But acetate is decomposed on a different time scales compared to other OM.

Referee #1: *P15985-15986 These two figures are probably too busy. It may be helpful to select representative parameters to present and leave the rest in the supporting information.*

Response: Changed accordingly. The diagrams for radiocarbon age, grain size, Oleanen ratio and acetate are now included in the supplement (Fig. S5 and S6).

C8739