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Organic carbon stored in a thermokarst affected landscape on Baldwin Peninsula, Alaska

Loeka L. Jongejans[1], Jens Strauss[1], Josefine Lenz[1,2], Francien Peterse[3], Kai Mangelsdorf[4], Matthias Fuchs[1,5] and Guido Grosse[1,5]

[1]*Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Potsdam, Germany, loeka.jongejans@awi.de*

[2]*University of Alaska Fairbanks, Institute of Northern Engineering, Fairbanks, USA*

[3]*Utrecht University, Department of Earth Sciences, Utrecht, Netherlands*

[4] *Helmholtz Center Potsdam - German Research Center for Geosciences, Potsdam, Germany*

[5] *University of Potsdam, Institute of Earth and Environmental Sciences, Potsdam, Germany*

Abstract

As Arctic warming continues and permafrost degrades, more organic carbon (OC) will be decomposed in high northern latitudes. Still, uncertainties remain in the quality and quantity of OC stored in permafrost. This study presents OC data from permafrost deposits on the Baldwin Peninsula, West-Alaska. We analyzed cryostratigraphical, biogeochemical and biomarker parameters of yedoma- and drained thermokarst lake basin (DTLB) deposits as well as thermokarst lake sediments to identify the size and quality of OC pools in ice-rich permafrost. Here we show that two thirds of soil OC in this region are stored in frozen DTLB deposits and that the lake sediments have the highest volumetric OC content. The n-alkane distribution shows, however, that OC stored in yedoma is of higher quality than that stored in DTLB deposits. These findings highlight the importance of molecular OC analysis for determining the potential future greenhouse gas emissions from thawing permafrost.

Keywords: Arctic, thermokarst lake development, organic carbon, biomarkers, biogeochemical cycling

Introduction

The Arctic region is especially vulnerable to climate change as it is warming twice as fast as the global mean (Overland et al., 2014). Rapid and large-scale permafrost degradation in ice-rich permafrost, such as late Pleistocene yedoma, may contribute additional positive feedbacks to atmospheric warming. With climate warming, previously freeze-locked OC can be decomposed resulting in increased greenhouse gas emissions into the atmosphere. It is therefore highly relevant to characterize the OC pools so that the vulnerability and amount of OC in thawing permafrost soils can be determined. By analyzing sediment samples from yedoma, drained thermokarst lake basins (DTLB), and thermokarst lakes we aim to estimate the size and quality of the subsurface OC stored in our study region.

Study sites and methods

The study site is located at the western coast of the Baldwin Peninsula, Northwest Alaska (66°40'N, 162°15'W). The Baldwin Peninsula is characterized by continuous permafrost and consists of a sequence of marine, glaciomarine and glacial sediments that are well exposed along coastal bluffs (Huston et al., 1990; Pushkar et al., 1999). During field reconnaissance in summer 2016 we identified several exposures with fine-grained, ice-rich permafrost deposits and large syngenetic ice wedges that we classified as typical yedoma. A large portion of the peninsula has been affected by severe permafrost degradation and multiple thermokarst lake basin generations are also visible in satellite imagery.

In order to characterize OC pools in the study area, field sampling of one yedoma coastal bluff, three DTLB coastal bluffs and coring of a thermokarst lake was carried out in summer 2016. In total, 81 samples have been collected. We analyzed the cryostratigraphy (absolute ice content, bulk density BD), biogeochemistry (total organic carbon TOC, total nitrogen TN, C/N, stable carbon isotopes $\delta^{13}C$) and biomarkers (*n*-alkanes) of the three different landscape units. We analyzed the CPI (carbon preference index), an n-alkane derived index, to assess the quality of OC. In addition, we estimated the OC budget by using deposit thickness and coverage, wedge-ice volume (WIV), BD and TOC (Table 1).

In a final step, a land cover classification map was made of Baldwin Peninsula in order to calculate the coverage for each landscape unit.

Table 1: Input organic carbon budget calculations per landscape unit. WIV from Ulrich et al. (2014).

Landscape unit	**WIV[1]** [vol%]	**BD** [10^3 kg m^{-3}]	**TOC** [wt%]
Yedoma	46.3	0.80	1.9
DTLB	8.9	0.78	9.9
Thermokarst lake	0	0.78	14.4

Table 2: Volumetric and absolute OC budget estimate per landscape unit.

Landscape unit	**Vol. OC budget** [kg m^{-3}]	**Abs. OC budget** [Mt]
Yedoma	8	17
DTLB	24	36
Thermokarst lake	113	5

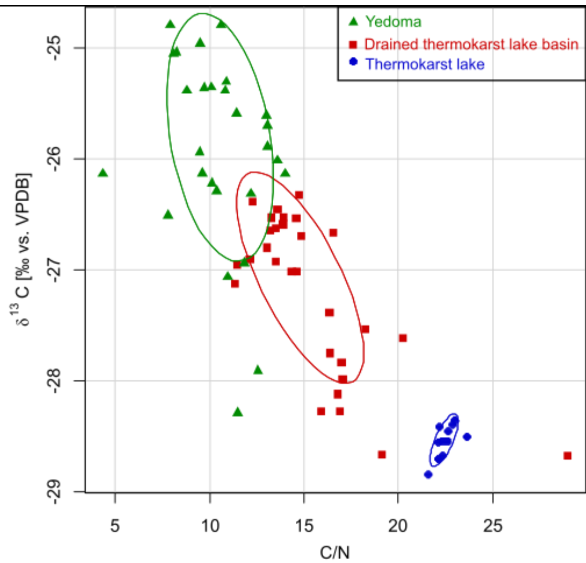

Figure 1: Scatterplot of C/N and δ^{13}C per landscape unit.

Results and Discussion

We estimated the OC budget of the Baldwin Peninsula (~450 km^2) (Table 2). Thermokarst lake sediments have the highest volumetric OC budget with 113 kg OC/m^3 compared to yedoma deposits with only 8 kg OC/m^3 and DTLB deposits with 24 kg OC/m^3. These volumetric estimates fit well to previous estimates by Schirrmeister et al. (2011) and Strauss et al. (2013). Nevertheless, DTLB deposits store 70% of the OC, as they cover 65% of the area. The total OC budget of the frozen sediments on Baldwin Peninsula is 53 Mt.

An indication for the OC quality is presented in Figure 1, which shows the C/N in relation to δ^{13}C of the three landscape units. The plot shows a clear trend from low C/N and high δ^{13}C in yedoma, intermediate values for DTLB and high C/N and low δ^{13}C in the thermokarst lake sediments. We explain this trend by a combination of the origin and the state of degradation of the OC. Low C/N and high δ^{13}C in yedoma indicate low productivity and dry, cold conditions during accumulation (Schirrmeister et al., 2011). The high δ^{13}C in the thermokarst lake sediments corresponds to lake productivity (Meyers, 1994), and the high C/N reflects the freshness of the material. The intermediate values of the DTLB deposits indicate the mixed character of the heavily disturbed landscape due to thermokarst processes. The higher CPI in yedoma (mean: 11.6) compared to DTLB (mean: 8.8) indicates less degradation of OC in yedoma than in DTLB deposits. Therefore, the yedoma OC is of higher quality for future degradation.

Conclusions

The OC calculations show that two thirds of OC on Baldwin Peninsula are stored in frozen DTLB deposits and that the lake sediments have the highest volumetric OC content. However, OC stored in yedoma is of higher quality than that stored in DTLB deposits, as indicated by the CPI, indicating the higher potential of OC decomposition in yedoma deposits.

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