Greenhouse gas production potential of drained lake basin sediments from the Yukon Coastal Plain

Verena Bischoff[1,2,3], Jan Schwarzbauer[1], Jens Strauss[3], Hugues Lantuit[3,4] & Juliane Wolter[2,3]

[1]*Faculty of Georesources and Materials Engineering, RWTH Aachen University, Aachen, North Rhine-Westphalia, Germany*

[2]*Institute of Biochemistry and Biology, University of Potsdam, Potsdam, Brandenburg, Germany*

[3]*Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Section Permafrost Research, Potsdam, Brandenburg, Germany*

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

INTRODUCTION

Permafrost carbon pools are vulnerable to climate warming and have the potential to alter both terrestrial and global carbon cycles. Upon permafrost thaw, increased decomposition of organic-rich deposits in the extensive Arctic wetlands could lead to high greenhouse gas production and emission to the atmosphere. This study investigates processes and intensity of organic matter decomposition and associated potential greenhouse gas production in thawed sediments from drained lake basins on the Yukon Coastal Plain in the western Canadian Arctic.

METHODS

We conducted one-year low-temperature (4 °C) incubation experiments, assessing the greenhouse gas production potential upon thaw under aerobic and anaerobic conditions in the active layer, transition layer, and permafrost layer of sediment cores from adjacent drained lake basins (Fig. 1). The study was supplemented by comprehensive geochemical and biomarker analyses of *n*-alkanes and *n*-alkanols on day 0, 90 and 365 of the incubation experiments.

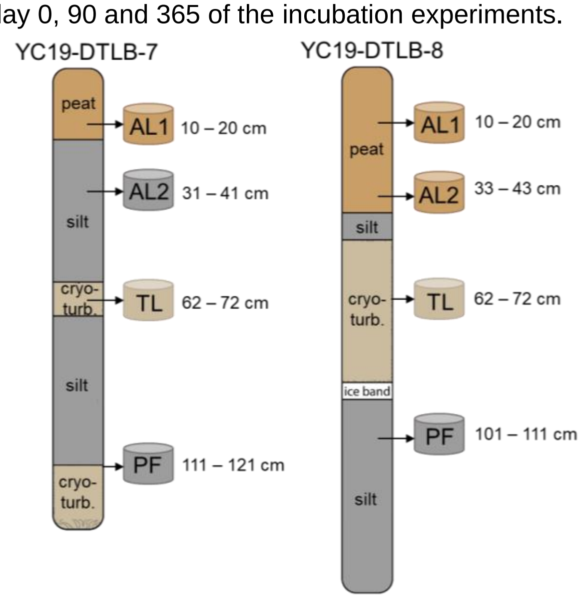

Figure 1: Overview of analyzed sediment samples.

We used one-way ANOVAs to identify differences in greenhouse gas production potential among mineral, organic and cryoturbated samples as well as among active layer, transition layer, and permafrost samples. To test significance of changes in geochemical and biomarker parameters we further performed paired t-tests on before- and after-incubation datasets.

RESULTS

Preliminary results after the first 90 days of incubation revealed the distinct short-term GHG production potential of heterogenous samples under aerobic and anaerobic conditions (Fig. 2 and 3).

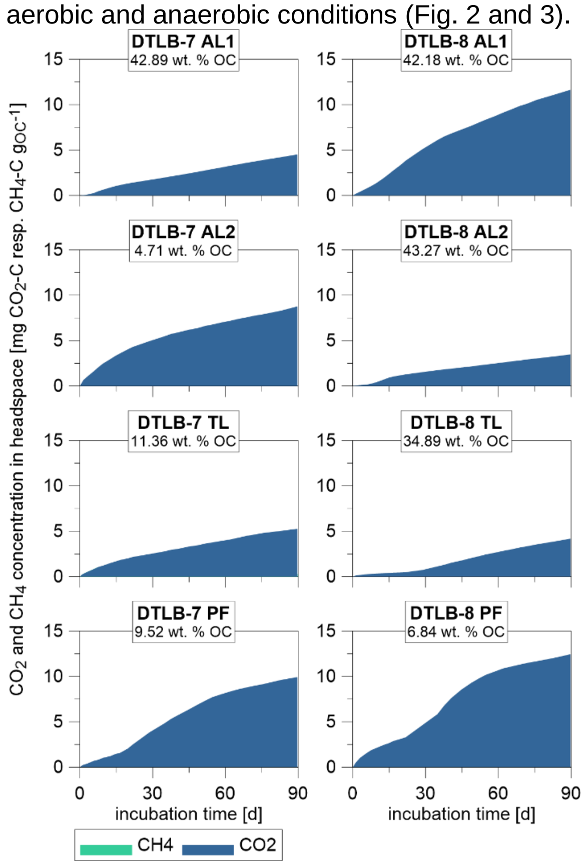

Figure 2: Composition of greenhouse gas production under aerobic conditions.

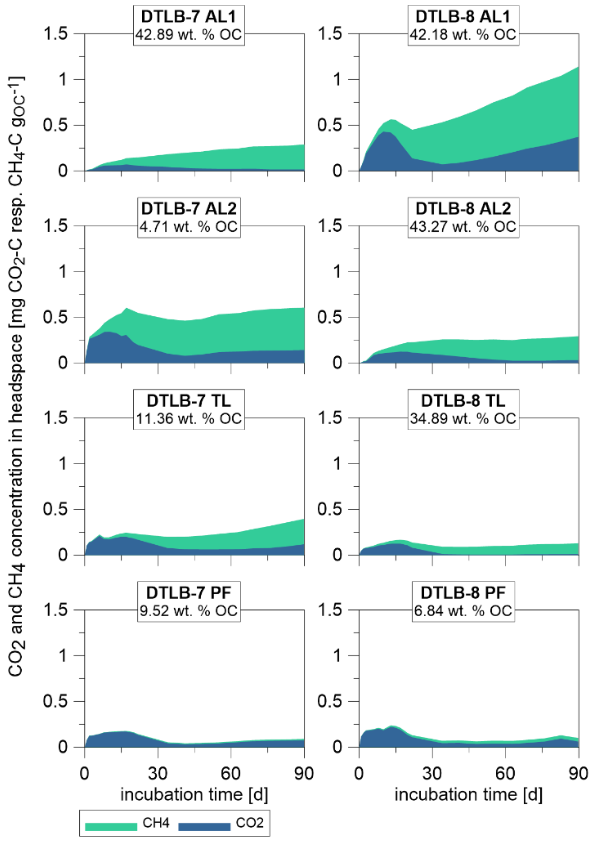

Figure 3: Composition of greenhouse gas production under anaerobic conditions.

The analyzed sediment samples exhibited high C:N ratios, low $\delta^{13}C$ values and distinctive *n*-alkane and *n*-alkanol distribution patterns, comprising long-chain lengths and pronounced odd-over-even resp. even-over-odd predominances. After the first 90 days of 4 °C aerobic and anaerobic incubation, changes in geochemical parameters TOC, TN, and C:N ratio were insignificant. *n*-Alkane and *n*-alkanol concentrations increased, with higher accumulation of *n*-alkanols than *n*-alkanes, reflected in increasing higher plant alkanol indices (HPA) in all samples.

DISCUSSION

Geochemical parameters and biomarker indices pointed to a high input of terrestrial vascular plant waxes to the organic matter of the drained lake basin sediment cores and low degrees of degradation of the material.

Incubation experiments revealed a higher carbon turnover of up to 2.7 % of the available organic carbon to GHG under aerobic conditions within the first three months of incubation. Decompostion of labile carbon pools from mineral permafrost layers matched that of surface peat samples, whereas presumable nitrogen limitation retarded short-term carbon mineralization in pioneer peat layers that accumulated shortly after lake drainage.

On the short term, the GHG production under anaerobic conditions exhibited a high depth-dependency, with permafrost layer samples deviating from the otherwise observed high methanogenesis in active and transition layer samples. The combination of high CH_4 production and short lag times of maximum production rates suggests that the sediments readily provided ideal conditions for methanogenic microbial species or microbial communities were already well established in the sediment. High contributions of the potent greenhouse gas methane of up to 94 % enhanced the climate forcing effect of anaerobic GHG production. Consequently, the determined relative climate forcing is higher under anaerobic compared to aerobic conditions in active and transition layers, suggesting that waterlogged conditions within drained lake basins are more unfavorable in the short term.

While established degradation proxies C:N ratio, $\delta^{13}C$ and CPI did not trace significant degradation of terrestrial organic matter during the first three months of the incubation period, we observed major shifts in the lipid composition.

CONCLUSION

Carbon pools in drained lake basins on the Yukon coastal plain are highly sensitive to thaw. Trajectories of hydrologic conditions in drained lake basins determine the pace and form of decomposition of the organic carbon pool and hence, potential greenhouse gas emissions. Thaw depth progression under aerobic conditions in drained soils could cause immediate and high peaks in greenhouse gas production, though initially high production rates are expected to decline over time. Further we conclude that drained lake basins could provide perfect conditions for methanogenesis under anaerobic conditions and hence produce a highly unfavourable mix of greenhouse gases.