SUBSTRATE POTENTIAL OF ORGANIC MATTER IN TERRESTRIAL PERMAFROST DEPOSITS FROM NE SIBERIA FOR MICROBIAL GREENHOUSE GAS PRODUCTION

Kai Mangelsdorf[1], Janina G. Stapel[1], Lutz Schirrmeister[2], Georg Schwamborn[2], Brian Horsfield[1], Dirk Wagner[1]

[1] GFZ German Research Centre for Geosciences – Helmholtz Centre Potsdam, Germany
[2] Alfred Wegener Institute – Helmholtz Centre for Polar and Marine Research, Potsdam, Germany

Introduction

The assessment of the substrate potential of permafrost organic matter (OM) for microbial greenhouse gas (CO_2 and methane) production is an important approach to understand the impact of thawing permafrost on future climate evolution. This topic is of high relevance in today´s geoscience research, due to the current debate on the temperature vulnerability of permafrost deposits and its climate feedback on the already currently observed global warming. Especially, the substrate potential of the organic matter stored in deeper potentially thawing permafrost deposits as well as the interplay between the organic substrates and the distribution of living and past microbial communities in Late Pleistocene and Holocene permafrost deposits are in the focus of the current study.

Our investigation was part of the CarboPerm project funded by the German Federal Ministry of Education and Research (BMBF) and was an interdisciplinary Russian-German cooperation on the formation, turnover and release of carbon from North Siberian permafrost landscapes. Sample material derived from two terrestrial permafrost locations in the NE Siberian Arctic. The first core was drilled at the coast of Bour Khaya Peninsula comprising Late Pleistocene to Early Holocene deposits separated by an ice wedge. The second location was on Bol´shoy Lyakhovsky Island (eastern Laptev Sea), where four cores were recovered covering in sequence Eemian (MIS 5e) to Holocene permafrost deposits.

Results

The microbial life markers (intact phospholipids, PLs) prove the presence of currently living microorganisms in the entire permafrost sequence at both locations and show the highest concentration in the uppermost samples indicating an abundant microbial life in the active layer (thawed during arctic summer). Usually, the PL signal strongly decreases in the underlying permafrost deposits. Furthermore, the Phospholipid fatty acids inventories (PLFAs) indicate cell membrane temperature adaptation to cold environmental conditions via both the ratio between *iso*- and *anteiso*-fatty acids (FAs) as well as saturated and unsaturated FAs. Biomarkers for past microbial biomass (bacterial branched and archaeal isoprenoid GDGTs) reveal often similarities with the TOC content and show highest abundances in Late Pleistocene deposits, especially from MIS 3.

Pore water analysis reveals the presence of free low molecular weight organic acids (LMWOA) such as acetate being excellent substrates for microbial methane generation. At Buor Khaya the substrate depth profiles from Late Pleistocene deposits below the ice wedge show significant similarities to the TOC content. This points to a link between the organic matter and the LMWOA concentrations solved in the pore water and to the potential of those permafrost layers to provide substrates for microbial greenhouse gas production. In contrast, in the active layer the LMWOA concentrations are low reflecting an active microbial turnover in the surface layers (Ganzert et al., 2007). At Bol´shoy Lyakhovsky Island generally a similar trend can be observed.

Ester cleavage experiments on the residual OM resulted in the release of ester linked LMWOAs forming a potential substrate pool when released in the future. At both locations these bound LMWOA profiles are even better correlated to the TOC content suggesting that the deeper permafrost deposits (older organic material) are not significantly different from those in the surface sediment (fresh organic material in the active layer).
The interglacial permafrost deposits from the Eemian are lean in OM and bound acetate, they reveal low Hydrogen Index data and a low aliphatic character (obtained by pyrolysis GC) indicating stronger degradation of the OM. In contrast, higher OM accumulation with increased aliphatic character is observed in Late Pleistocene intervals MIS 3 and MIS 4.

Conclusions

Abundant and active microbial life is indicated in the active layers of the investigated permafrost deposits of Buor Khaya and Bol´shoy Lyakhovsky Island. In contrast, microbial life is significantly lower and less active in the underlying permafrost deposits. Increased past microbial life within the permafrost sequence is linked to periods of higher terrestrial OM accumulation, often showing an increased aliphatic character. These organic-rich intervals might reflect formation under moister and warmer environmental conditions during the Late Pleistocene, which causes shallow anaerobic soil conditions favorable for microbial communities. Thus, differences in the quality and amount of the OM in the permafrost deposits seem to reflect past changes in the hydrology and local depositional environment. Eemian interglacial deposits are lean in OM amount and quality, which might be the result of intense degradation during the time of deposition, since the Eemian is suggested to represent a warm and dry climate interval in the study area presumably supporting aerobic microbial degradation.
The Late Pleistocene permafrost intervals with high OM accumulation are rich in potential substrates for methanogenesis. Thus, with regard to the generation of the greenhouse gas methane the OM freeze-locked in the permafrost deposits appears to be not much different in terms of OM quality than the younger surface organic material from the active layer. Therefore, the future potential for greenhouse gas generation from permafrost deposits seems to depend on the quality and amount of the stored OM rather than on the age (Stapel et al., 2016). As a result of increased rates of deeper permafrost thaw in a warming Arctic, the observed similarities imply a significant impact on future generation of greenhouse gases from thawing permafrost areas with comparable OM deposits, including a positive feedback on climate evolution.

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References

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