QUANTITY, ORIGIN AND DEGRADATION STATE OF ORGANIC MATTER IN SUBSEA PERMAFROST ON THE EAST SIBERIAN ARCTIC SHELF

B. Wild[1], N. Shakhova[2], O. Dudarev[2,3], A. Ruban[2], D. Kosmach[3], V. Tumskoy[4,5,6], T. Tesi[7], H. Joß[1], H. Alexanderson[8], M. Jakobsson[1], A. Mazurov[2], I. Semiletov[2,3], Ö. Gustafsson[1]

[1] Stockholm University, Sweden
[2] Tomsk Polytechnic University, Russia
[3] Pacific Oceanological Institute, Russian Academy of Sciences, Russia
[4] Moscow State University, Russia
[5] Institute of Geography, Russian Academy of Sciences, Russia
[6] University of Tyumen, Russia
[7] Institute of Marine Sciences, National Research Council, Italy,
[8] Lund University, Sweden

Introduction

More than two thirds of subsea permafrost are thought to be located on the East Siberian Arctic Shelf (ESAS) where rapidly rising sea levels caused the inundation of previously terrestrial permafrost landscapes in the early Holocene. Subsea permafrost on the ESAS has likely been thawing since then by the combined effect of geothermal heat from underneath and the thermal gradient from warmer ocean water above. This effect might intensify in the coming decades as ESAS water temperatures continue to rise. Subsea permafrost thaw exposes organic matter to microbial degradation to form the greenhouse gases CO_2 and CH_4, but also provides flow paths for CH_4 stored in deeper deposits (e.g. CH_4 hydrates, thermogenic/petrogenic CH_4) to reach the surface. Both mechanisms may contribute to the strongly elevated CH_4 activity in the ESAS waters above subsea permafrost compared to in the overlying atmosphere (Shakhova et al., 2010).

This study focusses on the Buor-Khaya Bay on the ESAS where particularly high thaw rates of 14 cm year^{-1} (average for past three decades) have been observed (Shakhova et al., 2017). Based on a unique set of three drill cores, we characterize the quantity, origin and degradation state of organic matter through the subsea permafrost with higher resolution across the current thaw front, to improve our understanding of its vulnerability to decomposition upon thaw.

Results and Conclusions

The three cores show high variability even at the small scale of our study, emphasizing its development in a dynamic and heterogeneous landscape. Lithological analysis and optically stimulated luminescence dating suggest the alternating deposition of aeolian silt and fluvial sand over the past 160 000 years. Lignin biomarker analysis at the thaw front further indicates the contribution of organic matter from both tundra and boreal forest, at least the latter likely transported by rivers from locations further south. Nevertheless, low acid-over-aldehyde ratios support only limited degradation of lignin under aerobic conditions.

Overall, the thaw front was characterized by low mineral surface area and low organic carbon content of on average 0.7 ± 0.2% (± standard deviation). This range is lower than that of Pleistocene Ice Complex Deposits, thermokarst and lake sediments preserved at near-by terrestrial sites, but similar to that of Pleistocene fluvial and alluvial deposits (Schirrmeister et al., 2011). In spite of the low organic carbon content, the high thaw rates of subsea permafrost in the study area correspond to an annual thaw-out of 1.4 kg organic carbon m^{-2} $year^{-1}$; this organic carbon might be substrate for microbial decomposers to form CH_4 and CO_2. Quantifying thaw and degradation rates across the heterogeneous subsea permafrost area will help to constrain the Arctic greenhouse gas budget and its feedback to climate warming.

References

Schirrmeister, L., Grosse, G., Wetterich, S., Overduin, P.P., Strauss, J., Schuur, E.A.G., Hubberten, H.W., 2011. Fossil organic matter characteristics in permafrost deposits of the northeast Siberian Arctic. Journal of Geophysical Research: Biogeosciences 116, G00M02.

Shakhova, N., Semiletov, I., Gustafsson, O., Sergienko, V., Lobkovsky, L., Dudarev, O., Tumskoy, V., Grigoriev, M., Mazurov, A., Salyuk, A., Ananiev, R., Koshurnikov, A., Kosmach, D., Charkin, A., Dmitrevsky, N., Karnaukh, V., Gunar, A., Meluzov, A., Chernykh, D., 2017. Current rates and mechanisms of subsea permafrost degradation in the East Siberian Arctic Shelf. Nature Communications 8, 15872.

Shakhova, N., Semiletov, I., Salyuk, A., Yusupov, V., Kosmach, D., Gustafsson, Ö., 2010. Extensive methane venting to the atmosphere from sediments of the East Siberian Arctic Shelf. Science 327, 1246–1251.