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Soil carbon unlocked from MIS 5 to MIS 1 aged North Siberian permafrost: state and fate of decomposition

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At Bol'shoy Lyakhovsky, New Siberian Archipelago, multiple permafrost cores were obtained providing a Late Quaternary environmental record with deposits from marine isotope stages MIS 5 to MIS 1. This exceptionally long record is used to evaluate the stored potential of the freeze-locked organic matter (OM) to serve as substrate provider for greenhouse gas producing microorganisms. We relate modern signals of OM degradation from MIS 1 deposits to previous glacial-time deposits (MIS 4 and MIS 3) and to interglacial deposits (MIS 5), which may serve as an analogue for a future Arctic warmer than modern.

From the oldest to the youngest, the composite record includes re-frozen MIS 5 lake deposits (sandy silt), floodplain deposits (sandy silt) from MIS 4, Ice Complex (i.e. Yedoma) deposits from MIS 4 to 3 (sandy silt), and alas deposits (sandy silt) from a drained and re-frozen thermokarst basin with MIS 1 ages. Whereas glacial-time deposits (MIS 4 and MIS 3) are fairly ice-rich with a median at 43 wt% ice content, interglacial deposits (MIS 5 and MIS 1) are moderately ice-rich with a median at 31 wt% ice content. In terms of total organic carbon content glacial-time deposits have moderate values with a median at 2.4 wt% and interglacial deposits have low values with a median at 0.4 wt%.

Deposits from MIS 4 and MIS 3 possess an increased aliphatic character and therefore higher OM quality in terms of biodegradation compared to deposits from MIS 5 and MIS 1. The strongest primal and future substrate potential is stored within the glacial-time deposits, especially in those layers deposited during environmental conditions with increased moisture. The interstadial MIS 3 deposits hold the highest concentrations of pore-water acetate, which serve as optimal substrate for greenhouse gas generating microorganisms once it is unlocked from the perennially frozen ground. MIS 3 deposits also contain the highest concentrations of organic acids ester-bound to the organic matrix, implying an increased and still stored future substrate pool. In contrast, interglacial MIS 5 deposits are distinctly depleted in both primal and future substrate pools, whereas MIS 1 substrates are partly depleted in that sense.

Incubation experiments reveal that moderate CO_2 and low CH4 concentrations can be generated from the deposits (after 285 days at 4°C). MIS 4 and MIS 3 deposits produce markedly higher amounts of aerobic and anaerobic CO_2 than MIS 5 deposits. CH4 production was only observed in MIS 5 and in a few MIS 1 samples. This points to the fact that greenhouse gas production potentials depend on particular soil properties and environmental conditions during OM deposition and the degree of degradation prior to incorporation into permafrost.