Thermokarst-lake methanogenesis along a complete talik (thaw bulb) profile

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Thermokarst (thaw) lakes emit methane (CH_4) to the atmosphere, with the carbon (C) originating from terrestrial sources such as the Holocene soils of the lakes' watersheds, thaw of Holocene- and Pleistocene-aged permafrost soil beneath and surrounding the lakes, and decomposition of contemporary organic matter (OM) in the lakes. However, the relative magnitude of CH_4 production in surface lake sediments versus deeper thawed permafrost horizons is not well understood. We assessed anaerobic CH_4 production potentials from 22 depths along a 590 cm long lake sediment core from the center of an interior Alaska thermokarst lake, Vault Lake, that captured the entire package of surface lake sediments, the talik (thaw bulb), and the top 40 cm of thawing permafrost beneath the talik. We also studied the adjacent Vault Creek permafrost tunnel that extends through ice-rich yedoma permafrost soils surrounding the lake and into underlying fluvial gravel. Our results show, in the center of a first generation thermokarst-lake, whole-column CH_4 production is dominated by methanogenesis in the organic-rich surface lake sediments [151 cm thick; mean ± SD 5.95 ± 1.67 μg C-CH_4 per g dry weight sediment per day (g dw^{-1} d^{-1}); 125.9 ± 36.2 μg C-CH_4 per g organic carbon per day (g C org^{-1} d^{-1})]. The organic-rich surface sediments contribute the most (67%) to whole-column CH_4 production despite occupying a lesser fraction (26%) of sediment column thickness. High CH_4 production potentials were also observed in recently-thawed permafrost (1.18 ± 0.61 μg C-CH_4 g dw^{-1} d^{-1}; 59.60 ± 51.5 μg C-CH_4 g C org^{-1} d^{-1}) at the bottom of the talik, but the narrow thicknesses (43 cm) of this horizon limited its overall contribution to total sediment column CH_4 production in the core. Lower rates of CH_4 production were observed in sediment horizons representing permafrost that has been thawed in the talik for longer periods of time. The thickest sequence in the Vault Lake core, which consisted of combined Lacustrine silt and Taberite facies (60% of total core thickness), had low CH_4 production potentials, contributing only 21% of whole sediment column CH_4 production potential. No CH_4 production was observed in samples obtained from the permafrost tunnel, whose sediments represent a non-lake environment. Our findings imply that CH_4 production is highly variable in thermokarst-lake systems and that both modern OM supplied to surface sediments and ancient OM supplied to both surface and deep lake sediments by in situ thaw, as well as shore erosion of yedoma permafrost, are important to lake CH_4 production. Knowing where CH_4 originates and what proportion of produced CH_4 is emitted will aid in estimations of how C release and processing in a thermokarst-lake environment differs from other thawing permafrost and non-permafrost environments.

References

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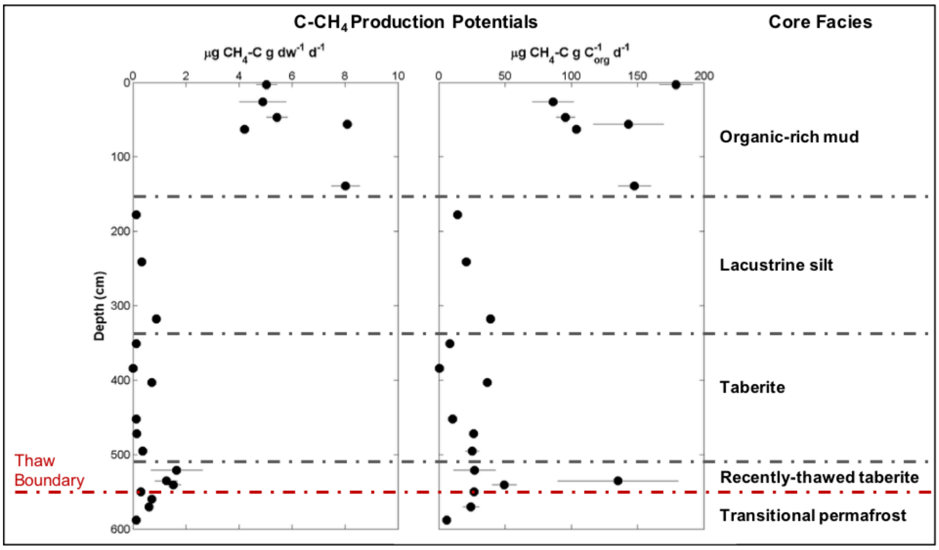

Figure 1: CH_4 production potentials in the Vault Lake core. Samples were anaerobically incubated at 3°C. CH_4 production potentials are represented as mean value ± SD among replicates normalized per gram dry weight sediment (left) and per gram organic carbon (right)