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Greenhouse gases (CO_2, CH4, and N2O) entrapped in Alaskan and Siberian ice wedges: a direct evidence of the microbial activity within ground ice

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Ice wedge are one of the dominant components of massive ground ice in terrestrial permafrost. Due to repetitive thermal cracking and the downward infiltration of snowmelt and soil pore waters, ice wedge contains organic and inorganic compounds and microbes. Previous culture-based microbial sequencing assays discovered microorganisms the ice wedges, however, these studies did not address whether the microorganisms are active within ice matrix in subfreezing temperatures. Here we present preliminary results of greenhouse gas (GHG) measurements in gas enclosed in Pleistocene-aged ice wedges from central Siberia (Cyuie, Churapcha, and Syrdakh) and Alaska (Fox Permafrost Tunnel). Our results show the GHG mole fractions ranging from 0.5 $\sim$ 18% CO_2, 70 $\sim$ 13284 ppm CH4, 20 $\sim$ 40451 ppb N2O in the Fox tunnel, Alaska. We measured 8.2 $\sim$ 13.8% CO_2, 1.3 $\sim$ 22.5 ppm CH4, 1959 $\sim$ 80988 ppb N2O in Churapcha, 7.4 $\sim$ 13.2% CO_2, 11.0 $\sim$ 91.2 ppm CH4, 74 $\sim$ 5539 ppb N2O in Cyuie, and 5.1 $\sim$ 10.7% CO_2, 3.3 $\sim$ 9.1 ppm CH4, 405 $\sim$ 13987 ppm N2O in the Syrdakh ice wedge. We found no clear evidence that the observed GHGs were produced by abiotic processes. Molar ratios of δ(N2/Ar)of the enclosed air and bubble shapes the ice wedges studied in this study were created mainly by snow (and/or hoar) compaction without melting. Stable carbon isotope ratios of CO_2 (δ13C-CO_2) from the four ice wedges indicate a biogenic origin of the CO_2. Geologic CH4 production is unlikely due to low temperature condition. Inverse relationship between CH4 and N2O mixing ratios is observed in all sites, providing further evidence of microbial methanogenesis due to the inhibitory effect of N-oxides on methanogens. Further study is needed to determine whether microbial nitrification and denitrification existed in the past. Our results demonstrate that aerobic and anaerobic respiration occurred within the ground ice.