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Origin and Distribution of Methane Entrapped in Calcareous Alpine Proglacial Soil

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Methane (CH_4) is an important greenhouse gas. The atmospheric methane concentration has been increasing in recent years, which is caused by imbalance between sources and sinks. Methane has been recently discovered to be entrapped in calcareous Swiss Alpine proglacial soil. This CH_4 can be released upon mechanical impact and acidification. However, the amount, distribution and environmental fate of this entrapped CH_4 in proglacial environment remain unknown.

The entrapped CH_4 in proglacial soil may be of modern or ancient origin. Modern origin includes ongoing or recent microbial CH_4 production (methanogenesis) in subglacial or proglacial environments. An ancient origin mainly refers to CH_4 produced thermogenically. This soil entrapped CH_4 might be a common phenomenon along the entire glacial forefield, or it might only be present at few locations and depth. We present results of studies from two Swiss Alpine Glacier catchments, Wildstrubel Glacier (Canton Valais) and the Griessfirn Glacier (Canton Uri). Our main goals were 1) to assess the origin of CH_4 entrapped in various glacial environments (subglacial, proglacial and supraglacial, soil and bedrocks) using geochemical and microbiological evidence; 2) to assess the spatial distribution of entrapped CH_4.

We performed geochemical analysis (CH_4 content, gas wetness ($[C_1]/[C_2\text{-}C_3]$ alkane ratio), CH_4 stable ^{13}C- and ^{2}H-isotopes, TOC) on subglacial, proglacial, and supraglacial soil samples collected from well-aerated and water-logged locations. Geochemical analysis was also selectively conducted on pore-water samples and on rock samples collected from different geological formations along the catchments. We also performed batch incubations on soil samples collected from subglacial, proglacial water-logged and supraglacial zones. In addition, for the aforementioned three types of samples, we also performed molecular analyses targeting the *mcrA* gene, which encodes the α-subunit of the enzyme methyl-coenzyme M reductase, catalyzing the final step in methanogenesis.

Substantial amounts of CH_4 were found to be entrapped in all soil samples in both glacial catchments. Results of the soil geochemical analyses provided strong evidence that the entrapped CH_4 is mainly of thermogenic origin. Meanwhile, batch incubations of samples collected from proglacial water-logged zones and supraglacial zones indicated an active microbial methane production. This is in line with the results from our molecular analysis. Methane was found to be entrapped along the entire proglacial forefield with little difference in soil-methane content at the Griessfirn Glacier forefield. We also found much higher soil methane content at Wildstrubel Glacier compared with Griessfirn Glacier.