Electron acceptor-based regulation of microbial greenhouse gas production from thawing permafrost

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INTRODUCTION

Permafrost contains about 35% of the global soil organic carbon (0-3 m depth). As a consequence of global warming, the active layer thickness is steadily increasing and its organic carbon is becoming available for degradation, causing a concomitant release of CO_2 and CH_4. The climate forcing feedbacks of permafrost thaw are determined by the rate of organic carbon degradation and to which degree it is released as CO_2 or CH_4. Methane is produced under anoxic conditions, but the factors that regulate its production are poorly constrained.

In this study, we investigate how CH_4 production is influenced by competing anaerobic processes with focus on the role of iron and sulfate reduction.

METHODS

We collected drill cores down to 1.5-2.2 meters depth from three lowland ice wedge polygon sites in Adventdalen on Svalbard. The cores were cleaned, divided into 25 cm depth sections and analyzed for water, total carbon, total iron and sulfate content. Addditionally, we prepared anoxic batch incubations at 4°C to follow the production of CO_2 and CH_4 by time as well as the turnover of iron and sulfate after thaw.

Figure 1 | **a:** Drilling with hand-held drilling equipment at the Ice Wedge South site. **b:** Partial core fresh out of the ground. **c:** Core section after cleaning. **d:** Core divided into samples for each 25 cm depth interval. **e:** Batch incubation. **f:** Subsamples for total iron analysis.

PRELIMINARY RESULTS

- The CO_2 production was orders of magnitude higher than the CH_4 production (Figure 2).
- The CO_2 and CH_4 productions were positively correlated with the total carbon content (Figure 3).
- The CH_4 production showed a significant negative correlation with the availability of iron and a negative trend with higher sulfate concentrations (Figure 4). This supports that alternative electron acceptors may inhibit methanogenesis in thawing permafrost.
- The CO_2 and Fe^{2+} productions showed a significant correlation in the permafrost samples (Figure 5), which suggests that iron(III) minerals may be important electron-acceptors in the system.

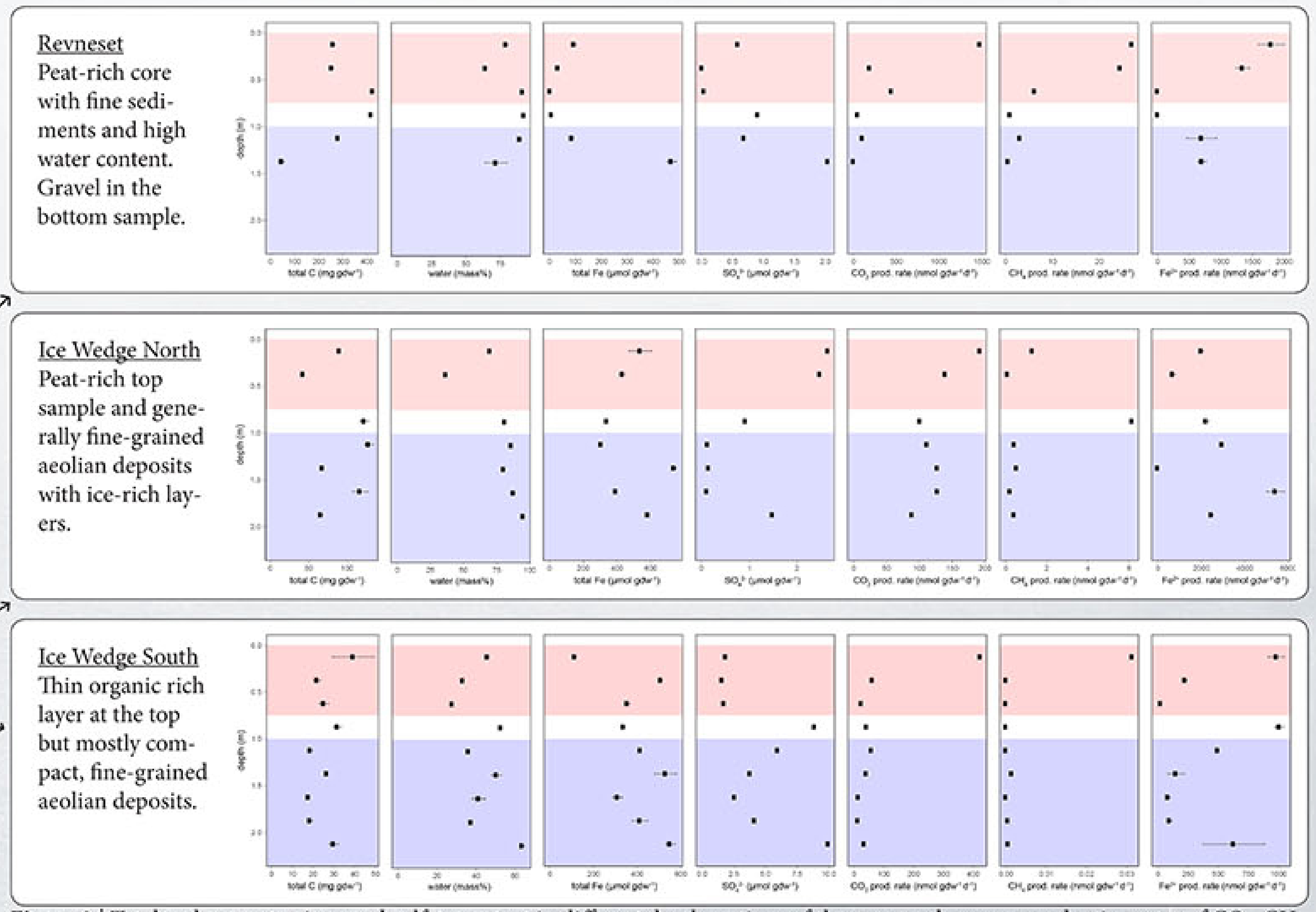


Figure 2 | Total carbon, water, iron and sulfate content in different depth sections of the cores and average production rates of CO_2, CH_4 and Fe^{2+} after 2 months of incubation. The red, white and blue areas indicate the estimated active, transient and permafrost layers, respectively.

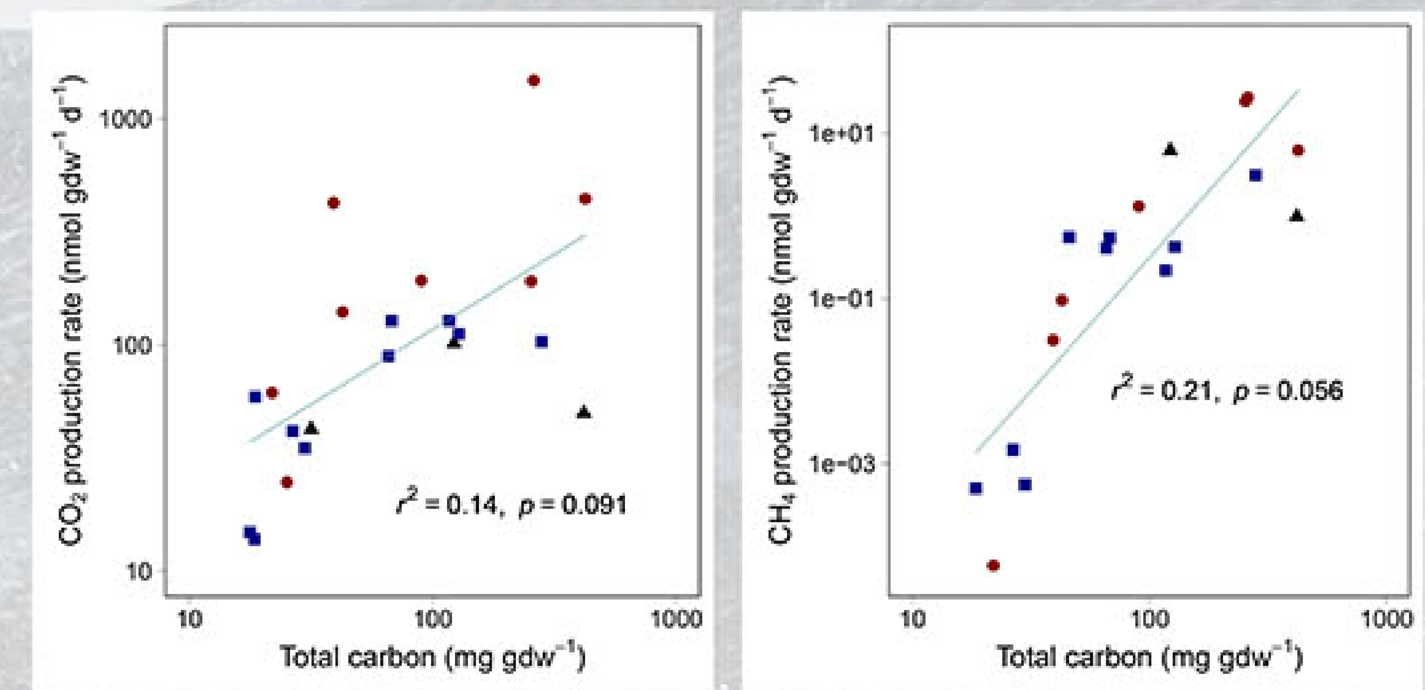


Figure 3 | CO_2 (left) and CH_4 (right) production rates with total carbon. Active layer (*red circles*), transient layer (*black triangles*) and permafrost samples (*blue squares*).

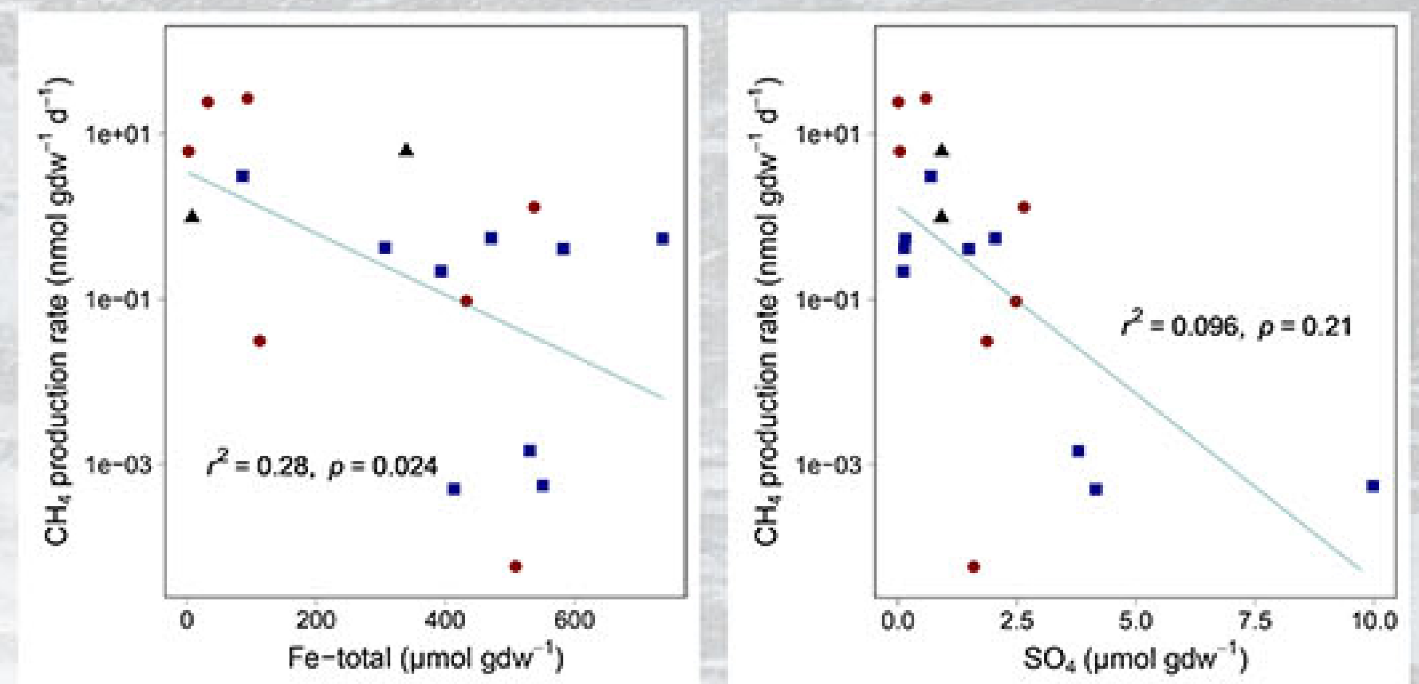
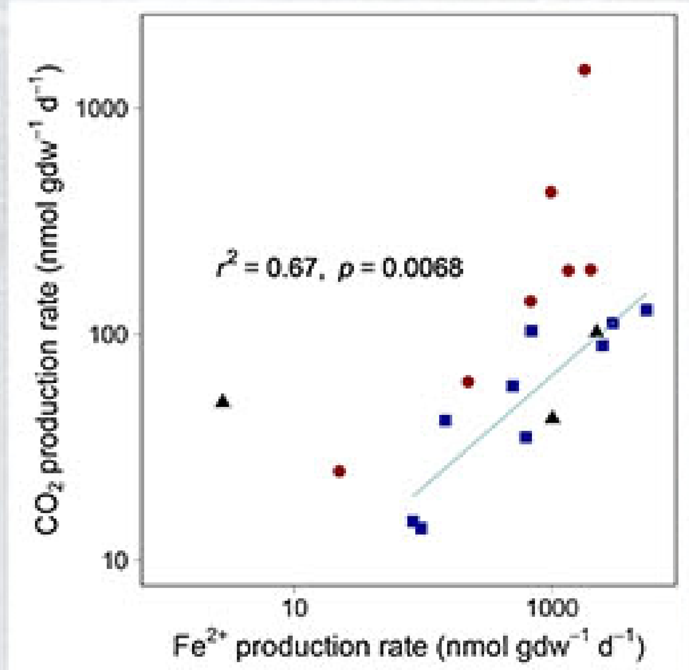


Figure 4 | CH_4 production rates with total iron content (left) and sulfate content (right). Active layer (*red circles*), transient layer (*black triangles*) and permafrost samples (*blue squares*).

Figure 5 | CO_2 production rates with Fe^{2+} production rates. Active layer (*red circles*), transient layer (*black triangles*) and permafrost samples (*blue squares*). The regression line is fitted to the data from the permafrost samples.



ONGOING WORK

- The batch incubations will be followed for a year to track changes in rates and possible shifts in the dominating processes.
- Amendment experiments have been prepared to specifically investigate the effects of amendment with organic carbon, sulfate, molybdate and iron(III)-minerals.
- The bacterial and archaeal community structures will be examined to elucidate correlations between the prevalent microbial groups and the dominant respiration processes.