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Understanding the Methane Cycle in Riverbeds

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INTRODUCTION

Methane (CH_4) is the second most important greenhouse gas, and the increase of atmospheric CH_4 concentrations has accelerated significantly in recent years. One suspected reason is an increase in emissions from natural sources such as freshwater sediments or wetlands. Rivers are not only an important contributor to atmospheric CH_4, but also account for much of the uncertainty in global budgets. This project has the aim to better understand the CH_4 cycle in riverbeds.

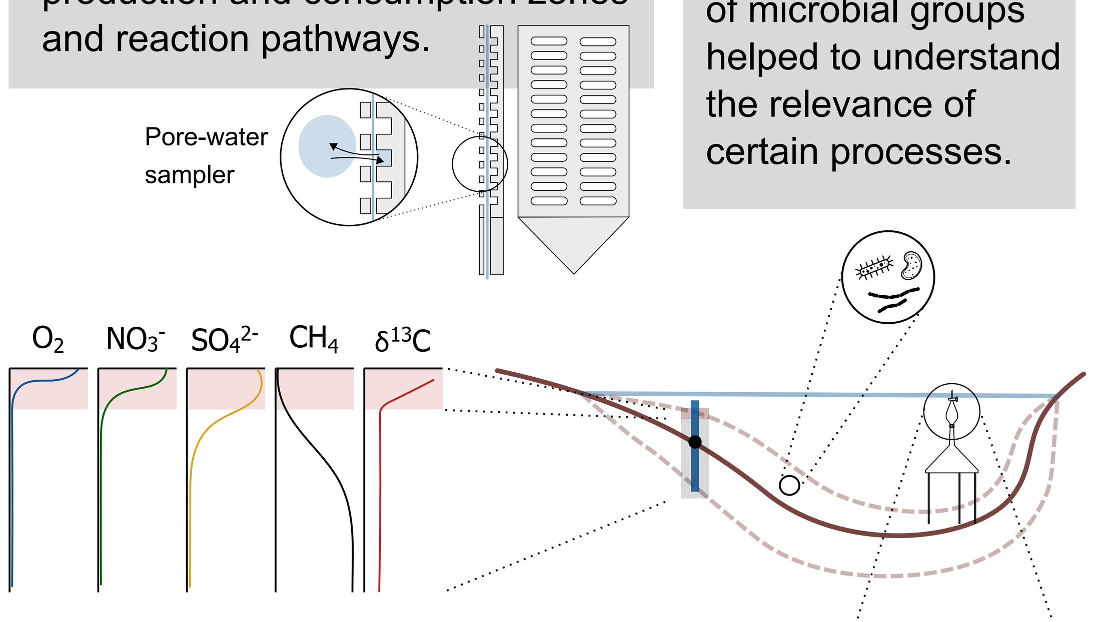
METHODS

1) Measurement and modeling of geochemical profiles

Geochemical profiles were measured to get depth-distributions of CH_4 and important reactants. Modeling and stable isotope analyses were used to identify production and consumption zones and reaction pathways.

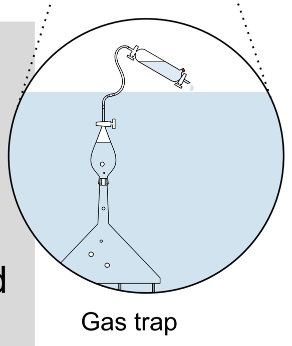
2) Analysis of microbes in the sediment

The microbial community distribution was studied with 16S-rRNA sequencing. The abundance of microbial groups helped to understand the relevance of certain processes.

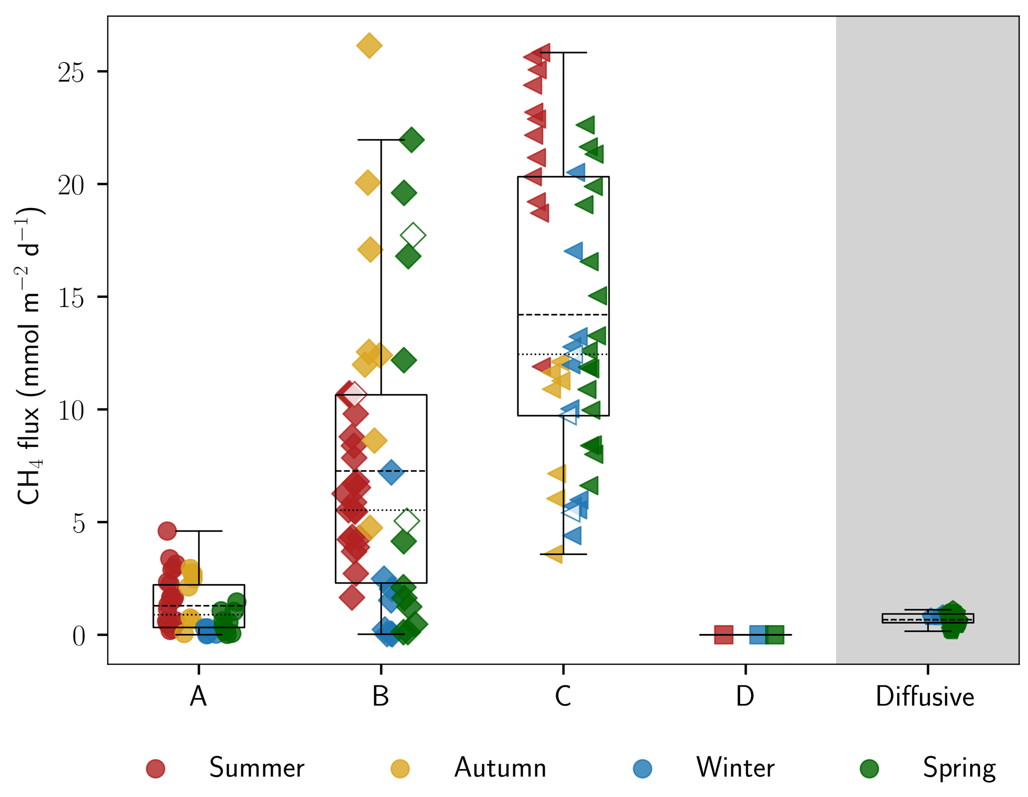


3) Gas trapping and diffusive flux estimation

Gas traps were built and monitored for a full year to quantify ebullition. For a comparison, diffusive fluxes were calculated from dissolved CH_4 concentrations in surface water.

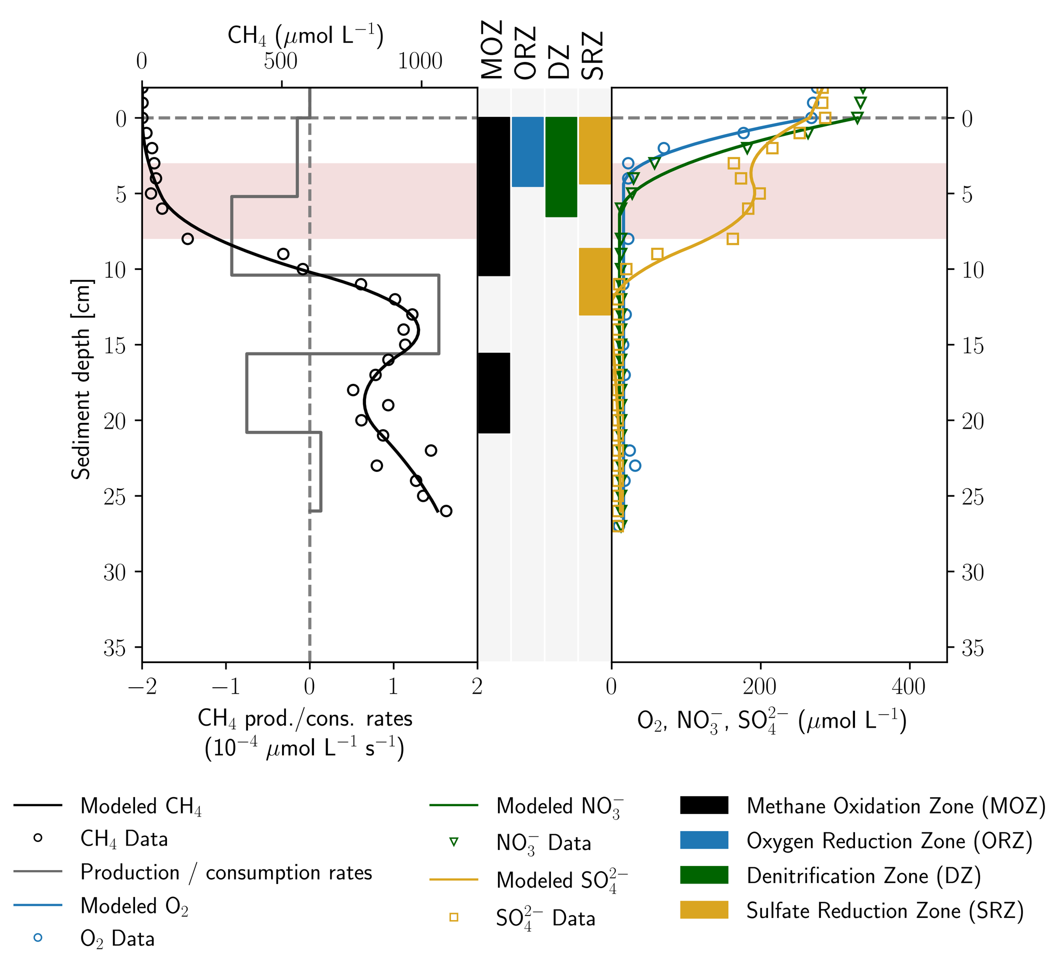


2 TRANSPORT OF METHANE TO THE ATMOSPHERE MAINLY BY EBULLITION



Ebullition released more CH_4 from the river bed to the atmosphere than calculated diffusive transport. One site showed active methane production even during winter. Highest gas emissions were observed in the central section of the river. Ebullitive fluxes at our test sites were similar to fluxes measured in tropical reservoirs.

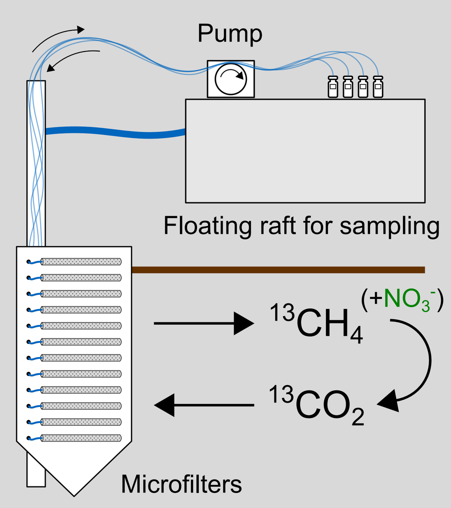
3 AEROBIC AND ANAEROBIC METHANE OXIDATION



The methane oxidation zone was identified through an enrichment in isotopically heavier CH_4 and modeling. Gradients of O_2 and NO_3^- were too steep to clearly identify which reduction reaction was coupled to CH_4 consumption. Organisms using O_2 reduction and denitrification were present.

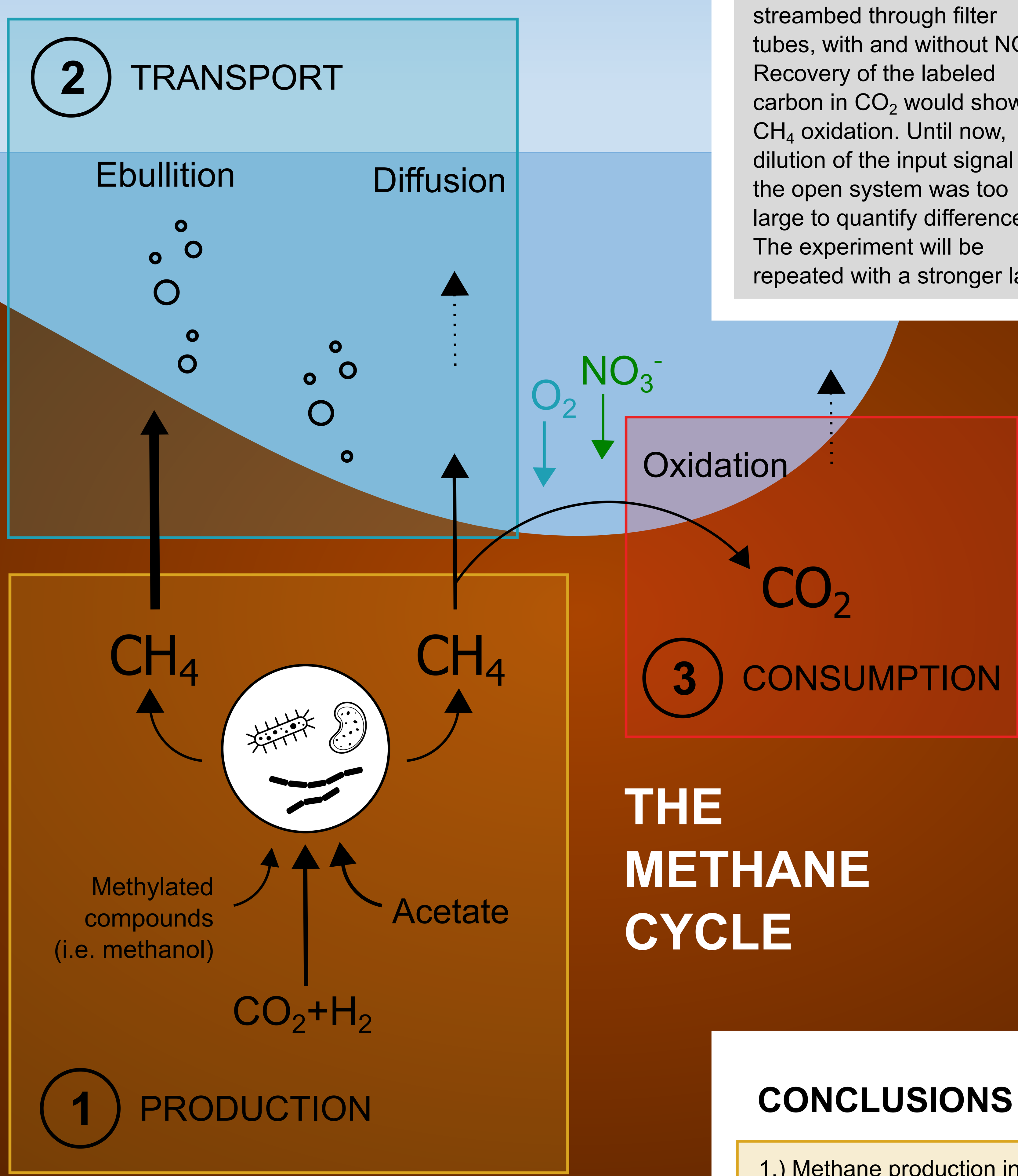
In-situ labeling experiment

To clarify the role of nitrate (NO_3^-) for CH_4 oxidation, CH_4 with isotopically labeled carbon was injected into the streambed through filter tubes, with and without NO_3^-. Recovery of the labeled carbon in CO_2 would show CH_4 oxidation. Until now, dilution of the input signal in the open system was too large to quantify differences. The experiment will be repeated with a stronger label.



Organic carbon

Fermen-tation



THE METHANE CYCLE

The redox ladder
= Order of reduction reactions

Oxygen reduction
$O_2 \rightarrow H_2O$

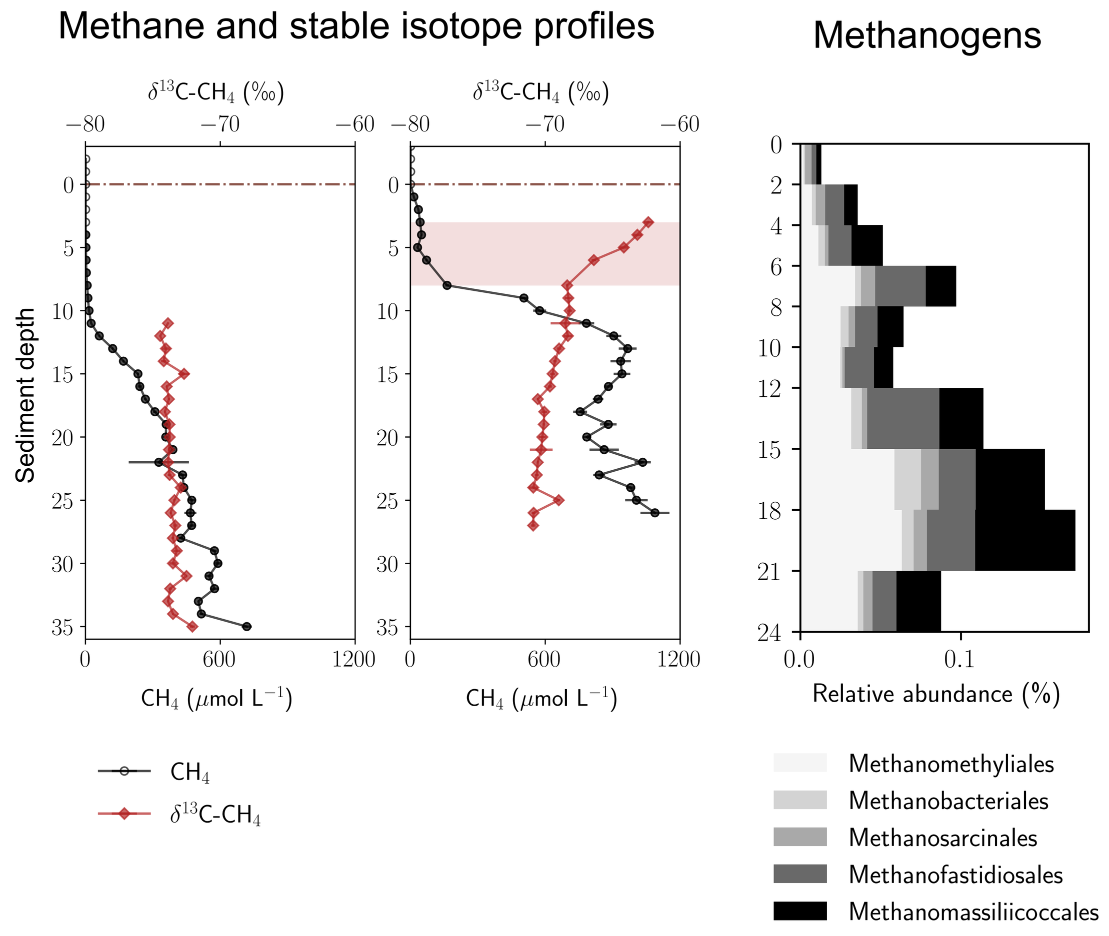
Denitrification
$NO_3^- \rightarrow NO_2^- \rightarrow N_2$

Iron-/manganese reduction
$Fe(OH)_3 \rightarrow Fe^{2+}$
$MnO_2 \rightarrow Mn^{2+}$

Sulfate reduction
$SO_4^{2-} \rightarrow H_2S$

Methanogenesis

1 METHANE PRODUCTION BY ANAEROBIC ARCHAEA



Methane producing archaea (metanogens) were abundant in the sediment and high CH_4 concentrations were measured at most sites, but concentrations were spatially heterogeneous. The isotopic signature suggested that CO_2 and H_2 were likely substrates, but also organisms using methylated compounds such as methanol were present.

CONCLUSIONS

1.) Methane production in the riverbed was substantial, but concentrations varied in space. Methane was actively produced during winter at one site.

2.) Ebullition released more methane to the atmosphere than diffusive fluxes. Ebullition was largest in the center of the river.

3.) Isotopic enrichment and modeling results showed methane oxidation. Quantifying which reduction reactions were coupled to the CH_4 oxidation was not possible due to very steep geochemical gradients, but there was a potential for CH_4 oxidation coupled to O_2 reduction and denitrification. CH_4 oxidation did not significantly reduce emissions, because most CH_4 escaped as gas bubbles.

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