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Modeling nitrogen use in anaerobic methane-oxidizing microbial consortia: The enduring enigma of N_2 fixation

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Marine sediments are effective biofilters that oxidize methane and prevent much of release into the water column and atmosphere. Here we explore environment-microbe interactions of the microbially mediated anaerobic oxidation of methane (AOM) through reactive transport modeling. We established simulations of spatially resolved microbial consortia composed of methanotrophic archaea (ANME) coupled metabolically to sulfate-reducing bacteria (SRB), expanding on our previous work ([1]) by incorporating a description of anabolism, which allows us to focus on nitrogen utilization. Our simulations showed that growth efficiencies derived from estimates of catabolic energy yields, anabolic energy requirements and energy dissipation resulted in growth yields consistent with observations when using ammonium as the nitrogen source. Furthermore, nitrogen demands could be fulfilled without causing significant ammonium drawdown within or surrounding the microbial aggregates.

However, some archaea and bacteria involved in AOM – a process with limited energy yield - have been shown to fix N_2 (e.g., [2]), which requires a significant amount of ATP and reducing equivalents. When extending our model to allow for N_2 as the N source, the predicted growth yields decreased but remained substantially higher than yields derived from measurements when N_2 fixation was active, suggesting that physiological controls are important. To investigate possible triggers for this energy-consuming process, we explored intracellular controls on N processing using a flux balance model of ANME. Our simulations showed that even significant leakage of N-rich compounds is unlikely to induce N_2 fixation, pointing to redox and pH homeostasis as likely factors that induce N_2 fixation in anaerobic methane oxidizing communities.

References

[1] He, X., Chadwick, G.L., Kempes, C., Orphan, V. and Meile, C. 2021. Controls on interspecies electron transport and size limitation of anaerobically methane oxidizing microbial consortia. *mBio*, 12 (3), Art. No. e03620-20

[2] Metcalfe, K. S., Murali, R., Mullin, S. W., Connon, S. A., & Orphan, V. J. 2021. Experimentally-validated correlation analysis reveals new anaerobic methane oxidation partnerships with consortium-level heterogeneity in diazotrophy. *The ISME Journal*, 15(2), 377-396.