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Constraining the sources of archaeal tetraether lipids in multiple cold seep provinces of the Cascadia Margin

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Due to their robust preservation in marine sediments, archaeal isoprenoid glycerol dialkyl glycerol tetraethers (iGDGTs) play a crucial role in reconstructing past sea-surface temperatures (SSTs) and understanding marine carbon cycling. The widely used TEX_{86}-SST proxy, which estimates SST based on the ratio of cyclized iGDGTs, traditionally assumes these compounds originate primarily from planktonic, ammonia oxidizing Nitrososphaerota (*syn*. Thaumarchaeota). However, the potential for contributions from other sources complicates the application and interpretation of the TEX_{86} proxy. This study investigates the influence of non-planktonic archaeal sources, particularly benthic methane-cycling archaea, on the sedimentary iGDGT composition. Using a Bayesian mixing model, we incorporate compound-specific $d^{13}C$ and relative abundance measurements of iGDGTs collected from multiple cold-seep provinces of Cascadia Margin to infer relative contributions, $d^{13}C$ signatures, and iGDGT lipid distributions of three primary endmembers: planktonic, benthic methane-cycling, and benthic non-methane-cycling.

Our findings indicate the iGDGT lipid pool in these cold seep systems is primarily composed of planktonic and benthic methane-cycling archaeal sources, with minimal input from benthic-non-methane cycling archaea. Consistent with previous work, we estimate a predominant (*ca.* >50%) planktonic signal in the sedimentary iGDGT lipid pool, yet with notable variability in methane influence across the three sampled sites, ranging from *ca*. 2% - 45%. Our study shows a robust, linear relationship between benthic methane influence and the iGDGT methane index (MI) and estimates that a benthic methane-cycling contribution of less than *ca.* 20% (MI < 0.4) does not significantly affect TEX_{86}-SST estimations (i.e., errors less than ± 3 - 5 °C). Consequently, we suggest a revised MI threshold of 0.4 for identifying methane-impacted sedimentary samples in non-polar regions. However, relying on MI solely as a binary indicator of methane impact may overlook more nuanced processes occurring in the sediment or other potential iGDGT sources. Finally, our study explores the relationship between the glycerol configuration of sedimentary iGDGTs and methane influence. We observe a higher presence of iGDGTs in the anti-parallel configuration in sediments with higher methane impact, suggesting that methane-cycling archaea may dominantly synthesize iGDGTs in this configuration.