

**CRENARCHEOTAL ECOLOGY AND LIPID FLUXES IN LAKE SUPERIOR:
IMPLICATIONS FOR THE TEX₈₆ TEMPERATURE PROXY**

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The TEX₈₆ is a proxy for reconstructing past surface water temperatures by analyzing the relative ratio of cyclopentane rings in the lipids of aquatic *Crenarchaeota*. The higher the surface water temperature, the higher the relative ratio of cyclopentane rings in the membrane lipids of the aquatic *Crenarchaeota*. Initially developed for marine systems, the TEX₈₆ was adapted for use in lacustrine systems (Powers et al., 2004). A study analyzing a suite of 50 globally distributed lakes for TEX₈₆ determined that the proxy does not work in all lake systems, and that the degree to which the proxy correlates to seasonal vs. annual mean surface water temperatures seems to vary with latitude. (Powers et al. unpublished)

Besides the empirical relationship between TEX₈₆ values and lake surface temperatures (LST), little is known about the ecology of the organisms that produce these lipids in the lacustrine environment. Crenarchaeotal abundance can be seasonal with highest concentration in the winter months for the Dutch coastal North Sea (Wuchter et al., 2005), which is supported to some extent by the lake calibration, which shows a high correlation to both mean annual lake surface temperature and to mean winter lake surface temperature. In addition, in the marine environment these organisms are aerobic ammonium oxidizers (Wuchter et al., 2006). To accurately use the TEX₈₆ in lacustrine systems, it is important to comprehend where in the water column, and at which time of year the lipids are being produced that are incorporated into the sediment record. This knowledge will give a better understanding about what temperature the TEX₈₆ actually reflects.

To resolve these questions we initiated a study in Lake Superior combining sediment trap collection of settling particulate materials over the annual cycle and filtration of suspended particulate matter from lake water to create vertical profiles of crenarchaeotal and lipid abundance. Lipid and molecular biological analyses were applied to both suites of samples to correlate the lipids present with the archaea producing them. Initial results show that the *Crenarchaeota* live throughout the water column of the lake when it is not stratified,

but seem to migrate below the thermocline during stratification. In addition, identification of the archaeal ammonium monooxygenase gene suggests that they are likely oxidizing ammonium aerobically in this system, confirming a role in Lake Superior nitrogen cycling that was previously unknown. Furthermore, the sediment trap data show the seasonality of the flux of TEX₈₆ lipids, allowing us to calculate a flux weighted temperature for comparison to sediment core top data and onsite water-column temperature records from various depths. The information from this study should be applied when interpreting TEX₈₆ temperatures from sediment cores.

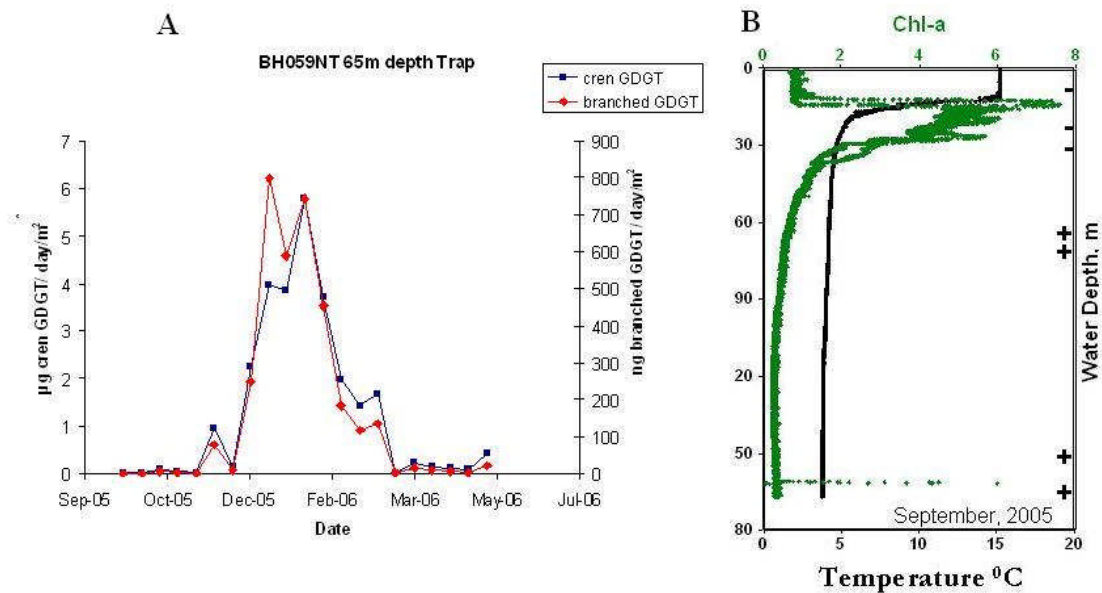


Figure 1. A: Crenarchaeotal and branched GDGT flux data from the Lake Superior sediment trap at 65m depth showing, seven months of data. B: vertical profile of water column in Lake Superior on September 2005. + = AMO gene detected – = AMO gene not detected

REFERENCES

- Powers LA, Werne J.P., Johnson TC, Hopmans E.C, Sinninghe Damsté J.S, Schouten S, (2004) Crenarchaeotal membrane lipids in lake sediments: A new paleotemperature proxy for continental paleoclimate reconstruction? *Geology* **32**:613-616
- Wuchter C, Schouten S, Wakeham SG, Sinninghe Damsté J.S (2005) Temporal and spatial variation in tetraether membrane lipids of marine Crenarchaeota in particulate organic matter: Implications for TEX₈₆ paleothermometry. *Paleoceanography*, **20**: PA3013, doi:10.1029/2004PA001110.
- Wuchter C, Abbas B, Coolen MJ, Herfort L, van Bleijswijk J, Timmers P, Strous M, Teira E, Herndl GJ, Middelburg JJ, Schouten S, Sinninghe Damsté J.S. (2006) Archaeal nitrification in the ocean. *Proceedings of the National Academy of Sciences of the United States of America* (33): 12317-12322