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Assessing temperature response in archaeal tetraether distributions in marine sediments

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Isoprenoid glycerol dibiphytanyl glycerol tetraethers (isoGDGTs) form the basis of the marine temperature proxy TEX_{86}, which has been applied to sediments spanning the Jurassic to modern. GDGTs are membrane-spanning lipids which can have 0-8 cyclopentane moieties (GDGT-n), or one cyclohexane and 4 cyclopentane rings in the case of crenarchaeol (cren) and its isomer (cren'), where higher temperatures lead to GDGTs with more rings. Although most membrane adaptation occurs in GDGT-0 and cren, only GDGT-1, -2, -3 and cren' are part of TEX_{86}. The sensitivity of TEX_{86} to temperatures above the modern range is poorly understood, with advocates for linear, exponential and logarithmic responses, leading to large uncertainties in reconstructions of warm climates. Here, we reexamine the GDGT relationship to temperature using previously published data from core tops and, to extend the temperature range of the study, ancient sediments, cultures, and mesocosms. The fractional abundances of the six main isoGDGTs in the core top, culture, and mesocosm dataset indicate that GDGT-1, GDGT-2, and GDGT-3 increase with temperature until they reach an optimum, then decrease in abundance (Fig. 1). Ancient sedimentary data confirm this trend when TEX_{86} is used to approximate temperature variation (Fig. 2). This contrasts the assumption of continuous increase of all three with temperature, observed when considering only core top samples.

We use gaussian curves to fit a temperature model to the fractional abundance of each GDGT to ocean temperatures using the core top dataset, and restrict this curve to fit modern and ancient sedimentary GDGT distributions. By optimizing for both temperature and fit, we obtain a temperature calibration better suited to warm climates, with a residual error similar to TEX_{86} calibrations in the modern.

Although much of the modern GDGT variability is captured using the six widely measured isoGDGTs, the closed sum effect indicates that - as recently shown for OH-GDGTs at low temperatures - we may be missing important components of the archaeal lipidome at higher temperatures. In this range, GDGT-4, previously detected in some modern high-temperature samples, may become important to describe temperature adaptation and to accurately reconstruct paleotemperatures for warm climate states.

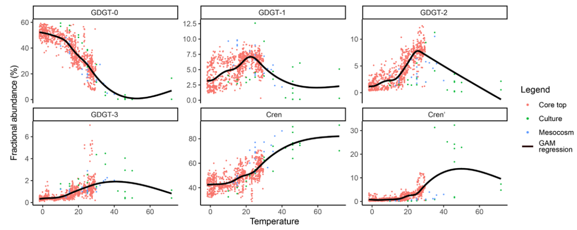

Fig. 1. Fractional abundances of isoGDGTs in core top, culture, and mesocosm samples against sea surface temperature (core top) or growth temperature (mesocosm and culture). Generalized additive models (GAMs) were calculated for each GDGT using a cubic splines smoother.

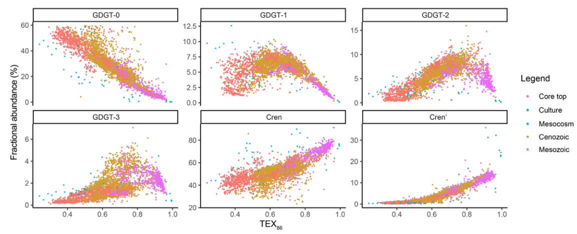

Fig. 2. Fractional abundances of isoGDGTs in core top, culture, mesocosm, and sedimentary samples against TEX_{86}.