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Testing a thermometer of the past: abiotic and biotic drivers of the brGDGT-based temperature proxy along a subarctic elevation gradient.

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BrGDGTs are used in a variety of paleoclimate archives to reconstruct changes in temperature and pH. However, the temperature dependency, currently determined on a global scale, can be confounded on smaller spatial scales. To determine the unique effect of temperature on the brGDGT distribution in northern Scandinavia, 37 soils have been collected along a Swedish and Norwegian altitude gradient (14 to 1200 m asl). At this site, we measured in-situ soil temperature (1 year), as well as soil chemical parameters (pH, Ca, K, Mg, Mn, Fe, Mn, Al, total P, total N). Furthermore, we reconstructed the composition of the bacterial community in the same soils, using 16S rDNA, to allow direct comparison with the brGDGT lipid signatures.

Although we sampled over a limited range in pH values (3.3-5.4), large changes in brGDGT concentration are observed over the pH gradient. In low pH soils (>4.0), total brGDGT concentration (normalized per g soil) is increased, caused by an increase in the concentration of brGDGT Ia. This results in increased MBT$^{5ME}$ values (0.53-0.7) in these soils. In high pH soils (pH>5.0) an increased concentration in 6-methyl brGDGTs is observed. These soils are characterized by a lower MBT$^{5ME}$ values, driven by a decrease in the fractional abundance of brGDGT Ia. Along the altitudinal gradient, pH (and soil calcium) is the main driver of the MBT$^{5ME}$ proxy ($r= -0.60$, $p<0.01$).

Along the Swedish and Norwegian altitudinal gradient, where a substantial change in temperature (-4.7 to 2.7 °C MAAT) was crossed, the MBT$^{5ME}$ only shows a poor correlation with atmospheric MAAT values ($r= 0.47$, $p<0.01$). When comparing the MBT$^{5ME}$ with in-situ measured soil temperatures (-2.5 to 4.3), that reflect the growth conditions of the soil bacteria better, the correlation is not improved (mean annual soil temperature: $r= 0.32$, $p=0.05$). A correlation with seasonal temperatures (Growing Degree Days [GDD]) results in a better dependency between the MBT$^{5ME}$ and soil temperature ($r= 0.44$, $p<0.01$), which can reflect that brGDGT are generally produced in non-frozen soil conditions.

However, at the Swedish and Norwegian altitudinal gradient, there is a significant correlation observed between the temperature (GDD) and soil chemical parameters. In general, soil pH is increased at lower temperatures ($r=-0.32$, $p=0.04$, $n=37$). Considering all soil chemical parameters,
the total concentration of K decreases closely with an increase in soil temperature (GDD: r = -0.63, p<0.01, n=37). The mechanism behind this is probably an interplay between local geology, and a temperature dependent extent of chemical and biological weathering. Because of this correlation, it is not clear whether MBT$^{5\text{ME}}$ varies exclusively in response to soil chemistry, with an indirect response to temperature changes.

Although the environmental driver determining the brGDGT signal can not be determined unequivocally, the bacterial community composition is clearly determined by soil pH. In those high pH soils (pH > 4.9) where increased concentrations of 6-methyl brGDGTs are produced, several Acidobacterial OTUs (specifically Acidobacteria subgroup 6) are increased. This indicates that the mechanism behind the changed fractional abundances is a pH-modulated bacterial community shift.