Organic Geochemical Perspective on Deglacial Paleoclimate in Central Alaska

Jennifer Kielhofer[1], Jessica Tierney[2], Charles Holmes[3], Ben Potter[4], Julie Esdale[5], Francois Lanoe[6], Nancy Bigelow[7], Joshua Reuther[8], and Matthew Wooller[9]

1 and 2) Depart. of Geosciences, Univ. of Arizona, 3 and 4) Anthropology Depart, Univ. of Alaska Fairbanks, 5) Center for Environmental Management of Military Lands, Colorado State University, 6) School of Anthropology, Univ. of Arizona, 7) Alaska Quaternary Center, Univ. of Alaska Fairbanks, 8) Archaeology Depart., Univ. of Alaska Museum of the North, 9) Water and Environmental Research Center, Univ. of Alaska Fairbanks

Introduction

This study uses organic geochemical techniques to investigate the paleoenvironmental context of human colonization of eastern Beringia (Alaska today) in the Late Glacial period (~15-10k cal. B.P.). Eastern Beringia is highly significant to archaeologists, as it is considered the primary route for human settlement of the Americas. Deglacial climate change may explain the timing and mechanisms of human occupation, yet few quantitative climate records exist for this period.

Here, we use branched glycerol dialkyl glycerol tetraethers (brGDGTs) from six loess-buried soil sequences to develop a paleotemperature record for Shaw Creek Flats (SCF), central Alaska (Fig. 1). These stratigraphic sequences, Swan Point, Mead, Camp/Broken Mammoth, Rosa-Keystone Dune, Cook, and Hurricane Bluff, are well-dated and also contain many of North America's oldest archaeological occupations. Paleotemperature estimates are based on the methylation of branched tetraether index (MBT), in which the degree of methylation in the brGDGTs reflects response to temperature change (Weijers et al., 2007; Tierney 2012). The newly-developed MBT'5me index further refines the correlation between brGDGT 5-methyl isomers and temperature (Naafs et al. 2017).

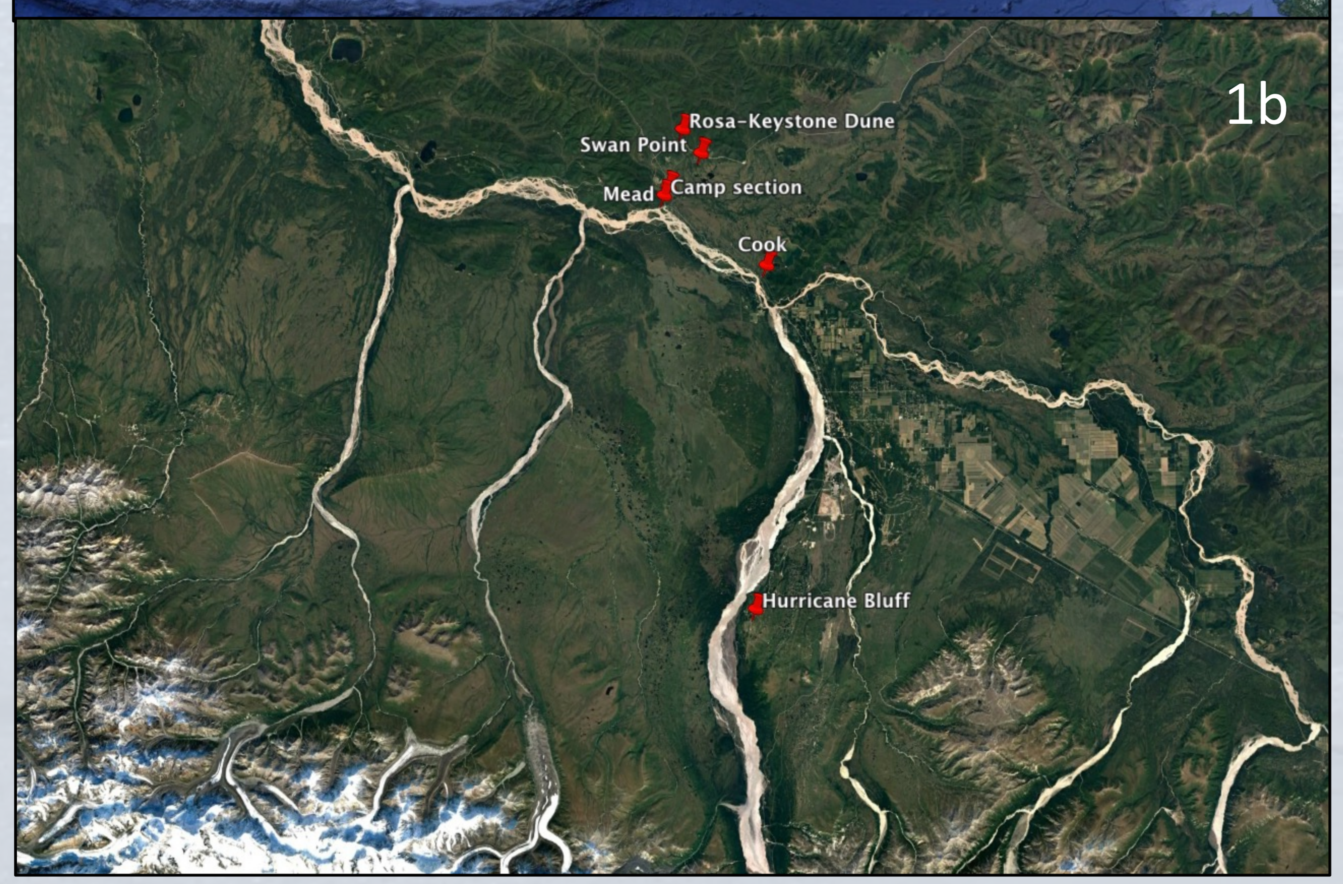


Figure 1. a) Google Earth image of the study region, b) Google Earth image of the study sites.

Methods

First, soil and sediment samples were collected from major stratigraphic units at each site (Fig. 2). Next, organic compounds were extracted from all bulk samples in the Organic Geochemistry Laboratory at the University of Arizona. Briefly, samples were freeze-dried, extracted with an accelerated solvent extractor (ASE) with dichloromethane and methanol (9:1), and purified using hybrid NH_2-silica gel columns to separate the n-alkanes (leaf waxes), GDGTs, fatty acids, and remaining compounds (Fig. 3). GDGTs were analyzed on a single quadrupole HPLC-MS system using the method of Hopmans et al., 2016 to fully separate the brGDGT isomers.

Mean annual air temperature (MAAT) was estimated from the MBT'5me index using the calibration of Naafs et al., 2017:

MAATsoil (ºC) = 40.01*MBT'5me - 15.25

(n=350, R2 = 0.60, RMSE = 5.3ºC)

Figure 2. Stratigraphy at the Broken Mammoth archaeological site (~14-13.5k cal. B.P.), showing the shift from Late Glacial sand and silt deposition (gray and yellow sediments) to stronger soil development in the Holocene (reddish upper soils).

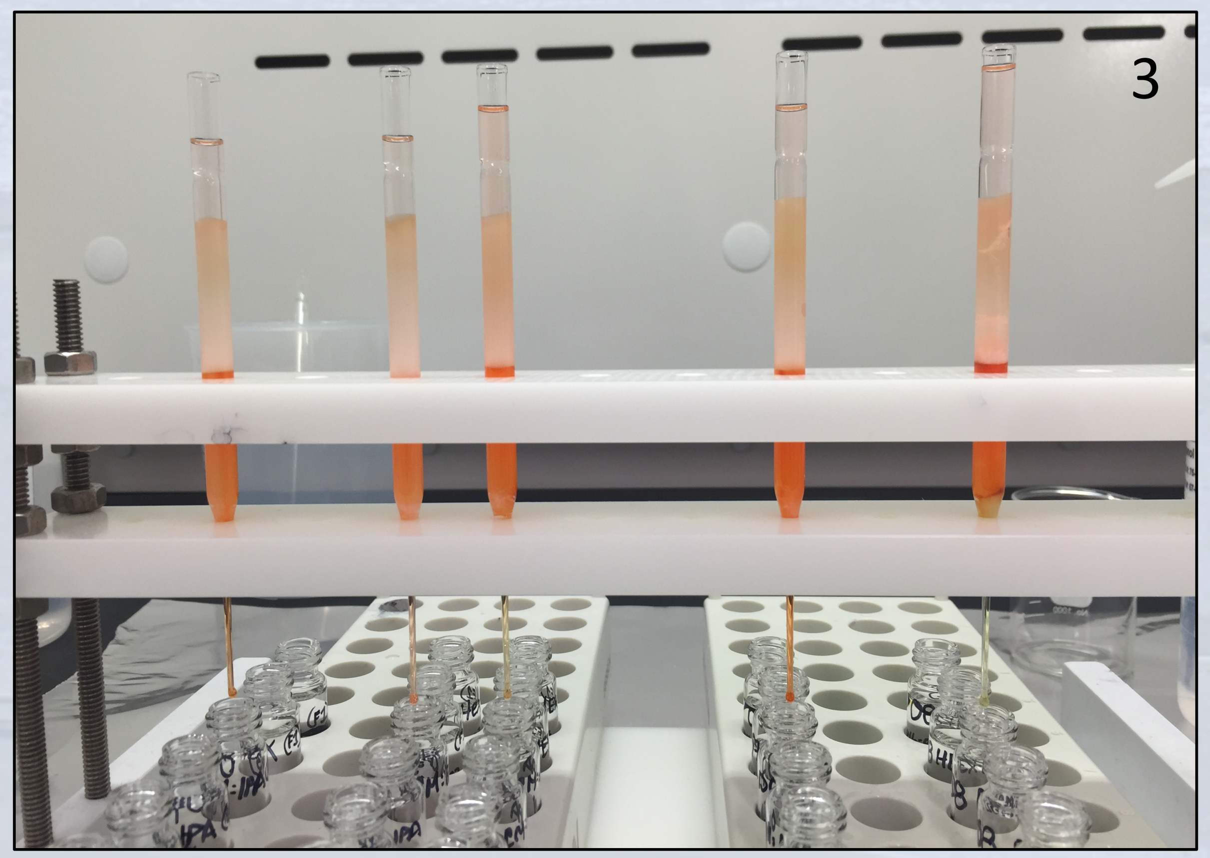
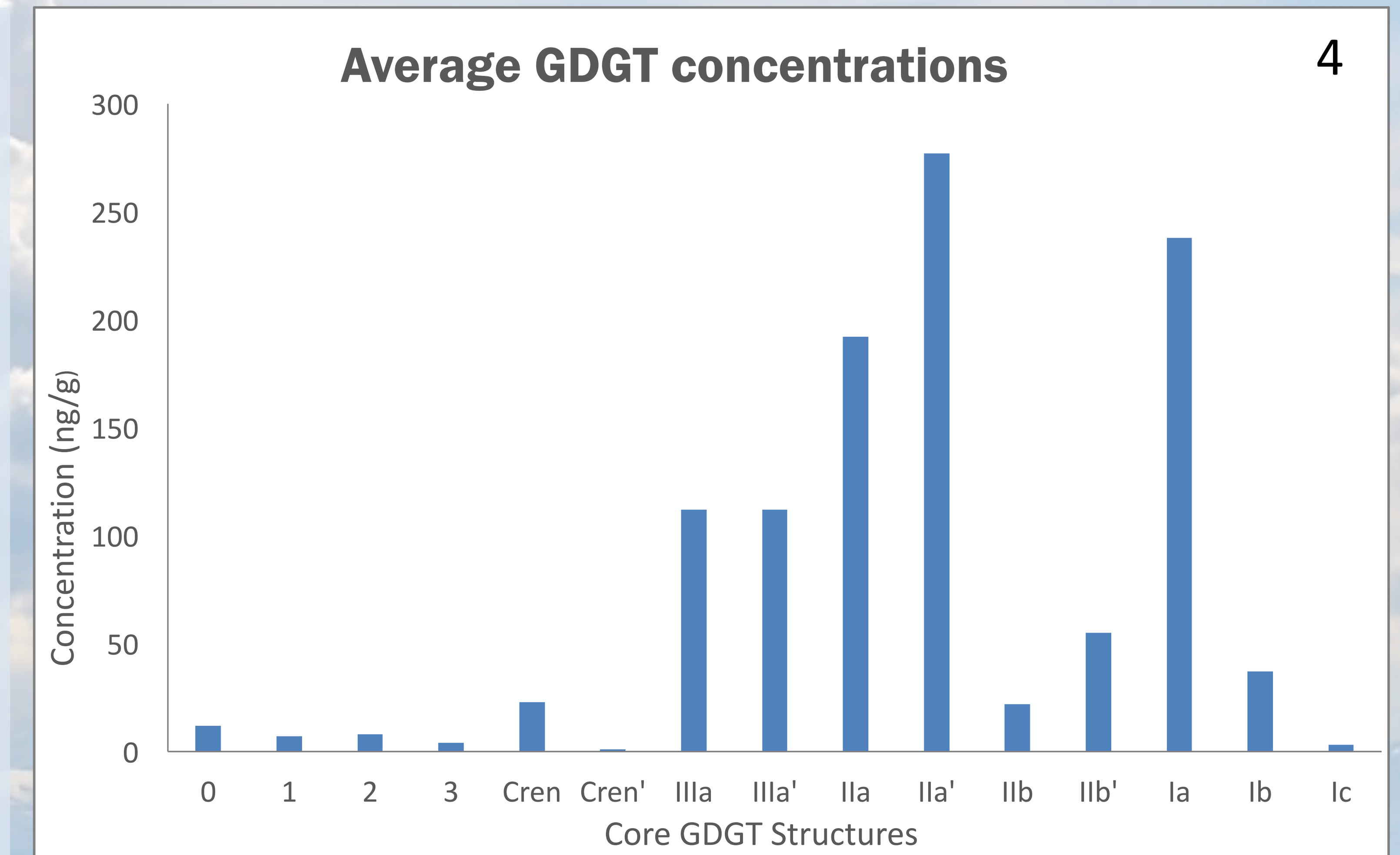


Figure 3. Central Alaskan samples as they are run through hybrid NH_2-silica gel columns and separated into various organic fractions.

Results



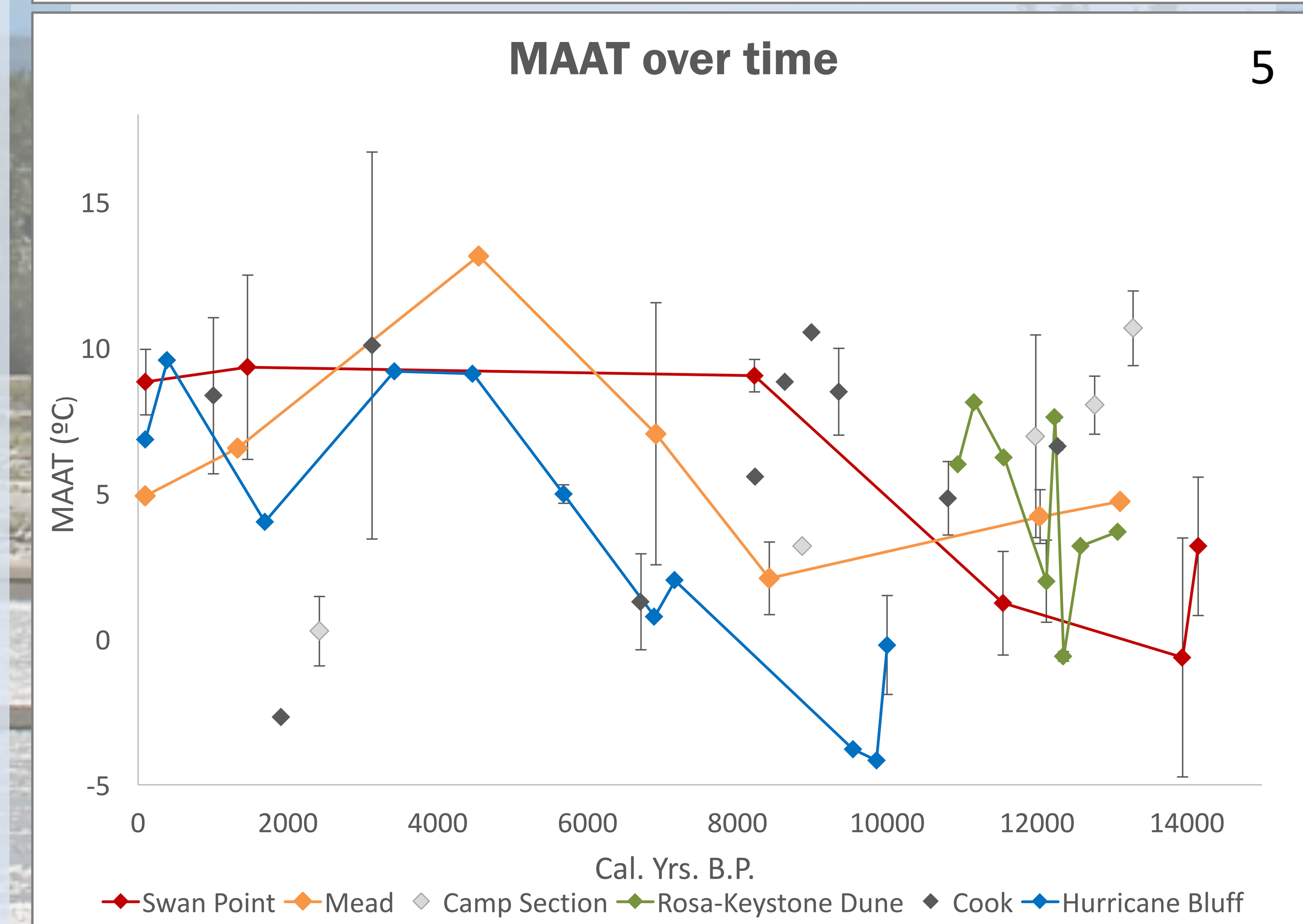


Figure 4. Plot shows the average GDGT concentrations for each core structure across all 6 study sites (average concentration for all samples).

Figure 5. Plot shows MBT'5me-derived MAAT data differentiated by site. Error bars reflect averaging of multiple samples within a single stratigraphic unit. Colored data points connected by straight lines represent sites that show increasing MAAT over time. Gray data points represent the two outlying sites that either show no trend in MAAT or decreasing MAAT over time.

Most samples had very low concentrations of isoprenoidal GDGTs (structures 0-Cren'), while brGDGTs (IIIa-Ic) showed moderate to high concentrations (Fig. 4). The Swan Point and Hurricane Bluff sites (the oldest and youngest archaeological sites, respectively) had the highest overall concentrations of GDGTs, while the Cook and Camp sites showed the lowest concentrations. The paleotemperature estimation shows an overall trend of increasing MAAT from the deglacial to modern, as expected (FIg. 5). However, trends differ by site and the Cook site and Camp section show either relatively little change in MAAT or decreasing MAAT over time.

Discussion & Conclusion

Preliminary data offer some insight into broader temporal trends in MAAT, as well as a possible signal of deglacial climatic variability at certain sites. However, contrasting signals from some of the sites (Cook and Camp) require an explanation. Higher concentrations of 6-methyl brGDGTs relative to 5-methyl brGDGTs characterize the Cook and Camp samples. This signature is typical of alkaline and/or arid soils and may interfere with the fidelity of the proxy (Naafs et al., 2017).

We also find that the brGDGT samples from modern soils yield temperatures of ~8ºC, which is warmer than modern MAAT (~2ºC). This suggests that brGDGTs may record summer rather than annual temperatures. Today, there is extensive soil biological activity and productivity during the summer, while soils and sediments below ground are frozen during the winter. It is likely that brGDGTs are dormant during the winter and do not adjust their cellular membranes to environmental parameters in this season. Therefore a summer temperature calibration may be more appropriate for this dataset.

Future Work

We plan on processing more samples from the Rosa-Keystone Dune site, to establish a full Late Glacial-to-Holocene record. Additionally, we plan on using modern soils to develop a regional summer temperature calibration, which we expect to yield a better fit with modern climatological data. Finally, we are developing leaf wax-based estimates of temperature (δD), precipitation source (δD), and vegetative moisture stress ($\delta^{13}C$) that will complement these paleotemperature estimates.

References & Acknowledgements

1) Hopmans, et al. 2016, "The effect of improved chromatography on GDGT-based palaeoproxies," Organic Geochemistry 93:1-6.

2) Naafs, B.D.A, et al., 2017, "Refining the global branched glycerol dialkyl glycerol tetraether (brGDGT) soil temperature calibration," Organic Geochemistry 106:48-56.

3) Reuther, J, 2013, "Late Glacial and Early Holocene Geoarchaeology and Terrestrial Paleoecology in the Lowlands of the Middle Tanana Valley Subarctic Alaska," PhD Dissertation, University of Arizona, 662 p.

4) Tierney, J., 2012, "GDGT Thermometry: Lipid tools for reconstructing paleotemperatures," Paleontological Society Papers 18:115-131.

5) Weijers et al., 2007, "Environmental controls on bacterial tetraether membrane lipid distribution in soils," Geochemica et Cosmochimica 71:703-713.

Many thanks to the NSF Arctic Social Sciences Program and the UA Graduate and Professional Student Council for project funding, and many thanks to Dr. Vance Holliday for assistance in the field.