New Approaches to Paleoclimate and Paleoenvironmental Reconstruction:  
Case Studies from the Ancient Maya, Sardinia, Alaska, and Iceland

2016 Summer I-Team UTRA: Phase I Proposal

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BACKGROUND:
The project PI’s were awarded a Brown University Seed Grant in 2015 to refine a new method of paleoclimate reconstruction developed by Professor Huang’s research group at Brown University’s Department of Earth, Environmental, and Planetary Sciences (DEEPS). This method involves the extraction and analysis of bacterial lipid compounds from animal bone which can serve as a proxy for paleoclimate and paleoenvironment. Seed funds have been used to collect animal bone samples from archaeological sites in Mexico, Guatemala, Sardinia, Iceland, and Alaska, as well as from modern comparative contexts. Processing of those bone samples is currently underway and methodologies are being refined as project collaborators decide upon the most effective means of extraction and analysis. These results will provide proof-of-concept data that can be used to explore questions related to ancient human-environmental dynamics in the proposed archaeological test areas. The Seed Grant funds include support for a laboratory manager and graduate student collaborators. Now that the project is successfully underway we would like to build on this interdisciplinary research framework and generate funded research opportunities for undergraduate students. The original proposed budget (that did not include undergrads) for our current Seed grant was $75k, but was cut by 20% to $60,000, making it even more difficult to accommodate any undergraduate students to the cutting edge research.

PROJECT SIGNIFICANCE:
Prior research by Professor Huang’s research group has shown that a key class of climate-sensitive bacterial lipid compounds, namely branched glycerol dialkyl glycerol tetraethers or b-GDGTs, is abundantly and well preserved in ancient bones. Ample research in the past few years has demonstrated that the molecular distribution of these bacteria-derived GDGTs in the environment faithfully records temperature, soil pH and, in relatively dry regions, precipitation. Our discovery opens up a promising new avenue to extract paleoclimatic and paleoenvironmental information directly from animal or human bone samples, eliminating a key problem in environmental archaeology of correlating such evidence directly to find contexts. Research is presently underway (supported in part by a Brown University Seed Grant) to demonstrate the efficacy of the new approach by analyzing a critical set of ancient, recent, and modern bone samples across major climatic and environmental gradients. This work includes experimentation to determine the time required for GDGT signatures to be fully registered upon bone burial at controlled temperatures.

Our study will develop major new methodologies that will have notable and broad impact on a range of fields and disciplines like archaeology, paleoclimatology, and paleontology. We stand to revolutionize archaeological understanding of ancient human responses to environmental conditions and changes by refining currently unattested environmental hypotheses and by complicating traditional exclusively cultural explanations with environmental qualifications. Direct reconstruction of climate conditions from buried bones with robust age control will allow
direct inference of climate and environmental impacts on ancient societies and key evolutionary events, while avoiding the ambiguity of using indirect geological archives as climate and environmental indicators. In cases where no suitable geological archives are present, the data from buried bones in soils can also be used for paleoclimate reconstructions (e.g. N. Alaska). Our approach may furthermore be useful in long-term diachronic and longitudinal studies of coupled natural and human systems. In the longer run, if our growth chamber incubation experiments prove to be successful, our study may provide an opportunity to define b-GDGT-producing bacteria, which so far have not been isolated. The cross-campus collaboration also serves to cement interdisciplinary campus connections and to explore opportunities for establishing a dedicated laboratory for archaeological applications of geochemical analysis.

UNDERGRADUATE INTERDISCIPLINARY RESEARCH OPPORTUNITY:
We envision a group of 3-4 undergraduates selected from a diversity of academic backgrounds to collaborate on the project. Some of these undergraduate collaborators will focus on exploring the dynamics of climate change and human history within a particular cultural context (see below) while others may work with project leaders in refining the methodologies. For some of the undergraduate collaborators, we hope this research opportunity will lead to continued collaboration and possibly result in an undergraduate honors thesis in the future. Briefly, we identify the research sites and some of the relevant questions of investigation that could be developed into an undergraduate sub-project:

**Ancient Maya, Middle Usumacinta River Basin, Guatemala:** This region was home to two Classic-period (AD 250-800) Maya kingdoms, Piedras Negras and Yaxchilan, both of which suffered political and demographic collapse in the ninth century AD. Analysis of b-GDGTs in bones will be used to test whether climate change was a factor in those severe socio-political changes. This work tests the efficacy of the new methodology in a tropical climate setting.

**S'Urachi, Sardinia** (Italy): During the first millennium BCE, western central Sardinia experienced radical changes in rural settlement and agricultural production. Although colonial encounters at least in part explain these transforms, analysis of b-GDGTs will be used to test whether climate change played a role in these settlement and agricultural changes. This work tests the efficacy of the new methodology in a Mediterranean environment.

**Gilshakki, Iceland:** Historic data and prior paleoclimate proxies provide a robust picture of Icelandic climate from AD 1300 to the present. Analysis of b-GDGTs from well-stratified deposits at Gilshakki, spanning the onset and progress of the Little Ice Age, will be used to test the efficacy of this method in a cold weather climate.

**Surshellir, Iceland:** Surtshellir cave formed in a massive fissure flow eruption at the time Iceland's first Viking Age settlers arrived. Archaeological data indicates its use as a sacrificial site for a limited span (80-100 year) immediately after the lava cooled enough to
Analysis of b-GDGTs from Surthellir will test the ability of this method to monitor changes in environmental variables at scales approaching the human life span in a highly controlled archaeological setting. **Cape Krusenstern, Alaska:** Samples from Alaska spanning AD 600-1500 can be used to test the relationship between climate change and human settlement in this Arctic region, prior to the Little Ice Age. The time depth of this data is crucial to our understanding of the scale in which these signatures stabilize (and thus the timescale of the environmental change observed). Moreover, the analysis of b-GDGTs from Alaska offers a second test of the new methodology in a cold weather climate.

**RESEARCH FRAMEWORK and MENTORSHIP:**
All research will be performed at Professor Huang’s research laboratory at Brown University over the summer of 2016. Professor Huang will provide overall project oversight during that time. The undergraduate collaborators will work alongside graduate students and laboratory managers in the laboratory, processing and analyzing the samples. Professors Scherer and van Dommelen and Mr. Smith will guide the integration of paleo-climate data with the cultural historical records of the respective research zones.

Prior experience in anthropology, archaeology, or geochemistry is not needed. However, we are especially eager to supporting students who are interested in an interdisciplinary research opportunity and are concentrating in Anthropology, Archaeology and the Ancient World, or one of the DEEPS concentrations.

**RATIONALE FOR EXPANDING THE RESEARCH TEAM**
The dynamics of coupled natural and human systems is a foremost scholarly interest, in part fueled by concerns over contemporary climate change. Our goal is to involve undergraduate students in this critical research and especially expose them to the importance of an interdisciplinary approach to such a complex issue. The addition of undergraduate project collaborators will significantly ease the burden on present personnel who currently have a significant backlog of sample to process and analyze. Quite simply, there is more than enough work to go around and many interesting sub-projects that can be developed around the case studies noted here.

**RELEVANT PUBLICATIONS**