"Land Erosion and Coastal Sedimentation in the Sub-Tropics During Rapid Planetary Warming: Environmental Magnetism of the Zumaia, Spain Paleocene-Eocene Thermal Maximum Record."

UROP Assistant Proposal

Applicant:

Faculty:

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<u>Statement of the problem/topic of the research</u>

Our world and climate are changing at rates faster than any other time in human history. This is due to undeniable anthropogenic processes and interactions with our natural world, including burning fossil fuels for energy and development. Rapid change in the warming climate has led to global temperature rise, the warming and acidification of the oceans, sea level rise, an increase in extreme weather events (including drought and extreme rainfall), and numerous other effects. Many of these changes are connected, either directly or indirectly, through feedbacks that we are only beginning to understand. Furthermore, as humans continue to alter the climate, planetary boundaries, or critical thresholds below which define a safe operating space for human civilization, are more likely to be exceeded (*e.g.*, Rockström *et al.*, Nature 1999; Mathias *et al.*, Scientific Reports 2017). For example, tipping points in the hydrologic cycle planetary boundary are likely connected to increased warming, as a warming atmosphere redistributes energy and precipitation patterns on the globe, both in space and season. The change in intensity of seasonal precipitation patterns could lead to drought stress followed by episodic intense storms. This may be particularly problematic in subtropical environments, and for coastal areas this changing hydrologic cycle can cause highly erosive and destructive storm events and increased sediment flux to productive marginal marine environments. While we have several modern examples of these feedbacks between rising temperature and seasonal precipitation (*e.g.*, throughout the Mediterranean region), our understanding of the long-term impact and critical thresholds for these events is limited: we must look to similar events in the geological past to better understand what our future may hold. In the project described below, I will study ancient subtropical coastal sediments from a period of rapid global warming to better understand how weathering and erosion, and by extension, the hydrologic cycle, responded to rapid warming.

Relevant background/literature review

In order to understand what is happening in the present, the study of past events is crucial. Conducting research on past climate events will help humans understand the potential impacts of rapid warming and increased seasonal precipitation. This knowledge could then be applied to present decisions based on how the natural environment has responded in the past. Therefore, our research must focus on specific periods of Earth history with similar magnitudes and rates of warming. Today's "thousands of gigatons of greenhouse gases" have not been added to the atmosphere at a similar rate since the early Paleogene at least 56 million years ago (Bowen *et al.*, EOS 2006), during the Paleocene-Eocene Thermal Maximum (PETM). The PETM is our best, although imperfect, natural analog to present-day climate change: during this event, massive volumes of isotopically light carbon were added to the oceans and atmosphere, similar to the present and projected amount, resulting in 5-9°C of warming of sea surface temperatures, 5-9°C of warming on the continents, and rapidly (<200,000 years) altered the carbon and hydrological cycles (Bowen *et al.*, EOS 2006; Carmichael *et al.*, Global & Planet. Change 2017). A better understanding of the climate forcings and feedback during the PETM will improve scientists' understanding of the potential effects of present climate change, information that is crucial for understanding the safe operating space for human civilization and to mitigate future impacts that climate change causes to the Earth.

Our study location in Zumaia, Spain is special because it contains a richly preserved PETM record from which we hope to gain a better record of precipitation and erosion on land, and sediment transport to near-shore marine environments during a rise in global temperatures of similar magnitude although probably slower rate than today's climate. The ancient coastal marine sediments are now exposed along the sea cliffs in Zumaia. Previous work has measured the light-stable carbon isotope stratigraphy for the Zumaia section (Schmitz *et al*. Palaeo3 1997); these data show us where we are in the PETM and enable us to correlate our record to other PETM records with precision and confidence, including those from the deep sea and continental North America. Past sedimentary research on the Zumaia and other nearby outcrops has unearthed a plethora of information on the physical and chemical weathering of rocks and provided a compelling cause for an increase in the amount and seasonality of precipitation during the PETM (Schmitz & Pujalte, Geology 2007; Carmichael *et al.*, Global & Planet. Change 2017).

During this research project, I will build on the Zumaia record by measuring its environmental magnetic record. The composition and size of magnetic minerals can provide information about the source of iron-bearing particles in sediments. For example, large, oxidized, and chemically heterogeneous minerals are most consistent with a terrestrial source delivered to the coast by erosion and sediment transport, whereas small, reduced, chemically homogeneous magnetic mineral assemblages are more consistent with an *in situ* marine source. These mineral assemblages have distinct physical properties that we can characterize to distinguish and quantify their relative abundances through a series of magnetic experiments. Ultimately, my objective is to use magnetic measurements of these sediments to test for the source (*i.e.*, provenance) of the iron-bearing particles preserved in the sediments: were they mostly produced in the marine environment or were they weathered from rocks and soils on land? These observations will then help me understand and test ideas about how the hydrologic cycle has been recorded in subtropical coastal marine sediments during a rapid warming event.

<u>Specific activities to be undertaken and timeline</u>

Component-specific magnetic measurements, such as magnetic hysteresis, isothermal remanent magnetization (IRM) curves, magnetic susceptibility, the susceptibility to anhysteretic remanent magnetization (ARM), and first-order reversal curves (FORCs) on a select subset of samples, can identify the concentration, size, composition, and sometimes even the shape of iron-bearing minerals in bulk sediment samples. I will complete these measurements on an existing collection of ~100 samples from the Zumaia section provided to _________ from -__________.These measurements will yield the data to discriminate between, for example, magnetite and hematite particles based on composition and physical size, which will provide key insight to their source. Each sample will take approximately 1 hour to prepare and measure with all techniques, with the exception of the FORCs that take up to 5 hours per sample. Following data collection, I will analyze and synthesize the data using three different software packages specific to the different measurements. Depth plots, including carbon isotope data, as well as Day plots (that distinguish magnetic grain size) will be produced from the magnetic hysteresis, susceptibility, and coercivity measurements; I will also learn how to apply endmember modeling to these magnetic data so that I can quantify how sources have (or have not) changed before, during, and after the PETM. During the interpretation and synthesis process, I will combine isotope chemistry, physical sedimentology, and environmental magnetism to characterize these records, test for trends in the data, and test our understanding of continental weathering during the PETM at the Zumaia section. These data will also form the magnetic baseline by which to directly compare my results to environmental magnetic data from other subtropical PETM records in the NW Atlantic (*e.g.*, Lippert & Zachos, Paleoceanography) and Italy (Dallanave *et al.*, G-Cubed 2010). Because the FORC measurements require so much time for collection and analysis, they will be generated during the second semester of this project. This approach allows me to use the data collected in this first phase of the project to select the most representative samples for the more time-consuming FORC, and, potentially, electron microscopy measurements.

<u>May 2018</u>

Week 1: Generate sample inventory, sub sample, and prepare samples for measurement

Week 2-4: Complete Magnetic Hysteresis and Coercivity measurements on samples 1-40

<u>June 2018</u>

Week 5-8: Complete Magnetic Hysteresis and Coercivity measurements on samples 41-100

<u>July 2018</u>

Week 9-13: Data reduction of May/June data

<u>August 2018</u>

Week 14: Complete ARM and Bulk Susceptibility measurements on samples 1-100

Week 15-16: Generate summary, support, and work plan for Fall 2018

<u>Relationship of the proposed work to the expertise of the faculty mentor</u>

___________ is an Assistant Professor of Geology & Geophysics, an affiliate of the Global Change and Sustainability Center at the University of Utah, and is the director the Utah Paleomagnetic Center (www.pmag.earth.utah.edu). He has an extensive publication record of paleoclimate research in marine and terrestrial settings, is a former member of the Earth Systems Evolution Program of the Canadian Institute for Advanced Research, and has lead or co-lead two international meetings on Paleogene climate since 2015. In 2012, he sailed on International Ocean Discovery Program Expedition 342, which was dedicated to recovering detailed sediment records of climate change over the past 60 million years of Earth history from the northwest Atlantic Ocean. __________ specialty is applying magnetic methods to study many different Earth system science processes. I first met him after a guest presentation he gave for my Oceanography class; I was interested in his work and wanted to learn more about Expedition 342, so I arranged a meeting with him. Since that initial meeting and tour of his lab, we have met once a week to discuss scientific papers he would assign me to read based on the questions I asked about Earth science, magnetism, and climate. These question-driven discussions lead to me becoming most excited about the Zumaia research opportunity, and additional readings and discussions focused on background for the project described above. This project is an important first step in a larger project ________ has with_______, which will expand on the magnetic record of sediment sources with organic biomarker techniques.

Relationship of the proposed work to the student's future goal

Over the past few years my passion for science and our climate has increased tremendously and I feel that the only way I can contribute to help curb our climate problem is by increasing the degree of knowledge in the climate change discipline. Being introduced to this project and learning more about paleoclimate has fueled my curiosity of and interest in scientific research. With this research proposal, I want to expand this curiosity and generate new ideas on climate change.

I first came to _________ in hopes of doing some sort of climate change research, but our weekly discussions on different climate publications also introduced me to the idea of graduate school. Not only do I plan on expanding the knowledge of paleoclimate in relation to our current climate, but I also want to have this research opportunity to figure out if graduate school is the right decision for me. Because so much of graduate school is independent research, I want to gain research experience now to make better post-graduate decisions next year. In summary, I find this project a strong fit for me because it is an ideal opportunity to expand my education in climate science and in the scientific research process well beyond the traditional classroom.

Works Cited

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