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Proposed Research

The sedimentary geologic record can be used as a window into past conditions of the Earth, including the climate in which sediments were laid down. During the Cenozoic, there are many examples of shifts in global climate. Potentially significant to the modern climate in which humans live are the hyperthermal events that occurred during the Eocene. Hyperthermals are relatively brief (100,000 years) warming events, some of which coincide with the release of massive amounts of carbon from terrestrial reservoirs. The best understood of these hyperthermals is the Paleocene-Eocene Thermal Maximum (PETM), which occurred 55.5 million years ago. During the PETM, 6,800 Gt of carbon were added to the shared carbon pool of the atmosphere and ocean, and global temperatures rose 5-9° C (Sluijs et al. 2006, Zachos et al. 2008). Slightly more recently (53.7 Ma), the Eocene Thermal Maximum 2 (ETM2) occurred.

The isotopoe excursion denoting ETM2 is about half the size of the PETM isotope excursion (Lourens et al. 2005), and generally much less well understood.

In summer 2011, three cores —200m cores will be drilled from the alluvial strata of the Eocene Willwood Formation in the Bighorn Basin, Wyoming. One core will capture ETM2, predicted to be —40m thick, as well as the sedimentary record both before and immediately after the hyperthermal. The PETM has been well-researched in the Bighorn Basin; an ETM2 core represents an opportunity to study this second, smaller excursion in the same area. Furthermor,

the ETM2 has not been studied in continental strata, and this core will provide a window in to the continental response to a hyperthermal event that is smaller than the PETM.

I propose using this core to reconstruct the local climate during the ETM2 and to compare and contrast that climate record to what is already known about the PETM in the Bighorn Basin. The Willwood fluvial strata consist of interbedded channel sandstones and paleosols formed on overbank mudstones. Three aspects of the paleosols will be analyzed to reconstruct the paleoclimate. First, geochemical analysis will provide quantitative analysis of mean annual precipitation (MAP) following the methods of Nordt and Driese (2010), as well as information on temperature change during the ETM2 excursion (Ekart et al., 1999). Detailed descriptions of paleosols in the core will provide a morphologic approach to interpreting paleosol moisture conditions (e. g., Kraus, unpub. data). In addition, quantitative grain size analysis of the paleosols will provide silt/clay ratios, which Newbury (2010) found to be linked to seasonality of precipitation during the PETM. Analyzing multiple paleosol proxies produces a more robust climate interpretation (e.g., Prochnow, et al., 2006)

I also propose to make thin sections in order to analyze paleosol micromorphology. Micromorphologic analysis provides a better understanding of the paleoenvironment in which a paleosol formed, particularly the seasonality of moisture, vegetation cover, and short-term cyclicity in the local climate (e.g., McCarthy et al, 1998). While there is not necessarily a set relationship between every micromorphological feature and a related paleoenvironment (Kemp 1999), coupling thin section observations with the geochemical, macromorphologic, and grain size data will add a level of fine detail to the assessment of local paleoenvironment.

Robust data sets encompassing paleoclimate exist for the PETM in the Bighorn Basin (e.g., Kraus and Riggins 2007). These data sets will allow me to compare and contrast annual rainfall, temperature, and conditions of paleosol formation during both the PETM and ETM2. This synthesis has the potential of providing important insight on local climate response to global warming events of different magnitudes.

The investigation and comparison of local climate change in response to carbon inputs of different magnitudes is particularly relevant considering current global climate conditions. Understanding what effect increased carbon can have on continental climate — and how that

effect might vary depending upon the magnitude of the carbon release — has important implications as to how local climate in continental areas may respond to a rise in global temperatures. Finally, my project will be part of a broader investigation of the impacts of hyperthermals on early Eocene plants and animals. The paleoclimatic reconstructions from my study will be integrated with the research of other geoscientists who are part of the coring project. In particular, the research group is examining the responses of plants and animals to the ETM2 hyperthermal and the speed with which they responded to this episode of global warming.

Much of the budget for this project is built into the NSF grant of my advisor, MJ Kraus. However, because the NSF reduced funding to all principal investigators, several key areas of my proposed research cannot be funded by the grant, and further funding is necessary:

Thin sections will be essential to micromorphological studies of the Willwood paleosols. As swelling clays are a component of these paleosols, the thin sections will also have to be cut and polished with oil rather than water. Having thin sections professionally made will cost \$33 per thin section; \$1000 is requested to have 30 thin sections made.

Grain size analysis of the paleosols in the core will be used to assess changes in climate seasonality. Samples will be analyzed using a Malvern Mastersizer at the INSTAAR sedimentology lab. If I prepare and run the samples there, the cost will be \$15 per sample; \$1500 is requested to analyze 100 samples from the ETM2 core.

References

- Ekart D. D., Cerling T. E., Montanez I. P., and Tabor N. J., 1999: A 400 million year carbon isotope record of pedogenic carbonate: Implications for paleoatmospheric carbon dioxide. *American Journal of Science*, vol. 299, p. 805-827.
- Kemp, R. A., 1999, *Micromorphology of loess-paleosol sequences: a record of paleoenvironmental change: CATENA* vol. 35, p. 179-196.
- Kraus, M. J. and Riggins, S., 2007, Transient drying during the Paleocene—Eocene Thermal Maximum (PETM): Analysis of paleosols in the Bighorn Basin, Wyoming: *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 245, p. 444-461.

- Lourens, L. J., Sluijs, A., Kroon, D., Zachos, J. C., Thomas, E., Rohl, U., Bowles, J., and Raffi, I., 2005, Astronomical pacing of late Palaeocene to early Eocene global warming events: *Nature*, vol. 435, p. 1083-1087.
- McCarthy, P. J., I. P. Martini, et al., 1998, Use of micromorphology for palaeoenvironmental interpretation of complex alluvial palaeosols: an example from the Mill Creek Formation (Albian), southwestern Alberta, Canada: *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 143, p. 87-110.
- Newbury, S, 2010, The Sedimentary Response to Climate Change During the Paleocene-Eocene Thermal Maximum, Southeastern Bighorn Basin, Wyoming, USA: MS Thesis, University of Colorado.
- Prochnow, S.J., Nordt, L.C., Atchley, S.C., Hudec, M.R., 2006: Multi-proxy paleosol evidence for middle and late Triassic climate trends in eastern Utah. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 232, 53-72.
- Sluijs, A., Schouten, S., Pagani, M., Woltering, M., Brinkhuis, H., Sinninghe Damste, J. S., Dickens, G. R., Huber, M., Reichert, G.-J., Stein, R., Matthiessen, J., Lourens, L. J., Pedentchouk, N., Backman, J., Moran, K., and the Expedition 302 Scientists, 2006: Subtropical Arctic Ocean temperatures during the Palaeocene/Eocene thermal maximum: *Nature*, vol. 441, p. 610-613.
- Zachos, J. C., Dickens, G. R., and Zeebe, R. E., 2008, An early Cenozoic perspective on greenhouse warming and carbon-cycle dynamics: *Nature*, vol. 451, p. 279-283.