Bighorn Basin Coring Project (BBCP) Workshop: June 24 – June 27, 2007 in Powell, WY

Workshop Summary

The Bighorn Basin Coring Project (BBCP) workshop was held at Northwest College in Powell, Wyoming from June 24-27, 2007. The BBCP aims to recover sediment cores from the Bighorn Basin to investigate the high-frequency climatic and biotic variability of a continental depositional system during the greenhouse conditions of the early Paleogene. The workshop was organized by Will Clyde (University of New Hampshire), Scott Wing (Smithsonian Institution), and Philip Gingerich (University of Michigan) and included 35 participants (Appendix 1). Participants came from all over the world, represented a broad spectrum of scientific backgrounds, and included both academic and industry representatives. The main objective of the workshop was to determine the scientific, administrative, and logistic framework for the BBCP.

Background

The early Paleogene is the most recent interval of earth history that is characterized by greenhouse climate conditions where global mean annual temperatures were up to 10°C higher than today and CO_2 concentrations may have been >1000 ppm. Superimposed on this background greenhouse climate state are a series of short-term extreme warming events ("hyperthermals") that are hypothesized to be orbitally paced and may have triggered significant biotic changes. The best known of these hyperthermal events is the PETM (Paleocene-Eocene Thermal Maximum) which is characterized by a global carbon isotope excursion and coincides with major changes to marine and continental ecosystems. At present, the cause of these hyperthermal events remains unknown although a variety of hypotheses have been proposed.

The Bighorn Basin preserves the most complete early Paleogene continental sequence in the world, and includes a ~50 meter thick PETM interval. Cores of this early Paleogene stratigraphic record will make it possible to develop high resolution (1,000-10,000 year sampling interval) proxy records of climate change, carbon cycling, and biotic change from unweathered material to investigate the response of a terrestrial depositional system to hyperthermal events such as the PETM.

Day 1

The first day of the workshop was devoted to determining the main scientific questions that can be addressed by coring the Bighorn Basin and developing a set of well-constrained hypotheses that could be tested through this research. After several initial presentations gave participants some background on the Bighorn Basin, we broke up into disciplinary groups (Paleoclimate, Paleobiology, Geology) to address a series of questions. After regrouping, we then compared and integrated the results of our break-out discussions. Based on these discussions, the main “scientific drivers” for coring the Bighorn Basin fall into three general categories each of which has several more specific questions that could be addressed by studying the proposed cores.

(1) *What are the causes and effects of hyperthermals (e.g. PETM, Elmo, others?) during the Paleogene greenhouse world?*

- Are hyperthermal events besides the PETM preserved in the Bighorn Basin stratigraphic record?
- Do hyperthermals correlate with observed biotic events and is their temporal distribution consistent with orbital pacing?
- What is the temperature sensitivity to pCO_2 changes at the PETM and other hyperthermals?
- Does the detailed shape of the carbon isotope excursion across the PETM reveal clues about the cause of this (and other) hyperthermals?
- Is the internal carbon isotopic variability within the CIE consistent between terrestrial and marine records, illustrating the global nature of the CIE?
- Are there observable lags between the CIE and other paleoenvironmental indicators (e.g. biomarkers, pollen)?
- How are floral and faunal changes related during hyperthermals? Do faunas respond to floral change or vice versa?
- How did the PETM and other hyperthermals effect the hydrological cycle (e.g. monsoonal circulation) in the Rocky Mountain region?
- What was the continental sedimentary response to the PETM and other hyperthermals (e.g. effects on pedogenesis)?

(2) *Do continental sedimentary systems, like that preserved in the Bighorn Basin, exhibit astronomically controlled cyclicity?*

- Are the facies stacking patterns in the Bighorn Basin cyclic?
- If so, are the periods of those cycles consistent with predictions for astronomical control?
- If so, do the dominant periodicities change through the sequence and is there a relationship of this to the PETM or other hyperthermals?
- Is there a periodicity preserved within the CIE itself and does it match marine records?

(3) *What is the detailed paleogeographic evolution of the Bighorn Basin during its early Paleogene phase of tectonic evolution?*

- Are there paleohydrological changes through time and space that reflect climatic and/or tectonic changes in the basin?
- Are major changes in facies stacking pattern or paleosol development coincident across the basin or time-transgressive?
- Are landscape level changes in the basin more often driven by extrabasinal (e.g. climate) or intrabasinal (e.g. subsidence) processes?

During the course of Day 1, participants also discussed several other questions related to the BBCP. For instance how do the main "scientific drivers" relate to ongoing research in other areas? Some of the specific scientific issues in related fields that could be addressed by the BBCP include:

- Determining whether “cryptochrons” are real reversals of the geomagnetic field
- Determining the paleoelevation of the Bighorn Basin during the early Paleogene

- Comparing stratigraphic records from outcrop to those attained from core records.
- Comparing the PETM to current anthropogenic effects on the carbon cycle.

In an effort to clearly articulate why cores will be helpful in a basin that is characterized by such excellent outcrop exposure, participants also probed the question "what kinds of records can be recovered from cores that can not be recovered from outcrops?" Many of the responses to this question relate to the freshness of core samples compared to outcrop samples which are often strongly affected by weathering. It was determined that cores would allow better evaluation of:

- Diagenesis and pedogenesis (without overprinting effect of modern weathering)
- Paleosol color
- Magnetic mineralogy
- The three dimensional framework of stratal architecture
- Unexposed transitional facies
- Unrecognized ashes and glassy material

Finally, participants addressed the question"What are the merits of core records compared to outcrop records?" Some of the responses included:

- Ease of data collection on cores (especially on physical properties by using downhole geophysical tools) allows for higher resolution sampling.
- More and different analytical methods are applicable to cores (e.g. continuous spectrum analysis)
- Archiving of cores provides a common stratigraphic record for different research groups and helps tie together widely dispersed surface sections.

Day 2

Day 2 focused on coring logistics and site planning, including discussion of how best to target sites that can be fully integrated into the existing outcrop framework. The day ended with an evening field trip to Polecat Bench, one of the classic PETM sites in the basin, and one of the most complete Paleocene-Eocene boundary sites in the world. Many of the presentations and much of the discussion during this day focused on the methodologies that would likely be used to address the scientific questions at hand. Participants split into methodological break-out groups (Geophysics, Geochemistry, Paleobiology, Sedimentology) in order to generate a list of methodological approaches that would likely be used during the BBCP. These include:

Geophysics

- Downhole geophysical logging (resistivity, gamma ray, sonic)
- Core scanning (color, density, magnetic susceptibility, P wave velocity, gamma ray)
- Paleomagnetism
- Seismic survey (especially for a longer core)
- XRF scanning

Geochemistry

- Single and double element isotope paleothermometry
- XRD and/or XRF of clays and iron oxides
- Clumpy isotope method ($\Delta 47$)

- GDGT paleothermometer and paleosol pH
- Major element chemistry
- Depth to calcic horizon
- δD of n-alkanes
- $\delta^{18}O$ of soil carbonates
- Total weight percent organic carbon
- Total weight percent carbonate
- $\delta^{13}C$ bulk organic and carbonate nodules
- $\delta^{13}C$ of biomarkers
- $\delta^{13}C$ of bulk goethite
- $\delta^{13}C$ of monospecific pollen assemblages

Paleobiology

- Conifer/Angiosperm Biomarkers
- Pollen analysis
- High resolution correlation to outcrop records of faunal and floral change

Sedimentology

- Sedimentological logging on core catcher samples
- Observation of ephemeral weathering characteristics
- Grain size analyses
- Petrographic characterization
- Trace fossil analysis
- Paleosol analysis

Further discussion centered on the timing of these methods. Certain methods would need to be applied on site during drilling (e.g. geophysical logging, sedimentological logging) whereas others would be best done on an off-site (but local) temporary laboratory (e.g. geochemical sampling). Other analyses could occur later, when the cores get permanently curated (e.g. XRF scanning).

Day 3

Day 3 was devoted to a field trip around the basin with stops at several of the proposed coring sites. The goal of the day was to evaluate these sites in the context of their relevance to the main scientific questions outlined on Day 1. The following links lead to the informal field trip guides for the Day 2 (Polecat Bench) and Day 3 field trips can be found at the links shown below.

Polecat Bench Field Trip Guide (Day 2)
http://earth.unh.edu/clyde/BBCP/BBCPDay2FT.pdf

BBCP Field Trip Guide (Day 3)
http://earth.unh.edu/clyde/BBCP/BBCPDay3FT.pdf

Day 4

During the last day of the workshop we discussed the administrative plan for the project and considered how post-drilling science would be organized and funded. Two morning presentations covered the organization structure of other scientific drilling programs (e.g. IODP) and potential outreach initiatives that could be associated with the BBCP. At the end of the day we broke into groups to debate the prioritization of the coring sites and ended the meeting with a consensus prioritization for coring the basin.

Administrative Structure and Scientific Organization

- Steering Committee
- Science Committee
- Outreach Committee
- Industry Relations Committee

Potential Outreach Initiatives

- "Market" Bighorn Basin as best place in world for study of Phanerozoic earth history
- Coordinate scientific activities with the renovation of the Washakie county museum in Worland
- Presentation to the Wyoming Geological Association and other relevant local groups
- Contact water well drillers and other related local industries
- Contact relevant politicians (e.g. Alan Simpson)
- Plan another coring workshop at GSA

Consensus Prioritization

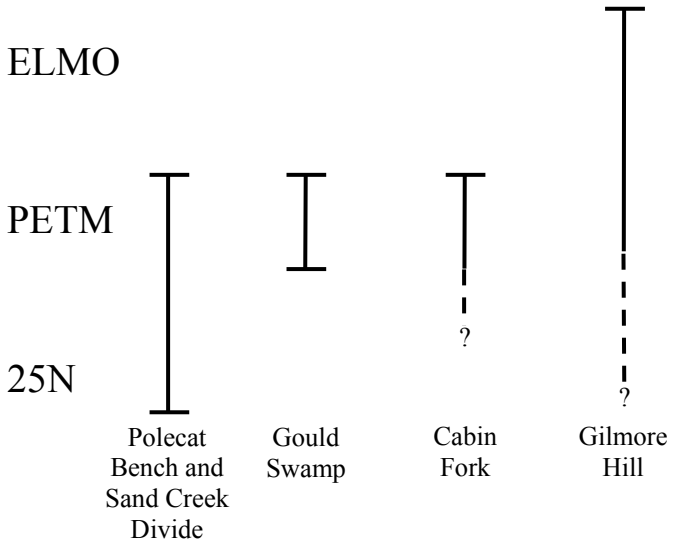
Priority 1: Polecat Bench

Priority 2: Gould Swamp if good organic material is found during pilot drilling

or

Gilmore Hill if good organic material is not found during pilot drilling at Gould Swamp

Priority 3: Cabin Fork



Post-Workshop Activities

After the workshop, Scott Wing organized a small pilot drilling project to help determine the preservation potential of several important biomarkers. During the first week of August, two holes were drilled using compressed air in an area west of Basin, Wyoming. The cuttings from these holes were collected for lithological logging and geochemical analysis. Initial bulk stable isotope results by Aaron Diefendorf indicate that the CIE is well developed here (Appendix 2). Aaron is currently performing other analyses to determine the level of biomarker preservation in these relatively organic rich sediments that span the PETM.

Appendix 1 – List of participants at the Bighorn Basic Coring Project (BBCP) Workshop

Name	Insititution
Adams, Jason	University of Colorado
Bloch, Jon	University of Florida
Bowen, Gabe	Purdue University
Chew, Amy	Stony Brook University
Clyde, Will	University of New Hampshire
Cuba, Nick	Yale University
Currano, Ellen	Pennsylvania State University
Diefendorf, Aaron	Pennsylvania State University
Foreman, Brady	University of Michigan
Freeman, Kate	Pennsylvania State University
Fricke, Henry	Colorado College
Gingerich, Philip	University of Michigan
Harrington, Guy	University of Birmingham, United Kingdom
Hicks, Jason	Denver Museum of Nature and Science
Holroyd, Pat	University of California, Berkeley
Hutchison, Howard	University of California, Berkeley
Johnson, Kirk	Denver Museum of Nature and Science
Koch, Paul	University of California, Santa Cruz
Kraus, Mary	University of Colorado
Locklair, Rob	Northwestern University
May, Steve	Exxon Mobil
Nielson, Dennis	DOSECC
Peppe, Dan	Yale University
Raynolds, Bob	Denver Museum of Nature and Science
Röhl, Ursula	Bremen University, Germany
Schouten, Stefan	Royal Netherlands Institute for Sea Research (NIOZ)
Secord, Ross	University of Michigan
Smith, Francesca	Northwestern University
Smith, Mike	University of Montana
Snell, Katie	University of California, Santa Cruz
Strait, Suzanne	Marshall University
Tsukui, Kaori	University of New Hampshire
Waszczak, Ron	ConocoPhillips
Westerhold, Thomas	University of Bremen
Wilf, Peter	Pennsylvania State University
Wing, Scott	National Museum of Natural History
Wood, Aaron	University of Michigan

Appendix 2

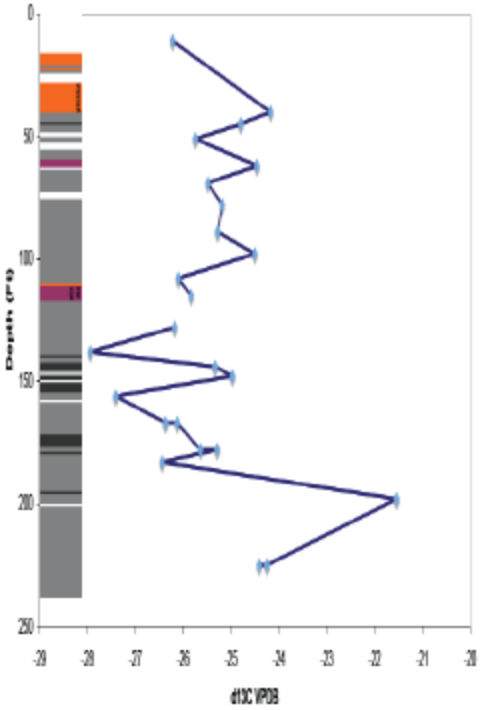


Figure showing preliminary bulk carbon isotope results from drill cuttings at "Gould Swamp" site. The low $\delta^{13}C$ values between ~200 fbs and ~50 fbs likely represent the CIE. (A. Diefendorf unpublished data)