Coring Project in Bighorn Basin: Drilling Phase Complete

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Scientists have begun a new project to recover and study sediment cores in the Bighorn Basin of Wyoming to investigate the high-frequency climatic and biotic variability of a continental depositional system during past episodes of greenhouse conditions. The project, called the Bighorn Basin Coring Project (BBCP), focuses on the early Paleogene (~50–65 million years ago), the most recent interval of Earth history characterized by greenhouse climate conditions. During the early Paleogene, global mean annual temperatures were up to 10°C higher than today, and carbon dioxide (CO_2) concentrations may have been more than 1000 parts per million [*Zachos et al.,* 2008] compared with the roughly 390 parts per million today.

Superimposed on this background greenhouse climate state were a series of short-term extreme warming events called hyperthermals. The best known early Paleogene hyperthermal event is the Paleocene-Eocene Thermal Maximum (PETM; ~56 million years ago), which is characterized by a large global carbon isotope excursion and coincides with major changes to marine and continental ecosystems [*McInerney and Wing,* 2011]. At present, the causes of these hyperthermal events remain unknown, although several hypotheses exist.

Hyperthermals may represent the best natural analogs to current, anthropogenic changes in climate because they are similarly characterized by significant global warming caused by the geologically rapid release of carbon to the atmosphere. Because the causes of hyperthermals are not yet fully known, it is also possible that current global warming could trigger a hyperthermal-like feedback not currently accounted for in global climate models. Understanding the causes and effects of hyperthermals may help inform future climate predictions and educate the public about potential impacts of those changes to other parts of the Earth system.

Project Development

The Bighorn Basin is an intermontane basin that formed during the Laramide orogeny and experienced rapid subsidence and aggradational fluvial deposition from the early Paleocene through the early Eocene (~65–50 million years ago). It preserves the most complete early Paleogene continental sequence in the world and includes an approximately 50-meter-thick PETM interval [*Gingerich,* 2001]. Cores of this early Paleogene stratigraphic record make it possible to develop high-resolution (down to a 1000-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.

But before such cores could be attained, extensive fieldwork on outcrop exposures in the basin was conducted over the past several decades that provided the detailed stratigraphic context necessary to choose drill sites for BBCP that target specific hyperthermals. Initial planning for the drilling endeavor occurred during a 2007 workshop in Powell, Wyo. A drilling plan was generated during the following year, and U.S. National Science Foundation funding was secured in 2010.

The new core records will be used to address several outstanding questions that are difficult or impossible to answer using discontinuous and weathered surface sections. For instance, what is the detailed shape of the carbon isotope excursion across the PETM and other hyperthermals? Does this shape reveal clues about the causes of hyperthermals? What is the relationship between carbon cycling and temperature change during hyperthermals? How did continental sedimentation change during hyperthermals? What was the biotic response to hyperthermals, as seen in microfossils and biomarkers? Do the fluvial sediments in the Bighorn Basin show orbital-scale cyclicity?

Core Recovery

After a final planning workshop in Denver from 25 to 27 March 2011, drilling commenced on 13 July 2011. Coring lasted about 3 weeks and went extremely well, resulting in more than 900 meters of core recovered. As planned, two overlapping cores (6.2 centimeters in diameter) were drilled at each of three sites; the depth objectives outlined in the drilling plan were successfully achieved at each site. Two of the sites (Basin Substation and Polecat Bench) target the PETM, and the third site (Gilmore Hill) targets two smaller hyperthermals known as ETM2 and H2 (Figure 1). All but one of the holes were drilled using only municipal water (no drilling mud or polymer additives), which significantly reduced the chance of organic contamination. This is an important consideration given that BBCP scientists plan to use several organic geochemical methods on samples from the cores to investigate climatic and biotic changes across the hyperthermals. Despite abundant smectitic (expandable) clay in the target rocks, the cores were effectively captured in a thin transparent Lexan™ liner. Core recovery was greater than 98% for each hole.

Most of the science crew members had not participated in a scientific drilling project before, so a significant amount of on-site training was necessary. On-site outreach efforts were centered on the "Scientists in Action" series hosted by the Denver Museum of Nature and Science (DMNS). The BBCP program, entitled *Drilling for Climate Change*, was designed to bring live, real-life scientific programing to Earth science teachers at

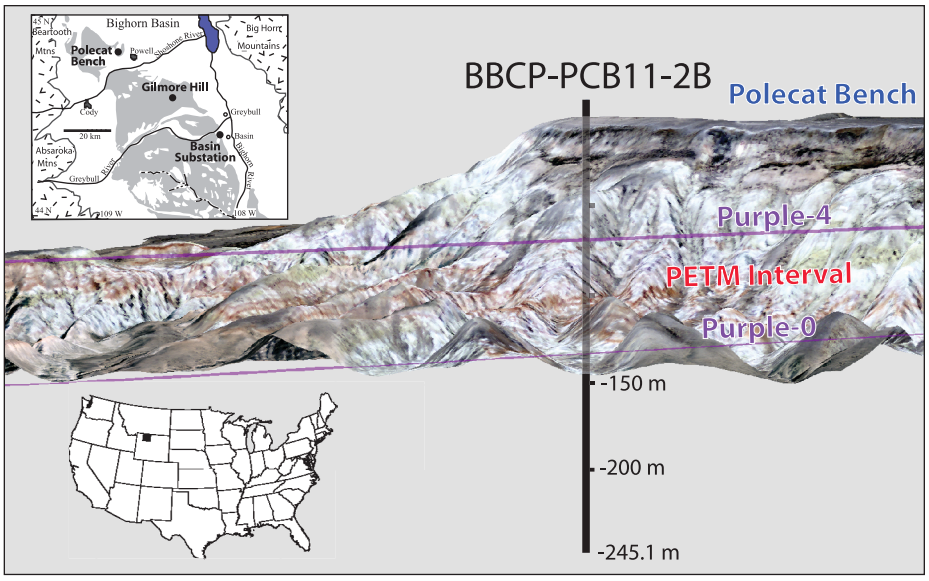

Fig. 1. Digital elevation model (DEM) of Polecat Bench near Powell, Wyo., showing a graphical representation of core BBCP-PCB11-2B extending 245.1 meters below the surface. Outcrop research shows the Paleocene-Eocene Thermal Maximum (PETM; an episode of extreme warming ~56 million years ago) to span the interval between the purple-colored paleosol mudstones labeled Purple-0 and Purple-4. The two purple beds are represented as planes fit to bed traces in the field. ArcScene image of DEM is viewed along strike of beds without vertical exaggeration. Inset at bottom shows location of Bighorn Basin in Wyoming, and the detailed map shows the location of the three drill sites within the Bighorn Basin (shaded regions represent the Willwood Formation, formed ~56–53 million years ago during the early Eocene).

remote locations. After an introductory video that provided background on climate change and drilling, the teachers were linked via live satellite video feed to the drill site, where DMNS scientist Kirk Johnson explained (and showed) the various parts of the project and fielded questions from the audience. Three different sessions were conducted, and a total of 173 teachers were reached.

Core Analysis and Data Sharing

Coring ended on 4 August 2011, and the cores were shipped to the Bremen Core Repository in Germany, where the BBCP Science Party is meeting from 9 to 27 January to split, describe, scan, sample, and archive the cores. As part of the planning process, a policy for sampling, sharing data, and archiving data was developed for BBCP (based primarily on the Integrated Ocean Drilling Program policy) that may be helpful for other continental scientific drilling projects. This and other information about the BBCP can be found at http://earth.unh.edu/clyde/BBCP.shtml.

The BBCP team includes individuals from 18 institutions in four countries, including universities (e.g., University of New Hampshire, University of Michigan, Purdue University, University of Colorado, Northwestern University, University of Bremen, Royal Netherlands Institute for Sea Research, Pennsylvania State University, University of Birmingham, University of Minnesota), museums (e.g., Smithsonian Institution, Denver Museum of Nature and Science), industrial partners (e.g., ExxonMobil), and government organizations (e.g., Bureau of Land Management).

References

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—William C. Clyde, Department of Earth Sciences, University of New Hampshire, Durham; E-mail: will.clyde@unh.edu; Philip D. Gingerich, Museum of Paleontology, University of Michigan, Ann Arbor; and Scott L. Wing, Department of Paleobiology, National Museum of Natural History, Washington, D. C.