Leg 208

Runaway Climate: Methane, Extreme Global Warming, and Massive Deep-Sea Changes

May 5, 2003 Scientists and technicians from around the world will arrive in Rio de Janeiro tomorrow after spending two months at sea on the *JOIDES Resolution* near an ancient submarine mountain chain off Africa, known as the Walvis Ridge. Here they studied the effects of a massive release of methane that caused extreme global warming 55 million years ago.

The scientists set out on Ocean Drilling Program (ODP) Leg 208 to test a hypothesis that 55 million years ago roughly 2000 Gigatons of methane was released to the ocean and atmosphere. The additional methane in the atmosphere triggered a gigantic greenhouse event that resulted in extreme global warming. This event, often referred to as the Paleocene-Eocene Thermal Maximum, is unique in Earth history in terms of magnitude and rate of warming, as well as in the manner in which it began. Geochemists speculate that methane escaped from submarine clathrates, ice-crystals that trap methane and are distributed in sediments on the outer edges of continental margins worldwide. For reasons that remain unknown, the clathrates suddenly began to decompose on a massive scale, increasing the amount of methane in the atmosphere and ocean. This decomposition process appears to have lasted for a period of 40,000 years, ultimately warming the planet by more than 5°C.

Sediments far below the seafloor hold clues to the cause of this warming. Co-Chief Scientist Jim Zachos, University of California, Santa Cruz, explained, "The rapid release of methane 55 million years ago should have left a distinct signature in the form of calcite poor or clay rich layers, the distribution and thickness of which would be controlled by the total mass of methane released."

This is because the rapid release of such a large mass of methane and subsequent oxidation to carbon dioxide would have significantly altered ocean chemistry. The added carbon dioxide would have increased the overall acidity or corrosiveness of seawater. This, in turn, increases the dissolution of calcite shells of microplankton, which are the dominant component of seafloor sediments, leaving behind only non-soluble clays. The dissolution of calcite would initiate in the deepest parts of the ocean and rapidly spread upwards as additional carbon dioxide entered the ocean. The overall extent and duration of dissolution would ultimately be controlled by the total mass of methane released.

"By establishing the vertical extent of carbonate dissolution, as well as the duration of dissolution, it should be possible to determine the total amount of carbon dioxide that was added to the ocean during the event," Zachos continued.

Retrieving the sediments proved to be a formidable challenge. To accurately reconstruct past climate, technicians needed to retrieve the sediments without deformation of layers and other structures.

"Imagine the difficulties of retrieving a layer of sediment about 1 meter (m) thick with the consistency of mud from 200-300 m below the seafloor at a water depth of 4800 m without disturbing the centimeter-scale layering," said Dick Kroon, Co-Chief Scientist from Vrije Universiteit Amsterdam.

Technicians used a device known as the Advanced Piston Corer (APC) to obtain the cores. The extreme stress placed on the system, however, quickly began to take its toll on the APC. In the very first hole, the steel core barrel literally snapped in half from the enormous stresses applied while attempting to extract it from the sediment. The lower half of the barrel could not be retrieved, and the hole had to be abandoned. On several other occasions, the steel rods that secure the core barrels came back to the surface twisted or bent.

"At this point, we were a little concerned about whether we could achieve our objectives," said Zachos.

Determined, the drilling crew made the necessary repairs, adjusted their drilling strategy, and pushed on. Their efforts ultimately paid off; the thin boundary layer was recovered at 5 sites in water depths between 2500 and 4800 m. Remarkably, at each site the layer was fully intact and in perfect condition.

Initial examination of the sediments provided immediate insight into the scale of calcite dissolution during this event. Micah Nicolo, a graduate student at Rice University, remarked, "When the cores were opened in the ship's lab, we were stunned by the change in colors of the sediment, from bright white carbonate to deep red clays."

Each core, regardless of depth, yielded a sequence of carbonate-rich sediment dissected by a distinct, dark clay layer, varying in thickness from 100 to 50 centimeters. The base of each clay layer, regardless of depth, contained essentially no calcite—indicating dissolution of calcite sediment throughout the ocean.

Ellen Thomas, Wesleyan University, studied additional impacts of the methane release: "The extent of dissolution may explain why so many bottom dwelling organisms that precipitate calcite shells became extinct at that time."

The scale of carbonate dissolution recorded in these cores is significant. It is suggestive of a much larger flux of methane, possibly double original estimates. It may also point toward an additional source of greenhouse gas. "It far exceeds what has been estimated by models assuming a release of 2000 Gigatons of methane," said Kroon.

The initial results also suggest that the deposition of carbonate shells on the deeper reaches of the seafloor did not resume for at least 50,000 years, and that the total recovery time to a "normal state" took as long as 100,000 years. This result suggests that full recovery from these extreme events takes considerable time.

The cores recovered on this leg may also provide insight into the ultimate cause of the thermal maximum. Toward the end of the Paleocene epoch, the planet was slowly warming due to rising levels of carbon dioxide emitted from volcanoes.

Zachos stated, "Several of us suspect that the melting of clathrates and rapid release of methane was initiated by gradual warming that pushed the climate system across a physical threshold."

Once started, the release of methane and resultant warming fuels the release of more methane, a positive feedback effect, a phenomena that is a concern for future warming. Studies of these and other cores recently recovered in the Atlantic and Pacific will hopefully allow the Leg 208 and other scientists to test these and other ideas on the origin of this unique climatic event.

ODP is an international partnership of scientists and research institutions organized to study the evolution and structure of the Earth. It is funded principally by the US National Science Foundation, with substantial contributions from its international partners. The Joint Oceanographic Institutions manages the program. Texas A & M University is responsible for science operations, and Lamont-Doherty Earth Observatory of Columbia University is responsible for logging services.

Photographs from Leg 208 are available on the web at http://www-odp.tamu.edu/public/life/leg208.html.

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