# Leg 158

## Hot Springs Create Mineral Deposits On The Ocean Floor

**January 23, 1994 COLLEGE STATION, TX** -- For centuries, people have extracted copper, gold and precious metals from mineral deposits on land that were believed to have formed on the ocean floor. The Ocean Drilling Program (ODP), headquartered at Texas A&M University, recently sent an international research team to the Mid-Atlantic Ridge in one of the most ambitious geological explorations of the seafloor ever undertaken to analyze the formation of mineral deposits more than two miles below the ocean's surface.

At this location, a superheated cocktail of seawater and toxic chemicals hot enough to melt lead billows out of the seafloor. This fluid, driven by heat from molten magma deep below the earth's crust, erupts into murky clouds that rise nearly 1,000 feet above the ocean bottom. Chemical reaction occurring as this fluid mixes with cold seawater causes the formation of chimney-like pipes called "black smokers." These freestanding pipes, which commonly reach heights exceeding 100 feet, are known to contain minerals similar to those mined on land.

A total of 49 scientists and technicians onboard the research drill ship *JOIDES Resolution* went to a site nearly 1,900 nautical miles east of Miami where for 50,000 years black smoker chimneys have collapsed and regrown to create a mound on the seafloor. Mounds of this sort were first discovered in the Pacific Ocean in the 1970s. Scientists thought that the sporadic volcanic activity along the slow-spreading Mid-Atlantic Ridge could not produce sufficient heat to create black smokers, but two fields were discovered in the mid-1980s, and by last summer, four more areas of black smoker activity in the Atlantic Ocean had been found.

"These chimneys or black smokers are made up of minerals containing copper, iron and zinc, which we can study while they form mineral deposits that might one day be exposed on land," says Dr. Susan Humphris with Woods Hole Oceanographic

Institution, co-chief scientist during the drilling expedition.

This site was discovered during a reconnaissance survey called the Trans-Atlantic Geotraverse (TAG). By drilling at the TAG hydrothermal mound, scientists were able, for the first time, to study the chemistry and plumbing system of the hot springs and collect samples from more than 300 feet below the surface of the seafloor.

Drilling into this mound on the ocean floor was no easy task, despite having a set of tools specifically designed to help recover these samples.

"Since the only samples that have ever been recovered from this environment were scratched from the surface of the mound, we didn't know what kind of drilling conditions to expect," says Dr. Jay Miller, staff scientist with the ODP at Texas A&M University. "Drilling these types of heavy minerals on land is tough enough, but trying to do it through more than two miles of water is really challenging."

Miller was the lead scientist under co-chiefs Humphris and Dr. Peter Herzig of Germany during the geological exploration.

"Now that we have a three-dimensional understanding of the geometry and composition of the mound, we can start to answer some of the questions about how these ore deposits form, how they change with time, and what impact they might have on the biologic community which we know flourishes anywhere hot water leaks out of the seafloor," says Miller.

Scientists collected rock samples to study the permeability, pressure and temperature structure beneath an active hydrothermal system. Other research conducted included studying the nature of the chemical reactions between water and rock, the mechanisms of mineralization below the seafloor, the architecture of the mound, and the evolution of a major black smoker system.

"The results of drilling at the TAG mound represent a significant step forward in our understanding of how some of the large base metal ore deposits on land were formed at the seafloor millions of years ago," says Herzig with the Institut fur Mineralogie und

Lagerstattehre der Rheinisch Westfallschen in Germany. "We have learned how complex these seafloor mineral deposits are and we begin to realize that the activity of those ore factories in the deep sea must have a considerable impact on the composition of both seawater and the oceanic crust."

Scientists from Australia, Canada, France, Germany, Great Britain, Japan, Spain, Sweden and the U.S. conducted their research onboard the *JOIDES Resolution* for two months collecting rock samples from beneath the surface of a mound made up of ore minerals.

The Ocean Drilling Program is funded by the U.S. National Science Foundation, Canada, Australia, the European Science Foundation Consortium, Germany, France, Japan, and the United Kingdom to investigate such topics as earth's history and evolution, climate change and the formation of the ocean crust.

Texas A&M University, science operator, operates and staffs the drill ship and retrieves cores from strategic sites around the world. Lamont-Doherty Earth Observatory of Columbia University is responsible for downhole logging.

Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), an international group of scientists, provides scientific planning and program advice. Joint Oceanographic Institutions, Inc., a nonprofit consortium of 10 major U.S. oceanographic institutions, manages the program.

Note: U.S. members of JOIDES are: University of California at San Diego, Columbia University; University of Hawaii, University of Miami; Oregon State University; University of Rhode Island, Texas A&M University, University of Texas at Austin; University of Washington, and Woods Hole Oceanographic Institution. The European Science Foundation Consortium consists of Belgium, Denmark, Finland, Iceland, Italy, Greece, The Netherlands, Norway, Spain, Sweden, Switzerland and Turkey.

## Science Background

The following information is a brief scientific description regarding the study of hydrothermal systems.

Hydrothermal circulation is one of the fundamental processes associated with crustal accretion along oceanic spreading centers. Driven by heat from magmatic intrusion and emplacement of new crust, seawater circulates through the permeable portions of the crust and upper mantle, and discharges at the seafloor as both high-temperature focused and lower temperature diffuse fluid flow. The circulating hydrothermal fluids interact with the oceanic basement in a complex series of water-rock reactions that not only influence the physical properties and composition of the crust, but also give rise to the development of seafloor mineral deposits. These reactions result in changes in the chemistry of the material recycled into the mantle by subduction, and also play a role in regulating the chemical composition of seawater. However, the extent of alteration and its impact on global geochemical mass balances is still very poorly constrained.

Hydrothermal vent systems also provide unique habitats that support chemosynthetically-based biological communities that are especially adapted to the physicochemical environment and ephemeral nature of vents. Reduced gases in the discharging fluids are converted into biochemical energy through microbially-mediated oxidation. Most noteworthy are the free-living sulfide oxidizers and the sulfide oxidizing endosymbionts associated with the vent invertebrates that obtain their energy through sulfide oxidation and their carbon through C02 fixation. These primary producers provide the basis of the trophic structure that supports the large biomass of macroinvertebrates endemic to deep-sea hydrothermal vents. Deep-sea hydrothermal vents also provide a unique environment for the study of the thermally-restricted hyperthermophilic microorganisms - that grow optimally above 80 degrees celsius.

The surficial expression of submarine hydrothermal systems has now been investigated at fast, intermediate, and slow-spreading ridges, at intraplate volcanic centers, and in island arc settings, both in backarc basins and in forearc regions. However, knowledge of the subsurface part of the hydrothermal system is indirect, and has been derived by combining studies of altered rocks recovered from oceanic spreading centers and from ophiolites, with experimental work and theoretical modeling. All of these approaches have been combined into simple conceptual models of the progression of alteration reactions that occur within the oceanic crust.

ODP Leg 158 was designed to address these issues by investigating fluid flow, alteration and mineralization and associated geochemical fluxes, microbiological processes, and the subsurface nature of an active hydrothermal system on a slow-spreading, sediment-free mid-ocean ridge. Hydrothermal systems on unsedimented ridge axes dominate global hydrothermal activity, and hence are an important contributor to global mass and energy fluxes. The site chosen for this study was the active TAG hydrothermal mound - a large, mature deposit composed of massive sulfides, making it equivalent in size to some of the deposits in the Cyprus, Oman, and other ophiolites.