MEETING GEOLOGICAL SOCIETY OF AMERICA

Life—Potential, Slow, or Long Dead

BOSTON, MASSACHUSETTS—Talk about life—not just rocks—at this month's annual meeting of the Geological Society of America was common. Lively topics included the potential for life on Mars, the pace of life below the sea floor, and how to decipher the evolution of ancient life.

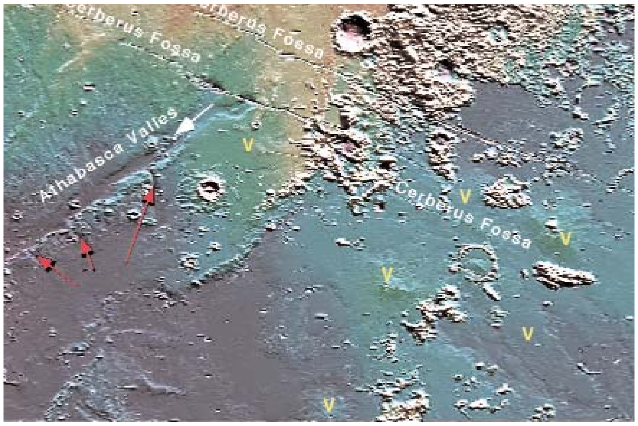
A Gusher on Mars

The Cerberus Fossae region could soon become a hot spot for planetary scientists and astrobiologists searching Mars for potentially life-sustaining water. At the meeting and in an upcoming paper, researchers describe evidence that water rushed out of the great cracks that make up 1000-kilometer-long Cerberus Fossae and surged across the landscape within the past 10 million years, carrying with it whatever may remain of any possible subsurface life, past or present. The findings make the area a prime candidate for scientific rovers scheduled to touch down in 2004.

This is not the first time Cerberus and water have been linked. In the 1980s, planetary scientists studied images of the area returned by the Viking orbiters. Some thought they saw deposits laid down by running water, whereas others thought the whole area was a dry lakebed. Still others saw nothing but fields of lava flows.

Since Mars Global Surveyor (MGS) went into orbit in 1997 and began returning sharper pictures and strikingly detailed topography, researchers have zeroed in on the true nature of Cerberus. At the meeting, planetary scientists Susan Sakimoto of the Goddard Earth Sciences and Technology Center (GEST) at NASA's Goddard Space Flight Center in Greenbelt, Maryland; Shauna Riedel of GEST; and Devon Burr of the University of Arizona (UA) in Tucson, reported how the improved imagery and topography allowed them to trace lava flows across plains and through valleys in the south, all the way back to fissures in Cerberus Fossae.

Clearly, the Cerberus region is largely lava-covered, not a lakebed. But it also shows signs of massive water flows. In an upcoming *Geophysical Research Letters* paper, Burr, Alfred McEwen of UA, and Sakimoto will report unambiguous signs that water flowed out of the southernmost fracture of Cerberus Fossae and southward across the plains. The channel system of Athabasca Valles, which stretches southwestward from the western Cerberus Fossae, reminds these researchers of the Channeled Scabland of the northwestern United States, an area scoured by huge floods when an ice dam holding back a glacial lake in present-day Montana busted near the end of the last ice age. In Athabasca Valles, flat-topped mesas 100 meters high, with teardrop-shaped tails hundreds of meters long, point downstream, paralleled by 10-meter-deep grooves. These features speak of catastrophic water flows reaching 1 million to 2 million cubic meters per second, the researchers say, or more than five times the flow of the Amazon River.



Leaky cracks. The fissures of Cerberus Fossae have alternately spewed water and lava down Athabasca Valles (shaded relief map).

CREDIT: S. SAKIMOTO/MOLA/JPL/NASA

Burr and her colleagues suggest that the fissures, lavas, and water flows of Cerberus Fossae are the surface manifestation of deep-seated magma that could have kept the Cerberus subsurface at temperatures hospitable to life for tens of millions of years. The magma rises toward the surface, they suggest, opening vertical cracks before it. On the way it encounters water, which apparently can gush out before or after lava eruptions to create the intermingled channels and flows seen in images and topography, then it sinks into porous lavas and freezes.

And all this activity has been geologically recent. William Hartmann and Daniel Berman of the Planetary Science Institute in Tucson have estimated from the number of impact craters pocking the surface that Cerberus has been active "in the last 10 million years, maybe less," says Hartmann. That means the magma and its heat are probably still down there, and Cerberus could surge again.

Planetary scientists will soon get a better look at Cerberus. Mars Odyssey could detect ice within a meter of the surface when it starts to make observations from orbit in February. And Athabasca Valles is one of four sites in the NASA competition for landings by one of the two Mars Exploration Rovers scheduled for launch in 2005. Winners won't be decided until this spring, but all the hot, watery hubbub coming out of Cerberus Fossae "makes Mars a lot more attractive from the point of view of astrobiology," says Hartmann.

Lazy Deep Life

Bacterial life is often said to be "thriving" under the most difficult of conditions: encased in rock kilometers beneath the surface, buried under millions of years' worth of ocean sediment, or floating in cloud droplets. But if Steven D'Hondt is right, life on the edge is nothing like life in the fast lane. He and fellow oceanographers Scott Rutherford and Arthur Spivack of the University of Rhode Island (URI), Narragansett Bay, reported at the meeting that, by their best estimate, sub–sea-floor bacteria—which some have claimed constitute more than half of all bacteria on the planet—live at an incredibly slow pace. "Either these things are taking very few breaths very rarely, or they're generally inactive," said D'Hondt.

Determining how frenetic deep life is presents an experimental challenge. Rather than directly measuring the rate at which bacteria break down the organic matter buried in sediments, the Rhode Island group gauged how quickly deep sediments are consuming a key chemical: sulfate. When bacteria break down organic matter to use the energy stored in its chemical bonds, they shuttle electrons through a series of compounds. The favored choice for the last in the line is dissolved oxygen, when it's available. But oxygen disappears deeper than a few centimeters below the sea floor, so bacteria make do with the sulfate ion of seawater, chemically reducing sulfate to sulfide.

To gauge how fast bacteria are consuming sulfate and therefore how fast they're "breathing," D'Hondt and his colleagues compiled measurements of how quickly the concentration of sulfate decreases down the length of sediment cores retrieved around the world by the Ocean Drilling Program. They then combined each sulfate concentration gradient with the rate at which sulfate can diffuse through sediment. That gave them the rate at which bacteria are consuming sulfate and therefore the rate at which they're producing energy.

Deep-sediment bacteria, it seems, are not all that energetic. Based on counts of bacterial cells in deep-sea cores, each cell on average is metabolizing at a rate one-100,000th that of the least active bacteria in near-shore sediments, the URI group reported. "The cells are either adapted to live at rates 10^5 times lower than anything observed," says Spivack, "or some of what's being measured as viable cells is the remnant of dead cells."

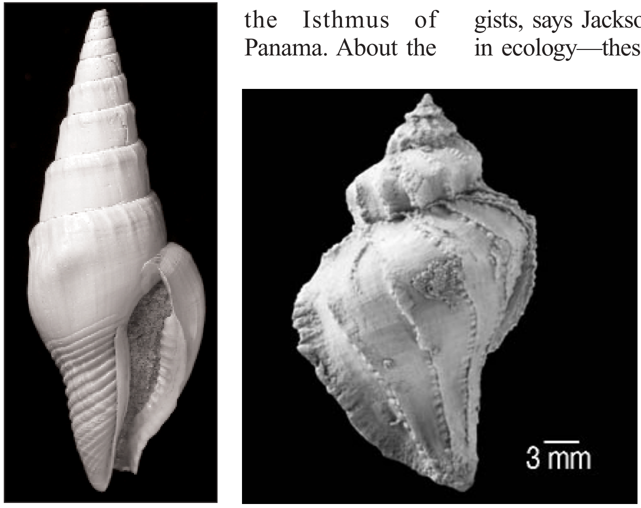
Most researchers are willing to believe the cell counts are OK and deep-sediment bacteria lead incredibly dull lives. "Very low rates seem fine to me," says geochemist and astrobiologist David Des Marais of NASA's Ames Research Center at Moffett Field, California. "These folks are perking along at a very low rate." Oceanographer John Parkes of the University of Bristol, U.K., who made the bacterial cell counts, sees ways for bacteria to get along under the stringent constraints from the sulfate analysis. For one, sulfate is probably not the only electron sink in sediments, he says. The iron of sediment minerals, for example, could steal electrons from sulfide over the millennia, which would recycle sulfide back to sulfate for reuse by bacteria and ever so slightly speed up the pace of deep life.

There may also be a way for bacteria to shut down nearly all their metabolic machinery without abandoning the vegetative life and producing spores. Although cells might on average divide only once in 100,000 years, says Parkes, it may be that a tiny fraction of them are far more active—dividing, say, once every 10 years—while the rest drop to a "maintenance" level of metabolic activity, just enough to hold body and soul together but not enough to grow. Microbiologists don't know how low bacteria could go or how they would do it, but those in deep-sea sediments seem to know how to go slow and steady enough, if not to win the race, at least to keep them in the game.

Starving in the Caribbean

A massive collection of some 200,000 fossil shells may have solved a long-standing mystery: What caused the transformation of an entire Caribbean sea-floor community a couple of million years ago? The answer: starvation. The snails and clams of the southwestern Caribbean appear to have run short of food, and that in turn led to a makeover of bottom life into the coral reef–dominated ecosystems seen today. The success bodes well for the new ecological approach to fossil collection.

Just what happened in the tropical western Atlantic Ocean and Caribbean Sea as the world slid from the relative warmth of the Pliocene epoch into the ice ages of the Pleistocene has sparked debate for almost 2 decades. Variously described as a mass extinction or a faunal turnover involving both appearances and disappearances of species, the Plio-Pleistocene faunal event seemed to be related to the gradual closure of the seaway across what is now the Isthmus of Panama. About the time the isthmus rose and blocked the westward current linking the Atlantic and Pacific, the waters of the Caribbean seem to have cooled. Judging by the species and genera of snails and clams that disappeared, especially those preserved around Florida, some paleontologists concluded that this cooling weeded out mollusks that couldn't take the cold. Others blamed the food chain: Mollusks that ate phytoplankton (or ate other animals that did) faced lean days, thought these paleontologists, when redirected currents caused a drop in the productivity of the microscopic plants floating in the overlying waters.



Losers. Caribbean predatory snails suffered declines in abundance and species diversity about 2 million years ago.

Paleontologists Jonathan Todd of The Natural History Museum in London, Jeremy Jackson of the Scripps Institution of Oceanography in La Jolla, California, and colleagues didn't think either side could prove its case on the evidence they had—often museum drawers stuffed with fossil shells. "Unfortunately, museum collections are great storehouses of rare taxa," says Todd, "but they really underrepresent common taxa." Paleontologists tend to pick up one of every species they find, he notes, blurring the distinction between rare and common species. Yet scientists can learn far more about why faunal changes occur by studying the changing proportions of rare and dominant species than by the traditional counting of new and extinct taxa, Todd says.

In 1986, Jackson and Anthony Coates of the Smithsonian Tropical Research Institute in Balboa, Panama, began the Panama Paleontology Project to "gather the sort of data that an ecologist wants," says Jackson, who began his career as an ecologist. "I'm a person obsessed with sampling," he adds. So far, that has meant going to 463 sites in Panama and Costa Rica (as well as offshore dredge sites) and collecting 202,897 specimens spanning the past 12 million years. Unlike most other collections—made largely by oil geologists, says Jackson, who were not interested in ecology—these included "everything you can get from" the face of a room-size outcrop and in several bags of dirt. Classifying fossils by how they fed and what they fed on "gives us insight to the changing regional ecology through time," says Todd.

With their new ecological insights, Todd and his colleagues think they have a much clearer picture of what happened in the Plio-Pleistocene event, at least in the southwest Caribbean. A major extinction did strike the mollusks, but it came around 2 million years ago. "That's a million years too late to be a simple, direct response to the closing of the isthmus," says Jackson. Lots of new mollusk genera appeared in the same interval, so that, unlike in a mass extinction, the extinctions had no effect on the total diversity of molluscan life.

There was a dramatic ecological change, however. The relative abundance of predatory gastropods—snails that feed on clams and other animals—plummeted and the abundance of filter-feeding clams living off the plankton declined, but the abundance of clams and snails with other life habits and diets did not change. That pattern makes Jackson think that a drop in productivity in overlying waters, rather than a cooling, drove the southwestern Caribbean toward present-day ecosystems in which productivity is centered in coral reefs and shallow seagrass meadows.

That looks right to paleontologist Warren Allmon of the Paleontological Research Institution in Ithaca, New York. But he notes that just what caused productivity to change remains unknown, and concurrent extinctions as far north as the coast of Virginia could conceivably have a different cause. A few hundred thousand more specimens may be in order.

–RICHARD A. KERR

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