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From Yellowstone to Mars

CU researchers help steer the quest for life on other planets

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Tom McCollum, a geochemist at the University of Colorado's Laboratory for Atmospheric and Space Physics, takes the temperature of a hydrothermal spring in Yellowstone National Park's Lower Geyser Basin on Aug. 6. Scientists think life on Earth and, perhaps, on Mars and elsewhere, originated in such environments.

YELLOWSTONE NATIONAL PARK, Wyo. — They are alive. The boiling, Caribbean-blue hellholes. The carpets of green, yellow, white, black and orange bathed in scalding runoff.

We are alive because untold trillions of microbes have lived. How the world's microbes — the planet's richest trove of life — survive and shape our world is the key to understanding the origins of life on Earth, scientists from the University of Colorado and elsewhere say. The $720 million Mars Reconnaissance Orbiter that launched Friday is NASA's latest bet that the same holds true elsewhere.

A series of missions to Mars has been dedicated to finding hints of past microbial life. In November 2006, from 190 miles above our neighbor planet's rusted deserts, the Mars Reconnaissance Orbiter will begin an exhaustive, two-year search.

What the spacecraft really is looking for is a former Yellowstone.

Model for early life

Grand Prismatic Spring, at Yellowstone's Midway Geyser Basin, is among the national park's most popular attractions. The same combination of water and magma that so reliably flush the contents of the nearby Old Faithful keeps the great pond's turquoise waters at a near-boil.

Bathed in the blistering trickle from Grand Prismatic's silicate lips are swaths of orange and brown that even casual visitors know to be microbial colonies.

Norman Pace, a thin man of 62, looked out over the spring's vaporous surface last weekend. He was among a minority on the boardwalk without a camera. But then, Pace was no tourist.

He once floated a bit of furnace wool in the spring. A week later, it came out pink — colonized with hydrogen-eating "extremeophile" microbes somehow at home in the 190-degree water. At such temperatures, human cells become a denatured soup.

The CU professor and renowned microbiologist has studied Yellowstone's pools for decades, using genetic mapping techniques he helped pioneer. But even Pace doesn't know exactly what's in the pools or the thick biological carpets — formed by billions of microbes per cubic inch — on display here and elsewhere in the park.

"What's going on out there?" Pace asks. "It's really wild cards."

But he and others have learned enough to believe what their genetic maps say: Places like Yellowstone's hydrothermal springs probably were the font of life on Earth, which had been seeded with interstellar amino acids, carbohydrates, vitamins and other building blocks.

The strict grammar of physical chemistry says the same probably was true of life on Mars and, for that matter, anywhere else.

"The requirements for life and the way that life does it are going to be the same everywhere in the universe," Pace says.

NASA is betting billions on it.

Tiny life, everywhere

Pace was at Yellowstone with several scientists and journalists for a workshop on life in extreme environments, sponsored by the Center for Astrobiology at the CU's Laboratory for Atmospheric and Space Physics. Astrobiology integrates space, life and geological sciences to explore the origins of and environments friendly to life on Earth and beyond.

Pace's CU research group has found masses of microbes on shower curtains, in the air surrounding therapy pools and in the rocks of Boulder's Flatirons. A gram of soil — any soil — contains about a billion microscopic creatures, he says. Microbial mats form in mud puddles, and the smell of fresh rain is the aroma of microscopic life.

Others have found live microbes in ocean sediments hundreds of yards beneath the ocean floor. Steven D'Hondt, a University of Rhode Island professor of oceanography and lead scientist on his university's NASA Astrobiology Institute team, estimates that up to 5 percent of all life on Earth may be beneath the ocean floor. D'Hondt led the 2002 ocean drilling expedition that first discovered such microbes.

Radiation and drought-resistant microbes also have turned up in Chile's Atacama desert, one of Earth's driest places. It is our planet's best imitation of modern Mars. Farther south, CU researcher Diane McKnight last week reported that, with the reintroduction of water, long stretches of microbial ecosystems in a dried-out stream of Antarctica's McMurdo Dry Valleys were revived after 20 years of desiccated dormancy. The implication, she said, is that long-dormant Martian microbes, should they exist, could be revived.

At Yellowstone, Pace can't help pointing out the greenish tinge of the water pouring off the Lower Falls. It's microbial algae, he says.

"We live in a microbial world," he says. "It's all around us."

Sorting out life

Pace is a pioneer of molecular phylogeny, which maps and categorizes life based on DNA codes, and not how an organism looks or behaves. His work has shown that organisms whose cells contain nuclei — "eukaryotes" such as people, plants and fungi — are but three tiny twigs on the genetically accurate tree of life, which is so big that "you might be hard-pressed to tell a human from a pig," Pace says.

Just one in 100,000 of these creatures will grow in a Petri dish, where scientists can examine it more thoroughly. Molecular phylogeny has identified 150,000 microbes, half which remain nameless, and the number is growing. Only 6,000 ever have been cultured.

Yellowstone's microbes can thrive in water so acidic it burns holes in shoes. The rainbow of microbial pigments is a living thermometer.

The grays, pinks, whites and yellows lining the edges of the hottest pools and in fine streamers in the nearest runoff can live above 167 degrees. The deeper oranges and blacks farther downstream are pigments that photosynthesizing cyanobacteria use to protect themselves from the same sunlight they live on. Such organisms, often in the form of thick mats, are more comfortable in water below about 140 degrees.

Pace calls these cyanobacteria "arguably the most important organism that is so underexploited." Unlike E. coli — the glucose-eating bacterial engines behind industrial pharmaceutical bioengineering — cyanobacteria simply need hot water and sunlight to produce.

What exactly makes up the microbial mats — which appear to consist of a symbiotic mishmash of organisms numbering in the billions per square inch — remains a mystery.

"Looking at the microbial world is a little bit like dropping into the Amazon Basin in 1500 A.D.," Pace says. "But we're looking down and saying 'palm trees.' We can't see the monkeys and jaguars."

This grates at him. Economically significant triumphs in environmental microbiology predate Pace's work. A Yellowstone microbe called Thermus aquaticus is the poster-child example.

It produces a high-temperature enzyme called Taq polymerase, which is key to the polymerase chain reaction that genetic researchers use to rapidly amplify small quantities of DNA. Despite this, grant money remains scarce for such environmental surveys.

"I'd love to have the money to go sequence my butt off," Pace says.

Microbes in space

If our ignorance of life on Earth remains deep, so does NASA's confidence that we're at least looking for extraterrestrial life in the right places. The agency has plopped down billions to search for life on Mars, the most recent installment being for the Mars Reconnaissance Orbiter, which now is racing toward its destination.

David Des Marais, lead scientist of the Astrobiology Institute at NASA Ames Research Center, long has done research at Yellowstone. Des Marais co-authored a 1993 paper recommending that NASA focus on finding remnants of Yellowstone-like thermal springs on Mars.

The new orbiter's combination of instruments is designed to do that. Among the six devices that will scrutinize Mars is a primary camera that can discern a manhole-sized formation from orbit. The camera was built by Ball Aerospace & Technologies Corp., based in Boulder.

"Mars has provided an exquisite record of its origins," says Des Marais. "I would be amazed if we didn't come up with some kind of chemical signature."

Key to the task will be a near-infrared instrument called CRISM, which can spot silica deposits as small as 65 feet in diameter. Previous orbiters could spot silica deposits only bigger than about 12 miles wide. They came up empty.

Silica, or silicon dioxide, makes quartz and sand. It also makes up about 70 percent of basalt and rhyolite, the dominant volcanic rocks at Yellowstone. When silica dissolves and later precipitates onto cooler surfaces, it becomes a brittle rock called sinter.

Boiling water dissolves and transports Yellowstone silica, then dumps it when it cools off in outflows and geysers. In the outflows live microbial mats. The precipitating silica fossilizes the mats into sinter, which can advertise past microbial presence for eons.

At Excelsior Geyser, a few dozen yards below Grand Prismatic Spring, fossilized bacterial mats layer yards deep.

"It's 100 percent fossils here," Des Marais says. "It's a classic site as far as showing what we want to look for on Mars."

If the Mars Reconnaissance Orbiter spots major silica deposits, the story isn't over. Fossilized microbes require up-close verification.

The next landers will be Phoenix Mars, scheduled to touch down on the Martian north pole in 2008, and the Mars Science Laboratory, a mobile, robotic science lab scheduled to arrive in 2010.

But even if these missions find fossilized microbes, the search for life just will be starting, Des Marais says.

"If we're going to play this game, we have to go beyond our solar system," he says. "I really think this life thing is going to take a while."

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