MICROBIOLOGY

Can Deep Bacteria Live on Nothing But Rocks and Water?

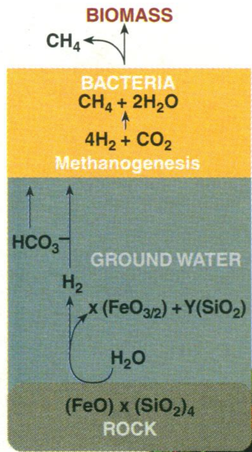
Nearly all living things owe a big debt to the sun. That's because the lowest link in the food chain consists of green plants and microbes that capture the sun's energy to produce food and oxygen. Even bacteria growing far beneath Earth's surface and at deep-sea hot springs have some tie to photosynthesis, depending either on organic matter or on oxygen. But on page 450, two researchers from the Pacific Northwest Laboratory in Richland, Washington, report that they've dipped more than a thousand meters into basalt rocks near the Columbia River and found bacteria that seem to get along fine without either. They live on rocks alone.

The microbes appear to get energy from hydrogen generated in a reaction between iron-rich minerals in basalt, a volcanic rock, and ground water. Hydrogen-eating bacteria aren't new, but all the ones found to date have depended on other microbes to make their hydrogen—or required oxygen to metabolize it. These organisms, in contrast, "don't need that first part of the food chain," says microbiologist Derek Lovley of the University of Massachusetts. "You just have the hydrogen consumers living off a geochemical reaction." If the laboratory evidence supporting the claim holds up, says Eugene Madsen, a microbiologist at Cornell University, "it [will] add another piece to the puzzle of what organisms can do and where they can do it." Some researchers think it might even shed light on the early evolution of life.

Even if the microbes turn out to get sustenance in a less unusual way, the finding still adds to a 15-year series of discoveries that have revealed bacteria in places where scientists once thought nothing could live. Microbes have been found living on organic matter in sediments hundreds of meters below the Pacific Ocean and in granite several kilometers down in Canada and Sweden. Others have turned up near boiling-hot vents in the oceans, where they metabolize sulfides from the Earth's crust with the help of oxygen, produced by photosynthesis, in seawater. Such findings led some scientists to predict the existence in deep rocks of microbial communities that subsist on geochemical energy alone.

And that's what microbiologist Todd Stevens and geochemist James McKinley seem to have found in ground water in Columbia River basalt aquifers at the Department of Energy's (DOE's) Hanford Site in eastern Washington. As researchers for DOE's Subsurface Science Program, they were surveying the area not for novel microbes, but to find out how bacteria might be affecting the composition and spread of the plumes of radioactive compounds and other pollutants in ground water beneath Hanford.

When the team drew water samples from wells up to 1500 meters deep in several aquifers, they found abundant bacteria—far more than they expected, because basalts contain little of the organic carbon that usually feeds bacterial growth. High levels of hydrogen and biologically generated methane suggested an active methanogenic community—anaerobic organisms that use hydrogen as an energy source to convert dissolved carbon dioxide to biomass, giving off methane as a byproduct.



Support for that hypothesis came when McKinley evaluated the ratio of carbon-13 to carbon-12 in carbon dioxide dissolved in the ground-water samples. Methanogens push up the ratio because as they metabolize carbon dioxide, they preferentially use up molecules containing carbon-12, which forms a more reactive bond. The ratios, McKinley found, pointed to the presence of methanogens.

The mystery was the source of the hydrogen they were living off. Most other anaerobic methanogens—common in such settings as freshwater swamps—get energy from hydrogen given off by other microbes. If that was true of these deep-living methanogens, they would still have a tenuous link to the rest of the biosphere. But the hydrogen levels seemed to be 1000 times higher than could be contributed by other kinds of microbes in the water.

A clue to its source came when a spark from a welder's torch set off an explosion of hydrogen gas in a nearby research well filled with basalt cobbles. "Those of us who had been studying the bacteria down in the basalt flows instantly made the connection," Stevens says. He and McKinley guessed that the basalt itself was giving off hydrogen when its ferrous silicates reacted with water.

To confirm their hunch, they mixed crushed basalt and deoxygenated water in the laboratory and found that the mixture did, indeed, generate hydrogen. Finally, they sealed ground water containing the bacteria together with basalt for up to a year and proved that they could get the bugs to grow in this unpromising medium.

Their results aren't entirely unexpected. "We knew it was only a matter of time before subsurface chemolithotropic [rock-eating] microbial communities analogous to the deep-sea hydrothermal vents would be discovered," Madsen says. But, he adds, "this ... goes one step further by detaching such ecosystems from biogenic oxygen." Stevens and McKinley think this ecosystem could shed light on such fundamental questions as how organisms survived on Earth before the evolution of photosynthesis 2.8 billion years ago.

Some doubts remain, however. Lovley explains that many observers "are skeptical about whether this reaction of hydrogen production will actually take place" in nature. Stripping water of its hydrogen atoms requires reducing conditions—high in electron donors rather than acceptors—"way [beyond] anything anybody else has seen" in the Earth's crust, says Arthur White, a geochemist at the U.S. Geological Survey in Menlo Park, California. And although the reaction appears to take place with freshly crushed basalt in the laboratory, it might not occur on old rock surfaces underground. If it doesn't, the bacteria might be getting their hydrogen from a volcanic vent—still a diet of rocks. Or they might be relying on some hidden biological source, in which case they would not be so remarkable after all.

T. STEVENS

Making do. Deep-living bacteria—red in the fluorescent-labeled image—survive on basalt *(green)*, perhaps by metabolizing hydrogen liberated from ground water. (Scale bar equals 5 μm.)

Stevens acknowledges that he and McKinley have "several lines of circumstantial evidence." To make a stronger case, he says, they need to find out the mechanism by which basalt donates the electrons to split water. They also want to know whether the microbes themselves promote hydrogen generation, perhaps by producing a chemical that erodes the basalt surface. These bacteria, after all, seem to be masters of self-reliance.

–Jocelyn Kaiser