# Newfound Bacteria Fueled by Radiation

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They are the microbes from hell, or at least from hell's Zip code.

A team of scientists has found bacteria living nearly two miles below ground, dining on sulfur in a world of steaming water and radioactive rock. A single cell may live a century before it gets up the energy to divide. The organisms have been there for millions of years. They will probably survive as long as the planet does, drawing energy from the stygian world around them.

The microbes, found in water spilling out of a fissure in a South African gold mine in 2003, are not entirely new, the researchers report in today's issue of Science. They are similar to ones found in other extreme environments and among the most primitive life forms ever described.

What is unusual is that their underground home contains no nutrients traceable to photosynthesis, the sunlight-harnessing process that fuels all life on Earth's surface. Such a community is an oddity on this planet — and is of interest to people looking for life on other ones.

"There is an organism that dominates that environment by feeding off an essentially inexhaustible source of energy — radiation," said Tullis C. Onstott, a geoscientist at Princeton University who led the team. "The bottom line is: Water plus rocks plus radiation is enough to sustain life for millennia."

The surfaces of other rocky bodies in the solar system are all too cold, too hot, too dry or too toxic to support the kind of life known on Earth. Their subterranean environments, however, are likely to be more hospitable and stable. More important, many may contain the short list of ingredients that seem to be all the South African microbes need.

"This is a very nice potential model of the habitability of Mars, Jupiter's Europa and other moons," said Steven D'Hondt, an astrobiologist at the University of Rhode Island, who was not involved in the project. "The sorts of ecosystems you could get there could certainly be something like this."

Onstott agreed.

Mars is known to have both subsurface water and uranium. Onstott's team's findings suggest that even without volcanoes to warm the Martian environment, organisms that may have evolved in a more temperate time may survive there.

"The existence of radiation may be enough to keep life going, and perhaps even thriving and evolving," he said. "I think this really increases the likelihood that we will find life beneath the surface of Mars."

For more than two decades, microbiologists have been able to find and retrieve permanent colonies of bacteria living hundreds or even thousands of feet below ground. In virtually all cases, however, the subterranean environments contained carbon-based molecules from decayed plants or animals. The energy in those molecules' chemical bonds was all traceable to the sun, captured by plants through photosynthesis.

The microbes from the South African mine appear to exist outside this food chain. The underground chemistry appears to go like this:

First, water molecules — $H_2O$ — are split by radioactive particles. The result is hydrogen, oxygen and hydrogen peroxide. The latter two substances then attack the mineral pyrite (also known as iron sulfide or "fool's gold"), making sulfate through a process called oxidation.

The bacteria then uses the hydrogen to turn the sulfate back to sulfide, a process known as reduction. In doing so, it captures some of the energy in the sulfate's chemical bonds, which it uses to make ATP, the molecule that is the universal coin of energy exchange in living things.

Radiation then splits more water, producing more hydrogen peroxide, which turns the sulfide back to sulfate, effectively "recharging the battery."

The deep underground water where the bacteria live is loaded with these nutrients. But the exceedingly torpid organisms are using only a fraction — perhaps as little as one-billionth — of what is available to them. They live 45 to 300 years between cell divisions; in comparison, some strains of *E. coli* bacteria can divide every 20 minutes under ideal conditions.

"For some reason it is advantageous to grow slow rather than fast in this environment," said Lisa M. Pratt, a geologist and astrobiologist at Indiana University, who is one the authors of the Science paper.

"Philosophically, that is very interesting, because on the surface it is advantageous to grow fast and use nutrients before something else does," she added.

All of the microbes are members of the phylum *Firmicutes*. One strain dominates, and there are a few others.

The dominant bacterium does not yet have a scientific name. Some of the researchers have almost finished reading its entire genome, which will allow them to figure out how closely related it is to *Firmicutes* found elsewhere. A study published last winter established that large phylum as unusually ancient — it was the first branch after the common ancestor of all bacteria, which emerged about 3.5 billion years ago, according to the fossil record.

A chief obstacle in research on deep-subsurface microbial communities is proving that what people find was not carried in by them, their equipment or the drilling apparatus.

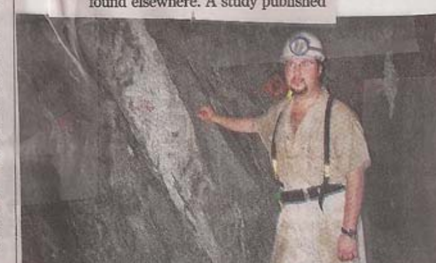
This team — which included American, Taiwanese, German and South African scientists — showed that none of the microbes they found were like ones found in surface water near the mine.

They also dated the water by measuring the amount of helium in it. Helium is produced by radioactive decay, and thus is evidence of how long the water had been underground. It appears to be a mixture of water that came from the surface as recently as 3 million years ago, mingled with water already there from 2.5 billion years ago.

"They did a nice job of constraining and characterizing the environment of that system," said James K. Fredrickson, a geomicrobiologist at Pacific Northwest National Laboratory in Richland, Wash., who was not on the team.

The research was principally done by Li-Hung Lin, a former graduate student of Onstott's who is now on the faculty of National Taiwan University.

He descended three times to the part of the tunnel where the fissure was hit to get samples. It was 1.7 miles underground, and the temperature of the rock was 125 degrees Fahrenheit.



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**Scientist Duane P. Moser stands nearly two miles below the Earth's surface, in the South African mine where the bacteria were discovered.**