EARTH SCIENCE

Deep-Living Microbes Mount A Relentless Attack on Rock

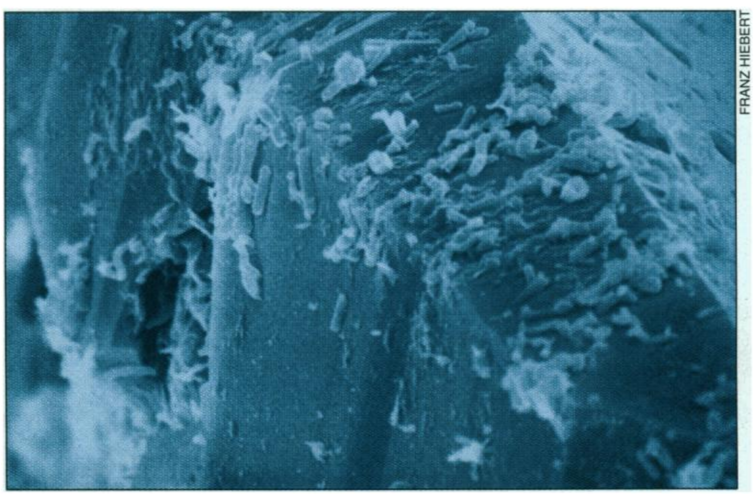
Call it the secret life of planet Earth. Generally, researchers think of what goes on deep below Earth's surface as purely geological, uninfluenced by living things. But lately, geologists and microbiologists have started to wonder whether they have been overlooking a biological factor in deep-earth processes: deep-living bacteria. These secretive organisms have turned up in sediments hundreds of meters below the Atlantic coastal plain, in ancient soils under the Department of Energy's Hanford Site in Washington, even nearly 3000 meters down in a borehole drilled in Virginia by Texaco. What are microbes doing in all these unlikely places?

A paper on page 278 of this issue of *Science* offers one answer. Some of these bacteria, say geologists Franz Hiebert and Philip Bennett of the University of Texas, Austin, may be dissolving the rock they live in, etching and pitting grains of quartz and other materials. Hiebert and Bennett base their hypothesis on experiments done in an unusual environment: a shallow bed of water-saturated sediment where bacterial growth has been, in effect, fertilized by spilled oil. But over geologic time, says Francis Chapelle of the U.S. Geological Survey (USGS) in Columbia, South Carolina, such microbial activity could have a significant impact in more conventional settings. Rock-etching bacteria, for example, could explain the networks of pores that make it possible to extract oil from the sedimentary rock in many oilfields. Beyond that, says Bennett, the finding adds to a growing recognition that "things we once saw as abiotic, slow geologic processes may involve microbes."

That bacteria and other microorganisms can erode rocks isn't an entirely new idea. Organic acids released by microbes at Earth's surface are known to dissolve the mineral "cement" in sedimentary rock, helping to turn the rock into sand and soil. In recent years, as researchers like Chapelle traced populations of acid-producing bacteria deep underground, they began to think that rock dissolution might be going on there as well. But what geologists had not been able to do, Chapelle says, "is actually look at sediments before and after" the bacteria go to work. That simply isn't feasible in natural settings, he explains, because bacteria that were dissolving quartz and other minerals would be likely to have noticeable effects only after thousands of years.

To observe the process in action, Hiebert and Bennett went to an unusual environment that offered the setting for a nicely controlled study: an aquifer in Minnesota that was contaminated with crude oil in 1979, when a pipeline burst. There, says Chapelle, "everything is accelerated because you have this huge carbon source"—food for the subsurface bacteria. With bacterial metabolism running at top speed, Hiebert and Bennett were able to do before-and-after experiments. They lowered porous plastic cylinders packed with chips of quartz and feldspar into wells penetrating the water-logged sediments 6.5 meters down, below the oil pool, and left them there for 14 months.

When they hauled up the cylinders and examined the contents, they saw a dramatic transformation. In contrast to the pristine appearance of control samples, the feldspar chips retrieved from the aquifer were deeply pitted, and even the quartz—virtually insoluble under most conditions—was lightly etched. The culprits, say Hiebert and Bennett, were easy to pick out: Clumps of bacteria had attached themselves to the mineral grains, often where the surfaces were most deeply eroded. By digesting hydrocarbons from the oil and exuding acids, the researchers propose, the bacteria had created corrosive "micro-reaction zones," dissolving the minerals' silica and metal ions.



FRANZ HIEBERT

Stonemasons. Laboratory-grown bacteria colonize a quartz crystal. Underground relatives of these microbes can break down organic molecules, releasing acids that erode minerals.

Other investigators say the finding fits nicely into a broader picture of bacteria as sculptors of the subterranean environment. Chapelle and his USGS colleagues Peter McMahon and Derek Lovley, for example, have studied a menagerie of different bacteria hundreds of meters down in South Carolina aquifers, where the microbes seem to act like lock-keepers, opening and closing flow paths for groundwater. Chapelle and his colleagues found that some bacteria dissolve iron minerals by transforming insoluble ferric iron to the soluble ferrous form, a process that could open pores and enhance flow. But when the dissolved iron encounters sulfide, produced by other kinds of bacteria, the sulfide and soluble iron precipitate out of solution, forming layers of pyrite ("fool's gold") that are impermeable to the water flow. Add in Hiebert and Bennett's work, says Chapelle, and bacteria seem to create "a complex mosaic of porosity enhancement and destruction."

Microbes might play still other roles in geology, to judge from results of a 5-year survey of underground microbial life, conducted by the Department of Energy (DOE) at DOE sites and in Texaco's deep Virginia well. "I'd say that there are bacteria almost everywhere" in the sediments explored so far, says microbiologist William Ghiorse of Cornell University, who took part in the DOE's Deep Microbiology Program. And the diversity of bacteria was as striking as their distribution—so broad that DOE researchers are even talking about the possibility that the deep-living bacteria harbor entirely new metabolic activities. That, in turn, could mean new styles of interplay between the bacteria and the rock and water that enclose them.

In an upcoming phase of the program, Frank Wobber, its DOE manager, wants to study a new question: Besides asking how subsurface bacteria affect geology, he wonders how geologic processes could have carried living things so deep into the planet. "When you find these organisms at great depths," he says, "you have to ask, 'Where did they come from?'" Microbes from the soil could easily infiltrate shallow aquifers like the one that Hiebert and Bennett studied, but in very deep sediments, like those in the Texaco well, the microbes may have been entombed when the rock was first deposited, tens or hundreds of millions of years ago. If so, the deep Earth might be a den of survivors, toughened by millennia of evolution in their harsh environment. Attacking rock might be just one of their feats.

–**Tim Appenzeller**