Microbes Two Miles Below Earth Surface in South Africa

June 27, 1999 Princeton, New Jersey A persistent question in the 20th Century has been: Is there life of any kind on Mars? Back on August 8, 1996, the media was full of headlines about signs of life on Mars in a chunk of meteorite discovered in Antarctica. When the meteorite was examined microscopically, scientists found rice-shaped "globules" in tiny cracks on the rock which resembled bacteria. The carbon in those fossilized globules dated back to about three and a half billion years ago when Mars probably had water on its surface and was warmer.

Now there are scientists going two miles down in our own earth and so far have found more than 11,000 new strains of subterranean bacteria which have never been seen or studied before. The way they get down two miles into the earth is in South Africa's East Driefontein gold mine. It's one of the deepest excavations in the world. At the bottom of the mine, radioactivity and heat from earth's core raise the temperature to 120 Degrees Fahrenheit or more - and the atmospheric pressure is double that on the surface. Princeton University geologist Tullis C. Onstott has been down twice to bring back rocks to study the microbes in a research project linked directly to NASA and the search for other life in the solar system and beyond.

The conditions two miles beneath earth seem intolerable for any life form and I asked him what he experienced on his first trip down.

Interview:

Tullis C. Onstott, Ph.D., Professor of Geology, Princeton University, Princeton, New Jersey:
"The feeling you get in terms of pressure is not that great, but the temperature is profound. Your skin prickles immediately as sweat begins to pour. And for me, for some reason or other, I seem to sweat profusely! So, quite quickly your clothes become totally saturated and stick to your skin and your gloves and boots which are all mandatory mining gear begin to fill with water.

Then if you aren't acclimatized - and on my first trip down I wasn't acclimatized at all - you can march along fairly well, but you are constantly under the oppression of heat and by the end of 45 minutes of marching and crawling eventually and then toting maybe several tens of pounds of rocks with you on the way back - it becomes pretty exhausting. You're completely wiped out. You can barely think. On the trip back my first time down, we stopped to collect water from a bore hole where the water was coming out at 55 Degrees Centigrade which is quite hot.

It was in a very closed environment, a room, a chamber which reeked of ammonia which was residue from drilling explosives and if it hadn't been for the helpers they supplied me I literally wouldn't have been able to carry out the water analyses that we did do. Fortunately we did, because that water contained a most interesting organism. Microbiologists working with me - Jim Frederickson and Tom Keith - were able to extract a remarkably thermal-tolerant radiation-

tolerant bacterium that could live on a variety of inorganic substrates.

Photo Credit © 1999 by Duane Moser, Princeton University.
Coring 3.2 kilometers below South Africa surface horizontally into East Driefontein Gold Mine to study microbiology of carbon leader.

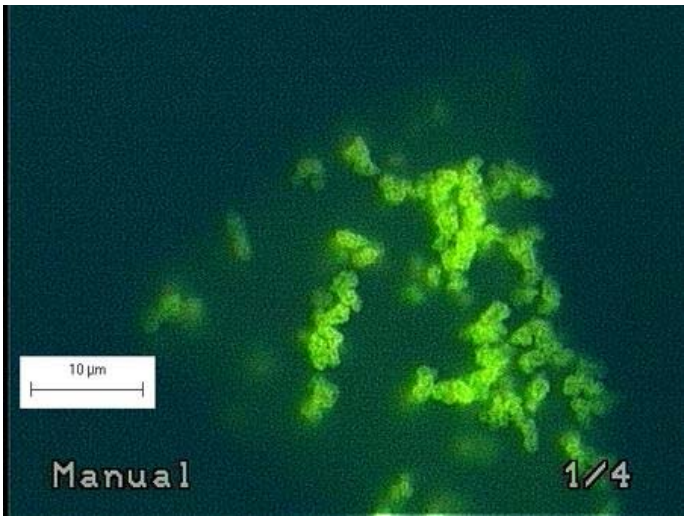

Photo Credit © 1999 by Duane Moser, Princeton University.
2000x of organism that was cultured from hot fissure water (60 Deg. C.) at 3.2 kilometers depth in Kloof Mine.

MEANING THAT IT COULD BE IN TEMPERATURES UP TO 200 DEGREES F. AND BE HANDLING RADIOACTIVITY AND METALLIC TOXINS?

That's exactly right. It was really optimally growing at about 70 Deg. Cent. - this particular micro-organism which was a thermos organism and is normally associated with oxygenated environments. But this one was found in an environment in which it could live off of iron metal, sulfate and nitrogen compound and even cobalt and uranium. It could utilize as sources of energy.

IF IT'S THERE TWO MILES UNDER THE SURFACE OF THE EARTH IN ALL OF WHAT WE WOULD CONSIDER TO BE INTOLERABLE CONDITIONS, THERE IS A POSSIBILITY - MAYBE EVEN A LIKELIHOOD - THAT THE SAME KINDS OF ORGANISMS COULD BE IN OLYMPUS MONS UNDERGROUND ON MARS?

This is probably one of the most intriguing analogies that can be drawn with the work that has been done by many microbiologists at the Dept. of Energy laboratories and other places for the last almost ten years now. It is certainly a strong motivator. It keeps us focused on trying to understand how these organisms can survive in this energy-poor environment. There's not a lot of energy available down there and how they can survive and for how long? How

long can they sustain their existence down there? We don't fully understand all the factors that enter the equation that allows them to be so resilient in these environments?

HOW DO SUCH BACTERIA END UP TWO MILES DOWN TO BEGIN WITH?

(Laughs) Well, that is probably - that was the focus of our second expedition down to South Africa. It has also been the focus of the work of what used to be known as the Sub Surface Science Program at the Dept. of Energy run by Frank Lauber. They developed a series of geological tests designed to understand whether or not these organisms were injected into these environments because of man's activities - drilling, sampling for oil, water, those kinds of things - or whether in fact, they were there as a result of geological processes - ground water flow, flow through fracture zones - or entrapment when those sediments first formed hundreds of millions of years ago. And Tommy Phelps at Oak Ridge National Lab; D. C. White at the Univ. of Tennessee, and others, developed techniques which allowed us to determine whether in fact the bacteria were the result of mining contamination, or drilling contamination, or were in fact indigenous to the rocks themselves.

WHAT'S THE CONCLUSION SO FAR?

In many of the cases where we have been working, you can look at different rock samples - you can ascertain what part of the rock represents potentially contaminated from surface micro-organisms, potentially contaminated material - and those which the overwhelming majority of the evidence is not contaminated. And in those uncontaminated rock samples, you do find a variety of micro-organisms. And in many cases, those micro-organisms are previously unidentified species of bacteria. They exhibit metabolic properties which are compatible with the sub surface environment in which they are found.

THE DISCOVERY ARTICLE SAYS, "MORE THAN 11,000 NEW STRAINS OF THESE SUBTERRANEAN BACTERIA HAVE BEEN CULTURED, BUT ONLY A FEW HAVE BEEN STUDIED AND NAMED." THAT'S AN EXTRAORDINARILY LARGE NUMBER THAT SUGGESTS THAT SOME HOW BACTERIA GO HAND AND HAND WITH ROCK ALMOST?

That's absolutely right, down to a certain depth. So, those 11,000 strains, as you say, many of them have not been studied in detail. They are archived. We actually have culture collections - one at Florida State run by David Bockwell and another at Portland run by David Boone - and they literally have these things stored away on liquid nitrogen. They have students working away trying to understand all the things these organisms can do and how they are genetically related to the more common surface organisms that we find around us where we live.

WOULD IT BE FAIR TO SAY THAT THE DISCOVERY OF THESE DEEP MICROBES HAS MADE SCIENTISTS IN GENERAL LESS SKEPTICAL OF FINDING WHAT WE'LL CALL EXTRATERRESTRIAL LIFE OR ORGANISMS ON OTHER PLANETS IN OUR SOLAR SYSTEM?

Major paradigm shift there - major, major paradigm shift. And I should emphasize at this point that Tommy Gold has probably been the biggest proponent of this very early on. It's clear that to all of us that once you become convinced - or once you begin to realize just how tenacious bacteria can be - in fact, they don't have necessarily a finite life span to them like you and I - they can live for eons essentially - as long as they have enough energy. Then you realize that in a planet like Mars where all the evidence points to an environment very similar to earth's 4 billion years ago - that life near or on the surface of Mars implicitly means that life existed beneath the surface of Mars. And even though Mars has chilled down and lost a large proportion of its atmosphere and developed a kilometer big zone of ice beneath its surface - there's almost the probability that life exists beneath the surface of Mars is extremely high. Once we recognize that life exists beneath the surface - miles beneath the surface at our planet today - it's almost unquestionable that it must

exist beneath the surface of Mars - now.

AND COULD ANY OF THEM END UP BEING AN X-FILES ORGANISM THAT COULD SUDDENLY UNLEASH SOMETHING TERRIBLE ON THE EARTH?
Absolutely not. Absolutely not! In fact, these rocks - these bacteria are used to living in rocks! Gaining their energy from minerals and inorganic nutrients and things. They are not used to competing with all the viruses and bacteria that exist in ourselves.

AND THE INFORMATION FROM YOUR RESEARCH WILL GO TO NASA AND PEOPLE WHO ARE ACTUALLY INVOLVED WITH SPACE EXPLORATION?
We are collaborating with scientists at JPL and at Johnson Space Center and at Ames. We literally want these scientists who are trying to search for life in meteorites and at Mars to come down to South Africa - to develop the tools that they want in the lab for searching for life on Mars - take them to out site in So. Africa and try them out. At South Africa deep underground, chances are that environment is the closest analogy to the conditions that we'll find in the sub-surface of Mars. The tools that you need to get 3 kilometers down in Mars should be tested out in the environment of So. Africa. There are actually active programs of research right now both at NASA and at Los Alamos National Labs - trying to develop robotic tools that can drill down 3 kilometers down on Mars, collect samples, ascertain whether those samples contain some components which indicate living processes are ongoing on Mars.

OR FINDING ORGANISMS EXACTLY LIKE YOU'RE FINDING IN SOUTH AFRICA.
That's exactly right. To find whether or not and whether or not a bacterium exists in the deep sub-surface of Mars - and that bacteria is very similar to Earth organisms - and is not a contaminant carried to there by our spacecraft - would mean literally that the finger of God has touched two planets instead of just one. And it has incredible implications for the very origin of life - whether or not life originated on the surface and whether or not life originated on Mars first and was transported to earth later on via meteorites. Just to find some sort of life that is similar to earth organisms has remarkable implications, not only for the original life, but the spread of life out through the solar system.

More Information:

One of the strangest organisms Professor Onstott and his colleagues have found so far is a bacteria that secretes large quantities of magnetite. The strange bacteria take iron from the water in the deep rock and combine it with an electron acceptor that produces large quantities of fine grain magnetite which is a highly magnetic by-product. And the microbes do this at extremely high temperatures. So far, no one understands exactly how this bacteria precipitates the magnetite, but the organism is being studied at Oak Ridge National Lab in Tennessee.

Credits