Intriguing Discoveries from Mine Fissure Water Organisms

Unique organisms found in deep underground water pockets in South Africa's gold mines are redefining life as we know it. They may even help give earthlings an insight into whether life exists or at least existed on other planets. Marleen Smith reports.

How does life begin and evolve? Is there life else where in the universe? What is the future of life on earth and beyond?

These questions have for many decades, even centuries, been fundamental to man's natural curiosity over his immediate and not so immediate surroundings.

They are also the three great unknowns being pursued officially by the Astrobiology Institute of America's National Space Agency (NASA). Research now being done on underground water caught in deep anaerobic pockets in South Africa's gold mines - scientifically called fissure water - may provide more than one answer. In fact, intriguing discoveries have already been made - already redefining our conventional understanding of life.

Because these mines are the deepest excavations in the world, they provide easy access to rock formations and groundwater far below the earth's surface.

Although the research started a mere seven years ago, some of the

Dr Esta van Heerden, with a NASA sticker on her helmet, and Prof Derek Litthauer working in Kloof gold mine at Fochville in the North West to extract living organisms from fissure water.

Another organism, as yet an unnamed new species, was isolated aerobically at 60°C. (For each kilometre one descends beneath the earth's surface, the temperature increases with between 10 to 15°C).

Three new organisms, unknown to man until now, have been found in the fissure water pockets. A further 20 to 30 are also presumably new, although tests are still being conducted to verify this.

Esta forms part of a group of researchers whose work on the mine fissure water is being funded by NASA, the US's National Science Foundation and South Africa's National Research Foundation. The funding is channeled through a program called Life in Extreme Environments (LexEN).

HOW IT ALL STARTED

The project started in 1996 when American geological researchers discovered a living micro-organism at a depth of 3,2 km in a borehole in a South African gold mine. It was alive despite having been trapped there for millions of years.

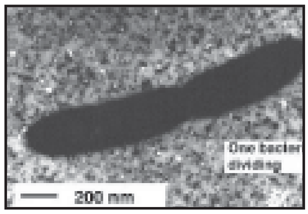
Further investigations led to the discovery of more "extremophile" organisms (living in extreme environments), which prompted establishment of a new research project. It has since been led by the US' Princeton University. The group, predominantly American, recently received membership of NASA's Astrobiology Institute (NAI). American interest in the project revolves in large part around its potential contribution to space research, particularly relating to the question whether there is, or has been, life on Mars.

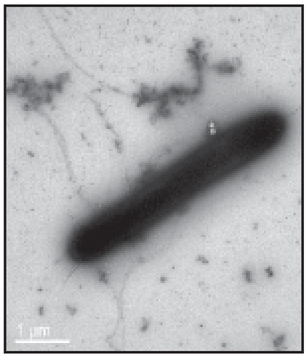
"The ecosystems we are investigating represent the closest analogy to

A team of Free State University researchers collecting fissure water samples in the Kloof gold mine at Fochville in North West. From left are Prof Derek Litthauer, student Mieder Foster, Dr Esta van Heerden and student TJ Malindi. The humidity at the borehole where they are working is 100% plus and the water temperature between 55 and 60°C.

discoveries have already stretched the known habitat limits for life, says Free State University biochemist Dr Esta van Heerden.

Living organisms have been found as deep as 3,2 km. *Alkaliphilus transvaalensis*, a new genus and species, was isolated from a water containment dam with a pH of 11,3. It is one of the most alkali-loving organisms ever described.





Top right
An electron-microscopic enhancement of the anaerobic microbe Thermus multireducens, *a fissure water organism that can reduce a range of metals and survives at very high temperatures.*

Middle right
An electron-microscopic image of Alkaliphilus transvaalensis, *a new genus and species, that was discovered in fissure water. It is one of the most alkali-loving organisms ever described.*

Bottom right
Geobacillus thermoleovorans *survive in fissure water as hot as 60 to 65°C.*

Three students at the Free State University applying an advanced DNA technique to determine the nature of organisms found in mine fissure water. From the left are Michelle Pienaar, Dr Carlien Pohl and Jay Lee.

Dr Esta van Heerden (left) and Free State University student Jacqueline van Marwijk test the reduction of metals by organisms found in fissure water.

what might exist beneath the surface of Mars," Esta says.

Their research became particularly relevant after water was discovered on Mars three years ago.

Water is known to currently exist on the Red Planet as ice in the northern ice cap and as vapor in faint clouds. Planetary geologists believe, however, that vast quantities could remain trapped under the surface.

According to a CNN report many theorise that such groundwater remains in a frozen state. However, some images suggest that recent underground volcanic forces have heated this water into a liquid state or that seepage of liquid water into some of the many canyons on Mars may have occurred.

GUIDELINES

Which is where Esta's group comes into the picture. Their research can provide invaluable guidelines for the future design of instruments to detect life in these presumed waters on Mars missions.

The next mission will take place in January 2004, during which three craft will be deployed on Mars. Two of them will be large versions of the small space rover which earlier sent back amazing pictures of the planet. Together with the third, a craft of the European Space Agency, they will investigate its atmosphere and composition of its rocks. More importantly, they will be able to drill into Mars' surface to sample the soil for signs of life.

Soil samples will be heated up to temperatures of 800°C and the emitted gases analysed to ascertain if life exists or existed. The ultimate proof will be if they succeed in isolating the organic compounds associated with life: DNA and proteins.

"The study of deep underground ecosystems in ancient groundwater is directly relevant to the search for extant life in the subsurface of Mars," Esta explains further.

"Our investigations determine the type of pre-biotic (pre-life) compounds that can be formed in an isolated geological terrain where a thermal event has eradicated microbial life. We also try to establish whether life itself could have been spawned there.

"If life can exist in geological formations up to three kilometres below the earth's surface, it makes discovery of life on planets such as Mars or the moons of Jupiter so much more plausible."

OLDEST 'FOSSIL IMPRINTS' OF LIFE ON EARTH

As far as the origin of earthly life goes, fissure water has the potential to provide some of the most reliable clues yet: "The water pockets are like fossil imprints — literally as ancient as earth itself," Esta says.

"They have been among a few closed, undisturbed environments since the formation of the world."

The microbial communities they are discovering now, have been sequestered from earth's surface and its atmosphere for tens to hundreds of millions of years. They have likewise been isolated from the environments that support their activities, and have thus turned into a dormant state.

Esta and her fellow researchers are spending much time to find the necessary means to reactivate and cultivate each found organism. New DNA techniques have simplified this work significantly by enabling them to isolate microbial DNA directly from soil or water samples taken at these great depths.

MORE BENEFITS TO SOCIETY

By finding and cloning the functional genes of the fissure water organisms, natural products can be produced to benefit society. It is believed that the unique organisms and enzymes found in fissure water may hold many advantages to especially the mining industry.

More particularly, it may advance bioleaching or bioremediation technologies and the environmental rehabilitation of areas contaminated by heavy metals. Such biological rehabilitation methods are much more cost-effective than the alternative chemical and mechanical techniques, both in terms of money and environmental and human exposure.

For instance, one of the anaerobic microbes discovered in fissure water at a heat of 60°C – *Thermus multireducens* – can reduce a range of metals. These include hazardous cadmium and radio-active uranium. It also converts chrome (VI), which is particularly hazardous to humans, into the less dangerous chrome (III). This organism should therefore be a handy tool in the remediation of mine wastes.

Other fissure water micro-organisms may be used to reduce the levels of hazardous gases in mines. A number have been found to be autotrophic, meaning they make organic carbon from carbon dioxide while consuming sulphide, methane and hydrogen.

It has been proven that methanotropic micro-organisms (living off methane), as found in fissure water, can cost-effectively degrade trichloroethylene in groundwater. This pollutant is associated with almost all industrial processes.

Fissure water organisms may also have a host of applications on a level different from mining. The simplest example, Esta says, are the enzymes used in washing powders to remove protein and fatty stains. They can also serve as biological catalysts to manufacture specialist compounds, such as medicines, that are normally very difficult to manufacture through conventional chemistry.

As the fissure water organisms are used to function at high temperatures, their applications can be used effectively in heated environments, such as warm water.

HIGH DIVIDENDS FOR FREE STATE UNIVERSITY

The project is yielding high institutional dividends for the Free State University, Esta says.

Apart from international exposure and publicity, they also gain in large additional amounts of research funds and expensive equipment. American and Free State students are participating in an exchange scheme as a further consequence of the project.

Although these extras are all important to Esta, she finds the primary significance of their project on a more fundamental level:

"Someone had the vision to check whether there is, or at least was, life so deep under the earth's surface," she says.

Enquiries:
Esta van Heerden, tel (051) 401 2472
Derek Litthauer, tel (051) 401 2122