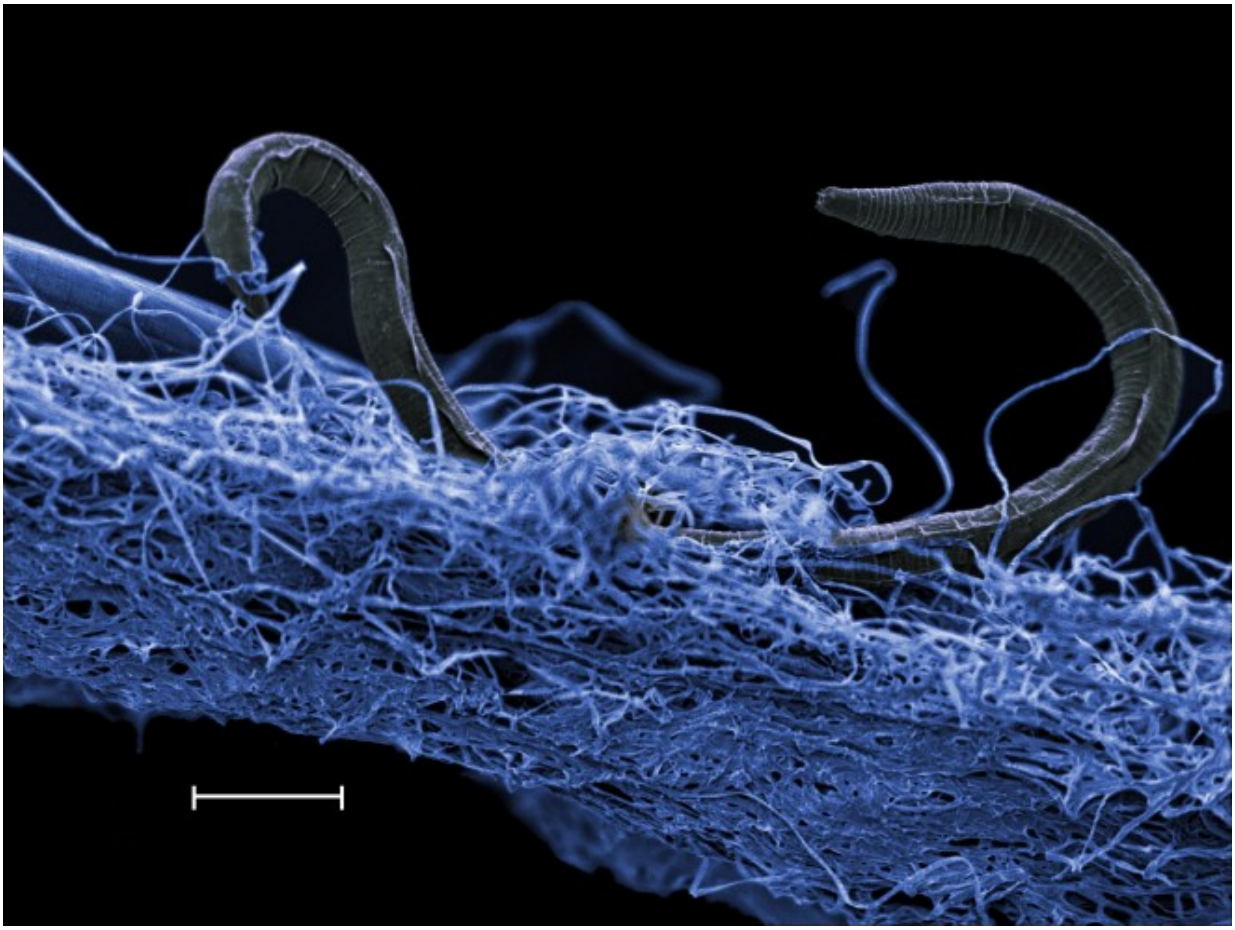
Many worlds, subterranean edition

December 1 2015, by Marc Kaufman



Scanning electron microscope blue-tinted image of a nematode on biofilm, collected from Kopanang mine almost one mile below surface. Credit: Borgonie, ELi

One of the richest lines of research for those thinking about life beyond

Earth has been the world of microscopic creatures that live in especially extreme and hostile environments here. The realm of extremophiles has exploded in roughly the period that exoplanet discoveries have exploded, and both serve to significantly change our view of what's possible in nature writ large.

I was reminded of this with the publication today of a paper on extreme life in the deep mines of South Africa. This is not a brand new story, but rather significant step forward in a story that has implications galore for the search for life beyond Earth.

The extremophile chronology in South Africa goes like this:

First there was the microbe D. Audaxviator, "the Bold Traveler," found living in lightless solitude more than two miles down a South African gold mine. Nothing alive had ever been found in rock fractures at that depth before.

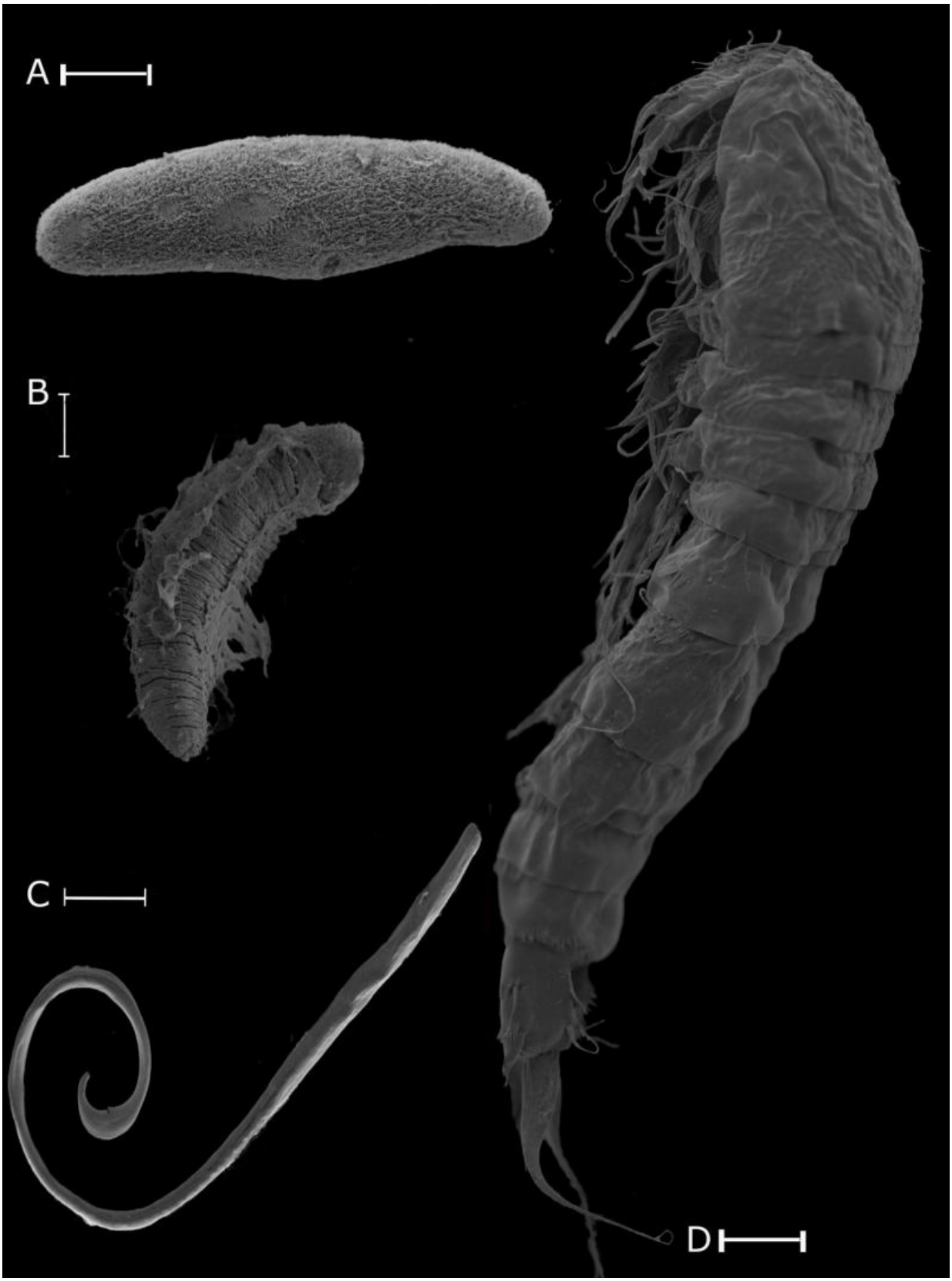
Then there was H. Mephisto, the "Worm From Hell," the first complex, multicellular creature (a type of worm) found living at almost equal depths in the same group of mines.

Now the researchers who made both of those discoveries have discovered a "veritable zoo" of multicellular creatures living in the wet rock fissures of the gold and diamond mines of the Witwaterstrand Basin of South Africa, roughly

a mile below the surface.

The earlier discoveries (reports about them were published in 2006 and 2011) had already changed scientists' understanding of life in the rocky underworld. They had also given encouragement to those convinced that microbes and maybe multi-celled creatures can survive in fissures deep

below the surface of Mars and other moons and planets. The latest jackpot carries this shift in thinking further.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Scanning electron miscope images of species of worms and a crustacean from Driefontein and Kopanang mines. Credit: Borgonie, ELi

"It is very crowded in some places down under," said Gaetan Borgonie of ELi, a Belgian nonprofit that studies extreme life, and of South Africa's University of the Free State in Bloemfontein.

Borgonie, lead author of a paper about the "veritable zoo," said that his discovery in 2011 of a new species of nematode at great depth had been dismissed by some as a "freak find." But now, he said, "the fact that we have found in two mines, in different water, two ecosystems featuring several types of invertebrates hopefully puts that notion to rest as wrong."

He called the findings, published this week in the online journal Nature Communications, "particularly good news for Martian research. If life ever arose there, these findings suggest it may be more likely to remain alive in the subsurface" where it would be protected from the deadly radiation on the Martian surface. The same can plausibly be said of faraway exoplanets, too.

Borgonie has been working with Princeton University's Tullis Onstott, who pioneered the search for extreme life in the South African mines, the deepest man-made cuts in the world. I had the rather searing (and fascinating) experience of joining Borgonie and some colleagues while researching a book on astrobiology some years ago.

Onstott said the number and variety of creatures – worms in particular – found so deep underground was "just startling." He said the paper makes clear that previous estimates of the amount of life (biomass) underground and under the bottom of the oceans have been too low.

Those estimates have ranged from 20 to 50 percent of the total mass of life on Earth.

There are, of course, extremophiles of all sorts. Some can withstand intense heat (think the ocean floor Black Smokers and Old Faithful), some live in permanent ice (think Antarctica), some in very salty and very alkaline environments, some up in the atmosphere, some in the presence of intense radiation.

There's every reason to think that if a biosignature is ever detected from an exoplanet, it will be from a creature distinctly on the extremophile side. While extremophiles are literally everywhere on Earth, it seems worthwhile to probe a little further into the world of deep subterranean life.

Scientists, including Borgonie (right), deep underground at Northam Platinum mine in South Africa. (Marc Kaufman

The newly-described mile-deep zoo was collected over a two-year period from water that was determined, by carbon dating, to have rained down more than 12,000 years ago. It then made its way deep underground through rock cracks and fissures. That's not a particularly long period of time in a Martian or other planetary or lunar context, but the earlier finds involved considerably more longtime residents.

The initial South African extreme extremophile —the bacterium Desulforudis Audaxviator—came out of boreholes in tunnel walls almost two miles down the Mponeng gold mine. Onstott's team determined the new species had lived and evolved at that depth for millions of years (between two and 40 million,) and had been totally cut off for all that time from the sun or anything that it influenced or made possible.

They also determined that it had survived on chemical food sources that derive from the radioactive decay of minerals in the surrounding rock, and that it lived in an ecosystem of one. Its genome was sequenced and in 2012 an organism with DNA 99 per cent identical to that of D. audaxviator was found in boreholes more than half a mile deep near Death Valley in eastern California.

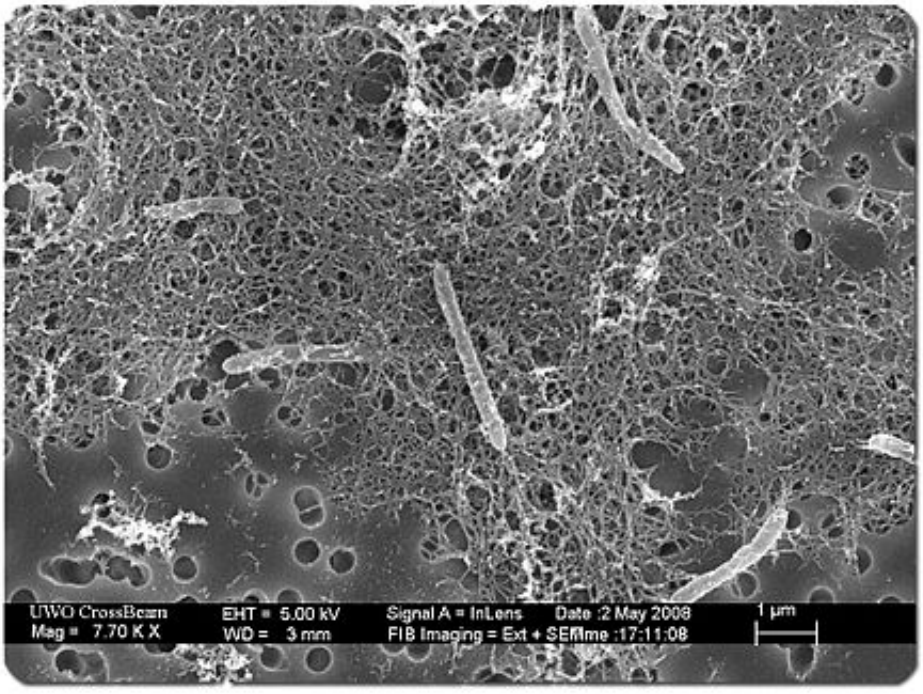
While tens of thousands or tens of millions of years deep underground is not long in the history of Mars or any other celestial body, Mars scientists now say that life doesn't have to dig down too far —maybe one to three yards—to be largely protected from the killing radiation that began to dominate the Martian surface after much of the the planet's atmosphere was stripped away. And if some creatures can migrate miles down, many more might be living meters down on otherwise hostile planetary and lunar surfaces.

A thermophile, such those living in hot springs like this one from Yellowstone National Park, is an organism that thrives at relatively high temperatures 106 and 252 °F).

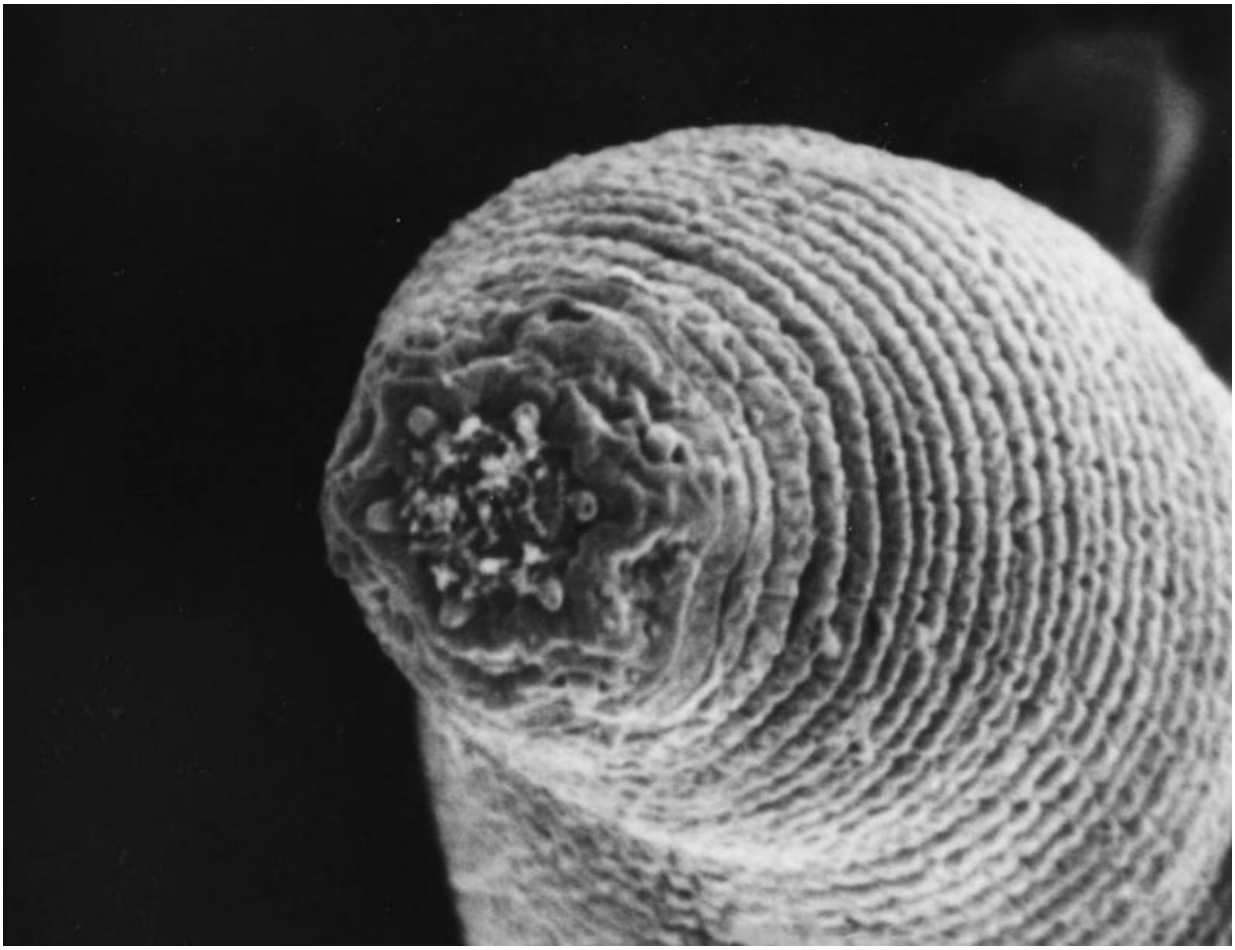
The discovery of H. Mephisto, the "worm from hell," was as surprising as that of D. Audaxviator because it is multicellular, was found at great depth, and had itself evolved into a unique creature. The newly reported "zoo" of multicellular animals found at one mile down are little different from species on the surface, so either they arrived much later or they were already adapted in ways that allow them to flourish in such harsh conditions. Many were found in biofilms, a gauzy collection of microorganisms encased in a protective coating and connected to the rock walls of the boreholes.

Carl Pilcher, director of NASA's Astrobiology Institute had this to say about the new findings: "This study shows that Earth's microscopic and near-microscopic life is amazingly versatile, with organisms including tiny animals able to thrive deep below Earth's surface. The subtitle for this paper could be 'Biofilms can grow anywhere.' And that should probably be what we are thinking as we explore other planets and delve into their subsurfaces in search of habitable environments."

These particular deep subterranean creatures are surely not living on other planets. But as a proof of concept, as it were, the South Africa mines show that extreme life in the deep, rocky subsurface does indeed find a way, and given the slightest chance will create many worlds.



The rod-shaped D. audaxviator was recovered from thousands of liters of water collected deep in the Mponeng Mine in South Africa. Credit: Micrograph by Greg Wanger, J. Craig Venter Institute, and Gordon Southam, University of Western Ontario



Halicephalobus mephisto, the first multicellular organism found far below Earth's surface, is a ravenous bacteria eater. Credit: Borgonie, University of the Free State

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