Searching for Alien Life, on Earth

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Wolfe-Simon inoculates a test tube containing a high concentration of arsenic with a sample of arsenic-tolerant microbes from Mono Lake. Credit: Henry Bortman

If you spend an afternoon walking along the muddy shore of Mono Lake, with the eastern flank of the Sierra Nevada mountains looming majestically in the background, you'll no doubt discover, as others have before, that it is a place of bizarre natural beauty.

But if you spend your afternoon walking the lakeshore with geomicrobiologist Felisa Wolfe-Simon, you'll also discover that the mud you're walking on may hold an important secret. It may be home to life whose biological makeup is fundamentally different than that of any known life on Earth, life so different from standard terrestrial biology it can literally be considered alien.

Indeed, if the more speculative aspect of Wolfe-Simon's research bears fruit, rather than honors going to Mars or Europa, Mono Lake may go down in history as the first place in our solar system where alien life was discovered. And even if that part of her work doesn't pan out, Wolfe-Simon may still make a significant contribution to our understanding of life's origins.

In her work at Mono Lake, Wolfe-Simon is particularly interested in micro-organisms that utilize arsenic in novel ways. To you and me, arsenic is a poison. Here's why: our bodies, like all other known life forms on Earth, depend on phosphorus; it's an essential component of both DNA and ATP (adenosine tri-phosphate), the primary energy currency of life. Chemically, arsenic is similar in many ways to phosphorus, so it's easy for arsenic to sneak in to our cells and get incorporated into our biological structures without being detected. Once it's there, however, it doesn't behave like phosphorus. It's like a bull in a china shop; it's too energetic; it wreaks destruction. But for some microbes, it's a different story: arsenic is their friend.

Because Mono Lake is a closed basin (it has no outlet), chemicals wash down into the lake from the Sierras and stay there. Arsenic is one of the chemicals that builds up, both in the lake water and in lakebed and shoreline sediments. The concentration of arsenic in Mono Lake is more than 700 times what the EPA considers safe.

Despite this abundance of arsenic, however, a number of microbes are known to live comfortably in Mono Lake mud. Not only can they tolerate arsenic, they can use it as an energy source. What Wolfe-Simon wants to find out is what else these microbes can do with arsenic. Specifically - this is where the speculation comes in - have any of the Mono Lake organisms become so enamored of arsenic that they have found a way to incorporate it into their basic biological structures in place of phosphorus?

“The most conservative idea is that we might find an organism that looks just like organisms we know, however it has some very unique and novel way to survive high concentrations of arsenic. And maybe it conserves phosphorus in a way we’ve never seen,” says Wolfe-Simon, who as a member of the NASA Astrobiology Institute is a research scientist with Harvard University and the US Geological Survey. “On the other side of the extreme would be we find an organism that can completely replace or never needs to use phosphorus in the first place.”

Just to be clear: finding an organism that didn’t need phosphorus, that used arsenic instead, would be one of the most significant scientific discoveries of all time. It would mean that Mono Lake was home to a form of life biologically distinct from all other known life on Earth. It would strongly suggest that life got started on our planet not once, but at least twice, that the origin of life on Earth was not a freak accident requiring highly specialized circumstances, but a relatively commonplace event. And that in turn would strengthen the argument that life is likely to be present on other worlds as well. Not too shabby a result for an afternoon stroll by a mountain lake.

To perform her experiments, Wolfe-Simon collected samples of lake water and lakeshore mud in August 2009 and brought them to Ron Oremland’s USGS lab in Menlo Park, California. The experiments consists of putting about one milliliter of sampled lake water or mud into a test tube that contains an artificial simulation of Mono Lake water’s chemical makeup - Wolfe-Simon is running two sets of experiments in parallel, one using mud, the other lake water - and adding glucose, vitamins and all of the other chemical goodies that life needs to thrive. With one crucial exception: instead of adding phosphorus to the mix, Wolfe-Simon adds arsenic. A lot of arsenic. In the highest-concentration experiments, nearly 40,000 times the EPA safety level.

When the clear liquid in the test tube turns cloudy (becomes turbid), Wolfe-Simon moves to the next phase of the experiment. “If it gets cloudy, it kind of suggests that something is growing,” she explains She then extracts a one milliliter of liquid from the first-round test tube and squirts it into a second test tube, which again contains a high arsenic concentration. The effect is to increase the ratio of arsenic to phosphorus in the environment, because the only phosphorus available is what has come along for the ride from the original sample, which has now been diluted ten-fold. After each dilution, Wolfe-Simon waits a few days to see whether the liquid becomes turbid again. If it does, she repeats the transfer, to another test tube with yet another ten-fold dilution.

“At first we’ll get normal organisms, organisms we might recognize. They may be very interesting, but they’re gonna be the same type of biology that we’re used to. And then slowly, over time, [we’ll be] left with anything that can really survive under an arsenic, no-phosphorus condition,” Wolfe-Simon says.

This experiment, of course, is performed not in one single set of test tubes, but in several sets, each containing a slightly different brew of chemicals. It will take several months of trial and error to achieve verifiable or even suggestive results.

If Wolfe-Simon doesn’t find alien, arsenic-based life in Mono Lake, her research could still help deepen our understanding of how life on Earth, the kind we already know about, got started. Although there are many competing theories about life’s origin, it’s generally agreed that, because on early Earth material was being spewed out from the planet’s depths by volcanoes and hydrothermal vents at a far greater rate than it is today, arsenic was more prevalent billions of years ago, arguably where and when life first evolved, than it is in modern times. Early forms of life may have developed strategies for dealing with the potential harmful effects of arsenic.

Indeed, says Wolfe-Simon, arsenic may have played an important role in the early evolution of life. “We think arsenic was abundant in a variety of the... niches where life may have evolved,” she says. Because Mono Lake contains so much more arsenic than most other places on Earth, it offers an excellent natural laboratory for probing how microbes may have behaved in early arsenic-rich environments.

Moreover, if Wolfe-Simon can find organisms that use arsenic in previously unknown ways, the impact of the discovery may not be limited to a story about arsenic. It may open up whole new ways of thinking about how creative microbiology on early Earth might have been in utilizing and incorporating a variety of chemical elements that, while no longer commonly used by biology today, played a critical role in allowing life on Earth to gain a foothold.

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Source: Astrobio.net, by Henry Bortman