Remote Sonoma County landscape offers microscopic peek at life's beginnings

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October 20, 2013

Roger Raiche, right, and David McCrory stand at the Grotto Pool Spring where several unique microbes have been discovered at The Cedars north of Cazadero, California. Photo taken on Monday, October 7, 2013. (BETH SCHLANKER/ The Press Democrat)

October 19, 2013

Scientists looking for clues to the origins of life on Earth have discovered new life forms right here in Sonoma County that may shed light on how life evolved — and how it might be detected elsewhere in the universe.

A three-year study of alkaline ponds at The Cedars, a vast but remote serpentine area north of Cazadero, has uncovered microorganisms never before detected, existing in the kinds of harsh conditions believed to reflect those that first gave rise to life, scientists say.

Researchers hope studying these unique microbes and how they function may impart information about the biochemical reactions that imbued inorganic substances on early Earth with the spark of life.

"In the next few years, we're going to know a lot about these organisms, and that, I think, will stimulate a lot of thinking in these kinds of areas — both in the origins of life and in the limits of life," said Kenneth Nealson, a professor with the University of Southern California's Wrigley Institute who participated in the research published last month.

Its very appearance hints at the insights that might be yielded by The Cedars into how primitive or even extra-terrestrial life began and functioned in a hostile, anaerobic environment.

Terms like "unearthly," "other-worldly" and "moonscape-like" have been used to describe the dramatic, rugged terrain located off a winding, private dirt road that crosses Austin Creek a half-dozen times and passes through a series of locked gates.

Squint, and it's easy to imagine the raw, barren scarp that rises a thousand feet above the headwaters to Austin Creek existing somewhere on another planet. A Mars rover would look at home against its reddish hues and crumbling scree.

Below the sheer ridgeline, white crusted ponds lined with cream-colored silt, and "mineral falls" coated with thick, glistening yellow evoke the kind of primordial soup from which the first creatures on Earth might have emerged.

During summer months, the dry, rocky creek bed reveals spring-fed pools encrusted with fragile calcium carbonate structures and terraced formations that contribute to the strangeness of the place.

"You really do feel like you're somewhere different — you've been transported," said Michael Cohen, an associate professor of biology at Sonoma State University, who is conducting his own studies of microorganisms from springs for potential use in biofuel production.

"I think it's about the most extraordinary place in the county," said Ralph Benson, executive director of the Sonoma Land Trust, which owns a small chunk of it.

What differentiates the isolated region from most of what surrounds it is the massive outcropping of serpentine rock on which it's located, the result of a mineral called peridotite that got jammed up onto the continent at the boundary of moving tectonic plates tens of millions of years ago. Peridotite, a key constituent of the planet's mantle, is more commonly found many miles beneath the earth's crust.

Peridotite is unstable, producing serpentine when it interacts with water under pressure. This interaction also releases calcium bicarbonate, methane, hydrogen and high pH fluid like that which bubbles up through the rock at The Cedars, accounting for the ultra-alkaline ponds and calcium carbonate formations.

But these springs otherwise appear to lack essential elements for life as we know it, like oxygen, salt in any real quantity and other electron acceptors that would offer potential for conversion of energy, scientists say.

The spring water has pH levels approaching 12 — about the same as lye. Though the microorganisms within exist in a density so low it's a fraction of what's commonly found in drinking water, they survive, and do so consistently, despite the odds, Nealson said.

Nealson, who has studied life at the extremes of temperature, described the deep-spring at The Cedars as "one of the most challenging environments I've ever seen."

"The essence is that, when you put it all together, there is no life on Earth that should really be living there," he said. "It kind of broadens the places that you might look (for life) in our own solar system, or even outside our own solar system, if we ever get there."

The research team's findings complement ongoing studies at other serpentine areas around the globe, primarily on the seafloor, where the raw materials of early Earth come together.

And they fit well with the prevailing theory of life beginning in highly alkaline waters from the conversion of peridotite produced within the planet.

"This is probably the most accepted idea right now for the origin of life, that it arose out of an area similar to what you'll find in these springs, except probably in the ocean," said Cohen at SSU.

Unlike smaller serpentine sites elsewhere in California and the West Coast, this serpentinization process is active and ongoing at The Cedars, so it can be studied real-time.

Access is constrained by terrain and surrounding private properties. But it remains comparatively more accessible than other areas of active serpentinization, like The Lost City hydrothermal field deep under the Atlantic, where similar geochemical and microbiological mysteries have drawn the attention of the scientific community over recent decades.

Ongoing weathering of the serpentine at The Cedars also creates specialized soils that support a unique and diverse variety of plant life. At least seven species are found nowhere else.

"There's serpentine all over California, but if I were going to point to a place that just has a whole number of unique things about it, it would be The Cedars," said UC Davis professor Susan Harrison, a plant ecologist specializing in serpentine flora. "It's sort of like Madagascar or the Galapagos or something. It has just the potential for some cool evolutionary stuff to happen."

Located about nine miles east of Timber Cove, The Cedars was once part of a larger territory occupied by the Kashaya Pomo in the days before European homesteaders found their way onto its remote lands, according to the Sonoma Land Trust.

A hunting lodge brought visitors to Cazadero beginning in the late 19th century, and areas beyond were utilized on a limited basis for ranching, logging and mining. Chromite and magnesite deposits discovered late in the century led to mining of chromite, in particular, which peaked during World Wars I and II to meet wartime demand.

The area draws its name, mistakenly, from the trees that are prevalent in the area — they are cypress, not cedars.

Scientists from a variety of disciplines have come to know The Cedars for its distinct geology, diverse and rare plant-life, and the potential of its microbial life, thanks largely to the stewardship of former Cal Berkeley botanist Roger Raiche and David McCrory, his partner in Guerneville-based Planet Horticulture.

Raiche, who first learned of the unexpected, fascinating terrain on a fluke more than three decades ago, made it his mission to study the plant-life there, including new species he discovered.

"It's so different," Raiche says. "It's hard to believe you're still in Sonoma County.

He and, later, McCrory were certain of the land's unique scientific value, and invested years in an effort to ensure it would be protected. Finally, they bought 520 acres encompassing the main canyon after the property went on the market in the mid-1990s and none of the conservation agencies they contacted was in position to buy it.

The overall area remains a patchwork of private and public ownership, with about one-fifth of it currently in public hands. But after years of lobbying by Raiche and McCrory, title to the critical, main canyon was transferred in 2011 to the Bureau of Land Management through the efforts of the Save the Redwoods League, the San Francisco-based Gordon and Betty Moore Foundation, and the California Coastal Conservancy. BLM already owned an adjacent 1,500-acre property and has identified the landmass as an Area of Critical Environmental Concern, requiring special management to defend it from damage. It offers the agency's highest level of protection.

The Sonoma Land Trust also has acquired 40 acres near the entrance to the canyon, as well as scattered conservation easements. In 2009, the nonprofit organization published a collaborative, long-term plan for preserving a 35,000-acre Cedars Conservation Region, with very limited public access.

The intent is to preserve the relatively pristine condition of the land and the ongoing geochemical change that is occurring there, though the Land Trust organizes occasional docent-led tours.

Long-term plans include a trail network connecting the larger Cedars area with the Austin Creek State Recreation Area, perhaps providing hikers a glimpse of the canyon, BLM Field Manager Rich Burns said.

But given the private ownership of the road and the fragility of the main canyon, there will likely never be direct public access by car, Burns said.

"The scientific value is its real public value," Benson said. "We hope over time to make sure the whole area's protected."

In the meantime, Raiche and McCrory have welcomed dozens of groups and research teams with diverse interests, including a group led by the La Jolla-based J. Craig Venter Institute for genomic research.

The JCVI team, which included collaborators from USC, like Nealson, and Delft University in the Netherlands, spent three years sampling and isolating bacteria and other microbes from three of the many spring-fed ponds in the main canyon. Among their findings was a consistent population of organisms in all three ponds indicating they had mastered survival strategies despite the sterility of their environment.

Genome sequencing determined that organisms from two ponds fed both by deep and shallower springs were similar to those found in other serpentine areas like The Lost City, as well as terrestrial sites as far flung as eastern Canada and Portugal, Nealson said.

But one of the ponds was fed only by a very deep-source spring at least 2 kilometers below the surface and in which researchers found a community of microbes whose genomic identity tags matched nothing previously recorded.

Nealson said the researchers thought at first they might have made an error in the sequencing, but repeated sampling and sequencing proved that was not the case.

These "enigmatic and interesting" rarities probably are not ancient life forms themselves, Nealson said. But they come from a very old water source perhaps millions of years old, where they subsisted in the absence of sunlight and oxygen, probably very like early life. Thus, they could yield "guideposts to thinking about early metabolism," Nealson said.

"The idea (now)," he said, "is to try to identify as many of the genes of these five groups as we can, and sit down and say 'What's the most likely thing that they're doing, and does it look like any of the two of them might be working together?'"

"Whether or not it's really an important part of our sort of repertoire of trying to understand the origin and early evolution of life, we'll know in another decade, probably," he said. "When it's new, you never know quite where it's going."

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