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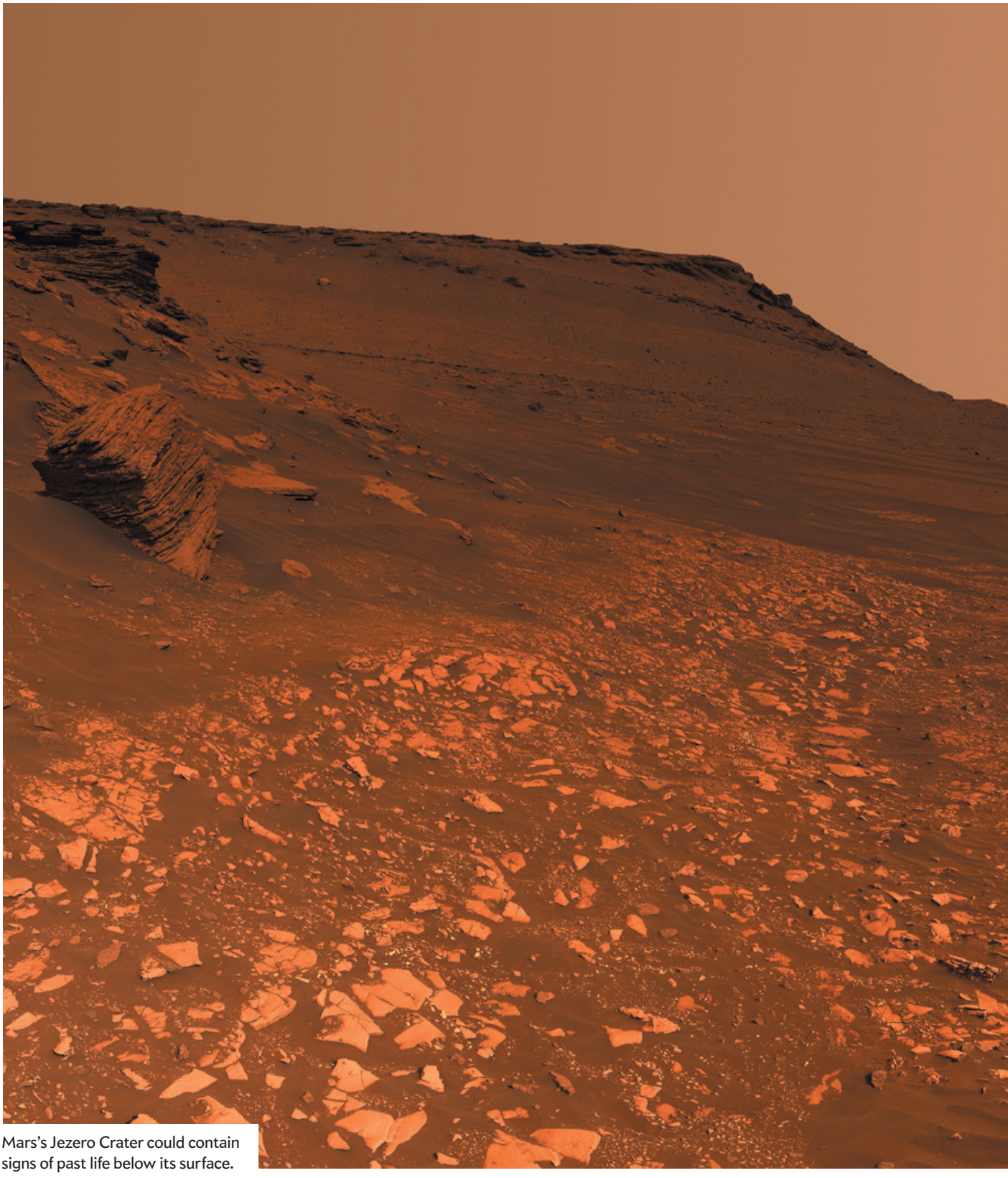
ADVANCES



Mars's Jezero Crater could contain signs of past life below its surface.

NASA/JPL-Caltech/ASU/MSSS

INSIDE

EXTRATERRESTRIAL LIFE

Mars's Downfall

Life on Mars may have been its own worst enemy

Although we know early Mars was wetter, warmer and more habitable than today's freeze-dried desert world, researchers have yet to find direct proof that life ever graced its surface. If such life did exist, however, as a new study suggests, it could have helped tip the planet into its current inhospitable state. The findings further identify certain regions of Mars—including Jezero Crater, where NASA's Perseverance rover now roams—as most likely to host signs of this past life.

Re-creating Mars as it was four billion years ago using climate and terrain models, researchers concluded methane-producing microbes could once have thrived mere centimeters below much of the Red Planet's surface, consuming atmospheric hydrogen and carbon dioxide while protected by overlying sediment. But that buried biosphere would have ultimately retreated deeper into the planet, driven by freezing temperatures of its own making—perhaps to its doom. Their study, published in *Nature Astronomy*, proposes that the interchange among hydrogen, carbon dioxide and methane (all heat-trapping greenhouse gases) would have triggered global cooling that covered most of Mars's surface with inhospitable ice.

"Basically what we say is that life, when it appears on the planet and in the right

condition, might be self-destructive," says study lead author Boris Sauterey, a postdoctoral fellow at Sorbonne University. "It's that self-destructive tendency which might be limiting the ability of life to emerge widely in the universe."

In 1965 the late chemist and ecologist James Lovelock—then a researcher at NASA's Jet Propulsion Laboratory—argued that certain chemical compounds in an atmosphere act as biosignatures indicating life's presence on another world. On Earth, for instance, the coexistence of methane (from methane-producing bacteria, called methanogens) with oxygen (from photosynthetic organisms) constitutes a potent biosignature: each gas eradicates the other in ambient conditions, so the persistence of both indicates a steady replenishment most easily explained by biological sources. Lovelock's work forms the basis of today's scientific search for alien life. It also informs the Gaia hypothesis, which he codified with biologist Lynn Margulis during the 1970s. This hypothesis, named after a "Mother Earth" deity from Greek mythology, suggests that life is *self-regulating:* Earth's organisms collectively interact with their surroundings in a way that maintains environmental habitability. For instance, higher global temperatures from excess atmospheric carbon dioxide also boost plant growth, which in turn siphons more of the greenhouse gas from the air, eventually returning the planet to a cooler state.

In 2009 University of Washington paleontologist Peter Ward put forward a less optimistic view. At planetary scales, Ward argued, life is more self-destructive than self-regulating and eventually wipes itself out. In contrast to the Gaia hypothesis, he named his idea after another figure from Greek mythology: Medea, a mother who kills her own children. To support his "Medea hypothesis," Ward cited several past mass extinction events on Earth that suggest life has an inherently self-destructive nature. During the Great Oxidation Event more than two billion years ago, for instance, photosynthetic cyanobacteria pumped huge amounts of the gas into Earth's oxygen-starved atmosphere. This eradicated the earlier dominant life-forms: methanogens and other anaerobic organisms for which oxygen was toxic. "You just look back at Earth's history, and you see periods where life was its own worst enemy," says Ward, who was not involved in the new study. "And I think this certainly could've been the case on Mars."

On Earth, though, the flood of oxygen also proved crucial for biological diversification and the eventual emergence of our biosphere's multicellular ancestors—showing that defining a situation as Gaian or Medean might be a matter of perspective. Until life is found on other worlds, however, we are left to examine the question through theoretical studies such as Sauterey's.

Kaveh Pahlevan, a research scientist at the SETI Institute, who was not involved in the study, says that the work "does broaden the way we think about the effects that biospheres can have on habitability." But he notes that it considers only the planet-altering effects of one metabolism type. The study would not capture the intricacy of something akin to the Great

TECH

A Daring Collection

Flying robots scoop up rare plants from inaccessible places

On a knife-edge ridge on the Hawaiian island of Kauai, a delicate plant with a tuft of yellow flowers sprouts from the rock. The only sounds are the wind, the murmur of waves far below—and the hum of a drone. That drone carries a suspended robotic arm stabilized with its own propellers, which slices through the plant's stem before gently lifting it away. As the tiny *Schiedea* specimen's leaves flutter in the air, the drone descends and delivers it directly to researchers waiting below.

This scene—repeated dozens of times with various species as part of a new study—shows how drones can help scientists pluck rare and endangered plants from spots that would otherwise be dangerous, if not impossible, for humans to reach. "It's a fabulous development and use of technology to get a lot more infor-

Mamba lifts a sample of *Wilkesia hobdyi.*

Ben Nyberg/National Tropical Botanical Garden

Oxidation Event, which hinged on the conflicting influences of methanogens and cyanobacteria. Sauterey acknowledges this limitation: "You can imagine that a more complex, more diversified [Martian] biosphere would not have had the negative effect on planet habitability that just methanogens would have had," he says. The study highlights how a complex ecosystem, like that of early Earth, may be essential to recovery from otherwise catastrophic environmental change.

Beyond life's potential fate, the study suggests a way to find it: Although the researchers did not explore the possibility of present-day methanogens lurking deep within Mars's subsurface, they did pinpoint places untouched by ice for large swaths of the planet's history where such microbes could have once thrived closer to the surface. One spot is Jezero Crater, the current target of the Perseverance rover's search for biosignature-bearing materials. But it is possible that fossil evidence of early methanogens would be under too much sediment for the rover to reach.

The study also identified two even more promising sites: Mars's Hellas Planitia and Isidis Planitia regions. These targets fit with a broader rising interest in examining the Martian subsurface for signs of life, says California Institute of Technology geobiologist Victoria Orphan, who was not involved in the study. Sauterey's research, Orphan says, is "a reference point to help stimulate debates and deeper thinking about future missions."

Sauterey is careful to point out that the new work is hypothetical—and that just because parts of Mars's crust were once habitable does not mean the planet was ever inhabited. Whether or not ancient methanogens ever lived on Mars, however, the results of the study illustrate how life itself can set the conditions for its own flourishing—or fizzling—on any world in the cosmos. Even single-celled organisms have the power to transform an otherwise habitable planet into a hostile place. And, Sauterey darkly adds, "with the technological means that we have, humans can do that even faster." —*Allison Gasparini*

mation than a person trudging around," says Warren Wagner, a botanist at the Smithsonian Institution. He was not part of the study but is a research associate at the National Tropical Botanical Garden, one of the institutions involved.

The work, described in *Scientific Reports*, builds on decades of botanical investigations of Kauai's more than 250 native plant species. Historically, botanists have rappelled down the island's sheer rock faces to grab samples of specific plants that they can raise in a nursery to perpetuate species at risk of extinction. Study co-author Ben Nyberg, a geographer and drone specialist at the National Tropical Botanical Garden, and his team instead used a commercially available drone to heft a separate robotic unit built from scratch named the Mamba. An operator controls the Mamba's propellers to keep it steady and maneuver it sideways precisely enough to snag each plant.

The Mamba's sampling components include a foam-padded grasping arm that can move like a wrist and a hook that draws a plant's stem toward a blade. Next, the team plans to equip the Mamba with other tools, such as a vacuum to suck in plant material or a nozzle to spray a slurry of seeds and growing medium onto a cliffside for replanting.

Similar drone systems could help researchers access other forbidding areas such as the tabletop mountains that jut above the Amazon jungle or the "sky islands" of the southwestern U.S.—isolated mountain ranges rising abruptly from the desert. "Basically this allows users to reach completely inaccessible areas, wherever they may be," says Nyberg, who is completing a Ph.D. at the University of Copenhagen.

"Many of the rarest and most endangered species found only in Hawaii prefer these cliff habitats, but surveys of their population sizes and collections of seeds have involved great risk to the field biologists skilled enough to do so," says botanist Ann Sakai. The seeds collected during this study—which may belong to an entirely new species of *Schiedea*—are now growing at the University of California, Irvine, with help from Sakai and her husband, Steve Weller. Both have studied *Schiedea* for more than three decades. "They have been able to map in detail the population in a way that we could just never do by rappelling," Weller says. —*Susan Cosier*