Roving the red planet: New paper documents first Mars mission soil samples

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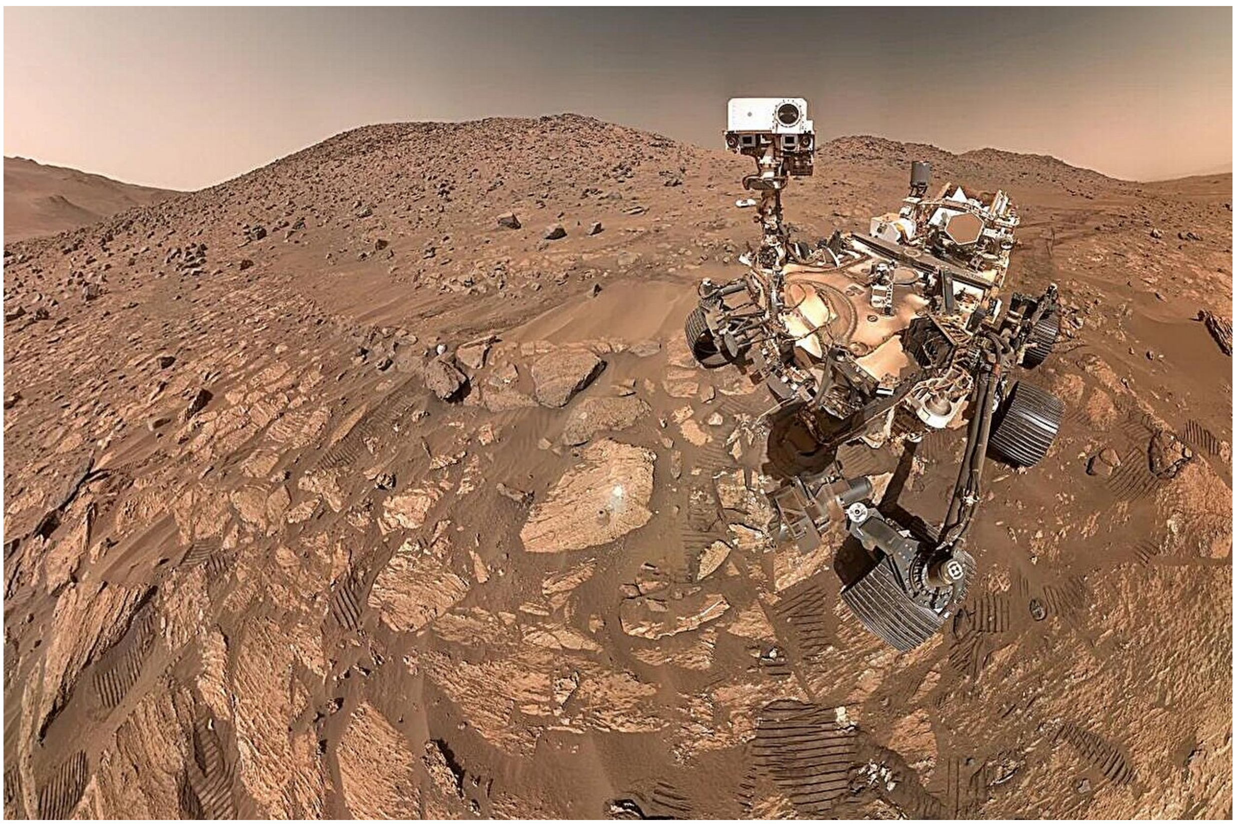

NASA's Perseverance Mars rover took this selfie in July 2024. Credit: NASA/JPL-Caltech/MSSS

A new paper released today documents the first soil, airfall dust, and rock fragment samples collected by NASA for return from Mars. The

University of Nevada, Las Vegas astrobiologist leading the specimen selection team discusses what the samples so far reveal.

The paper is published in the *Journal of Geophysical Research: Planets*.

To date, the only objects from Mars that humans possess are meteorites that crash-landed here on Earth. Thanks to NASA's Mars 2020 Perseverance Rover Mission, scientists for the first time in history are able to retrieve handpicked samples—ranging from rock cores the size of a piece of blackboard chalk, to collections of fragmented rocks the dimensions of a pencil eraser and miniscule grains of sand or dust that could fit on the tip of a needle.

Percy, as the rover is nicknamed, launched from Cape Canaveral, Fla. in July 2020, and arrived in February 2021 at Jezero Crater—a 28-mile-wide former lakebed selected for its potential to help scientists understand the story of Mars's wet past. The years-long mission seeks to determine whether Mars ever supported life, understand the processes and history of Mars's climate, explore the origin and evolution of Mars as a geologic system, and prepare for human exploration.

The specimens are currently slated for return to Earth sometime in the mid-to late-2030s. In the meantime, NASA has so far collected 28 of the mission's target of 43 samples.

"The samples will help us learn more about Mars, but they can also help us learn more about Earth because the surface of Mars is generally much older than the surface of Earth," said UNLV College of Sciences professor Libby Hausrath, an aqueous geochemist who investigates interactions between water and minerals.

She's a member of the NASA Mars Sample Return team that helps determine which specimens the rover will bring back to Earth for inspection by powerful lab equipment too large to send to Mars. She's also the lead author of the new research article.

"There are many possibilities for spinoff technologies used for space exploration that can then be used on Earth," Hausrath added. "And one of the biggest benefits we get from the space program is that it's exciting for students and children, and can help attract people into science—we need all the future scientists to help with science topics like these and others."

The project fulfills a decades-long dream for Hausrath, who fell in love with Mars while pursuing her Ph.D. and partnered with an advisor to write a proposal to work with data from NASA's Spirit and Opportunity rovers.

"This was one of my career goals for a long time, to be able to serve on a Mars mission, so I was really excited to have this opportunity," Hausrath said. "It really is just incredible the level of detail and precision that the Perseverance rover has. To get the data back and be able to target a specific rock or soil area, and be able to take measurements and decipher information from a tiny sample or specks of dust on another planet is just mind-blowing."

Why scientists care

Unlike Earth, Mars doesn't have plate tectonics constantly shifting and tilting the planet's surface. Similar to the way scientists study a tree's rings or examine a cave's stalactites for historical climate pattern changes, researchers are able to glean information about Mars's 4 billion-year-old existence by using the rover's instruments to core rocks and dig soil samples for clues to the history of Mars, including possible signs of past life.

Examining the rocks' geochemistry and airfall dust also has the potential to shed light on how Mars's climate heats and cools and its relative temperature. This information may also tip off how the planet formed, reveal clues about the early solar system, and help pinpoint the time period when life arose on Earth.

"During early Mars history, the planet is believed to have been warmer and had liquid water, which is much different than its current environment, which is very windy, dry, and cold," said Hausrath. "I'm really interested in water and what kinds of environments can be habitable. And Mars, in particular, is quite similar to Earth in lots of ways. If there was past life on Mars, we might be able to see signatures of it."

The mission also serves as a de facto scouting mission that could unlock clues about the similarities or challenges that humans might face during future trips to the red planet. To highlight the importance of recon, Hausrath recounted the experience of the first astronauts on the moon.

"The lunar regolith is actually really sharp so it was cutting holes in the astronauts' spacesuits, which is something scientists hadn't anticipated," she said. "There's a lot of dust and sand on Mars's surface, and bringing back samples is of great interest and value to scientists to figure out how future human astronauts could interact with the particles swirling in the air or potentially use them for building materials."

How the rover works

Percy boasts a cache of futuristic instruments that scientists can manipulate from millions of miles away. It can measure chemistry and mineralogy by shooting a laser from a distance of several meters. It has proximity instruments that can measure fine-scale elements. Researchers use the rover's wheels to make trenches, allowing them to see below the planet's surface. Science, engineering, and navigational cameras transport images back to Earth.

"It's like a video game to see these images of Mars up close," said Hausrath. "You can zoom in, see the rocks and soil, pick out a spot to measure, figure out the chemistry and mineralogy of a specific rock—it's just incredible that we're able to do these things that seem like they're out of science fiction."

Hausrath is one of the team's tactical science leads. During daily meetings, members collaborate on instructions to send back to the rover for collection.

"There are some instruments that just can't be miniaturized and sent to Mars," Hausrath said, "so once the samples are back on Earth, we'll have much finer resolution, be able to measure smaller amounts of each of the samples and with higher precision, and look at things like trace metals and isotopes."

Until then, the samples are being held on Mars in small tubes and are either being stored on the rover or at the Three Forks depot, a swath of flat ground near the base of an ancient river delta that formed long ago when it flowed into a lake on the planet's Jezero Crater. Scientists have mapped an intricate layout, so that the samples can be found even if buried under layers of dust.

Eventually, they'll be retrieved by a robotic lander that'll use a robotic arm to carefully pluck the tubes into a containment capsule aboard a small rocket that will ship them to yet another spacecraft for the long ride home to Earth.

What the rocks reveal

On Earth, life is found nearly everywhere there's water. The Percy team is on a mission to find out if the same was true for Mars billions of years ago, when the planet's climate was much more like ours. The rock and soil samples are being pulled from the once water-rich Jezero crater as well as the crater rim—a swath laden with clay minerals, which result from rock-water interactions and look similar to soils on Earth.

Until the samples are back on Earth, scientists won't be able to say for sure whether they contain traces of microorganisms that may have once thrived on the red planet. But so far, there are strong indicators that bolster previous predictions about water flowing freely on Mars an estimated 2 billion years ago.

Percy's cameras show that the surface crust differs from the soil below, with larger pebbles on top versus finer grains below the surface. Some particles are coarse and weathered, evidence that they likely touched water and thus are a sign of habitable environments in the past. Atmospheric measurements provide signs of recent processes likely including water vapor in soil crust formation.

The bedrock is abundant with olivine, a mineral also found in Mars meteorites. Olivine can undergo serpentinization—a process that occurs when olivine interacts with water and heat—which on Earth indicates the potential for habitability.

But perhaps the most exciting find (and one of Hausrath's personal favorites) is a rock with "leopard spots" nicknamed "Cheyava Falls," after a Grand Canyon waterfall. The rock contains phosphate, which is of interest to scientists because it's a major building block of life on Earth—from energy metabolism and cell membranes to DNA and rNA.

Analysis continues. The NASA team is looking forward to collaborating with the European Space Agency (ESA), which plans to launch its rover, the Rosalind Franklin, in 2028. It will carry equipment to Mars capable of drilling 200 cm below the surface—much deeper than Percy's 4–6 cm drill.

"That would probably get beneath the effects of radiation, so we'd be able to see things we haven't seen before potentially if there were traces of organic molecules in the past on Mars," Hausrath said.

The journey back home

NASA, in partnership with ESA, is currently slated to bring the specimen tubes home sometime between 2035 and 2039. When the samples cross back into Earth's orbit, their first stop will be a receiving facility where they'll be carefully inspected to determine whether they're safe for release to researchers. The overall cache of 43 rock and soil samples will include five witness tubes to test for potential contamination.

"Planetary protection is top of mind for the mission—making sure Mars is protected from us and that we're also protected potentially from Mars," Hausrath said. "The goal is maintaining safety from the samples in case there are any concerns for human hazards and also preventing any contamination from us impacting the samples."

After clearance, she said, researchers around the world will be able to request pieces of these "international treasures" for study, similar to the current program for accessing Mars meteorites.

"One of the really cool things about the mission is that it is so international and the samples are really a global effort," Hausrath said. "It's really great for us to work together to bring these samples back for this goal that benefits all of us."

More information: E. M. Hausrath et al, Collection and In Situ Analyses of Regolith Samples by the Mars 2020 Rover: Implications for Their Formation and Alteration History, *Journal of Geophysical Research: Planets* (2025). DOI: 10.1029/2023JE008046

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