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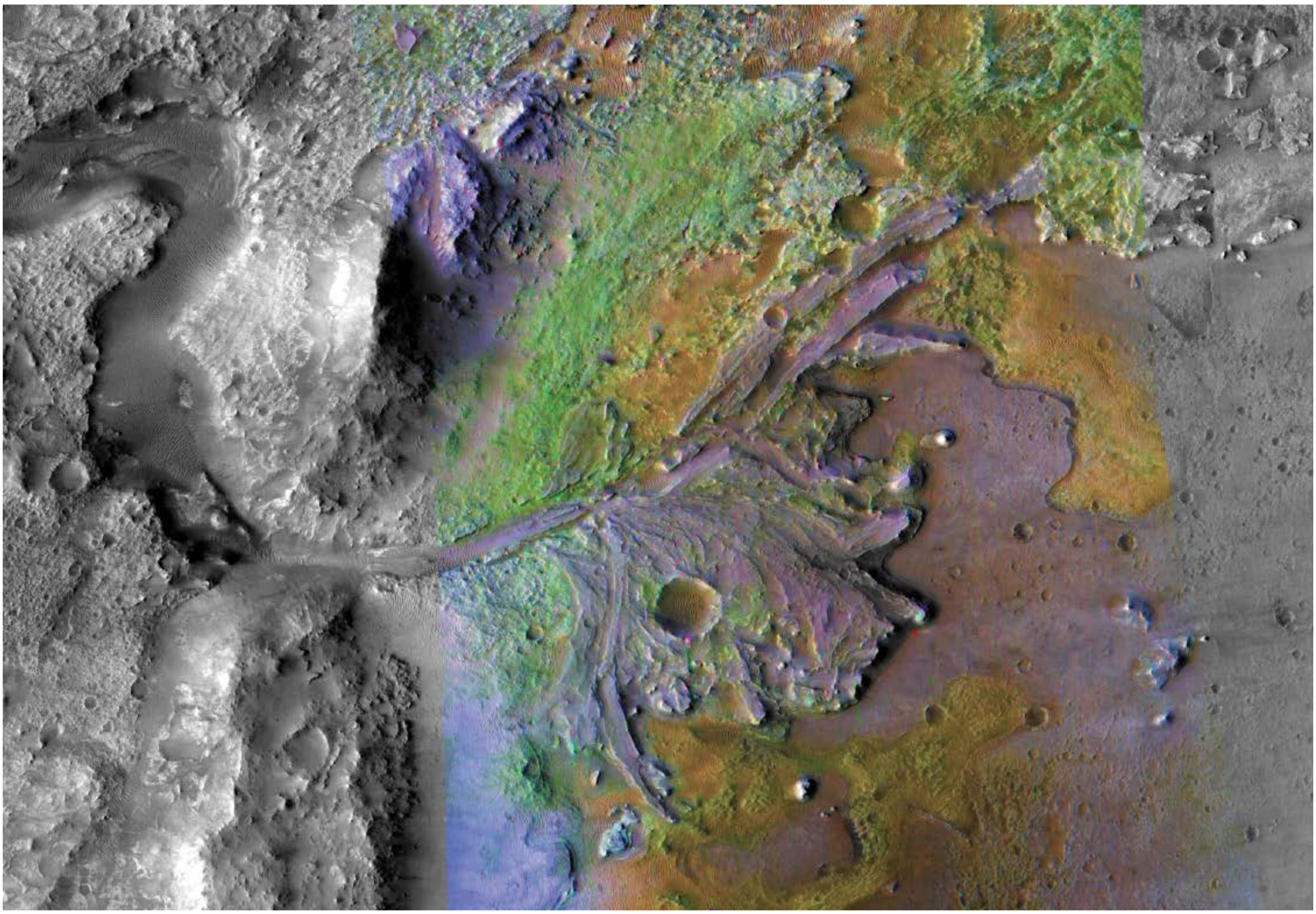
A Flip-Flopping Climate Could Explain Mars's Watery Past



NASA/JPL/JHUAPL/MSSS/Brown University

Scientists have long debated how enough water could have existed on Mars—with its thin atmosphere and great distance from the Sun—to create such features as this apparent delta in Jezero Crater. The feature may have formed when rivers shepherded claylike minerals (green) into a crater lake early in Mars's history.

In the 1970s, images of Mars taken by the Mariner and Viking spacecraft revealed enormous channels and valley networks—both of which are reminiscent of catastrophic floods and river drainage systems on Earth. The fluvial features were the first sign that 3.8 billion years ago, the planet was once a lush oasis, awash with oceans, lakes, and rivers.

But how was early Mars so wet? That question sparked a 40-year-long debate that has divided planetary astronomers into two camps: those who think that Mars must have once contained a thicker and warmer atmosphere—which made the Red Planet hospitable to liquid water and potentially the evolution of life—and those who think that Mars was mostly cold save for short bursts of warmth.

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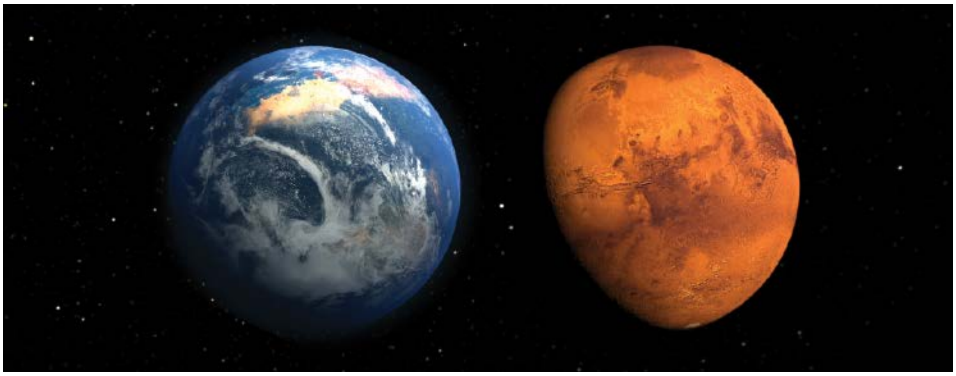
A new hypothesis might reconcile both camps, some scientists say. In a study accepted for publication in *Earth and Planetary Science Letters*, Natasha Batalha, a graduate student from Pennsylvania State University in University Park, and her colleagues suggest that Mars flip-flopped between a deep-freeze climate and a habitable one (see http://bit.ly/Marscycle).

Batalha's adviser at Penn State, coauthor James Kasting, said that he previously supported the hypothesis that early Mars was long enshrouded in a thick, warm atmosphere, but he no longer does. "We now agree with the geologists who say that Mars had to be cold most of the time," he said, speaking of himself, Batalha, and their coauthors. However, Mars somehow got "warm enough for long



NASA's Goddard Space Flight Center

Artist's conception of a lush, early Mars (left) with a thick atmosphere and abundant water compared to arid, present-day Mars (right) with its thin atmosphere. A new hypothesis suggests that lush periods just long enough to form water-created surface features, such as canyons, punctuated much longer, planet-wide frozen spells.

enough to form the valleys" and other fluvial features we see today.

A Climate That Oscillates

Although multiple theories have tried to explain how these fluvial features formed on early Mars, Batalha and her colleagues assert that those explanations all overlooked a phenomenon that is crucial for Earth: the carbonate-silicate cycle.

Volcanoes on Earth spew carbon dioxide into the air, creating an atmosphere that's thick with greenhouse gases. This increases the temperature of the planet, which increases rainfall. The precipitation then scrubs the carbon dioxide from the air by forming carbonic acid. When the acid splashes the surface, it dissolves silicate rocks and creates carbonate, which is then carried into the oceans, where it is eventually subducted into the Earth's mantle. The cycle completes itself—a half a million years later or so—when volcanoes spew carbon dioxide back into the air.

Could a similar cycle have existed on Mars? Batalha thought it was worth investigating. But when she and her colleagues added the cycle to an atmospheric model for early Mars, they found a stark difference from the Earth.

Because the Red Planet is so far from the Sun, the cycle begins on a world coated with glaciers. Volcanoes spew greenhouse gases into the atmosphere, increasing the temperature until it's finally warm enough to rain. Downpours then scrub the potent gases from the atmosphere rapidly, shutting down the greenhouse and plunging the planet back into its glaciated state. Whereas on Earth the cycle acts as a built-in temperature control system, keeping our planet habitable on million-year-long timescales, the team's simulations showed that on Mars it forces the planet to oscillate between a glaciated world and a habitable one.

"We were really surprised to see that when you add this to these early Martian atmospheric models you get these dramatic climate cycles that give you about 10 million years of warmth in between these 120-million-year frozen states," Batalha said. "And 10 million years is exactly the amount of time that you need to form all these fluvial features that we see on Mars."

"The idea is a happy medium," said Ramses Ramirez, an astronomer at Cornell University in Ithaca, N.Y., who was not involved in the study. "Maybe Mars was mostly cold, but then you had very transient warm periods, marrying the two hypotheses."

Where Are All the Carbonates?

But simulating such climate cycles on early Mars doesn't mean they actually happened. To model them, Batalha and her colleagues had to endow the Red Planet with an early history of plate tectonics. Plate tectonics on Mars is still a speculation, although there is some evidence for linear volcanic zones and steep cliffs that could have been generated by fault lines. The researchers also had to add a lot of carbon dioxide and hydrogen to the Martian atmosphere that scientists aren't certain were present in the planet's early days.

"There's no way to go back 3.8 billion years ago and study what the atmosphere was made of then," said Batalha. "In fact, we have a hard time nailing down what's going on in the Martian atmosphere today," she continued, referring to the mysterious methane signatures that scientists have seen belching from the Red Planet but can't yet explain.

Still, Batalha and her colleagues are pretty sure the young planet once outgassed plenty of hydrogen. Previous studies have found that meteorites from Mars are rich in hydrogen compared to rocks on Earth, supporting the notion that abundant outgassing of the element may have occurred there.

But whether the planet also outgassed a lot of carbon dioxide is a harder question to answer. Itay Halevy, an astronomer at the Weizmann Institute of Science in Israel, who was not involved in the study, and Ramirez both told *Eos* that if that outgassing occurred, Mars should be overrun with carbonate rocks—and it isn't.

But Batalha and her colleagues have a reply to that too: An atmosphere laced with carbon dioxide would also form highly acidic rain, they say, which would remove any carbonates from the surface and place them soundly underground. And Ramirez agrees that this is plausible. "There are some craters where you can see that there could be some carbon dioxide [locked in the rocks in the form of carbonates] in there," he said. "It's hard to tell how much there is."

"You just have to dig deeper"—metaphorically and physically, Batalha said.

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