PLANETARY SCIENCE

A Smashing Source of Early Martian Water?

The Red Planet is bitterly cold, bone dry—at least at the surface—and nearly airless. And it seems to have been that inhospitable for at least several billion years. But planetary scientists are deeply divided over whether the very earliest Mars was more conducive to the origin of life. "Geologists say there was all this water, overflowing lakes, and massive erosion," says planetary geologist Michael Carr of the U.S. Geological Survey in Menlo Park, California. But climate modelers can't explain why Mars would have been any warmer in its earliest days than it is today. Now, on page 1977, a group of physics-inclined planetary scientists proposes a solution to that conundrum: giant asteroid impacts.

The great impacts that pockmarked early Mars and their ejecta would have thawed the frozen planet's subsurface water and led to "episodes of scalding rains followed by flash floods," the scientists write. The group has a "perfectly plausible way of making rain on Mars," says planetary physicist Kevin Zahnle of NASA's Ames Research Center in Moffett Field, California, a co-author of the paper. "The details have to be worked out, but fundamentally, this is the answer." That stance gets some support from planetary scientists, but most researchers particularly intimate with the geologic record of earliest Mars disagree. "It's a valiant effort," says Carr, but "I'm skeptical that it really does much to explain what we're seeing."

Long dry. Four billion years ago on a wet Mars, water drained from craters down long channels.

This early Mars mystery cropped up when, 30 years ago, planetary geologists saw their first signs that water had run free on the surface of early Mars. Branching channels on the ancient, heavily cratered highlands looked for all the world like river valleys. Large crater rims were worn down as if swept by persistent rains. And, more recently, geologists have recognized that great craters appear to have been filled to overflowing by rain on early Mars. "The amount of erosion is huge," says Carr. On the other hand, climate modelers can't stuff enough greenhouse gases into a martian atmosphere to compensate for the chilly faintness of the sun 4 billion years ago.

In making the case for impacts, atmospheric scientists Teresa Segura and Owen Toon of the University of Colorado, Boulder, along with Anthony Colaprete and Zahnle of Ames, point to the 25 largest martian impact craters. Ranging from 600 to 4000 kilometers in diameter, the craters formed after the planet's formation 4.5 billion years ago and before about 3.8 billion years ago. For comparison, the Chicxulub impact that wiped out the dinosaurs formed a 170-kilometer crater. Even the small end of the range of martian impactors considered in the new paper—a 100-kilometer object—delivered about 4×10^{26} joules of energy to the planet, the equivalent of 100 to 1000 dinosaur killers, says Zahnle.

With that much energy dumped on Mars, things got hot in a hurry. When one of those "small-end" impactors hit, it threw out enough hot rock to cover the planet to an average depth of 7 meters, the group calculates. When the rock vaporized by the impact eventually cooled and condensed, a 1600-K "rock rain" fell to cover the surface globally to 2 meters' depth. Within a few weeks, global surface temperatures reached 800 K. Now water everywhere was vaporized or melting: the water in the asteroid, the crustal water where the asteroid hit, the water in the polar caps, and, most novel in this study, the water frozen just beneath the preimpact surface (*Science*, 14 June, p. 1962) that is heated by all that hot ejecta. Parts of the subsurface would have stayed above freezing for at least a year in the case of a 100-kilometer impactor, the group calculates, for more than a century after a 250-kilometer impactor hit, and for millennia for the largest impacts.

All that thawed water would have made for plenty of erosion, the group says. A 100-kilometer impactor would have triggered 2 meters of rain over the entire planet within a few years and melted 3 meters' worth of ice. A single 250-kilometer impactor might have freed up 50 meters of water. One such impact would be enough, they calculate, to erode the mysterious valley networks. And at least 10 such objects hit Mars before the planets swept up the last of the debris from the solar system's formation.

Planetary scientists have a range of reactions to this picture of a cold, dry early Mars punctuated by episodes of sizzling rain every 100 million years or so. "The idea is well founded," says planetary scientist Stephen Clifford of the Lunar and Planetary Institute in Houston, Texas, who specializes in martian hydrology. "Ultimately, the geologists are going to have to come around."

Some Mars geologists don't think they will have to do so. Ross Irwin of the Smithsonian Institution's National Air and Space Museum in Washington, D.C., allows that impacts might have contributed to some of the earliest erosion, when the biggest asteroids were hitting, but later valley formation and the flooding of large craters seem to have required far more water than impacts could have supplied. Carr agrees that "the valleys are only part of the problem. The amount of erosion is enormous. You're talking kilometers of water," not the 50 meters from an impact.

To win any more supporters, Segura and her colleagues need to develop a better idea of the cumulative effect of both large and smaller craters over time, researchers say. But James Kasting of Pennsylvania State University, University Park, who has been struggling with the early Mars climate problem for 20 years, is not hopeful: "I'm pessimistic that any of us is going to solve it until we get some geologists up there."

–RICHARD A. KERR

PLANETARY SCIENCE

... And an Icy Patch at Mars's South Pole

Space scientists have discovered a new hiding place for water on Mars. In a paper published online by *Science* this week (www.sciencemag.org/cgi/content/abstract/1080497), three geologists report that they have found a kilometer-wide patch of water ice at the edge of the southern polar cap. The orbiting Mars Odyssey spacecraft first glimpsed the water ice in February, exposed when an upper layer of carbon dioxide ice ("dry ice") evaporated in the –20°C heat of the martian summer. This discovery might literally be the tip of an iceberg: Some Mars scientists believe that the entire southern polar cap could be water ice, covered by a thin layer of dry ice.

When Mars Odyssey began photographing the martian surface, says Phillip Christensen of Arizona State University, Tempe, "this region was one of the first pictures we took." What caught scientists' attention was a relatively flat piece of land that was colder than the adjacent exposed soil. More-

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