Running Water Eroded a Frigid Early Mars

New data suggest that precipitation—rain or snow—and flowing water helped shape Mars in its first billion years, despite the subzero climate.

When Mars was young, did its valleys resound with pelting brooks and falling rain, or was the planet always cold and dry? Therein lies a conundrum. For decades, spacecraft have been returning images of lacy networks that look like systems of river valleys—evidence, said geologists, that precipitation-fed streams and rivers had heavily eroded Mars in its first billion years. Yet climate models have long had early Mars locked in a deep freeze even colder than today’s, unable to have snow beyond the poles, much less rain. “There’s been a complete discordance between geomorphology screaming ‘rain!’ and the climate models saying ‘It’s impossible!’” says Mars geologist Michael Carr of the U.S. Geological Survey in Menlo Park, California.

In recent months, geomorphology has been winning out. New analyses of the first direct measurements of martian topography have reinforced the case for running water. “It looks more and more as if you do need precipitation,” says Carr. Planetary scientist Oded Aharonson of the California Institute of Technology (Caltech) in Pasadena agrees that “there’s been a shift [toward] a somewhat wetter Mars, implying a more hospitable planet” in its earliest days, when any martian life would have been getting its start.

Yet the conundrum remains: Although there’s now agreement that there must have been some precipitation on early Mars, how could it have occurred on a planet that was cold, if not severely frigid? Geologists are coming up with a number of possibilities. Perhaps early Mars was more like today’s Dry Valleys of Antarctica, some suggest, where a dusting of snow melts and runs down short-lived rivers in high summer. Or perhaps it rained only on a rare summer’s day.

The puzzle began with the Viking mission in the 1970s. In images returned by Viking and later spacecraft, geologists could see some features that seemed to have been gouged out by running water—the so-called valley networks. But debate has been dragging on over whether they were carved by rain-fed streams and rivers, the products of a “warm and wet” climate, or by a process called sapping in which spring water eats away at the rock face at the head of a stream. Sapping seemed more likely under a frigid, dry climate like that of today. But new evidence from Mars Global Surveyor is changing that perception.

Surveyor, which arrived at Mars in 1997, carries an instrument called the Mars Orbiter Laser Altimeter (MOLA), which bounces a light beam off a spot on the surface and measures its height the way a radar measures distance. After several years and 671,121,600 laser shots, MOLA provided geologists with a stunning, imagelike topographic map of Mars accurate to a few me-
low-density, "immature" drainage systems

They set out to see just how densely valley

And so began the age of a Martian climate

By watching virtual rain runoff, "we

can easily say whether a terrain is lunar or terrestri'

A typical such study by planetary scien-

tists Brian Hynek and Roger Phillips of

planetary scientist Tomasz Stepinski of

A wetter early Mars. The latest topography (blue is lower)

Several recent studies combining MOLA data and the lat-

est images from Surveyor and Mars Odyssey have now persuaded Aharonson and others that the limited erosion they are seeing was to a significant degree the work of precipitation.

A typical such study by planetary scientist Brian Hynek and Roger Phillips of Washington University in St. Louis, Missouri, will be published in Geology. They set out to see just how densely valley networks cover the surface. Previous tallies had found that the treelike patterns of martian valley networks were unreasonably sparse—with few branches on a single short trunk and few twigs on the branches. Such low-density, "immature" drainage systems are typical of the feeble erosion of sapping

on Earth. Hynek and Phillips overlaid

MOLA topography on the higher quality

though still less-than-definitive camera im-

ages from recent missions and then mapped out valleys as far as they could.

Using the latest data made quite a differ-

ence. "The combination of MOLA and the best [camera] images really clarifies where valley networks are," says Hynek. "Now we see roughly an order of magnitude more valley networks than previously estimated." That makes the martian valley networks about as dense as the least dense runoff-fed

forced sapping proponents, such as Carr, to take precipitation seriously. But the limited amount of erosion suggests that it wasn't the result of a "warm and wet" early Mars. As Howard pointed out at a session on "The Mysteries of the Martian Rivers" organized at the fall meeting of the American Geophysical Union (AGU) in San Francisco, something like a few hundred meters of the landscape were removed in the first half-billion to 1 billion years of Mars history.

That's the amount of erosion that rain and melting snow can cause in just 1 million to

10 million years on a terrestrial desert, Howard notes. However runoff shaped Mars, he says, it must have taken its time. "It looks like a warm early Mars is dead," observed planetary scientist Arden Albee of Caltech after listening to the AGU session.

Researchers are coming up with a variety of ways in which runoff could have eroded the surface of early Mars in a leisurely fashion. Last December atmospheric scientist Teresa Segura of the University of Colorado, Boulder, and her colleagues suggested that the heat of huge asteroid impacts could have momentarily mobilized frozen water and driven heavy rains for decades (Science, 6 December 2002, p. 1866). Tens of millions of years of cold, dry climate would have prevailed between impacts, stretching out the erosion over long periods of time.

At the LPSC last March, planetary scientists Pascal Lee and Christopher McKay of NASA's Ames Research Center in Mountain View, California, pointed to possible terrestrial analogs of erosion on early Mars in the high Arctic and Antarctica's Dry Valleys, where it is "always cold, sometimes wet." On Mars, just enough warmth to melt snowfall at the height of summer might have been summoned when the planet tilted far over on its side every few million years (Science, 11 April, p. 234). And planetary scientist Eric Gaidos of the University of Hawaii, Manoa, and geochemist Giles Marion of the Desert Research Institute in Reno, Nevada, are suggesting that water might have gushed onto the surface of a cold Mars from time to time if the long-term cooling of the planet's interior progressively froze some deep groundwater, which in turn could have squeezed shots of water onto the surface. So there may be more than one way to wet a planet.

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