fraying of the telomeres, the structures that cap the ends of the chromosomes, may be a signal that triggers this cell death.

In work reported in the 29 April issue of the *Proceedings of the National Academy of Sciences*, the Baylor group found that the telomeres were markedly shorter—by about 25%—in the hearts of patients who died of heart failure than in people who died of other causes. The telomere shortening was accompanied by a reduction in the concentration of TRF2, one of the proteins normally present in the telomeres, and by activation of a so-called checkpoint kinase that triggers apoptosis in response to DNA damage. The TRF2 reduction apparently triggered those changes. Schneider and his colleagues showed that they could produce telomere shortening and apoptosis in cultured heart cells by blocking production of TRF2, whereas adding TRF2 blocked those changes.

There may well be other routes to apoptosis in heart failure, however. Gerald Dorn and his colleagues at the University of Cincinnati have produced a mouse model of cardiac hypertrophy by overexpressing a protein called Gαq in the animals. This protein is part of the pathway by which the cardiac muscle responds to stimulation by hormones such as adrenalin. Overproduction of Gαq effectively overstresses the heart.

To find out what causes the apoptosis that eventually develops in the hearts of the modified animals, the Dorn team used DNA microarrays containing 90 apoptosis-related genes. Four of the genes turned out to be overexpressed in the hearts of modified mice compared to normal animals. The researchers focused on one, known as *Nix*, because it works through the mitochondria, releasing a cell-digesting enzyme called a caspase that helps carry out the final cell destruction in apoptosis.

In work described in the July 2002 issue of *Nature Medicine*, Dorn and his colleagues found that if they overexpressed *Nix* in the hearts of mice, the animals developed severe DCM and died shortly after birth. "The seeds of destruction are planted in the [failing] heart," Dorn says. But, he adds, the result is "actually a little bit cool" because it also suggests that caspase inhibitors, which are being developed to treat a variety of degenerative diseases, might be useful for treating heart failure.

Indeed, the current work on cardiomyopathies and heart failure has turned up numerous potential targets for therapies. The occasional death of a young athlete will continue to shock, but the research on their hidden killers is now turning up some promising leads that could eventually benefit a broad range of heart patients. —JEAN MARX

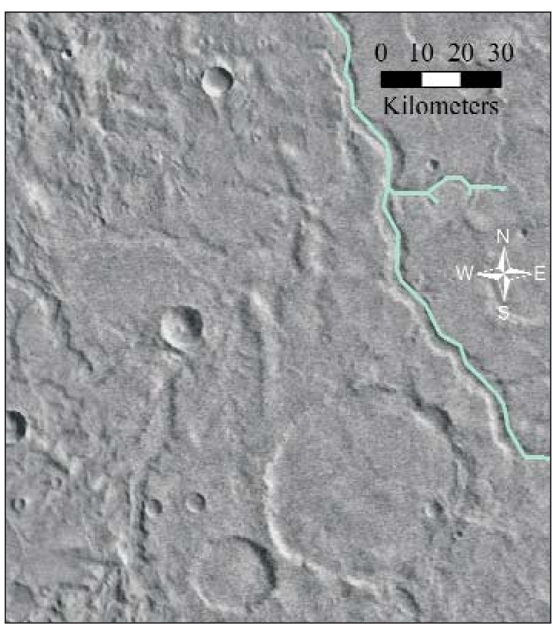
Planetary Science

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 plashing 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.



A dry early Mars. A 25-year-old image reveals only a simple, short, presumably spring-fed drainage system (blue).

CREDIT: B. HYNEK/WASHINGTON UNIVERSITY

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 meters of altitude—versus the previous 1 kilometer uncertainty. Such precise knowledge of the martian surface should hold clues to how it was shaped.

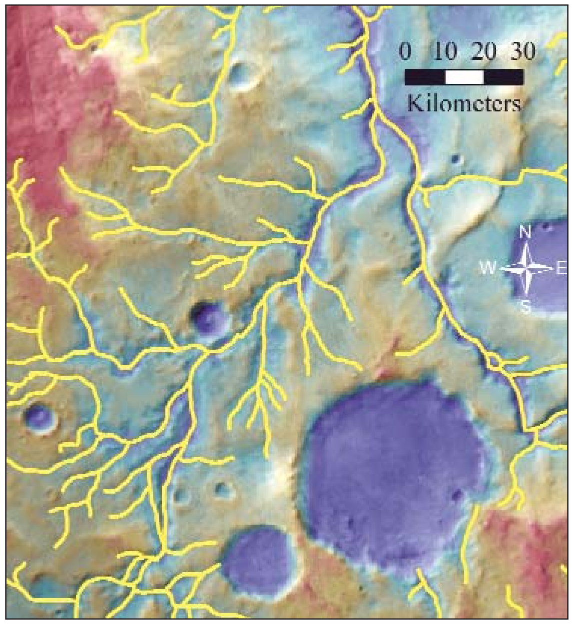
Planetary scientist Tomasz Stepinski of the Lunar and Planetary Institute in Houston and his colleagues put the MOLA topographic data in a model designed to separate wet weather from dry. In essence, this model drizzles "computational rain" on a terrain and watches the virtual wet stuff drain off. Surfaces already eroded by rain-fed runoff, such as most areas outside of glaciated terrain on Earth, show virtual draining patterns quite unlike those of surfaces that no water had ever touched, such as lunar terrain shaped by impact cratering.

By watching virtual rain runoff, "we can easily say whether a terrain is lunar or terrestrial," says Stepinski. "Mars terrain is somewhere in between terrestrial and lunar. Maybe there was some rain on Mars, but to a small degree. The [terrain] roughness is not dominated by fluvial erosion; it's a mix of fluvial erosion and cratering." There was never enough sustained rainfall, for example, to dominate the heavy cratering of 3.9 billion years ago and earlier, says Stepinski. And there has certainly been no sustained rain since then, despite suggested episodes of a warm and wet climate in later Mars history (*Science*, 12 February 1993, p. 910).

Aharonson of Caltech and colleagues at the Massachusetts Institute of Technology in Cambridge have also found signs in the MOLA data that flowing water caused limited erosion on early Mars. The shapes of the main channels of drainage basins, they found, are flatter and less concave than rain-fed channels on Earth and have frequent abrupt drops. Those are both signs that flowing water did not have a chance to thoroughly reshape the initial form of the land. At first, Aharonson thought the MOLA data pointed to the low flows of groundwater sapping. But several recent studies combining MOLA data and the latest 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 scientists 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 images from recent missions and then mapped out valleys as far as they could.

Using the latest data made quite a difference. "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 drainage systems on Earth and generally more dense than systems carved by sapping alone. Planetary geologist Robert Craddock of the Smithsonian Institution's National Air and Space Museum in Washington, D.C., and his colleagues got similar results when they identified drainage networks in MOLA topography using a computer program and checked their reality with the latest images from Mars, as they reported at last March's Lunar and Planetary Science Conference (LPSC) in Houston.



A wetter early Mars. The latest topography (blue is lower) overlaid on new images reveals a dense, complex drainage system (yellow), suggesting erosion by rain or melting snow.

CREDIT: B. HYNEK/WASHINGTON UNIVERSITY

Moreover, some of the newly apparent networks reach nearly up to the crests of ridges and crater rims. That would be unlikely with sapping, as Mars geologist Alan Howard of the University of Virginia in Charlottesville pointed out at the Joint Assembly of European and American earth science societies held in Nice, France, in April. There's precious little ground up there to store the water needed for sapping, he noted, but precipitation could simply fall on the crest and run down.

All these signs of runoff erosion have 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.

–RICHARD A. KERR