PLANETARY SCIENCE

Water Everywhere on Early Mars But Only for a Geologic Moment?

Planetary scientists pursuing water and life on Mars must reconcile mounting evidence of a young planet awash in life-sustaining water with a growing realization that the martian surface was likely almost always dry

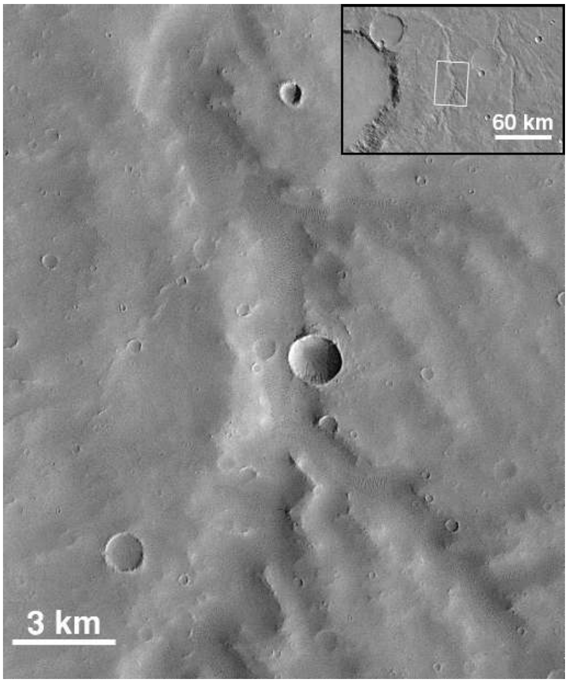
The early Mars of human imagination has swung from invitingly moist to brutally dry and back again more than once in the past half-century. Hopes for some sign of life that might have struggled into existence in that first billion years of martian history have likewise been alternately buoyed and dashed. In recent years, much of the news has been decidedly wet: a shallow, salty sea, rivers languidly flowing into crater lakes, and an exploding palette of spectral colors denoting water-altered minerals.

Most of these sorts of once-wet martian features are in the running to be the lone landing site for the next U.S. Mars rover, the $1.9 billion Mars Science Laboratory (MSL). Its mission: "follow the water" to understand whether the planet has ever been able to support microbial life.

But while the media were touting these striking examples of "sustained" liquid water on early Mars, less heralded evidence has been pointing to far less hospitable conditions. "I'm absolutely convinced there were periods of time when there was a very moist climate," says long-time Mars geologist Michael Carr of the U.S. Geological Survey in Menlo Park, California, but "I'm skeptical the wet conditions were persistent." In fact, says Mars fluvial geologist Robert Craddock of the National Air and Space Museum (NASM) in Washington, D.C., "the thinking has shifted to maybe punctuated, short-lived" episodes of warm and wet conditions. The rest of the time—maybe 999 years out of 1000—the surface of Mars would have been cold and drier than any desert on Earth and less hospitable to life.

Dry, with wet moments

The vision of a wet early Mars got a big boost in 2004 when the Opportunity rover spied fossil sand ripples now exposed on the Meridiani Planum of Mars. Only water flowing on the surface—not groundwater—could have formed ripples with their particular shapes. So was born the "shallow, salty sea" of early Mars, which has been drying up ever since. Rover team members have been increasingly emphasizing that almost all of the salty sediments of the Opportunity site were laid down as windblown dunes that were later altered by briny, acidic groundwater (*Science*, 5 January 2007, p. 37). That groundwater may have oozed to the surface to puddle between dunes once in a great while, allowing those water-formed ripples to form, but even then it may have been too briny for even the most salt-tolerant life known on Earth (sciencenow.sciencemag.org/cgi/content/full/2008/529/1).



Wet, but only briefly. The "warm and wet" times when water cut this valley network could have lasted mere centuries.

Another way to have sustained, continual water flow on the surface of Mars has also lost ground of late. Imaging by the Viking orbiters in the late 1970s revealed so-called valley networks—branching channels up to several hundred meters deep—that formed during the Noachian geologic era of Mars, roughly the planet's first billion years. Many planetary geologists thought the channels were carved by water seeping up from underground. Springs emerging at the head of each valley would have weakened the rock of the valley head wall, causing it to collapse into an amphitheater shape, then the spring water would have slowly eroded the debris away. Such seepage, or "sapping," was supposed to have formed some similar amphitheater-headed canyons on Earth. But a recent study published in *Science* (23 May, p. 1067) presented strong evidence that one classic sapping valley, Box Canyon in Idaho, resulted from one or more catastrophic floods.

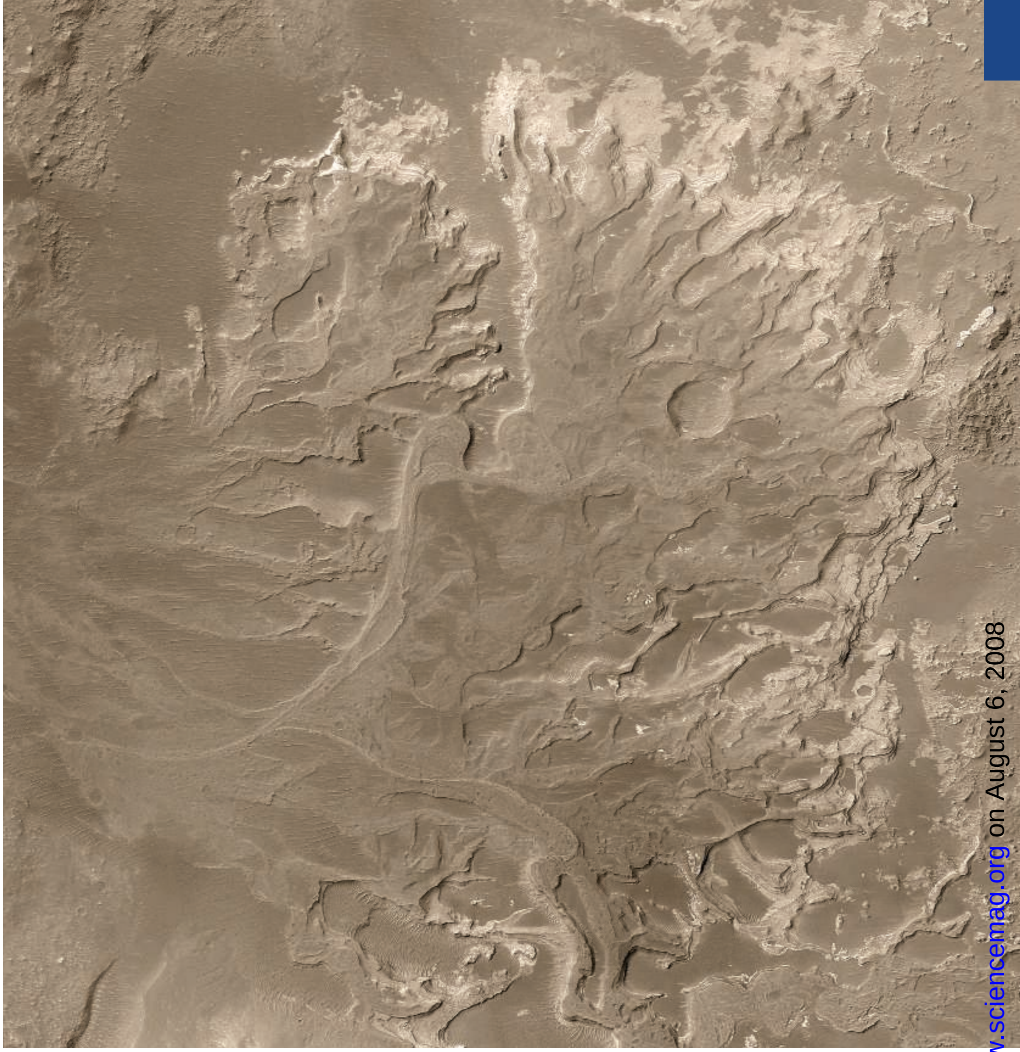
Now most experts think the treelike, twig-to-branch-to-trunk valley patterns on early Mars came about the same way most such patterns do on Earth: as drainage systems of rain-fed streams and rivers. But how could even the scarce rain of, say, the Nevada desert—going on for the better part of a billion years—leave so much of early Mars still standing? "Maybe Mars wasn't even like Nevada," says planetary geologist Ross Irwin of NASM. Maybe it was only something like Nevada once in a great while.

Fluvial geomorphologists Sanjoy Som and David Montgomery, both of the University of Washington (UW), Seattle, presented some of the latest evidence for such ultrarare rain at the Astrobiology Science Conference in Santa Clara, California, this past April. Using orbital imaging and altimetry, they compared signs of how water had flowed through 10 of the largest martian valley networks with flow-related characteristics of terrestrial drainage systems. For example, prolonged flows on Earth tend to widen channels and flatten their slopes downstream. The researchers concluded that even in the Noachian, Mars was much as it is today—cold and dry—with only rare episodic gushes during brief warm and wet intervals.

Early Mars was like the Atacama Desert of the high Andes, only more extreme, says planetary scientist Tomasz Stepinski of the Lunar and Planetary Institute in Houston, Texas. Stepinski says the UW analysis supports conclusions he and others had reached earlier by mathematical analyses of valley network patterns: "If there was precipitation, it was probably in the form of bursts. Mars didn't have the time to develop the intricate [drainage] patterns seen on Earth." Instead, he says, martian erosion works the same way it does on the Atacama: by prolonged dryness punctuated by an extraordinary gully washer of a storm.

On Mars, "it probably wouldn't have taken millions of years" of rainfall to carve the val-

How persistent? The sediment-laden flows that formed Eberswalde delta could have been short-lived.



ley networks, says Craddock. "Our best estimate is that valley networks were only active hundreds or at most thousands of years. It may have been punctuated events scattered over a long time of martian history."

Paradoxical puddles

While valley networks were pointing toward an almost-always-dry early Mars, planetary scientists were also finding signs that early Mars was wet—so wet that water drained into crater lakes. Press releases heralded this evidence for "pervasive and long-lasting" wetness that had "the potential to support life." But some researchers say that those lakes—which include three or four out of seven sites in the final running for the MSL rover landing—could have filled and dried up again within a geological moment.

The latest evidence for a persistent lake on early Mars comes from 45-kilometer Jezero crater, planetary scientists Samuel Schon, Caleb Fassett, and James Head of Brown University reported at the Lunar and Planetary Science Conference in Houston last March. Examining the latest high-resolution images from Mars Reconnaissance Orbiter (MRO), they point out features—such as distinctive cross-bedding of sediment layers—that form only when river channels meander across a delta building out into a lake. And delta channels can meander only if the standing water the delta is growing into remains more or less steady at one level. That implies a "long-lived" lake in Jezero crater, the group says, much as proposed for 65-kilometer Eberswalde crater, a potential MSL target.

The problem is that no one can put a number on "long-lived." "There's almost no question these [crater] deposits are fluvial," says fluvial geomorphologist Douglas Jerolmack of the University of Pennsylvania, but "there's also a lot of evidence they could have been done very rapidly." In 2004, Jerolmack and colleagues used a computer model to estimate that Eberswalde's fan of sediment could have formed in several decades to centuries. Fluvial geomorphologists Montgomery and Craddock both agree that geologists could well be looking at lake deposits built up by one or more brief gushes down valley networks like the one that fed Jezero.

Watery colors

The latest watery news of early Mars came last week, when *Nature* published the most comprehensive spectral survey yet of Mars, setting off a media storm. The MRO spectrometer discovered the spectral signatures of clays—the product of prolonged water weathering of rock—at a couple of thousand sites. Mars was a warm, soggy, water-logged planet for hundreds of millions of years in its early history, news stories proclaimed.

The *Nature* paper by planetary scientist John Mustard of Brown and 35 MRO colleagues was a good bit more restrained than its media coverage. Although it pointed to the existence of clays, it never placed them definitively on the surface of the planet. Primitive life might have arisen in the subsurface, Mustard notes, ever so slowly feeding on chemicals from the rock. But nothing in the spectral data contradicts the valley network picture of a surface almost always dry.

If the "punctuated precipitation" model is correct, how did Mars generate such rare, geologically momentary episodes of rain? Some researchers credit cosmic collisions. In a 2002 *Science* paper, planetary scientist Teresa Segura of Northrop Grumman Space Technology in Redondo Beach, California, and colleagues proposed that large asteroids or comets striking the martian surface flung hot rock and rock vapor around the planet; the heat vaporized water and ice stored beneath the surface and in the polar caps, driving it into the atmosphere (*Science*, 6 December 2002, p. 1866).

Not everyone was convinced. "I had problems with the *Science* article," says Craddock, as did others. The atmospheric physics of Segura's model was incomplete, some noted, and the very large impacts they modeled would have come too early in Mars's history to explain the observed fluvial geology, among a number of criticisms.

Segura and colleagues listened and are back with a new and improved paper that is in press in the *Journal of Geophysical Research*. They added more atmospheric processes to their model and considered smaller, later arriving impacters. The more detailed model supports the conclusions of the earlier one: Impact-induced greenhouse conditions could have lasted for centuries, driving up to 18 meters of rainfall. The group calculates that rainfall due to Noachian impacts would have eroded away at least 50 meters of the planet's surface—roughly the amount of erosion that planetary scientists estimate actually occurred. The once-doubtful Craddock thinks that "what they've done now is the best solution we have. Now we need to test it a little."

–RICHARD A. KERR

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