Confirmation That Mars Is a Changing Planet

An announcement of stunning new results from Mars on Dec. 6, 2006, indicates that water may be flowing on the surface of that planet today. Marsha Freeman reports.

In the minds of men, Mars has been changing throughout the ages, as the capability of scientific instruments advanced. When ground-based telescopes gave way to visiting spacecraft, the myth of intelligent beings on Mars disappeared, and new mysteries evolved.

As the most Earth-like planet, Mars has held special interest, in that it is the most likely place in the Solar System that could have supported at least primitive life. So leaving aside little green men, or H.G. Wells' depressing creatures in *The War of the Worlds,* the question is posed: "Was there life on Mars?"

Even with the discovery over the past decade of the flourishing of life in extreme environments on Earth, the presence of liquid water remains a prerequisite. So to answer this most profound question, the current space missions have been designed to search for evidence of water on Mars.

There have been many hints, and more recently, evidence that is almost irrefutable, that water existed on the surface of Mars. But, until now, it was unclear whether liquid water was there billions, millions, or tens of thousands of years ago, or even in recent decades.

On Dec. 6, scientists described a discovery made through an intensive effort to compare images of Mars over time taken by the Mars Global Surveyor orbiter. The results led them to conclude that there is liquid water underground *today* on Mars, which periodically spurts up to the surface.

The high-powered Mars Reconnaissance Orbiter, which has just begun its science mission at Mars, along with the in-service European Mars Express, are using radar to search for reservoirs of ice and/or liquid water under the surface of the planet. More surprises can be expected.

The Long Road to Mars

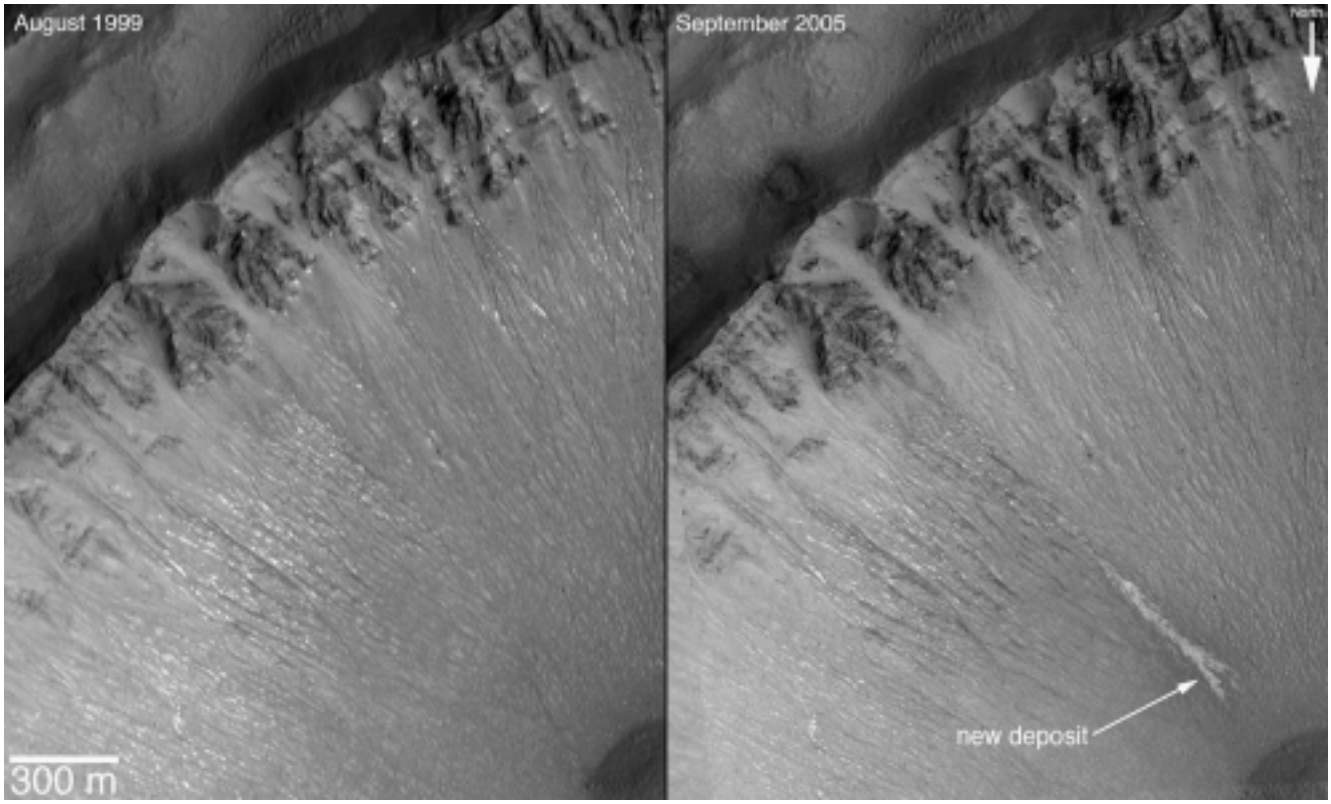
Two centuries ago, using ground-based telescopes, astronomers could see shades of light and dark material, somewhat fancifully interpreted as structures made by intelligent life forms. Periodic changes in the surface features of Mars led to the idea that the differences in coloration were due to vegetation, the growth of which waxes and wanes with the planet's seasons.

When the Space Age first brought men's sensory equipment closer to Mars, during the 1960s Mariner fly-bys, scientists were disappointed to find that not only was there no evidence of intelligent beings, but that Mars looked hauntingly like the dry, dead, pock-marked Moon.

The first Mars orbiter, Mariner 9, provided a closer look at the planet, revealing a landscape with dazzling geological features, including very large impact craters, the largest canyon in the Solar System (Valles Marineris), and the largest known volcano, Olympus Mons. It was clear that even were Mars today a relatively unchanging world, it had undergone an evolution similar to that of the Earth.

The mid-1970s Viking mission sent two orbiters and two landers to Mars, providing global measurements along with the first-ever "ground truth." A new Mars was revealed. The orbiters could see features ten times smaller than Mariner 9.

The Viking orbiters obtained 52,000 images of the surface of Mars, and helped characterize the planet's atmosphere.



NASA/JPL/Malin Space Science Systems

Using imagery from the Mars Global Surveyor, scientists have intensively studied intriguing gully formations inside craters and on slopes on Mars. Mars Orbiter Camera scientists have located a new, light-colored deposit of material inside a crater in a 2005 photograph (right), which was not there when the same crater was photographed in 1999. Their conclusion is that an eruption of liquid water from underground created these new soil deposits, some time over the past six years. There is liquid water on Mars.

Water vapor, it was found, is highly variable, depending upon local time, elevation, latitude, and the season. Mars, like Earth, has changing weather. Photographs taken by the Viking landers showed periodic layers of morning frost on surface rocks on Mars, demonstrating the movement of water ice and vapor around the planet. The Viking orbiters confirmed earlier evidence that there is a cache of water in the permanent ice cap at the north pole of Mars.

Some of the most dramatic evidence of previously existing significant amounts of liquid water on the surface, was seen in the photographs of Valles Marineris, with ancient river channels, connected valleys, and layers of material in the sides of the canyons. The most likely explanation for these features was an earlier warmer, wet Mars, with flowing water on its surface. The question became: Did liquid water exist on Mars long enough for life to have been able to flourish there?

Over the past decade, and to the present day, the next-generation, post-Viking spacecraft have all found more evidence that liquid water once existed on the surface. These include NASA's Mars Global Surveyor, Mars Odyssey, and Mars Exploration Rovers, and Europe's Mars Express spacecraft. But if liquid water did exist, how long ago was that?

In the year 2000, members of the Mars Global Surveyor (MGS) imaging team released spectacular photographs that showed gullies that had been formed inside the slopes of craters. These were similar to such formations on Earth, and suggested that they had been formed by liquid water running down the crater slopes. MGS also observed the layering of rocks, possibly from lakes of water, and identified the presence of gray hematite, a mineral that forms in an aqueous environment.

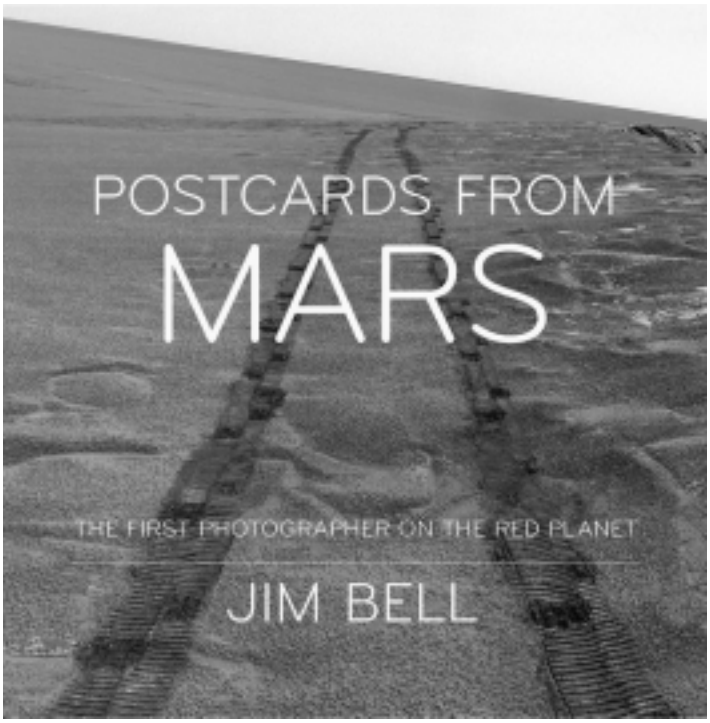
The long-lived Mars Exploration Rovers, *Spirit* and *Opportunity,* have verified from their on-the-ground excursions, the historical presence of water on Mars. *Spirit* found an assortment of rocks and soils, after a 2.6-kilometer drive to the Columbia Hills, of minerals such as the iron-hydrogen-oxide mineral, geothite, which bear evidence of extensive exposure to water. *Opportunity,* right at its landing site in Eagle Crater, examined an outcrop of rock that had been saturated, and formed under gently flowing surface water.

Europe's Mars Express orbiter has been returning data since early 2004, and confirmed water ice in the south polar cap of Mars. Its radar instrument has mapped layers at the pole, determining the thickness, and history, of the cap of ice. Its Omega near-infrared instrument has identified clays and sulfate minerals in ancient terrain, formed at a time when water may have been present on the surface.

As Mars Express continues to probe deep under the sur-

You Are There

Postcards From Mars
by Jim Bell
New York: Dutton, 2006
196 pp., hardcover, $50.00



Since January 2004, the two Mars Exploration Rovers, *Spirit* and *Opportunity,* have been sending back postcards from Mars. Previous cameras in place on the planet, such as the 1970s Viking landers, or the 1997 diminutive Mars Pathfinder rover, *Sojourner,* "acquired images," which is a technical, science-driven, resource-limited activity, scientist and author Jim Bell explains. The Viking landers did not rove. Pathfinder was short-lived and had very limited photographic and data transmission capability.

The Mars Exploration Rovers were outfitted with technology that allowed scientists, and the public, to see Mars as it would look to the human eye. Because the rovers could use the orbiting Mars Odyssey spacecraft as a link to transmit large amounts of data back to Earth, images have been at a much higher resolution than if the rover were to carry all of its own communications equipment. Because the rovers were designed for longer life (although no one expected them to be soon starting their third Earth year on Mars), scientists have been able to take the time to compose photographs, not simply point and shoot pictures.

Over the course of their travels, the panoramic cameras (Pancam) aboard *Spirit* and *Opportunity* have not only taken breathtaking color panoramas of their surroundings; they have photographed the Earth from Mars; the red planet's two small moons; their own shadows; pieces of, and the impacts from, their landing gear; and their tracks in the Martian soil.

Jim Bell has shared 150 of the more than 100,000 pictures taken by the rovers' Pancams in this magnificent book. To do them justice, it takes time to examine them, comparable to that required by the scientists to compose and process them.—*Marsha Freeman*

face, to discover whether ice or liquid water are present, NASA's recently arrived Mars Reconnaissance Orbiter is imaging geological features as small as a kitchen table, identifying minerals and materials at high resolution, using radar to probe underground to search for ice, and monitoring the Martian atmosphere and dust storms.

Right Before Our Eyes

On June 22, 2000, a team of scientists who had been studying high-resolution images from MGS reported that features they discovered were evidence that liquid water on Mars had made its way to the surface more recently than billions of years ago, when it is assumed the planet was warmer and wet. They proposed that seepage of water from below the surface might even be continuing at the present time.

Their evidence was about 120 sites where gorges, or gullies, had been created by material excavated by the action of flowing water from surrounding cliffs and sides of craters. From the alcove, or source of the water seepage, were seen channels that would have been carved out by the water. A fan-like apron formed at the end of the channels, where debris carried by the water was deposited.

The scientists, led by Michael Malin and Ken Edgett, investigators for the Mars Orbiter Camera, estimated that the features they observed would indicate liquid water 300-1,300 feet below the surface. Since the sites are not near volcanic regions, the researchers could not explain how the subsurface water, on this very cold planet, could be in liquid form.

Because more than 90% of the sites occur south of the equator at high latitudes, nearer to the colder polar regions, it

was assumed that any seepage coming to the surface would freeze almost instantly. Malin and Edgett proposed that when the water emerges and quickly evaporates, it freezes, due to low pressure and temperature on the surface of Mars. This block of frozen water produces an "ice dam."

Pressure would build behind the dam from the liquid water underneath, they surmised, and at some point, water would break through. A flood of water would run down the gully, carrying debris along with it, similar to flash floods on Earth. The most provocative conclusion from their research was that these features indicated floods on Mars, that while temporary, are much more recent than had been expected in the past. Key to this conclusion was an accurate estimate of the age of the features they were seeing.

Determining the age of a surface of another solid planet is generally done by counting the number and density of impact craters. This method is unworkable on Earth, where the geology, atmosphere, and biosphere constantly change the planet, erasing its past. On the airless Moon, where there is no weather and little evidence of geologic or volcanic activity for eons, this method is an accepted approach.

Mars falls in between. As far as we know, there is no biosphere reshaping the planet, but weather, seasons, climate change, and geologic activity are clearly evident there, at least from the past. In examining the sites where the gullies were found, Malin and Edgett reported that there was very little cratering, so they assumed that these are younger surfaces—millions, rather than billions, of years old, using the cratering rate to determine age.

The Mars Orbiter Camera imaging team continued their quest to find out more about these gullies. They instructed the MGS to revisit many of the sites, repeatedly imaging them, to see if anything had changed since 1999.

On Dec. 6, the team made a remarkable announcement. Examining photographs taken by MGS in 2004 and 2005, and comparing them to images of the same sites in 1999, two previously imaged gullies had bright new deposits. This suggests that at some time *during the past six years,* liquid water erupted from below the surface, and carried sediment through a channel.

"These observations give the strongest evidence to date that water still flows occasionally on the surface of Mars," stated Michael Meyer, lead scientist for NASA's overall Mars Exploration Program. "The shapes of these deposits are what you would expect to see if the material were carried by flowing water," explained Michael Malin. The two fresh deposits are each several hundred yards long.

Dr. Malin said in an interview after the announcement that the evidence suggests that the material that flowed down the side of the slopes moved very slowly, and was "dirt mixed in with something that gave it mobility." There is evidence that it "was changing its properties as it was moving downslope," as it picked up material along its path. The flow was "easily diverted around very, very subtle topography, and it has very long, finger-like terminations at the ends of these flows. Those are all attributes of something that has liquid water in it."

Over the years, the imaging team has discovered thousands of gullies on slopes inside craters and other depressions on Mars, and now have so far found two with new deposits. Could the new deposits simply be excavated material that has been moved around by the wind? The scientists think not.

Based on examination of the dark color of the soil unearthed by the wheel tracks of the two Mars rovers, photographs of real-time dust devils that kick up dark-colored sand, dark-colored material excavated from fresh craters, and the color of dust slipping down slopes, the team has eliminated the possibility that what they are seeing is subsurface material in the new crater wall deposits, since the color is not the same.

They propose that the light tone of the new deposit material in the gullies could be from surface frost continually replenished by ice within the body of the deposit. Another possibility is that a light-colored crust forms on the top of the deposit, as salts in the water become more concentrated.

Dr. Malin explained that the team thinks there is "a trickle of water initially . . . building up pressure behind the ice dam. . . . Eventually there's a rapid release of many thousands of cubic meters of water that comes out; swimming pool amounts of water come rushing out of the ground in a very short, brief event, and then the surface refreezes; then more water builds up time and pressure, and eventually breaks again." He likened the sudden water release to being out in the desert during a flash flood.

The imaging team also reported, at the briefing and in their paper published in the Dec. 8, 2006 issue of *Science* magazine, that their study of fresh meteorite impacts on Mars, also observed since 1999 by MGS, provide a direct measurement of the present-day impact cratering rate on Mars. They conclude, based on this new data, that the model used to predict the rate of new craters that is used to determine the age of features on the surface of the Moon and Mars, is consistent with the observed rate. This confirms that the gullies they are observing are indeed young surfaces.

As the scientists were presenting their new findings, mission controllers at NASA's Jet Propulsion laboratory in California were struggling to recontact the MGS, which had gone silent at the beginning of November 2006. No contact has been reestablished.

Apparently it has finished its mission, but MGS has done yeoman's service in advancing our understanding of the constantly changing planet Mars.

As the intensive, multi-mission study of Mars continues, on the ground and from orbit, sites are being examined for the next generations of landers and scientific laboratories that will continue the search for water, and possibly, life, on Mars. Their ultimate job is to prepare the way for the human explorers who will answer the most profound questions about the Solar System planet most like the Earth.