Rovers Discovering Mars Secrets and Questions

by Marsha Freeman

Scientists discussing the process of planetary exploration often say that what they learn during a mission will pose more questions than are answered. In the case of Mars, nothing could be truer.

All of the successful landers that have been deployed to the surface of Mars in the past have been set down in sites chosen, largely not for their scientific interest, but to meet the criterion of safety. There was no point in choosing the most interesting region of the planet, if there were little chance the rovers would survive the descent and landing on the surface. And many of the most interesting sites scientifically, are in regions where the topography prohibited such risky landings.

But the success of the 1997 Mars *Pathfinder* mission, with its miniature *Sojourner* rover, verified the approach of landing on the surface by deploying air bags to protect the spacecraft, even in rocky terrain; it encouraged the engineers to employ the same technology to set down two rovers this year at sites chosen by the scientists of NASA, rather than its engineers.

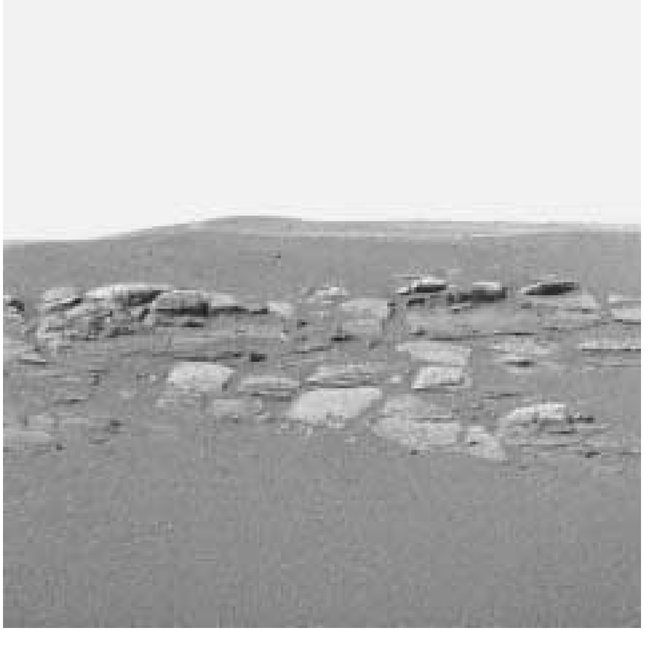
NASA's decadal approach to Mars exploration is to "follow the water" on the red planet, seeking confirmation on the ground, of clues gained from orbit that at one time Mars was a warmer, wet planet, with rivers, lakes, and perhaps oceans.

The two sites for the Mars Exploration Rovers, named *Spirit* and *Opportunity,* were chosen because they indicate the past presence of water on Mars. *Spirit's* Gusev Crater appears, from orbit, to have once been home to a large lake, with outflow channels leading into rivers. *Opportunity's* Meridiani Planum is covered with the mineral gray hematite, which on Earth, often forms in the presence of water. Scientists hope that *in situ* intensive investigation of these two sites will confirm their orbital hypotheses.

The first phase of the rovers' exploration was the "wow" phase, that produced three-dimensional color panoramic images. At Gusev Crater, an inviting series of hills in the distance, and smaller craters inside the larger Gusev, whet the scientists' appetite. At Meridiani Planum, the outcrop of bedrock inside the small crater where the rover landed promised to provide the first look at ancient rock formation on Mars.

But so far, the rovers have found no evidence of past water at Gusev Crater, nor any gray hematite at Meridiani Planum which they can say, without hesitation, formed in the presence of water. Mars does not give up its secrets easily.

The rovers are now engaged in their less dramatic, but more important, intensive study of the rocks, soil, and atmo-



While the primary assignment for the Mars Opportunity *rover is to find the origin of the crystalline gray hematite seen from orbit, its serendipitous landing inside a small crater at Meridiani Planum, has led scientists to focus its initial exploration on this outcrop of bedrock, which reveals the ancient history of the planet.*

One of Opportunity*'s first assignments was to examine the soil near its landing site. This patch of soil, 1.2 inches across, captured by its microscopic imager, unexpectedly revealed circular or spherical grains. The one in the lower left is about 0.12 inches across, or about the size of a sunflower seed.*

sphere at their respective sites, using the identical suite of instruments each carries along as they move from one target of study to the next. Scientists are searching for the "ground truth" to the features found through remote sensing from Mars orbit.

The two explorers are not yet even half-way through their three-month mission on Mars, so science team members are hopeful that before the Mars Exploration Rover mission is completed, at least some questions will be answered, though more will be raised.

The Mysterious Spherules

The huge amounts of data streaming back to Earth from the Mars rovers is allowing the scientists to start to eliminate hypotheses, about phenomena they did not even know existed.

On Feb. 4, the science team announced that the examination of a patch of soil in the small crater where *Opportunity* landed—its first scientific investigation—did not reveal the presence of hematite, but did reveal strikingly spherical pebbles among the mix of larger particles that are sitting on a bed of fine sand. "There are features in this soil unlike anything ever seen on Mars before," stated principal investigator Dr. Steve Squyres.

The spherules appeared in pictures of the soil taken by the rover's microscopic imager, which is able to resolve features as small as 0.2 inch, or the size of a sunflower seed. Dr. Ken Herkenhoff, from the U.S. Geological Survey's Astrogeology Team, noted that "the variety of shapes and colors" indicates the presence of "particles brought in from a variety of sources."

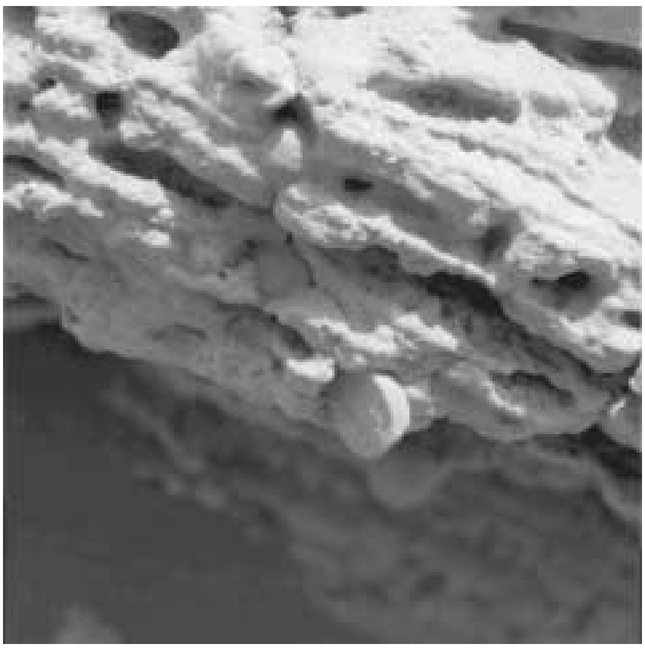
The variety was interesting, but the spherules themselves were intriguing, as "there are only so many ways to make really round grains," Dr. Squyres explained. Dr. Hap McSween from the University of Tennessee cautioned that not only the action of water, but a number of "straightfoward geological processes can yield round shapes."

The spherules could have accreted from minerals precipitated from a liquid water solution; or they could have formed into droplets from material heated and thrown up into the atmosphere, from volcanic eruptions or meteor impacts. Some of the small pebbles have holes in them, perhaps produced by volcanic processes, when gas bubbles formed in the solid material, according to Dr. Squyres.

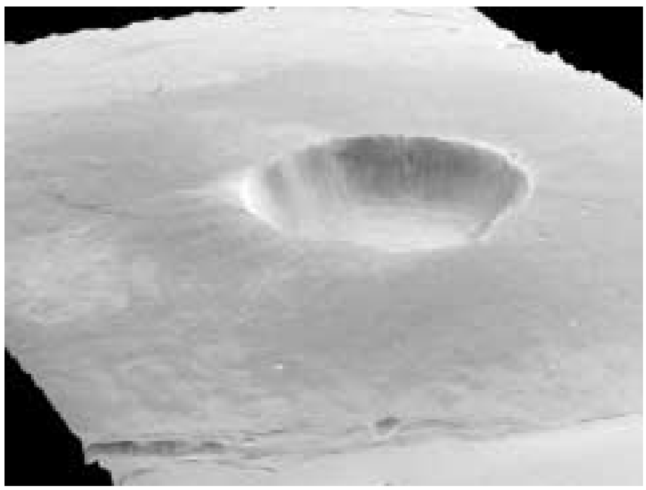
One day later, on its 12th day on Mars, *Opportunity* drove more than ten feet toward the right side of the outcrop of bedrock, and over the next two days, nestled up to take a closer look at a rock called Snout (since renamed Stone Mountain, even though it is only a few inches in height).

On Feb. 9th, scientists reported that microscopic images of Stone Mountain revealed yet more tiny spherules, seen embedded in the layers of the rock, "like blueberries in a muffin," as Squyres described them. And the photographs provided one explanation as to why *Opportunity* found these tiny spheres in the soil.

The layers in the rock, Squyres reported, are made of a fine material, either dust or sediment, and are only fractions



The microscopic imager showed spherules, similar to those found in the soil, embedded in the matrix material of the outcrop rock. One spherule appears just about ready to fall off, on to the soil. A crack in the rock can be seen tracing back up the rock from the visible spherule.



The major agent of change on the surface of Mars is no longer liquid water, but its constantly-changing weather, and dust storms. This photograph, taken on Jan. 19 by Europe's Mars Express *orbiter, is a three-dimensional oblique image of the summit* caldera *of the volcano Albor Tholus. On the far left rim of the crater, bright "dust fall" (rather than snow fall) seems to be flowing from the surrounding plateau into the* caldera.

of an inch thick. The spherules appear to be made of a different material than the rock's primary layered material, or matrix. The matrix is a tan or buff color, and the tiny spheres are very gray. "That's a hint that they may be different in composition," he reported.

Apparently, millions of years of sandblasting from the periodic dust storms that rage on Mars, has exposed many of the spherules; and in the images, some are seen just barely hanging on to the matrix material. Also visible in one microscopic image is a string of tiny embedded spheres, which may have cracked the apparently softer matrix rock layers.

Dr. Squyres proposed that the spherules found in the soil had fallen off the outcrop of rocks nearby and rolled downhill. But how did they form in the first place?

It was now possible to start to eliminate hypotheses, because the same phenomenon was found in two different contexts. The idea that the spherules formed when ash from a volcanic eruption was suspended in the air, agglomerated, and fell from the sky, Squyres said, was losing favor, because it would tend to produce spherules of the same material as the rock's matrix, which now seems unlikely.

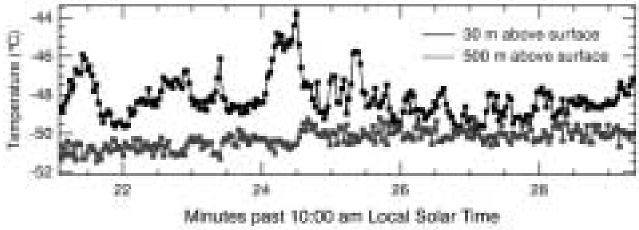
It is still possible, from the data acquired so far, that the tiny spheres formed when molten rock froze in mid-air and formed into glass beads. But the most interesting possibility is that spherules may have formed as the layer of rock formed, concreting as dissolved minerals flowed through the rock, precipitating granular nucleation points which then grow over time into spheres. If that is the case, one would expect to find layering preserved in the spherule.

The scientists are confident that with its suite of instruments—which can not only image the spherules in detail, but use spectrometers to unearth its composition—*Opportunity* may even ascertain that these particles contain some of the hematite the rover was sent to find.

Mars Thermals

If there were once liquid water on the surface of Mars, carving out canyons and creating the geological landscape, it is long gone. Frozen water exists in both its north and south poles, and there are indications from orbital measurements that caches of water ice reside not far from the surface. At the present time, however, and in its recent history, the agent of change on Mars has been its weather—the daily and seasonal variations in temperature that change the composition of its atmosphere as ice sublimes, and create winds and violent global dust storms on the planet.

The two rovers on the ground each carry a miniature thermal emission spectrometer, or Mini-TES, which is a smaller version of the same instrument carried on the orbiting Mars *Global Surveyor.* By designing experiments to coordinate observations from orbit looking down, with data from the rovers looking up, atmospheric scientists will be able to produce a seamless weather map for Mars, from the ground to a few hundred miles above the surface. Refining the prediction of



Measurements taken by the Mini-TES instrument aboard Spirit *revealed that in mid-morning, thermals—or transitory warm air masses—pass over the rover. The thermals appear at about 100 feet above the surface of the planet.*

the weather on Mars is critical to the high-precision landing of future spacecraft. In addition, on-going—not just historical—geologic processes on Mars will be better understood, such as how the layered bedrock at Meridiani Planum is being eroded, allowing the "blueberry" spherules to drop out on to the soil.

The main task for each Mini-TES is to measure and characterize the thermal emissions of rocks and soil, to determine their mineral composition. But twice a day, the Mars *Global Surveyor* (MGS) passes over the rovers, and scientists can instruct the rover's instrument to look up, while the orbiter's Thermal Emission Spectrometer looks down at the rover site. Mini-TES on the rover can "see" temperature differences up to three miles above the rovers; MGS can measure temperature down to about three miles above the surface.

During a briefing at NASA's Jet Propulsion Laboratory on Feb. 12, Dr. Don Banfield from Cornell University presented data taken by the Mini-TES aboard the *Spirit* rover on its 12th day on Mars, as it "stared" at the sky. Measurements were taken every two seconds, producing data of changes taking place about 100 feet and at nearly 1,000 feet above the surface, mid-morning local time at Gusev Crater.

Dr. Banfield reported that very significant changes (7° Fahrenheit) in temperature were measured, passing intermittently over the rover. As the ground warms in the morning Sun, the hot air rises through convection, moving away from the surface, and is replaced by cooler air. The change is such, he said, that, were you standing there, you would feel the difference in temperature. These periodic temperature changes are called thermals on Earth. It is the first time they have been seen on Mars. Dr. Banfield said that these warm air pockets rise to about 300 feet.

Over the weekend of Feb. 15-16, *Opportunity* was instructed to look at the sky, while MGS was looking down. The data received from these coordinated measurements are now being analyzed. Scientists hope to be able to create a seamless temperature profile for the Martian atmosphere, from these simultaneous and complementary measurements. They hope to be able to better describe the conditions that create the dust storms, that today are the agents of change on a constantly changing Mars.