Rovers Find Proof, Mars Was Once 'Soaked' With Water

Scientists have long thought that there was once water on the surface of Mars, based on orbital photographs. Now they have on-the-ground proof. Marsha Freeman reports.

A planet-shaking announcement was made on March 2 at a special briefing held at NASA headquarters in Washington. Scientists announced that data returned by the two Mars Exploration Rovers confirmed that at one time in its history, there was water on Mars. Photographs of canyons and dried-out riverbeds taken from orbit had shown evidence of water there in the past, but now there is "ground truth." The presence of water, science leader Dr. Steve Squyres stated, means this site "was a habitable place."

Water is the only known *necessary* ingredient for life. On Earth, simple life forms have been found in the most extreme environments—even those similar to Mars—and even if there is no sunlight or air, if there is water, there is life. Although the Mars rovers *Spirit* and *Opportunity* will not be able to answer the question of whether there has been, or is, life on Mars, they have now answered the question of whether the prerequisite, liquid water, was present.

Meridiani Planum, the Oklahoma-sized plain where *Opportunity* is exploring, was chosen as the landing site because orbital measurements had revealed a layer of gray hematite on the surface. This mineral forms in the presence of water on Earth, and so would provide a footprint for the existence of past water on Mars. Fortunately, *Opportunity* missed its prime target by a few miles, and did not land on the open plain, but inside one of a number of small craters in the area. The crater is 72 feet in diameter and nearly 10 feet deep.

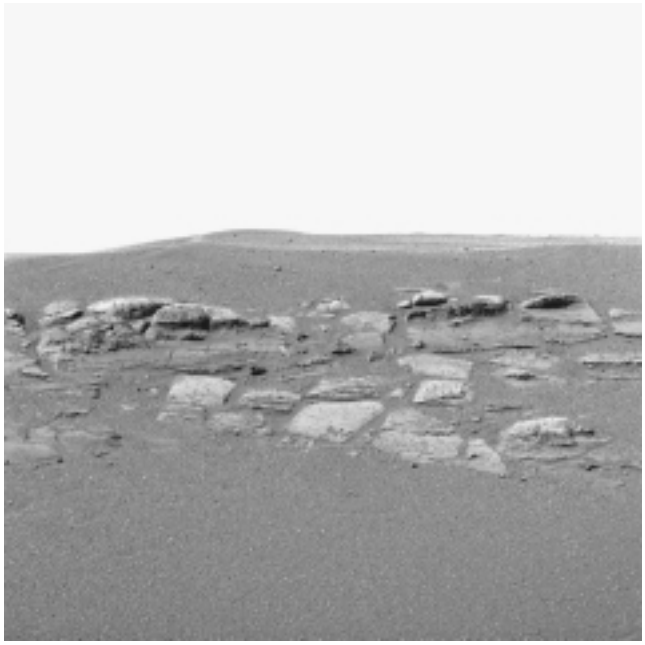
Lying only tens of feet from the landing site, within easy reach, was an outcrop of rocks that scientists immediately recognized as having formed in the very early days of Mars, billions of years ago. The bedrock sits on the wall of the rover's small crater, and was thrown up near the rim when the crater was made by a meteor impact. The bedrock, since named Opportunity Ledge, tells the story of the ancient history of Mars.

The Chemical Evidence

The data that led the scientists to make the categorical statement that Meridiani Planum was once "soaked" with water, was returned from three of the scientific instruments located on a deployable arm on *Opportunity*. Each set of data from the spectrometers takes at least 10 hours to collect, and then two or three days to transmit back to Earth. The scientists have been patiently waiting for the results of their experiments.

It is only natural that the scientists studying the features on Mars rely on what they know about the geology, chemistry, and history of the Earth to try to inform their understanding of Mars.

Lyndon LaRouche has posed the possibility, however, that chemistry on Mars may not be entirely comparable to that of the Earth. In his article titled, "On the Subject of Tariffs and Trade" (*EIR*, Feb. 13), he discussed the challenge faced by the human race, to overcome the limited supply of indispensable minerals natural to Earth, that will be increasingly depleted as population grows. "We need a physical chemistry which does not continue to rely upon blind faith in 'magic numbers' to seem to explain away how the Solar System actually generated the repertoire of what is already known as the naturally-found periodic table of the Solar System," LaRouche wrote. "We must get out of the intellectual prison of our current textbooks, and go to Mars, hoping to find the different physical chemistry, which will help us to develop a physical chemistry—including a nuclear physical chemistry—beyond what we know from studies on Earth."



The discovery by the Opportunity *rover that Mars once had water, was made through the intensive analysis of this field of rocks in an outcrop of bedrock near the landing site.*

The two Mars Exploration Rovers are providing the most detailed insights into the similarities, and the differences, between the chemistry of Mars and the Earth.

The rover's Alpha Particle X-Ray Spectrometer, or APXS, which reveals the elemental composition of rocks and soil, identified large amounts of sulfur in outcrop rocks. *Opportunity* spent a few days at the part of the outcrop called El Capitán; and in that region, a rock named McKittrick was found to contain the highest concentration of sulfur ever observed on Mars. The APSX uses radioactive curium-244 to bombard a target area with alpha particles and X-rays, causing a cascade of reflective flourescent X-rays. Each chemical in the soil or rock is identified by a unique spectrum or footprint reflecting the energy level of the radiation produced.

If the sulfur concentration were found only on the surface of McKittrick as a coating, that would have been interesting, but not conclusive. In fact, the sulfur was found inside the rock, after the rover's Rock Abrasion Tool (RAT), drilled a circular hole about 0.16 inches deep and 1.8 inches in diameter. The spectra from McKittrick also showed the presence of bromine.

The examination of another section of El Capitán, at the rock dubbed Guadalupe, found similarly high concentrations of sulfur, but with very little bromine. The scientists report that this "element fractionation" typically occurs when a watery brine slowly evaporates and various salt compounds precipitate out, in sequence, over time.

In addition, data collected by the Miniature Thermal Emission Spectrometer (Mini-TES), which identifies the minerals present, showed that the sulfur is present in the form of mineral sulfates. The scientists think the salt that is probably most prevalant is magnesium sulfate, which can be found at the local drugstore in the form of Epsom salt, on Earth. The salt content may be as much as 40%, an "astounding amount," which would mean the water it precipitated from is "like the Dead Sea," stated Dr. Benton Clark.

A third instrument, the Mössbauer spectrometer—contributed to the mission by the University of Mainz in Germany—specializes in identifying various forms of iron-bearing minerals. At the El Capitán site, the instrument detected the presence of jarosite—an hydrated iron sulfate, which contains water in the form of an hydroxyl as part of its structure. Typically, jarosite spends time in an acidic lake or acidic hot spring environment, on the Earth.

The scientists find no other explanation for these results, than that water was involved in the history of the ancient bedrock. Dr. Squyres reported that there are two possibilties: that the rocks were formed through the deposition of volcanic ash into layers that were porous, and that ground water later percolated through the rocks, changing their chemistry; or, that the rocks were formed out of sedimentary layers, when salts and minerals that were dissolved in water periodically precipitated out into sold form.

If there were a salty sea in the region of the crater where *Opportunity* sits, there is no topographic evidence for it today. There is no basin that could hold an ocean, or observable shoreline. But Dr. Squyres cautioned that does not mean that the topography was not quite different in the past.

At the March 2 special NASA briefing, another piece of new evidence for past water on Mars was discussed by Dr. Benton Clark, from Lockheed Martin. Very detailed photographs taken by the rover's Microscopic Imager reveal that inside the outcrop rocks are tiny holes, or voids, which Dr. Benton said are called "vugs." These voids, he explained, match the distinctive appearance of hollows that form in rocks on Earth, where crystals of minerals grow when the rocks sit in briny, or salty, water. Later, when the crystals themselves disappear, because they are eroded by the wind or dissolve in water, the holes or molds that they created are left behind.

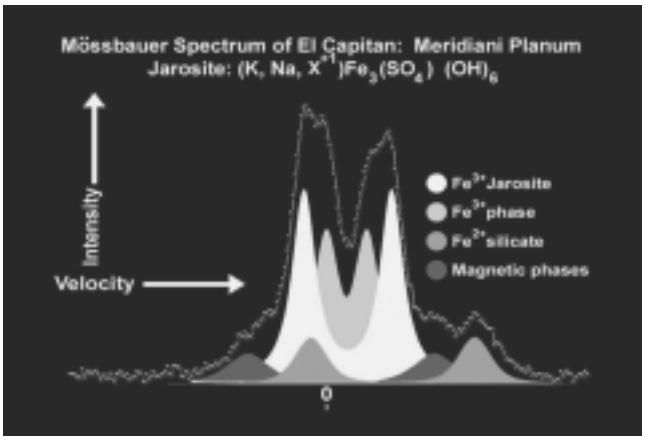
Some of these Mars vugs have disk-like shapes, with wide midpoints and tapered ends. This is consistent with sulfate minerals that crystallize within the rock matrix, either pushing the matrix material aside, or replacing it.

A Closer Look at the First Hints

Since it opened its panoramic-camera eyes on Mars a few hours after landing on Jan. 25th, *Opportunity* has been sending back intriguing hints that there may have been water in Mars' past. Additional data collected recently, which represent a broader-scale, yet more detailed examination of *Opportunity's* small crater on Meridian Planum, are adding to the evidence for water which has been confirmed in Mars' chemistry.

When *Opportunity* first imaged the outcrop, geologists recognized that many of the rocks were made up of layers, different from the volcanic basalt rocks at the *Spirit* rover

Two of the rocks in the El Capitán formation that Opportunity *targetted for detailed study, were the triangular-shaped McKittrick—in the center of this photograph—and Guadalupe, further up. Both have been drilled into with the rover's Rock Abrasion Tool, indicated by the circular drilling patterns seen in the photo.*



The key data collected by the Mössbauer spectrometer at the El Capitán rock collection was the identification of the iron sulfate mineral, jarosite. Its spectral signature is seen in the two light-colored peaks to the right and left of center of this graph.

base in Gusev crater, halfway around the planet. The layering could have been produced by periodic depositions of volcanic ash, or sediments of minerals that precipitated out from a briny water solution.

On its 17th day on Mars, Feb. 10, *Opportunity* had rolled to within striking distance of the rocks at the outcrop, and the panorama photographs showed clearly that the layers in the bedrock were not always parallel to each other, like a perfect layer cake. Instead, the layers appeared to have cross-bedding, or different thicknesses within a layer, indicating their formation would have been from some sort of flowing motion. This motion could have been from wind, or water.

Standing water, such as a lake or ocean, could have created the layers, as the water evaporated, leaving the minerals behind. Or they could be the result of the same process, in the periodic action of water—in ebbs and flows.

One of the most interesting outcrop rocks for the study of rock layering, is called Last Chance. It appears to have evidence of a geologic feature known as ripple cross-stratification. The thin layers (0.4-0.8 inches thick) at the base of the rock are dipping down toward one side. In the upper right corner of the rock, layers also dip to the right, giving the rock a weak concave geometry. The combination of this thin, cross-layered bedding, combined with the concave geometry, suggest the action of small ripples with sinuous crest lines.

The scientists point out that although the wind can produce ripples, on Earth they rarely have crest lines, and never form steep, dipping layers at such a small scale. The most probable explanation is that the ripples were formed in the presence of moving water.

Opportunity will do an intensive, all-instrument investigation of Last Chance, and geologist and science team member Dr. John Grotzinger said at the March 2 briefing that he hoped the scientists will be able to narrow down the possibilities, and conclude that it was water that created these features on the ancient Mars rocks. At least they will be able to "narrow the range of possibilities," Dr. Grotzinger said.

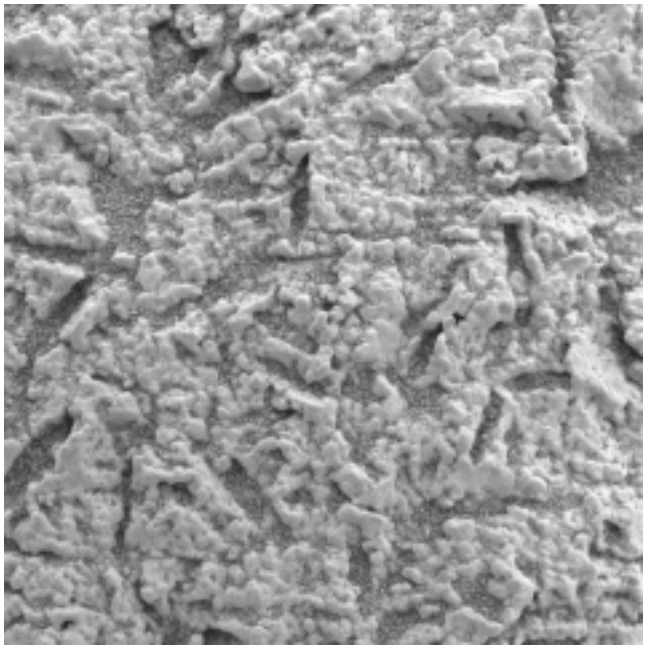
Another hint of the action of water that has been evident since the end of January, is the presence at Meridiani Planum of round, grey-colored particles, Since then, everywhere that *Opportunity* has looked, it has found these spherules. They are on top of the fine-grained soil, underneath the surface, and on, as well as inside, the outcrop rocks.

Until early March, the scientists were entertaining three possible processes for the creation of these curious spherules: droplets of molten volcanic glass, called *lipilli,* cooled into a "volcanic hailstorm," and dropped from the sky; droplets of soil material that became heated and tossed into the atmosphere from a meteor impact, fell from the sky; or, concretions were formed inside the rocks around small grains of material that were dissolved in water, and precipitated out.

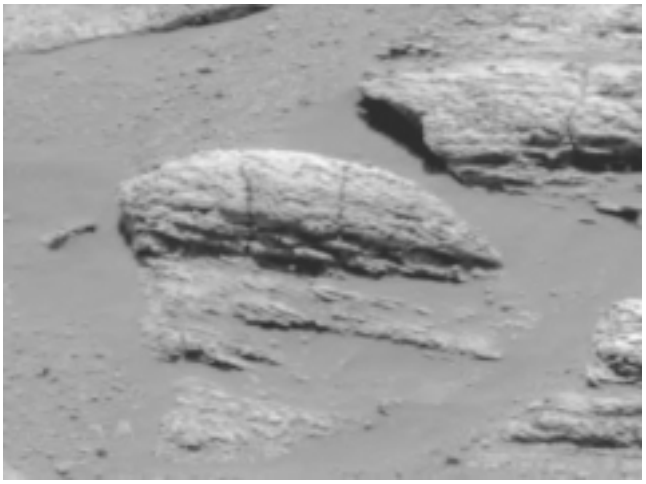
At the March 2 briefing, the science team members presented new material concluding that concretion, in a water environment, created the rounded spherules. They observed that the spherules found in the rocks, when the rover's Rock Abrasion Tool drilled down inside, did not deform the rock layers in which they reside. This indicates that the spherules did not come bounding in from the sky. Similarly, their presence throughout the rock's interior indicates they formed inside the rock and were not imported.

Spirit Finds Water, Too

The *Spirit* rover is working inside a large crater the size of Connecticut, named after 19th-Century Russian astronomer



Peering inside the rocks at El Capitán, scientists found voids created by crystals that have since disappeared, called vugs. The Microscopic Imager took this picture on Opportunity*'s 28th day on Mars, which highlights these hollows inside the rock. The area in the picture is about 1.2 inches across.*



This image, taken at the outcrop rock named Last Chance, shows layers making up the rock which are not parallel, or which are cross-bedded. Scientists say the most probable explanation of the ripples in the layers is the presence of moving water.

Matvei Gusev. This site was chosen for the rover's landing because orbital photographs suggest Gusev crater was once filled with water, as there are outflow channels, and what appear to be beachheads there.

As *Spirit* was first on the scene, landing on Jan. 3, three weeks before *Opportunity,* it returned the first *in situ* data on the characteristics of Mars soil, soon after it rolled off its lander. Just as the Apollo astronauts left their footprints on the Moon, *Spirit* left its wheel tracks on the Martian soil.

Navigation engineers, responsible for safely guiding the rover around its terrain, noticed from the first post-drive images that the soil seemed to be sticking to the rover's wheels. It is possible, scientists believe, that this cohesion in the soil could be from layers of dust that have been compacted; or, that brine, or salty water, has created a kind of cement. It seems the soil could be "sticky" from salty water oozing from underground.

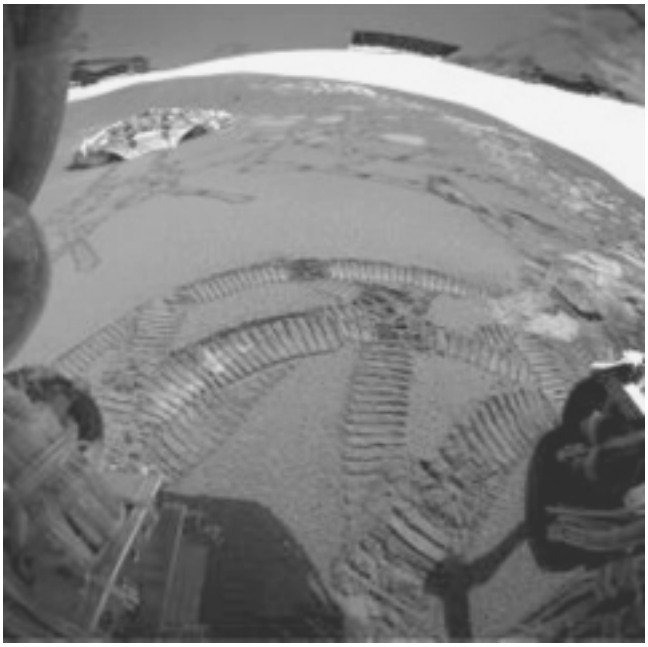
At the end of February, as engineers and scientists were examining *Spirit's* tracks, Dr. Lutz Richter of the German Space Agency, who is a rover science team member, said, "I would compare the rover tracks to the boot prints of geologists walking around on Earth. They immediately give us information about the nature of the material on which we are roving." He explained that "the material we are on has given way to the weight of the rover in some places. We can measure the amount of sinkage, and that tells us the strength of the material we are on. . . . So far, we have seen a lot of variation."

Their analysis has led the scientists to believe that the surface material at Gusev Crater contains a thin crust covering the soil. Dr. Richter reported that preliminary chemical analyses indicate high amounts of chlorine and sulfur on the topmost layer of the soil. He said that there must have been at least trace amounts of water at work, to produce this chemistry. There are a few possibilties. "Perhaps a few hundred thousand years ago," he proposed, "the atmosphere might have been saturated, and could have been responsible for this recent crust at the Gusev site."

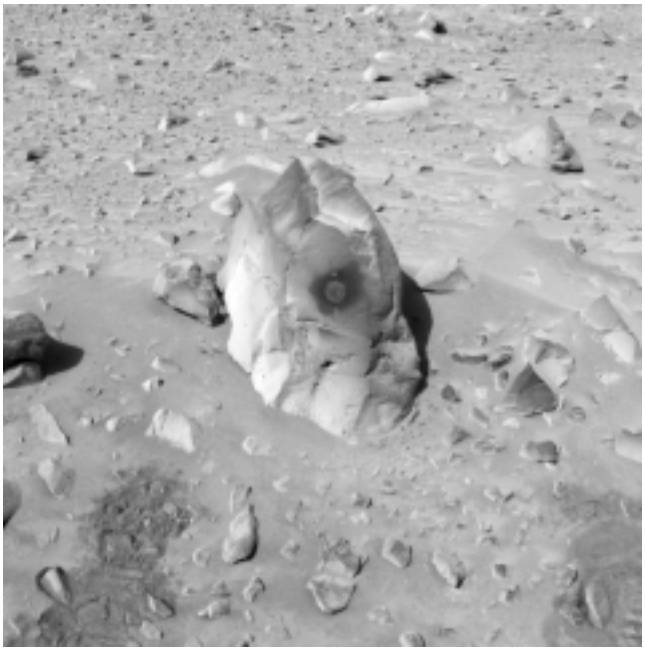
On its 45th day on Mars, on Feb. 17th, *Spirit* returned images of fine-grained soil it was studying in a small depression called Laguna Hollow. Inside the Hollow, scientists could see irregular patterns of lines and polygons. Such patterns are found on the Earth, Dave Des Marais from the science team explained, when you have freeze-thaw activity, "such as in tundra. You can also get that in a salt flat, where the salt, by warming, or by wetting and drying, expands and contracts. This forms a very characteristic polygon pattern. You can do it with mud flats, with mud cracks."

Des Marais speculates that because these patterns are still visible on the surface today, they could be due to an active, ongoing process on Mars.

At a briefing at the Jet Propulsion Laboratory on March 5, scientists discussed another hint from *Spirit*'s adventures, that small amounts of water existed at Gusev Crater. The interior of a dark volcanic rock named Humphrey, which was examined after the rover's Rock Abrasion Tool had scraped away the surface, contains bright material in cracks and crevices that looks like minerals crystallized out of water, reported Dr. Ray Arvidson. "If we found this rock on Earth," he explained, "we would say it is a volcanic rock that had a little fluid moving through it." The amount of water suggested by Humphrey's crystals is far less than what is indicated in the mineral structures found by *Opportunity,* but could be a hint of more extensive findings, soon to come.



The tracks the rovers make in the soil are a result of their rolling on their six wheels to their next target. But the tracks provide information about the cohesion and other characteristics of the soil, and can also be a marker for water. This clear set of tracks was made by the Opportunity *rover, and photographed on its 37th day on Mars. The outcrop of rocks is visible on the horizon, and on the far left is the lander that the rover has left behind.*



At the Spirit *site, scientists have not found layered rocks; but Humphrey, seen here, which is volcanic, has its own interesting features. In order to examine what is inside, the Rock Abrasion Tool was used to dust off a small section of the surface, and then used its diamond-head drill to make a shallow hole.*

What Could Live There Now?

At the March 2 briefing, Dr. Clark threw out the intriguing idea that there are micro-organisms that could live in the high-sulfur environment that the rovers have found on Mars. They would have to be able to hibernate during the colder, winter spells, perhaps in the form of spores, and then re-animate in the warmer weather.

Dr. Clark believes that one Earth-bound, sulfur-reducing microbe that could make a home on Mars is *Desulfotomaculum,* which could live off the sulfate found in the Martian rocks. Terrestrially, it is found in soil, water, and geothermal regions, and also in the intestines of insects and animal rumens. It reduces sulfur compounds to hydrogen sulfide. Sulfur is its energy source, so "it can work independent of the Sun," Dr. Clark explains. It can also form spores, "so it can hibernate" over the Martian cold spells.

It does need some hydrogen for its metabolism, but there is ample evidence of the existence of hydrogen on Mars, probably in the form of water ice, under the soil of a large area of the planet. In equatorial regions in the summer, some of that ice may melt. There may also be supplies of liquid water residing underground.

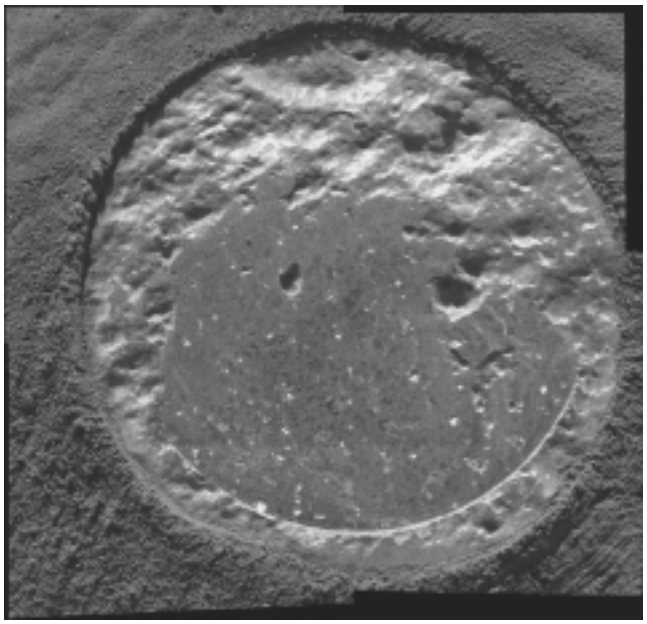
How would you know if you have found them? Dr. Clark says that you would have to be able to carry out isotopic fractionation. "When living organisms process sulfur, they tend to fractionate isotopes differently from geological or mineralogical" processes. To do that intricate examination, samples will have to be brought back to Earth.

Finding fossils would be no easy task on Mars. Dr. Grotzinger explained that on Earth, finding fossils preserved in ancient rocks is very rare, as they will likely be on Mars. But the signatures for past life, like the signature in Mars' chemistry for the past presence of water, will be on the agenda as more and more sophisticated robotic missions, and finally people, make their expeditions to the Red Planet.

What's Next?

Opportunity is still in the midst of its investigations inside its small crater. It will be heading over to a different area of the outcrop where there is a rock that has a bowl shape. Inside, the panoramic cameras indicate, is a cache of the small, rounded spherules that rolled down the side of the carter and collected there. The scientists plan to take measurements of surrounding rock, and then of the bowl, and compare them. By subtracting out the minerals that are similar, they hope to see if there are any differences that can be attributed to the cluster of spherules.

More studies will also be done of the heavily layered rocks in another Ledge region called Big Bend, to see if more can be learned about the water history of the site. Dr. Grotzinger said that the cross-bedding there appears to be different, which could indicate a different mineralogy. He expressed optimism that the additional data will resolve



This mosaic of images taken inside the hole drilled into Humphrey, is almost two inches in diameter. The Microsopic Imager can only capture a portion at any time of the area that has been ground away by the abrasion tool, so a number of images have been carefully stitched together to create this one. It shows sinuous veins inside the volcanic rock which could be evidence of water trickling through the material.

The next spacecraft bound for Mars in NASA's campaign, will be the Mars Reconnaissance Orbiter, to launch in 2005. It will be able to image the landscape to see details as small as a table, will scan for underground layers of water and ice, and will identify surface minerals. Scientists will use what they have learned from the rovers on the ground, to refine their search from orbit.

some of the questions about water on Mars, over the coming weeks.

After it completes it intensive study of the ancient outcrop rocks, *Opportunity* will head toward the rim and then venture out of its small crater. As it crosses the plain, scientists plan to search for the hematite the rover was sent there to find. Crystalline gray hematite forms in the present of water on Earth. Orbital data indicates Meridiani Planum should contain significant amounts.

To the east on Meridiani Plain is a larger crater, named Endurance, which is about 40 yards away. Endurance appears, from orbital photographs, to have brightly colored material on its rim, said Dr. Joy Crisp at the briefing. That material may be similar to the outcrop *Opportunity* has been exploring; but because it is nearly 100 feet deep, the material exploded up to the rim when the crater was formed may be even older than the outcrop at Opportunity Ledge.

Spirit will continue its excursions inside Gusev Crater, also heading toward a crater rim; that of a smaller crater within Gusev, to examine outcropped rocks there.

At the briefing, a string of reporters tried to pin the scientists down as to how much water existed at Meridiani Planum; when, and for how long it was there; whether it was underground or on the surface; and whether it was persistent, or came in ebbs and flows. Dr. Squyres insisted that these questions could not be answered with the suite of instruments aboard the two rovers currently on Mars.

In order to squeeze more secrets out of the rocks and soil on Mars, samples must be brought back to laboratories on Earth. In that way, trace elements, to the level of parts per billion, could be detected in the material. Isotopic differences in elements could provide further clues as to their age. An entire armamentarium of the world's most sophisticated scientific instrumentation would be brought to bear to investigate the samples.

NASA headquarters Lead Scientist for Mars and the Moon, Dr. Jim Garvin, outlined the next steps in the space agency's Mars exploration program at the briefing. More sophisticated orbiters, a lander that is a mobile laboratory, and additional infrastructure are planned. And a decade from now, samples from Mars should be reaching laboratories on Earth. Dr. Ed Weiler, NASA Associate Administrator for Space Science, said that as envisioned in President Bush's exploration initiative, these will be precursors for the first human missions to Mars.

Three kinds of missions will follow in the future, Dr. Weiler explained. These will include a sample return, both for scientific inquiry and in preparation for manned missions; *in situ* astrobiology, where instruments are sent specifically to search for past signs of life; and, the landing of equipment and infrastructure to prepare for the manned missions, and to test the environment for characteristics such as the toxicity of the soil.

Will it be possible to know conclusively, if life ever existed on Mars? Probably not until we go there ourselves.