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Around the Lander in 80 Sols

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ARES VALLIS, MARS—It's like a whole new landing site. One advantage of Mars Pathfinder over its Viking predecessors is the rover, Sojourner, which is proving to be a capable miniature geologist. Now more than 80 Martian days—called Sols, each of which is approximately 24 hours, 37 minutes long—into the mission, Sojourner continues to provide new perspectives on the Pathfinder landing site. Sojourner is giving the engineering team a wealth of data and experience that will be useful when the next rover reaches the red planet in 2002.

A prime example of the new perspectives provided by the rover came on Sol 76 (September 19, 1997), when Sojourner peeked behind the 0.2–0.8 m-high boulders of the "Rock Garden." This vista contained a beautiful set of wind-blown drifts that were not visible to the lander's stereo imaging system (Figure 1). The drifts occur on the downwind (southwest) side of a cluster of imbricated boulders and are analogous to the variety of wind-tails seen behind cobbles and pebbles throughout the landing site.

Sojourner began examining the Rock Garden site south of the lander in August. It continued this exploration into mid-September. The main objective was to obtain Alpha Proton X-ray Spectra (APXS) measurements of the relatively dust-free rock surfaces in this area (see *Eos*, September 16, 1997, pp. 389–390 for more information). The solar-powered rover is now operating only during the day. A battery designed to allow for night time operation of the APXS quit around Sol 60, yet it lasted about 52 Sols longer than originally projected.

Between July 5 and September 23, Sojourner obtained APXS spectra of eight different rocks (and a second spectrum for one of these rocks) and 7 different soils. According to the Mars Pathfinder science team, the soil spectra include the flat, white, rocklike feature known as "Scooby Doo." Although Scooby Doo is too well cemented for the rover wheels to scratch, the APXS data suggest it is more like the soils than the rocks because its chemistry matches that of the soil.

The rover left the Rock Garden in mid-September and headed counterclockwise toward the east. It stopped at a rock named "Chimp" and took APXS data. Now the rover is headed on a long trek back around the lander to the ramp magnet near "Barnacle Bill" rock (this magnetic plate located on the ramp used by Sojourner to get down to the surface on July 5th, has been collecting magnetic dust settling from the atmosphere). No more APXS data are planned to be obtained during the next 10 or more days; instead, the rover team will give Sojourner its most vigorous workout.

The rover has already lasted more than 10 times longer than originally planned, and now is an ideal time to perform engineering tests that will help in designing the Mars Surveyor 01 rover. The 01 rover will land in January 2002 and is expected to explore tens of kilometers of the ancient cratered highlands for at least 365 days. The new rover will collect and cache samples for eventual return to Earth.

During its counterclockwise journey back around the lander, Sojourner will venture over different terrain, a little bit further out from the lander than it was when it drove through the area in early August. The engineering data provided by the rover is also useful to science. In particular, the physical properties of soils can be investigated and images from the rover's forward cameras can provide information about rock and soil textures (Figure 2).

Once the rover returns to the ramp magnet, it will deploy the APXS on the magnet to determine the elemental composition of dust that has accumulated there since early July. Magnetic dust was also collected on circular magnets attached to the lander. Images taken by the lander camera reveal that the magnetic dust is red, meaning that some of the iron in the dust is oxidized.

Magnetic dust is being analyzed via a combination of methods. The magnetic attraction is examined by observing how dust adheres to an array of circular magnets of differing strength. Clues to the mineralogy are obtained via multispectral visible/near-infrared imaging (the lander imager, IMP). The elemental composition of the dust can be determined by placing the APXS on the ramp magnet. The magnetic experiment was organized by a group under Jens Martin Knudsen of the Niels Bohr Institute for Astronomy, Copenhagen, Denmark.

The team from Copenhagen explains that determining the composition of the magnetic material is critical for distinguishing between the two main "pathways" by which rocks weather on Mars: did they weather in a warm, wet environment far in the Martian past, or did they weather slowly under present cold, arid conditions? The key element here is titanium (Ti). According the Knudsen's team, "The magnetic phase formed via precipitation in water will not contain the element titanium" [*Magnetic Properties Team*, 1995]. Thus an APXS measurement of the ramp magnet may provide a critical clue about the past climate and weathering regime on Mars.

After the ramp magnet observation, what will Sojourner do? According to rover team member Joy Crisp of the Jet Propulsion Laboratory, plans are still being debated. The ramp magnet is near rocks Barnacle Bill and Yogi, which were examined in July. Crisp says the team still needs a close-up rover image of Barnacle Bill, which will help determine whether the rock is igneous or sedimentary. Barnacle Bill created quite a stir in July when the team announced preliminary APXS results suggesting that this rock may have a more silica-rich composition, like volcanic

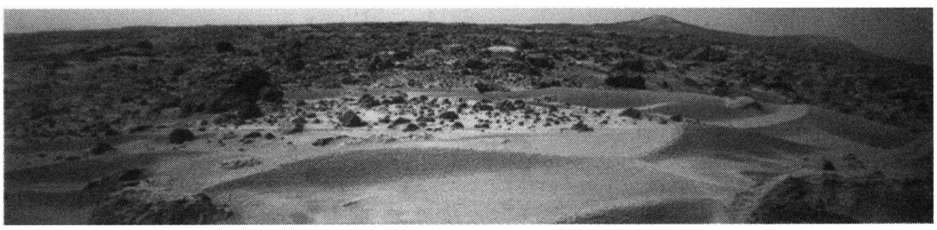

Fig. 1. A new perspective on the Pathfinder landing site was provided by Sojourner when it snapped this image from behind the "Rock Garden." The image reveals drifts of wind-blown sediment that are invisible to the imager on board the lander. The now famous "Twin Peaks" are about 0.8 km away. The drifts are less than 40 cm high. The image was obtained from Sojourner's right camera on September 19, 1997. Illumination is from upper left.

Fig. 2. Rover-eye view of "Half Dome" rock. This image was obtained September 14, 1997, from the right-forward camera on Sojourner. Images like this are providing exciting textural information. Half Dome, for example, exhibits pits and a linear texture. The linear features trending from lower left to upper right might be flutes caused by wind (sand blasting) or water action (during the floods that once passed through the site). The rock is less than 0.6 m tall. Illumination is from upper left.

andesites, than was expected. But is the rock an andesite? Textures revealed by rover camera views would help make this determination.

Eventually, the rover might be taken back to the Rock Garden area and a dark drift affectionately named "Mermaid Dune," or the rover might venture north. The terrain to the northwest and north of the lander slopes gently uphill. Viking orbiter images suggest that this slope is a tail of sediment deposited by the Tiu and Ares Valles floods in the lee of the "Twin Peaks" mountain, which lies southwest of the lander. If the rover drives up this slope, it might provide a better view of a butte located about 0.8 km to the north that is barely visible to the lander's cameras, once again providing a fresh perspective on a landing site that seems to look new with each incoming rover image.

It is now autumn at the Pathfinder landing site. Northern autumn arrived about the same time that Pathfinder's sister-ship, the orbiter Mars Global Surveyor, arrived on September 11. Temperatures continue to range from highs around -9°C to lows of -79°C. A few more dust devils were detected to be passing over the lander, and meteorological observations are continuing. Uplink and downlink communication sessions for Mars Pathfinder have become much more limited since the arrival of Mars Global Surveyor. In addition to Global Surveyor, Pathfinder competes for communication time on NASA's Deep Space Network with Galileo, which is orbiting Jupiter, and will soon also compete with Cassini, which is set to launch for Saturn in mid-October. Winter will arrive at the Pathfinder site in February 1998. If all goes well, Pathfinder and Sojourner might see spring arrive in mid-July 1998.—*Ken Edgett, Arizona State University, Tempe*

Reference

Magnetic Properties Team, Magnetic Properties Experiment on Mars Pathfinder, Ørsted Laboratory, Niels Bohr Institute for Astronomy, University of Copenhagen, Denmark, 14 pp., 1995.

Mars Has Crustal, Complex Magnetic Field

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Scientists working on the Mars Global Surveyor project announced last week that new satellite evidence indicates that the magnetic field around Mars is most likely of crustal rather than dynamo origin. They also say that the field is much stronger than previously anticipated and that it could greatly vary in strength in different locations on the planet.

"Based on evidence collected over several orbits, we now have strong evidence that the field is of crustal origin," says Mario Acuña, an astrophysicist at NASA's Goddard Space Flight Center who is the principal investigator for the magnetometer and electron reflectometer instruments on the satellite.

The new findings follow the satellite's dramatic detection on September 15 of the outermost boundary of Mars' magnetic field—or bow shock—shortly after the Surveyor began an elliptical orbit around the planet.

Scientists have long debated whether Mars has a magnetic field. The findings have implications for understanding the history, geology, and thermal evolution of Mars and for reexamining theories of magnetic fields. A magnetic field shields a planet from fast-moving, electrically charged solar particles that could affect and erode its atmosphere and surface. The field also can protect against some cosmic rays, which are an impediment to life.

Crustal origin of Mars' magnetic field indicates that that the ferromagnetic rock on the surface "remembers" and is preserving an older, internal magnetic field that may no longer exist. The crustal remembrance, says Acuña, is similar to a nail that remains magnetized after being brought into contact with a magnet. Crustal origin also could indicate that, even though the dynamo inside the planet's core once was strong enough to leave behind its signature in the crustal rocks, the dynamo now may be frozen and no longer spinning, and the planet's internal heat source may be gone. However, Acuña says he does not rule out the possibility that a weak magnetic field originating in the planet's core could be found at a later date.

The finding of a crustal magnetic field may not necessarily imply that Mars is geologically dead, says Janet Luhmann, a research scientist at the Space Science Laboratory at the University of California at Berkeley. "It doesn't mean that there isn't another kind of geology going on," she says. "It's just that the combination of convection and rotation required to create a dynamo is not present."

Mars' magnetic field could be very complex and likely varies in intensity from region to region depending on surface rock and whether an area is facing the solar wind, says Acuña. Determining the history of the planet, he says, is in some ways detective work. "We have to construct the geology and composition that explains the signature observed and which is consistent with other things we know about Mars," he says, adding, "My suspicion is that Mars will occupy a special place as being unique in magnetic properties. It may not be a clearly magnetic or nonmagnetic planet."

The strength of the Martian magnetic field has surprised scientists. While early speculation suggested the field would be just 30–60 nT strong, recent evidence suggests the field is 400 nT strong — almost as strong as Mercury's field. Acuña says that when measurements are taken closer to the Martian surface, they could reveal an even stronger field. Earth's magnetic field, by comparison, is 3000 nT. The new findings also indicate that the planet's magnetic field is stronger than that of meteorites suspected of having originated from Mars, Acuña says.

One hindrance to understanding magnetic fields is that different planetary fields do not fit into a known, neat general theory. "We do not have a general theory of magnetic fields that will apply with equal validity to all Earth-like planets," says Sean Solomon, director of the Department of Terrestrial Magnetism at the Carnegie Institution of Washington, and president of AGU. Solomon adds "Every time we've gone to a new planet, we've been surprised."—*Randy Showstack*