PLANETARY SCIENCE

Pathfinder Tells a Geologic Tale With One Starring Role

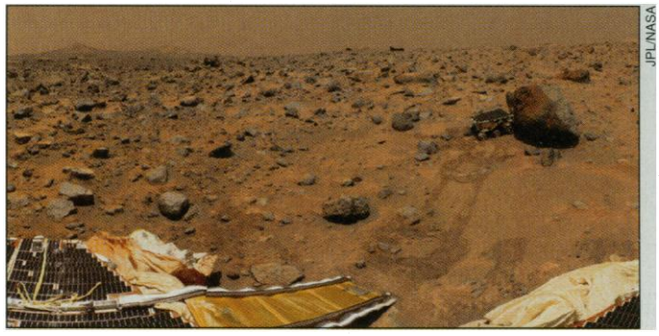
SAN FRANCISCO—From the moment Mars Pathfinder bounced to a stop on the rolling, rock-littered surface of Mars, the lander and its wheeled companion, Sojourner, wowed scientists with their maneuvers—and with the torrent of data they sent back to Earth. The deluge continued for almost 3 months and delivered 3 gigabits' worth of data, including 16,000 images and 20 chemical analyses, before the craft finally fell silent in early October. Now, team geologists have had time to weave this wealth of information into a single story about the patch of martian surface that Pathfinder explored, and they have found that the landing site was not what they had expected.

Pathfinder researchers had hoped that the landing site would reveal a grab bag of different rock types deposited by great ancient floods, and initial results supported that idea. But, at the fall meeting of the American Geophysical Union here last month, many Pathfinder researchers suggested that a single rock type lies behind the varied shapes, colors, and textures that Pathfinder observed. The same volcanic rock acquired diverse guises by being tumbled in flood waters, shattered by a nearby impact, gouged by the wind, and coated by varying amounts of martian dust, these researchers argued.

"That is not what we expected in selecting this landing site," says team member Harry McSween of the University of Tennessee, Knoxville. But the identification of a single rock type may allow geologists to understand the history of an alien landscape in unprecedented detail—an exercise essential to future Mars missions designed to return martian rocks to Earth.

The growing evidence that Barnacle Bill, Yogi, Bamm-Bamm, and the rest of the gang are chips off the same rock comes from both Sojourner's direct measurements of the rocks' compositions and the lander's imager, which recorded subtle color variations in the rocks. At the meeting, team members Thanasis Economou of the University of Chicago, Heinrich Wänke of the Max Planck Institute for Chemistry in Mainz, Germany, and their Pathfinder colleagues reported that the Sojourner rover did indeed measure a range of compositions when it set its alpha proton x-ray spectrometer against the surface of five different rocks. But many of the measurements showed high levels of the element sulfur—much more than any crystalline rock could incorporate into its structure. Separate measurements showed that the reddish soil at the site is enriched in sulfur, too. When the amount of sulfur in the rocks is taken as a measure of the amount of dust on their surfaces, the compositions of all five rocks converge. "I don't believe there are different types of rocks at the landing site," said Wanke. "All ... are almost identical in composition, but what varies is the dust cover."

Pathfinder team members studying rocks through the lander's camera see the same underlying uniformity. Judging by brightness and subtle differences in "redness," Scott Murchie of the Applied Physics Laboratory in Laurel, Maryland, and his Pathfinder colleagues divided surface rocks into two classes: darker, less red rocks such as Barnacle Bill, which tend to be smaller and more angular, and brighter, redder ones like Yogi, which are larger and more rounded. The color variations mimic the palette seen in dark rocks dusted in the laboratory with varying amounts of a bright red powder of oxidized iron, says Murchie. And the side of at least one very red rock scoured by wind-driven sand appears darker and less red, he says. All this suggests that the redness is only a coating. "I think we can explain most of the elemental and spectral variations as just due to varying amounts of dust on the rock," says Murchie. The "rusty," sulfur-laden dust seems ubiquitous on the martian surface, but where it came from is still a mystery.



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One rock, many colors? Color enhancement accentuates the redness of Yogi (by rover) and the grayness of Barnacle Bill (by rover tracks), but they may be made of the same rock.

To explain how a single rock type could look so varied, Daniel Britt of the University of Arizona in Tucson and his lander imaging team colleagues have spun a tentative geologic tale. In this scenario, all the rocks originated in a single layer of volcanic bedrock hundreds of meters thick. At the landing site, the bedrock may lie tens of meters below flood debris. The catastrophic floods that swept the region from the south a billion years ago or more may have picked up chunks of this volcanic bedrock from areas tens of kilometers away and quickly dropped them at the site. These flood-borne rocks are large, rounded, and red, as expected of rock tumbled short distances in floods and then left exposed to the elements—including dust—for perhaps half the age of the solar system.

The same volcanic rock could also have reached the surface of the landing site by another route, giving it a very different appearance. Just 2.2 kilometers away lies Big Crater, a 1.5-kilometer scar left by an impact that would have flung out chunks of bedrock. Those chunks could explain the smaller and more angular rocks at the site. Because these rocks were ejected long after the last of the floods, their dust coats are thinner and they look darker. Adding to the site's diversity, winds have abraded some rocks and, in certain places, exposed a few centimeters of "rock" made of soil solidified by a sort of chemical cement, said Britt.

Not everyone on the Pathfinder science team is inclined toward the one-rock story. The rover team's Henry Moore of the U. S. Geological Survey in Menlo Park, California, has noted loose pebbles and rocks pocked by small holes, presumably left when pebbles fell out. To him, these rocks look like conglomerates, sedimentary amalgamations of sand and pebbles from many different sources (*Science*, 17 October 1997, p. 380). "I think you can make a fair case for [such] a variety of rocks," agrees Pathfinder project scientist Matthew Golombek of the Jet Propulsion Laboratory in Pasadena, California. But Britt isn't convinced. "I'm a rock guy," he says. "I look at a lot of [terrestrial] rocks. Every Pathfinder picture I've seen looks like either a fresh [volcanic] rock or a weathered [volcanic] rock. I have yet to see anything that looks like a sedimentary rock."

"The bottom line," says Golombek, "is that we have very crude tools to analyze these rocks." Help is on the way, although it won't arrive anytime soon. In April 2001, NASA plans to launch the Mars Surveyor 2001 Lander-Rover Mission, which will deliver a bevy of remote-sensing instruments designed to see through the dust layers, as well as a rover-mounted drill to bore 5 centimeters into rocks and extract a core for possible later return to Earth. Promises Steven Squyres of Cornell University, who is leading the 2001 instrumentation effort: "By hook or by crook, we're going to get down below this stuff."

–Richard A. Kerr