PLANETARY SCIENCE

Possible Glimpse of Earth-like Geology In Mars Rock

One small rock on the vast, rusty desert of Mars has riveted the attention of geologists on Earth. The rock, dubbed Barnacle Bill for its pitted appearance by members of the Mars Pathfinder mission, has a strangely familiar makeup, according to an analysis by Pathfinder's rover, Sojourner. It contains far more of the ubiquitous substance silica than any known rock in the solar system outside Earth.

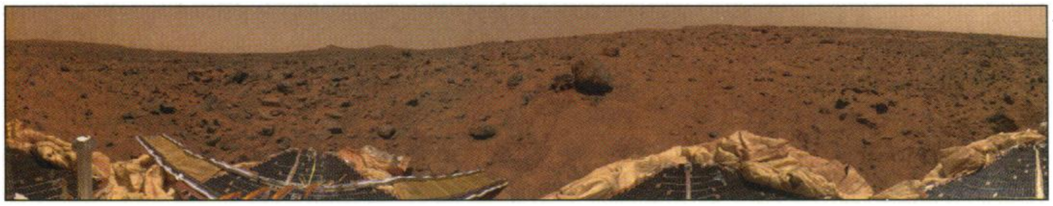
"That is an intriguing and tantalizing result," says geologist Kevin Burke of Rice University in Houston. Intriguing, because high-silica-content rocks on Earth generally come from volcanic eruptions fueled by the sinking of plates of surface rock into the planet's interior, a process thought to be uniquely terrestrial. Tantalizing, because the Pathfinder lander and Sojourner will be hard pressed to pin down whether the rock really is volcanic or whether it's the product of some other process, such as sedimentation or meteorite impact. Nor can Sojourner, with its limited range and capabilities, tell researchers how common such silica-rich rock is on Mars. "It's an initial result," says Burke. "Exactly what the significance is, we can't tell."

The one certainty seems to be that some process on Mars has concentrated silica, which consists of silicon combined with oxygen, until it constitutes about 60% of Barnacle Bill, or at least its surface. The football-size rock was the first that Sojourner analyzed with its alpha proton x-ray spectrometer (APXS). This instrument exposes the rock to a radioactive source of protons and alpha particles and analyzes those particles and x-rays bouncing back from the rock's outer 100 micrometers or so at energies that depend on the rock's mixture of elements. The indications of high silica in Barnacle Bill stunned geologists because ordinary basalt, the kind of rock expected to make up most of the martian surface, is only 45% to 50% silica.

Two-thirds of Earth is also covered with basalt, in the form of ocean crust, and Burke notes that "it's quite hard to make rocks with more silica." Earth does so in deep-sea trenches, where plate tectonics sends water-laden slabs of ocean plate slanting down into the mantle. On the way down, the water percolates upward into mantle rock above the slab, where it, in effect, distills some of the mantle's silica into a silica-enriched magma that feeds chains of volcanoes like the Andes, the Cascades, and the Aleutian Islands. These volcanoes mostly produce a rock called andesite, after the Andes, that contains about 60% silica, just like Barnacle Bill.

Same silica content, same process? Not necessarily, say planetary geologists. For one thing, the high silica ratio doesn't prove that Barnacle Bill is an andesite, much less one produced by plate tectonics. It could also be made of small bits of basalt combined by the force of a large meteorite hit, or by sedimentary processes, with bits of an even more silicic rock. In ordinary volcanoes with no obvious link to sinking tectonic plates—and there are plenty of those on Mars—silica-poor minerals can sometimes crystallize and settle to the floor of the magma chamber, leaving magma enriched with silica. The resulting rock can range from andesitic in composition to as much as 75% silica.

A geologist could at least tell whether Barnacle Bill is a mixture of rocks or a single lava by picking it up, breaking it open with a rock hammer, and inspecting it to see



JPL/NASA

Pathfinder's world. The rover Sojourner is analyzing a rock called Yogi in this 360-degree still life. Tracks in the martian dust lead back to Sojourner's first target, the silica-enriched Barnacle Bill.

Flawless Hardware, Fallible Humans

No one had ever dropped a rover on another planet and tooled around the alien landscape, so some problems might have been expected when Mars Pathfinder arrived at its destination last month. Surprisingly, they did not come during the probe's high-speed, Rube-Goldberg-like crash landing. In fact, the Pathfinder lander and its rover Sojourner have put on flawless mechanical performances. Instead, it's the software and "humanware" that have proved imperfect.

Right off, Sojourner and the lander had trouble conversing via radio. By repeatedly shutting down and restarting the rover's modem, a trick that often works on a home computer, controllers quickly solved that problem, but they never found its cause. Later, the lander's computer repeatedly dropped what it was doing and reset itself, throwing operations into disarray. Tests on the ground pinned down that problem to a software flaw. A software fix transmitted to the lander seems to have eliminated the glitch.

Human behavior proved more difficult to perfect. Supervisors eventually had to send excited engineers home to get some rest after errors possibly due to fatigue—such as running the rover up onto a rock—began cropping up. And 2 weeks into the mission, what mission manager Richard Cook of the Jet Propulsion Laboratory (JPL) in Pasadena, California, calls "troubling miscues" began disrupting communications between the lander and mission operators at JPL. On one occasion, mission managers sent commands to the lander while its receiver was still turned off to conserve power, losing a whole day of operations. On another, they failed to be as precise as needed when they told operators of NASA's world-girdling network of radio dishes, the Deep Space Network (DSN), how to pick up Pathfinder's feeble signal, and another day was lost.

"Telling [the DSN] what we want has been the problem," says Cook. "You have to be precise, and it's taken us some time." After back-to-back days of broken communications 16 days into the mission, JPL engineers carefully edged back into a reliable radio link with Pathfinder. They also began long-range planning of communications operations that should smooth out the link to Pathfinder. "We did know we were going to have to learn as we went along," says Cook. Perhaps the rest of Sojourner's trip will go as smoothly as its arrival on the Red Planet. –R.A.K.

whether it has the fine-grained texture of a lava or is a coarse agglomeration of particles. Pathfinder is a good deal less capable than a human field geologist, but color imaging from the lander has already suggested that Barnacle Bill is uniform down to the centimeter scale, as expected of an andesite.

If Barnacle Bill continues to look like an andesitic lava, it could lend support to a new picture of Mars's geologic past. Today, Mars has neither oceans nor any signs that plate tectonics is at work there. It appears to be a "one-plate planet," encased in a single, thick layer of cold, immobile rock, as our moon has been for billions of years. But geophysicist Norman Sleep of Stanford University proposed in 1994 that the great northern lowlands of Mars, which cover one-third of the planet and lie 3 kilometers below the ancient highlands of the southern hemisphere, are the martian equivalent of ocean basins. Sleep proposed that they formed 3 billion to 4 billion years ago by the same drifting of plates still operating on Earth.

Sleep's proposal has been controversial. "It's worth considering the concept of plate tectonics on an early Mars," says planetary physicist David Stevenson of the California Institute of Technology in Pasadena. But he adds that "it's hard to know how to test it or develop a convincing theoretical argument."

Andesitic lavas would certainly bolster the case for plate tectonics on Mars if they turned up all across the planet. But finding more even at the Pathfinder site won't be easy. Barnacle Bill was the only bona fide rock to be cleanly analyzed in the rover's first 18 days. Operational problems, apparently resolved now, caused repeated delays (see sidebar), but the rocks themselves are presenting challenges as well.

APXS analysis of another rock, called Yogi, at first suggested that it was more basaltic than Barnacle Bill, but a closer look at the rock face analyzed by APXS revealed what looked like a coating of dust and weathered minerals, says team member Ronald Greeley of Arizona State University in Tempe. Viking lander images had suggested that martian rocks would have such problem coatings (*Science*, 19 April 1996, p. 347). That leaves the makeup of the rock itself still uncertain, says Greeley. Although the APXS analysis of the third rock, Scooby Doo, had not been released at press time, team members are now describing it as more like a crust of solidified soil than a rock.

Both the lander and rover seem to have weeks and even months of productive work ahead, however, so team members remain upbeat about getting a look at a lot more rocks. "Things are never quite as simple as you might like them to be," says Greeley, "but that makes it interesting."

–Richard A. Kerr

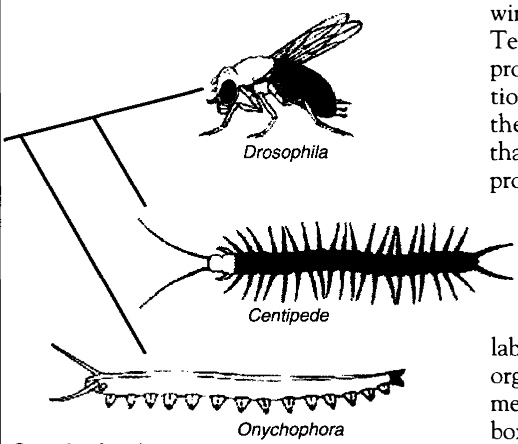
MEETING BRIEFS

A Developmental Biology Summit in the High Country

ALTA, UTAH—The ski hills surrounding this old silver-mining town provided an exhilarating setting for more than 1000 scientists who gathered here from 5 to 10 July for an unusual joint conference of the International Society of Developmental Biologists and the Society for Developmental Biology. A head-spinning assortment of topics from evolving gene families to fruit fly eyes abetted the high-altitude daze.

Segmentation's Origins

Biologists have long believed that the diverse body segments of most insects—head segments with antennae, for example, and thoracic segments with wings and legs—evolved from the many identical segments of more primitive arthropods that looked like today's centipedes and millipedes. In the 1980s, researchers thought they might have a simple explanation for the genetic changes responsible for this diversification of segments: a duplication and diversification of genes. But at the Utah meeting, Jennifer Grenier and colleagues in the lab of developmental biologist Sean Carroll at the University of Wisconsin, Madison, described new results challenging that explanation.



Standard rations.
Insects don't have more *Hox* genes than related groups; they just use them differently. (Red shows *Ubx* expression; blue is *abd-A*.)

GRENIER *ET AL.*, *CURRENT BIOLOGY*

The older explanation grew out of the discovery that the fruit fly genome carries eight consecutive "*homeobox*" (*Hox*) genes, named after the conserved DNA sequence they all contain. Because each *Hox* gene helps a particular segment acquire its unique identity during development, the find suggested that the insects' evolutionary ancestor had only a few *Hox* genes, and that insects acquired distinct structures on their segments as extra copies of these genes accidentally cropped up in insect DNA and then specialized.

If so, then other surviving descendants of this hypothetical ancestor would be expected to lack some of the fly's eight *Hox* genes. But Grenier and her colleagues now report that they have detected all eight genes in centipedes and even in onychophorans—wormlike creatures that are often described as "living fossils," the closest living relatives to the group that gave rise to the arthropods, including insects. (The work is also described in the 1 August issue of *Current Biology*.) Because ancestors of the two groups diverged from insect ancestors long before the insect body plan subdivided, says Grenier, the finding implies that "the gene duplications didn't happen during insect evolution. They were much more ancient."

Indeed, says geneticist and Nobel Prize winner Ed Lewis of the California Institute of Technology in Pasadena, one of the earliest proponents of idea that *Hox* gene duplication brought about insect segment diversity, the Grenier team's work "quite nicely" puts that theory to rest. As an alternative, Grenier proposes that segment diversity arose from changes in *Hox* gene activity.

To analyze the *Hox* genes of centipedes and onychophorans, Grenier, fellow Carroll lab members Theodore Garber and Robert Warren, and Australian collaborator Paul Whitington first purified the organisms' DNA, and then used the polymerase chain reaction to amplify their homeobox regions. The researchers then sequenced the regions and compared them with fruit fly sequences. They found that each fly *Hox* gene has a related or "orthologous" gene in the centipedes and onychophorans.

Having ruled out the simplest theory of insect segment diversification, Grenier and her co-workers went on to explore whether changes in gene regulation, either of the *Hox* genes themselves or of the genes the *Hox* genes control in turn, might explain it instead. The group found major differences in the ways embryonic fruit flies, centipedes, and onychophorans deploy orthologous genes. For example, the *Hox* genes *Ubx* and *abd-A* are expressed primarily in the abdominal segments of fruit fly larvae, but in the centipede embryo the two genes are active in all seg-