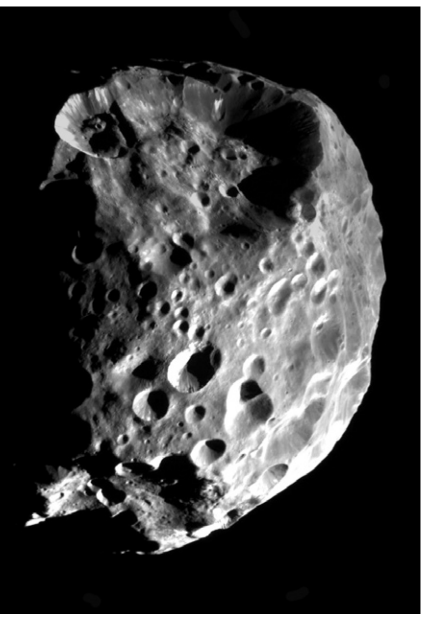
Twins Separated at Birth?

Two JPL-led missions have given us our closest looks yet at two icy bodies from the outer reaches of the solar system. But although both objects presumably came from the Kuiper Belt, which lies beyond the orbit of Pluto and contains rubble from the solar system's formation some four and a half billion years ago, their recent histories are very different. Comparative studies of the two will no doubt tell us quite a bit about how the solar system evolved.

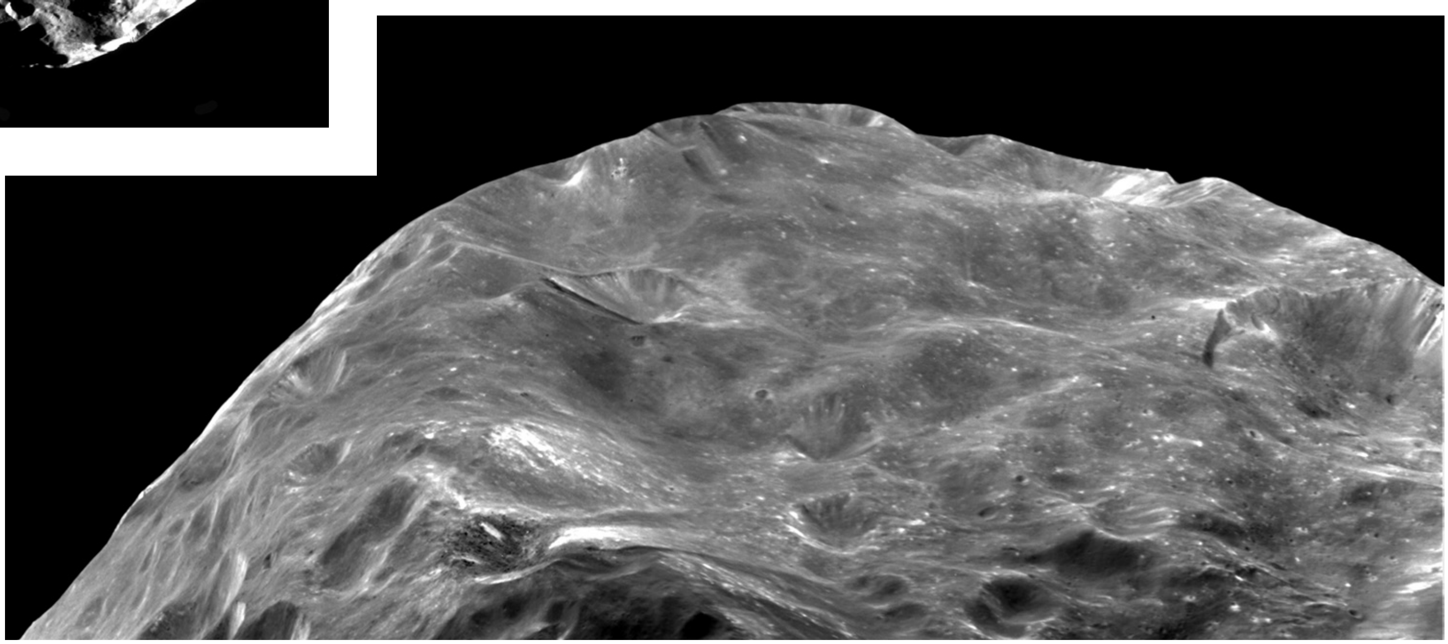
One of them, 214-kilometer-diameter Phoebe, is now a moon of Saturn, which it orbits in the wrong direction—a sure sign that it's not from around there. But assuming it didn't wander much closer to the sun before it was captured, it should be a pretty pristine sample of the material from which the solar system condensed. On June 11, the Cassini spacecraft trained all its instruments on Phoebe from a distance of about 2,068 kilometers—a thousand times closer than the Voyager missions' best view. (Cassini slipped into orbit around Saturn on the evening of June 30, Pasadena time.) The results show that Phoebe's surface is a patchy mix of water and carbon-dioxide ice, water-bearing minerals, solid organic compounds similar to those found in primitive meteorites, things that might be clays, and some unidentified materials. Its bulk density was measured at about 1.6 grams per cubic centimeter—much lighter than most rock but somewhat heavier than ice, suggesting a mix of ice and rock similar to Pluto and to Neptune's moon Triton. Temperature maps show that Phoebe cools off rapidly at night, suggesting a loose, porous surface; radar maps also indicate a dirty, rocky exterior.

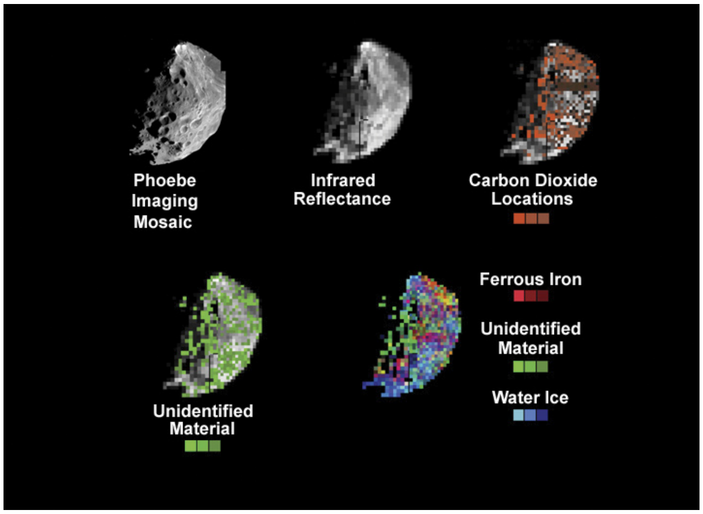
Meanwhile, a spacecraft named Stardust reached the halfway mark on its mission to sample the dust surrounding Comet

Below: This mosaic of the entire moon shows that Phoebe's dark coating is sliding down the walls of the large crater at the north pole, revealing a bright interior.



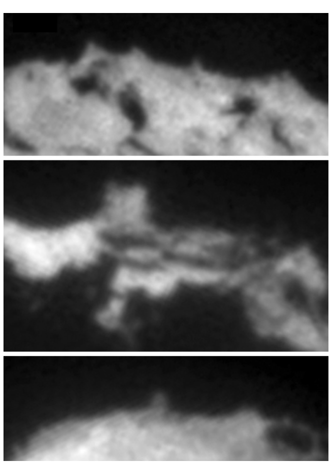
Below: A crater in Phoebe's south-east quadrant exposes at least two alternating bright and dark layers hundreds of meters thick. The layers may be blankets of bright subsurface material that were ejected from other craters and acquired dark patinas as they aged. Bottom: The south polar region has crater walls over 4 kilometers high, and numerous small craters penetrate the dark surface. In both shots, each pixel is 80 meters wide.

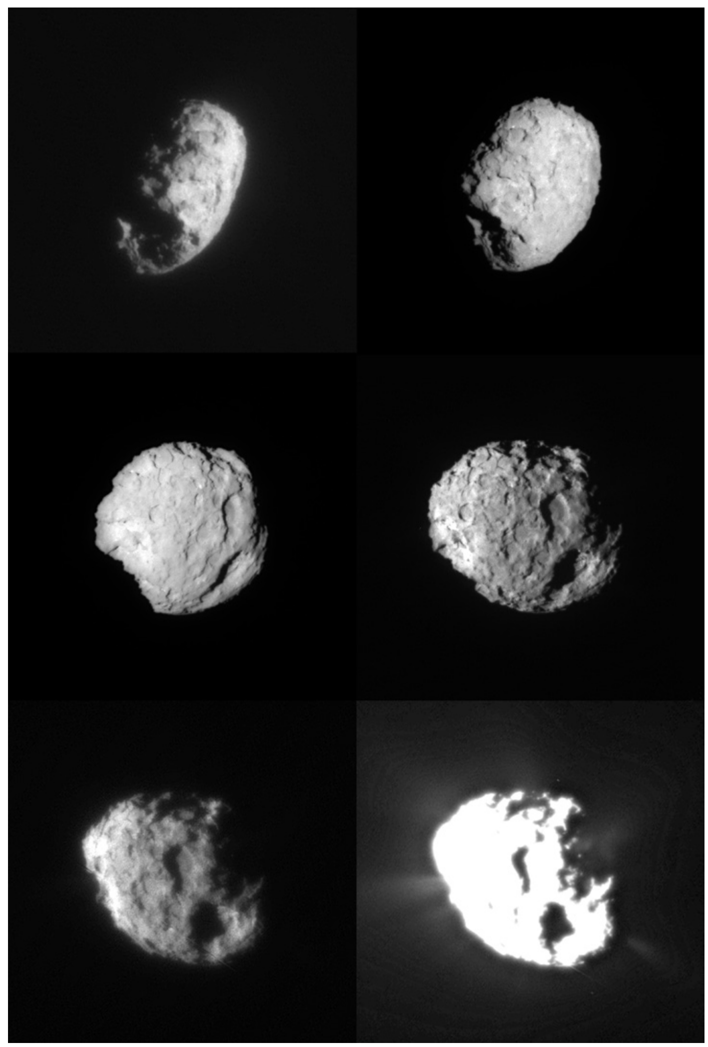




Above: Data from Cassini's visual and infrared mapping spectrometer, and a reference photo (upper left). The frozen carbon dioxide bolsters a Kuiper belt origin for Phoebe.

Wild 2 and return the material safely to Earth in 2006. On January 2, Stardust flew to within 236 kilometers of the comet's nucleus, collecting thousands of particles and taking hits from raisin-sized debris chunks in the process. At six minutes before closest approach, the spacecraft, which is half a light-hour from Earth, had to figure out on its own how to roll sideways to just the right angle so that the rotating mirror on the navigation camera would keep the comet's head in view as it went by—a feat equivalent to shooting a movie of a passing telephone pole from the side-view mirror of your SUV—at 13,000 miles an hour. These pictures, the most detailed ever of a comet's nucleus, were released to coincide with four papers on the encounter published in the June 18 issue of *Science*. The images show a 5.1-kilometer-diameter body with a surface rigid enough to support towering spires and mesas like those seen in a Roadrunner cartoon—vastly different from the fluffy snowball scientists expected to see. And instead of being fairly quiescent, more than two dozen jets shoot out in all directions. Presumably, uneroded bits of the nucleus between jets (which can blast out from just below the surface at hundreds of kilometers per hour) become the spires. □—*DS*





Right: A set of views from Stardust's flyby of Comet Wild 2, adjusted to constant scale, begins at upper left. The bottom right image has been overexposed to highlight the jets.
Left: Small mesas and pinnacles 100 meters tall can be seen on the comet's limb.

Quantum Memories?

No, not in some futuristic computer, but in human brains. Postdoc Mike Sutton, along with Erin Schuman, an associate professor of biology at Caltech and an associate investigator for the Howard Hughes Medical Institute; undergrad Nicholas Wall; and Girish Aakalu (MS '99, PhD '02) have found that the release of a single packet of a substance called glutamate can alter the junction between nerve cells. Adjusting the strengths of these junctions' connections is thought to be at the heart of learning and memory. The report appears in the June 25 issue of *Science*.

Neurons communicate at synapses, tiny gaps between the ends of nerve fibers, where one nerve cell signals the next by secreting chemicals called neurotransmitters that jump the gap. These chemicals, which include glutamate, are manufactured within the neuron and stored in pouches called vesicles. So the dumping of one vesicle's contents—some 10,000 molecules' worth of neurotransmitter—into the synapse is the elemental unit of synaptic communication. "This is known as the 'quantal' nature of synaptic transmission," says Sutton, "and each packet is referred to as a quantum." A typical burst of neuronal activity leads to the release of dozens of vesicles in less than a second, but the spontaneous opening of just one, called a miniature excitatory synaptic event, or "mini" for short, was thought to have no biological significance—mere background chatter.

Sutton didn't set out to look at minis, but at how changes in synaptic activity regulated protein synthesis in the receiving cell. The original experiment was designed to remove all types of activity from the cell, so he could add things back incrementally and observe how protein synthesis was affected. "We were going on the assumption that the spontaneous glutamate release—the minis—would have no impact, but we wanted to formally rule them out," he says.

Sutton first blocked the action potentials—electrical signals in the sending cell that cause glutamate release. Normally, a cell receives hundreds of glutamate packets from its neighbors every second. But when the action potentials are blocked it receives only the minis, which arrive about once per second. Sutton then blocked both the action potential and the release of any minis. "To our surprise, the presence or absence of minis had a very large impact on protein synthesis in dendrites," he says. (Dendrites are the neuron's treelike branches that collect incoming signals and send them on through the cell to a long fiber called the axon, which in turn makes synapses with other dendrites.) It turned out that the minis inhibited protein synthesis, which increased when they were blocked. Further, says Sutton, "it appears the change in synaptic activity needed to alter protein synthesis is extremely small—a single package of glutamate is sufficient."

Sutton notes that it is widely accepted that synaptic transmission involves the release of different numbers of glutamate packets, adding, "Minis may provide information about the characteristics of a given synapse (for example, is the signal big or small?), and the postsynaptic or receiving cell might use this information to change the composition of that synapse. And it does this by changing the complement of proteins that are locally synthesized." This ability to rapidly make more or fewer proteins allows for quick changes in synaptic strength. Ultimately, he says, this ability may underlie long-term memory storage.

"It's amazing to us that these signals, long regarded by many as synaptic 'noise,' have such a dramatic impact on protein synthesis," says Schuman. "We're excited by the possibility that minis can change the local synaptic landscape. Figuring out the nature of the intracellular 'sensor' for these tiny events is now the big question." □—*MW*

It's sometime between 1:00 and 4:00 a.m. on Saturday in the Avery House lounge. Ruth Nickerson (seated, in red), Melissa Xin (seated, in blue), and, standing, from left, Dan Pragel, Diana St. James, and Lynne McGrath read *Julius Caesar* to Yogesh Sharma and Ken Kuo (at table).

All's Well That Ends Well

Caltech students are normally more comfortable with space-time than with sonnets, but that all changed for 24 hours. From 4:00 p.m. Friday, May 28, and continuing nonstop through 4:00 p.m. Saturday, Caltech students, staff, faculty, JPL employees, and spouses and friends of the same read aloud almost every single word Shakespeare ever wrote—all 39 plays and 154 sonnets, plus the verse masterpieces "The Rape of Lucrece" and "Venus and Adonis"—so much material that it had to be read in five sessions simultaneously in order to fit it all into 24 hours.

By anyone's standard, that's a lot of Shakespeare, but Readathon co-organizers Nicholas Rupprecht, Ryan Witt, and Parag Bhayani think it's worth the effort. All three have appeared in Caltech's annual productions of Shakespeare's plays, and were excited about a public reading of the seldom-performed works, albeit sans costumes and props.

The lack of costume changes was a good thing, as the speaking parts per play vastly outnumbered the readers. Rupprecht, a junior in mathematics, figured out the cast assignments, trying to match the genders of characters and readers as often as possible while minimizing situations where readers had to hold up both ends of a conversation. "A few of the plays had only three readers," says Rupprecht. "But the histories were a nightmare because they tend to have so many speaking parts and there's so much interaction between characters. It took me about an hour and a half on each history to figure out how to split the play up into four roles."

Rupprecht signed himself up to read continuously for the entire 24 hours, but the student most likely to suffer from a literary identity crisis was Matt Wroten, who pulled 20 of the 60 roles in *Henry VI*

From left: Readathon organizers Bhayani, Rupprecht, and Witt.

Part 2. "That's what he gets for picking Benedick in *Much Ado About Nothing,*" explains Rupprecht, noting that the role is one of the most coveted in all of Shakespeare.

And if you missed it, the odds of a repeat performance (or something similar) next year are "extremely good," says Rupprecht. Until then, photos and other info can be found at http://shakespeare.caltech.edu. □—*RT*

Think and Click

We're one step closer to the day when paralyzed patients will be able to use brain impulses to operate computers, robots, motorized wheelchairs—and perhaps even automobiles. In the July 9 issue of *Science*, Caltech neuroscientists Sam Musallam, Brian Corneil, Bradley Greger, Hans Scherberger, and Richard Andersen report that monkeys can move the cursor on a computer screen just by thinking about it.

The Andersen lab's approach departs from most previous work, which relied on signals from the portion of the brain's motor cortex that controlled the portion of the body that the prosthetic was intended to replace. The new study demonstrates that higher-level signals, also referred to as cognitive signals, emanating from the posterior parietal cortex and the high-level premotor cortex (both involved in higher brain functions related to movement planning), can be decoded as well. Says Musallam, this work "shows that a variety of thoughts can be recorded and used to control an interface between the brain and a machine."

The study involved three monkeys, says Andersen. "We have him think about positioning a cursor at a particular goal location on a computer screen, and then we decode his thoughts. He thinks about reaching there, but doesn't actually reach, and if he thinks about it accurately, he's rewarded."

Besides picking up the "goal signals" that told where the monkey was thinking of reaching, the researchers also recorded "value signals." The reward for performing the task varied, and the monkeys were told in advance what reward to expect. (The type of fruit juice or the size of the sip could be changed, for example.) The monkey's reaction to the promised reward was the value signal.

Since the goal signals are high-level and abstract, they could be used to operate a

Postdocs, from left, Dane Boysen (PhD '04), Calum Chisholm (PhD '03), and Tetsuya Uda, the vice president, president, and chief technical officer respectively of a startup company called Proton Power, collaborated with four UC Berkeley MBA students to snag the $25,000 grand prize in Berkeley's sixth annual business plan competition. They plan to market an economically viable fuel cell developed in the lab of Associate Professor of Materials Science and Chemical Engineering Sossina Haile (*E&S* 2003, No. 1).

Watson Lectures Set

Next fall's Watson lineup begins on October 13, when David Goodstein, vice provost, professor of physics and applied physics, and Gilloon Distinguished Teaching and Service Professor, will tell us what's going to happen as the world's petroleum production starts to run dry. Then, on October 27, Michael Dickinson, the Zarem Professor of Bioengineering, will explain how flies fly, or, more accurately, how they control their in-flight maneuvers. On November 10, Christof Koch, the Troendle Professor of Cognitive and Behavioral Biology and professor of computation and neural systems will take us along on his quest for consciousness (see the story beginning on page 28). And finally, on January 26, 2005, Paul Dimotakis (BS '68, MS '69, PhD '73), the Northrop Professor of Aeronautics and professor of applied physics, will describe Caltech's role in helping determine the cause of the breakup of the Space Shuttle *Columbia*. As always, the lectures are at 8:00 p.m. in Beckman Auditorium; admission is free. Streaming videos of the lectures are posted online at http://today.caltech.edu/theater/ about a week after the event. □

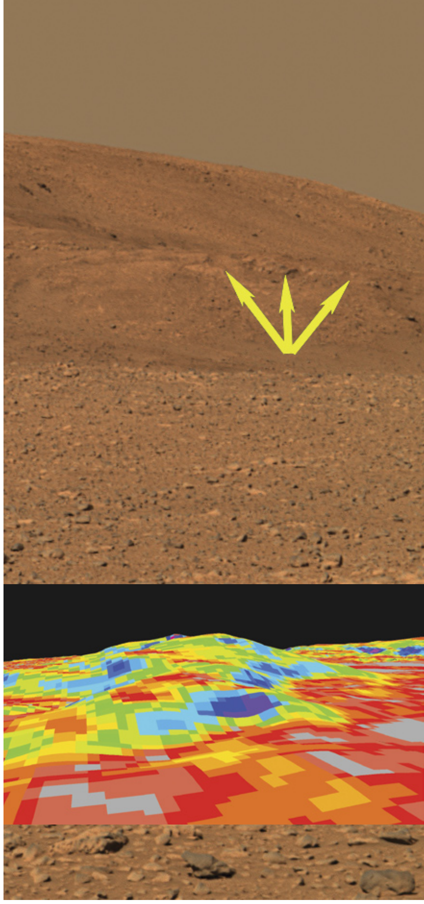
number of devices, and once the patient's goals are decoded, the prosthetics themselves could perform the lower-level calculations needed to achieve them. In other words, a prosthetic arm could use the goal signal "reach up and to the right for the apple" to trigger the calculation of the trajectory commands for that movement.

And since the brain is a busy place, with thoughts leaping about like, well, monkeys, the value signals could be used to help the prosthesis figure out whether you really want the apple or are just trying to decide what to snack on. Such a filtering system might be needed to keep the arm from responding to every fleeting thought.

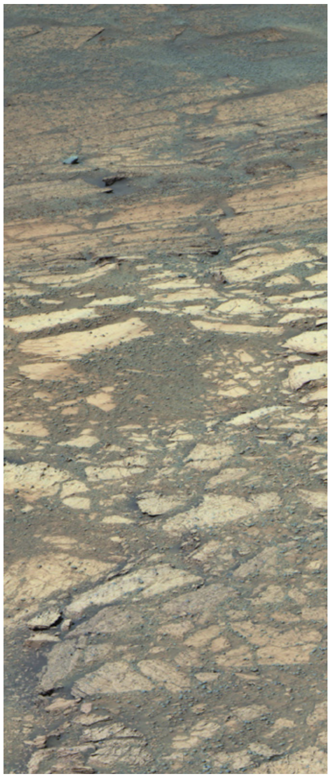
The value signals can also be used to fine-tune performance. "These signals could be rapidly adjusted to expedite the learning that patients must do in order to use a device," Andersen says. And he notes that value signals might be useful for monitoring the patient's moods more effectively. "It's like reading a patient's body language," says Musallam. "You can pick up how someone is feeling, without them having to tell you directly."

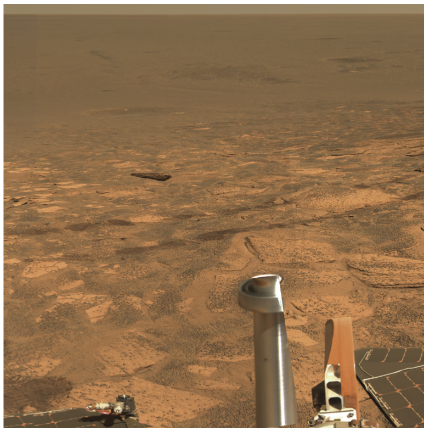
Says Andersen, "This suggests that a large variety of cognitive signals can be interpreted, which could lead, for instance, to voice synthesizers that operate by the patients' merely thinking about the words they want to speak."

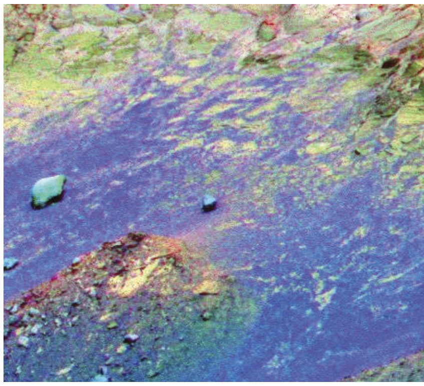
Andersen is the Boswell Professor of Neuroscience. Musallam and Greger are both postdocs in his lab; Corneil and Scherberger are former members of the lab, now at the University of Western Ontario and the Institute of Neuroinformatics in Zurich, Switzerland, respectively. □—*RT*

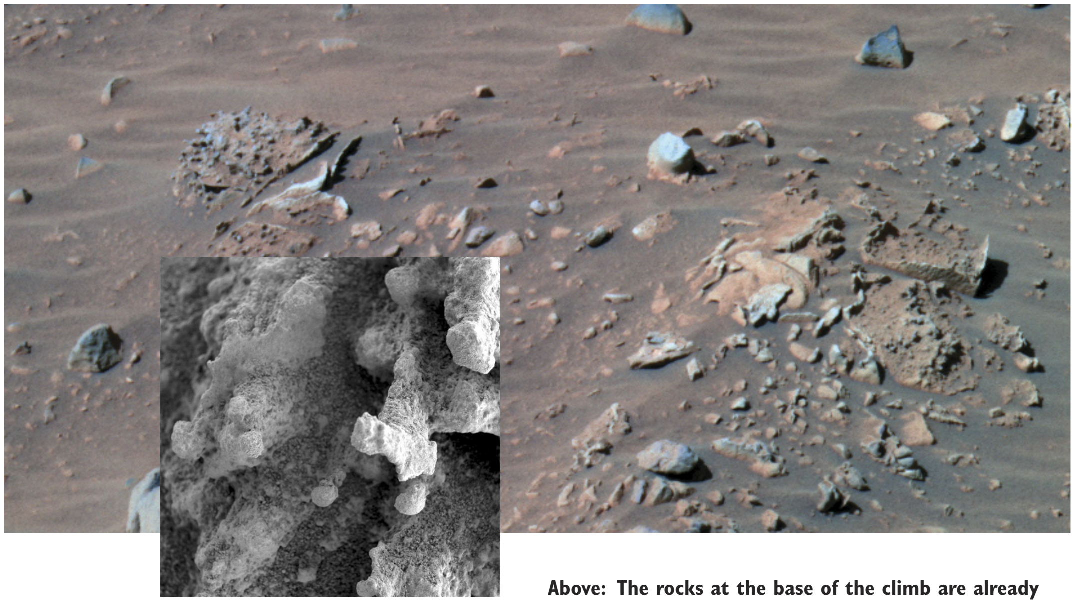


Right: After driving more than 3.4 kilometers from its landing site, JPL's Mars rover, Spirit, has reached the base of the Columbia Hills. This view, from about 300 meters away, shows boulder-strewn slopes and what may be an outcrop (arrowed) along the ridge line of the closest flank, called "West Spur." How to get there is the question—the elevation map (inset) from JPL's Mars Global Surveyor shows slopes from gentle (red) to steep (blue). The most direct route goes through the big blue-purple patch, so the rover team may try the longer but safer approach around to the left.

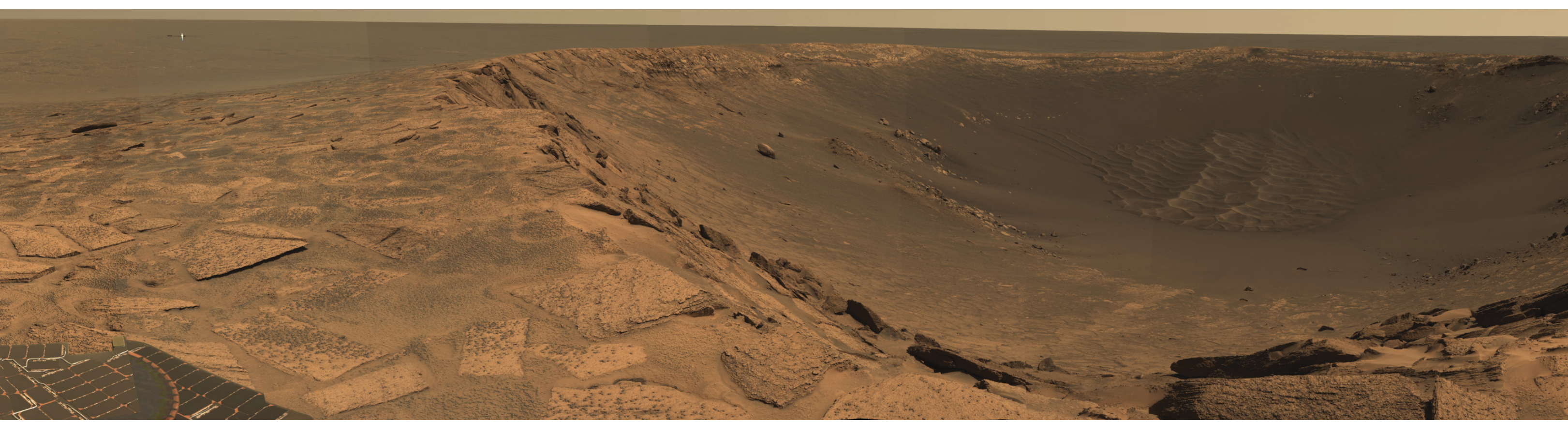


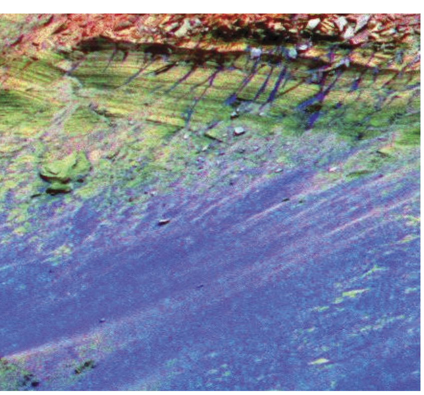






Above: The rocks at the base of the climb are already intriguing—this false-color image shows a weird, knobby rock, dubbed "Pot of Gold" (upper left), that is unlike anything ever seen on Earth. A close-up (inset, shown 1.5 times actual size) from Spirit's microscopic imager reveals that the knobs are on the ends of stalk-like protuberances, like the eyes on a crab. And the Mössbauer spectrometer shows that Pot of Gold contains hematite, although it is not yet clear if water was involved in its formation. Other rocks, like those at the right of the image, look like loaves of bread whose crusts remained intact as the interiors rotted away. Some rocks are so far gone that only the crust remains; in one striking 3-D image (http://photojournal.jpl.nasa.gov/catalog/PIA06286), a delicately balanced piece of crust resembles the head of a cobra poised to attack.





Meanwhile, Spirit's twin, Opportunity, is beginning a gingerly descent into a high-school-stadium-sized crater called Endurance. The rover entered at the left-hand side of the panoramic view (above), after JPL engineers tried it at home on a 25-degree sandy slope (far left, opposite page) littered with rocks and simulated Martian "blueberries"—the hematite-rich granules discovered at Opportunity's landing site that are all over this part of Meridiani Planum. The real blueberries can be seen in this false-color picture (middle, opposite page) of the rocks at Opportunity's current location, some five meters below the crater's rim. At least three bands of rock, distinguishable by their color and texture, are visible downslope of the rocks currently being examined, hinting at a complex past that geologists hope to unravel by methodically moving to progressively deeper strata. And a broad assortment of mineral types can be seen in a false-color image (left) of the crater's rim: the cyan blue is basaltic rocks, the dark green is a mixture of iron oxide and basalts, and the reds and yellows are sulfate-rich dusty materials.