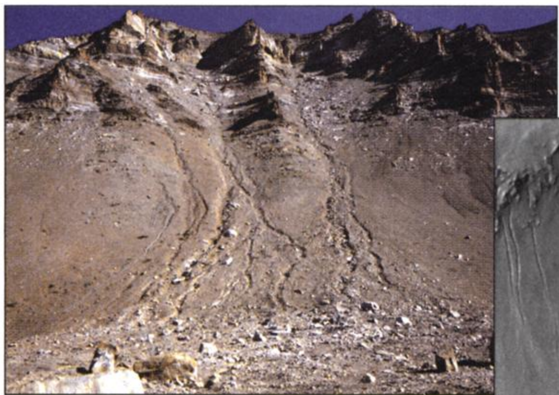
MEETING LUNAR AND PLANETARY SCIENCE CONFERENCE

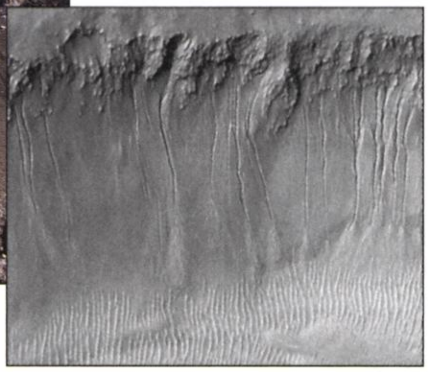
Rethinking Water on Mars And the Origin of Life

HOUSTON—Last month, planetary scientists gathered here at NASA's Johnson Space Center to consider the rocky (and icy) bodies of the solar system, from motes of dust to the terrestrial planets. Mars got the lion's share of attention, including second thoughts on whether water has shaped gullies and layered sediments there, but the prospect of interstellar travel—by bacteria on bits of rock blasted from the planets—also came up.

Not-So-Wet Martian Gullies?

Hopes for life on Mars got a boost last summer—at least in the public imagination—with the release of dramatic pictures of gullies carved into martian cliffs. The images, sent back by the orbiting Mars Global Surveyor, evoked water gushing from the rock, perhaps in recent times. And where there's been liquid water there could be life, or at least the remains of ancient living things (*Science*, 30 June 2000, pp. 2295 and 2330). But now that Mars researchers have had a chance to reconsider such a possibility, some are pouring cold water on the idea.





All of a kind? If martian gullies *(right)* formed as some earthly ones *(above)* do, there might be no need for life-sustaining groundwater on Mars.

CREDITS (LEFT TO RIGHT): FRANÇOIS COSTARD; NASA/MSSS

Although several presentations at the meeting suggested ways that aquifers beneath Mars's frigid surface might create the gullies, others pointed to strikingly similar features on Earth that are produced by nothing more than ephemeral patches of melting snow. This "suggests you don't need water seeping from underground" to explain the features, says planetary scientist Michael Hecht of the Jet Propulsion Laboratory in Pasadena, California. Without water remaining liquid underground, prospects for life or fossils within easy reach would be greatly dimmed.

In their *Science* paper presenting the gully images, planetary scientists Michael Malin and Kenneth Edgett of Malin Space Science Systems Inc. (MSSS) in San Diego suggested water from a permeable, water-filled layer of rock—an aquifer—exposed in a cliff face as a likely explanation. (MSSS designed, built, and operates the camera on the Mars Global Surveyor.) The cold, they argued, would freeze an outer carapace of the aquifer, but building water pressure behind it could eventually break through, excavating an alcove in the cliff face, cutting a channel down the slope, and depositing the debris in an apron at the base of the cliff. That scenario, however, didn't fly with some planetary scientists. The surface of Mars is so cold—on average –70° to –100°C—that any water within 2 or 3 kilometers of the surface, never mind a meter or two, should be permanently frozen, they noted.

At the meeting, a number of researchers offered ways to make a seeping aquifer work. Perhaps many subterranean intrusions of magma, too small to be detectable, keep near-surface water liquid; a thick surface layer of insulating "soil" might hold in enough of the planet's internal fires; or the water could be too briny to freeze. But the most striking presentations were new images of gullies, not from Mars but the high Arctic of Earth. Geomorphologist François Costard of the University of Paris-South in Orsay and colleagues hauled out slides from field trips in the late 1980s to Jameson Land in East Greenland, where they studied geologic features formed around glaciers. There they saw what looked for all the world like martian gullies—alcoves high on a cliff, channels running down from each, and aprons of debris at the end of each channel. There were even low levees of debris bordering each channel, just as on Mars. But there was no aquifer emerging from the cliff, no seeps of any kind. Geologist Pascal Lee of the SETI Institute in Mountain View, California, and colleagues reported finding similar, though smaller, gullies in far northern Canada on Devon Island.

Seepless gullies on Earth draw on the past winter's snow, not aquifers, say Costard and Lee. Snow caught in an alcove melts in the spring, saturating the steep surface beneath it with water and weakening the rock until a chunk collapses and a mixture of water and debris flows downslope. "It's a classic process," says Costard. The same simple explanation might work on Mars, he says, if climate there has changed enough—perhaps through the periodic tilting of Mars's rotation axis—to bring frost, which now forms around the poles, or even snow, which may fall today, to the midlatitudes of Mars where most of the gullies are now found.

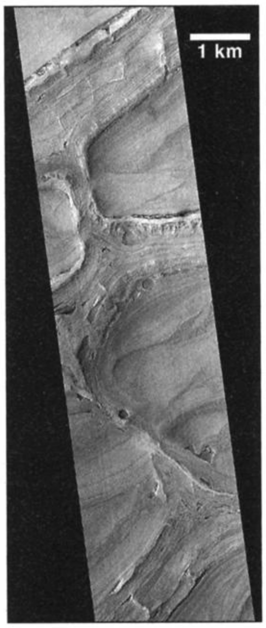
Edgett doubts, however, that a purely surface process would work on Mars. He notes that the channels tend to originate at the same layer of rock in a formation, suggesting that something about that rock—presumably an aquifer—controls the formation of gullies. On the other hand, Edgett has noted a central peak of an impact crater replete with gullies. Where would the water come from to feed a seep high on a central peak, he wondered? Snow might work. A closer look at the 65,000-plus Mars Global Surveyor images already back from Mars, as well as more Earth analogs, seems in order.

Layered Mars Not Always Wet?

While gullies on Mars got much of the attention in the conference's sessions on the Red Planet (see above), last year's other big martian splash—layered sediments said to be laid down in lakes or even shallow seas (*Science*, 8 December 2000, p. 1879)—kept a lower profile. The basic issue was the same, however: How much water, if any, do layered sediments imply existed on the martian surface?

Layering by itself doesn't tell planetary geologists much; layers of fine-grained material could be wind-blown dust or ash spewed by volcanoes, for example. Without being able to put eyeball to sediment grain, Mars geologists must decipher the origin of layered terrains from the shape of the landscape. At the meeting, one suite of layered terrains set in the huge impact crater Hellas got strong support as the bed of an ancient, ice-covered lake. But in discussions of other terrains, volcanic ash and water-lain deposits generally got equal billing.

The Hellas basin would certainly make a fine lake. Formed perhaps 4 billion years ago by a planet-rocking impact, it spans 2000 kilometers of the martian southern hemisphere, plunges 8 kilometers below its surroundings, and would potentially drain 20 million square kilometers of the planet. In order to find out if water ever did flow into Hellas, carrying sediment with it, planetary geologists Jeffrey Moore of NASA's Ames Research Center at Moffett Field, California, and Don Wilhelms, retired from the U.S. Geological Survey's (USGS's) Astrogeology Branch, inspected images and topographic data that the orbiting Mars Global Surveyor returned in recent years.



Muddy lake bottom? "Honeycomb" terrain may be ice impressions in lake muds.

By their analysis, deposits in Hellas do display the shapes of an ancient lake bed. Wind erosion has partially cut away Hellas sediments, exposing a layered structure in the rock all across the crater. One distinctively layered band of sediment nearly circles the crater margin like a bathtub ring. This discontinuous band has shelflike and scarp structures of the sort that ice-covered lakes in the Dry Valleys of Antarctica produce at their margins, say Moore and Wilhelms. If the climate about 3.5 billion years ago—when the sediments were laid down—was anything like today's, they note, a Hellas lake would have been covered by hundreds of meters of ice that could have shaped the margins of the deposits by blocking sediment inflow and piling it at the margins. To judge by the valleys that flow into Hellas on the east and south, much of the sediment may have flowed in after the heat of nearby volcanic activity melted ice-rich sediments. And one area, the low point of the basin, has a unique "honeycomb" structure (see figure), as if blocks of the last ice of a vanishing lake had sunk into the soft bottom mud. As a consistency check, Moore and Wilhelms determined that the altitude of the margin deposits around the crater remains constant, as a good bathtub ring should.

Listeners at the meeting took the layered sediments of Hellas to be promising as remains of an ancient lake. "We also see evidence for water and standing water deposits in Hellas," says planetary geologist James Head of Brown University in Providence, Rhode Island, who has looked at much the same data with Bradley Thomson of Brown.

But participants often associated layering elsewhere on Mars with volcanic ash deposits rather than waterborne deposits. Baerbel Lucchitta of the USGS in Flagstaff, Arizona, pointed to new images of layered deposits in the bottom of Valles Marineris, the great crack in the planet's midsection, that are closely associated with small fissures resembling volcanic vents, all of which reminded her of the explosive, ash-producing portions of the 1783–84 Laki fissure eruption in Iceland. Elsewhere on Mars, the layered deposits near the volcano Arsia Mons look very much like the layered ash from the 1790 eruption of Hawaii's Kilauea rather than lava, noted planetary geologist Laszlo Keszthelyi of the University of Arizona, Tucson.

Proving that particular martian deposits are ash fallen from the sky rather than material carried in by water is difficult, but "a lot of us are more comfortable with a volcanic explanation," says Peter Mouginis-Mark of the University of Hawaii, Honolulu. "I just look at these deposits and think, 'Boy, that looks like a pile of ash,' " says Keszthelyi. "Many if not most [of the] layered deposits could be ash deposits."

Kenneth Edgett of Malin Space Science Systems Inc. in San Diego, who with Michael Malin of MSSS caused the stir last year by advancing an aqueous origin for layered sediments, concedes that from orbit "there's no way to know" whether water was involved in most of the layered deposits. To be sure about it, rovers will have to check them out up close, he says, and pretty smart ones at that.

No Life From the Stars

The origin of life on Earth, just half a billion years after Earth formed, seems so incredibly unlikely that some scientists have wondered about an alternative: Perhaps life arose in a single improbable event somewhere else in the galaxy and then drifted from one solar system to the next until it arrived here. Now planetary physicist Jay Melosh of the University of Arizona, Tucson, has put the statistical kibosh on that scheme. He reported at the meeting that he's done the numbers on interstellar panspermia, and the chance that life in another solar system may have hitched a ride on a bit of rock that fell to Earth is vanishingly small. "It appears solar systems are biologically isolated," says Melosh. "It looks like we'll have to find the origin of life in our own solar system."

Ironically, it was Melosh's work in the 1980s that provided theoretical support for the transfer of life among the planets of a single solar system. Rocks from Mars and the moon were being identified among meteorites collected on Earth, but it wasn't clear how that could be. Melosh showed that rock at or very near the surface of Mars, say, could be blasted to escape velocity by a nearby large meteorite impact without being melted or vaporized by the shock. Then it would be just a matter of time and luck before the rock could collide with Earth. The inner solar system must be adrift with bits of all the rocky planets, enough in the case of Mars that roughly 15 martian meteorites fall to Earth each year.

Melosh has now done calculations of the chances that a rock launched from a terrestrial planet in one solar system will land on one in another system. Using a Monte Carlo technique that simulates how the orbits of launched rocks evolve, Melosh found that Jupiter slings about as many martian rocks out of the solar system each year as fall on Earth. He then followed the ejected rocks toward the stars, where another version of the Monte Carlo orbit program calculates "that about one meteorite ejected from a planet belonging to our solar system is captured by another stellar system every 100 million years." But he's not done yet. Another calculation shows that only 1 in 10,000 rocks captured in orbit about another star hits a terrestrial planet in that system. So, according to these calculations, you'd have to wait 1 trillion years for an Earth-to–extrasolar planet transfer.

Even so, "I was pretty liberal in estimating a probability," says Melosh. He assumed all stars were liable to have habitable planets, and that every rock would be launched carrying viable life that would survive the vacuum, cold, and cosmic rays of deep space for the tens of millions if not hundreds of millions of years required for the trip. "We don't have to worry about extrasolar panspermia," Melosh concludes.

Geophysicist Norman Sleep of Stanford University has made similar calculations. "Given that impact ejection and travel over interstellar distances are not likely to be good for microbes," he says, "the chances of life getting transferred into our solar system in this way are essentially nil." Earth's neighboring stars probably were closer and moved more slowly when our solar system formed in a star cluster, he notes, but conditions on any newly formed planets back then were not very conducive to life. Melosh has entertained other suggestions for upping the odds, such as a close encounter of stellar systems, "but so far no one's come up with anything that seems plausible." Origin of life researchers may have to settle for the least implausible of improbable events.

–RICHARD A. KERR

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