such vital importance to HIV, the multiple transport mechanisms may serve as backups for each other. "It's not uncommon for HIV to incorporate redundancy—to have multiple ways of getting a job done," says Greene. Still others, like Emerman, have already placed their bets on a single candidate—in his case, on integrase.

"I don't think everybody is right here, but I don't yet have a betting line on who might be and who's not," says Coffin. "I'm standing aside waiting for the dust to clear."

Inside the black box

While controversy reigns over nuclear import, mystery shrouds HIV's movements within the nucleus itself. "If the trip from the plasma membrane to the nuclear envelope is a gray box, the rest is a black box," says Trono. "Biologists don't know much about intranuclear trafficking, in general."

Despite this ignorance, researchers are beginning to realize that, just as HIV co-opts cytoplasmic factors, it also takes control of nuclear factors. Trono's unpublished observations, for example, suggest that shortly after HIV enters a cell, it triggers factors involved in regulating gene expression to rush out of the nucleus. Trono stresses that the meaning of the observation remains unclear. But he hypothesizes that HIV might be recruiting these factors to ensure that its genes are expressed efficiently once they are integrated in the host's chromosomes. Most locations on a chromosome are not suitable for gene expression. Yet HIV's genes seem to be expressed very effectively, almost regardless of where they integrate. "That is quite a success that you need to explain," says Trono. "These factors might help to create a sort of transcriptional honeymoon for the provirus right after it integrates."

Turning these emerging insights into therapeutics will clearly take some time. A few researchers are already trying to block viral nuclear localization signals, for instance. But because these sequences are similar to those of many cellular proteins that reside in the nucleus, some fear this strategy could lead to serious side effects. Also, the complexity of the challenge causes many drug companies to shy away from developing drugs that block multisite interactions between large proteins, says Coffin, such as those that occur as HIV travels through the cell.

But Gallo is optimistic, comparing the study of HIV's trek through the cell to the early days of research on viral entry. "Look at what happened in a short time in that area," he says, alluding to the new drug candidates spawned by viral entry research. "Who knows what can happen here. You can't predict what'll come, but that something will come is very likely." **–MARINA CHICUREL**

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PLANETARY SCIENCE

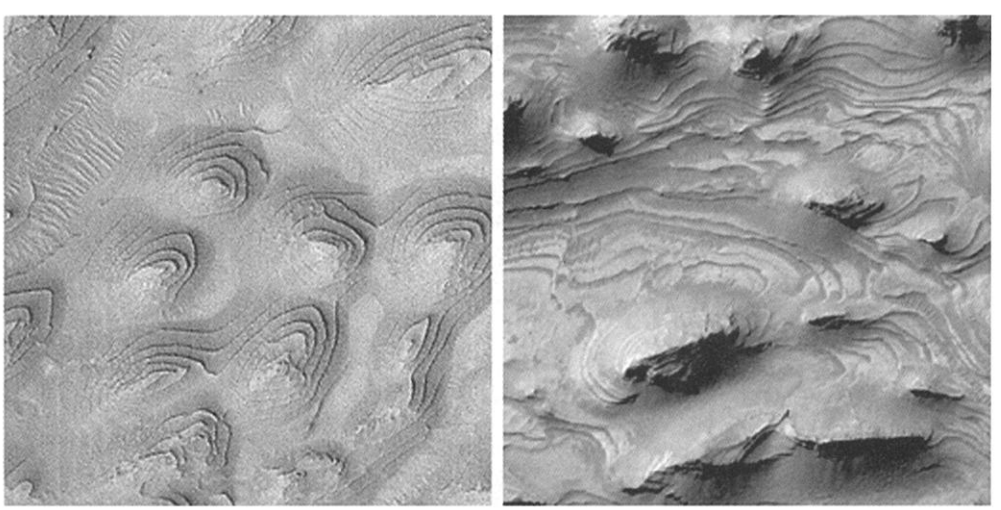
A Dripping Wet Early Mars Emerging From New Pictures

The latest images from the Red Planet are suggesting that water ponded across its equatorial region eons ago, just when life might have been emerging

Mars, water, life. That explosive mixture comes together again on page 1927 of this issue, where a sampling of hundreds of spacecraft images shows crisply detailed sediment layers on Mars. Although the authors offer more than one interpretation, the one they prefer has the sediments laid down beneath broad lakes and shallow seas at a relatively clement time in the planet's history. The images don't have the visceral impact of the springlike seeps reported earlier this year, but the geologic implications of the pictures plus supportive signs from earlier missions mean that these possible lake sediments will be prime candidates for NASA missions seeking signs of past life on Mars.

The new hints of extensive standing water on Mars as much as 4 billion years ago—about when life got started on Earth—comes after 3 decades of studies of layered martian terrains. "A lot of the pieces are not new" in the *Science* paper, says Mars geologist Michael Carr of the U.S. Geological Survey, but the new study "brings all these bits and pieces together with much better support for layered deposits and makes a good story out of it"—not that the story will lack controversy. "They make a good case that [the terrain] is layered," says planetary geologist James Head of Brown University, "and the most likely interpretation is they are sediments. That's pretty impressive. The part that will be debated will be the origin of the sediments. Sediments don't necessarily mean water."

The controversy over how much water Mars ever had and when, if ever, liquid water flowed on the surface began with the first successful Mars orbiter, the U.S. Mariner 9 spacecraft. Arriving in 1971, it confirmed the dry, desolate, moonlike appearance of large areas of Mars imaged by earlier flyby spacecraft. But Mariner 9 also discovered so-called valley networks, reminiscent of river-carved valleys on Earth. Many researchers argued that groundwater oozing from the headwalls of valleys, rather than rain and running rivers, could sculpt such features, obviating the need for a "warm and wet" early Mars. But more signs of water—water that once stood in pools, lakes, and even oceans—appeared in many of the 50,000 images returned by the pair of Viking orbiters that arrived in 1976. Hints of a shoreline around the northern lowlands suggested to Mars geologist Timothy Parker of the Jet Propulsion Laboratory in Pasadena, California, that there had been an early



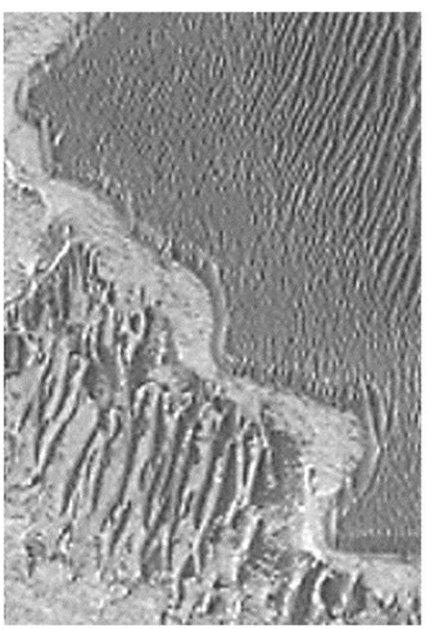
CREDIT: MALIN AND EDGETT, MSSS/JPL

An edgy face of Mars. Some erosive force, perhaps the wind, has sculpted layered sediments into stair-stepped hills inside an impact crater *(left)* and a chasm. Images are about 1.2 kilometers square.

ocean (*Science*, 4 December 1998, p. 1807). And reports of craters containing lakelike sediments, some of them layered, suggested that some impact craters had held water at some point in Mars's history. But the reality, extent, and age of oceans and lakes remained controversial.

Then Mars Global Surveyor (MGS) arrived. Carrying the Mars Orbiter Camera (MOC), it began returning a torrent of images in 1999 so sharp that features as small as a few meters could be discerned, compared with the 25- to 50-meter resolution in Viking images. At Malin Space Science Systems Inc. in San Diego, Michael Malin, MOC principal investigator, and Kenneth Edgett scan the incoming images daily for features of geologic interest. Most dramatic were the springlike seeps that Malin and Edgett reported in *Science* last summer (*Science*, 30 June, p. 2330). The rivulets of sediment on impact crater walls showed that some fluid, presumably involving water as a brine or melted ice, briefly flowed from the ground within the past few million years. But Malin and Edgett were also seeing a steadily growing number of images, now in the hundreds, of layered terrains.

Malin and Edgett compiled a survey of layered terrains that turned up a more consistent picture than seen before. As they report in their *Science* paper, layered rock is exposed at most longitudes in the martian equatorial region but is concentrated in five low-lying areas there, including the canyons of Valles Marineris and northern Hellas basin, a 2200-kilometer impact crater. Layers most commonly fill impact craters. In places, craters seem to have been completely covered by layered material—possibly akin to the easily eroded chalk Cliffs of Dover—that has since been partly eroded away, perhaps by the wind. The layered rock tends to come in three sorts—many thin, stacked layers each a few meters to tens of meters thick; one massive layer hundreds of meters to a few kilometers thick; or a thin, dark layer that often caps mesas where much erosion has occurred. Where they occur together, mesa-forming layers are on top, massive layers below that, and thin layers on the bottom. Neither the sources of all this sediment nor its means of transport are evident in the images. However it got there, it seems to have arrived early in Mars's history, according to Malin and Edgett, a time called the Noachian more than about 3.5 billion years ago.



A crowning event. Whatever laid down the layered sediments of Mars, the last layer was thin and dark-colored. Image is 0.75 kilometer across.

CREDIT: MALIN AND EDGETT, MSSS/JPL

Malin and Edgett favor water as the motive force behind the layered sediments. "On Earth, water is most effective at producing" strong layering, says Malin. Add in the fact that the images show layered sediments have piled in, and even filled, some craters—where wind-blown dust would likely blow in and out again rather than accumulate to great depths—and the MOC images "strongly hint water was involved," says Malin.

In their preferred scenario, a thicker, warmer atmosphere than today's would have dumped rain on the highlands, and flowing water would have carried clay, silt, and sand into crater lakes and perhaps some shallow seas between craters. They place this scenario during the Noachian, the time of heavy, crater-forming bombardment, when the terrestrial planets swept up the last of the debris lingering from their formation (*Science*, 1 December, p. 1677). The heat of large impacts may have sterilized the surface as late as 3.9 billion years ago, but impacting objects also could have brought in life-giving water and left abundant thermal springs where life may have gotten started. Once the water was gone—into the subsurface or outer space—erosion over the eons, perhaps by the wind, could have begun to expose the layers.

The notion of pervasive standing water on Mars is sure to get a mixed reception. "They're terrific images," says planetary geologist Alfred McEwen of the University of Arizona in Tucson, a MOC team member, but "the interpretations are going to be controversial. They do look sedimentary, and [in MOC images] they look similar from place to place. It's a little dangerous, but it's reasonable to conclude they formed by a similar process and from similar materials. But there are lots of processes that produce sedimentary deposits," from water and wind erosion to erupting volcanoes and cratering.

The debate over the origin (or origins) of martian layered sediments starts with the source of the sediments. Malin and Edgett are inclined toward erosion of the highlands as the predominant source, while Head favors a role for volcanic ash, and planetary geologist Nathalie Cabrol of NASA's Ames Research Center at Moffett Field, California, points to impact ejecta as another likely player. Carr takes a more ecumenical approach. Seeing no obvious path taken by the sediments, such as a river channel, he concludes that "water pools in the craters and acts as a trap for material blowing around." (Malin and Edgett also offer a "substantially more exotic," but in their view less likely, alternative: a martian atmosphere whose mass—and thus the ability of its winds to pick up and carry volcanic or impact dust—waxes and wanes so as to produce the layering.)

The central question underlying all these scenarios is how much surface water the planet ever enjoyed. In Head's latest analysis of MGS altimetry data, a shorelinelike profile appears around the northern lowlands, but no one, including Head, sees the case for an ocean as closed yet. As to lakes, this year Cabrol published her latest analyses of Viking images showing what she believes to be craters filled with typical lake sediments, including deltas where water had flowed in. And in a number of meeting abstracts, Parker has documented a flow path from sediment-filled Argyre crater along a trough connecting a series of one-time crater lakes that runs downhill 4000 kilometers to the northern lowlands.

Even if they accept that standing water trapped at least some of the sediments, scientists disagree about just when the layers formed. Malin and Edgett believe the layers are likely Noachian by analogy with the layered sediments in Valles Marineris. Rather than relatively young lake deposits laid down long after the chasms of Valles Marineris split open the ancient rock there, they believe these layers are ancient rock protruding from the walls of Valles Marineris. "That's unconvincing," says McEwen. He sees the Valles Marineris deposits as later, younger additions. "All we can say is they're younger than 3 [billion] to 4 billion years."

Understanding the nature of sediment layering on Mars is going to take time. "Doing fieldwork would be terrific," notes McEwen. Barring that, "we need some way of getting age dating of the materials and compositional information [from orbit] at high resolution." Orbital missions in this decade would return the compositional analyses through high-resolution spectroscopy. Dating would require rovers with instruments that have not yet been designed. The story of Mars, water, and life will be a while in the telling. **–RICHARD A. KERR**