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OF THE WEEK

RESEARCH NOTES

ARTICLES

DEPARTMENTS

COVER: White Bengal tigers sun on the lawn of their new habitat—a spacious, moated exhibit at the Smithsonian Institution's National Zoological Park in Washington, D.C. The National zoo's partially completed revision plan, as well as design changes at many other zoos, reflect an evolving philosophy and an expanding knowledge of wild animal husbandry. See p. 106. (Photo: National Zoological Park, Washington, D.C.)

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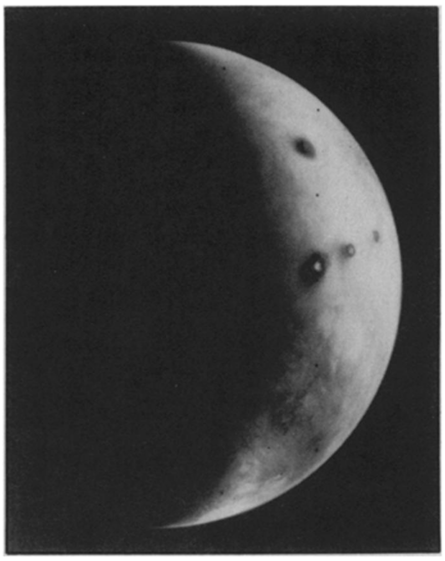
SCIENCE NEWS OF THE WEEK

Viking's Life Search: Tantalizing Signs and an Agonizing Wait



NASA-JPL

View by Viking 2, now also in Mars orbit.

And then there were three. On the morning of Aug. 7, the Viking 2 spacecraft entered its orbit around Mars, forming a tryptich with the lander and orbiter jointly known as Viking 1. Unlike its predecessor, which began its orbiting career locked in a path whose low point was always over the (later changed) prime touchdown site for its piggy-back lander, Viking 2 settled into a nonsynchronous orbit whose low point would advance around the planet by 42° per day. This will help mission scientists scan the 5,000-odd kilometers in the northern high 40s of Martian latitude where they plan to find a site for the Viking 2 lander's scheduled early-September descent to the surface.

Even as project officials were cheering the newcomer's safe arrival, however, members of the Viking biology team were confronting a potentially far more momentous issue: New and surprising data—difficult to explain away by any immediately apparent chemical theory—in the search for life on Mars.

The last of the Viking 1 lander's three life-hunting instruments to make its initial report was the carbon-assimilation experiment, designed by Norman H. Horowitz of the California Institute of Technology. This experiment looks for microorganisms that take in gaseous atmospheric carbon compounds and incorporate the carbon into organic material by such processes as photosynthesis or chemical fixation. A 0.25-cubic-centimeter soil sample is sealed into one of the device's tiny test chambers with a mixture of natural Martian air, water vapor and radioactively labeled carbon dioxide and carbon monoxide. During incubation the soil is exposed to a sunlight-simulating xenon lamp that is filtered to remove ultraviolet wavelengths that can cause misleading reactions. After five days, the atmosphere is flushed from the chamber by a surge of helium and the sample is heated to 625°C to vaporize any organic molecules that may have formed. The resulting labeled gases are forced into a vapor trap and adsorbed by a filter material. Any unassimilated radioactive CO_2 and CO are driven through the trap by continued helium pressure to a waiting geiger counter. This, in turn, reports their presence as an initial large, nonbiologic peak in the data. The trap is then heated to 700°C to drive off the adsorbed organics—presumably the labeled remains of the micro-Martians—thus providing the much smaller but possibly all-important second data peak.

The first peak from the Martin soil sample yielded a radioactivity level of 7,400 counts per minute. According to Horowitz, who has been less than optimistic in the past about the chances of Martian biology, if there were no life in the sample, the second peak ought to be about 15 counts per minute, roughly 0.2 percent of the first one. When the second peak actually came in, he says, "my reaction was sheer incredulity." The number: 96 counts per minute, about 1.3 percent of the first peak and nearly six and

a half times the predicted figure.

For comparison, Horowitz cited similar tests of three soil samples from the dry valleys of Antarctica, once thought to be among the few lifeless spots on earth and still seen as among the least lively. Though all three produced higher first peaks than the Martian sample even when sterilized (the sterile counts ranged from 13,000 to 107,800 cpm), the second peaks were all substantially lower (from 11 to 40, not in the same order), with the second peaks ranging from 0.14 percent to as little as 0.04 percent of the initial ones.

With their striking data in hand, Horowitz and his colleagues then had to begin what could be a long detective process of weeding out all possible non-biologic causes. The vapor trap could be faulty, blocking too much of the unassimilated CO_2 and CO from their normal, first-peak release and creating a misleading ratio between the peaks. Or perhaps the UV filter on the lamp in the test cell, designed to block wavelengths that can (on earth) trigger organic synthesis from carbon monoxide and water vapor in the presence of silicates, is useless if longer wavelengths somehow produce the same reactions on Mars. With such high stakes, that little peak in the data will have to survive the most demanding of cross-examinations before its tentative message can win acceptance. Nonetheless, chief Viking biologist Harold Klein acknowledged that "the information does suggest at least the possibility of biological activity in the sample being incubated."

Even if no sources of error are found, however, the experiment has a long way to go. First, another 0.25 cubic centimeter of the same soil sample will be sterilized by heating it for 3 hours at 160°C, after which a new supply of labeled gases will be let into the chamber to see if a *lower* second peak results when the experiment is repeated; this cycle should be complete by Aug. 23. Then a third bit of soil will be tested (without being sterilized) to see if it yields another *high* second peak. "In biology," says Horowitz, "it's a cardinal rule that you don't believe it if it hasn't happened at least twice."

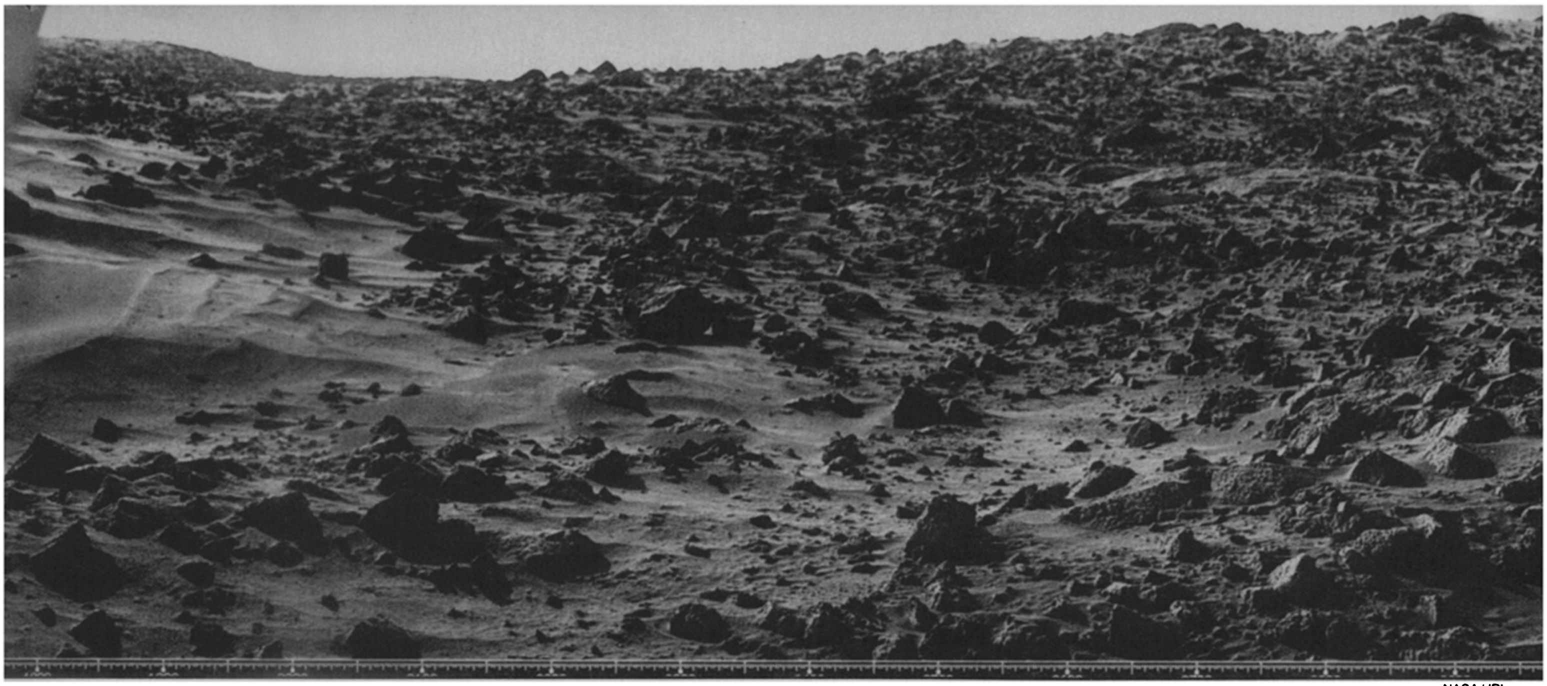
That dictum applies as well to Viking's two other biology instruments, both of which have produced their share of raised eyebrows with their own surprising data. The unexpectedly large release of oxygen reported by the gas-exchange experiment (SN: 8/7/76, p. 84) suggested the possible presence of peroxides and superoxides in the soil, but the carbon-assimilation experiment, says Horowitz, involves a reduction reaction, the opposite chemical process. "If anything," Klein says, "the superoxides would tend to decrease the size of that second peak." Meanwhile, a team of scientists at NASA's Ames Research Center is studying a variety of test soils to try to produce a similar gas-exchange reaction.

The third experiment, which searches for microorganisms that might metabolize labeled carbon compounds from a nutrient and release labeled, gaseous "exhalations," provided its second surprise last week while still studying its first soil sample. The initial dose of nutrient had produced a data curve, reflecting the radioactivity of the released carbon-containing gases, that rose dramatically before leveling off. This prompted the idea that the reaction was a chemical one that slowed down as some key ingredient was exhausted. A second dose of nutrient, however, actually caused the curve to drop, with the pattern of the decrease seemingly ruling out such obvious technical problems as a leak in the test chamber. The drop seemed ever more perplexing than the initial rise, leaving both scientists and engineers baffled as to its cause.

Many of the Viking biologists have also been eagerly awaiting data from the lander's gas chromatograph/mass spectrometer (GCMS), whose organic chemical analysis of the Martian soil could reveal much about the available raw materials from which life might form.

It has been a suspenseful wait. On July 28, when the lander's extendable scoop delivered soil samples to the biology instruments, an inorganic chemistry device and presumably the GCMS, the GCMS failed to signal that it had received its share. On Aug. 3, the scoop was sent out for a repeat attempt, but on its way back with the dirt, it stuck. Big trouble. The instruments were depending on the scoop for subsequent soil samples, and geologists measuring the physical properties of the surface material were counting on it to scrape, dig and generally maneuver the terrain around. For four days, more than 50 people at JPL and at prime contractor Martin-Marietta Corp. in Denver worked shifts as long as 18 hours a day to understand the problem, finally sending the lander a series of commands to gingerly move the scoop arm through its paces. Almost as if nothing had been wrong at all, it responded perfectly.

In the meantime, however, the GCMS team, headed by Klaus Biemann of the Massachusetts Institute of Technology, had decided to let their instrument proceed with its work, banking on the chance that there was soil inside and that it was merely the soil-level indicator—a hair-thin wire known to have broken in tests on earth—that wasn't working. First results from the instrument were ambiguous. They did reveal carbon dioxide with a carbon-isotope ratio indicating the possible presence of a soil sample, but a preliminary study of about 300 integrated mass spectra from the device failed to reveal the overt presence of organic compounds. "We haven't looked for them in any detail," said Biemann at the time, "but if there would be large amounts, then we would stumble across it." One possibility was that only a small sample was in the GCMS test cell. A second-stage analysis late this week, in which the same possible sample would be heated to 500°C (versus 200° the first time) was expected to give more revealing indi-



NASA/JPL

Dramatic early morning lighting makes for a spectacular high-resolution panorama of Martian landscape. Sharp crests of crusted sand dunes indicate that the most recent wind storms moved sand from upper left to lower right, also evident by small deposits downwind from many of the rocks.

cations—and perhaps some vital information. The sample that had been waiting in the newly revived scoop was to be placed in another GCMS test cell on Aug. 11, with a third to be gathered 9 days later.

The inorganic chemistry of Mars—the basic elements in the soil—are being measured with increasing accuracy by Viking's X-ray fluorescence spectrometer. The combining of more than 200 X-ray spectra has yielded percentage ranges for 7 elements in the instrument's sample, upper limits (to be refined further) for 18 more elements and for 2 element groups, and a specific estimate for one: iron. The device reported 14 percent, plus or minus 2 percent, of iron in the sample. Team member Benton Clark of Martin-Marietta says that as little as 1 to 2 percent iron, well-oxidized, might be enough to give the planet's surface its intense, ruddy color. The increasingly accurate elemental abundances also sustained the possibility of water-soluble salts, which fits theories of water rising through the surface material and leaving evaporites that could produce a slight crust. At least, the sample does *not* consist of rock fragments each of which is completely coated with iron oxide, says team leader Priestley Toulmin III of the U.S. Geological Survey. "The reason that this is important," Toulmin says, "is that many of the photochemical mechanisms that are being discussed with reference to these biological results depend on fresh, unweathered rock material containing ferrous iron, in general being exposed to the atmosphere and not being armored by a coating of any sort." He adds that the low content of trace elements in the sample is reminiscent of terrestrial ultramafic rocks—rich in olivine and pyroxene, low in feldspars and quartz. But such rocks on earth seem much more susceptible to weathering than those in the Martian sample. No known earthly rocks perfectly match the Viking instrument's spectra, he says. Few are even close. Mars, in short, seems to be very much its own planet. The next sample, to be collected Aug. 23, will probably consist of pebble-sized chunks rather than "fines," as the lander continues to examine the surprising diversity of its landing site. Additional data are expected from a magnet mounted atop the spacecraft, revealed by the cameras to have soil particles adhering to it, aligned in the magnet's bull's-eye pattern. A study of the particle concentrations on the magnet's weaker and stronger sides, combined with more data from Toulmin's instrument, could shed light on oxidation levels and other processes.

Composition of Mars Surface Sample

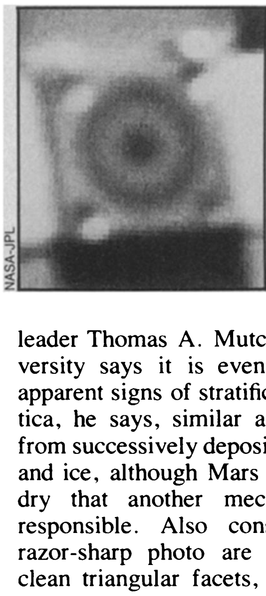
Preliminary Estimate

(< refers to upper limit)

Element	Percentage by Weight
Aluminum (A)	2-7
Silicon (Si)	15-30
Phosphorus (P)	<10
Sulphur (S)	0-6
Chlorine (Cl)	0-3
Potassium (K)	0-2
Calcium (Ca)	3-8
Titanium (Ti)	0.5-2
Vanadium (V)	<3
Chromium (Cr)	<5
Manganese (Mn)	<7
Iron (Fe)	14±2
Cobalt (Co)	<7
Nickel (Ni)	<5
Copper (Cu)	<0.5
Zinc (Zn)	<0.1
Gallium (Ga)	<0.03
Arsenic (As)	<0.02
Selenium (Se)	<0.015
Bromine (Br)	<0.015
Rubidium (Rb)	<0.01
Strontium (Sr)	<0.02
Yttrium (Y)	<0.02
Zirconium (Zr)	<0.02
Niobium (Nb)	<0.025
Molybdenum (Mo)	<0.05
Technetium to Uranium (Tc to U)	<2
Except Rare Earths: <3 total	
Wolfram (W) & Rhenium (Re): <0.1% total	
Osmium (Os), Mercury (Hg), Lead (Pb), Thorium (Th) & Uranium (U): <0.03% total	

Viking Inorganic Chemical Analysis Team, P. Toulmin et al.

The cameras are also providing stunning—and enlightening—high-resolution photos of the terrain around the site. One panorama reveals the sand and rocks with such clarity that lander imaging team leader Thomas A. Mutch of Brown University says it is even possible to see apparent signs of stratification. In Antarctica, he says, similar appearance results from successively deposited layers of sand and ice, although Mars is presumably so dry that another mechanism may be responsible. Also conspicuous in the razor-sharp photo are dark rocks with clean triangular facets, of a sort known on earth only among fine-grained, homogeneous basalts. Huge, complex sand dunes span the panoramic view, replete with wind tails behind the rocks and other features. Even Mutch seemed agog at the crisp images. The photos from the first day on the surface were impressive enough, he says, but "I don't know what I would have done had I seen this. I probably just would have levitated and gone up to the ceiling." □



NASA-JPL

Bull's-eye pattern left by wind-borne dust particles attracted to concentric magnets on back of photometric target atop Viking 1 lander.