Viking (I): End of First Phase of 70's Space Spectacular

The Viking mission has been a breathtaking extension of human observations to the surface of another planet. The cameras have recorded vivid pictures of the pink martian sky and red desert sands. Weather sensors have measured a daily pattern of light easterly afternoon breezes, and the barometer has recorded daily fluctuations as well as long-term trends. The first phase of the Viking mission ended on 8 November, when Mars passed behind the sun, interrupting radio communications with the planet.

Four spacecraft have been gathering data on Mars—two orbiters and two landers. While the landers have recorded the weather and landscape at two locations, the orbiters have recorded the global features, particularly through television imaging and infrared mapping. At the same time, the instruments on the lander have measured the trace elements of the atmosphere and conducted an extended sequence of experiments to learn the likelihood of the existence of life.

Because two orbiter-lander projects were undertaken in rapid succession, the requirements of day-to-day decision-making have left the mission scientists little time to process and evaluate data. Only about 2 percent of the planet surface has been photographed and reproduced so far. But the Viking spacecraft are due to continue operating—after the November hiatus—for 2 years.

As with most planetary missions, the full dimension of the scientific accomplishments of Viking probably will not be realized until well after the mission is completed. But enough information is already in hand to suggest that the mission is one of "historic proportions," as long-time Viking enthusiast Carl Sagan, of Cornell University, recently told the House Science and Technology Committee. The discoveries came in rapid succession.

Before the first Viking lander touched down, it found small amounts of nitrogen and argon in the carbon dioxide atmosphere, indicating that the tenuous gases of Mars had probably been thicker in the past. The first Viking orbiter, which had photographed a wide channel mouth at the intended first landing site, settled a vigorously argued debate about the nature of the many channels found in 1971 by Mariner 9. The pictures clearly showed that the channels were cut by running water.

Within weeks of the 20 July touchdown of the Viking 1 lander, two of the three life-science experiments onboard gave clear positive results. But an unexpected result from the third biology experiment caused the mission scientists to pause, and a negative result found when the soil was tested for organic molecules made most scientists pessimistic about finding life with this space mission.

Since Mars has long been thought to be the planet that, next to the earth, was most likely to support the evolution of life, the emphasis on the first exploratory mission to land on Mars was tilted heavily toward the search for life. Although challenged repeatedly by scientists who favored more elaborate physical and chemical measurements, the emphasis on biology prevailed. The first two landing sites were chosen for their likely proximity to water, ancient water in the Chryse channel and present water vapor at a mid-northerly latitude. Although these sites proved too rough, the eventual landings were at a site close to Chryse and at Utopia, another mid-northerly location. The selection of instrumentation for the lander was also tilted toward biology experiments—which were the heaviest instruments in the payload.

Carbon Chemistry and Water

The biology package on the Viking landers is a complex arrangement of miniaturized test cells, heaters, coolers, geiger counters, and gas chromatographs designed to perform variations of three basic experiments. The experiments differ slightly in the degree to which they predicate earthlike or Mars-like conditions, but all three test for life nourished by a metabolism based on carbon chemistry and water. Before the spacecraft were launched, succinct criteria were developed on the basis of dry earth soils, that were intended to give clear yes-no answers to the presence of three types of (earthlike) biological metabolism.

The first biology experiment was designed to test for evidence of photosynthesis under a lamp that simulates martian sunlight. Carbon dioxide prepared with radioactive carbon-14 was introduced into the soil chamber. After a period of incubation, any organic molecules formed from the radioactive CO_2 were to be decomposed (pyrolized) by heating and detected by their radioactivity. The predetermined positive criterion was satisfied by repeated tests at both landing sites. The explanation of this experiment is ambiguous, but scientists are nevertheless convinced that neither this result nor the others are experimental artifacts.

The second biology experiment was designed to find out if any component of the martian soil—such as a microorganism—would assimilate a nutrient solution containing organic compounds that had been labeled with radioactive carbon-14. Large amounts of radioactive carbon dioxide were given off after nutrients were added to a soil sample, indicating that something was oxidizing the carbon in the radioactive compounds. Moe than enough difference was found between "active" and sterilized soil samples to satisfy the present criteria. This was dubbed the labeled release experiment.

The third Viking biology experiment gave scientists a clue to something unusual in the soil chemistry of Mars. In the process of testing the reaction of the soil to a nutrient solution called "chicken soup," the third experiment found that the sample released a "puff of oxygen" when water vapor was present. That result did not agree with the positive criteria that have been established for various earth samples. Neither did it replicate the behavior of moon samples, which released hydrogen. The negative result for the third (gas exchange) experiment made the data from the entire package of life experiments more ambiguous, and raised the question whether chemistry or biology might be the better explanation.

A Dissenting Vote

No doubt many scientists would have favored a biological explanation over a chemical one if organic molecules had been found, in spite of the dissenting vote from the third biology experiment. But the Viking instrument for chemical analysis, a combined gas chromatograph and mass spectrometer (GCMS), found no light organic molecules at a sensitivity of 1 part per million and no heavy organic molecules at 1 part per billion. The finding was essentially the same at both sites.

"If the GCMS had found organic materials, particularly those of high molecular weight, and [the biology experiments] had found positive results, then my thinking would have swung around," says Bruce Murray, the widely respected Caltech scientist who is now director of the Jet Propulsion Laboratory and who has for many years argued the skeptic's side of the emotional life-on-Mars debate.

To those who would place so much emphasis on the organic material result, Carl Sagan points out that the positive biology experiments are "a thousand times" more sensitive per gram than the negative GCMS test. Sagan suggests that there may be bits of organic stuff, such as windblown spores, at concentrations too low to be detected by the GCMS.

Sagan's colleague in the advocacy of life on Mars, Joshua Lederberg at Stanford University, is inclined to view the biology results as negative. "Occam's razor clearly points toward a chemical hypothesis," he says. Lederberg does not think life is ruled out, but he concludes that "one is driven" away from the hypothesis of widespread life to the idea of "islands of life" in certain favorable regions. The negative results are "not just a question of sensitivity," according to Lederberg, but an indication that "the habitat is very inhospitable at latitudes so far south."

Go North for Life

The first lander is in an extremely dry equatorial desert, and the second is not far enough north to encounter regular frost. Lederberg, who characterizes himself as one of the original "go north" people, thinks it is now necessary to look in specifically favorable habitat zones, such as rough terrain in the far north where slopes facing south might heat up enough each day to melt frozen water.

While the puff of oxygen released in the third biology experiment did not fit the criteria for life, it signaled what many scientists believe to be the most important discovery about the surface of Mars. The generally accepted explanation is that there is a component of the soil oxidized beyond its normal chemical state on the earth—a so-called superoxide. Water reacts strongly with it, according to the general opinion, producing "normal" oxide and oxygen. Its chemical structure is not yet known, but something like a hyperoxidized state of iron (or other heavy metal) is often suggested.

The superoxide was not expected, and it changes the context of surface chemistry on Mars. Being a very powerful oxidizing agent, it could destroy organic molecules. To be produced in the first place, the superoxide would have to be the result of an unusual chemical reaction. From the Mariner 6 and Mariner 7 missions, ultraviolet light at wavelengths as short as 1900 Å was known to reach the Mars surface, and many space scientists hypothesize that a photocatalytic reaction boosts the red iron oxide coating of Mars materials into a superoxidized state.

The fact that the soil appears to contain a superoxide "does not, in itself, preclude the possible presence of life" at the two Viking spots, cautions Harold Klein of the Ames Research Center, the leader of the Viking biology team. But the superoxide coating is presumably pervasive enough in sunlit places to make sheltered places more appealing locations in which to look for life.

Although slightly sophisticated organisms could no doubt develop a shell or other protection, simple organic molecules would be defenseless. Lederberg thinks that organic molecules would be "burned out" at mid-latitudes as a consequence of oxidation activity, but that the oxide might not be such a problem at northerly latitudes, where water vapor could reduce it. Murray is more pessimistic. "My interpretation," he says, "is that anywhere the sun shines" is going to be highly oxidizing. "Organic matter is in effect fighting the ultraviolet flux," he says, "with the soil material being the intermediary." Mars now appears to have a soil chemistry considerably different from what was consciously considered when the Viking experiments were designed.

But a chemical explanation of the "ambiguous" results on Viking may eventually shed some light on the evolution of life. The first (pyrolytic release) biology experiment mimics plant photosynthesis, the second (labeled release) mimics animal metabolism, and the process of formation of the hyperoxide layer provides a potential source of chemical energy that is in some ways analogous to the oxygen reservoir in the earth's atmosphere. One suggestion for a new approach to the search for life on Mars is to look for a bug that would eat the superoxide, perhaps a microorganism analogous to the chemosynthetic bacteria known on the earth.

Another possible implication of the unusual Viking soil chemistry is that the superoxide existed on the earth during the first few billion years, and may have played a part in the evolution of the earth's oxygen atmosphere. The generally accepted theory is that the early atmosphere was chemically reducing and only became oxidizing after chlorophyll life-forms evolved. "Some people are beginning to wonder whether it really was the algae that produced oxygen," says Klein, or whether it was instead the interaction of water with a Mars-type superoxide. At the very least, the Mars soil discovery will force scientists to reconsider the possible effects of the ultraviolet radiation field of the early earth.

Ever since the Miller and Urey experiments in 1953 showed that an electric discharge could induce formation of organic molecules out of water, methane, and ammonia, some people have thought that the origin of life was quite easy. "Mars is going to make these people step back and recognize that the same energy source making these compounds was also breaking them down, probably very rapidly," says Klein. Sagan, however, finds more reason for hope in the Viking results. He points out that the first biology experiment shows evidence of a strong photoreduction process, in addition to the evidence for oxidation. He argues that the chemical evolutionary system of Mars would be further along the way to life because these two quasi-metabolic systems were already there. Not many others agree with that assessment, leaving Sagan now, as in much of the last decade, the most optimistic proponent of the likelihood of life on Mars.

Such a role does not seem to disturb him in the least. "For the entire history of the question," says Sagan, "it has been demonstrably true that the scientific consensus has been wrong" in times of optimism as well as pessimism. In such an emotional issue, he says, the scientific dialogue has not followed normal cues and the criterion of consensus cannot be taken as the guide to scientific fact. "One of the most significant achievements of the Viking mission," says Sagan, "has been to make the question of life a respectable one. I know many people whose view of the likelihood of life on Mars has moved orders of magnitude lifeward" since Viking landed.

Although it will take several more months before the Viking spacecraft finish the remaining biology experiments they have the capacity to undertake, the Viking team is looking toward the next mission. The plan they favor next is a spacecraft that can land in the safe, "boring" places and "rove" to the interesting places (estimated more likely to have life). But when asked last spring about the prognosis for the upcoming Viking experiments, Sagan replied that "If there are four or five Viking missions with negative results, I still think it would be a mistake to conclude no life exists—because Viking would need to be upgraded considerably to find life which lives at Mars [very cold] ambient temperature."—WILLIAM D. METZ