MARS–STILL A MYSTERY

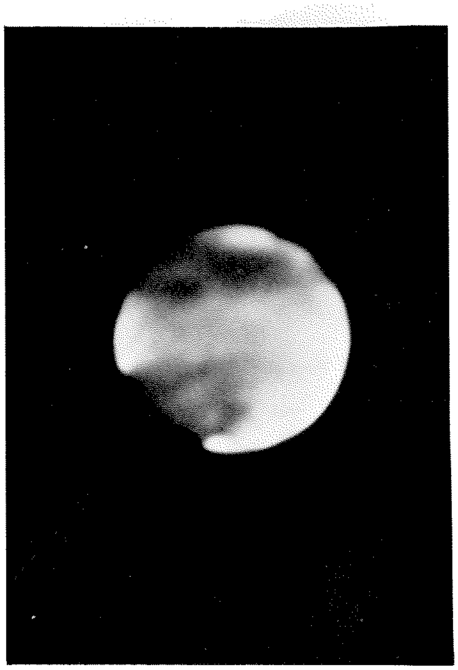
The Core of the Problem

Earth's nearest neighbor in the solar system, Mars, has always seemed the planet most like our own. But, with a diameter roughly only half that of the earth, Mars seemed too small for a molten core like the earth's to have formed in it while the planet was solidifying from the primordial gas—along with all the other planets—about 4.6 billion years ago. New evidence, however, indicates that Mars is an even more earthlike body than has previously been supposed.

"Mars undoubtedly has a large core—perhaps 1,000 miles in diameter," says Don Anderson, professor of geophysics and director of the seismological laboratory, "and it is probably at least partly molten."

Anderson postulates his model of the interior of Mars from two sets of information: 1) a model of the earth's interior based on a considerable body of seismic, ultrasonic, shock-wave, static compression, and petrological data; and 2) some very exact measurements made by the several Mariner spacecraft that have flown behind the planet. The data include an accurate measurement of the diameter of Mars—4,208 miles, or about 75 miles greater than scientists had thought before the Mariner flights. This measurement made it possible to derive a precise figure for the mean density of Mars; it was also possible to make precise measurements of Mars' gravitational pull on the spacecraft. Previous studies of the orbits of the two small moons of the planet supplied its moment of inertia, which is related to the flattening at the poles.

All these data lead Anderson and graduate student Thomas Jordan to conclude that Mars is a differentiated body like the earth, with a mantle, a core that is probably molten, and possibly a crust.



The core of Mars is much less dense than the earth's, but its mantle is denser. The reason for this is that the temperatures in the interior of the earth are much higher than those in Mars, and the gravitational field of the earth has pulled most of the iron out of its mantle and deposited it in its core. Much of the iron still remains in the Martian mantle.

To migrate through a planet's interior, metal must be in molten form, but indications are that all of the core of Mars hasn't yet separated from its mantle. This implies that Mars hasn't gotten hot enough to melt all the iron, sulfur, and nickel, which are the core-forming materials. But it is likely that the Martian core is richer in sulfur than the earth's, since sulfur compounds melt at lower temperatures than pure metals and therefore migrate at lower temperatures.

Since Mars has so many other earth-like features, one might expect it also to have a magnetic field, but it does not. A magnetic field requires two factors, of which Mars has only one—a molten core. The second, a large enough moon to maintain currents or motions in the molten core, is lacking on Mars. Mars does have two small satellites about five to ten miles in diameter, but this is in contrast with the earth's moon, which has a diameter of 2,160 miles.

In the earth the core rotates at a different speed from the mantle—a phenomenon called differential rotation. The gravitational tidal forces produced by the moon on the rotation of the earth cause its axis of rotation to change, producing the differential rotation that drives the motions in the core. These tidal forces vary because of the elliptical and inclined orbit of the moon and the elliptical shape of the earth, and they are effective because of the large mass of the earth's moon.

Mars is proportionately poorer in iron than the earth because of the redistribution of iron toward the sun in the formation days of the solar system. The planets nearer the sun got more iron. Mercury, the innermost planet, is the richest of all the planets in iron.

Of all the material in the inner solar system—including the meteorites, the moon, and the four small, inner planets—the earth is most representative of the primordial chemical composition of the solar system and most similar to the composition of the heavier elements in the sun. If it were possible to make one planet out of Mercury, Venus, Mars, and our Moon, that planet would be the same size as Earth and have the same amount of iron in it.

At a time when the planets were formed and the sun was still condensing, the sun brightened considerably for a time, and the solar wind blew hundreds of times stronger than it does today. This wind blew the light gases—hydrogen and helium—away from the four small inner planets toward the outer planets. The inner planets were too near the sun to retain the light gases in any abundance; but the outer planets were able to retain them, perhaps as great shells of light material around small earthlike—and even Mars-like—bodies made of rock and iron.

A Layer of Ice?

A puzzling sidelight on the question of life on Mars came up recently when Duane Muhleman, professor of planetary science and staff member of the Owens Valley Radio Observatory, found that temperature measurements of the Martian surface taken over the past six years indicate that the soil just below the surface is cooler than the soil a foot or more below that. This is just the opposite of the way soils behave on Earth and the Moon, where the warmer soils are on top during the daytime.

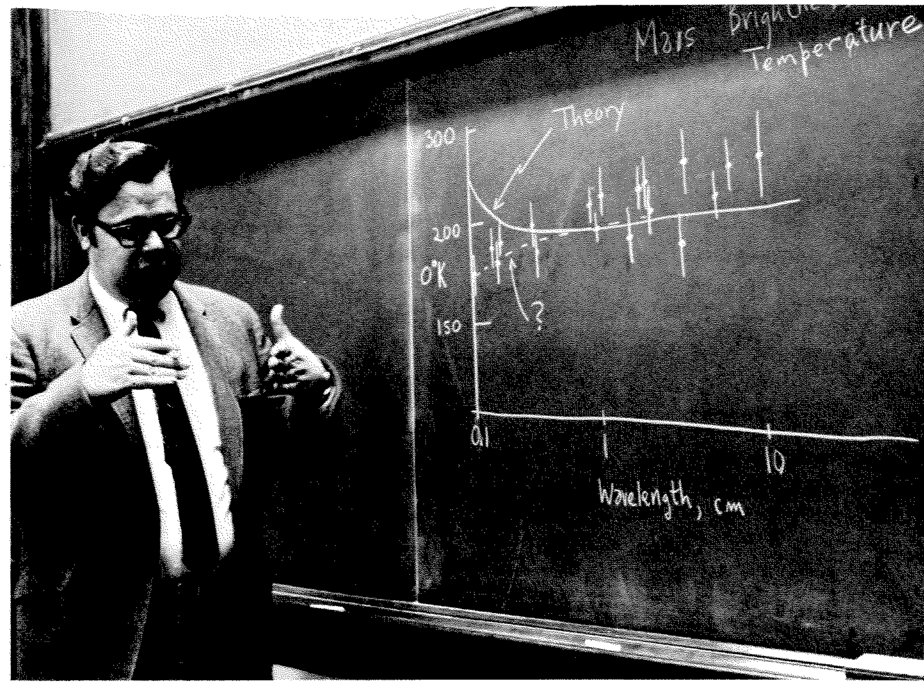
There's no immediate explanation for this phenomenon, but one of the hypotheses being advanced is that Mars has a layer of ice beneath its surface— and that could have tremendous implications for the possibility of life on Mars. If there is ice, there is water, and the presence of water is essential for life as we understand it.

Muhleman himself doesn't support the ice-layer hypothesis, preferring to attribute the anomaly to inaccurate measurements, which have been taken by radio astronomers around the world, using giant, dish-like antennae to pick up the radio waves emitted by the planet. But these measurements are difficult to do, partly because they must often be made at low angles to the earth through the densest layers of the atmosphere, and this tends to distort signals.

Another problem is that it's only feasible to study Mars when it's in line with Earth—about every two years—and the rest of the time it's too far away. This means that the planet is studied only when it's high noon there, the hottest time of the Martian day, and the measurements taken then are used to infer what the soil temperatures are during the coldest part of the Martian day.

Finally, Muhleman mistrusts the measurements simply because they're rarely checked. Most radio astronomers work at different wavelengths, since they don't want to study a frequency range already being investigated by somebody else. So, unless a researcher wants to go through the difficult and time-consuming process of checking somebody else's figures, those figures have to be taken at face value.

Muhleman, Glen Berge, a senior research fellow in radio astronomy, and geology graduate student Jeff Cuzzi will



Duane Muhleman, professor of planetary science, diagrams an explanation of his mistrust of the ice-layer theory about the surface of Mars (dashed line). Elementary theory (represented by the curved solid line) predicts increasing brightness temperatures with decreasing wavelengths. But actual measurements by many different radio astronomers indicate decreases in brightness temperatures with decreasing wavelengths.

be studying Mars using Caltech's big radio dishes in the Owens Valley next August, when Mars will make its closest approach to Earth in 15 years. But these studies are not likely to answer the ice-layer question. The best views of Mars during this period will be from the Southern Hemisphere, and—disappointingly—no radio astronomers on that side of the world will be studying Mars at that time in the important wavelength region.

One way to resolve the issue would be to fly radio sensors on the next two Mariner spacecraft, which are scheduled to orbit Mars next fall. With the instruments in Mars orbit, temperature measurements could be taken during the complete Martian day. Unfortunately, no such experiments are planned.

What all this means for the possibility of ice on Mars remains difficult to assess with any certainty. This question is another that apparently must wait for an answer until we can land an instrument package on the Martian surface—probably in 1975 when the Viking missions are scheduled.

Life on Mars? Possible, but Still Improbable

It's still improbable that life exists on Mars, but it's not as improbable as it seemed after the early Mariner-Mars fly-bys disclosed the planet's thin atmosphere and bleak, moon-like surface. At any rate, organic compounds that are believed to have been precursors to life on Earth are probably also being produced by sunlight on the Martian surface—or just beneath it.

That's about as far as Norman Horowitz, professor of biology and executive officer for the division of biology, is willing to go at this point toward answering one of the tantalizing questions of our time.

Horowitz and two collaborators, Jerry Hubbard and James Hardy of Caltech's Jet Propulsion Laboratory, have been working for the past year on a series of NASA-sponsored experiments in which formaldehyde, acetaldehyde, glycolic acid, and other organic compounds were produced in a simulated Martian environment. The researchers used gases known to be present in the Martian atmosphere, plus ultraviolet radiation in wavelengths known to reach the Martian surface. Horowitz thinks it likely that these compounds would react with ammonia—if Mars has ever had any—to produce amino acids.

The Martian conditions were simulated by using fine soil or pulverized glass in a gas mixture of 97 percent carbon dioxide, with added carbon monoxide and water vapor. This represented the atmosphere indicated by the data returned from Mariners 6 and 7. Both the soil and the glass were sterilized at high temperatures before being used in the tests.

The ultraviolet radiation, which approximated the radiation that strikes the Martian surface as indicated by the two Mariner 1969 spacecraft, was produced by a high-pressure xenon lamp. Some experiments used a low-pressure mercury lamp. A large number of tests, varying in duration from three hours to seven days, were conducted.

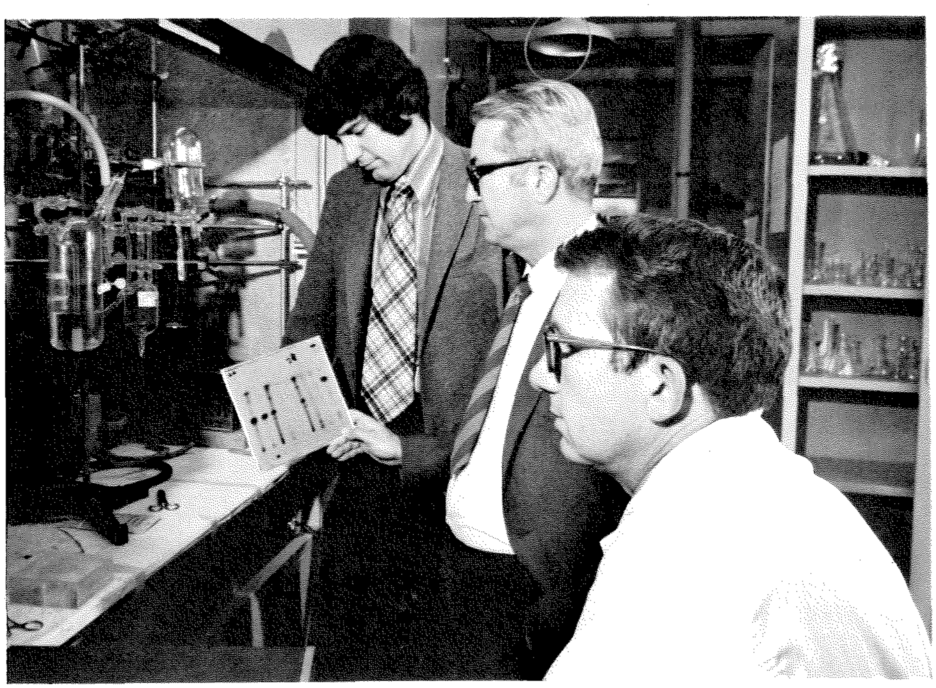
One of the key features of the experiment was its use of material to simulate the Martian surface. The organic compounds were produced by ultraviolet rays of wavelengths longer than 2,000 angstroms acting on the gases adsorbed on the surface material. Previous experiments had shown that ultraviolet rays in these wavelengths could not produce such compounds, but the earlier investigations had worked only with irradiation of the free gases.

Horowitz's experiment shows that radiation over a broad range between 2,000 and 3,000 angstroms can form the organic compounds. Wavelengths shorter than about 2,000 angstroms are thought to be absorbed by the heavy carbon dioxide content of the Martian atmosphere.

Ultraviolet radiation can also be a destroyer of life and lesser organic compounds, and on Mars the organic compounds may be constantly synthesized in the soil and constantly destroyed by the same radiation, resulting in a steady-state concentration of organic matter. Some compounds may sift down into the deeper soil and be protected from such destruction, and thus accumulate.

How much of these compounds the Martian soil may be producing depends in part on how much carbon monoxide and water there is in the planet's atmosphere. But even though it's only a small amount, there still could be considerable quantities of organic matter formed over geologic time. The experiment showed that irradiation over a longer period of time caused a larger conversion of carbon monoxide to carbon dioxide and organic products, up to a certain point. Reducing the amount of water vapor or the surface material reduced the organic accumulation.

The findings of the Horowitz team, announced in the March issue of the *Proceedings of the National Academy of Sciences,* considerably increase interest in the outcome of the data that will be returned from the two Mariner spacecraft to be launched in May and to go into orbits of Mars in November. Thereafter, for three months, television cameras and sensors will concentrate on an almost complete mapping of the Martian surface and an analysis of its cloud, dust, polar cap, and color characteristics. And in 1975 the United States will attempt to land two packages of life-detection instruments on Mars—which indeed may bring us much closer to a definitive answer to that tantalizing question.



Will life arise wherever conditions exist for the synthesis and evolution of organic compounds? Caltech professor of biology Norman Horowitz (center) and two colleagues at JPL—James P. Hardy and Jerry S. Hubbard—have found autoradiograph evidence of three: formaldehyde, acetaldehyde, and glycolic acid. Believed to be precursors of biological molecules on the earth, these compounds were found in tests simulating atmospheric and sunlight ultraviolet conditions on Mars. Horowitz, who has been studying the planet for a decade, thinks this is the most favorable indication for possible Martian biological evolution that has turned up in the last five years.