BIOLOGICAL IMPLICATIONS OF THE VIKING MISSION TO MARS

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Abstract. A central purpose of Viking was to search for evidence that life exists on Mars or may have existed in the past. The missions carried three biology experiments the prime purpose of which was to seek for existing microbial life. In addition the results of a number of the other experiments have biological implications: (1) The elemental analyses of the atmosphere and the regolith showed or implied that the elements generally considered essential to terrestrial biology are present. (2) But unexpectedly, no organic compounds were detected in Martian samples by an instrument that easily detected organic materials in the most barren of terrestrial soils. (3) Liquid water is believed to be an absolute requisite for life. Viking obtained direct evidence for the presence of water vapor and water ice, and it obtained strong inferential evidence for the existence of large amounts of subsurface permafrost now and in the Martain past. However it obtained no evidence for the current existence of liquid water possessing the high chemical potential required for at least terrestrial life, a result that is consistent with the known pressure-temperature relations on the planet's surface. On the other hand, the mission did obtain strong indications from both atmospheric analyses and orbital photographs that large quantities of liquid water flowed episodically on the Martian surface 0.5 to 2.5 G years ago.

The three biology experiments produced clear evidence of chemical reactivity in soil samples, but it is becoming increasingly clear that the chemical reactions were nonbiological in origin. The unexpected release of oxygen by soil moistened with water vapor in the Gas Exchange experiment together with the negative findings of the organic analysis experiment lead to the conclusion that the surface contains powerful oxidants. This conclusion is consistent with models of the atmosphere. The oxidants appear also to have been responsible for the decarboxylation of the organic nutrients that were introduced in the Label Release experiment. The major results of the GEX and LR experiments have been simulated at least qualitatively on Earth. The third, Pyrolytic Release, experiment obtained evidence for organic synthesis by soil samples. Although the mechanism of the synthesis is obscure, the thermal stability of the reaction makes a biological explanation most unlikely. Furthermore, the response of soil samples in all three experiments to the addition of water is not consistent with a biological interpretation.

The conditions now known to exist at and below the Martian surface are such that no known terrestrial organism could grow and function. Although the evidence does not absolutely rule out the existence of favourable oases, it renders their existence extremely unlikely. The limiting conditions for the functioning of terrestrial organisms are not the limits for conceivable life elsewhere, and accordingly
one cannot exclude the possibility that indigenous life forms may currently exist somewhere on Mars or may have existed sometime in the past. Nevertheless, the available information about the present Martian environment puts severe constraints and presents formidable challenges to any putative Martian organisms. The Martian environment in the past, on the other hand, appears to have been considerably less hostile biologically, and it might possibly have permitted the origin and transient establishment of a biota.

1. Introduction

The recent Viking mission emphasizes the prominent position that has been accorded to Mars in the exploration of our solar system. One reason for this prominence, and for Viking, is that Mars, among all the extra-terrestrial objects orbiting the Sun, is deemed the most likely to have, or to have had, living inhabitants. The discovery and characterization of present or prior life on Mars would, in the opinion of many, constitute a scientific finding of unparalleled significance to biology, and it would constitute a finding of major importance to planetology, especially to an understanding of the evolution of differences among the planets Venus, Earth, and Mars. For these reasons Viking carried several experiments that were designed to yield information of direct and indirect biological significance.

There are three possibilities for Mars: Life exists; life evolved but no longer exists; life never evolved. The discovery of existing life would be tremendously exciting. But the other two possibilities would also represent discoveries of profound importance. Venus, Earth, and Mars are roughly similar in size, mass, and distance from the Sun. Yet, Venus has a massive atmosphere rich in CO2 and a surface that is an inferno; Mars has a wisp of an atmosphere (also enriched in CO2) and a surface that is cold, devoid of liquid water, and exposed to highly reactive molecules in the atmosphere and to intense ultraviolet radiation. Earth has an atmosphere intermediate in density, low in CO2, rich in oxygen and nitrogen. Its surface temperatures lie predominantly in the range where water is liquid, and a great proportion of its surface is covered with liquid water. And most significant of all, it teems with life.

It is customary to think that life exists only on planets that provide the proper conditions for its maintenance. But the realization is growing that life itself may modify a planet’s surface and atmosphere so as to optimize conditions for its existence (Margulis and Lovelock, 1974, 1977). Even if it were demonstrated that life does not now exist on Mars, the question would remain whether Earth and Mars differed sufficiently in their early histories to permit the origin of life on the former but not the latter. Or, alternatively, did both planets permit the origin of life and then diverge dramatically? If so, did the type and extent of life that evolved play a major role in that divergence?

These questions are of fundamental scientific interest, but they may also be important questions to all of us on Earth. We have clearly reached the point where human activities are exerting global effects on the composition of the Earth’s atmosphere and perhaps its temperature. Atmospheric pollutants may affect the ozone layer and could modify the Earth’s albedo. The burning of fossil fuels has