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Did Mars Once Harbor Life?

"Exploration for a Martian Biosphere" (P22A) will present an up-to-date overview of current efforts to search for past and present life on Mars. Of all the other planets in our solar system, Mars is most capable of having supported life. But the highly successful Viking missions to Mars, launched by the United States in 1976, left us with more questions than answers about Martian life. On the one hand, two Viking landers searched for living organisms in soils on Mars and found none. On the other hand, orbital images confirmed that Mars was once more Earth-like and may have supported a biosphere at some time in the past. The talks in this session will present a post-Viking view of Mars Exobiology and suggest new exploration strategies for future missions.

Viking landers carried biology experiments designed to detect metabolic activity in Martian soils. But the results of those experiments were at best ambiguous and have been subsequently explained by inorganic processes. This view is consistent with the lack of liquid water on the surface of Mars, a substance regarded as essential for life. Mars' atmosphere is of such a low density (7.5 millibars, compared to 1000 on Earth) and its temperature so cold (-93°C to +13°C at the equator) that water can exist in only two states at the surface, ice or vapor. In addition, the thin, CO_2-rich atmosphere affords no protection from incoming radiation, and so the surface experiences a UV flux that would be fatal to terrestrial organisms. The surface of Mars is also highly oxidizing, and probably loaded with compounds destructive to organic materials. This may be why Viking's Gas Chromatography-Mass Spectrometry experiment detected no organic compounds, even though it could have found them at concentrations of one part per billion.

In bold contrast to present conditions on Mars, the Viking orbiter missions presented a remarkably different picture of the planet's early history. Orbital images provided compelling geological evidence that the climate of early Mars was once more Earth-like with an atmosphere dense enough for surface water to be stable. How dense and how warm the early atmosphere of Mars was remains controversial, but the undeniable presence of flowing liquid water was revealed by a variety of erosional channel forms, many similar to those formed by rivers here on Earth. In addition, some channel networks emptied onto large, flat-floored basins that may have held paleolakes. How long these ancient hydrological systems operated is uncertain, but ages obtained by impact crater counts calibrated to the lunar cratering record, suggested that liquid water was most abundant between 3.0 and 4.0 billion years ago, the time during which life emerged on Earth.

Could life have developed on Mars during this early, wet period, and later retracted into the subsurface as the planet lost its atmosphere? If an early biosphere existed, could aqueous sediments of the Martian crust have sequestered a fossil record of ancient life? If so, what is the best way to go about looking for it? In response to these new questions, Mars Exobiology has shifted focus and new strategies have begun to emerge that will help to direct the search for an ancient biosphere during the next decade or so of exploration.

Although the present consensus assumes the Martian surface to be lifeless, it is fair to say that the Viking landers provided access to a vety limited number of potential habitats for life, Could Martian life forms yet exist within ephemeral liquid water environments or "oases" not sampled by Viking? Prime candidates are subsurface environments where liquid water would be stable because of the higher temperatures and pressures. On Earth, subsurface hydrothermal systems and deep aquifers are known to harbor diverse associations of heterotrophic microorganisms. Furthermore, hydrothermal systems appear to have played a fundamental role in the origin of terrestrial life.

The structure of the present RNA tree suggests that the common ancestor of all living organisms on Earth was an extreme thermophile, that is, a microbe that preferred high temperatures. Interestingly, during late accretion of the Earth, the influx of huge, life-extinguishing bollides began to wane after about 4.0 billion years ago. Prior to that time the existence of extensive magma oceans would have hampered the emergence of life. The last life-threatening impacts could have occurred as late as 3.7 billion years ago, and such impacts may have forced the emerging biosphere through high temperature bottlenecks, thus accounting for the diversity and structure of the present RNA tree.

By 3.5 billion years life on Earth had diverged into various microbial forms, as indicated by fossil assemblages preserved in sediments of ancient volcanic terranes in Australia and South Africa. Hydrothermal environments were probably widespread on the early Earth, and they were probably widespread on early Mars as well. A number of geomorphic features in ancient terranes on Mars suggest hydrothermal processes may have been at work throughout the planet's history. What we most need from upcoming missions are high-resolution spectral data, which will allow the composition of the Martian surface to be mapped in detail. Almost two decades since Viking, we still know little about the mineralogy of the Martian surface. High-resolution spectral mapping will lay the groundwork for future landed missions to explore for traces of ancient life. We know that on Earth, the best long-term preservation of fossils, including biomolecules, occurs when organisms and their by-products are rapidly entombed as aqueous minerals precipitate from solution. Locating aqueous mineral deposits on Mars is an important first step in exploring for evidence of an ancient biosphere there. And even if Martian life never developed, such deposits still provide the best target for sampling the inventory of prebiotic chemicals that gave rise to life on Earth. This early prebiotic organic record, so crucial for origin of life studies, has been lost on our own planet by recycling of the crust. Mars, on the other hand, never developed plate tectonics, and preserves a much more extensive record of this early history.

In 1996 our commitment to Mars exploration will be renewed with launches of the Global Surveyor Program. This new series of missions will search for evidence of a biosphere (past or present), study the climate of Mars (past and present), and evaluate Martian resources that could be useful to humans. The search for water and associated aqueous sediments will be at the heart of the new exploration effort. Identifying key minerals and rock types from orbit will assist future mission planning by helping to target locations for robotic surface exploration and eventual sample return.

Carbonates are one of the most common repositories for biological information on Earth and theoretical models predict that this class of minerals should be widespread on Mars. Evaporites are an also important target because, on Earth, such minerals frequently incorporate fossils and organic compounds as they crystallize from solution. Fe oxides and Fe-bearing clays, are widespread on Mars, and may also carry biological information. But on Earth, the most striking examples of microfossil preservation are contained in ancient rocks composed of silica along with various phosphate minerals. Phosphate minerals as well as nitrates are required nutrients for organisms. If we can discover these or related minerals on Mars, we will have identified excellent targets in the search for an ancient Martian biosphere.—

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