SEARCH FOR LIFE: A SCIENCE RATIONALE FOR A PERMANENT BASE ON MARS,

V. R. Oberbeck, NASA Ames Research Center, Moffett Field CA 94035, J. R. Marshall, Arizona State University, Tempe AZ 85287, D. E. Schwartz and R. L. Mancinelli, SETI Institute, Mountain View CA 94043

Results of the Viking mission to Mars provided no compelling evidence for extant life, but oxidants could have masked evidence for biological activity[1]. The search for evidence that life originated on Mars remains a primary reason for further scientific exploration of the planet. Even if there was no extant life at the Viking sites, extant life may exist because most of the promising potential Martian habitats were not explored. It is noteworthy that prebiotic reactants and liquid water probably existed at the surface until about 3.8 Gyr ago[(2)]. During this period, Mars was subject to impacts that would have frustrated the origin of life. The time available between these planet-sterilizing events was longer than the time required to originate life on Earth[2]. Thus, there would have been sufficient time for life to originate on Mars before 3.8 Gyr ago. If life existed, it may either have become extinct at the surface, leaving behind fossils, or migrated into the groundwater after 3.8 Gyr ago. This implies that evidence for extant life should be sought beneath the surface and that evidence of extinct life should be sought in the older surface terrain. Mars remains the most promising extraterrestrial setting where life may have originated. The discovery of evidence for either extant or extinct life on Mars would profoundly affect mankind because it would suggest the possibility that life may have originated in many other places in the universe.

The National Research Council recommended searching for four types of indirect evidence for extant life during space missions. These include liquid water, organic compounds, electrolytes, and biogenic gases. However, they point out that none of these is proof that life exists. Conclusive evidence for life cannot be sought with Viking style missions[(3)] that search for these types of evidence nor do we believe can it be sought with other types of unmanned craft. For example, penetrators could conceivably deploy instruments that could search for this indirect evidence of extant life beneath the surface, but penetrators can only deploy limited payloads to a limited depth in a limited number of places. At best, the results obtained would only provide inconclusive evidence for life on Mars. Therefore, we believe that the search for extant life beneath the surface will be difficult indeed. The search for fossil evidence of life at the surface will also be extremely difficult to undertake. Such fossil evidence is likely to be very old[2] and the volume ratio of fossils to rock will probably be very small; only a centimeter layer of fossiliferous material may exist in hundreds of meters of sedimentary rock. The search for such layers could be quite time-consuming and would require the knowledge and experience of a well-trained geologist. Artificial intelligence techniques that could be used on unmanned surface vehicles (e.g., rovers) could easily mistake inorganic artifacts for fossil remains.

Because the positive results of a search for conclusive evidence for life on Mars would have profound implications for mankind, and because of the difficulties inherent in the search, we believe that this search is compelling justification for a permanent science base on Mars. In the event that extant organisms are found, a semi-permanent presence permits examination of extant life forms in order to prevent possible harmful forward and backward contamination. It is recognized that the same results may be achieved in carefully prepared clean rooms and planetary protection facilities on Earth, a semi-permanent facility on Mars would provide added protection of great value. Additionally, if extant lifeforms are found, they are best studied *in situ* .

The search for extant life should concentrate on subsurface locations. The disappearance of an appreciable atmosphere and associated liquid surface water about 3.8 Gyr ago[4,5] may imply that organisms, as we know them, could not now exist at the surface. It has recently been discovered that a large biomass of microorganisms extends to great depths within terrestrial aquifers[6] and Mars may have analogous environments. However, great effort must be expended in searching for such organisms and in keeping the samples pristine. On Mars, it may be

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possible to sample groundwater at selected sites near sapping channels. This would require complex drilling operations in rugged Martian terrain that can only be performed by humans in semi-permanent bases with laboratory facilities. Also, the careful field analysis of groundwater systems, required before extensive drilling is done, is not possible with unmanned landers.

The search for fossil evidence of past Martian life will require painstaking field analysis and detailed examination. Long drill cores may need to be examined, and large volumes of debris searched, for minute traces of extinct life. It is difficult to envision how a successful search for fossils could be carried out without preliminary geological field surveys followed by exhaustive on-site laboratory investigations.

A careful examination of ecosystem dynamics can only be accomplished by humans inhabiting a Mars base equipped with a laboratory. Interrelationships between organisms and their environments are so complex that one is compelled to study organisms in their natural habitat. For example, two elements that are important to organisms are nitrogen and sulfur. In terrestrial ecosystems, we know that cycling of these elements requires a community of co-existing organisms working in concert with the environment. Changing the environment leads to significant changes in the cycling. The types of *in situ* studies that would be required to determine biogeochemical cycles in these ecosystems would be virtually impossible with robotic missions. Such studies, performed by scientists on the surface of Mars, will expand our knowledge of nutrient cycling in an extraterrestrial planetary context. If we can learn how an extraterrestrial biota interacts with its environment, it would greatly expand our knowledge of the limits that planetary environments place on the existence of life. This, in turn, would provide additional evidence regarding the possibility of life elsewhere in the universe. The history of comparative planetology tells us that it is precisely the opportunity for the study of physical and chemical processes in different planetary settings that has offered completely new insights into planetary processes acting within our own terrestrial environment. The presence of humans in a semi-permanent base on Mars will permit similar new perspectives on the importance of processes that are integral with the possibly of origination of life elsewhere.

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