

# Modern myths of Mars

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## ABSTRACT

July 30, 2006 was the 30<sup>th</sup> anniversary of the Viking Mission's first Labeled Release (LR) life detection experiment on Mars. The strong response, together with supporting results from eight additional LR tests of Martian soil, established the presence of an active agent that was inhibited by heating. The data satisfied the pre-mission criteria for the detection of living microorganisms. However, the scientific community reacted cautiously, generally concluding that the activity in the soil was caused by chemistry or physics.

Over the last three decades, investigation of Mars has greatly increased. Soil, rock and atmospheric analyses have been made. Multi-spectral observations have been made from Mars and Earth orbits and from Earth-based telescopes. Knowledge of extreme habitats and bizarre life forms that populate them on Earth has increased dramatically. However, this vast amount of new astrobiological information has yet to be integrated into an objective scientific evaluation of the LR results and the possibilities for life on Mars. Indeed, in part upon misinterpretations of the new findings, myths have been embedded into the scientific literature of Mars. Based on these myths as key ingredients, a false "standard model" of Martian life potential has been developed. It has been accepted by much of the astrobiological community, and, through its endorsement, the world at large. This paper attempts to bring the supportable facts together in calling for a revision of the current consensus regarding life on Mars. It recommends actions to facilitate the paradigm change.

**Key words:** Life on Mars, astrobiology, extreme habitats, Viking mission Labeled Release experiment, Martian environment, water on Mars

## 1. INTRODUCTION

July 30, 2006 marked the 30<sup>th</sup> anniversary of the Viking Mission's first Labeled Release (LR) life detection experiment on Mars. Its strongly positive response established the presence of an active agent(s) in the Martian soil. In subsequent runs, the response from the soil was shown to be eliminated or substantially reduced by heating or by months-long storage in the dark at about 10° C, within the Martian ambient surface temperature.<sup>1</sup> Similar responses were obtained at the two Viking landing sites some 4,000 miles apart. The data satisfied and, through improvised additional LR sequences, exceeded the pre-mission criteria set for the detection of living microorganisms. However, the results were treated very cautiously, and the general scientific community concluded that the activity in the soil was chemical or physical, rather than biological.

Over the last three decades, the scientific investigation of Mars has greatly increased. Soil, rock and atmospheric analyses have been made on Mars. Multi-spectral observations have been made from orbit, and telescopic observations made from Earth. Our knowledge concerning extreme habitats and bizarre life forms that inhabit them on Earth has increased dramatically. However, this vast amount of new astrobiological information has yet to be integrated into a scientific evaluation of the possibilities and prospects for life on Mars. Indeed, despite these recent findings, and, in part, based upon their misinterpretations, a demonstrably erroneous "standard model" for Martian life has been developed. The model has been accepted by much of the astrobiological community, and, through its endorsement, the world at large. This paper attempts to bring together the relevant discrete findings about life on Mars, and justify a revision of the current consensus.

## 2. THE STANDARD MODEL

The generally accepted "standard model" for life on Mars postulates:

**The surface of Mars is inimical to extant life because of the absence of liquid water, the intense UV flux and an ubiquitous layer of highly oxidizing chemical(s).**

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**The absence of organic matter in the surface material is proof of the oxidizing layer and/or the effect of the UV flux, and of the absence of life.**

**Life may have existed on the surface in the geological past when conditions were more hospitable.**

**Extant life may inhabit underground oases where there is liquid water and environmental conditions provide a favorable habitat.**

Any claim to the detection of life on Mars must deal with each of the obstacles posed by this model and relevant corollaries resulting there from. This paper will attempt to show that the Standard Model and its corollaries, comprising the “Modern Myths of Mars,” are not supported in fact.

### 3. THE VIKING LABELED RELEASE EXPERIMENT

Because life is the most complex phenomenon, the detection of any chemical on Mars is unlikely to be accepted as proof of life. Therefore, the demonstration of active metabolism was the basis of the LR life detection experiment. A simple diagram of the experiment is shown in Figure 1.

The nutrients were selected for the LR based on theory and experiment. All the nutrients, or substrates, were simple Miller-Urey molecular compounds believed to have formed early on primitive Earth and, therefore, likely to have been incorporated into the earliest life forms, and probably retained throughout the evolutionary process. Each candidate nutrient was uniformly tagged with <sup>14</sup>C. Those nutrients having optical isomers were included as racemic mixtures to make either stereoisomer available to potential Martian life. The nutrients were used in minimal concentrations in pure aqueous solution to preclude possible toxicity as sometimes occurs when microorganisms are overly dosed with organic and/or inorganic matter. Table 1 presents the LR nutrients showing their concentrations and activities.

**TABLE 1. Labeled Release Nutrients**

<u>Substrate</u>	<u>Structure and label position (*)</u>	<u>Concentration</u>	<u>μCi ML<sup>-1</sup>*</u>	<u>Specific Activity (Ci/Mole)</u>
<sup>14</sup> C-glycine	NH <sub>3</sub> ·*CH <sub>2</sub> ·*COOH	2.5 × 10 <sup>-4</sup> M	4	16
<sup>14</sup> C-DL-alanine	*CH <sub>3</sub> ·*CH(NH <sub>3</sub> )·*COOH	5.0 × 10 <sup>-4</sup> M	12	48
<sup>14</sup> C-sodium formate	H*COONa	2.5 × 10 <sup>-4</sup> M	2	8
<sup>14</sup> C-DL-sodium lactate	*CH <sub>3</sub> ·*CHOH·*COONa	5.0 × 10 <sup>-4</sup> M	12	48
<sup>14</sup> C-calcium glycolate	(*CH <sub>2</sub> OH·*COO) <sub>2</sub> Ca	2.5 × 10 <sup>-4</sup> M	4	16

\*Total = 34 uCi, which yields 6.8 × 10<sup>7</sup> dpm ml<sup>-1</sup>

Thousands of tests were made on microbial species, covering all types available: pure cultures, mixed cultures and soils; and many field tests of soils were conducted over a wide range of environments during the 20 years of development of the LR. Examples of field tests made with the early “sticky string” version of the instrument, which ejected and reeled in a silicone-covered string to collect its sample, are shown in Figures 2 to 4. False positives were never obtained from sterilized samples. Certainty of response from living organisms, sensitivity<sup>2</sup> (to as little as ~300 cells/g), and rapidity of response provided a high level of confidence in the experiment.

### 4. THE LR PEDIGREE

An unsolicited proposal to develop the LR (originally “Gulliver”) experiment was submitted to NASA in 1958. After extensive review, the proposal was funded in 1959. The experiment immediately showed promise. This was detailed in quarterly and annual reports submitted to NASA. A new proposal for continuation had to be submitted to NASA annually for review for continuation. There was constant interaction with NASA throughout the project. The Viking Project was formed in 1969, and NASA invited competition for life detection experiments. Many proposals were submitted, including that for the LR, which again underwent the evaluation process. The LR experiment was selected by the four review committees established by NASA. Members included personnel from NASA, NSF, NIH and academia. They all accepted LR’s criteria for life: evolution of <sup>14</sup>C-labeled gas, followed by a heat-treated control producing little or no gas. Intensive reviews, scheduled and unscheduled, of the LR were performed frequently by

NASA and Viking Project committees and “tiger teams” during the additional ten years of development, all of which further increased the high level of confidence in which its many reviewers held the LR experiment.

## 5. THE LR ON MARS

After its flawless landing, Viking 1 performed the first LR experiment on July 30, 1976. The soil tested had been taken by the sampling arm from the surface to a depth of about four cm., placed in the distribution box and then dispensed to the LR. Immediately upon injection of nutrient, <sup>14</sup>C-labeled gas began evolving. After about three days, the volume of the accumulating gas approached a plateau, but continued to show a very slight increase. At the end of the eight-sol Cycle 1 test, a second injection of nutrient was made. A sharp decrease in headspace gas occurred until about 20 % of it was re-adsorbed by the sample, after which a slow re-evolution of gas over the eight sols of Cycle 2 restored the full amplitude of Cycle 1. The protocol called for a control in the event of a positive response. Accordingly, a duplicate soil sample was inserted into a fresh cell, heated for three hours at 160° C to sterilize it (the control procedure established for all Viking biology experiments), allowed to cool and then was tested. It produced virtually no response, thus completing the pre-mission criteria for the detection of microbial life. Those criteria did not require a positive response to a second injection. Further, the LR tests showed that, isolated in the dark sample distribution box and held at ~ 10° C, the soil lost its activity over a period of two to three months. However, the positive responses had been obtained from soil samples that, prior to nutrient injection, had been stored several days under those same conditions. All VL1 LR results, as shown in Figure 5, support, or are consistent with, the presence of living microorganisms.

Four thousand miles away, Viking 2 landed. Its LR results there were very similar to those of VL1. Based on knowledge gained from the Viking 1 LR results, more definitive controls were run to further discern the nature of the active agent. These included moving a rock to permit taking a soil sample not exposed to UV light for geological time. Its active response refuted an initially prevalent theory that the LR response was caused by UV light activation of the soil. Another test demonstrated that even modest heating of the soil significantly depressed its response. The active agent in the soil, initially responsive at 10°C, was greatly inhibited or inactivated by heating to 46° C or 51° C, as are a variety of terrestrial microorganisms when subjected to similar thermal differentiation (e.g. *E. coli* v other coliforms). As with VL1, months-long storage of the soil in the distribution box inactivated the agent. All LR results of VL2 are shown in Figure 6. As with VL1, all results support, or are consistent with, the presence of living microorganisms.

## 6. THE STANDARD MODEL SPECIFIC OBSTACLES RAISED AND REBUTTALS

Obstacles raised against acceptance of the LR data as proof of life, and the problems with each follow:

- a. **Failure to detect organics.** The Viking organic analysis instrument (GCMS), an abbreviated gas chromatograph-mass spectrometer designed to identify the organic material widely presumed to be present on Mars, found no organic molecules.<sup>3</sup> Based on this result, the strong consensus of the space science community was that the LR positive responses were not of biological origin. However, the GCMS Experimenter disclaimed his instrument as a life detector, saying as much organic matter as in 1 billion bacterial cells were required for a result<sup>4</sup>. Subsequently, it was reported<sup>5</sup> that several problems with the GCMS flight-type instrument further depleted its sensitivity. Upon announcing the detection of organic matter in the ALH4001 Martian meteorite, a NASA official explained that the Viking GCMS had not been sensitive enough to detect the level of organics found by the full-scale GCMS instrument by which the Martian meteorite was analyzed. It has also been shown<sup>6</sup> that the temperature applied in the Viking GCMS fell short of that needed to vaporize some heat-stable organic molecules in living cells, which, it was claimed, could explain the failure of the Viking GCMS to detect organic matter. Corrections designed to fix this problem, and to provide greatly increased sensitivity have been incorporated into newly designed planetary probe GCMS instruments. It is interesting to note that Viking, itself, produced evidence that organic matter is constantly forming on Mars, and is not destroyed by a strong oxidant. The Pyrolytic Release (PR) experimenters reported<sup>7</sup> “The data show that a fixation of atmospheric carbon occurs in the surface material of Mars under conditions approximating the Martian ones.” In the experiment, Martian soil was exposed to simulated Martian atmosphere containing labeled CO<sub>2</sub> and CO. After 120 hours, any non-fixed carbon gas was driven off by heat. Then, upon heating the soil to pyrolysis temperature, any carbon that had been fixed was vaporized into the headspace. Statistically significant amounts of labeled carbon gas were evolved from the Martian soil, providing evidence that fixation had occurred (but in insufficient amount to support a claim for biology). The formation and the persistence of the organic matter throughout the length of the experiment are evidence against the presence of

the oxidant(s) or any other characteristic of the soil that would destroy all traces of organic matter. The PR Experimenters reported<sup>8</sup> “Our findings suggest that UV presently reaching the Martian surface may be producing organic matter . . . the amount of product found could be considerable over geologic time.”

- b. **Strong Oxidant.** When, as stated above, sampling soil from under a rock on Mars demonstrated that UV light was not responsible for the apparent absences of life and organic matter, the presence of hydrogen peroxide and/or other strong oxidant(s) in the soil was proposed instead. This hypothesis was made despite findings by the Viking Magnetic Properties Experiment (Figure 7) that the surface material of Mars contained a large magnetic component, evidence against a highly oxidized condition.<sup>9</sup> The authors of the Viking Magnetic Properties paper concluded: “The possibilities as to the nature of the magnetic particles detected on Mars are here summarized. Some or all could be (1) highly magnetic, unoxidized mineral grains (metallic Fe, magnetite, pyrrhotite) forming the core beneath a reddish coating of limonite or hematite;” and added several lesser possibilities, none of which could render the surface material highly oxidizing. The evidence against an oxidant provided by the PR, discussed immediately above, was also disregarded by the pro-oxidant theorists. Since Viking, two Earth-based IR observations, by the ESA orbiter<sup>10</sup> and, most recently, data from the Rover Opportunity (Figure 8) have shown Mars surface minerals are primarily in reduced, not oxidized, form. It is difficult to make a case for the existence of an ubiquitous organic-destroying oxidant on the surface of Mars, or even its presence at both Viking landing sites to account for the LR positive results.
- c. **“Too much too soon.”** The LR positive responses, and the reaction kinetics were said to be those of a first order reaction, without the lag or exponential phases seen in classic microbial growth curves, all of which argued for a simple chemical reaction. However, Figure 9 shows terrestrial LR experiments on a variety of soils which produced response rates with the kinetics and the range of amplitudes of the LR on Mars.
- d. **Second Injection.** Second injections of nutrient produced no new evolution of gas, but, instead, quickly reduced the amount of gas accumulated from the first injection by about 20%. Although 2<sup>nd</sup> injection responsiveness was not part of the LR life detection criteria, the lack of a new surge of gas upon injection of fresh medium was subsequently cited as evidence against biology. However, a test of bonded, NASA-supplied Antarctic soil No. 664, containing less than 10 viable cells/g<sup>11</sup>, showed this type of response to a 2<sup>nd</sup> injection as seen in Figures 10a and 10b. (The high initial cpm of the sterile Antarctic soil reflects residual gas in the test cell used. This does not interfere with the demonstration of the effect of the 2<sup>nd</sup> injection.) Thus, the failure of the 2<sup>nd</sup> injection to elicit a response can be attributed to the organisms in the active sample having died sometime after the 1<sup>st</sup> injection, during the latter part of Cycle 1. The effect of the 2<sup>nd</sup> injection was to wet the soil, causing it to absorb headspace gas. The gradual re-emergence of the gas into the headspace with time seems to have occurred as the system came to equilibrium.
- e. **“No liquid water, no life.”** This contention is the primary one now cited by those not ready to accept the discovery of life by Viking’s LR. However, Viking, itself, gave strong evidence<sup>12</sup> of the presence of liquid water when the rise in the temperature of its footpad, responding to the rising sun, halted at 273° C. Snow or frost is seen in Viking images of the landing site (Figure 11). Together, these observations constitute strong evidence for the diurnal presence of liquid water. Theoretical modeling<sup>13,14</sup> and direct experimental evidence has been cited<sup>15</sup> that demonstrated liquid water occurring under Martian conditions. Odyssey has shown that much of Mars, including the 2 Viking landing sites, contains moderate to large amounts of hydrogen (interpreted as water, but called “ice”), much more than found in the Death Valley LR tests, within several centimeters of the Martian surface. Pathfinder has shown that the surface atmosphere of Mars exceeds 20° C part of the day, providing transient conditions for liquid water. The Spirit and Opportunity Rovers have taken images that suggest moist soil as seen in Figure 12. In explaining the stickiness of the soil, MER scientists have said that it “might contain tiny globules of liquid water,” or “might contain brine”<sup>16</sup>. Other images of Mars, such as Figures 13, show current, if intermittent, rivulet activity. The mounting evidence for liquid water on Mars has resulted in an emerging belief that there may be pockets of liquid water beneath the surface, constituting oases for life. However, there is no support of the life oases theory on Earth. Virtually the entire surface of our planet is inhabited by living microorganisms. NASA, despite declaring its “follow the water” route to finding life on Mars, has not sent a liquid water detection instrument there. Indigenous microorganisms have been found growing on the Earth’s South Polar Cap,<sup>17</sup> as seen in Figure 14, and within permafrost in the Arctic.<sup>18</sup> However, there is liquid water even in those frozen places. Very thin films of liquid water exist among the interstices of ice and minerals, enough to sustain an ecology of those highly evolved species.

**Desert Varnish.** In 1979, the author's attention was called<sup>19</sup> to the possible presence of desert varnish on some of the Martian rocks. Desert varnish had been reported<sup>20</sup> as being of microbial origin or containing products produced by microorganisms. Since then, many additional articles<sup>21,22,23,24</sup> have commented on the causal relationship between desert varnish and microorganisms. Details of the formation and composition of rock (desert) varnish and its specific potential relevance to extant life on Mars have been described<sup>25</sup>. Figure 15 shows what appears to be desert varnish on rocks at a Viking landing site. A recent news article<sup>26</sup> reports rekindled interest in desert varnish as evidence of life on Mars.

**Circadian Rhythm.** Re-examination of the kinetics of the LR Mars response indicated a possible biological component. It has been proposed<sup>27,28</sup> that the kinetics of evolution of labeled gas in the Viking LR experiment might be attributed to circadian rhythm, a universal biological phenomenon of all known living organisms. While indications of circadian rhythm were detected in the Viking LR data, they did not reach the point of strong statistical significance in the two papers cited. However, another paper<sup>29</sup>, using a non-linear approach, concluded, "Our results strongly support the hypothesis of a biologic origin of the gas collected by the LR experiment from the Martian soil." Additional work is underway to verify statistical significance for that conclusion,

**Atmospheric Indicators.** Adding to this rising tide of facts supporting the detection of life by the Viking LR experiment are the recent findings in the Martian atmosphere of methane, formaldehyde, and, possibly ammonia<sup>30,31,32,33</sup>, gases frequently involved in microbial metabolism, and, therefore, possible indicators of life. The methane occurred in amounts not deemed adequate for replacement of this short half-lived, UV-labile gas since volcanic activity, a potential non-biological source of methane, has not been indicated by thermal mapping of the entire planet. In the Earth's atmosphere, methane is sustained primarily by biological metabolism. Moreover, the methane detected on Mars was associated with water vapor in the lower atmosphere, consistent with, if not indicative of, the possibility of extant life.

## 7. THE PRESENT SITUATION

Perhaps most significant in the long, tortuous history seeking to determine what the Viking LR detected on Mars is that no condition or property inimical to the existence of life, or, indeed, even inimical to the survival and growth of some forms of terrestrial microorganisms, has been reported to exist on Mars.

**Over the 30 years since the landing of Viking, more than 40 attempts have been made to explain the LR results abiologically. To this date, no experiment has duplicated or realistically approximated the Mars LR positive and control results except when using living microorganisms.**

Science is not a democratic process, and paradigm-breaking discoveries have always been subject to skepticism and years of delay before acceptance by the scientific community. With the failure of all proposed alternative explanations of the Viking LR results, the time for accepting life on Mars may be on hand. The credibility of the LR results has been significantly advanced by what has been learned about life since Viking. Life is no longer constrained to the thin, fragile film on, above and below the surface of the Earth, as we were taught before Viking. We now know there is a Biologic Imperative on Earth. It has pervaded our planet's surface, depth and atmosphere, everywhere, including environments as hostile as some on Mars; with, perhaps, the only exception being red hot magma. Even if life never originated on Mars, we now know it could have been safely deposited there from Earth and/or other sources.<sup>34</sup> Since testing of the constraints on viable interplanetary transport between Earth and Mars, it has become more difficult to imagine a sterile Mars than a living one. In fact, it is becoming apparent that Earth and Mars may be part of the same biosphere.

## 8. FUTURE LIFE DETECTION EXPERIMENTS

It has been stated that newer, more modern methods should replace the LR in future life-seeking missions. While additional methods should certainly be sought, the abandonment of the LR technology is contrary to the teachings of science. Whether from life or not, the LR obtained a startling result on Mars. The scientific method teaches that, when a new finding is made, the best and least risky way to expand that beachhead of knowledge is to refine and re-apply the tool that made the initial discovery. Leeuwenhoek's microscope, which opened the science of microbiology, was not discarded for, say, methods seeking to detect the sounds of microbes. Leeuwenhoek's instrument was ardently developed into its modern descendants. However, the LR method has been cast aside for 30 years, and the extraterrestrial life detection methods now being developed will seek "biomarkers," molecules normally associated with

life. However, their results, if positive, will not pass the test of Ockham's Razor – just as the findings of what seem to be microbial fossils in Martian rocks did not. Unless active metabolism is demonstrated, it is unlikely that any experimental results will overcome scientific skepticism. Most lamentable is the fact that no life detection test has been sent to Mars since Viking, nor even an experiment to confirm or identify the “strong oxidant,” that produced the LR signal on Mars. The confirmation of such a surprising chemical activity of the surface of Mars would, itself, constitute a major scientific finding, which should have been sought in landings subsequent to Viking. Furthermore, the data from the one billion 1976 dollars spent on Viking have not yet been objectively reviewed for evidence of life. No credible scientific refutation of the LR results has been published, yet subjective statements such as “The scientific community does not accept the LR results as evidence for life” are commonplace.

A logical next step in pursuing the life on Mars question is the chiral adaption of the LR experiment, which builds on that experiment's legacy rather than abandon it. All known forms of life exhibit an exclusive or very strong preference for “left-handed” amino acids and “right-handed” carbohydrates over their respective enantiomers. The Chiral LR experiment to detect **active chiral metabolism, photosynthesis and circadian rhythm** is shown in Figures 16 and 17. While any chemical or “biosignature” can be refuted through the application of Ockham's Razor, the demonstration of active metabolism by any of these three methods would constitute indisputable proof of life. The Chiral LR experiment could not only prove the existence of life to even the most resistant to the Mars LR results, but could determine whether that life is related to ours. The most exciting result would be finding that it is not, thereby demonstrating a second, independent genesis, strongly implying that life must be plentiful throughout the universe - another paradigm-breaker. I have proposed the Chiral LR experiment to various space agencies many times, formally and informally, without its acceptance. Here and now, I propose it again.

## 9. RECOMMENDATIONS

On the basis of the case for life on Mars as set forth above, and in greater detail on the website <[spherix.com/mars](http://spherix.com/mars)>, the following recommendations are made in the interest of answering this paramount scientific question:

- a. A panel of independent scientists should be convened to study the Viking LR results and all other data bearing on the life issue. A full report of the findings and conclusion should be rendered. To date, there has been no formal peer review of this experiment and related data, with the negative conclusion having been rendered and promulgated by only several Viking scientists prior to publication by the Experimenters.
- b. Every spacecraft henceforth sent to land on Mars should carry a life detection test.
- c. The Chiral LR/Photosynthesis/Circadian Rhythm experiment should be sent to Mars at the earliest opportunity.
- d. Images of the same areas of Mars taken at different time intervals should be compared for temporal variations as evidence suggestive of liquid water. The suggestive images should also be compared with other types of Martian data in order to seek correlations with atmospheric water vapor, temperature and seasons. Life-suggestive color and pattern changes in the same features imaged at different times should be sought in the many images of the surface of Mars taken by orbiters, the Hubble Telescope, Spirit and Opportunity.

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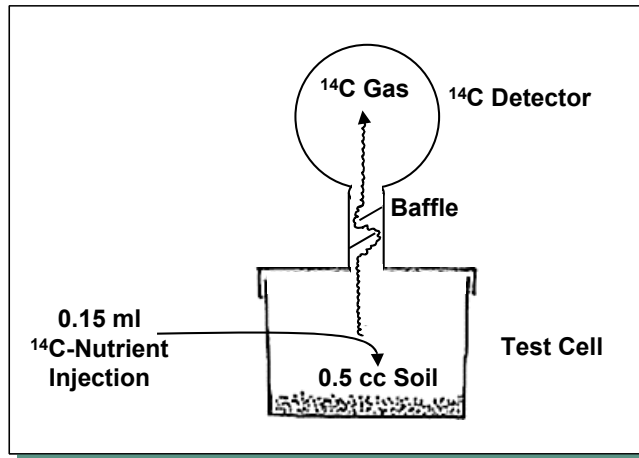
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**FIGURE 1. Schematic of the Viking Labeled Release Experiment**



**Mars Test Conditions:**

- Martian atmosphere, pressurized with He to 85 mb
- Central injection to provide wet to moist soil
- 7°C-10°C
- Dark

**FIGURE 2. LR Test at 12,000 Ft. (above timberline), on White Mountain, CA**



**FIGURE 3. LR Test on Death Valley Sand Dune**



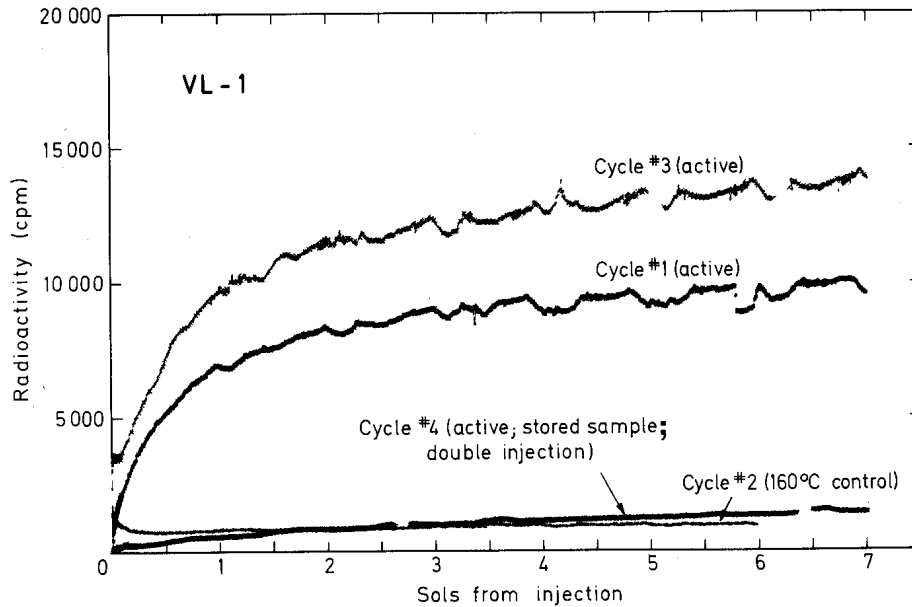
**Despite only 0.9% moisture in top 2 mm of sand, a strong positive response was immediately obtained.**

**FIGURE 4. LR “Sticky String” Test on Salton Sea Desert Flats**



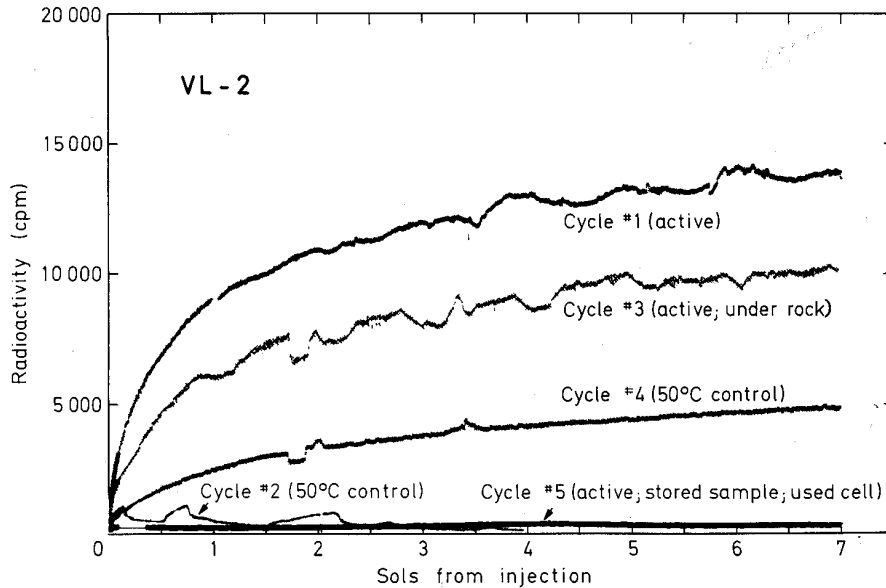


FIGURE 5. All VL 1 Cycles



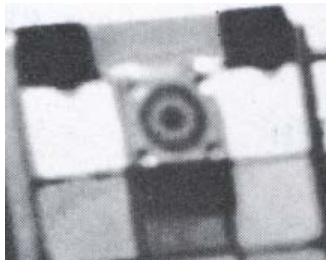
Comparison of radioactivity evolved following the first injection of radioactive nutrient to each analysis cycle of VL-1. A fresh sample was used for the active sequences of cycles 1 and 3 whereas the sample used for active cycle 4 was stored for approximately 141 Sols at 10-26°C prior to use. For cycle 2, a stored portion of the same sample used for cycle 1 was heated for 3 h at 160°C prior to nutrient injection. All data have been corrected for background counts observed prior to nutrient injection.

FIGURE 6. All VL 2 Cycles



Comparison of radioactivity evolved following the first injection of radioactive nutrient to each analysis cycle of VL-2. A fresh sample was used for each cycle except cycle 5 which used a sample stored approximately 84 Sols at 7°C prior to injection. The sample used in cycle 3 was obtained from under a rock. Cycles 1, 3, and 5 were active sequences, whereas cycles 2 and 4 were control sequences in which the samples were heated for 3 h at approximately 51.5°C and 46°C, respectively, prior to nutrient injection. Sample volumes were 0.5 cc except that for cycle 5 which contained 2.2 cc. All data have been corrected for background counts observed prior to injection.

**FIGURE 7. The Viking Magnetic Properties Experiment**



Reference test chart magnet image for VL-1 on sol 31.

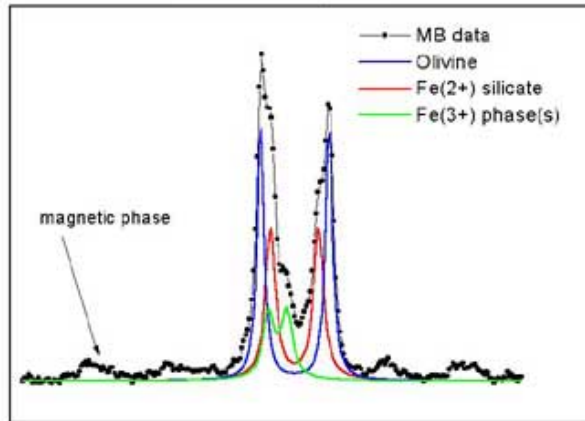


Reference test chart magnet image for VL-2 on sol 42.

2 mm to 4 mm of surface material were picked up by each magnet.

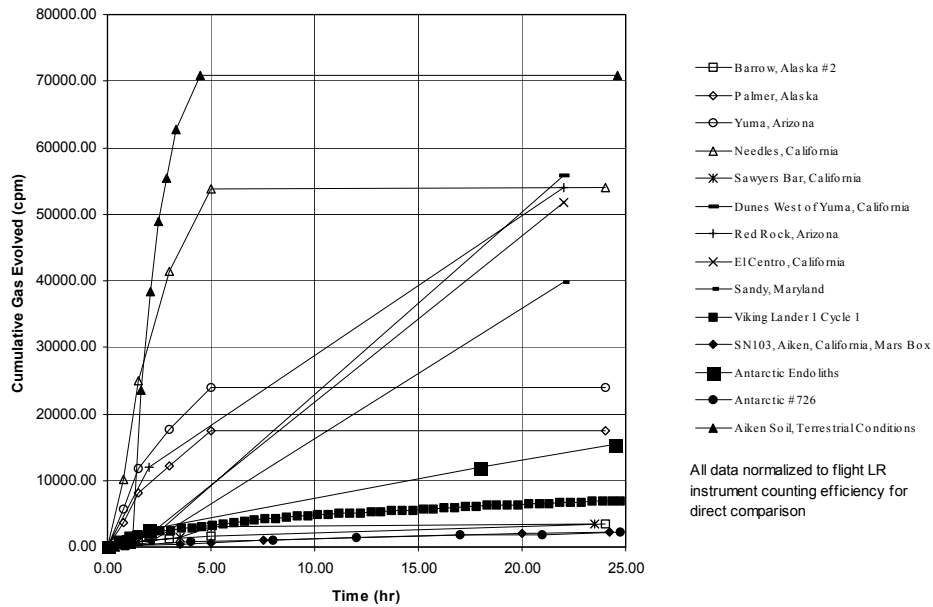
*"If there is a lot of material adhering to the magnet, it would certainly say that whatever the surface processes are on Mars, they are not innately highly oxidizing."* Robert Hargraves, Viking Magnetic Properties Experimenter

**FIGURE 8. Evidence of Reduced Surface Material on Mars**



Mössbauer Spectrum on Martian Soil, Meridiani Planum, Sol 11

**FIGURE 9. Comparison of Terrestrial and Mars LR Active Responses**



All data normalized to flight LR instrument counting efficiency for direct comparison

FIGURE 10a. Effect of 2<sup>nd</sup> Injection on Antarctic Soil.

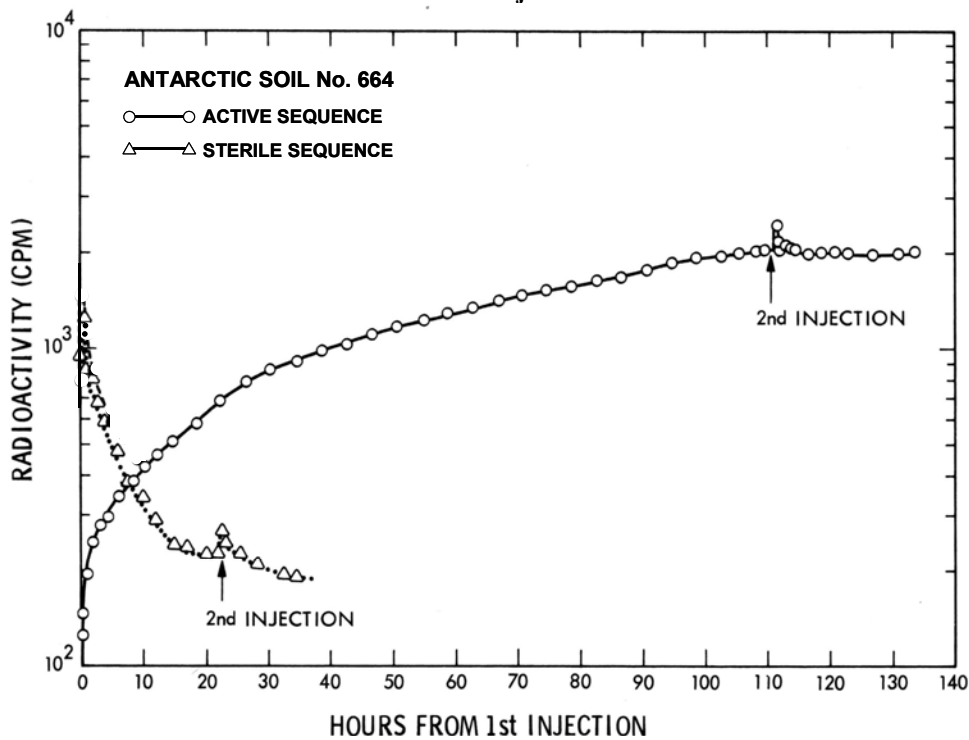
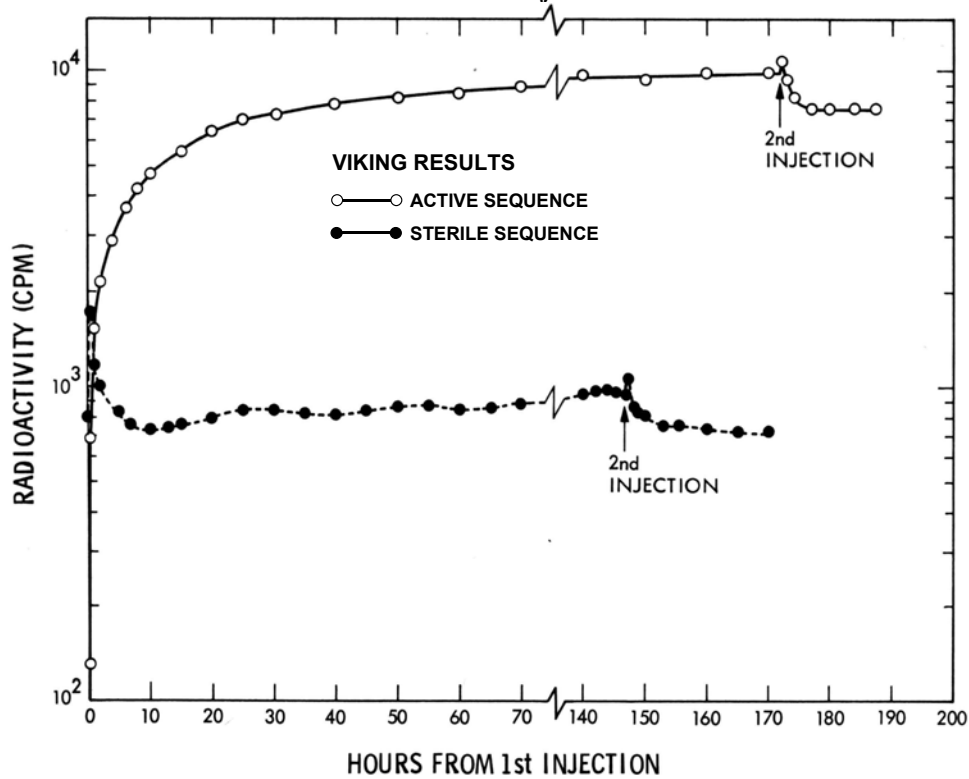


FIGURE 10b. Effect of 2<sup>nd</sup> Injection on Mars Soil.



**FIGURE 11. Heavy Frost or Snow at VL-2 Lander Site (Viking Lander Image 21I093)**

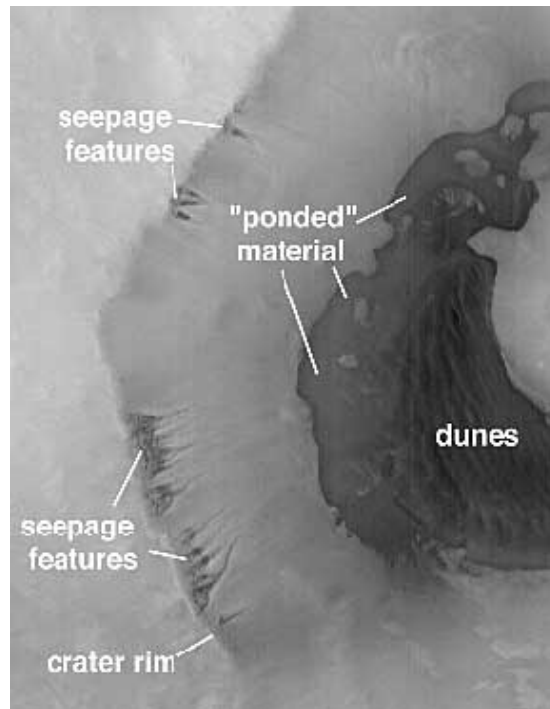


**FIGURE 12. Mud Puddles on Mars?**



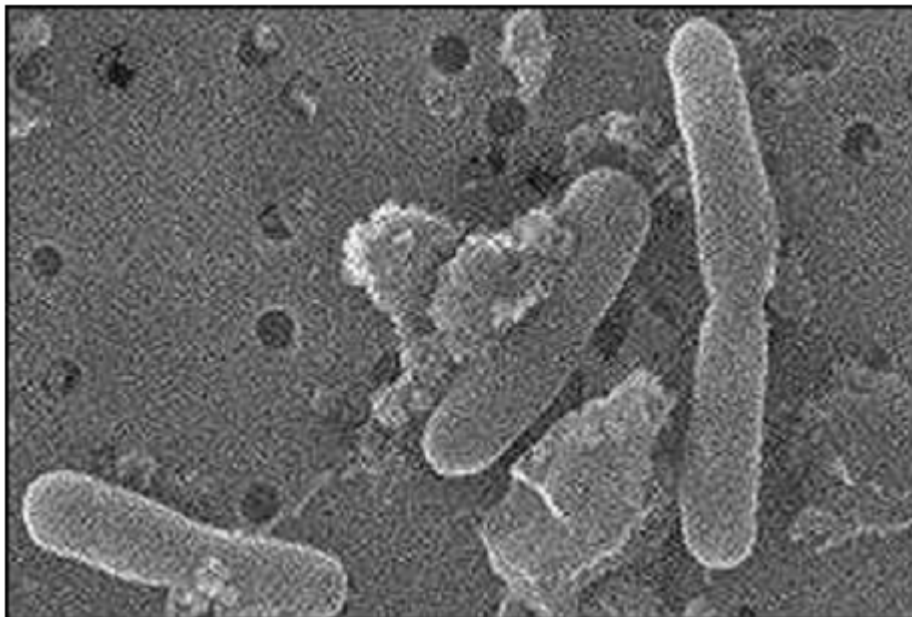
1P128287581EDN0000P2303L5M1

**FIGURE 13. Mars Global Surveyor Image**



**NASA Scientists propose that liquid water may currently seep from the walls of this unnamed crater in the planet's southern hemisphere.**  
Photo courtesy of NASA.

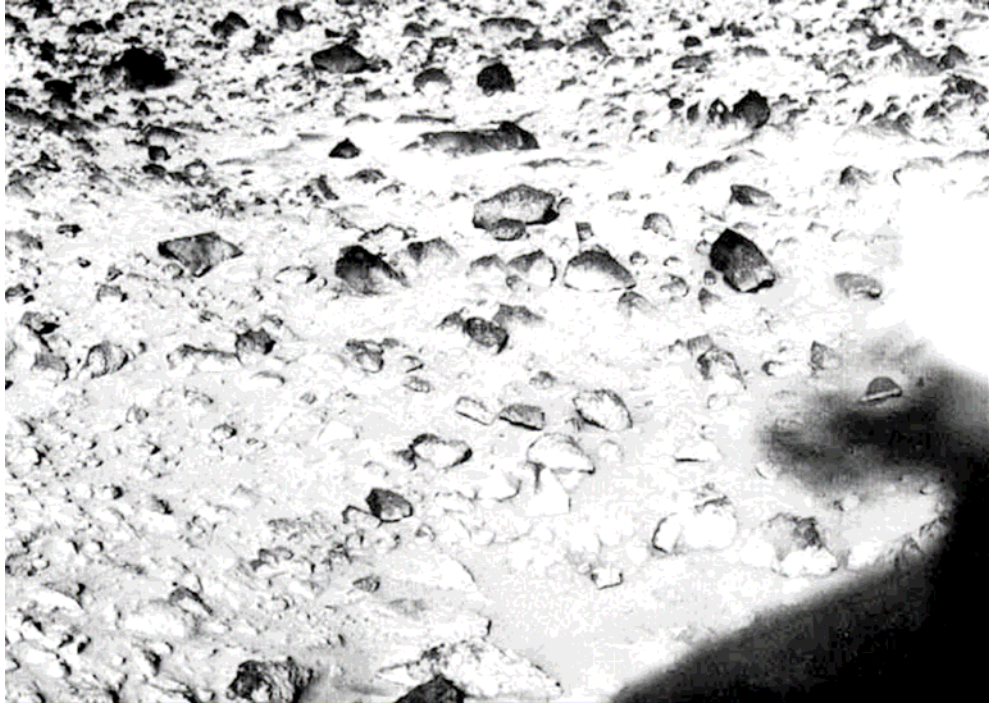
**FIGURE 14. Microbes at South Pole**



**Researchers have found evidence that microbes live in the ice at the Southern Pole.**  
BBC News Online, science editor Dr. David Whitehouse, July 10, 2000.

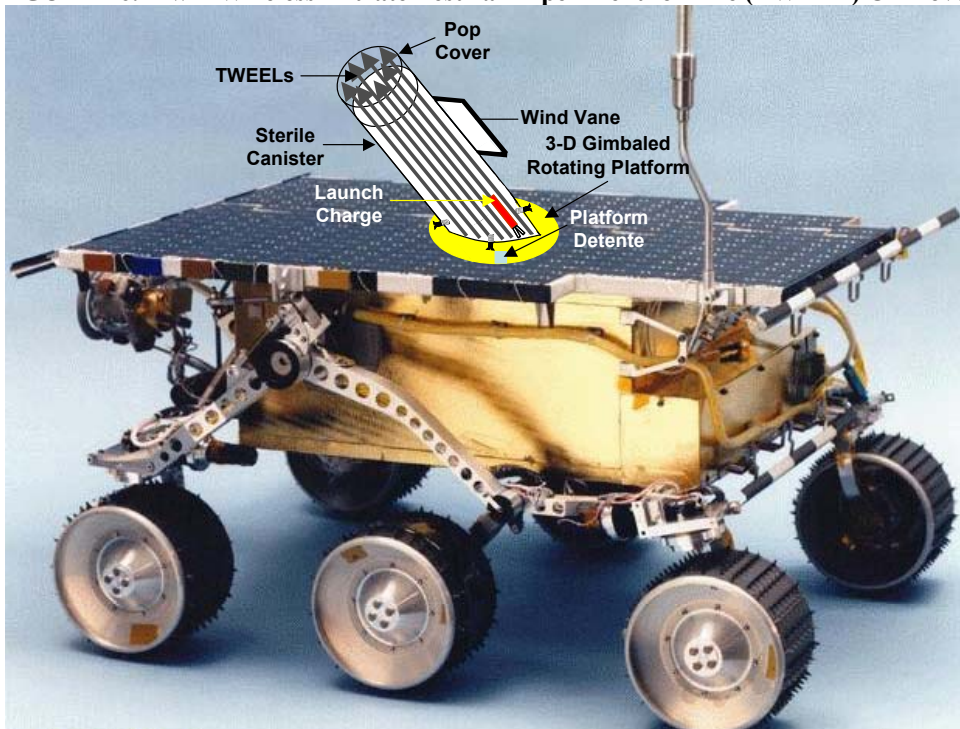


**FIGURE 15. Possible Desert Varnish on Mars**



Front-lighted rocks at Viking landing site show glistening sheen that may be desert varnish.  
*NASA Image, Credit: Barry DiGregorio*

**FIGURE 16. Twin Wireless Extraterrestrial Experiment for Life (TWEEL) On Rover**



**FIGURE 17. Twin Wireless Extraterrestrial Experiment for Life (TWEEL)  
Chiral LR/Circadian Rhythm/Photosynthesis Life Detection Experiment**

