Interpretation of new results from Mars with respect to life

Gilbert V. Levin*, Spherix Incorporated, 12051 Indian Creek Court, Beltsville, MD USA 20705

ABSTRACT

NASA has frequently stated that its highest priority is the search for extraterrestrial life. However, no life detection instruments have been sent to Mars since the Viking Mission in 1976 produced highly disputed evidence for microbial life in the Martian soil. The unfortunately lost Beagle 2 and the successfully landed Spirit and Opportunity are all devoid of means to investigate the Viking findings or otherwise to determine whether or not life exists or ever existed on the red planet. However, all of these spacecraft contain instruments that are designed to obtain data ancillary to that vital and supreme question. Imaging and spectral data have now arrived from the European Space Agency's orbiter, Mars Express, and from NASA's Mars Exploration Rovers Spirit and Opportunity. These data are discussed from the standpoint of their impact on the prospects for life on Mars, and, specifically, on the 1976 Viking Labeled Release (LR) experiments that the author claims proved the presence of active microbial life in the topsoil of Mars.

Keywords: Life on Mars, Spirit, Opportunity, Mars Express, Mars data 2004, water on Mars, organics on Mars, oxidants on Mars, ammonia on Mars, methane on Mars

1. INTRODUCTION

The primary objective of NASA's 1976 Viking Mission to Mars was to search for life. The results were highly provocative. The LR experiment demonstrated the presence[1] of a highly reactive agent in the surface material of Mars. The author's conclusion in 1997[2] that the activity was caused by living microorganisms in the soil has not been generally accepted by the scientific community. Maintaining the search for life as its highest priority, NASA has followed a careful, step-by-step program to that end. The European Space Agency's Mars Express currently orbiting Mars, and NASA's Mars Explorer Rovers Spirit and Opportunity have produced, and are producing, data of relevance to the possibility of life on Mars.

2. BACKGROUND

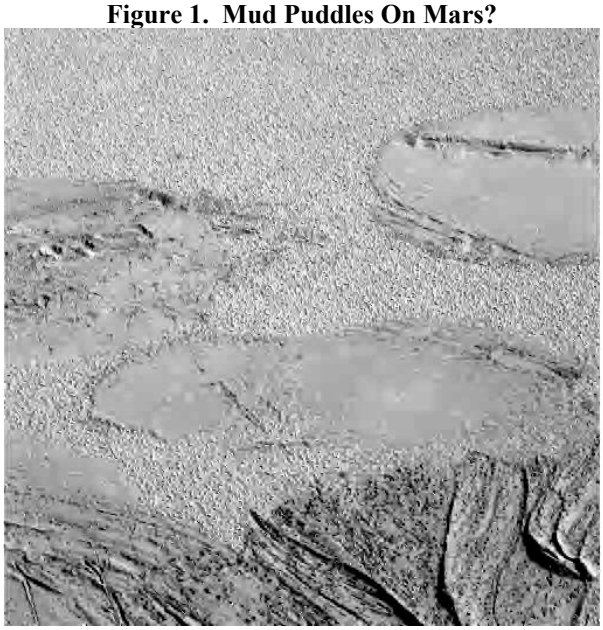
Important background for this paper is last year's report[3] by the author that NASA's Mars orbiter Odyssey had detected water within a few centimeters of the surface over very large regions of Mars, including the two Viking landing sites. However, the water was presumed to be ice. Publications by the Odyssey scientists have not addressed the possibility that the water may be in biologically available form despite the facts that Pathfinder found the near-surface atmosphere of Mars to be well above the freezing point of water[4], and experiments in the cited reference showing liquid water to exist under Martian environmental conditions. Because of the importance of this issue, the new data from Spirit and Opportunity are herein examined for possible indications of liquid water, the habitability of Mars, and implications for life.

3. NEW RESULTS

Early images beamed to Earth, such as that from Opportunity in Figure 1, caused a reporter viewing them at a press conference to ask the obvious question, "Is that mud?" The project scientist responding stated that, while it does look like mud, it can not possibly be mud, because liquid water cannot exist on the surface of Mars. This comment, however, ignored the experimental results reported above. An examination of images from the Rovers Spirit and Opportunity are relevant to this issue. The images should be reviewed against the background of surface temperatures as varying from below to above freezing reported by both Spirit and Opportunity.[5]

*e-mail glevin@spherix.com; phone 1-877-SPHERIX; fax 410-224-3010; web www.spherix.com

Figure 1. Mud Puddles On Mars?



1P128287581EDN0000P2303L5M1

Figure 2 shows part of the track made by the Rover Opportunity on Sol 37. The dark vertical channel has the appearance of a stream or the muddy remnants thereof. Partway down the course, the berries seem to be moved over towards the left side, as they would be deposited by flowing water. At the bottom of the picture, a portion of the Rover's track is shown. The sharp impression, having what appears to be vertical or nearly vertical walls, suggests the presence of liquid water. NASA scientists have said that there might be a possible unknown mildly bonding material in the soil, perhaps liquid water[6]. It is difficult to propose what seems to be a 90º angle of repose of the soil without some bonding material, typically moisture on Earth. It appears that the Rover passed over the area and the pressure from its tracks squeezed water out of the soil, the water having frozen as the temperature dropped. An alternative explanation would require this substance to have been in place prior to the Rover's travel. However, none of the surrounding area shows this type of formation. Were this image taken on Earth, few would interpret it other than as showing a muddy patch amidst rocks.

Figure 2. Opportunity Rover Track On Mars

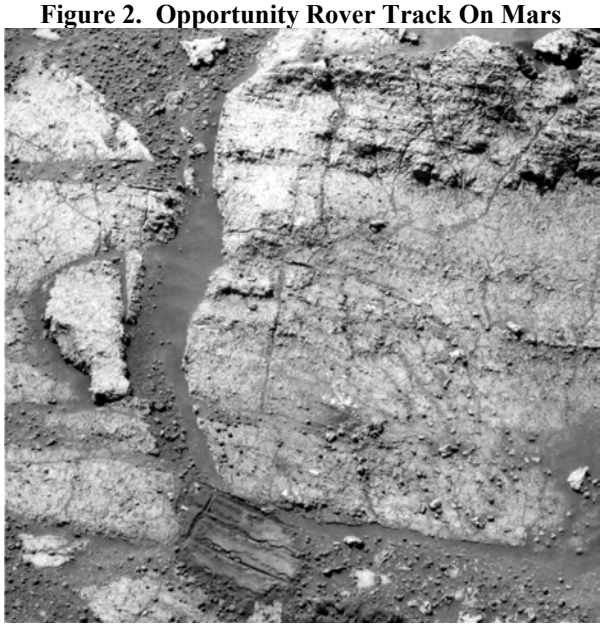


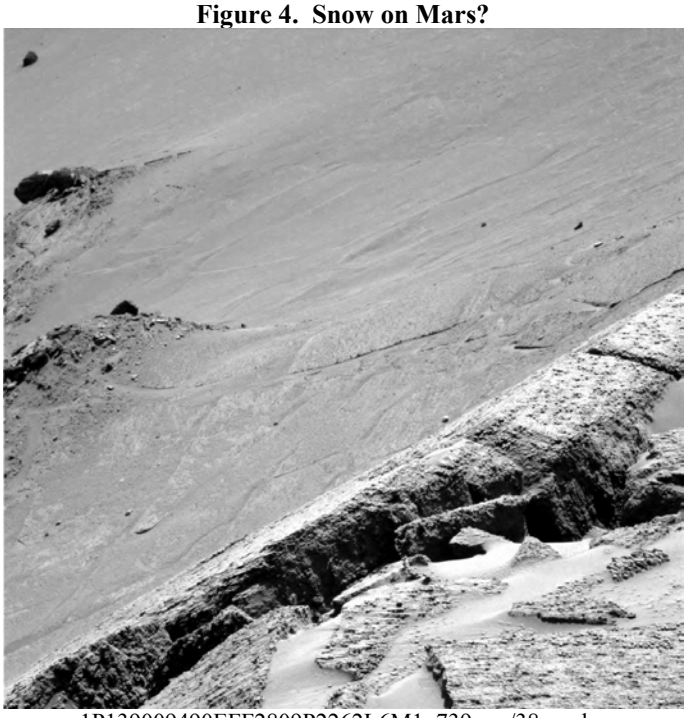
Figure 3 is an image from Opportunity taken after the Mössbauer Spectrophotometer had been applied to the surface of the soil. A whitish background material pervades this image. The impression left by the Mössbauer instrument has become white, and part of the impression has been filled over. While the filling may have been caused by retraction of the device disturbing the soil, the covering does not seem random, but more lobate, as if the material had flowed onto the disk area. To the right of the impression is a vertical line that also seems to be the product of flow. The entire region surrounding the impression of the Mössbauer and below it seems different from the surrounding area and brings to mind either an old, hardened, mudflow, or a present one. If the Mössbauer instrument caused the white material to appear in the disk impression, it might mean that the pressure or heat of the instrument caused water to flow out of the soil or mud and that subsequently the temperature dropped below freezing, producing ice. There is a reflective arc bordering the right side of the impression which also might be attributed to ice. The "berries" appearing in the lobate area seem smaller than those in the adjacent areas and are also less distinct, as if partially covered. An alternative explanation to that of ice would require either some very light colored material to lie just beneath the surface that became revealed where the Mössbauer instrument made its contact, or for the radiation from the Mössbauer to have changed the properties of the soil.

Figure 3. Ice and Mud?

1P139113486EFF2811P2535L5M1, 535 nm/20 nm bp

Figure 4 is another Opportunity image showing a bright white material lying in depressed areas of the rock. The material has no structure and appears as if it might be frost or snow. Again, those berries that do appear in some portions of the white material, seem to be partially covered with some of that material, suggesting that other berries may be completely buried in it. Figure 5 shows the ubiquitous whitish background common in these images, but, in addition, what could be taken for a small rivulet flowing, or having flowed, around the dense white island in the center of the picture. There is no unambiguous evidence to date the flow. However, the upper left area along the "bank" of the rivulet is darker than the general color in the rivulet, raising the question of current moisture. The same is true of the bank of the rivulet on the right side of the picture just above center. These, moist-appearing areas, do not contain any berries. Even more interesting are the sharply defined holes adjoining the large white mass in the lower portion of the picture. They have the appearance of sinkholes created by flowing water, past or present.

Figure 4. Snow on Mars?



1P139009490EFF2809P2262L6M1, 739 nm/38 nm bp

Figure 5. Water Holes?

1P138565929EFF2809P2297R2M1, 754 nm/20 nm bp

Another possible ”sinkhole” appears in Figure 6a. Lines of flow, indicated by tailings behind some of the berries establish the direction of flow toward the hole. No berries appear in the area just before the hole, and fewer berries appear in the flow path than in adjacent areas. Berries in the flow path seem to be immersed in the material surrounding them. Further examination of these features was made possible by the Opportunity Rover’s use of spectral filters. Figure 6b shows the same scene taken only about 3 minutes later. In Figure 6a, a 535 nm filter was used, while that of Figure 6b was 1,009 nm. The “fluvial” region near the right bank is darker in Figure 6b, consistent with the presence of moisture revealed by the larger wavenumber filter.

Figure 6a. Sink Hole?

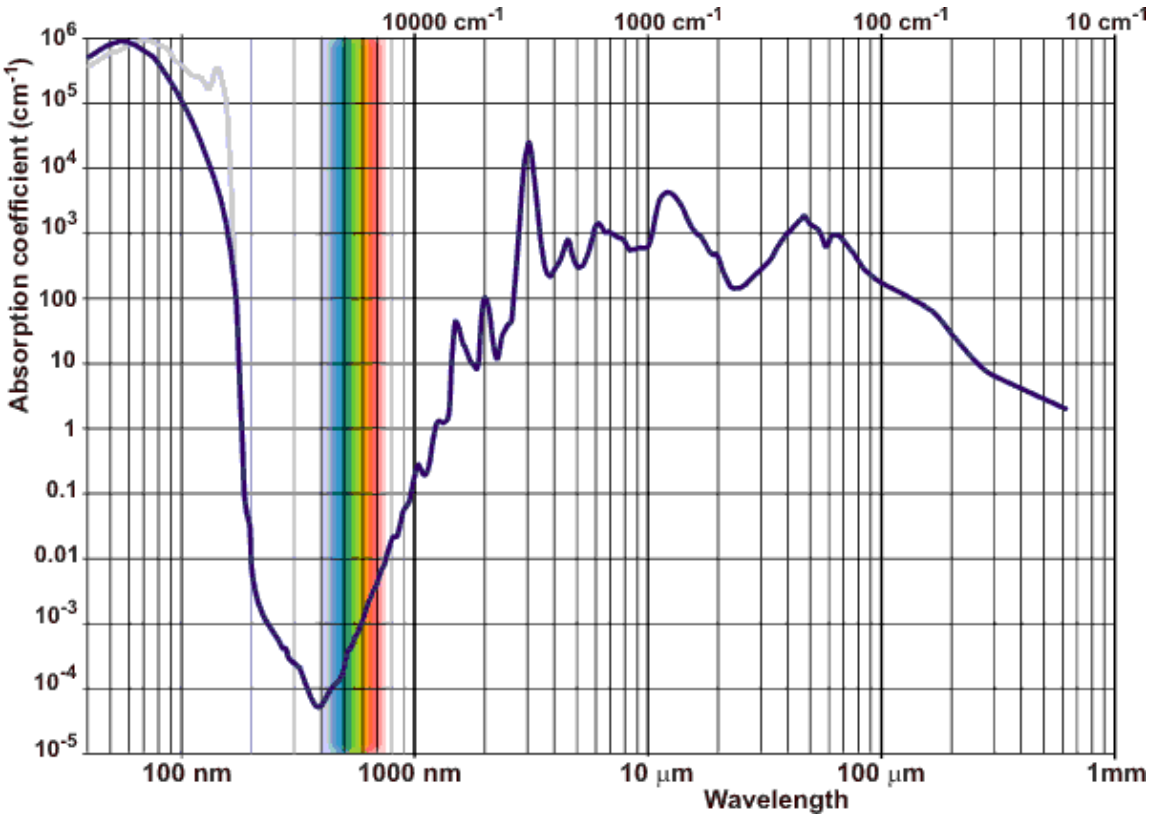
1P139377590EFF2831P2540L5M1, 535 nm/20 nm bp

Figure 6b. Filter-Enhanced Evidence for Liquid Water?

1P139377824EFF2831P2540R7M1, 1,009 nm/38 nm bp

Figure 7 provides the spectrum of liquid water[7]. It shows that, as the wavelength increases from about 400 nm to 1,000 nm, the spectral range embracing the filters, the absorption coefficient increases at a nearly constant, steep slope. Thus, liquid water absorbs light more intensely at 1,009 nm than at the 535 nm. This would mean that, if liquid water were present, any moist areas in the image taken with the 1,009 nm filter would appear darker than in the 535 nm image.

Figure 7. The Spectrum of Liquid Water



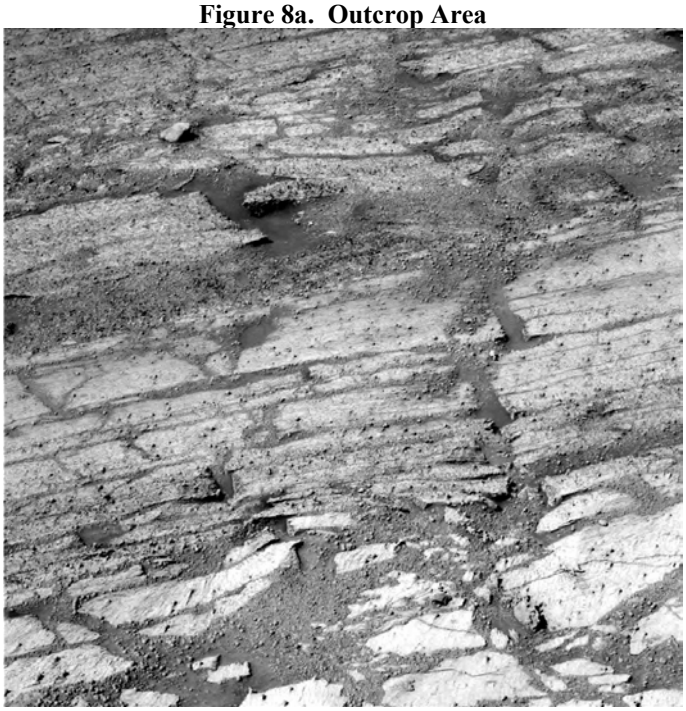
Credit: http://www.sbu.ac.uk/water/vibrat.html

Other Opportunity Rover images taken with filters support the presence of liquid water. One such pair, taken of an outcrop area, is given in Figures 8a and 8b. Figure 8b, taken at 753 nm, shows darker darks than does Figure 8a, taken at 535 nm, both with the same band pass width. The muddy-looking region at about 11:00 o'clock in the figures is darker in Figure 8b than in Figure 8a, for example. The wave number differences are not as great as in the previous pair of figures, but the increased darkness, indicating moisture or liquid water, is obvious.

Two different filters were used to take a pair of images of the track made by Rover on Opportunity. They are given as Figures 9a and 9b, taken at 535 nm and 753 nm, respectively, both at 20 nm band pass widths. Areas in the 753 nm image are darker than in the corresponding 535 nm image taken within one minute. The increased absorption with increased nm is, again, consistent with the presence of liquid water.

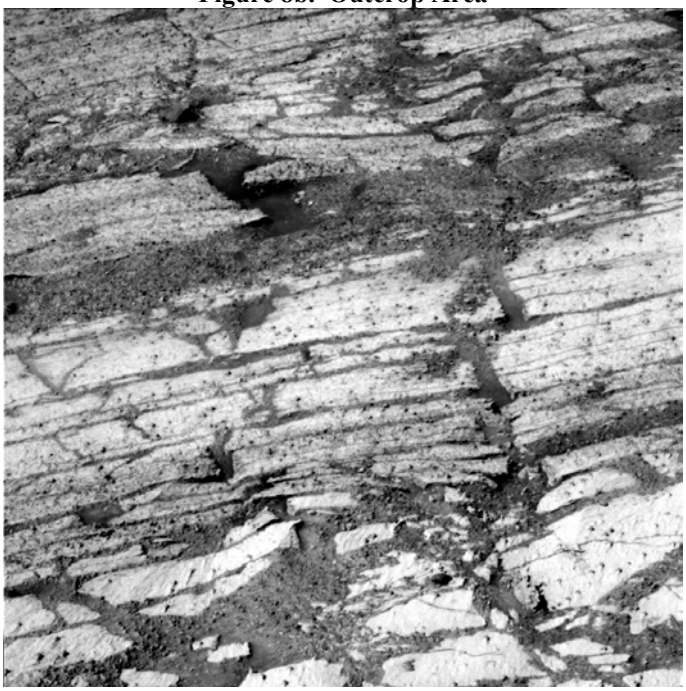
The next three images (Figures 10a, b, and c) are not as easily explained. They show a field of berries with a white "rubber chicken" superimposed. The images were taken at approximately one-minute intervals, at 432, 535, and 753 nm, respectively. The principal observation is that the rubber chicken seems to grow white wings with increasing nm. It is tempting to think of the emerging white areas as being thin ice brought into view by the larger nm filters. However, the absorption of ice varies greatly depending on depth and crystal size, so no conclusion is drawn with respect to the wings of the rubber chicken, except to call attention to this interesting filter-dependent feature. The increase in darkness with increasing nm in defined areas of the background is consistent with the presence of liquid water or moisture. The consistently white rubber chicken could be ice formed on those berries.

Figure 8a. Outcrop Area



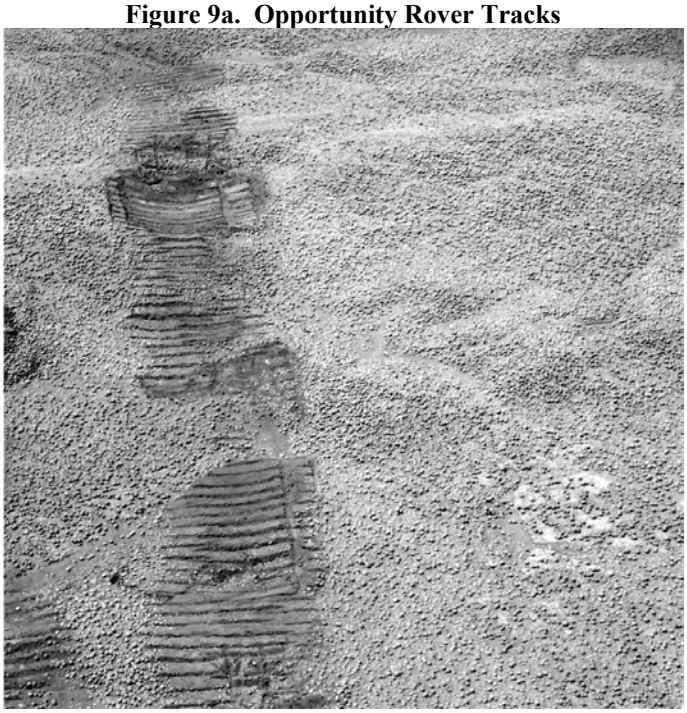
1P140084775EFF3160P2372L5M1, 535 nm/20 nm bp

Figure 8b. Outcrop Area



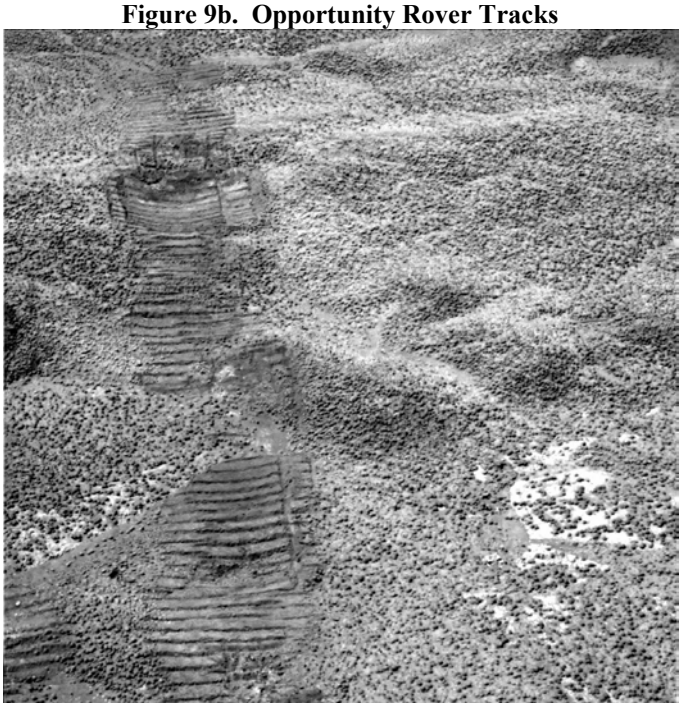
1P140084741EFF3160P2372L2M1, 753 nm/20 nm bp

Figure 9a. Opportunity Rover Tracks



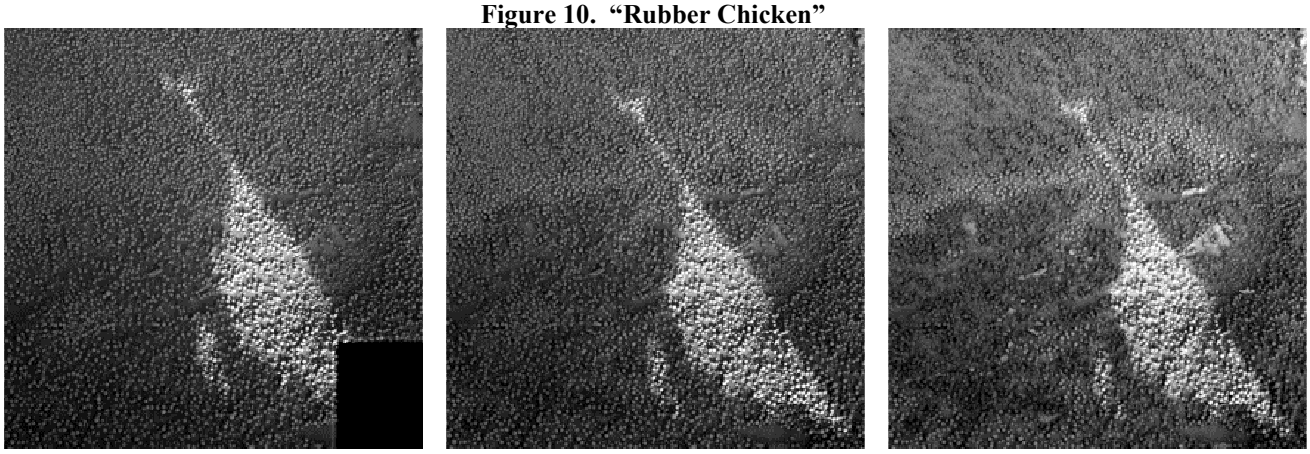
1P139722803EFF3054P2546L5M1, 535 nm/20 nm bp

Figure 9b. Opportunity Rover Tracks



1P139722770EFF3054P2546L2M1, 753 nm/20 nm bp

Figure 10. "Rubber Chicken"



10a 10b 10c

10a. 1P139563668EFF3034P2544L7M1, 432 nm/32 nm bp.

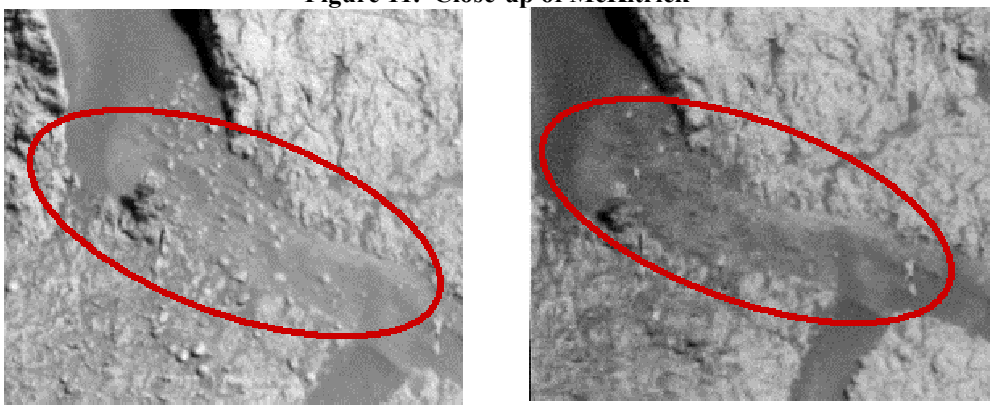
10b. 1P139563603EFF3034P2544L5M1, 535 nm/20 nm bp.

10c. 1P139563583EFF3034P2544L2M1, 753 nm/20 nm bp.

Figures 11a and b in the area of the rock "McKitrick" may be of special interest. They were taken only 645 seconds apart. Figure 11a was taken first with a 535 nm filter, 20 nm band pass width; and Figure 11b was taken with a 673 nm filter, with a band bass width of 16 nm. They are thus quite comparable. Attention is drawn to the areas encompassed by the superimposed ovals. In Figure 11a, the berries are quite distinct. However, in Figure 11b, the berries seem less distinct, as they would if submerged in liquid water. This difference in appearance could conceivably result from variation in depth of flowing water in the approximately 10 minute interval separating the two images. However, this difference may be an artifact of the slight difference in contrast evident between the two images. Images of the same area were taken on Sol 29 and Sol 36, before and after the RAT holes were drilled, as seen in Figures 12a and b. The same location in Figures 11 and 12 is readily identified by the wide vertical channel-like feature. This feature on Figure 12b is narrower than in 12a and indicates a higher edge on the left side. This would be consistent with the possibility that the water level in 12a was higher than in 12b, in which, as in the case of 11b, the berries seem more distinct in the image that might indicate shallower depths of water. This is further indicated by the undulations in the nearly horizontal channel, with their appearance in Figure 12b far more pronounced than in 12a, again indicating shallower water in 12b. The fact that the RAT hole was dug subsequent to the Sol 29 image would not seem to have any bearing on these observations.

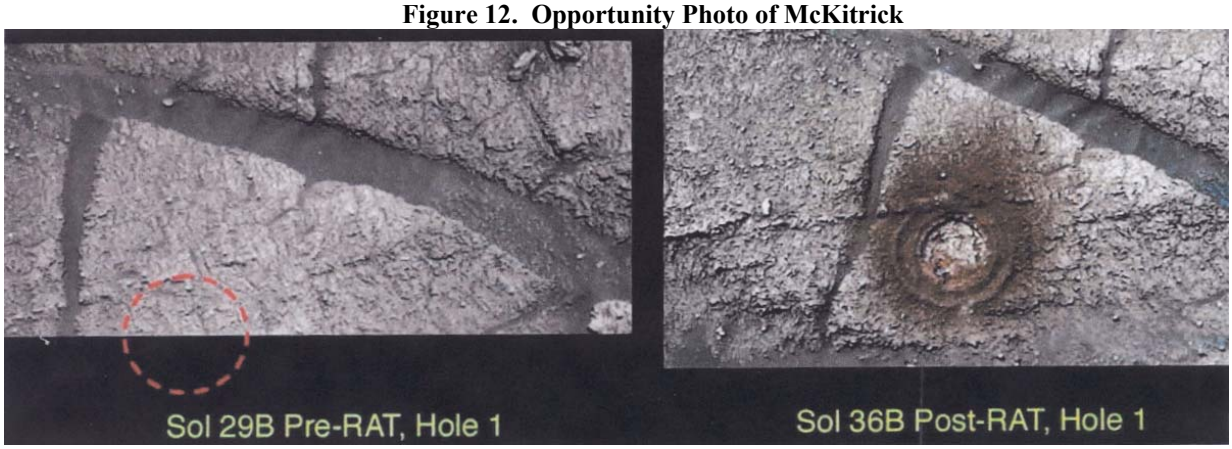
Figure 13 is a composite of the three images of the McKitrick area. The three images were combined to produce an image constructing the color of the area to the extent of the information available. The red dust is seen produced from the RAT hole, possibly indicating the iron content of McKitrick. It is noted, however, that the center of the RAT hole is largely white, possibly indicating the formation of frost since the hole was drilled.

Figure 11. Close-up of McKitrick



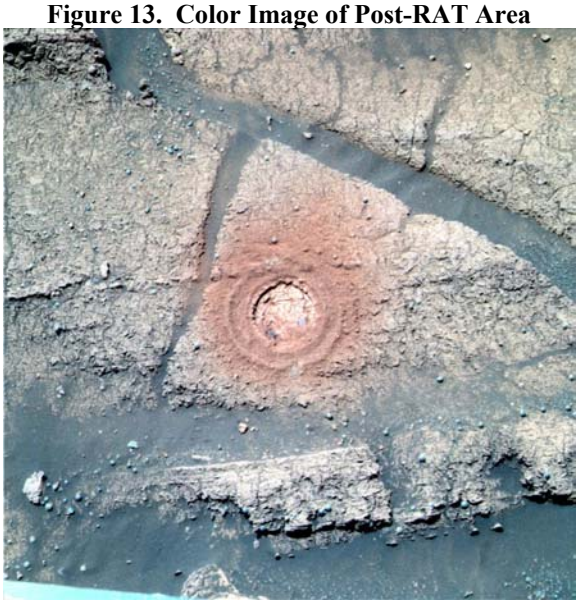
a. Possible Standing Water, Shallower b. Possible Standing Water, Deeper

Figure 12. Opportunity Photo of McKitrick



a. b.

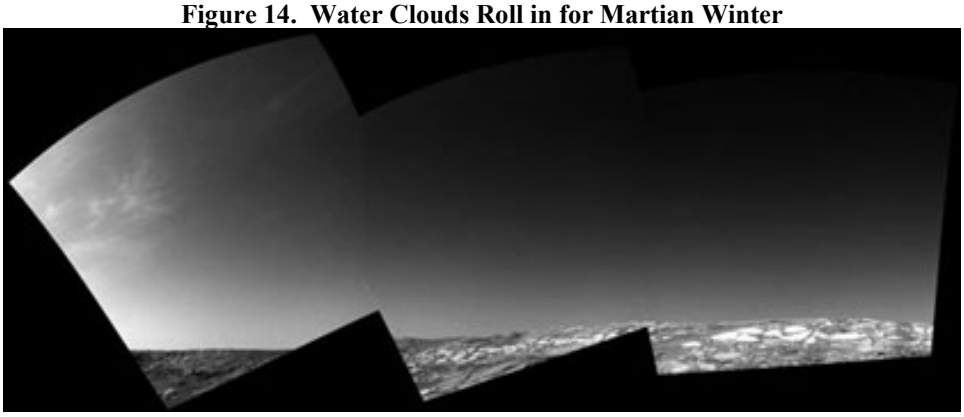
Figure 13. Color Image of Post-RAT Area



This image was constructed by combining the 3 filter images: 1P131384868EFF0504P2531L4M1.JPG, 1P131384899EFF0504P2531L5M1.JPG, and 1P131384923EFF0504P2531L6M1.JPG

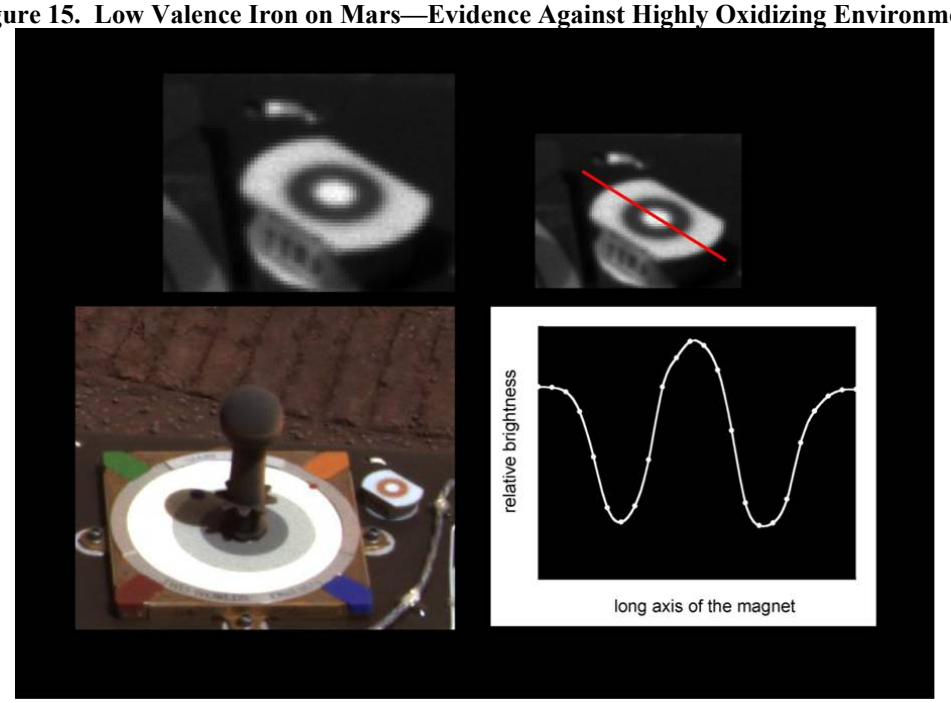
The source of the liquid water and/or ice may be possibly explained by Figure 14, which, according to the NASA caption, shows "water clouds near the surface up to heights of 20 kilometers." These low-lying water clouds are consistent with the model and analysis[8] made in 1998 to explain liquid water on Mars. Precipitation from these clouds could have produced snow, or, perhaps, rain when the temperatures were, as reported by both Spirit and Opportunity, above freezing. As explained in the above cited reference, any such liquid water resulting from the melting of snow or direct precipitation as rain would not immediately boil or entirely evaporate.

Figure 14. Water Clouds Roll in for Martian Winter



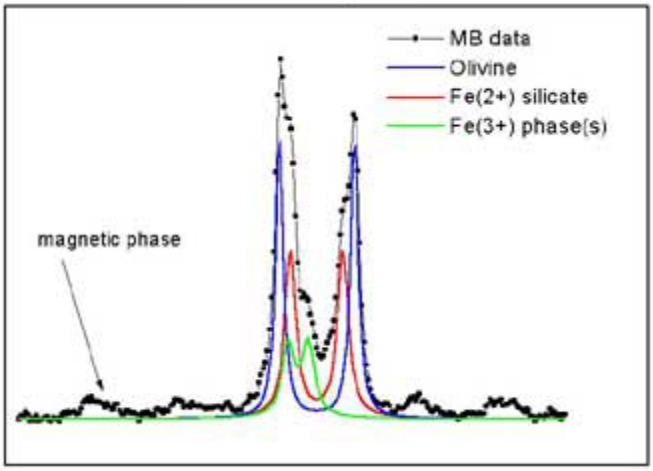
In an earlier paper[9], it was pointed out that the detection of magnetic iron at the Viking landing sites argued against the highly oxidizing soil widely postulated as an explanation of the LR results. Figure 15 shows the result of a magnetic experiment by the Opportunity Rover in which dust was collected from the air. As with Viking, significant amounts of soil were retained on the magnet. Thus, the Opportunity Rover landing site does not contain strong oxidizing agents. This is further supported by the Mössbauer analysis performed by the Opportunity Rover. The spectrum results, shown in Figure 16, identifies iron in the +2 state as being more plentiful than in the more oxidized, +3, state.

Figure 15. Low Valence Iron on Mars—Evidence Against Highly Oxidizing Environment



From website: http://www.jpl.nasa.gov/mer2004/rover-images/mar-05-2004/captions/image-20.html
This image composite highlights the Mars Exploration Rover Opportunity's "sweep" magnet, which scientists use to study the origins of dust in the atmosphere … scientists have concluded that nearly all of the dust particles in Mars' atmosphere are magnetic.

Figure 16. Mössbauer Spectrum on Martian Soil, Meridiani Planum, Sol 11



Credit: http://www.jpl.nasa.gov/mer2004/rover-images/feb-04-2004/mb_soil_opportunity-380.jpg

Methane and Ammonia:

Very recently, the detection of methane in the Martian atmosphere was reported by the ESA Mars Express orbiter[10]. This confirms earlier reports of Earth-based observations[11]. It is generally acknowledged that the presence of methane in the Martian atmosphere might be indicative of extant life. This is because the half-life of methane in the atmosphere, where it is subject to photolytic decomposition, is so short that its presence would require its continual production. This production could be effected by volcanic outpourings or by living organisms. However, in the considerable mapping of Mars by the various orbiting spacecraft, no active volcanoes have been detected. Vittorio Formisano, PI of the ESA Planetary Fourier Spectrometer, was quoted[12] as saying of volcanoes, "none of which have been found yet on Mars."

BBC News reported[13] on July 15, 2004, that researchers on the ESA Mars Express Orbiter have tentatively identified ammonia in the Martian atmosphere. As in the case of methane, but with even a shorter half-life in the atmosphere, ammonia must be constantly replenished to be present. Again, replenishment could be effected by active volcanoes or living microorganisms. In the article, a NASA scientist is quoted as having told BBC, "there are no known ways for ammonia to be present in the Martian atmosphere that do not involve life." The article concludes by stating, "but, so far, no active volcanic hot spots have been detected on the planet by the many spacecraft currently in orbit."

4. SUMMARY

The evidence presented strongly indicates the presence of liquid water or moisture at the Mars Exploration Rover sites. Recent or current mini-erosion features have been seen. Images taken through filters indicate the presence of moisture or liquid water. Evidence that could be interpreted as standing liquid water has been presented. Soil surface temperatures at both the Opportunity and Spirit Rover sites, as at the Viking Lander sites and the Pathfinder site, rise above freezing at some portion of the day, perhaps seasonally. It would thus seem that all factors necessary to constitute a habitat for life as we know it exist on current-day Mars.

5. CONCLUSIONS

Mars today could support many forms of terrestrial microbial life. Liquid water or moisture is present. There are some strong hints that atmospheric disequilibria may be caused by living organisms. None of the many new findings about Mars reported above or elsewhere conflict with, or render untenable, the conclusion that the Viking LR experiment detected living microorganisms in the soil of Mars.

6. RECOMMENDATION

With the demonstrated uncertainty of achieving successful spacecraft landings on Mars, each spacecraft lander should carry a life detection experiment. The proposed chiral LR experiment[14], should be among those experiments in that it builds on the LR legacy and could render unambiguous confirmation of life. It is important that whatever methods to detect life are sent to Mars, or elsewhere, they should be capable of measuring on-going metabolism, rather than merely detecting life-associated chemicals. The later, alone, cannot prove the presence of extant life.

ACKNOWLEDGMENTS

The author wishes to thankfully acknowledge the essential help of Susan Smith who found many of the desired images presented herein by tireless searching of the JPL Spirit and Opportunity websites. He also wishes to thank Ron Levin for his construction of the color image, Figure 13, from the raw images. Finally, but not least, he thanks Kathy Brailer for her enormous effort and help in assembling this manuscript.

REFERENCES

1. Levin, G.V. and P.A. Straat, "Viking Labeled Release Biology Experiment: Interim Results," *Science*, **194**, 1322-1329, December 1976.
2. Levin, G.V., "The Viking Labeled Release Experiment and Life on Mars," *Instruments, Methods, and Missions for the Investigation of Extraterrestrial Microorganisms, SPIE Proceedings,* **3111**, 146-161, July, 1997.
3. Levin, G.V., "Odyssey gives evidence for liquid water on Mars," *Instruments, Methods, and Missions for Astrobiology, SPIE Proceedings* **5163**, August 2003.
4. Levin, G., L. Kuznetz, and A. Lafleur, "Approaches to Resolving the Question of Life on Mars," *Instruments, Methods, and Missions for Astrobiology, SPIE Proceedings*, **4137**, 48-62, August 2000.
5. "Spirit takes temperature of Mars for first time," MarsDaily, www.marsdaily.com, January 8, 2004; http://origin.mars5.jpl.nasa.gov/gallery/panoramas/opportunity/.
6. "NASA to Announce 'Significant Findings' of Water on Mars Tuesday," R. Britt and L. David, space.com, update, 6:30 p.m. ET, March 1, 2004.
7. "Molecular Vibration and Absorption," http://www.sbu.ac.uk/water/vibrat.html.
8. Levin, G.V. and R.L. Levin, "Liquid Water and Life on Mars," *Instruments, Methods, and Missions for Astrobiology, SPIE Proceedings,* **3441**, 30-41, July, 1998.
9. Levin, G., "The Oxides of Mars," *Instruments, Methods, and Missions for Astrobiology, SPIE Proceedings*, **4495**, 131-135, July 2001.
10. Kerr, R.A., "Life or Volcanic Belching on Mars?" *Science*, **303**, 5666,1953, 26 March 2004.
11. Krasnopolsky, V.A., J. P. Maillard, and T. C. Owen, "Detection of Methane in the Martian Atmosphere: Evidence for Life," European Geosciences Union, 1st General Assembly, Nice, France, April 25-30, 2004.
12. "Formaldehyde, Ammonia, and Benzene Molecules on Mars? Would Probably Mean Life," L. Howe, www.earthfiles.com/news/printerfriendly.cfm?id=707).
13. "Ammonia may have been found in Mars' atmosphere which some scientists say could indicate life on the Red Planet," D. Whitehouse, Online Science Ed., BBC, reported in BBC News, July 15, 2004.
14. Levin, G.V., J.D. Miller, P.A. Straat, and R.E. Hoover, "A Sterile Robotic Mars Soil Analyzer," *Instruments, Methods, and Missions for Astrobiology, SPIE Proceedings*, **4859**, 78-86, August 2002.