Conclusive Evidence of Current and Past Life on Mars: A Detailed Review

Rhawn Joseph, Ph.D.
Contributing Editor, Senior Scientist, Cosmology.com

Abstract

The evidence for past and current life on Mars is reviewed. It is now established that Mars at one time, had a magnetic field (Schild & Levine 2010), and a well as rivers, streams, and oceans of water (Malin & Edgett 1999; Peron et al. 2007; Villanueva et al. 2015). There is also evidence, as based on detailed analyses of Martian meteors (McKay et al. 1996, 1998; Thomas-Keprta et al. 2002, 2009) and fossilized surface features (Rizzo & Cantasano 2009, 2011; Rizzo et al. 2015), that billions of years ago, (1) this watery world was also home to Martian microbes, including, possibly (2) cyanobacteria (blue-green algae) which may have constructed stomatolites on ancient shores. Although the Martian oceans long ago disappeared Mars has remained a living planet, as there is evidence of: (3) Martian microbial reproduction as based on the results from the Viking life detection studies (Levin 1976, 2010; Levin & Straat 1977); (4) waxing and waning of atmospheric methane (Mumma et al. 2004, 2009; Webster et al. 2015) whose most plausible source is living organisms; (5) and the presence of Martian fungi (as identified by experts in geology and biology), some which have been photographed growing out of the ground and littering the surrounding surface with spores (Joseph 2016). (6) In addition, fungi have been photographed growing atop the rovers Curiosity and Opportunity (2016), and within the rover Curiosity aluminum wheels which appear to have suffered severe biodeterioration (Joseph 2017). Collectively, this body of evidence indicates that Mars has been, and still is, a living planet, and that eukaryotes (fungi) have successfully colonized Mars.

Viking Mission Labeled Release (LR) Experiment Discovers Life on Mars

The Viking Mission Labeled Release (LR) experiment provided the first scientific evidence for life on Mars at two locations, almost four thousand miles apart, i.e. Chryse Planitia and Utopia Planitia, the two Viking landing sites on Mars (Levin 1976; Levin & Straat, 1976, 1979). The Viking LR experiment was simple and straight forward and involved taking a sample of Martian soil and adding a nutrient that contained radioactive carbon. The purpose was to detect the presence of radioactivity in the gasses released--an indication of biological activity. A control experiment treated a second sample that had been sterilized. In every experiment conducted, positive results were obtained from the unsterilized sample, including evidence that Martian microbes were rapidly multiplying.

Specifically, and as summarized by Levin (2010), the Viking life detection experiments were based on the assumption that even if complex life had evolved on Mars, they would be accompanied by microorganisms which are similar to terrestrial life and would be carbon-based, and that any the biochemical reactions would be aqueous. In the course of developing the LR experiment, and prior to transport to Mars, thousands of laboratory and field tests were performed and the LR proved to capable of detecting a very wide range of microorganisms, including pure and mixed cultures of aerobic, anaerobic and facultative bacteria, as well as algae, fungi, lichen, and sulfur bacteria. Negative LR controls verified the biological nature of the initial responses and a very strong case for reliability of the LR was established.

The LR experiment was therefore included in the Viking biology package, which, paradoxically, included two additional experiments devised by NASA--- the Gas Exchange (GEx) (Oyama et al., 1978) and the Pyrolytic Release (PR) (Horowitz et al., 1977)-- and whose reliability was questionable at best. Indeed, the GEx and the PR had not been calibrated properly, and proved unable to detect the presence of microbes on Earth, which were living in permafrost or frozen tundra. By contrast, and as described by Levin (2010) "the LR approach is unique among life detection systems in that it is not based on static chemical or physical properties in the sample, but on the detection of on-going metabolism. The method is extremely sensitive."

NASA, however, rejected the recommendations of numerous scientists as to the most promising locations for detecting life, and instead the two Viking space craft were sent to those regions of Mars the least likely to contain life. According to NASA, the exploration sites were chosen for safety (and not science).

Once on Mars, the Viking sampling arm obtained Martian soil samples which were distributed to all three life detection instruments. As described by Levin (2010), "The LR instruments operated flawlessly on Mars. Both Viking landing sites, some 4,000 miles apart,

produced strong responses and virtually nil 16˚C controls. The results (Levin and Straat, 1976, 1979) met the pre-mission criteria for the detection of life by the LR. Thus, the LR experiment proved there was life on Mars.

In a further effort to distinguish between biological and non-biological agents, additional, more defining controls were executed by commands from Earth" which again demonstrated on-going Martian metabolism. Seven different LR experiments were conducted, each of which yielded positive results.

Back on Earth, NASA devised several <i>ad hoc</i> experiments, so as to disprove these findings, and injected additional nutrients into those samples already established to be brimming with life. The addition of more nutrients did not increase the already established high levels of Martian biological activity, but caused temporary declines. Did the overdose kill them, or had they already died? According to Levin (2010) "A search of the library of terrestrial soil responses revealed that NASA-bonded Antarctic soil 664 had reacted to its second injection as had the Martian soils" and if not due to death "the decline in gas level was caused by re-adsorption of the evolved gas into the dampened soil."

Levin concluded that the LR experiment had proved there is life on Mars, and that the "amplitudes and kinetics of the Mars LR results were similar to those of terrestrial results, especially close to those of soils in, or from, frigid areas."

NASA, however, disagreed, and NASA scientists, instead, formed a consensus that "the LR had not detected life on Mars, but had detected a chemical or physical agent that had produced false positive results" (Levin 2010).

The consensus, however, was based not on the LR experiments, but the failure of the GEx and PR experiments, which had employed a gas chromotagraph and mass spectometer to test for organic material associated with living organisms. Yet these latter experiments were so poorly designed and so insensitive they were unable to find evidence of life, under similar conditions, on Earth. To detect life, these experiments required that a gram of soil had to contain over 100 million organisms. When the GEx and PR experiments were tested against Antarctic soil which was brimming with bacteria, they failed to find evidence of life.

The LR experiment, therefore, detected the presence of life on Mars; life forms which could have included not just archaea and bacteria, but algae, lichens, and fungi.

Fossilized Evidence of Biological Activity in Martian Meteorites ALH 84001.

It is now established that Mars at one time, had a magnetic field (, and a well as rivers, streams, and oceans of water (Malin & Edgett 1999; Peron et al. 2007; Villanueva et al. 2015). What became of the Martian magnetic field and the oceans of Mars is a matter of speculation. However, reports from the European Space Agency and other investigators, indicates that liquid water continues to percolate and to pool upon the surface of Mars (Renno et al., 2009). Its been said, "Where there is water, there is life, and in 1996 (and thereafter) Mckay and his team (1996, 1998; Thomas-Keprta et al. 2002, 2009) provided evidence that Mars was flush with microbial life for the first several hundred millions years after its formation.

We know this with certainty, because 4 billion years ago, some of that water, which was highly mineralized, seeped into cracks within Martian rocks and in so doing, fossilized microbial residue and excretions including magneto-fossils surrounded by carbonate globules.

Nearly 4 billion years would pass, and then, 16 million years ago, an asteroid or comet slammed into Mars with the explosive energy of a million nuclear bombs. The impact blasted chunks of Mars into space, which were ejected at 11,000 mph. One of those rocks was 4 billion years old. Its cargo? Fossilized evidence of Martian microbial activity.

For 16 million years that Martian meteor orbited the sun, and then, 13,000 years ago, it collided with the Earth. The outer portions of the meteor melted from the heat of entry, forming a black glassy crust. Then it crashed near the south pole. There it lay, exposed to the elements and the frozen wastes. And then, one sunny afternoon, on December 27, 1984, it was discovered, peeping out from beneath the snow, in a desolate region known as the Far Western Ice field, adjacent to a ridge of rocks named Allan Hills. Bobbie Score made the discovery. It drew her attention because the outer black shell had broken off, and the inside looked green. Score labeled it: ALH 84001. "84" for the year, and ALH for Alan Hills. and 001 because she believed it was so unusual it deserved to be the first to be analyzed.

ALH 84001 was placed in a sterilized clean bag. It weighed 4.25 pounds. Her field notes described the meteor as "highly shocked, grayish green. "She identified it as an achondrite, a rare type of meteor which is associated with planets, not asteroids. It was packed into an ice chest, and sent to NASA's Johnson Space Center where it was placed in a nitrogen chamber and freeze dried to remove any snow or ice or water. It was photographed, a chip broken off and examined, and then classified. However, in the lab, it no longer looked green, but more like a piece of broken cement.

Then it was sealed in a sanitized bag, and filed away along with other meteors, on the 2nd floor of the space center, and forgotten. Almost 6 years would pass before it true identity, and the secrets it held, would be discovered.

The first indication this meteor was unusual was in 1990, when David "Duck" Mittlefehldt analyzed a small chip with an electron microprobe. The signature of the x-rays ricochet off the meteor indicating it was similar other meteors known as SNCs--an acronym for three meteors

(Sherotty, Nakhla and Chassigny) believed to have originated on Mars. ALH would become the 10th SNC.

Donald Bogard and his colleagues, examined the meteor to help determine its origin. They studied the chemical composition of gasses inside black beads of glass-like material that had bubbled up when the rock was ejected from Mars by a violent shock. The gasses matched the Martian atmosphere perfectly as measured by the Viking space craft which sampled the atmosphere in 1976.

It was subsequently determined that ALH 84001 displayed magnetic properties, and could be properly categorized as a cataclastic orthopyroxenite. Various dates have been given for the rock, based on an analysis of radioactive decay. It was finally determined that ALH 84001 crystallized at ~4.5 Ga and was involved in a major impact event at 4.0 Gyr (thereby resetting the Ar/Ar clock). It was during this same time frame (4.5 to 3,8 billion years ago) that Mars still had a magnetic field and was flush with oceans, rivers, lakes and streams.

By measuring the effects of high energy cosmic rays which impacted the rock while it was in space they deduced it must have orbited in space for 16 million years. Further, by analyzing radioactive decay they estimated it must have sat in the Antarctic ice for 13 million years.

Carbon Compounds, Carbonate Globules, Magnetites: Evidence Of Past Martian Life

Mittlefehldt soon discovered ALH 84001 contained high concentrations of carbon compounds. He also observed rounded carbonate globs and spheroids inside the fractured surface which were visible to the naked eye. It was determined that these globules and elongated spheroids had been recycled through water, and were likely biologically produced. Carbonates are typically produced by creatures who live in the ocean, and are found in fossil beds of dead sea life.

It was determined that the orange carbonate globules had to have formed on Mars as the pattern of cracks would not have occurred upon striking the Earth. The globs also had the same isotopes as the Martian atmosphere, whereas the oxygen isotopes indicated they had formed in water. Thus, the Martian carbonate minerals and carbonate globules were most likely formed by

Martian microbes when Martian water seeped into the cracks when this rock was still part of Mars. The carbonate residues were formed in water, and where there is water, there is life.

The Martian carbonate globules, were also discovered to contain calcium rich cores coupled with dissolved carbonates and magnetite and iron-sulfides -which were likely produced via biological processes (McKay et al. 1996, 1998; Thomas-Keprta et al. 2002, 2009); i.e. carbonate and iron-eating bacteria. The outer rims were also oxidized in a pattern that indicated biological activity; that is rusting and reducing.

Everett Gibson and Christ Romanek, alerted by Mittlefehldt, studied the rock and found the carbonates had formed in water within temperatures habitable to life.

Kathie Thomas-Keprta (McKay et al. 1996; Thomas-Keprta et al. 2002, 2009) began examining the rock and found magnetic crystals. These crystals are typically created by water-living bacteria who use them for navigation. These crystals act like magnetic compasses; the magnetic properties coming from the magnetized iron. The magnetic crystals in the martian rock looked just like those created by water living bacteria. Moreover, the magnetite particles were determined to be similar chemically, morphologically, and structurally to magneto-fossils (McKay et al. 1996; Thomas-Keprta et al. 2002, 2009)); i.e. the fossil remains of bacterial magnetosomes, including those found in fresh pond water.

These crystals were well-organized, elongated and free of defects--which on Earth are considered as indisputable evidence of biological activity. Crystals which are non-biological have chaotic defects and are filled with impurities. This was not the case for those inside the Martian meteorite.

Microbes create <i>walls</i> and <i>rooms</i> inside their cell, miniature biological laboratories, where they engage in synthesis, including the creation of biological crystals. These crystals, although small enough to fit inside the cell, are large enough to hold an electric charge. Microbes also align their crystals into chains, so that the entire chain works like an electrical circuit, or magnet. This is exactly how the crystals discovered in the Martian meteor were organized.

Using an electronic microscope, E. Imre Friedmann, FSU, in PNAS 2001, also examined the Martian rock and also found the telltale "choo choo train" formations, which are likewise characteristic of those produced by Earthly bacteria. They were lined up like a string of pearls--like vertebra running up the back, and all were similar in size and shape and did not touch each other, meaning they were flexible and allowed the organism to move. Their purpose could only be to enable their owners to navigate by reacting to a Martian magnetic field. Mars had a very powerful magnetic field for the first 800 million years after the planet began to form.

Subsequently Thomas-Keprta and colleagues (2002, 2009)determined that 28% of the 100s of crystal grains were identical to those produced by earth bacteria. She called these crystals: Martian "magneto-fossils. As reported in PNAS, "unless there is an unknown and unexplained inorganic process on Mars that is conspicuously absent on the Earth and forms truncated hexa-octahendral magnetites, we suggest these magnetic crystals in the Martian meteorites ALH84001, were likely produced by a biogenic process. As such, these crystals are interpreted as martian magnetofossils and constitute evidence of the oldest life yet found."

In fact, 25% of the magnetite in ALH 84001 occurs only in association with the biologic activity. They are a byproduct of iron-eating hyperthermophiles who metabolize and convert iron oxide to magnetite. Moreover, these microscopic oxygen and iron mineral grains, were found alongside the carbonate globules adjacent to iron and sulphur grains. These minerals are only found together when they are created biologically and are identical to those produced by bacteria. Moreover, this biological material was found in association with fossilized polycyclic aromatic hydrocarbons which were also determined to be biologically produced (McKay et al. 1996; Thomas-Keprta et al. 2002, 2009).

Specifically, Simon Clemmet at the Zare labs used a laser mass spectrometer to probe the martian rock, and directed the ultraviolet laser beam at molecular targets heated to about 100 million degrees for one 10th of a millionths of a second. By measuring the speed of flight and changes of positively charged molecules as they struck a negatively charged plate, it was determined that many of the molecules consisted of polycyclic aromatic hydrocarbons (PAHs). PAHs are formed by biological processes and are the byproduct of cellular decay. PAHs are formed when bacteria die and begin to decompose. These PAHs, however, were not from Earth, but from Mars (McKay et al. 1996).

On Earth, PAHs are typically found in fossil molecules, and are derived from biological activity associated with plankton and early plant life. Although PAHs can be formed at very high temperatures from burnt tobacco or petroleum exhaust, these are also biological substances.

However, the Martian PAHs were different than those found in Earth's atmosphere and are unlike 99% of all PAHs found on this planet (McKay et al. 1996). They were also discovered inside but not on or near the outside of the meteor, which rules out contamination. In fact, the density of the PAHs increased in concentration within the interior of the meteor, with the greatest abundance fund next to the carbonate globules, in the same areas where the magnetic crystals were also the most abundant.

Thus, the highest concentration of PAHs were found in association with those portions of the meteorite rich in carbonates, and were determined to be indigenous. No evidence of laboratory or Earthly contamination was detected (McKay et al. 1996).

Therefore, it can be assumed that the Martian PAHs had been produced by microbes, bacteria, or even plankton and plants; which is not inconceivable as the red planet was awash with Martian oceans and great seas at the time the PAHs were formed (McKay et al. 1996; Thomas-Keprta et al. 2002, 2009).

In response to concerns about Earthly contamination, Richard Zare responded: "On the contamination issue we studied micrometeorites from the same meltwater in Antarctica and found a different pattern than we did in the Martian meteorite, and I don't see how contamination could look so different in two meteorites from the same area." Likewise, Simon Clement (1998) independently reported that he found no evidence of terrestrial contamination and concluded that the PAHs are extra-terrestrial in origin.

The PAHs were produced by Martians. When these creatures died they left PAHs.

In 2009, Thomas-Keprta, Mckay and colleagues, finally put the non-biological, contamination claims to rest: "The Martian meteorite ALH84001 preserves evidence of interaction with aqueous fluids while on Mars in the form of microscopic carbonate disks. Intimately associated within and throughout these carbonate disks are nanocrystal magnetites (Fe_3O_4) with unusual chemical and physical properties, whose origins have become the source of considerable debate. One group of hypotheses argues that these magnetites are the product of partial thermal decomposition of the host carbonate. Alternatively, the origins of magnetite and carbonate may be unrelated.For example, the magnetites might have already been present in the aqueous fluids from which the carbonates were believed to have been deposited. We have sought to resolve between these hypotheses through the detailed characterization of the compositional and structural relationships of the carbonate disks and associated magnetites with the orthopyroxene matrix in which they are embedded. We conclude that the vast majority of the nanocrystal magnetites present in the carbonate disks could not have formed by any of the currently proposed thermal decomposition scenarios. Instead, we find there is considerable evidence in support of an alternative allochthonous origin for the magnetite unrelated to any shock or thermal processing of the carbonates."

Magnetotactic bacteria are now known to be ubiquitous in terrestrial aquatic environments, and they appear to utilize the magnetic properties of magnetite in conjunction with the Earth's global geomagnetic field as an orientation mechanism. This is a process known as magnetotaxis, and when it is coupled with flagellar motility and aerotaxis, it allows an organism to locate and maintain an optimal position in vertical chemical gradients within aquatic environments by reducing a three-dimensional search problem to a one-dimensional search problem.

Perhaps the most profound implication of this study is that approximately one-quarter of the magnetite crystals embedded in the carbonate assemblages in Martian meteorite ALH84001 require the intervention of biology to explain their presence....these magnetites have remarkable morphological and chemical similarities to magnetite particles produced by magnetotactic bacteria, which occur in aquatic habitats on Earth. No single inorganic process or sequence of inorganic processes, however complex, is known that can explain the full distribution of magnetites observed in ALH84001 carbonates. Moreover, these types of magnetite particles are not known or expected to be produced by abiotic means either through geological processes or synthetically in the laboratory. Under these circumstances, our best working hypothesis is that early Mars supported the evolution of Martian biota that had several traits (e.g., truncated hexa-octahedral magnetite and magnetotaxis) consistent with the traits of contemporary magnetotactic bacteria on Earth.... We have therefore argued that these Martian magnetite crystals are in fact magnetofossils" and "constitute evidence of the oldest life forms known."

Methane And Martian Meteorite Eeta 79001

On October 31, 1996, British scientists and planetary geochemists, Colin Pillinger, Ian Wright, and Monica Grady, announced that they too had discovered evidence that life once existed and thrived on the red planet -Martian life that flourished as recently as 600,000 years ago.

The British team analyzed two different Martian meteorites, including the fist sized rock scrutinized by NASA scientists. Specifically, they discovered a variety of organic compounds including complex organic molecules produced by and associated with carbon-based life forms in a chunk of Mars (EETA 79001) that had been blasted out some 600,000 years ago. By analyzing the various atomic weights of these chemical substances, the British team also reported that the ratios discovered match those of the oldest fossils and bacteria found on Earth; e.g. archaebacteria.

Moreover, these scientists discovered "microbially produced methane."

Methane and Life on Mars

In 1996, evidence for "microbially produced methane" was discovered in Martian meteorite EETA 79001 (Pillinger et al 1996)). In 2003, Europe's Mars Express spacecraft tracked three separate methane plumes consisting of 19,000 metric tons of methane gas were detected in the Martian atmosphere. The Methane was detected by Michael Mumma of the Goddard Space Flight Center who employed infrared spectrometers on three Earth-based telescopes. Several possible emission sources were identified in the northern and southern hemispheres, in the vicinity of Arabia Terra, Nili Fossae and Syrtis Major. ((Mumma et al. 2004).

It has since been determined that Martian atmospheric methane levels varies over time and is punctuated by transient and major spikes in concentration, followed by declines, only to increase again (Mumma et al. 2004, 2009; Hand, 2009, Webster et al. 2015). For example, in July of 2013, "an upper limit of 2.7 parts per billion of methane" in the general vicinity of the

Gale Crater was reported whereas on September of 2013, methane levels significantly declined, fluctuating between a value of 0.18 ppbv to 1.3 ppbv (Webster et al. 2013). This was followed by a "tenfold spike" in levels of methane in the Martian atmosphere with increases in late 2013 and early 2014, averaging "7 parts of methane per billion in the atmosphere" (Webster et al. 2014).

A variety of life forms and innumerable microbes could easily flourish on Mars, some living in the permafrost, just inches beneath the soil, others hundreds of feet beneath the surface, or as determined by 70 experts in geology and biology these life forms, i.e. fungi, also grow in vast fields upon the surface. As based on the Viking LR experiments, the life forms may include aerobic, anaerobic and sulfur reducing bacteria, as well as algae, lichen, and fungi (Levin 2010) and which obtain energy from minerals, metals or the reduction of carbon dioxide. Those who digest carbon dioxide or who feast on other organics would in turn release various gasses including methane as a waste product which would accumulate in the atmosphere only to bleed away into space.

On Earth, 90% of all methane released into the atmosphere is produced biologically by living and decaying organisms.. Methane is released as a waste product by bacteria and archae. Other Earthly sources include termites, decay in anaerobic paddy fields, peat bogs and landfill. The other 10% is produced geologically, such as via plate tectonics and the interactions of water with molten lava belched out by volcanoes along with various gasses including methane. Even so, only minute concentration of methane exist in the Earth's atmosphere.

It is highly unlikely, in fact, it is improbable that the Martian methane plumes were produced by a non-biological sources. On Mars, whatever seeps into the soil, rock, or which comes to be locked beneath the surface of the planet, remains locked in place, including geologically produced methane.

However, methane produced by Martian organisms would leak out from the surface and into the atmosphere. Even so, on Mars methane is readily destroyed by chemical reactions or leaks into space due to the solar wind, the lack of a magnetosphere, and the sun's UV rays. Thus, the fact that methane has been repeatedly replenished, waxing and waning then waxing in concentration, indicates a living source must be continually excreting this gas.

Further, because of seasonal changes in the tilt and orbit of Mars, it would be expected that biological activity would be cyclic, and thus the amount of methane released should wax and wane over time--and this corresponds with the data (Joseph 2017).

Although fluctuations in biological activity is a reasonable explanation, it is possible that temperature changes also associated with alterations it the tilt and orbit of Mars, trigger the opening and closing of cracks in the surface which effects venting from the planet's interior. Likewise, these same temperature changes could cause various microorganisms to grow and to begin digesting and secreting methane.

In 2016, 30 geologists with an expertise in mineralogy and geomorphology, and 40 biologists with an expertise in fungi, identified vast fields of fungi growing and shedding spores, on the Martian surface (Joseph 2016).

Fungi on Mars

Fungi have the unique ability to flourish in almost any environment Carlile et al. 2001; Gostincar, et al 2010), including within and surrounding the highly radioactive Chernobyl Nuclear Power Plant (Dadachova et al. 2007); the radiation intense environment of space and on the outside windows of the space stations (Cook, 2000, Novikova, 2009, 2016; Vesper 2009); and on Mars: Based on photographic evidence provided by NASA, and as will be reviewed here: **(1)** in 2016, forty biologists and thirty geologists upon examining photographic evidence, agreed there is a high likelihood of life on Mars; and dozens of fungal-experts identified these specimens as "puff balls," "Basidiomycota" and "mushrooms" which grow out of the ground and shed spores (Joseph 2016; Dass 2017).

Subsequently, an examination of the Mars Rovers Curiosity and Opportunity, revealed **(2)** numerous colonies of fungi (or fungal/bacteria) growing atop the Rover decks (Joseph & Rabb, 2016), and **(3)** within the Rover Curiosity aluminum wheel wells (Joseph 2017a). As documented here in Section IV, the rover wheels have suffered severe damage and biodeterioration despite having been extensively tested at nearly 3-times Mars' gravity, and after being driven less than 10 miles in 5 years.

Lastly **(4)**, photos taken of Mars from space by NASA and the European Space Agency, reveals the presence of huge fungal/bacteria colonies which wax and wane in size. Moreover, the increase and decrease in size is associated with the waxing and waning of methane in the Martian atmosphere (Joseph 2017b).

The evidence reviewed in Sections II, III, IV, V, indicates that fungi have successfully colonized Mars.

II. Experts in Biology and Geology Agree There is a High Probability of Fungal Life on Mars

The Joseph (2016) study was based on a sample of 2,000 geologists specializing in mineralogy and geomorphology, and 2,000 biologists specializing in fungi; their email addresses obtained by paid assistants who searched the websites of every American, British, Canadian, Australian, New Zealand, Philippines, and Indian University, for scientists identified as experts in these fields. These experts received at least 3 email invitations over a 3 day period, and were provided secure links to a secure website with 25 photos of Martian specimens photographed by NASA depicting organisms previously judged to resemble fungi. Out of this invited sample, a total of 70 scientists--30 Geologists and 40 Biologists--completed the invitation-only online survey.

The study was designed so each expert could "vote by secret ballot" on the probability, on a 4 point scale, that these specimens were alive. Each participant also had the option of typing in the name and identity of the specimen.

Although all experts voted anonymously, their IP address served as the "registration" which (via the system's programming) prevented anyone from voting twice. Each IP address can be traced back to a computer and a generalized location, so as to prove each vote was legitimate. Moreover, the data typed in by each participant was linked to their IP address.

Two independent monitors, and NASA's Planetary Protection Officer and NASA's Director of Astrobiology, were provided the original email lists, copies of the email invitations with email addresses indicated in the BCC section; as well as all the raw data and IP addresses, from the Joseph (2016) study.

Statistical Analyses. A chi square analyses indicated a highly statistically significant consensus among the biologists who agreed there is a high likelihood of life vs non-life for 6 of the specimens (Figures 1-6). Chi square, however, provides only an approximation of significance values and becomes increasingly inaccurate with small sample sizes (Larntz 1978).

To maximize statistical power, a Fisher's exact test (Fisher 1922) was performed (by Y.A. of UCLA). The Fisher's exact test provides exact P-values and is more sensitive than other measures which provide only approximations (Fisher 1922; Larntz 1978). The Fisher's exact test is also designed for the analysis of categorical and contingency tables (as employed in the Joseph 2016 study).

Highly significant results were obtained, proving that Geologists and Biologists agreed there is likelihood of life (ratings 2,3,4) vs non-life (rating 1) on Mars, as based on the comparisons for the top 5 pictures chosen by Biologists ($p = <0.0008$) and Geologists ($p = <0.0004$); and the same is true of the top 7 photos; Biologists ($p = <0.0001$); Geologists ($p = <0.0001$). Dozens of experts also identified these living specimens as "puff balls," "Basidiomycota" and "mushrooms" (Joseph 2016, Dass, 2017).

Typically, the alpha level is set at < 0.05 (5%). However, in this study, the findings were significant well beyond the < 0.001 level. Hence, if one were to continuously redraw a sample from the same population of 2,000 biologists with an expertise in fungi, and 2,000 geologists with an expertise in geomorphology and mineralogy, we would expect to obtain the same exact results over 99.9% of the time.

Discussion. Thus, the overall pattern of results demonstrated that 40 experts in Biology and fungi and 30 experts in geology, formed a statistically significant consensus supporting a high probability that fungi are growing on Mars (Joseph 2016). Indeed, an examination of these specimens demonstrates these are not fossils, as before and after photos show they grow out of the ground, whereas other photos show they litter the surroundings with spores.

Subsequently, Dass (2017) reviewed these findings and confirmed that Martian "puff balls" "Basidiomycota" and "mushrooms" are growing out of the ground and sporing--evidence which was referred to as "obvious."

FIGURES 1- 7

The following seven photos of Martian specimens photographed by NASA on Mars, were judged by experts in fungi, as depicting life and having a high probability of life. Geologists also formed a statistically significant consensus and gave the highest rankings to five of the top seven chosen by Biologists.

Figure 1. *Consensus Biologists/Geologists. A majority of Biologists and Geologists agree that these are Martian specimens have a high probability of life and are most probably fungi.

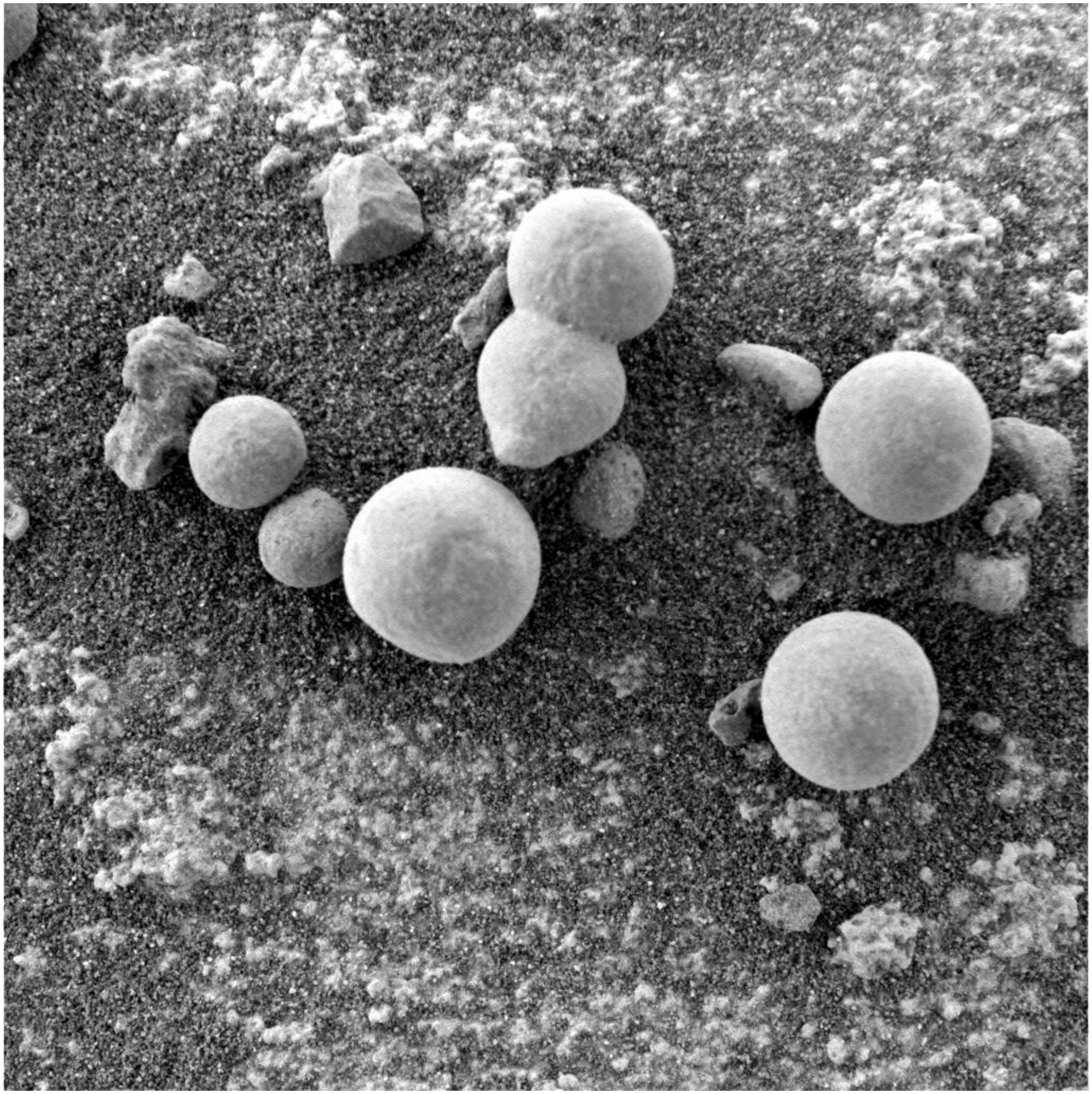

Figure 2. *Consensus Biologists. These and similar specimens were identified as similar to "puff balls" ("Basidiomycota"). Fuzzy-dust-like-spores litter the surrounding areas.

Figure 3. Consensus Biologists. Martian fungi shedding out skins with white spores littering the Martian surface. A majority of Biologists report that these are Martian specimens are living organisms; i.e. puff balls, (Basidiomycota)

Figure 4. *Consensus Biologists/Geologists

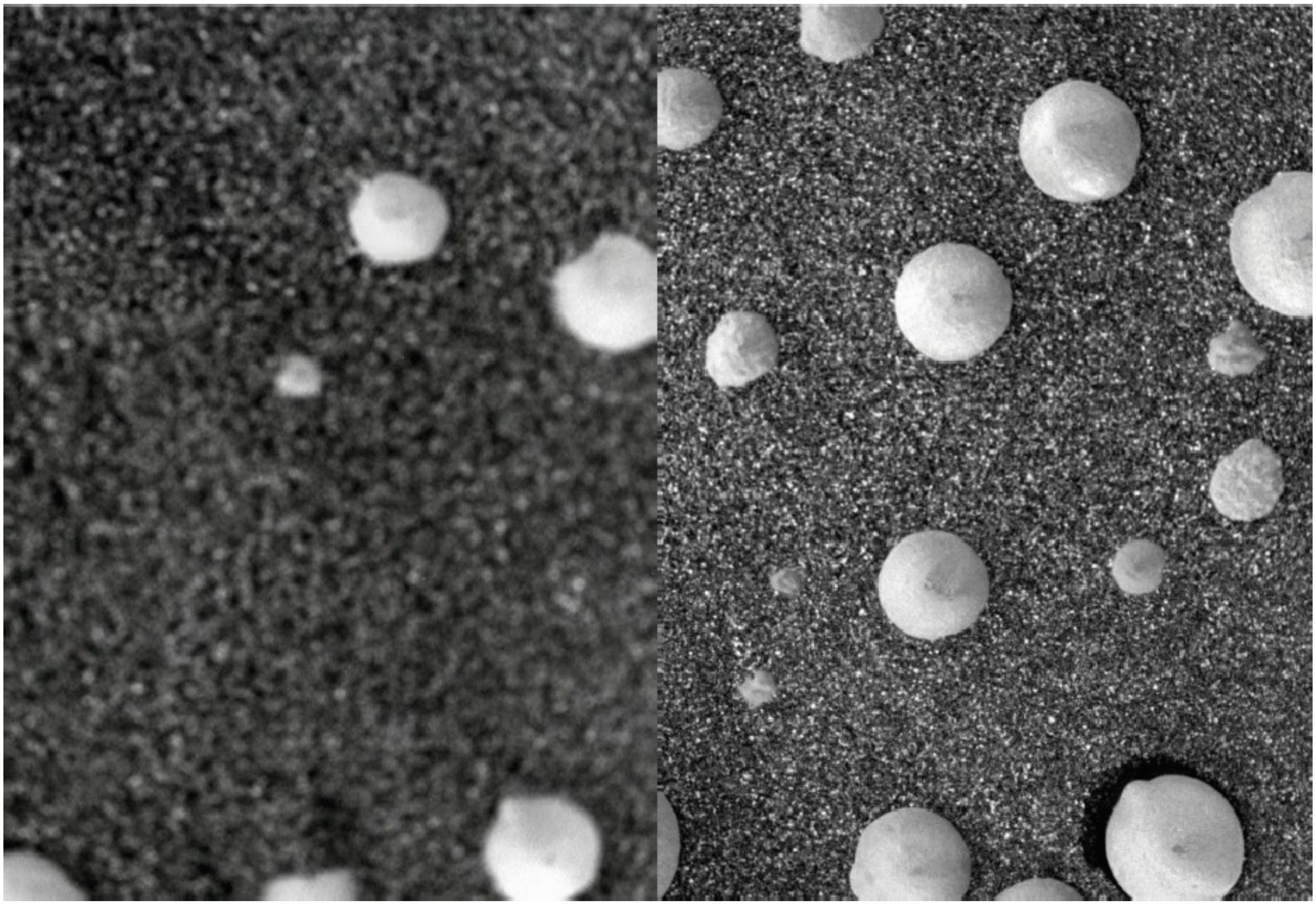

Figure 5. *Consensus Biologists/Geologists. Sol 1145-(left) and Sol 1148-(right). Photos taken three days apart showing Martian fungi growing out of the ground and sporing. A majority of Biologists and Geologists agree that these are Martian specimens are living organisms; i.e. "puff balls" (Basidiomycota).

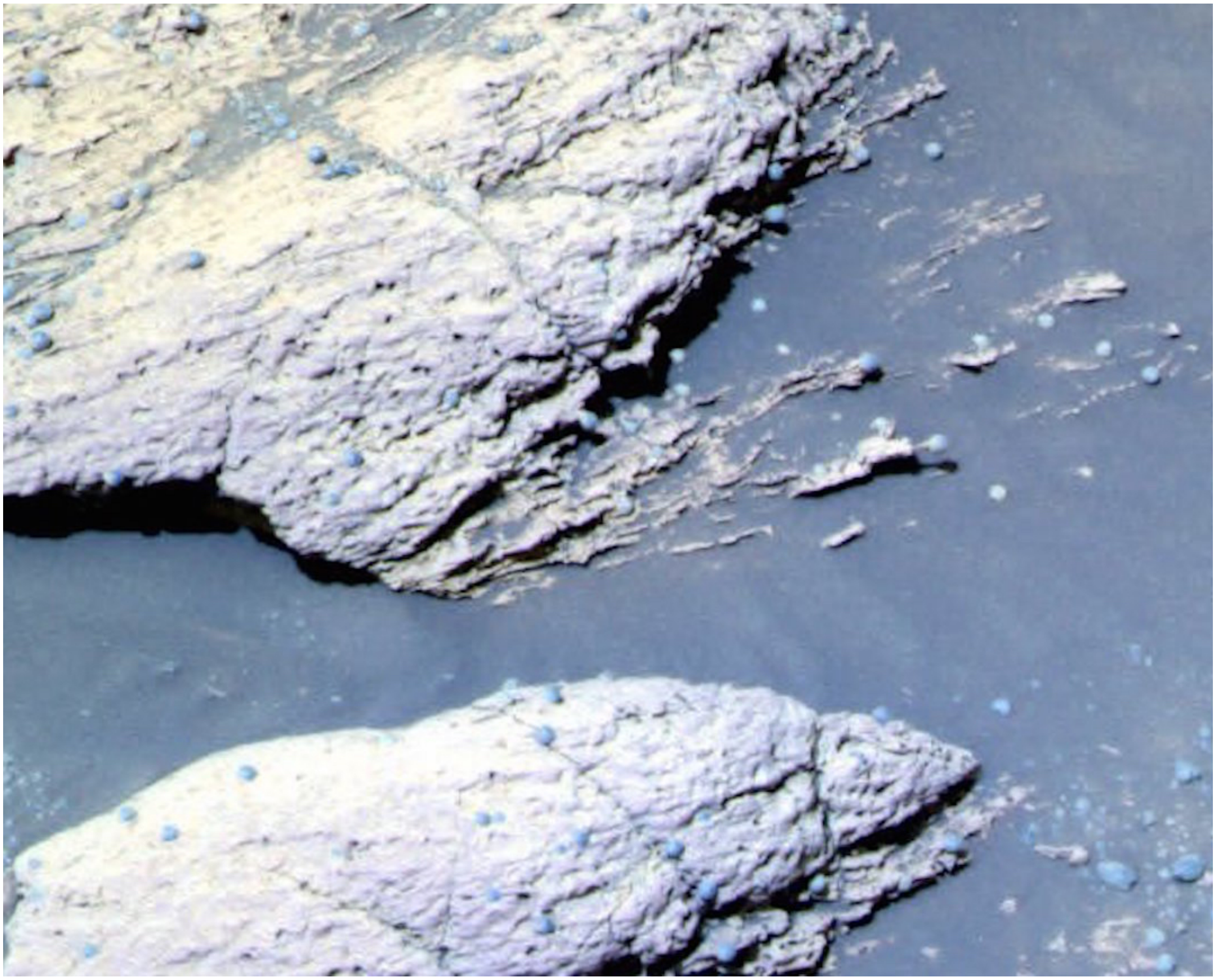

Figure 6. *Consensus Biologists/Geologists

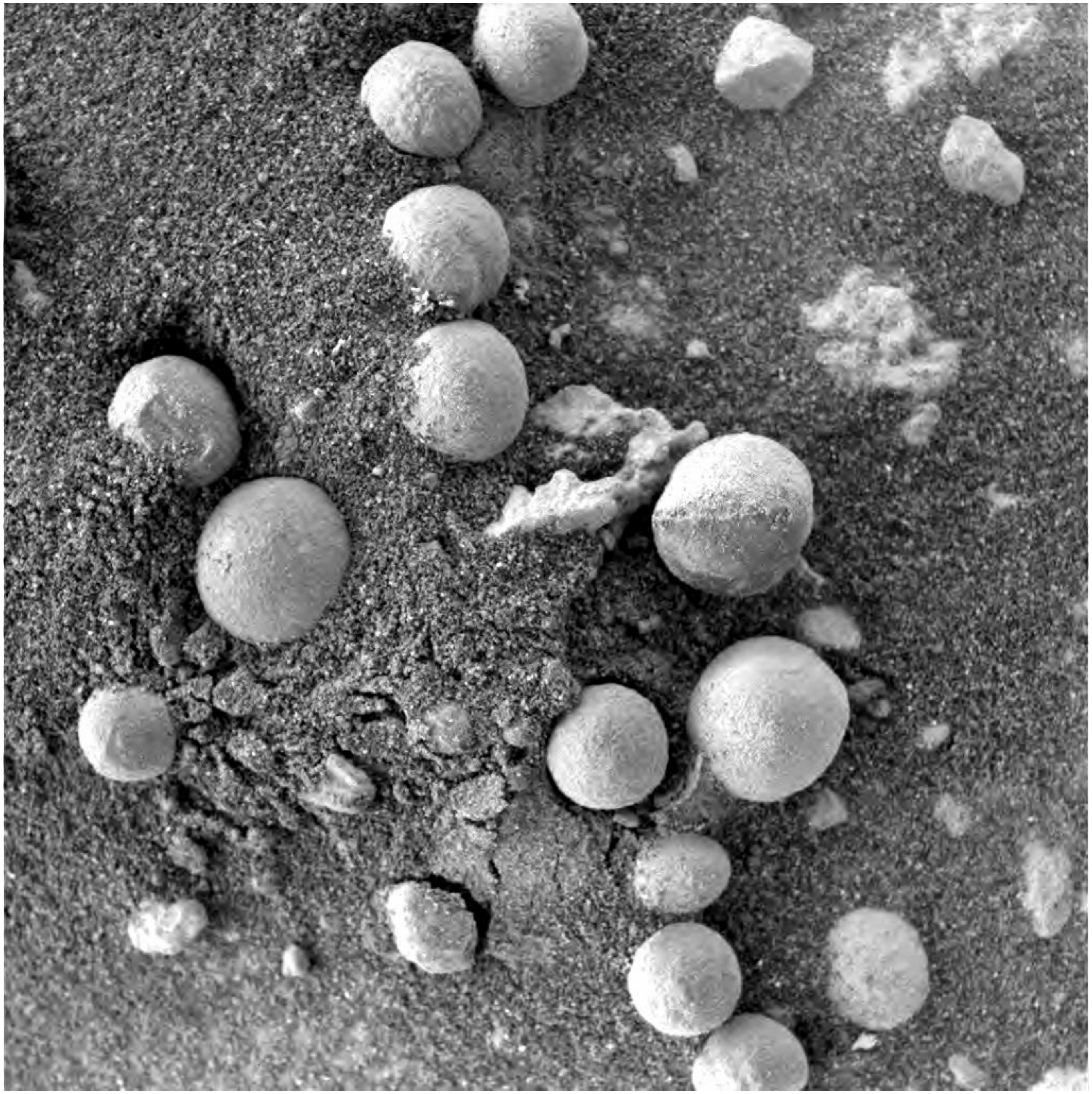

Figure 7. *Consensus Biologists/Geologists

III. Martian Fungi Contaminate the Mars Rovers Curiosity and Opportunity

A statistically significant consensus among biologists and geologists favoring life on Mars, has been established (Joseph 2016; Dass, 2017). These fungal life forms include "puff balls" "Basidiomycota" and were photographed growing and sporing on the Martian surface.

As fungi can colonize metal, plastics, etc. (Javaherdashti 2010; Little & Ray 2002), and have contaminated and damaged the exterior (as well as the interior) of the space stations

(Novikova et al. 2009, 20016, Vesper 2008), it was predicted that NASA's Mars Rovers should be contaminated with Martian fungi. This prediction was confirmed (Joseph 2017; Joseph & Rabb 2016). An examination of the following photos (Figures 8-14) taken by NASA of the rovers Curiosity and Opportunity, indicates that fungi have infiltrated the upper decks of both rovers.

FIGURES 8- 14

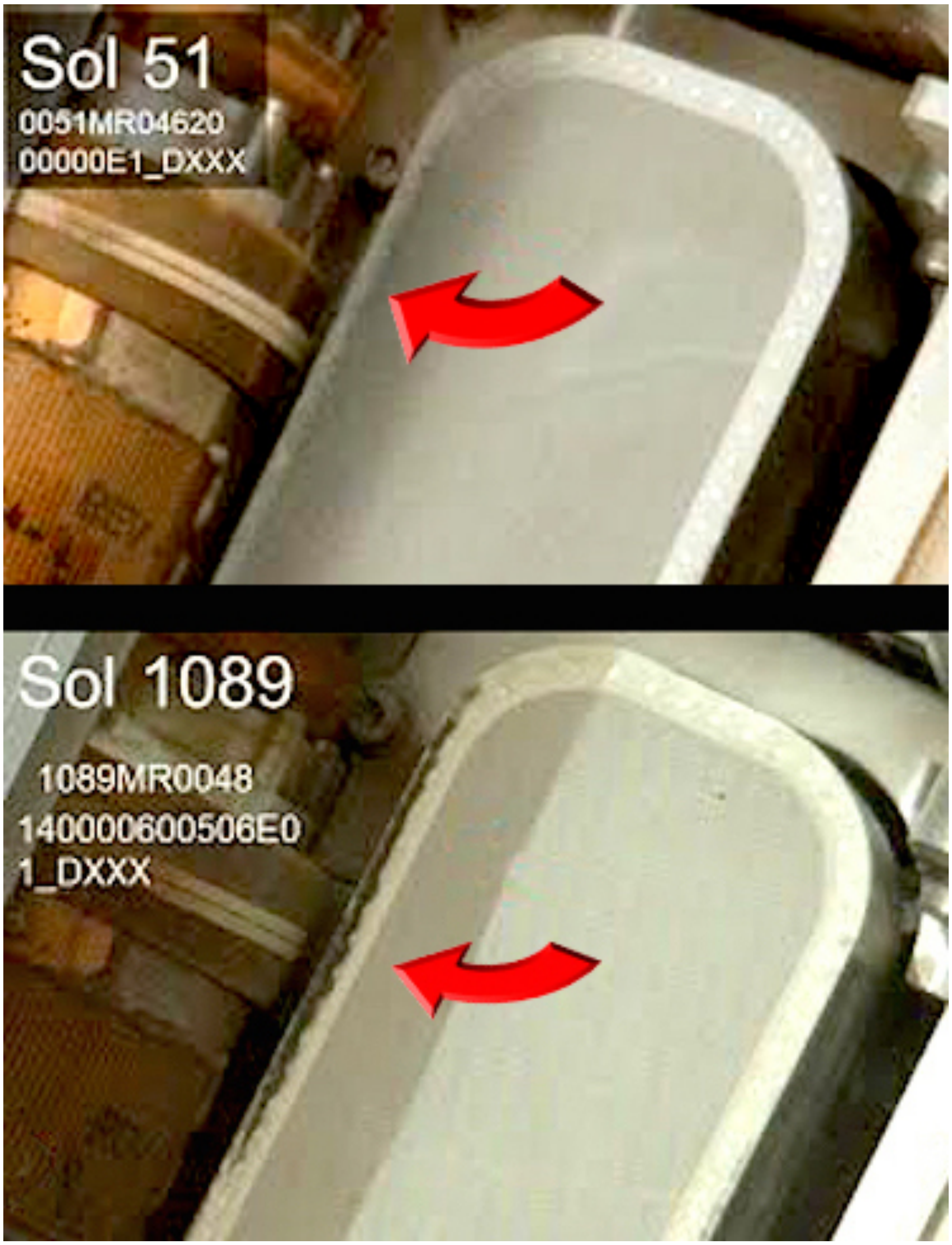

Figure 8: Mars Sol-51-(Before/Top) A portion of the Chem Cam deck of the Rover Curiosity. Photographed on Sol 51.(After/Below) Contamination of the Rover, Curiosity's Chem Cam deck, by Martian fungi 1038 Martian days later (Sol 1089).

Figure 9: A portion of the Chem Cam deck of the Rover Curiosity by Martian bacteria and Martian fungi (Sol 1089).

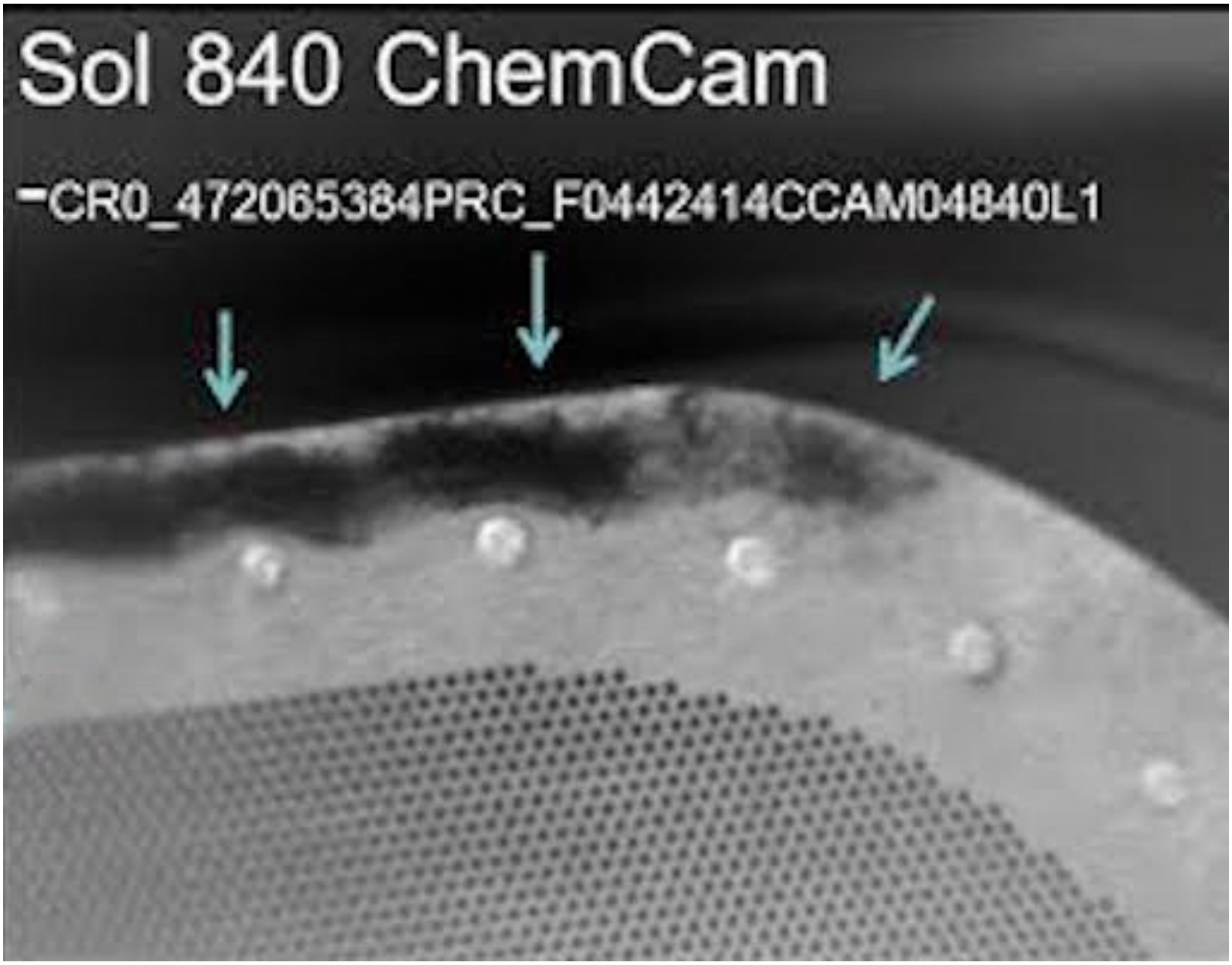

Figure 10: Mars Sol 840-Contamination of the Rover, Curiosity's Chem Cam deck, by Martian bacteria and fungi.

Figure 11: Mars Sol 1374--Contamination and bio-deterioration of the Rover, Curiosity's Chem Cam deck, by Martian bacteria and Martian mold/fungi.

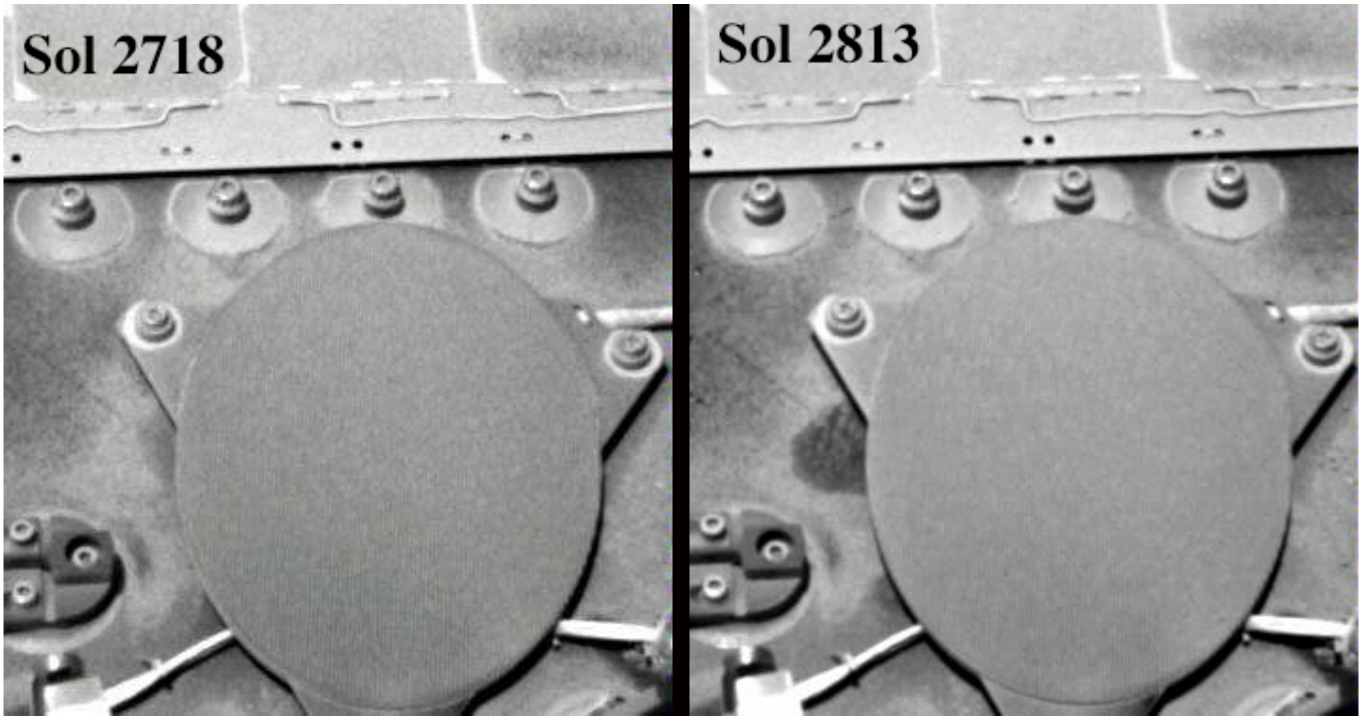

Figure 12: Mars Sol 2718 (left) vs Sol 2813 (right)--Growth of bacteria and fungi on the Rover, Opportunity, after 95 (Martian) days on Mars

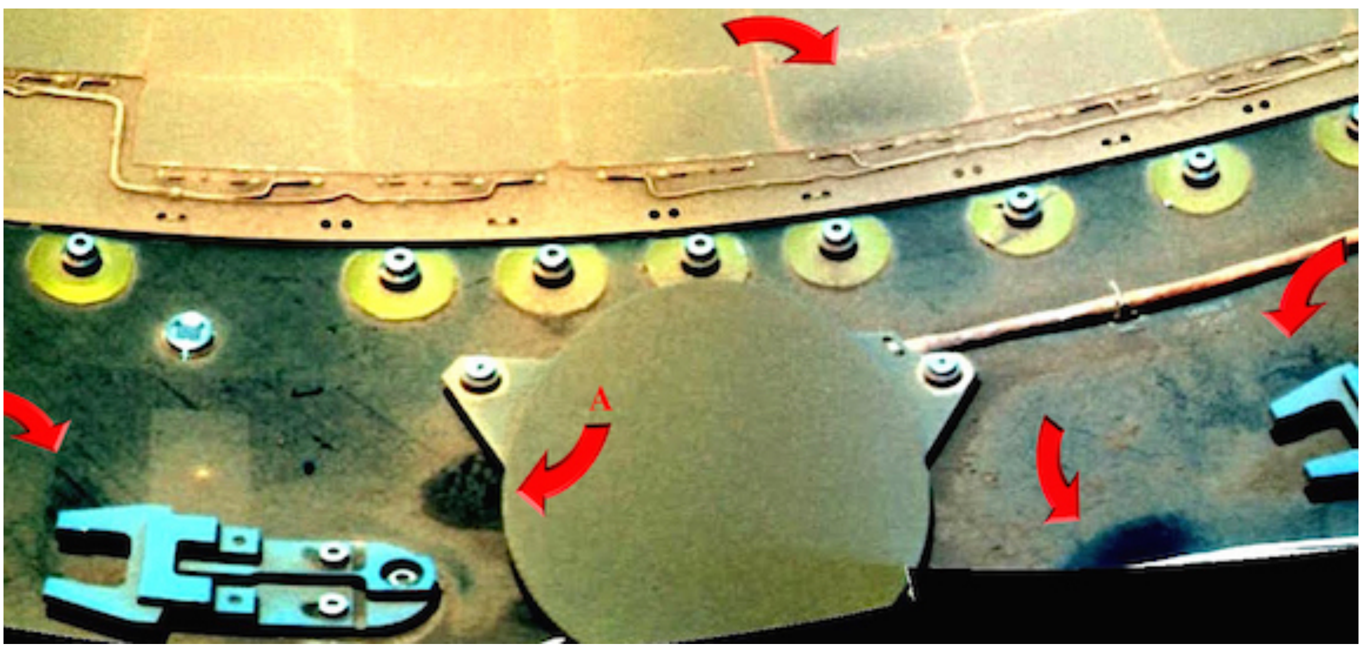

Figure 13: Mars Sol 2813--Contamination of the Rover, Opportunity, by Martian fungi.

Figure 14: Fungal/Bacterial contamination of the interior of the rover Curiosity's chem cam deck.

IV. Fungal Contamination and Biodeterioration of the Rover's Aluminum Wheels

Each of the rover Curiosity's six wheels were machined from a single, solid block of aluminum (see http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA20334). Aluminum can be severely damaged by fungal colonization (Javaherdashti 2010; Little & Ray 2002). An examination of photos taken of Curiosity's anterior wheel wells, indicates the presence of thick colonies of fungi (see Figures 15 to 21).

As detailed on the NASA website (see http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA20334) despite extensive, rigorous and brutal testing on Earth at nearly three times Mars gravity, once on Mars, and after driving just a few miles in less than 2 years, the Rover, Curiosity's aluminum wheels began to deteriorate, became brittle, and fissures and tears appeared. Some of these tears began to coalesce, with pieces breaking off, and forming large gashes and gaping holes (See Figures 15-21).

The deterioration of the tires accelerated as documented on April 18, 2016 (Sol 1,315) by NASA's engineers and rover project managers (see http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA20334) despite having been driving less than 10 miles in five years. NASA's engineers were dumbfounded, as it had been established these wheels could survive destructive touchdown scenarios as well as extensive driving over rough terrain consisting of hard pointed and spiked-shaped rocks, and suffering only scratches on the surface.

A close inspection of not just the interior of the wheel wells, but the tears, cracks, and holes, also reveals the presence of white fungal colonies (see Figures 15-21). Therefore, given the corrosive power of fungi, it can be predicted that the extensive and unexpected damage to the anterior wheels is largely a consequence of biodeterioration.

As can been seen in Figures 19, 20, the rover's wheels are caked with mud, and with masses of whitish substances growing within the wheel wells. On Earth, a single handful of mud or wet sand contains over 10,000 organisms and billions of bacteria and viruses.

In 1976-1977, the Mars Viking life detection instrument, known as the Labeled Release Experiment, yielded positive results and thus evidence of biological activity including evidence that Martian microbes were rapidly multiplying (Levin 1976, 1977; Levin & Straat, 1976). In 1996 and therafter David McKay and his team published evidence of fossilized biological residue in 3 meteors from Mars--Sherotty, Nakhla, and ALH 84001 (e.g., McKay et al. 1996, 1997; Thomas-Keprta et al. 2009).

Therefore, in addition to fungi (Dass, 2017, Joseph 2016, 2017, Joseph & Rabb, 2016), the biological evidence presented by Levin and McKay and his team, indicates that microbes have been living and multiplying on Mars for billions of years continuing into the present. Martian mud and sand, therefore, likely contain numerous microorganisms, including fungi, all of which have contributed to the significant and profound deterioration of the rover curiosity's aluminum wheels as depicted in the following photos (Figures 15-21) photographed by NASA.

FIGURES 15- 21

Figure 15. Biological corrosion of Rover Curiosity Wheels


Figure 16. Fungi/bacteria: Biological corrosion of Rover Curiosity Wheels

Figure 17. Fungi/bacteria: Biological corrosion of Rover Curiosity Wheels

Figure 18: White fungal contamination and severe bio-deterioration and damage to the Rover Curiosity's Aluminum wheels despite having been driven less than 10 miles across the surface of the red planet and mostly sitting idle for five years.

Figure 19: White fungi surrounding a huge hole with a metal flap protruding within the interior of the wheel well; and more holes, tears as well as mud and specks of white material on the exterior of the wheel.

Figure 20: Small tears, holes and mud on the outside of the wheel well, and within the interior, white substances which are either ice or fungi. On Earth, a single handful of mud may contain over 10,000 organisms and billions of bacteria and viruses which accompany bacteria on a ratio of 10 to 100 per bacterial cell.

Figure 21: Colonies and clumps of Martian fungi and bacteria within the rover Curiosity's wheel wells

V. Mars, Methane, Methanogenesis and the Waxing and Waning of Vast Fields of Martian Fungi

Martian atmospheric methane levels varies over time and is punctuated by transient and major spikes in concentration, followed by declines, only to increase again (Mumma et al. 2004, 2009; Hand, 2009, Webster et al. 2015). For example, in July of 2013, "an upper limit of 2.7 parts per billion of methane" in the general vicinity of the Gale Crater was reported whereas on September of 2013, methane levels significantly declined, fluctuating between a value of 0.18 ppbv to 1.3 ppbv (Webster et al. 2013). This was followed by a "tenfold spike" in levels of methane in the Martian atmosphere with increases in late 2013 and early 2014, averaging "7 parts of methane per billion in the atmosphere" (Webster et al. 2014).

On Earth, methane is primarily produced via microbial methanogenesis; a form of anaerobic respiration. Fungi (Lenhart et al. 2012; Liu et al 2015; Mukhin & Voronin, 2007) and other eukaryotes (Bruhn et al. 2012; Kepler et al. 2006; Liu et al 2015) produce methane usually via interactions with methanogenic archaea. However, Saprotrophic fungi produce methane independently of archaea; and production increases in response to increased levels of carbon dioxide and is inhibited by the presence of oxygen (Lenhart et al. 2012); a finding which is true for most methane producing species. Therefore, Mars is an ideal habitat for the growth of methanogens as the atmosphere is 96% carbon dioxide, there are negligible levels of free oxygen (Mahaffy, et al. 2013), and the electron acceptor in methanogenesis is carbon and carbon dioxide.

One likely source of Martian methane are the various species of fungi already identified on the Red Planet (Joseph 2016, Dass, 2017).

However, as documented in Figures 22-27, vast fields of what appears to be fungi and vast *forests* and *trees* of fungal mycelia, have also been photographed on Mars from space by NASA and the European Space Agency. Moreover, these forests and trees wax and wane in size, growing quite large only to dramatically decrease in size until they nearly disappear, observation which indicate growth followed by death and decay.

It is well established that fungi play a major role in the biodegradation of organic tissue, and thus the release of methane (Mukhin & Voronin, 2007). On Earth fungi provide methane to archae and other organisms, via vast branching fungal mycorrhizal mycelium. Likewise, close inspection of Figures 22-27 reveals the presence of what appears to be vast fields of fungal mycorrhizal mycelium.

Therefore, it appears that the waxing and waning of Martian atmospheric methane may be directly related to the growth and death of Martian fungi and other organisms as evidence in Figures 22-27.

FIGURES 22-27

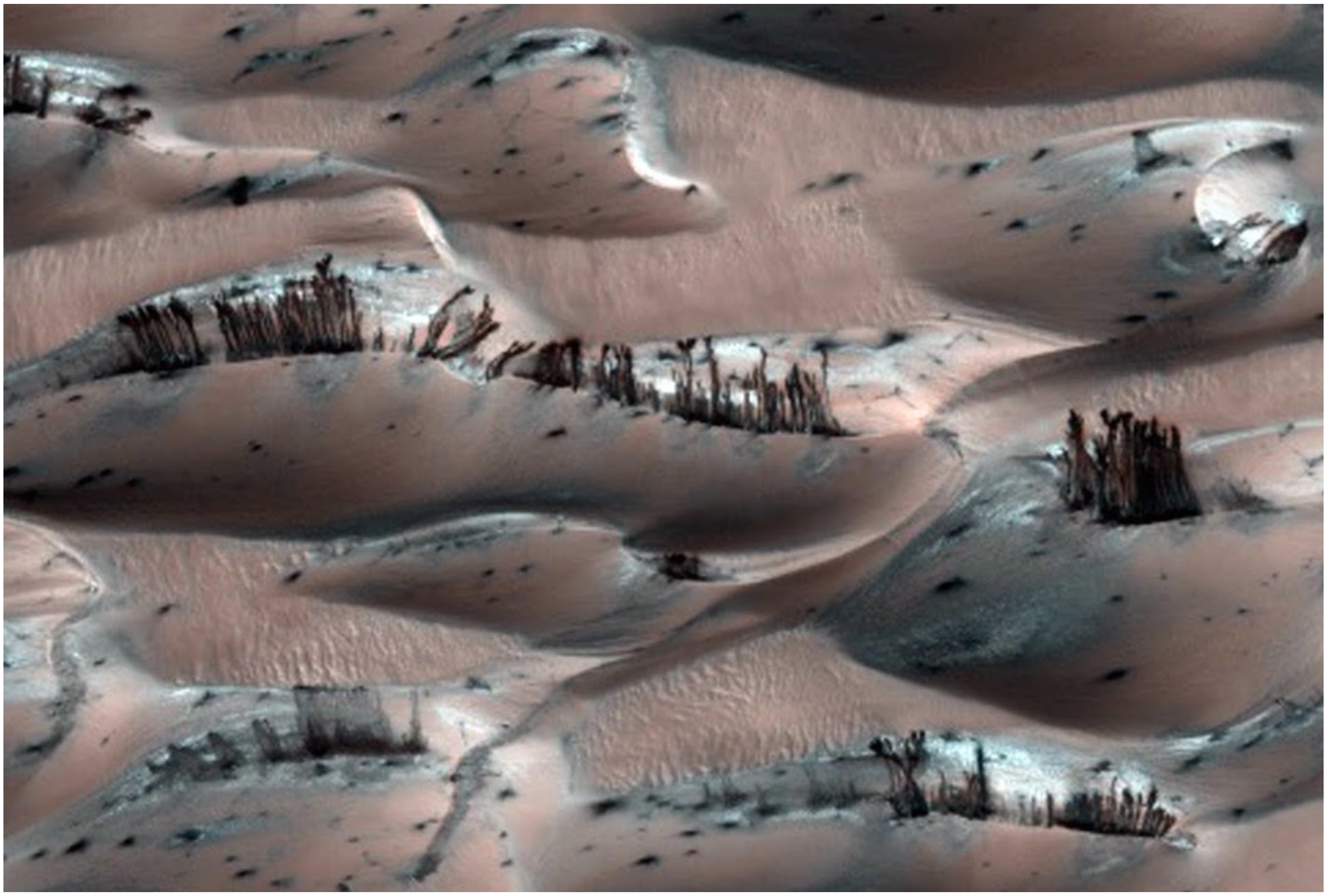

Figure 22: Mars ESP_007962_2635: Photo of Mars from space. River beds and bacterial/fungal growth.

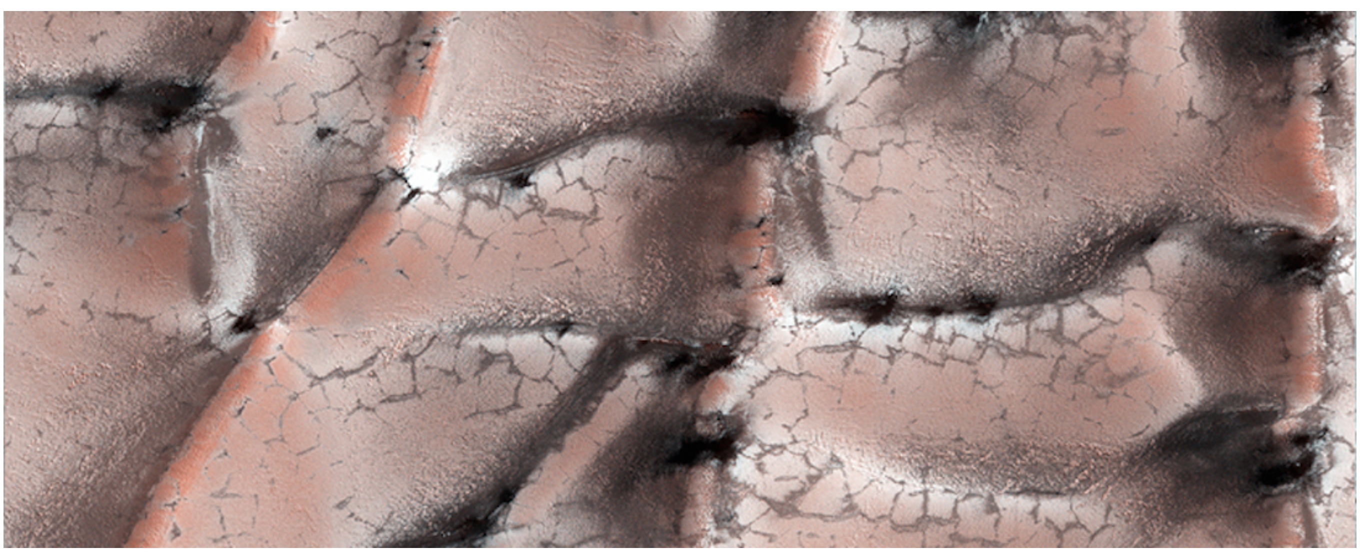

Figure 23: Mars ESP_033698_2605: Photo of Mars from space. Waning of bacterial/fungal growth.

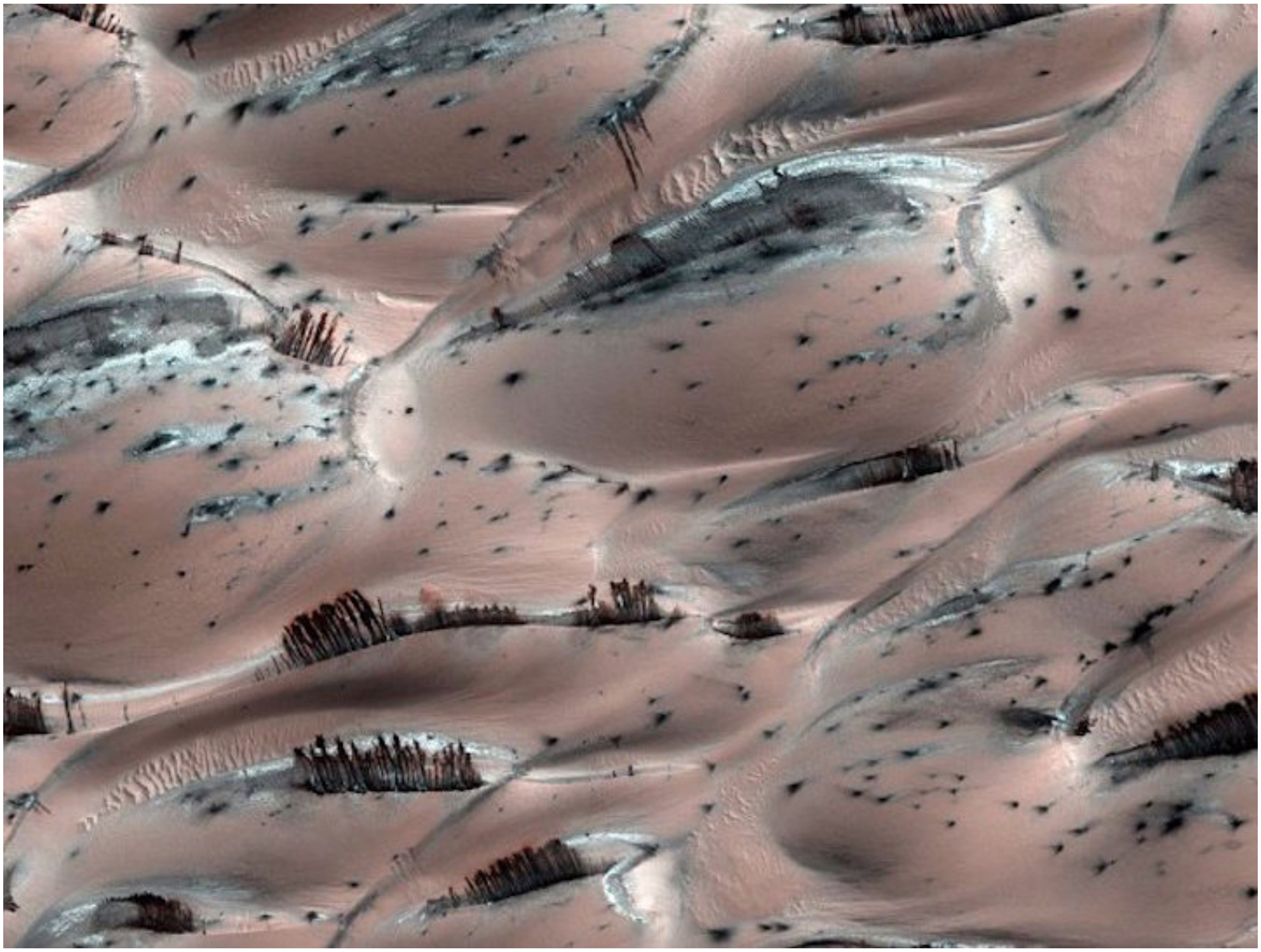

Figure 24. Photo of Mars from space. Waxing of growth.

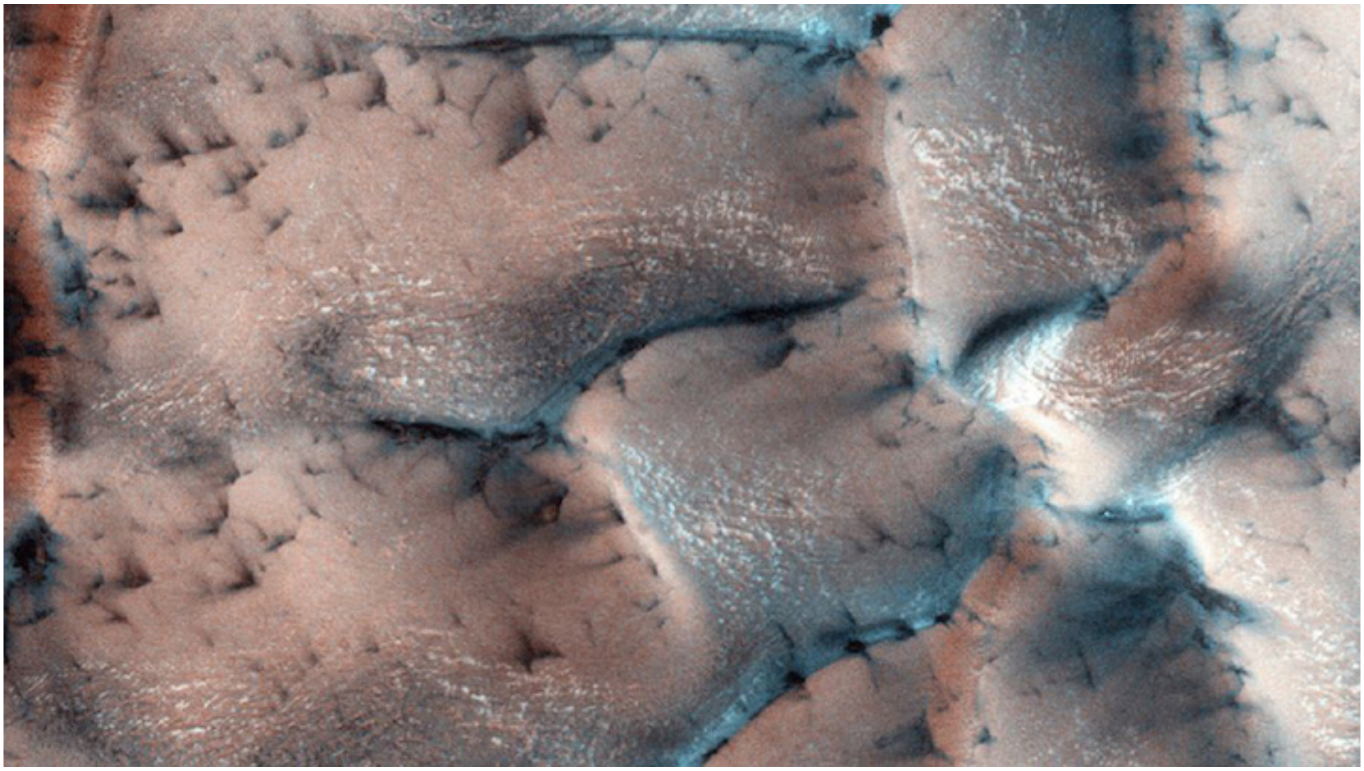

Figure 25. Photo of Mars from space. Waning of growth.

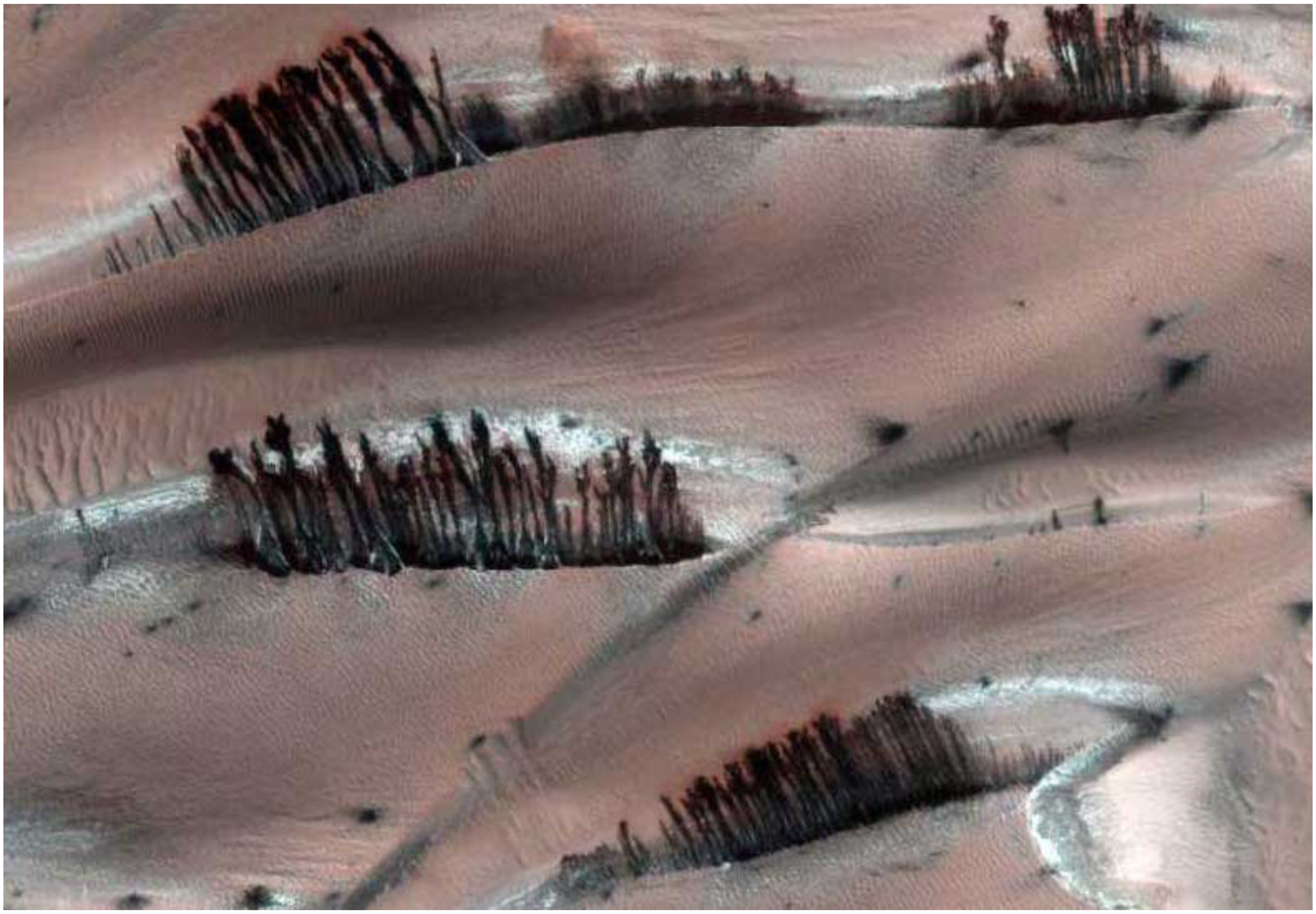

Figure 26. Photo of Mars from space. Waxing of growth.

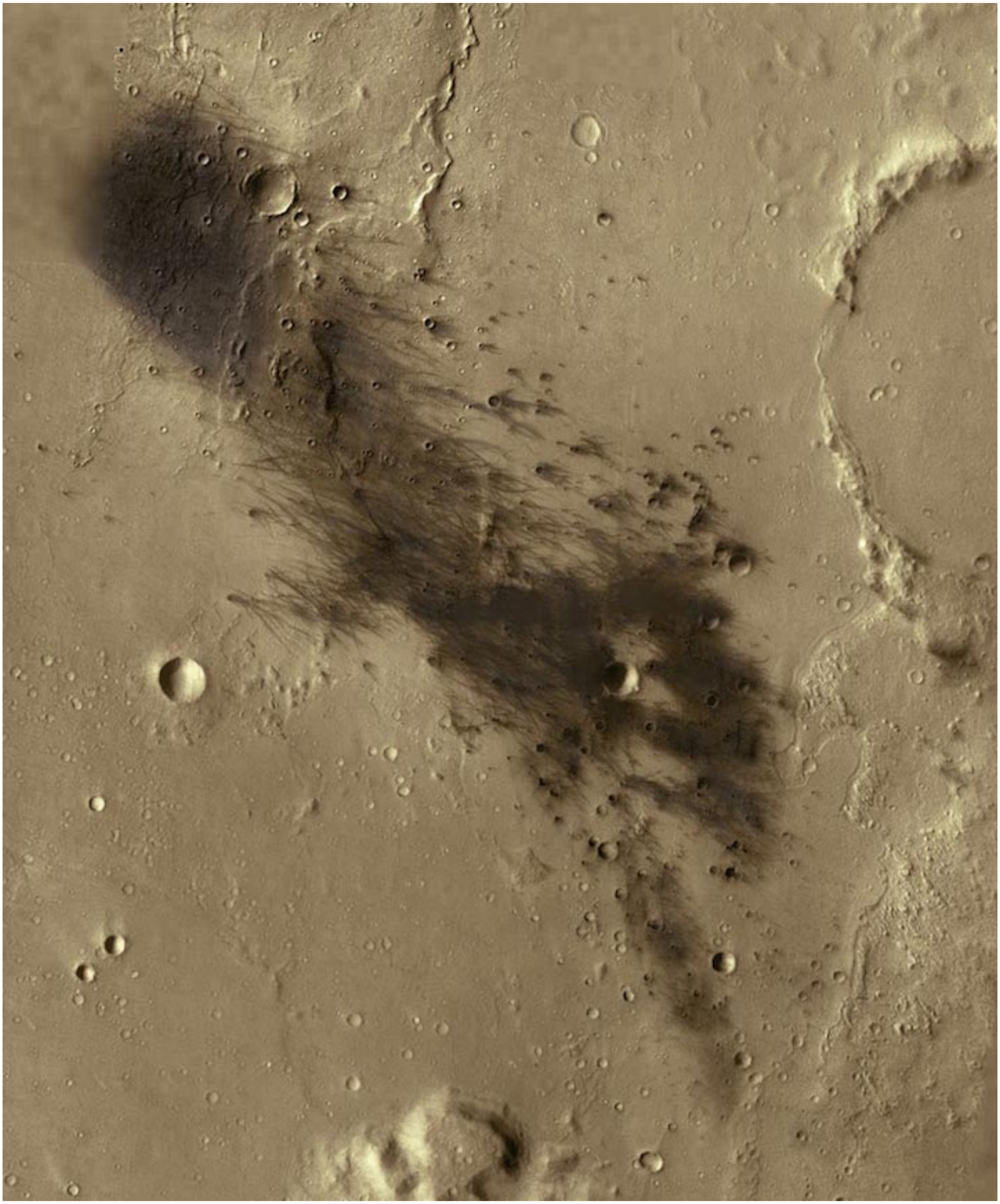

Figure 27: Mars Gusev Crater (ESA).

VI. DISCUSSION

There is also evidence, as based on detailed analyses of Martian meteors (McKay et al. 1996, 1998; Thomas-Keprta et al. 2002, 2009) and fossilized surface features (Rizzo & Cantasano 2009, 2011; Rizzo et al. 2015), that billions of years ago, (1) this watery world was also home to Martian microbes, including, possibly (2) cyanobacteria (blue-green algae) which may have constructed stomatolites on ancient shores. Although the Martian oceans long ago disappeared Mars has remained a living planet, as there is evidence of: (3) Martian microbial reproduction as based on the results from the Viking life detection studies (Levin 1976, 2010; Levin & Straat 1977); (4) waxing and waning of atmospheric methane (Mumma et al. 2004, 2009; Webster et al. 2015) whose most plausible source is living organisms.

In 2016, seventy experts in biology and geology formed a statistically significant consensus and identified the presence of fungi growing on the surface of Mars. Mushrooms, puffballs, and amorphous species which prefers to grow beneath the shelter of rocks were identified (Joseph 2016; Dass 2017). These latter species also resemble those growing in the shelter of the rover chem-cam deck (Figure 28) and those growing within the aluminum wheel wells of the rover Curiosity; the latter of which have suffered profound damage despite having been driven less than 10 miles in five years.

Figure 28: (Left) Fungal/Bacterial contamination of the interior of the rover Curiosity's chem cam deck. (Right) A majority of Biologists and Geologists agree that these Martian specimens have

a high probability of life and are most probably fungi.

Given evidence of past and present biological activity on Mars (Levin 1976, 1977, Levin & Straat, 1976; Mckay et al 1996, 1997; Thomas-Keprta et al. 2009), and the consensus of experts that fungi are growing on the Martian surface (Joseph 2016), it thus appears that fungi and a variety of microorganisms, have successfully colonized Mars.

REFERENCES

Bruhn, D., et al. (2012). Terrestrial plant methane production and emission. Physiol. Plant 144, 201-209.

Carlile, M. J., Watkinson, S. C., and Gooday G. W. (2001). The Fungi, 2nd edition, Academic Press.

Cook, R. (2000). Fungi on the outside of the Mir Space Station. Boston Globe, 10/1/2000.

Dadachova E., Bryan RA, Huang X, Moadel T, Schweitzer AD, Aisen P, **et al**. (2007). Ionizing Radiation Changes the Electronic Properties of Melanin PLoS One, doi:10.1371/journal.pone. 0000457.

Dass, R. S. (2017). The High Probability of Life on Mars: A Brief Review of the Evidence, Cosmology, Vol 27, April 15, 2017

Ettwig, K. F. et al. (2010) Nitrite-driven anaerobic methaneoxidation by oxygenic bacteria. Nature 464, 543-548.

Fisher, R. A. (1922). "On the interpretation of χ^2 from contingency tables, and the calculation of P." Journal of the Royal Statistical Society. **85** (1): 87–94.

Gostincar, C., Grube, M., de Hoog, S., Zalar, P., and Cimerman, N. G. (2010). Extremotolerance in fungi evolution on the edge. FEMS Microbiology Ecology, 71: 2-11.

Hand, E. (2008). Plumes of methane identified on Mars. Nature News. 10/21/08.

Javaherdashti, R. (2010), Microbiologically Influenced Corrosion, Springer.

Joseph, R. (2016). A High Probability of Life on Mars: Biologists' Top Five Candidates For Martian Life, Cosmology, 25, 1-25.

Joseph, R. (2017a). Martian Organisms Attack, Damage Curiosity's Rover Wheels After Only 10 Miles. Cosmology, Vol 27, 3/25/17.

Joseph, R. (2017b). Mars, Methane, Methanogenesis: Evidence of Life and Death on the Red Planet, Cosmology, Vol 27, 3/31/17.

Joseph, R., & Rabb, H. (2016). Martian Fungi & Bacteria Damaged the Mars Rovers. Cosmology, Vol 26, December 2016.

Keppler, F., et al., (2006). Methane emissions from terrestrial plants under aerobic conditions. Nature 439, 187-191 (2006).

Larntz, K.(1978). "Small-sample comparisons of exact levels for chi-squared goodness-of-fit statistics". *Journal of the American Statistical Association*. **73** (362): 253–263.

Lau, M.C.Y. et al. (2015). An active atmospheric methane sink in high Arctic mineral cryosols. The ISME Journal, DOI:10.1038/ismej.2015.13

Lenhart K. et al. (2012). Evidence for methane production by saprotrophic fungi. Nat Commun. 2012;3:1046. doi: 10.1038/ncomms2049.

Levin, G. (1976a), The Viking Biological Investigation: Preliminary Results, Science, 194, 4260, 99-105.

Levin, G. (1976b), Viking Labeled Release Biology Experiment: Interim Results, Science, 194, 1322-1329.

Levin, G. V. and Straat, P. A. (1977). Life on Mars? The viking labeled release experiment, Biosystems 9 :2-3, pp. 165-174.

Little, B., Ray, R. (2002). The Role of Fungi in Microbiologically Influenced Corrosion, Naval Research Laboratory, Stennis Space Center, MS 39529

Malin, M. C., and Edgett, K. S., 1999. *Oceans or Seas in the Martian Northern Lowlands: High Resolution Imaging Tests of Proposed Coastlines*, Geophys. Res. Letters, V. 26, No. 19, p. 3049—3052

McKay, D.S., Gibson, E.K., Thomas-Keprta, K.L., Hojatollah, V., Romanek, C.S., Clemmett, S.J., Chillier, X.D.F., Maechling, C.R., and Zare, R.N. (1996). Search for past life on Mars: possible relic biogenic activity in Martian meteorite ALH84001. Science 273: 924-930.

McKay, D.S., Thomas-Keprta, K.L., Clemett, S.J., Gibson Jr, E.K., Spencer, L. and Wentworth, S.J. (2009). "Life on Mars: new evidence from martian meteorites." Instruments and Methods for Astrobiology and Planetary Missions, 7441, 744102.

Mukhin, V. & Voronin, P. (2007) Methane emission during wood fungal decomposition. Doklady Biol. Sci. 413, 159-160.

Mumma, M.J., Villanueva, G.L., Novak, R.E., Hewagama, T., Bonev, B.P., DiSanti, M.A., Mandell, A.M., and Smith, M.D. (2009). Strong release of methane on Mars in northern summer 2003. Science. doi:10.1126/science.11,65,243.

Novikova, N (2009) Mirobiological research onboard the ISS, Planetary Protection. The Microbiological Factor of Space Flight. Institute for Biomedical Problems, Moscow, Russia.

Novikova, N et al. (2016). Long-term spaceflight and microbiological safety issues. Space Journal, https://room.eu.com/article/long-term-spaceflight-and-microbiological-safety-issues.

Perron, J. Taylor; Jerry X. Mitrovica; Michael Manga; Isamu Matsuyama & Mark A. Richards (2007). Evidence for an ancient martian ocean in the topography of deformed shorelines *Nature*. **447**: 840–843

Schild, R. & Levine, L. (2010). The Human Mission to Mars. Colonizing the Red Planet. Edited by Schild, R. & Levine, L.. Cosmology Science Publishers.

Thomas-Keprta K.L., Clemett S.J., Bazylinski D.A., Kirschvink J.L., McKay D.S., Wentworth S.J., Vali H., and Gibson E.K., Romanek C.S. (2002) "Magnetofossils from Ancient Mars: A Robust Biosignature in the Martian Meteorite ALH84001." Applied and Environmental Microbiology 68, 3663-3672.

Vesper, S.J., W. Wong, C.M. Kuo and D.L. Pierson. (2008). Mold species in dust from the International Space Station identified and quantified by mold-specific quantitative PCR. Research in Microbiology. 159: 432-435.

Villanueva, G.; Mumma, M.; Novak, R.; Käufl, H.; Hartogh, P.; Encrenaz, T.; Tokunaga, A.; Khayat, A.; Smith, M. (2015). "Strong water isotopic anomalies in the martian atmosphere: Probing current and ancient reservoirs". *Science*. **348**: 218–21.

Webster, G. et al. (2014). "NASA Rover Finds Active and Ancient Organic Chemistry on Mars." NASA.

Webster, C. R. et al. (2015). Mars methane detection and variability at Gale crater, Science, 347, 415-417.

This paper was rejected by the Journal of Cosmology because we could not independently verify the data sources to be sure they are correct and properly interpreted, and are awaiting a revised version of the paper from Dr. Joseph with these corrections. If the paper turns out to be publishable, it is a blockbuster, since it clearly establishes what many others such as Levin et al. have claimed about life on Mars, and what Chandra Wickramasinghe and Fred Hoyle have claimed about how life is transferred within proto-globular-clusters of the numerous proto-galaxies produced by the big bang. CHG