Lichens on Mars vs the Hematite Hoax. Why Life Flourishes on the Radiation-Iron-Rich Red Planet.

Article · June 2021

1 author:

Rhawn Gabriel Joseph
Cosmology.com

Lichens on Mars vs the Hematite Hoax.

Why Life Flourishes on the Radiation- Iron-Rich Red Planet.

(Fungus, Melanin, Calcium Oxalate, Photosynthesis)

Rhawn Gabriel Joseph*
Cosmology.com

Abstract

There is life on Mars as documented with 100 comparative photos. This evidence includes pigmented/melanized fungi and lichens, fungi shedding crustose and secreting calcium oxalate, fungi preparing to spore, spores on the surface sprouting embryonic mushrooms, fungus growing out of the ground, lichens with hollow stalks, vast colonies of lichens attached to rocks and oriented skyward similar to photosynthesizing lichens on Earth, and documentation that the claims of spherical hematite are a hoax--a byproduct of religious extremism at NASA--which is why the hematite claims were immediately rejected as inappropriate and implausible by a number of investigators who proposed instead they are tektites and accretionary lapilli produced by meteor impact and volcano. Be they on the surface or attached to Martian rocks they have no resemblance to terrestrial hematite. The "spheres" of Mars are uniform in shape and size (1mm or 3mm to 6 mm) and all were initially described as "yellow" "orange" "purple" and "blue" the pigmented colors of photosynthesizing organisms. Terrestrial hematite "spheres" are colored red to dark red, consist of less than 2% hematite which form a thin layer on the surface and have a wide variety of sizes and shapes and are infiltrated by fungi and lichens. A review of the Opportunity teams' methodology and instrumentation reveals that data was contaminated and confounded by numerous uncontrolled variables including problems with instrument calibrations and they relied on inference, speculation, data manipulation, and spectra from panoramic images that were selectively eliminated in a failed attempt to make it conform to laboratory samples. The iron-rich radiation-intense Red Planet provides an ideal environment for fungus and lichens to flourish and promotes growth and sporing and production of melanin which protects against while simultaneously utilizing radiation for metabolic energy. Algae secrete calcium and lichens and fungi produce calcium oxalate that "weathers" and dissolves minerals and metals which are utilized as nutrients and are stored on cellular surfaces. Terrestrial species are iron-rich and precipitate hematite which makes these fungi and lichens ideal bioindicators of metal and minerals; whereas on Mars they are likely supersaturated with these and other minerals and metals as reflected by spectral data. Fungi and lichens secrete calcium oxalate which coats and surrounds mycelium, but upon exposure to dry surface conditions forms waves of calcium "cement" that may cement these organisms to layers of calcium oxalate fossilizing and making them "harder than rock." Yet others grow out of the ground and are obviously alive. Given evidence documenting biological residue in Martian meteorites, biological activity in soil samples, seasonal increases in methane and oxygen which parallel biological fluctuations on Earth, and pictorial and quantitative morphological evidence of stromatolites fossilized tube worms and metazoans, growth of mushrooms and fungi, and vast colonies of rock-dwelling lichens, it is concluded that the evidence is obvious: There is life on Mars.

Key Words: Hematite Hoax, Tektites, Accretionary Lapilli, Calcium Oxalate, Lichens, Martian Mushrooms, Puffballs, Volcanos on Mars, Meteor Impact, Hematite spheres, Whewellite

*RhawnJoseph@gmail.com

I. INTRODUCTION: LICHENS, FUNGUS, METEORS, VOLCANOES, HEMATITE

1. Spheres of Mars: Lichens/Fungus vs Hematite, Meteor Impact, Mineral Precipitation, Volcano

Vast "colonies" of spherical formations have been photographed by the rover Opportunity upon the surface of Mars in the cratered planes of Meridiani Planum. What they are has been subject to great debate. Depending on locale, those on the surface range from less than 1mm to 3mm to 6mm in diameter (see Figures). Those attached to rocks and sandstone have appendages resembling "stems" topped with bulbous caps (see Figures). A number of investigators have argued that surfacing hugging spherical specimens are fungal puffballs and those attached to rocks are identical to colonies of lichens (Dass, 2017; Joseph 2006, 2014a, 2016; Joseph et al. 2019, 2020a,b; 2021; Rabb, 2018; Small 2015). Other investigators favor mineralized hydrated crystals fashioned as a consequence of bolide impact (Knauth et al. 2005; DiGregorio 2004; Royer et al. 2008), or the accretion of lapilli produced following volcanic eruption (DiGregorio 2004). Then there is the "hematite hoax."

2. Hypothetical Hematite:

NASA (2009) and the Mars Opportunity rover team have claimed the spheres are hematite (Christensen et al. 2004; Klingelhöfer et al. 2004; Soderblom et al. 2004; Squyres et al. 2004). Hematite is a mineralized iron oxide which, over thousands or tens of millions of years, slowly forms in hot springs (Anthony et al. 2005; Morel 2013), as well as in volcanoes when temperatures rise above 950 C (1740 F). NASA (2009) and the Mars rover Opportunity team, therefore, have hypothesized that Martian hematite may have been created in boiling hot springs and hydrothermal vents millions or even billions of years ago. However, there is no evidence to support this hypothetical hot springs/thermal vents scenario. Nor is there evidence of volcanic activity.

In an attempt to explain away the fact that the environment of Meridiani Planum has never been conducive to the creation of hematite, it has been claimed that under "dry laboratory conditions" "goethite" can be "converted to hematite" at 300°C (Christensen and Ruff, 2004). Mars, however, is not a laboratory, equatorial temperatures, as reported by NASA, seldom exceed 20°C. The last time surface temperatures may have reached or exceeded 300°C may have been when Eagle Crater was struck by a meteor at some unknown date in the past, or 3.8 billions of years ago during the heavy bombardment phase of planetary development.

In the absence of any direct evidence, those favoring the hematite hypothesis have based their arguments on false colors painted on panoramic images, the averaging of temperatures from those panoramas--despite the fact that the temperature gauges were not working-- or data manipulation and the selective removal of panoramic spectra in an attempt to make it resemble laboratory samples (Christensen et al. 2004; Klingelhöfer et al. 2004; Soderblom et al. 2004).

The problems with these Martian-hematite claims and scenarios are legion (Burt et al. 2005; DiGregorio 2004; Joseph 2006, 2008; Joseph et al. 2019, 20201a,b; Knauth et al. 2005). For example, the Opportunity team did not have the instrumentation capable of selectively examining the spheres for hematite. Moreover, unlike terrestrial hematite which is red or dark-red (Anthony et al. 2005), the Martian spheres were initially described as "yellow" "orange" and "purple" (Soderblom et al. 2004) and "blue" (NASA 2009). The only terrestrial analogs for "yellow" "orange" "purple" and "blue" spheres are pigmented and melanized lichens, algae, plants and mushrooms (Joseph et al. 2019, 2020,a,b,c).

An examination of supposed terrestrial analogs indicates there is little resemblance to the spheres of Mars. Depending on locations, the surface-spheres of Mars are uniform in size (1 mm, or 3mm to 6 mm) and spherical appearance (Knauth et al. 2005; Lin 2016). As a candidate for terrestrial analogs Chan et al. (2004) has proposed the "moqui marbles" ("hematite spheres") of Utah; which in fact differ dramatically from one another (Figures 8,9,13, 23, 25, etc), ranging in size from 1mm to 203 mm or more (Anthony et al. 2005; Chan and Parry 2002; Knauth et al. 2005) and have a wide range of shapes including what is best described as sharp pointed and jagged, and amorphous/nebulous, spherical-round ("female"), and those with numerous grooves and a Saturn-shaped spinning-top central bulge ("male"). By contrast the surface spheres of Mars have a distribution resembling vast colonies covering dozens to hundreds of meters and with a uniform shape, whereas the only analogs for those attached to rocks are photosynthesizing lichens (Joseph et al. 2019, 2020,a,b)

Furthermore, the hematite composition of the "hematite spheres" of Earth, is less than 2% and forms only a thin veneer upon the surface (Anthony et al. 2005; Chan & Parry 2002), with the remainder often consisting of sandstone infiltrated with fungi and lichens which provide the "cement" which binds these concretions together (Ayupova et al 2016; Claeys 2006; Owocki et al. 2016l Rajendrana et al. 2017). In addition, the outer surface of these terrestrial concretions are sometimes colonized by lichens.

The spheres of Mars were initially described as "purple" "orange" and "yellow" (Soderblom et al. 2004) as well as "blue" (NASA 2009) and in some photos also appear light-blue and blueish-green (Joseph et al. 2020a)--colors associated with melanized pigments and life. As to "blue berries" the only analogs are found on Earth: living organisms. The Opportunity team later ceased to mention these colors and instead described the spheres as pale white, the only analog examples of which are the spheres of Mars. Because living analogs are not acceptable to NASA (2009), its administrators present us with a tautology: the white spheres on Mars are hematite because there are white spheres on Mars.

"White" or "pale white" hematite is not round or spherical but appears as jagged, crystalized, sharp-edged and metallic-silver or crystal white (Beske-Diehl and Li 1993; Grove et al. 2017). Unless water bleached and hydrated terrestrial hematite is characteristically dark-red to black in color (Anthony et al. 2003). Terrestrial hematite does not resemble the spheres of Mars as documented by the comparative photographs in this report. Moreover, the Martian stems are hollow (Figure 5).

Not surprisingly, attempts to characterize the spheres of Mars as consisting of hematite are beset by so "many contradictions" that this interpretation was immediately challenged as "inappropriate" (Burt et al. 2005). Therefore, reasonable alternative explanations and origins have been offered (DiGregorio, 2004; Joseph, 2006, 2008; Knauth et al. 2005; Royer et al. 2008); e.g., bolide impact, volcano, mineral precipitation, lichens and "Martian mushrooms." Each of the views, including the biology of the radiated iron rich Red Planet, iron uptake, radiation as nutrient, melanization, biological weathering, oxalate "cementing" of spherical specimens, the "hematite hoax" and religious extremism among NASA scientists and administrators will be discussed in the following sections.

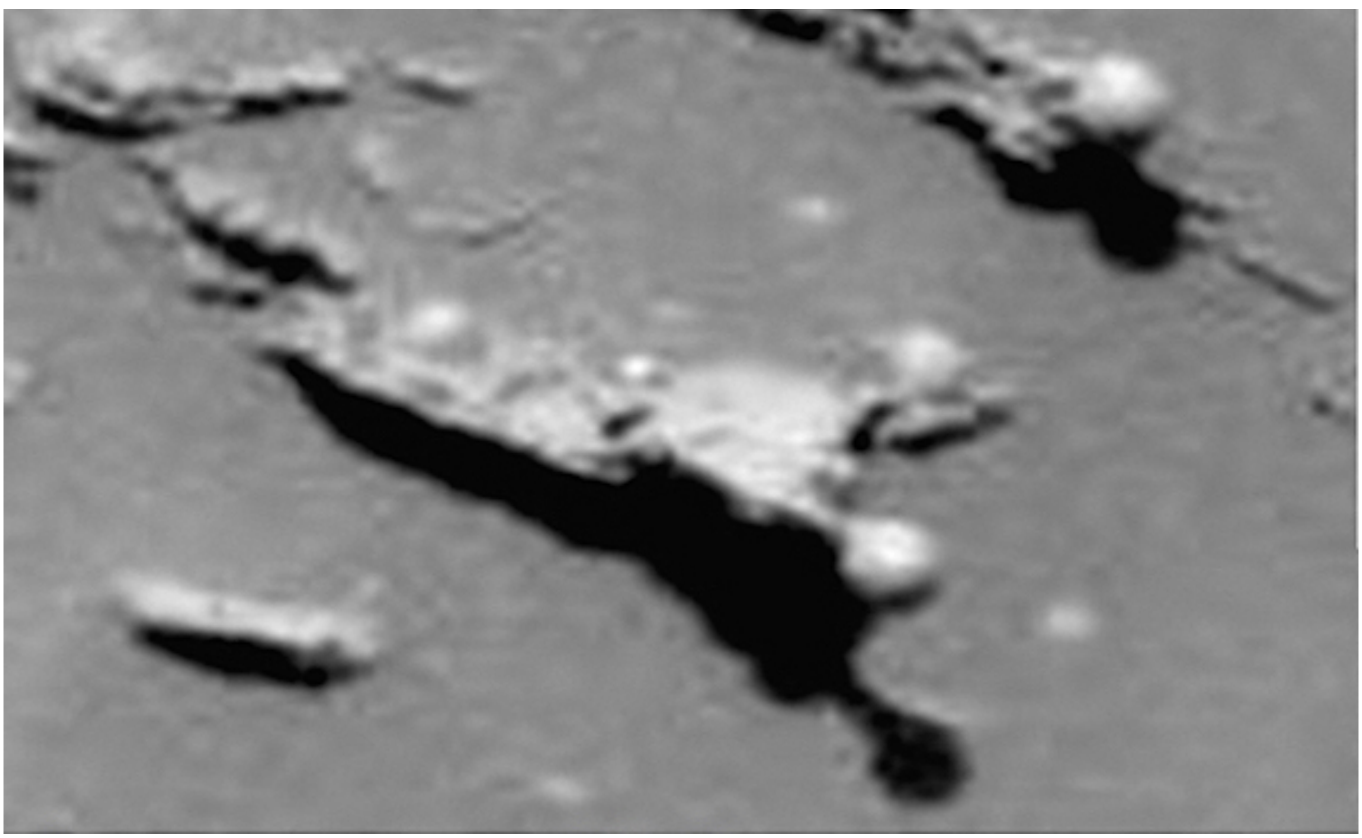


Figure 1: Opportunity - Sol 40. Lichen-mushrooms (lichenized fungi?) to 8 mm in length, with stems approximately 1 mm (or less) in width and bulbous caps 3mm to 6mm in diameter.

Figure 2: Opportunity Sol 37. Lichen-mushrooms (lichenized fungi?) on the surface and up outcrop are up to 8 mm in length, with stems approximately 1 mm in width and bulbous caps 3mm to 6mm in diameter. The bulbous caps may be fruiting bodies.

Figure 3: Dibaeis is a genus of lichenized fungi in the Icmadophilaceae family.

Figure 4: Opportunity - Sol 88. These lichen/fungi are up to 8 mm in length, with stems and apothecia 1 mm to 3 mm in width, with bulging hyphae atop and just beneath the rock surface. The bulbous cap may be a spore producing fruiting body. Note RATT grinding instrument impression red-circled. Stems are hollow (see Fig. 5).

Figure 5: Sol 88. Hollow stems/stalks serve to draw up and distribute nutrients and moisture.

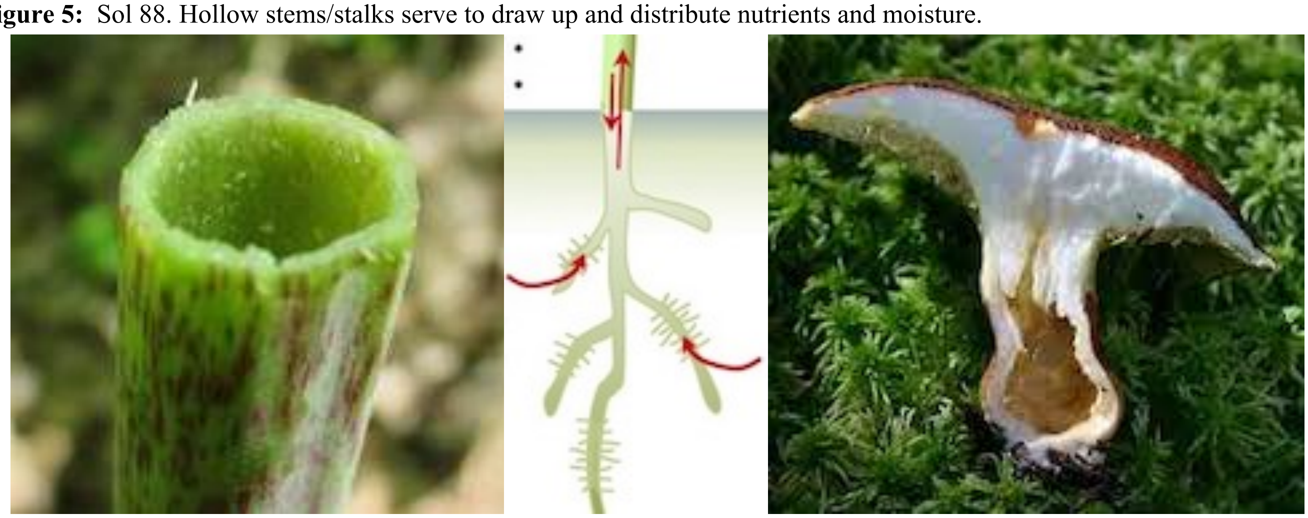


Figure 6: (Left: Photo by Janet Pesaturo / One Are Farm) (Right: Suillus cavipes, Hollow Bolete. Photo by Gary B.)

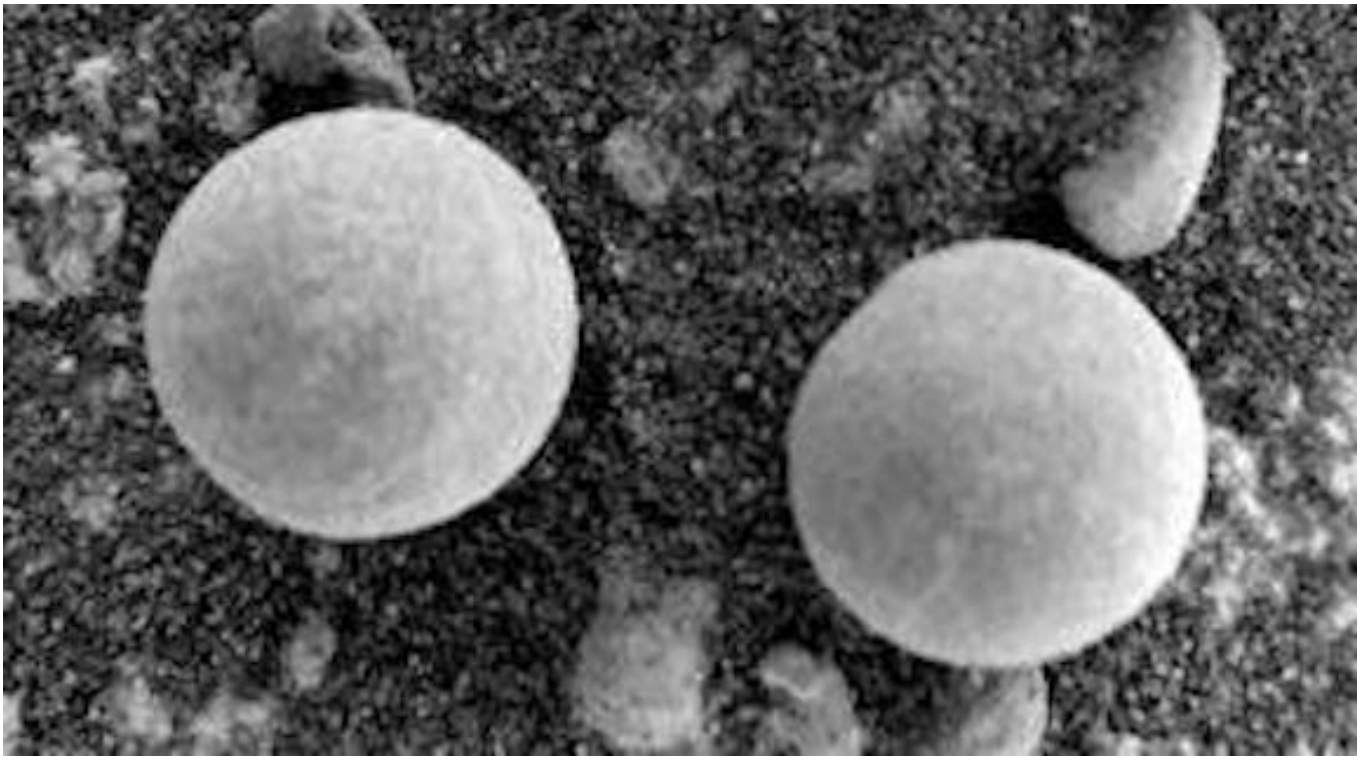


Figure 7: Sol 182. Martian Fungal Puffballs. There is no resemblance to terrestrial "hematite" spheres.

Figure 8. Terrestrial "hematite" spheres have a variety of shapes, sizes and are dark red to red in color and only the surface layers consist of hematite (Photo from andreyadreams.com).

Figure 9. Terrestrial “hematite” spheres / “Moqui Marbles, Southeast Utah.

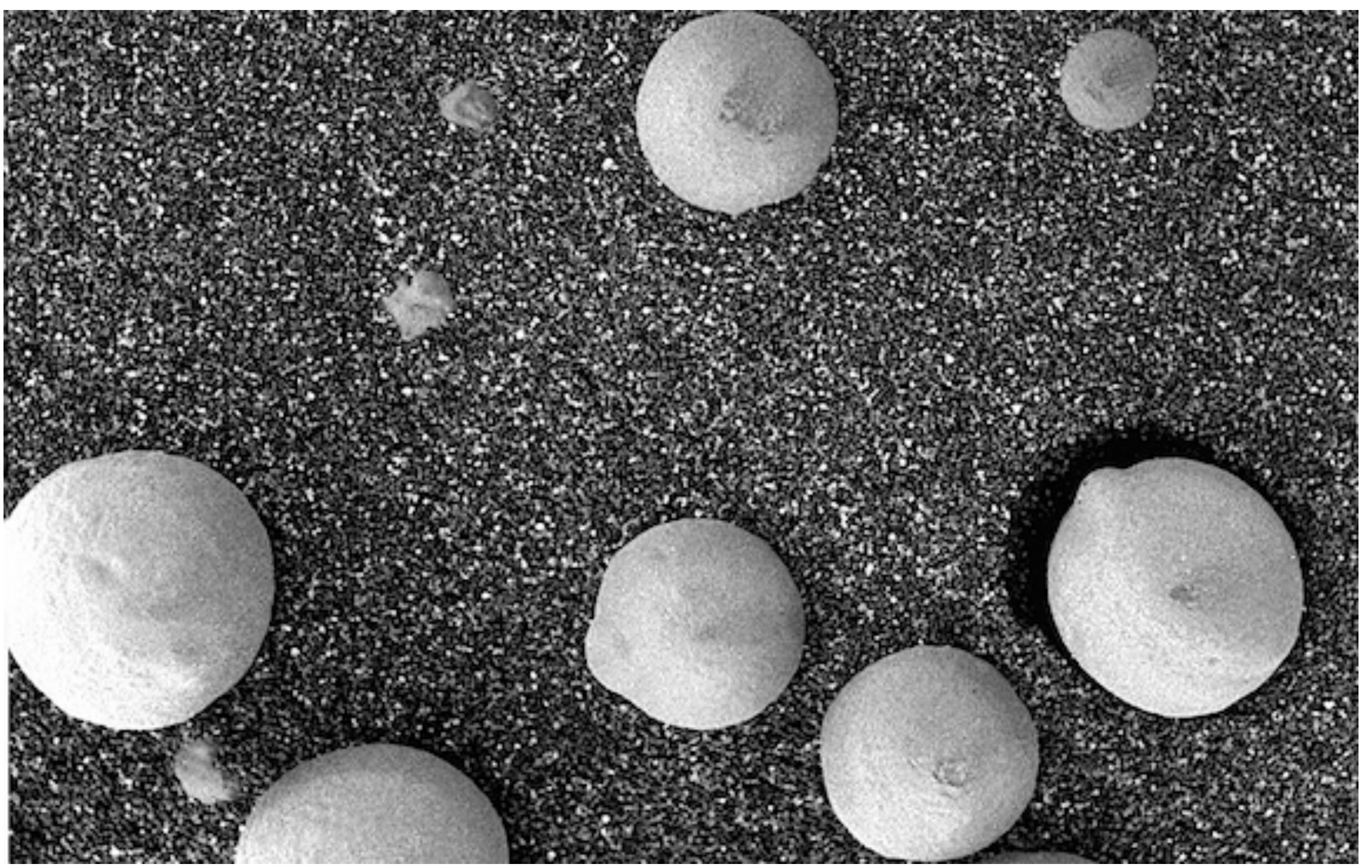


Figure 10: Sol 182. Martian Fungal Puffballs. There is no resemblance to terrestrial “hematite” spheres.

Figure 11: (**Left**) Fungal puffball (*Basidiomycota*) with stalk. (**Right**) Sol 257, Martian fungal Puffballs with stalk.

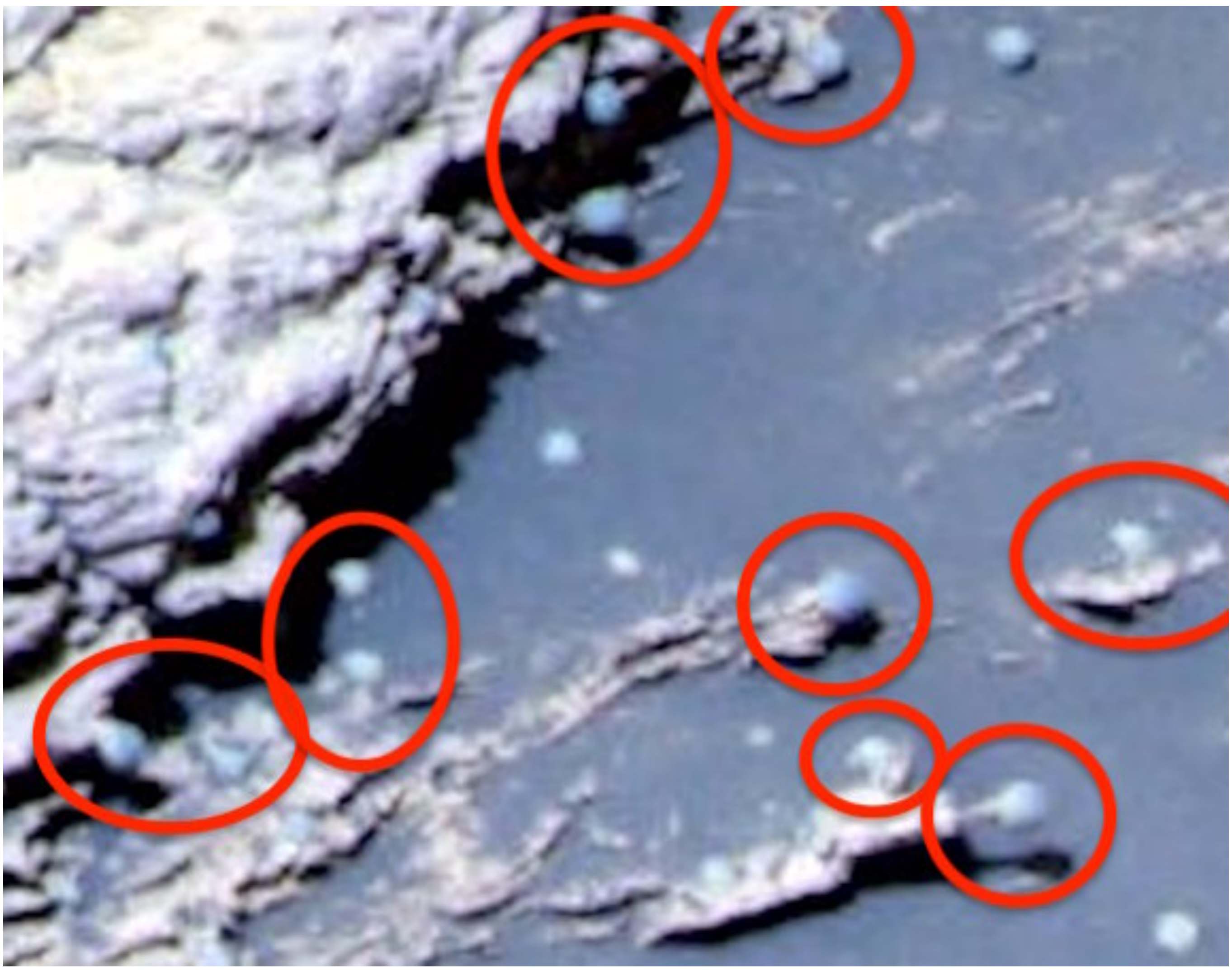


Figure 12: Opportunity Sol 37. Lichen-mushrooms (lichenized fungi?). These organisms have long stems and bulbous spherical caps. Those that have stalks/stems are supported by substrate above the ground. Those on the surface have only a short thick visible stalk

Figure 13: Terrestrial “hematite” spheres / “Moqui Marbles” Southeast Utah.

Figure 14: Sol 221. Martian fungal puffballs (*Basidiomycota*). No resemblance to terrestrial “hematite.”

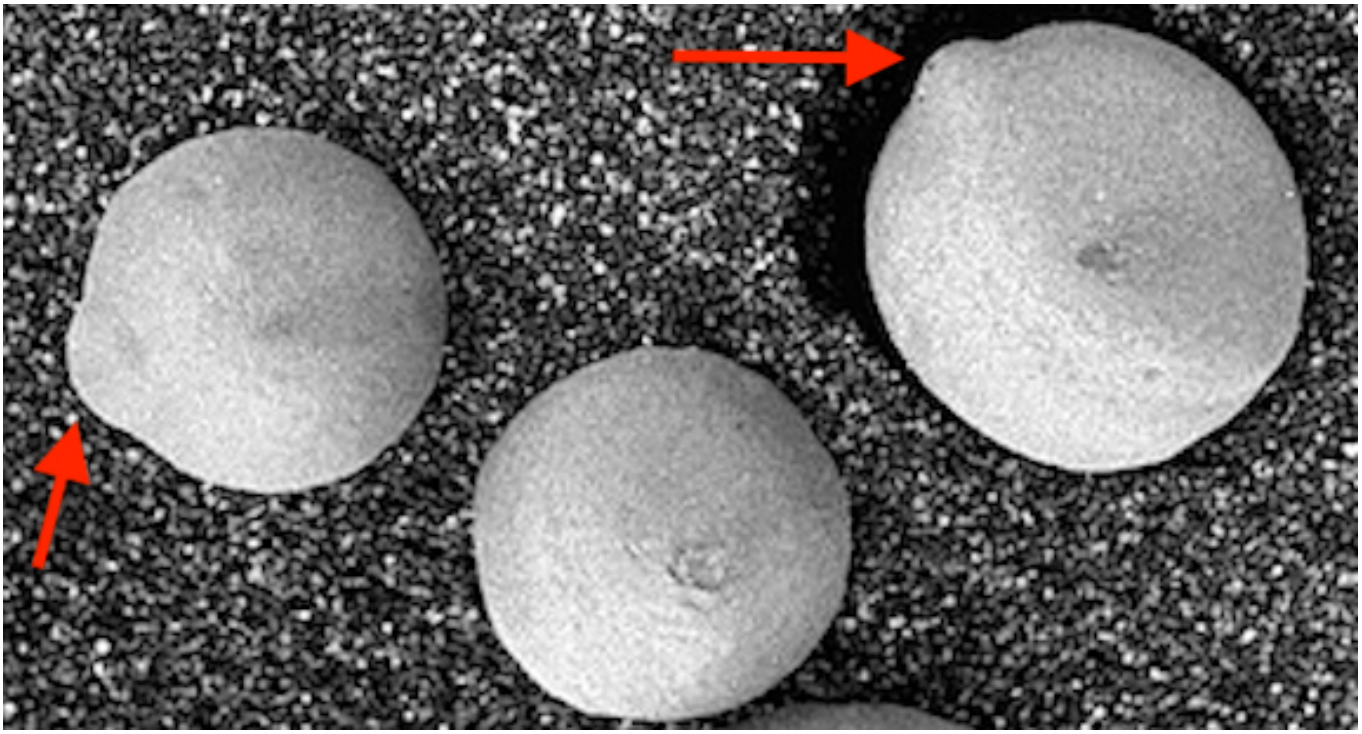


Figure 15: Sol 1148. Martian fungal "puffball." Compare "lemon-shape" bulge/stalk with Fig 15.

Figure 16: Terrestrial fungal "puffball" (*Basidiomycota*). Note and compare "lemon-shape" stalk bulge.

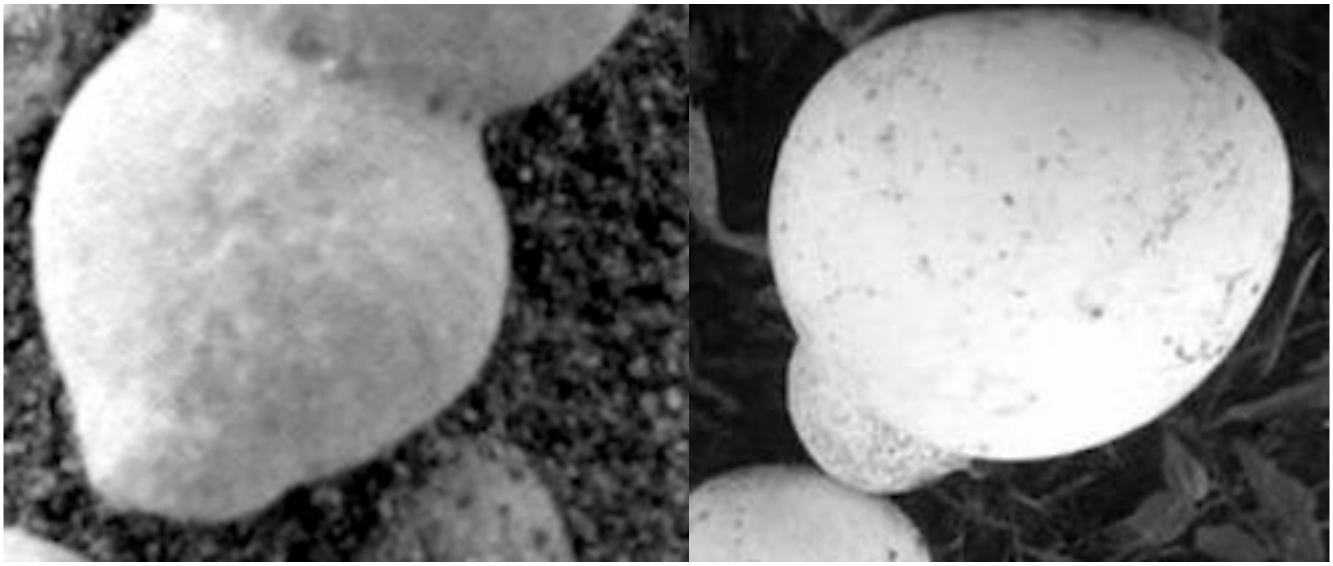


Figure 17: (**Left**) Sol 182. Martian fungal puffball. (**Right**) Terrestrial fungal "puffball" (*Basidiomycota*). Note "lemon-shape" stalk/bulge.

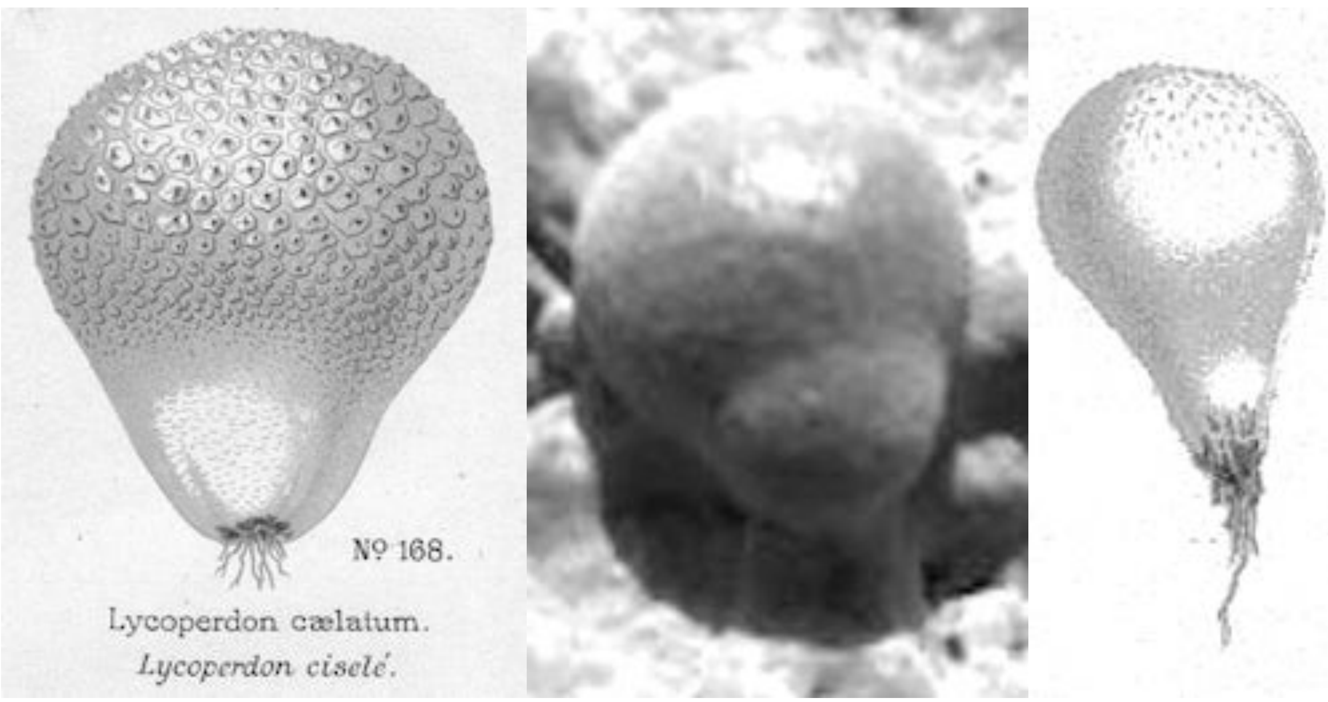


Figure 18: (**Bottom Left & Right**) Lichen *Lycoperdon* with mycelium growing from bulge/stalk. From Dufour, 1891. (**Center**) Sol 306. Martian fungal puffball embedded in what maybe calcium oxalate.

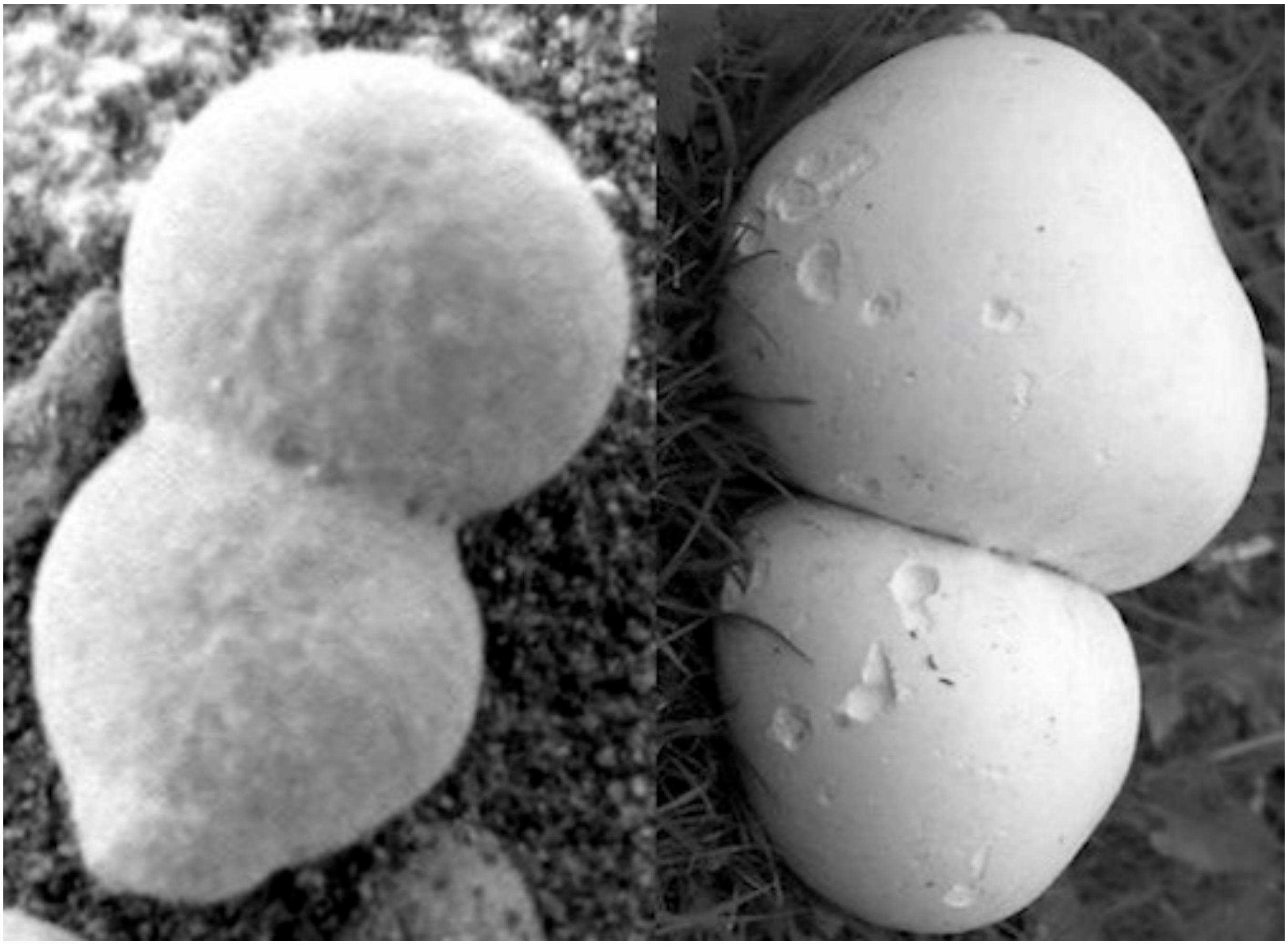


Figure 19: (**Left**) Sol 182. Note organic appearance the Martian specimen and membranes separating the hemispheres. (**Right**) Terrestrial puffball doublet.

Figure 20: Hematite doublet. Grooved. No membranes. No Resemblance to puffballs.

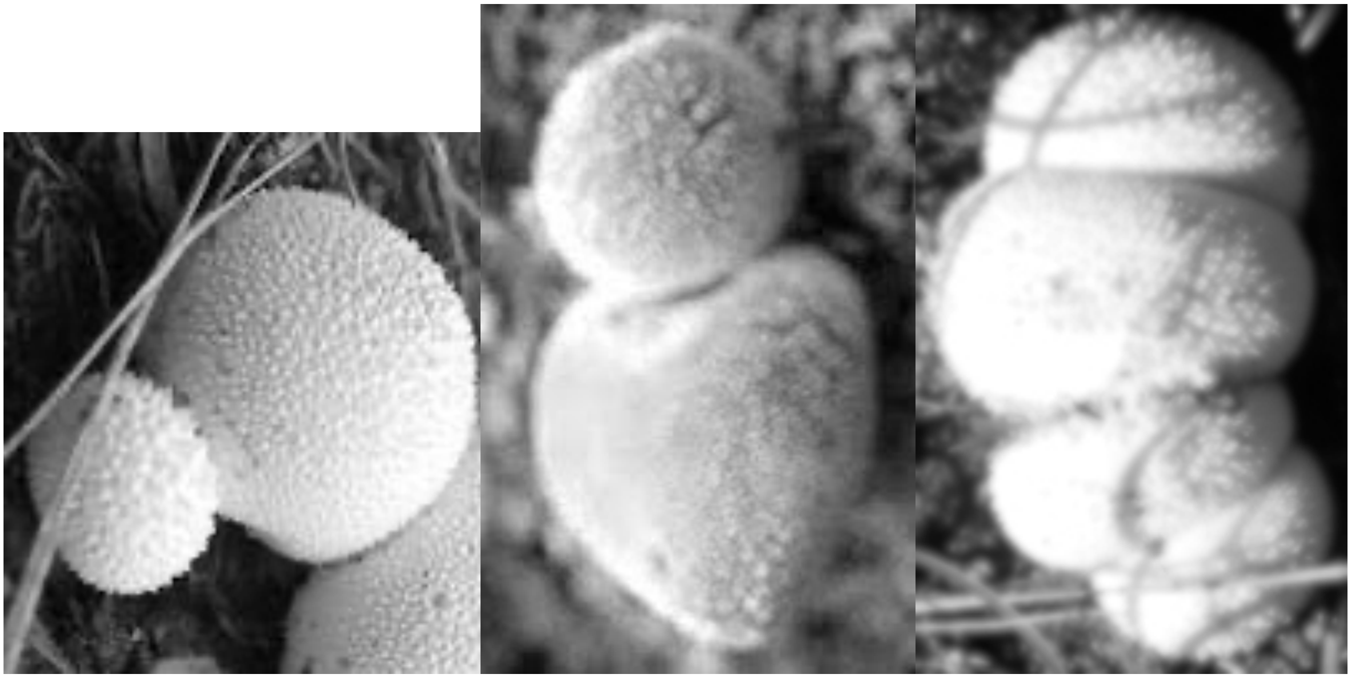


Figure 21: Terrestrial puffball doublets. Center photo by Rebriev et al. (2020). Right Photo by Joseph OBrien, USDA Forest Service. Note membranous tissue connecting the hemispheres.

Figure 22: Martian puffball doublets. Note membranous tissue connecting the hemispheres.

Figure 23: (**Left**) Sol 147. Martian Puffballs. (**Right**) Terrestrial "Hematite" spheres are not uniform in shape or size and are dark red in color. Photo by Dr. Dennis Eberl.

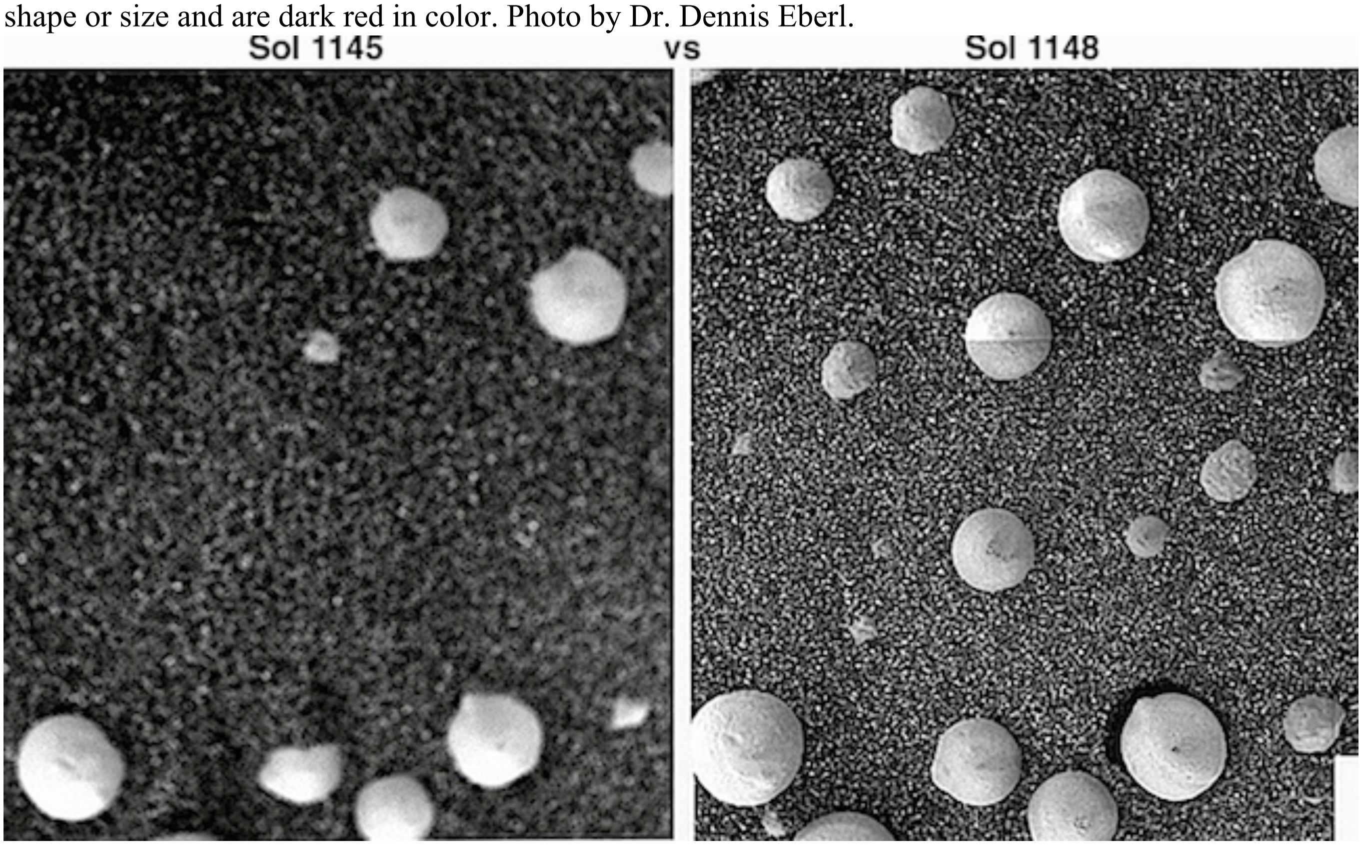


Figure 24: Sol 1145 and Sol 1148. Martian puffballs growing out of the ground and increasing in size.

Figure 25: Terrestrial "Hematite" spheres are dark red in color and differ greatly shape and size.

Figure 26: Martian spherical puffballs are uniform in shape, size (3mm to 6mm) and color.

3. Meteor Impact:

"Unlike all known terrestrial concretions" the surface-spheres of Mars "are uniformly spherical... and... uniform in their size distribution" and do not resemble the hematite spheres of Earth (Burt and colleagues 2005). Given the "high sphericity and near-uniform sizes of the spherules" Knauth et al. (2005) have proposed an "alternative explanation involving deposition from a ground-hugging turbulent flow of rock fragments, salts, sulphides, brines and ice produced by meteorite impact." Based on their analysis of the 1mm-in-diameter spherules Royer et al. (2008) also argued in favor of impact origin: the spheres formed from the aggregation or vapor condensation produced by large meteoritic impact cloud.

DiGregorio (2004) points out that accretionary spherical lapilli are often produced by meteorite strike such as is evidenced by the Chicxulub K/T boundary impact and other craters that are littered with spherical silica-rich glass tektites and accretionary lapilli ash that accreted around a nucleus of water (see Figure 27). He notes tektites begin as molten projectiles that spin through the atmosphere and develop a variety of aerodynamic shapes including "spheres" and that if they collide they may melt together forming doublets or triplets similar to some of the spheres on Mars.

Because tektite and lapilli also have voids and vesicles, DiGregorio (2004) argues when hydrated and if colonized by microbes, and if their contents include iron, there could result a wide variety of mineral phases, including, hypothetically, eventually producing hematite; thus accounting for the detection of hematite grains in the sands of Mars. Knauth et al. (2005) and DiGregorio (2004) have also suggested that an examination of the cracks in these impact-produced rocks and minerals may provide evidence of biology. However, DiGregorio also acknowledges that terrestrial accretionary lapilli and tektites have a silicate (not hematite) mineralogy. On the other hand, given that the spherical-hematite claims are based on speculation and faulty instrumentation, then it is quite possible that at least some of the Martian spheres may be tektites and lapilli as proposed by Burt et al (2005), Knauth et al. (2005), Royer et al (2008) and DiGregorio (2004).

4. Volcanic Precipitation Origin

DiGregorio (2004) also proposed that Martian ground-level spheres may have a volcanic origin thereby resulting in the accretion of lapilli: tightly bound collections of fine sand, dirt, and volcanic ash which forms a hard outer shell that surrounds a porous core and vesicles (see Figure 28). When hydrated in an iron-rich medium, these microscopic vesicles could serve as preferential sites for hematite precipitation. However, there is no evidence of a volcano in Meridiani Planum.

Figure 27: Tektites From Meteor Impact: Note dark color, pitted surface and only resemblance to the Martian spheres is that some concretions have semi-spherical shapes. **(Top)** Colombianite Tektite, Columbia (**Bottom Left** Tektites, from China, photo by Moussa Minerals & Fossils). (**Center Bottom**) Tektites embedded in stone and ash. (**Bottom Right**) Tektites from Southeast Asia.

Figure 28: Volcanic accretionary lapilli from Oahu, Hi (photo U.S. Geological Survey). Note dark grey color and spherical to semi-spherical shapes.

Figure 29: Embedded volcanic accretionary lapilli from the Minoan volcanic Santorini ash deposits. The problem with these terrestrial analogs is there is no evidence of a volcano or volcanic activity in the history of Meridiani Planum, Mars.

5. Supersaturated Precipitation Origin:

Based on his observations of spherical shape and size distribution Eberl (2021) has proposed spherical formation via the accretion of supersaturated crystals. Eberl (2021) observed what may be a gradual shift in shape depending on if the spheres are located on the crater rim or crater floor: left-skewed in the crater, right-skewed on the rim, with shapes progressively intermediate between the two. He has suggested this may be due to different crystal growth mechanisms and a consequence of very high levels of supersaturation that induced nuclei precipitation.

6. Biological (Algae, Lichens, Fungi) Origins:

Eberl's (2021) observations are not incompatible with biology. Different levels of moisture would also effect the growth (and fossilization) of fungi and lichens as would the amount and duration of sunlight on the rim vs the crater floor.

Lichens are a symbiotic organism consisting of a fungus and an algae/cyanobacteria. Kaźmierczak (2016, 2020) has provided comparative evidence suggesting that some spheres located on crater rims contain colonies of fossilized algae, with inner structures reminiscent of chloroplasts. Lin (2016) focusing on Martian surface spheres less than 1mm in diameter, believes that some resemble ooids fashioned by grains of sand cemented together by the calcium secretions of algae/cyanobacteria. Other investigators have also observed what may be spherical ooids attached to sandstone and rock and adjacent to specimens that resemble green algae, lichens, and veins of what may be calcium (Joseph et al. 2020d) or gypsum which is a favored habitat of algae (Bothe 2019; Jung et al. 2019).

Another team of investigators, examining 1mm-in-size-specimens that appeared in the crests of old rover tire tracks, have identified what may be tiny mushrooms with stems (Joseph et al 2021). The larger 3mm to 6mm ground-level spheres photographed on the surface of Mars are said to resemble spherical fungus as determined by over 30 experts who examined these photographs (Joseph 2016); an interpretation accepted by several teams of investigators and independent scientists (Dass, 2017; Joseph 2006; Joseph et al. 2019, 2020a,b,c, 2021; Rabb, 2018; Small 2015).

By contrast, spheres attached to rocks have elongated stems and topped by bulbous caps oriented skyward similar to colonies of photosynthesizing terrestrial lichens (Dass 2017; Joseph 2006, 2016; Joseph et al. 2019, 2020a,b,c; Rabb, 2018). Only colonies of terrestrial lichens resemble these rock-anchored Martian specimens (Figures 3, 34).

7. Weathering

Rock-dwelling endolithic crustose lichens and communities of algae and fungi grow between the grains inside "solid" rock leaving only the fruiting body exposed on the surface (Freidmann et al. 1988; Johnston & Vestal 1993). As to rock-dwelling Martian lichens, Chan (2004) argued these are hematite spheres that have been"weathered" out of the rock--a scenario for which there are no terrestrial analogs. It is well established, however, that fungi and lichens biologically weather surrounding stone, rock, metal and minerals via infiltration, hyphal and thallus growth, penetration and pressure induced swelling.

Fungi and endolithic (rock dwelling) lichens, including those living in the Mars-like deserts of Antarctica, also produce oxalic acid (oxalate) and other acids (Russ et al. 1996), which induces the weathering and dissolution of surrounding metals, minerals, and stone. The secretion of oxalate acids will dissolve minerals, iron and other metals which serve as nutrients for the fungus/algae/lichen consortium (Chen et al. 2000; Gadd, 1999; Glasauer & Gadd, 2013). Metal and mineral uptake promote biological metabolism, the production of chlorophyll (Chen & Sun, 2011) and provide energy for photosynthesis (Tooulakou et al. 2016) which contributes to the biogensis of these acids (Seal & Sen 1970). As surrounding rock and minerals dissolve, the morphology of these organisms is increasingly revealed and making it appear as if they are weathered from stone when it is these organisms which are weathering and metabolizing the surrounding substrate as they grow and engage in photosynthesis (Figures 30-38).

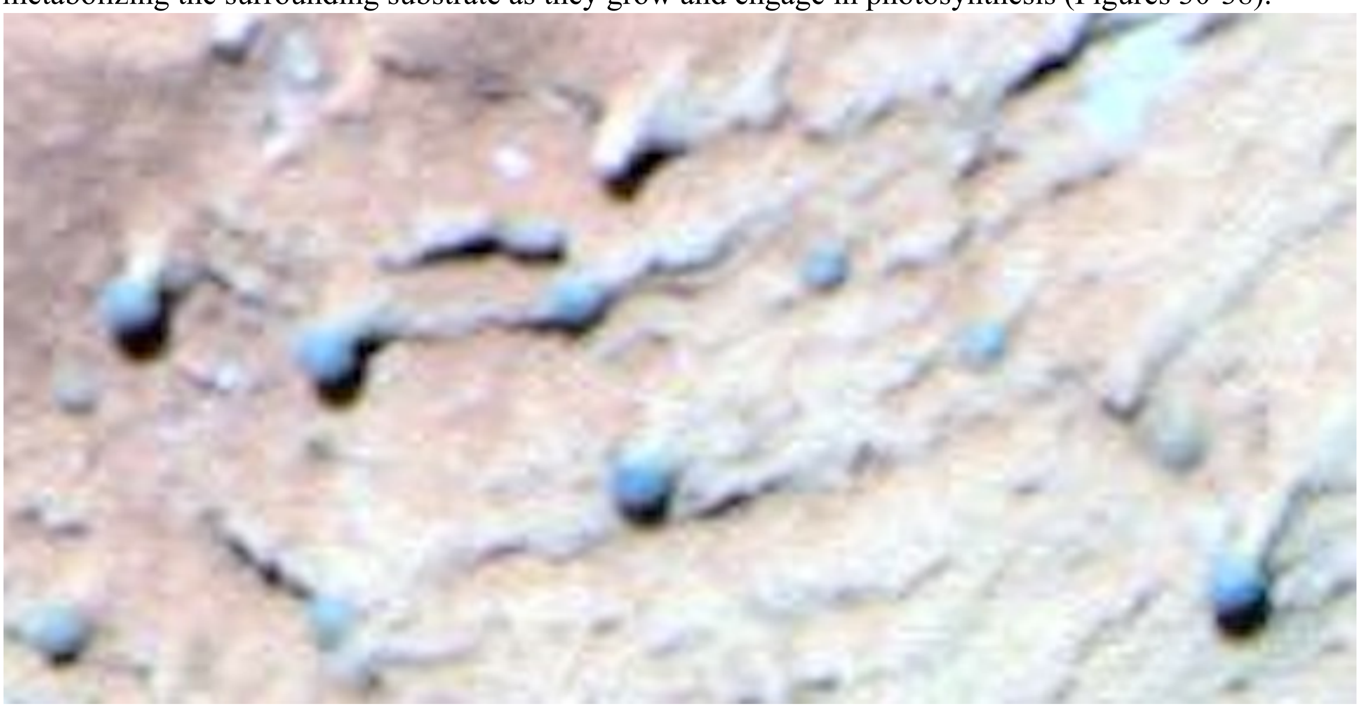


Figure 30: Sol 88. These Martain lichen/fungi are up to 6 mm in length, with stalks 2 mm to 3 mm in width, with hyphae atop and just beneath the rock surface. The bulbous cap may be a spore producing fruiting body.

Figure 31: Sol 88. These Martian lichen/fungi may be biologically weathering via oxalate acid, the surrounding matrix, dissolving and taking up metals and minerals. The bulbous cap may be a spore producing fruiting body. Oxalate is produced during daylight hours, thereby corresponding to increased metabolic and oxygen-producing photosynthetic activity and biological weathering of matrix.

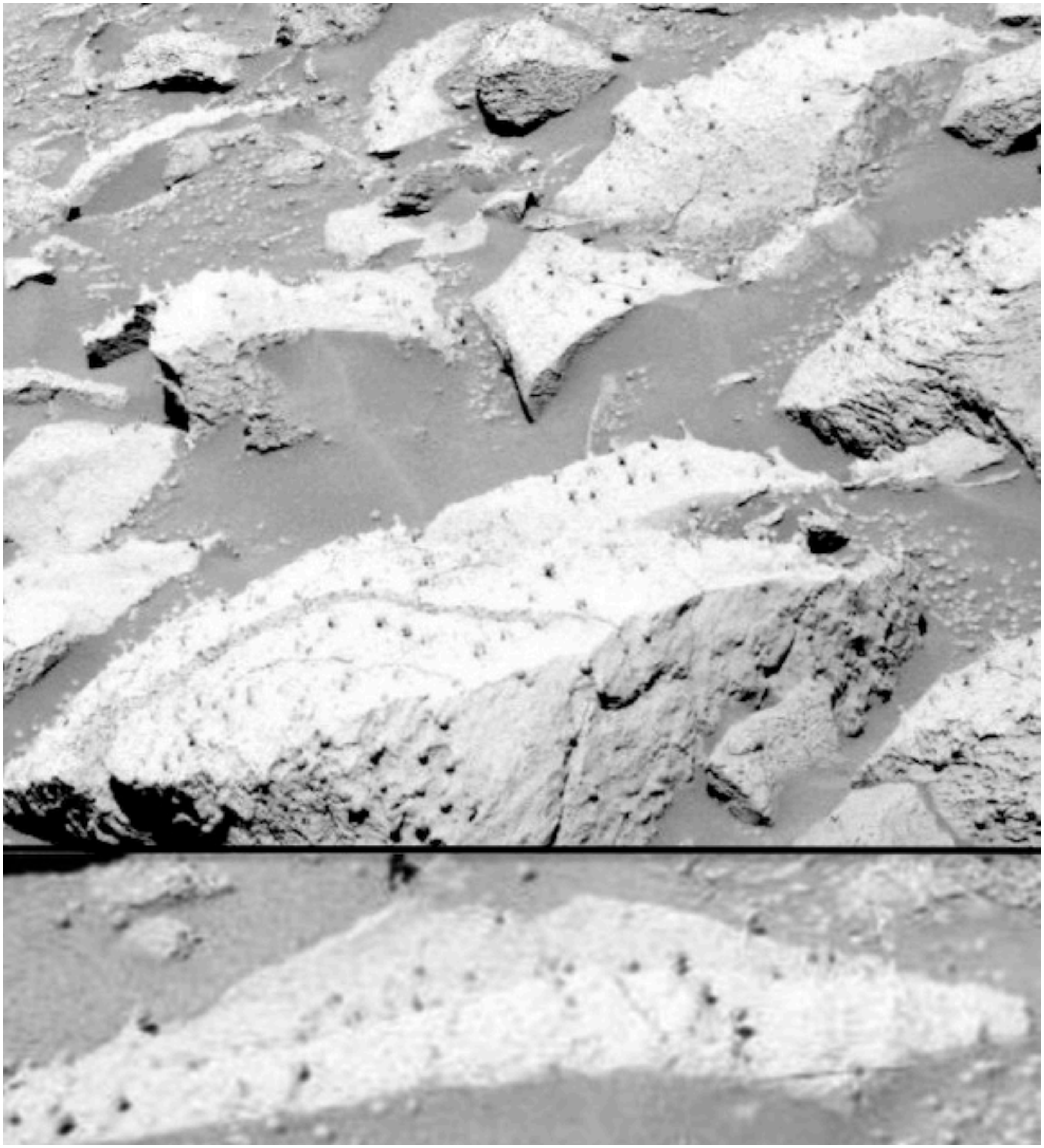


Figure 32: Sol: 85. Martian Lichen/fungi specimens are approximately 2 to 8 mm in length. These lichen/fungi may be biologically weathering via oxalate acid, the surrounding matrix, dissolving and taking up metals and minerals. The bulbous cap may be a spore producing fruiting body. Oxalate is produced during daylight hours, thereby corresponding to increased metabolic and oxygen-producing photosynthetic activity (Tooulakou et al. 2016; Johnston & Vestal 1993) and acting to dissolve surrounding matrix which is utilized as nutrients by and builds up on the cellular surface of lichens.

Figure 33: Sol: 85. Martian Lichen-fungi are approximately 3 to 8 mm in length and likely engaged in photosynthesis.

Figure 34: (Top) Sol 88. These Martian lichen/fungi are similar in morphology to (**Bottom**) the Lichen Dibaeis *baeomyces* which are pigmented, oxygen-producing photosynthesizing organisms.

Figure 35: Sol: 85. Colonies of Martian lichens attached by stems to rocks.

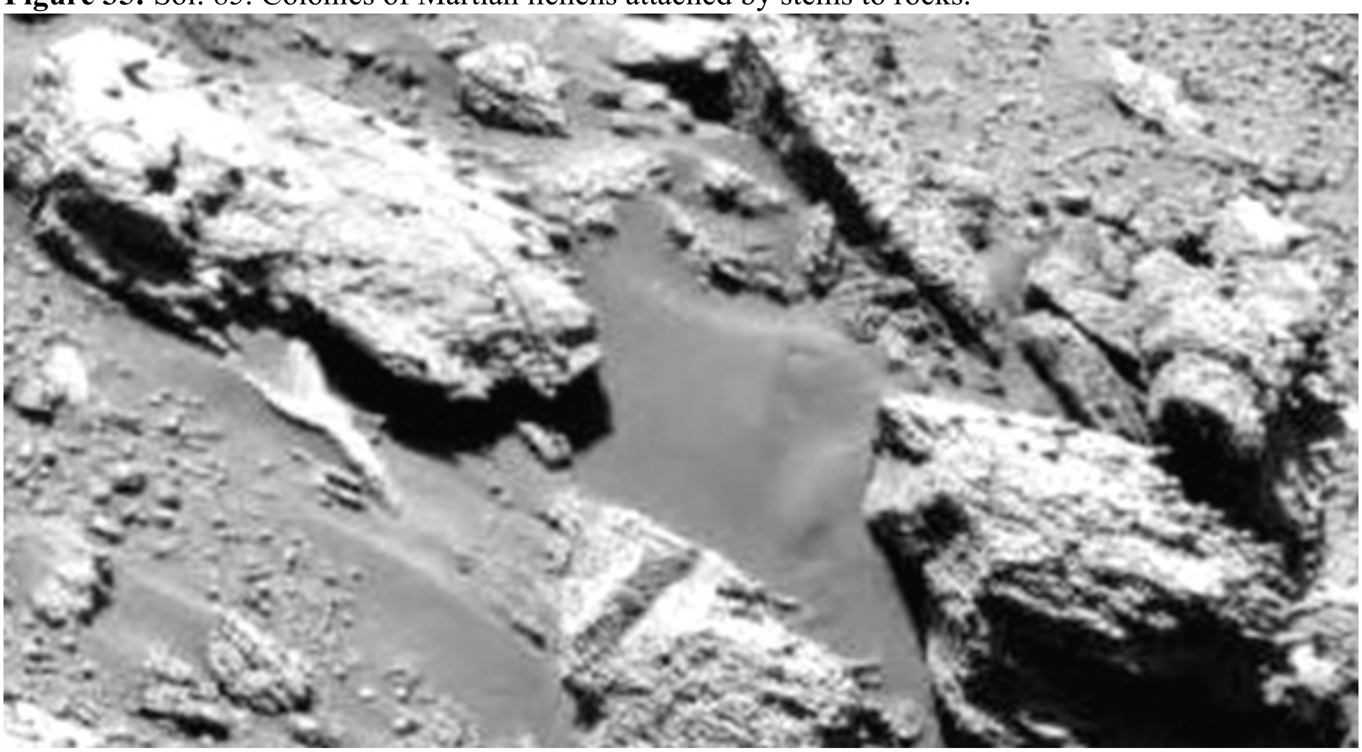


Figure 36: Sol: 85. Martian Lichen/fungi may be engaged in photosynthesis, biologically weathering surrounding matrix, and dissolving and taking up metals and minerals via oxalate acid which promotes photosynthesis.

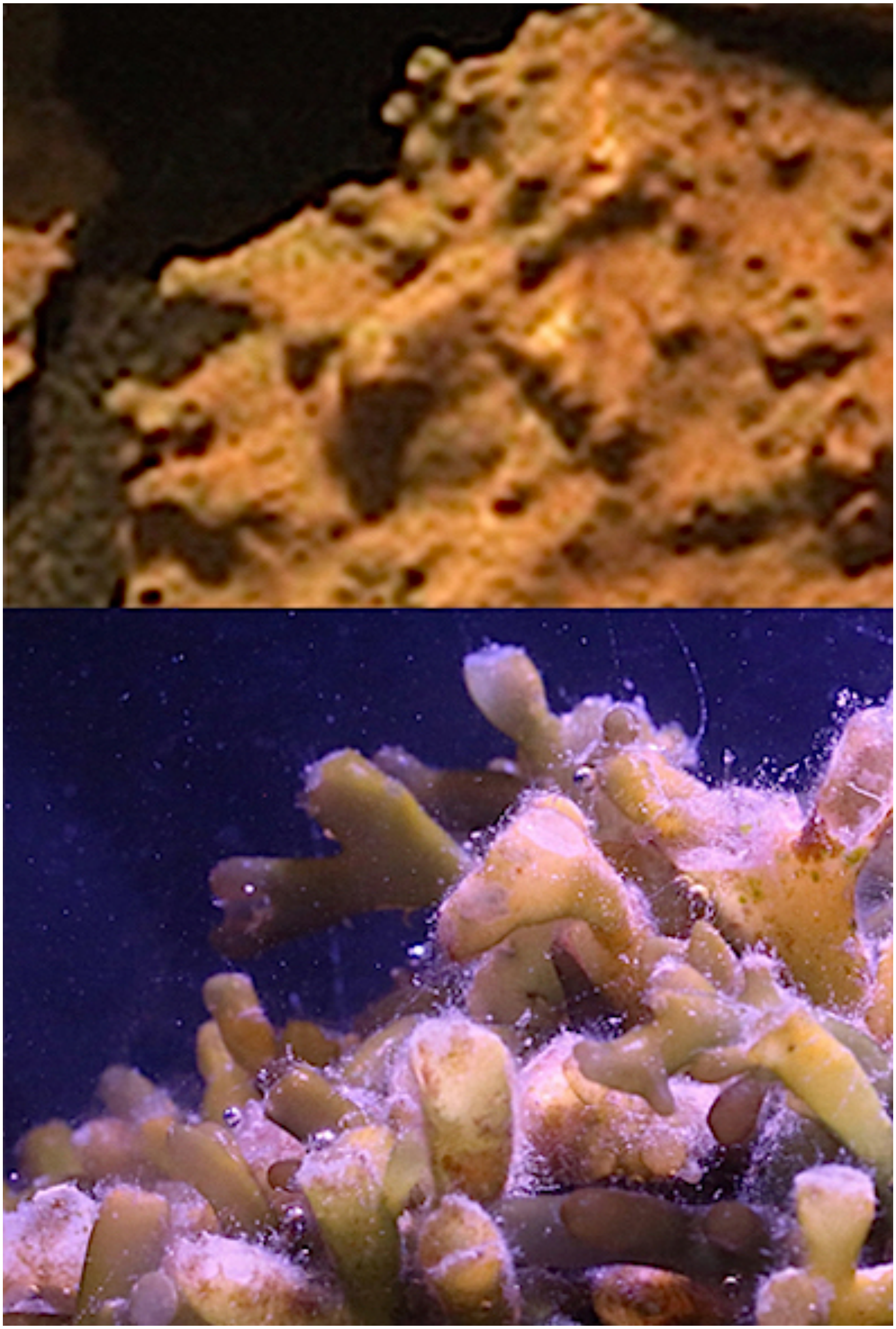


Figure 37: (**Top**) Sol 232: Gas-vent apertures for the release of oxygen secondary to photosynthesis within microbial mats; photographed in Gale Crater. (**Bottom**) Cone-like tubes for the venting of oxygen produced by photosynthesizing algae (reproduced with permission from Freeman et al. (2018)

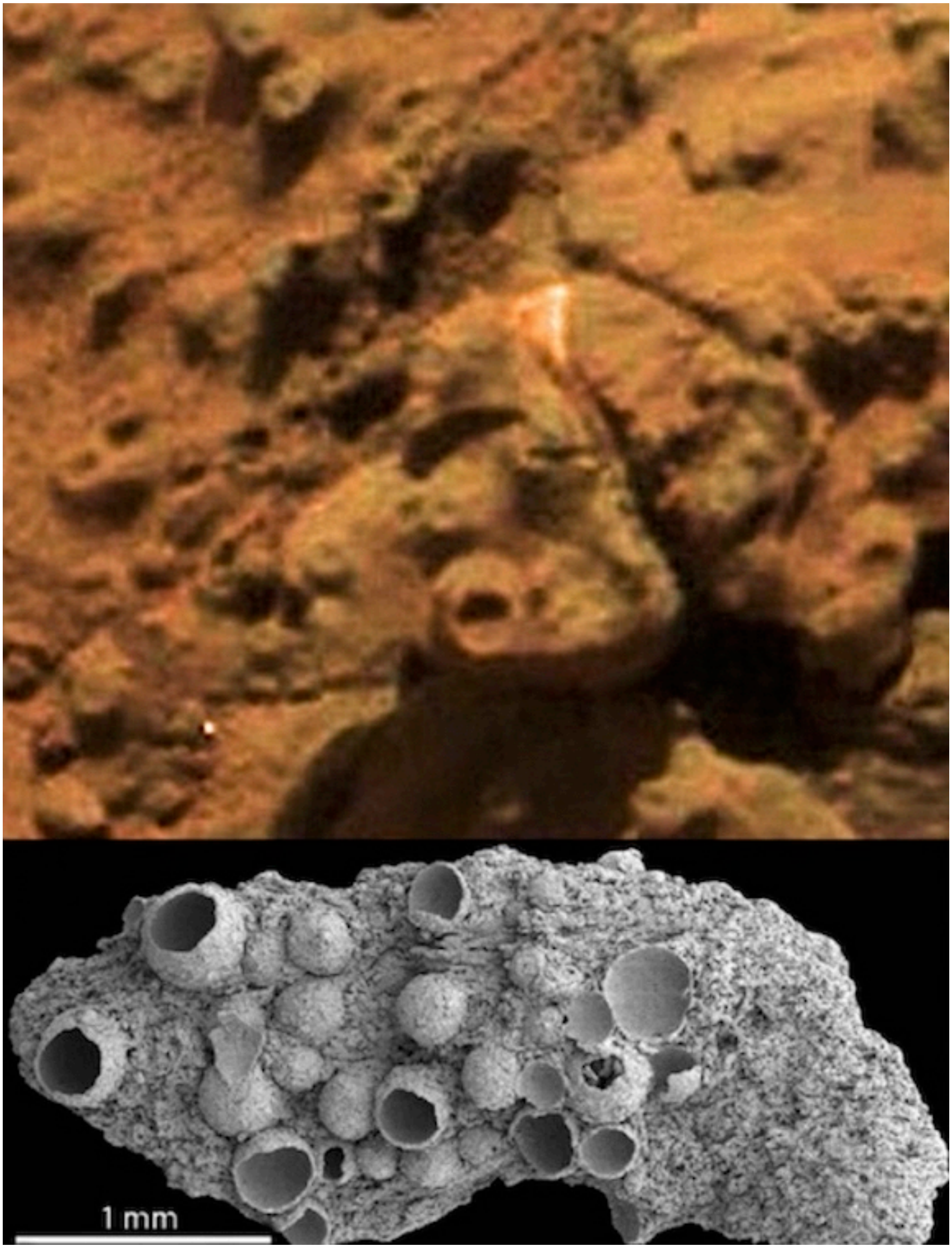


Figure 38: Sol 232 (Top): Specimens similar to gas-vent apertures for the release of oxygen secondary to photosynthesis. Photosynthesizing organisms respire oxygen and release gas bubbles via the surrounding matrix (most noticeable in water). (Bottom) Open globular structures, interpreted as formed by gas bubbles via cyanobacteria oxygen respiration within microbial mats (from Bengtson et al. 2009, reproduced with permission).

II. BIOSIGNATURES: CALCIUM OXALATE WHELWELLITE

8. Algae/Cyanobacteria Calcium Biosignatures

Fungi (mycobiont) and algae (photobiont) comprise the lichen symbiotic consortium. Calcium and calcium carbonate are precipitated in the mucous of cyanobacteria/algae via photosynthetic CO_2or HCO_3 (Barnes and Chalker, 1990; Graham et al. 2014; Mei et al. 2020). Calcium carbonate is a biological byproduct of their photosynthetic activity: Their mucous secretions of polysaccharides act as binding sites for Ca^{2+} thereby producing carbonate minerals and concentrations of calcium (Dittrich and Sibler, 2010; Kupriyanova et al. 2007; Samylina et al. 2016). Hence, cyanobacteria/algae produce calcium and calcium carbonates whereas fungi are capable of precipitating numerous metal oxalates including soluble Fe and calcium oxalate (Gadd 1999; Graustein *et al.,* 1977; Palmieri et al. 2019; Verrecchia, 1990). Coupled with high intake of iron (Bajpai et al. 2009; Hauck et al. 2007), lichens can produce oxalate acids, calcium carbonates or cement-like calcium.

Despite destruction by weathering and UV and other forms of ionizing radiation (Ertem et al. 2017; Bibring et al. 2006) calcium carbonate has been detected on Mars (Boynton et al. 2009; Krall et al. 2014; Sutter et al. 2012; Wray et al. 2016) Wray et al. (2016), for example, found evidence of calcium-rich Martian carbonates as detected by the Compact Reconnaissance Imaging Spectrometer aboard the Mars Reconnaissance Orbiter. The Thermal and Evolved Gas Analyzer on the Phoenix polar lander identified CO_2 release consistent with breakdown of Ca-rich carbonate in Martian soils (Boynton et al. 2009; Sutter et al. 2012), an interpretation supported by results from the Phoenix Chemistry Lab (Kounaves et al. 2010). Moreover, calcium biosignatures and calcium encrusted cyanobacteria and "Nostoc balls" have been observed in Gale Crater (Figures 42-45; Joseph et al. 2020d).

9. Whewellite Calcium "Cement" and Martian Hyphae/Mycelium

Oxalate is produced during daylight hours, thereby corresponding to increased metabolic and oxygen-producing photosynthetic activity (Tooulakou et al. 2016; Johnston & Vestal 1993). Terrestrial lichens and fungi secrete calcium saturated oxalate acid that may be transformed into calcium oxalate monohydrate crystals (Ascaso *et al.* 1982; Russ et al. 2013; Gadd, 1999; Glasauer & Gadd, 2013). Some species of algae and bacteria are oxalic acid consumers (Palmieri et al. 2019) and thus the fungi may feed the algae oxalate which promotes the synthesis of chlorophyll which is essential for photosynthesis.

Calcium oxalate crystals and the monohydrate (whewellite) and the dihydrate (weddelite) are produced extracellularly by fungi and lichens (Gadd, 1999; Glasauer & Gadd, 2013). Weddellite may form white encrustations on lichen and fungal hyphae/mycelium or form calcium hard layers on the surrounding surface (Figures 52-60). Lichens preferentially produce whewellite when on dry rock, and weddellite on hydrated rocks (Ascaso *et al.* 1982; Russ et al. 2013). Weddellite is a metastable mineral and decomposes to whewellite (Frey-Wyssling, 1981). Thus, whewellite is a monohydrate and weddellite a dihydrate which may assume a crystaline-tetragonal encrusted cemented appearance when exposed to dry surface conditions (Gadd 1999; Glasauer & Gadd, 2013). Depending on species, substrate, and moist vs dry condition, the crystals might appear as chain-like encrustations or mineral-like veins upon the surface, or form semi-independent masses or form waves of calcium-cement on the surface (Arnott, 1995; Horner *et al.*, 1995; Glasauer & Gadd, 2013). Depending on photosynthetic activity and the availability of moisture, their shapes and mass may change and wax or wane.

Studies have shown that oxalate crystals thicken and increase in size along cellular surfaces and will fill wall surface and voids (Gadd 1999; Russ et al. 1996; de la Torre Noetzel & Garcia 2020). Calcium oxalate may also form a membrane or sheath that wraps around and encrusts the hyphae, mycelium, fruiting bodies and algae photobionts (Russ et al. 1996). Oxalate, in so doing, provides cellular protection against environmental extremes (de la Torre Noetzel & Garcia 2020) but may harden and produce a calcium-enamel cement when exposed to prolonged dry conditions.

Martian lichens and fungi also appear to produce copious amounts of oxalate/whewellite which surrounds and coats mycelium, hyphae and fruiting bodies (Joseph et al. 2021 as depicted in Figures 42-50. This interpretation is supported by the fact that terrestrial lichens (and fungi) not only show high rates of survival when exposed to Mars-like conditions including the ability to rapidly regain photosynthetic capabilities (Brandt et al. 2015; De la Torre Noetzel et al. 2017; Meesen et al. 2014) but will secrete copious amounts of calcium oxalate monohydrate whewellite (de la Torre Noetzel and Garcia 2020; see also de la Torre Noetzel et al 2018). For example, when de la Torre Noetzel and Garcia (2020) exposed samples of lichens to space and Mars-simulated conditions for 18 months whewellite (calcium oxalate monohydrate) crystals formed on fungal cell wall surfaces and the lichen medulla.

Terrestrial spherical basidiomycetes (puffballs) and their interwoven hyphae also secrete and become encrusted with oxalate crystals (Gadd 1999). Spherical fungal puffballs (basidiomycetes) have been identified on Mars (Joseph 2016; Joseph et al. 2020a,b,c,d, Joseph et al. 2021). Martian algae, fungal, lichens and spherical puffballs have also been observed in association with veins of calcium and/or oxalate (Joseph 2020d; 2021) and with what appear to be mycelium, hyphae and dimpled photobionts that are encrusted with a white substance reminiscent of calcium oxalate whewellite (Figures 45-50).

Oxalate crystals are produced extracellularly along fungal wall surfaces, within the lichen medulla (Gadd 1999; de la Torre Noetzel & Garcia 2020) especially when exposed to dry or extreme surface conditions (Russ et al. 1996) and may form sheaths that envelop, surround and encrust the hyphae and mycelium tangles (Russ et al. 1996; de la Torre Noetzel & Garcia 2020) and in so doing forming a crystaline-tetragonal encrusted appearance (Gadd 1999; Glasauer & Gadd, 2013). Lichens exposed to Mars conditions produce calcium oxalate. As documented in sequential photos from Mars, spherical specimens resembling lichens, fungi and puffballs appear to be secreting or have become encased in or to be shedding whewellite and/or leprose/crustose (Figures 43, 52, 56-60; Joseph et al. 2021). Moreover, what may be oxalate has been observed to surround networks of Martian hyphae, mycelium, and fruiting bodies; and, as documented in sequential photos, filling in and covering what appear to be dimpled-donut shaped fruiting bodies or photobionts (Figures 45-50; Joseph et al. 2021).

Figure 39: Sol 304: Calcium biosignature within a rock crevice. Note holes produced in thick layers of calcium via oxygen release due to photosynthesis.

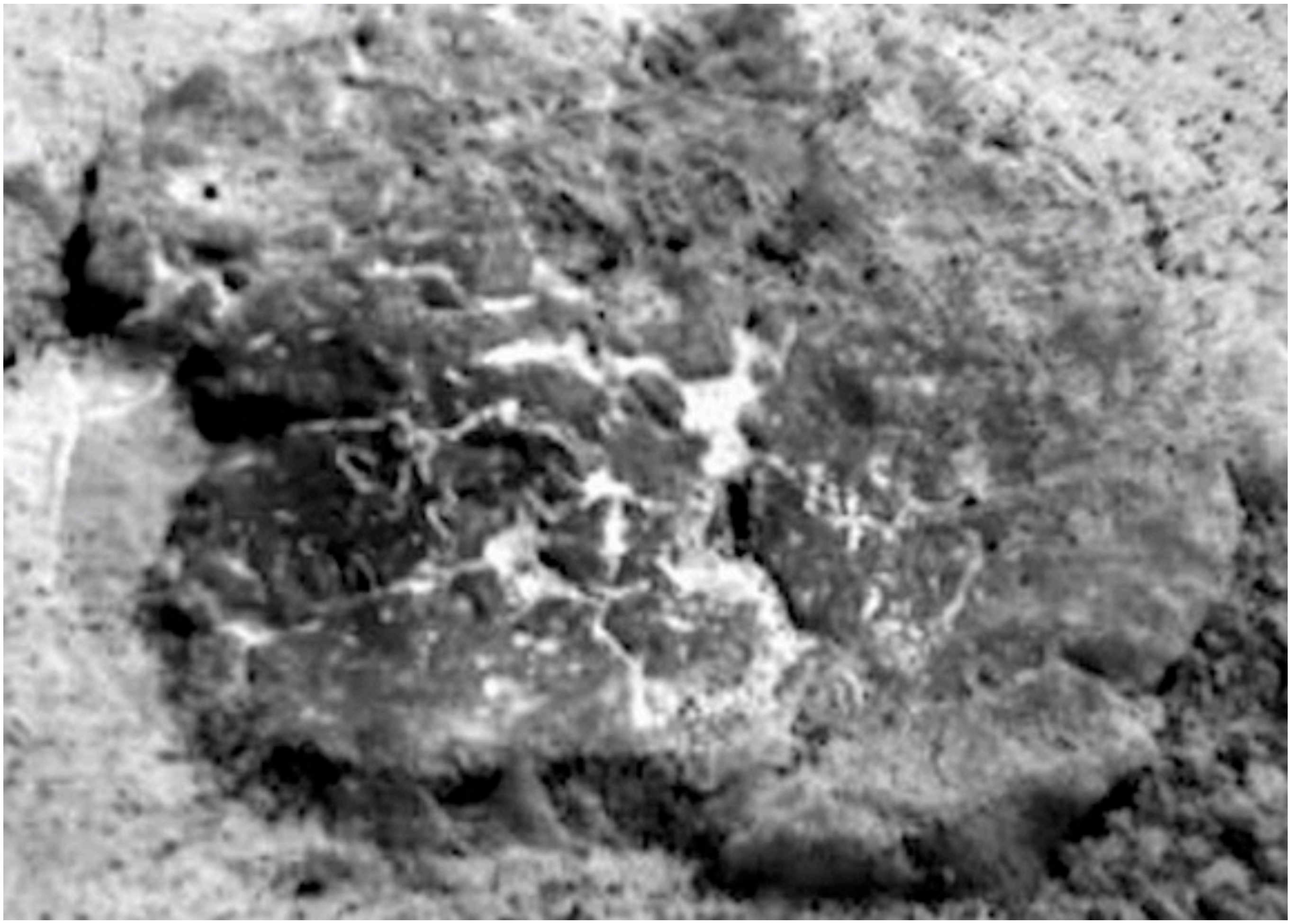


Figure 40: Sol 890: Calcium deposits within a microbial mat presumably fashioned by photosynthesizing algae. Note holes produced in veins/layers of .calcium via oxygen release due to photosynthesis.

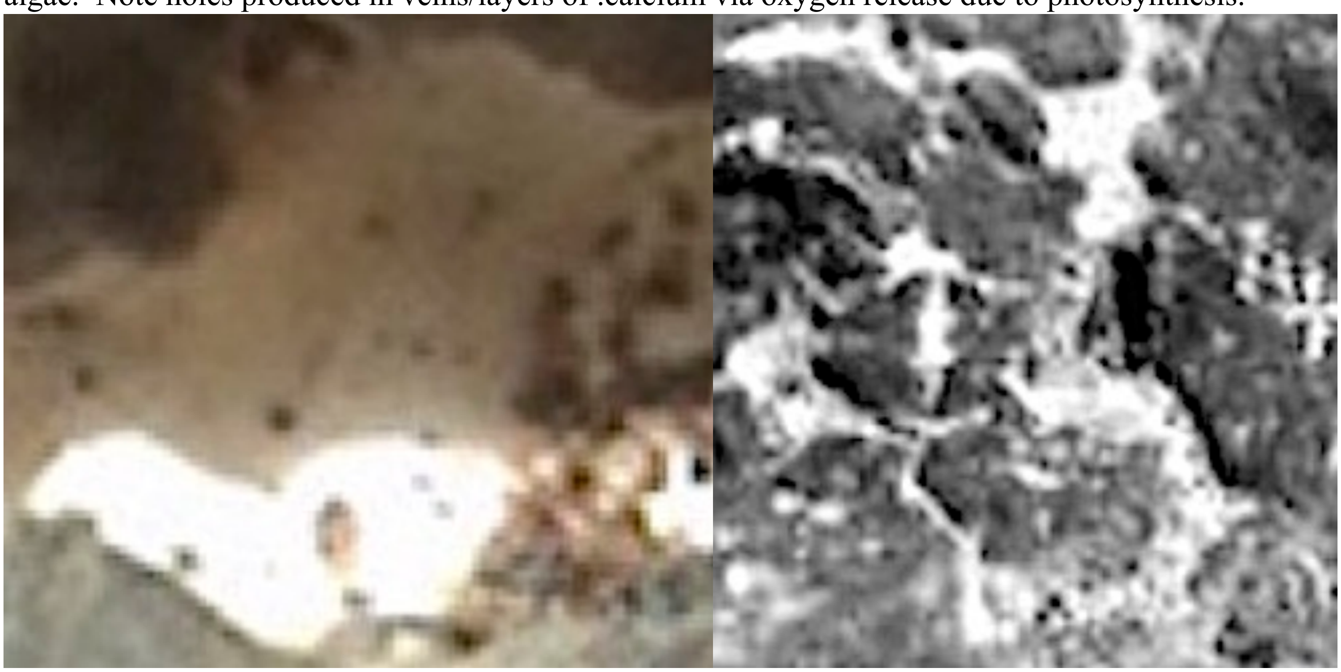


Figure 41: Sol 304 & Sol 890: Enlarged. Note oxygen-holes produced in veins/layers of calcium.

Figure 42: CR0_473216607PRC_F0442414CCAM02853L1. Calcium carbonate encrusted cyanobacteria (similar to *Nostoc flagelliforme)m* spherical "Nostoc balls," and vesiculous thalli (large and small micritic clots) possibly due to intracellular Ca- carbonates bio-mineralization or to calcification of extracellular calcium oxalate substances which have form calcified sheaths which surround and has embedded cyanobacteria. Note numerous oxygen vent created secondary to oxygen photosynthesis and gas release.

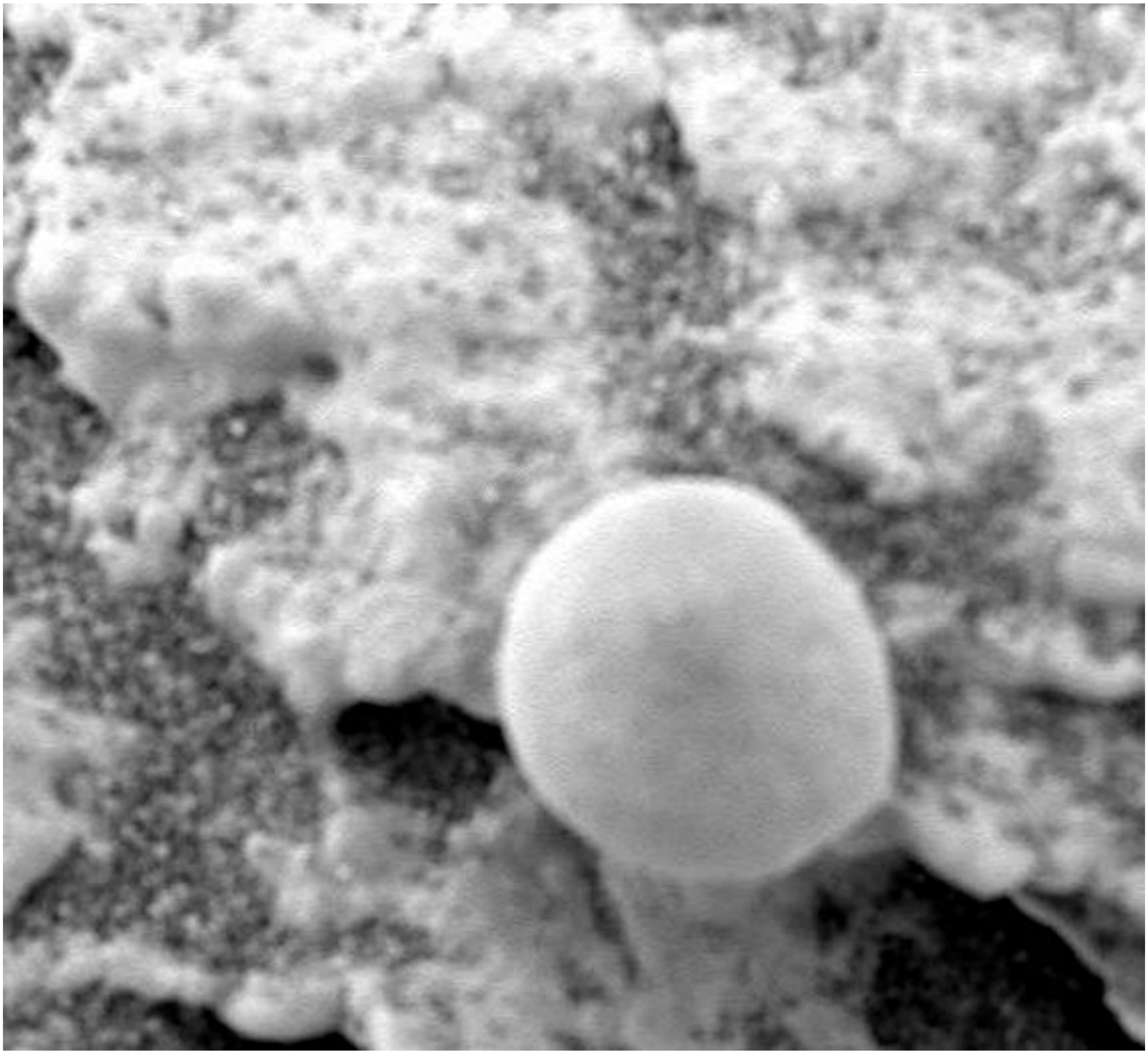


Figure 43: A lichenized fungus “cemented” into a calcium oxalate matrix. Calcium oxalate is synthesized during photosynthsis and is related to high levels of iron and mineral uptake following “liqufication” via oxalate acids. Note numerous holes like produced via oxygen gas release. Because calcium oxalate will under cementation when exposed to dry surface conditions, coupled with iron uptake, this specimen may have become solidified and fossilized and thus “harder than rock.”

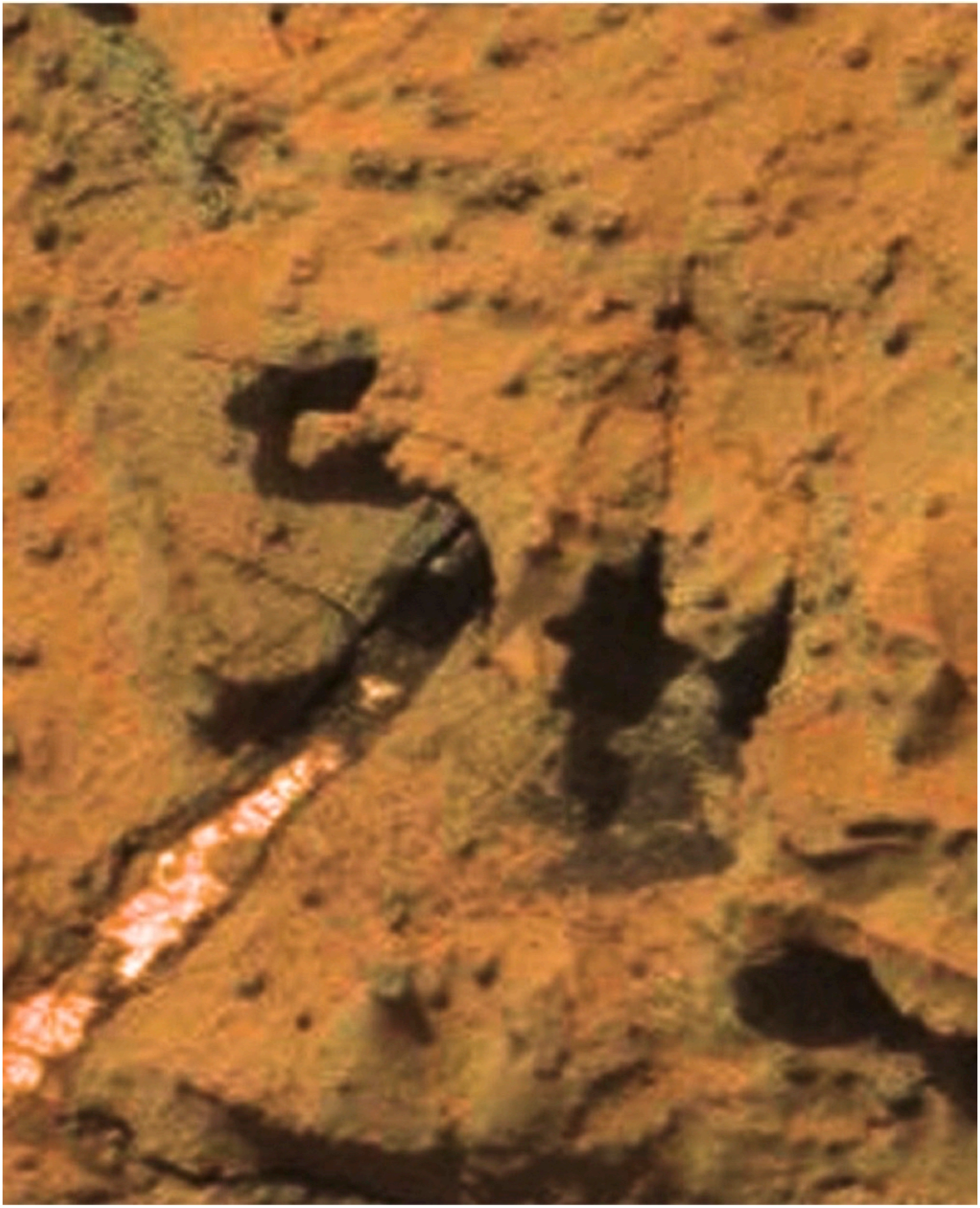


Figure 44: Sol 298: Specimens similar to dimpled ooids and algae (cyanobacteria) on the surface and interior of a Martian rock. The white deposit may consist of calcium or gypsum, which are associated with cyanobacteria.

Figure 45: Sol 298. Specimens similar to spherical ooids, dimpled lichens, green-blue-green-algae (cyanobacteria) and colonies of tubular algae-like organisms within the rock crevice. The thin white tube-like formation flowing downward (framed in red) is enveloping the bulbous specimen which may be a fruiting bodies. The white substance likely consists of calcium oxalate which is produced via the mucous secretions and metabolic activity of lichens and fungi.

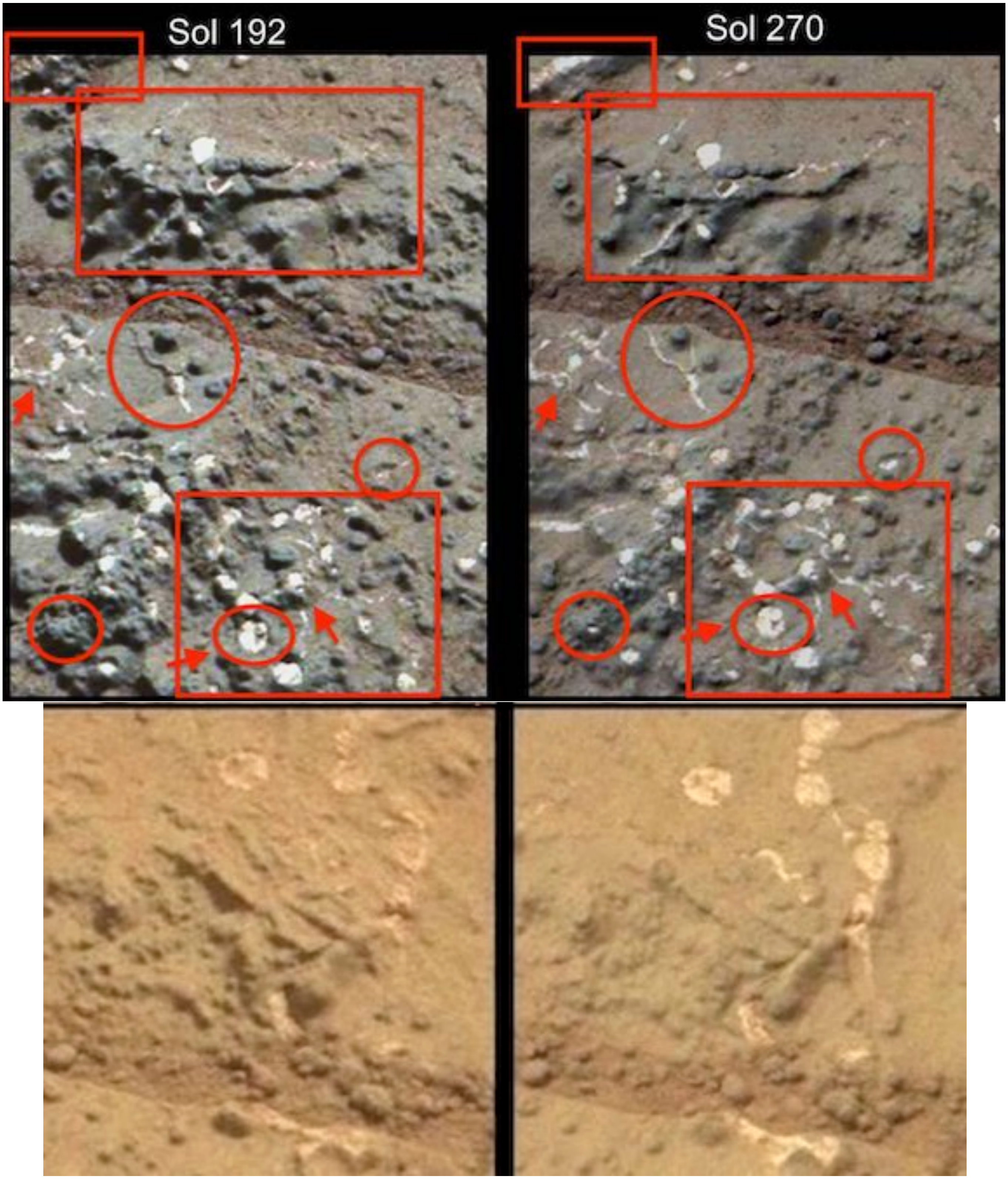


Figure 46: Growth. Sol 192 (**left column**) Sol 260 (**right column**). White specimens resembling plasmodium, bulbous fruiting sporangia and interconnected networks of mycelium and hyphae calcified with calcium oxalate crystals (weddelite). The dimpled specimens may be fungi, lichens or photobionts

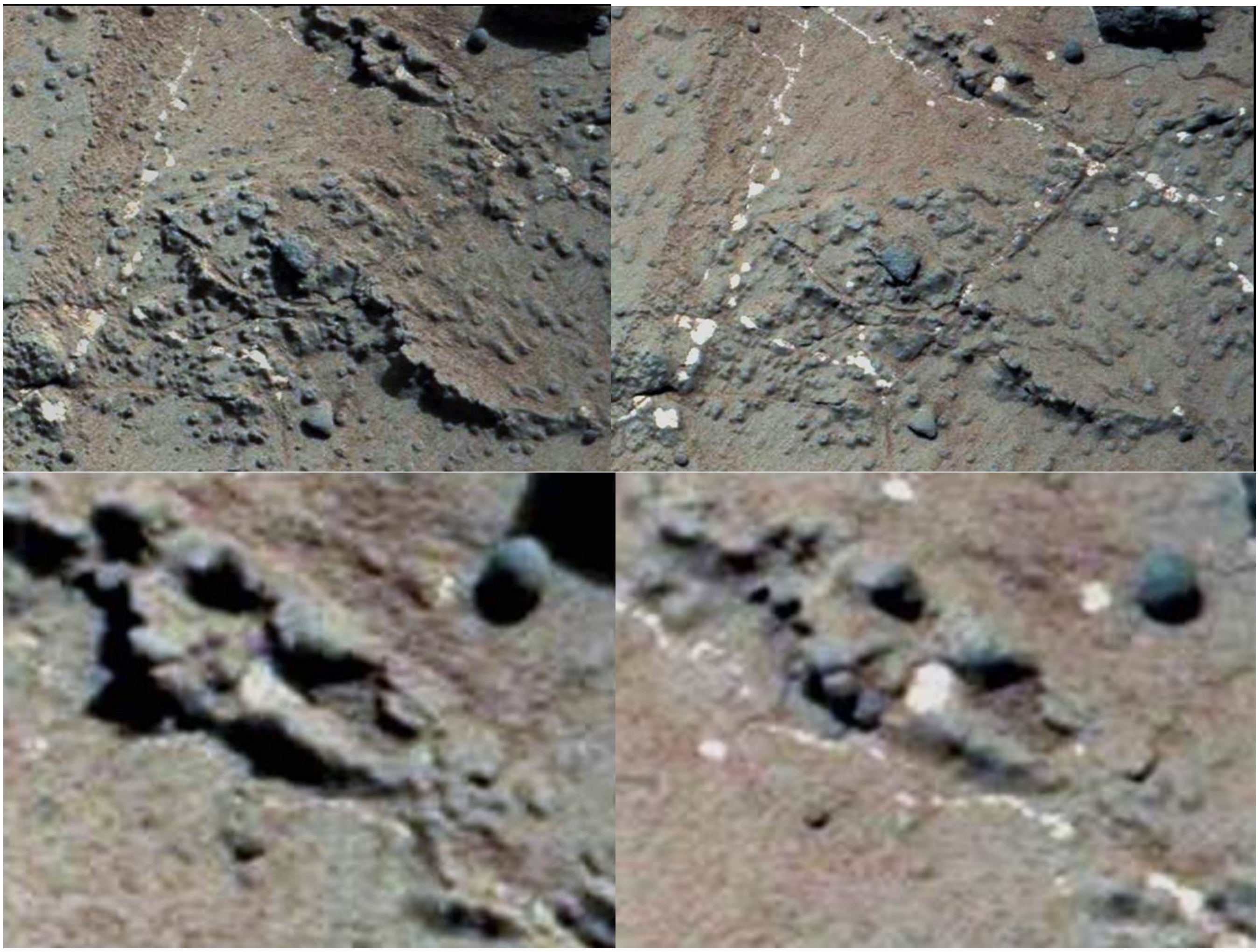


Figure 47: Growth. (Left Column) Sol 192 (Right Column) Sol 270

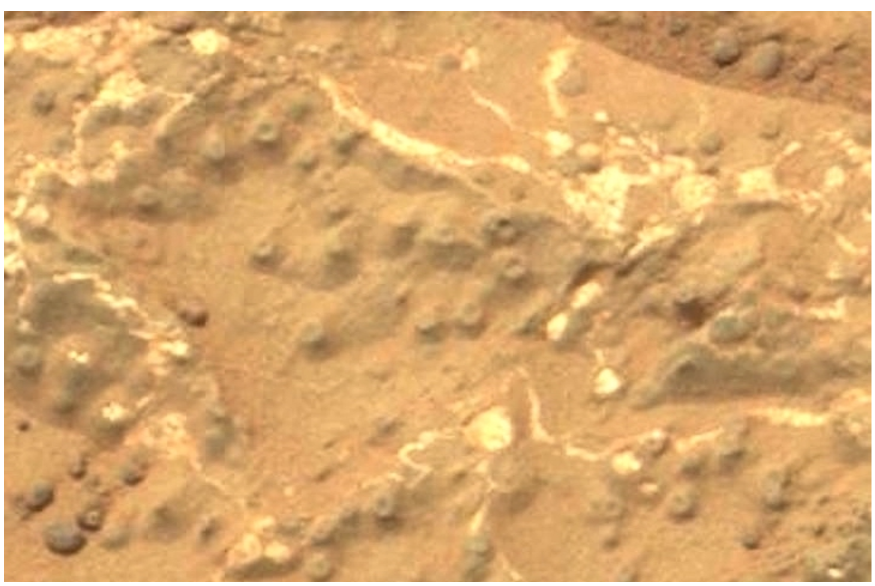


Figure 48: Sol 270 White specimens resemble plasmodium, the bulbous fruiting sporangia and interconnected networks of mycelium and hyphae calcified with calcium oxalate crystals (weddelite). The dimpled specimens may be fungi or Photobionts.

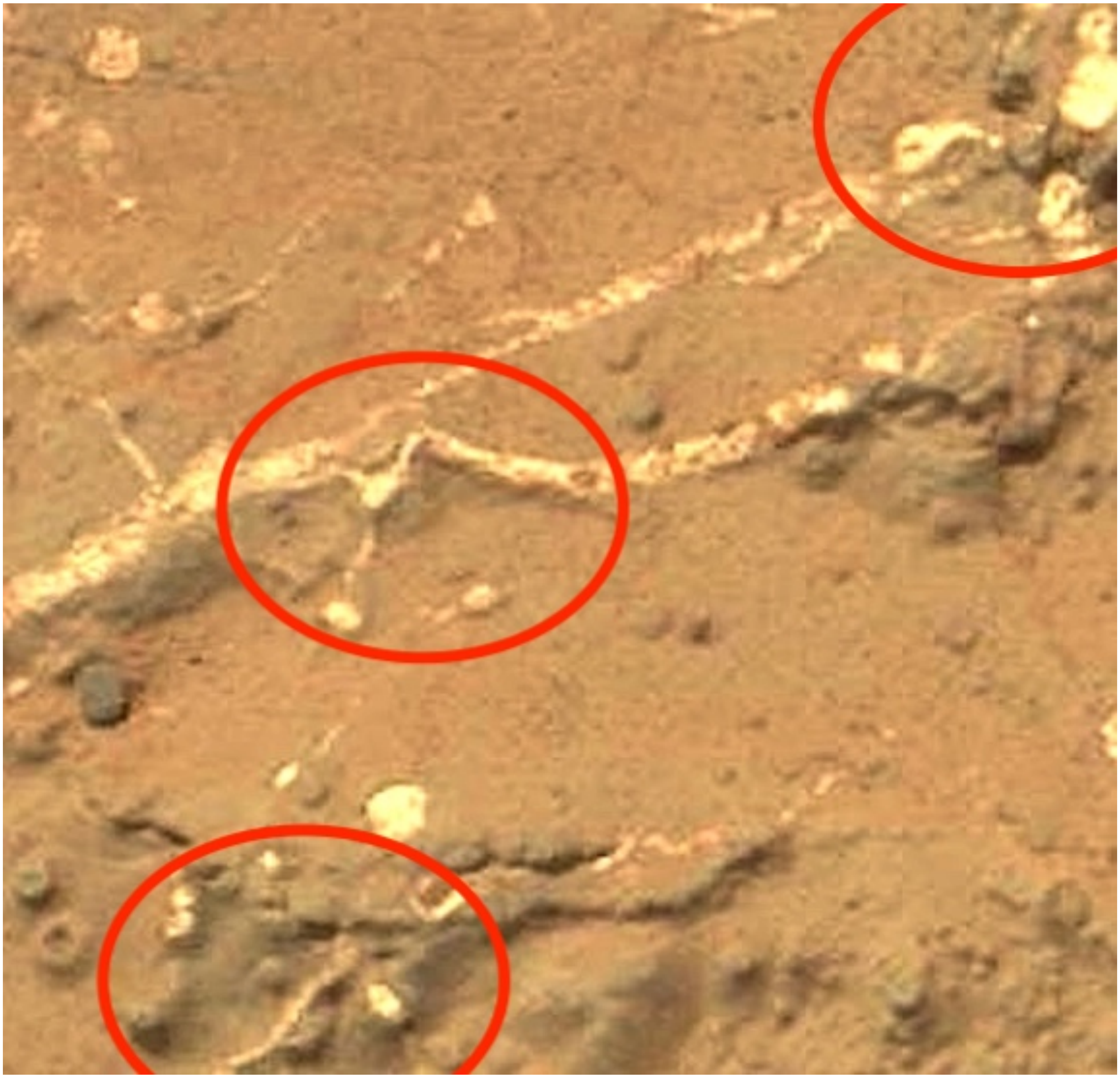


Figure 49: Strands that snake across and sometimes rise above the surface. These appears to calcified fungal mycelium or encrusted plasmodium and protoplasmic tendrils punctuated with fossilized bulbous fruiting bodies (sporangia) that have become encrusted and seemingly calcified with calcium oxalate crystals (whewellite/weddelite) which is secreted by fungi and lichens.

Figure 50: Sol 270 Donut-shaped fungi/lichens or photobionts --approximately 1-2 mm in size-- adjacent to networks that resemble plasmodium and bulbous fruiting sporangia which have become encrusted with calcium oxalate.

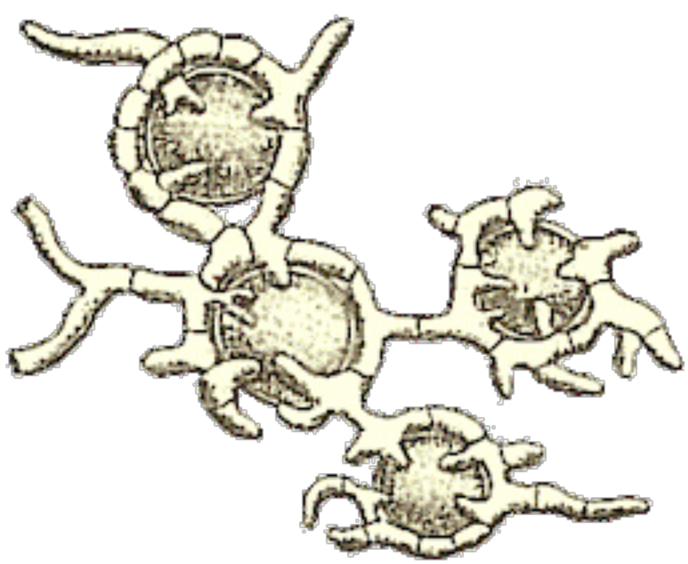


Figure 51: Fungal hyphae 'harvest' nutrients produced by the photobiont via fungal hyphae branching and encircling and penetrating a number of globose photobiont cells in order to harvest the photosynthetic products. From Schneider (1987).

10. Oxalate Acids, Whewellite & Calcium "Cement" Concretions

Cyanobacteria/algae produce calcium (Gadd 1999; Graustein *et al.,* 1977; Verrecchia, 1990) and terrestrial lichens and fungi secrete calcium saturated oxalate acid that may be transformed into calcium oxalate monohydrate crystal and calcium-cement (Ascaso *et al.* 1982; Russ et al. 2013; Gadd, 1999; Glasauer & Gadd, 2013). When exposed to environmental extremes and dry conditions, these oxalate accretions may form a hard, wavy, whewellite-calcium-phosphate-cement-like-crust which becomes harder than rock (Del Monte et al. 1987; Russ et al. 1995, 1996).

Mars is iron-rich (Boynton et al., 2008; Brückner et al., 2008) and upon oxidation the primary product is ferric (Fe^{3+}) iron and which is found in Martian volcanic rock and numerous minerals including Fe(II)-bearing basaltic rocks and pyroxenes (Arvidson et al., 1989; Bibring and Langevin, 2008; Christensen et al., 2001). Iron oxides provide metabolic energy for iron-cycling organisms, including algae, lichens, and fungi (Conorton et al. 2017; Wang & Pantopoulos 2011); species which can oxidize numerous organics and minerals thereby reducing ferric iron (Aisen et al. 2001; Lloyd, 2003). Ferric iron is the terminal electron acceptor for numerous organisms (Lloyd, 2003; Aisen et al. 2001).

Lichens have high levels of iron uptake. Colonies of lichens living in iron-rich environments may produce waves of oxalate-whewellite-calcium-enamel that builds on surrounding surfaces forming a whewellite cement (Del Monte et al. 1987; Glasauer & Gadd, 2013). As noted terrestrial lichens exposed to Mars-like conditions also produce what appears to be copious amounts of whewellite (de la Torre Noetzel & Garcia 2020).

Spherical Martian puffballs (basidiomycetes) have been identified by over 30 experts in fungi, lichens, and geomorphology (Joseph 2016; see also Dass, 2017); a view endorsed by several teams of international experts (Joseph et al. 2019, 2020a,b,c, 2021). Terrestrial spherical basidiomycetes and their interwoven hyphae secrete and become encrusted with oxalate crystals (Gadd 1999). Calcium and/or Calcium Oxalate-crustose like crystal coatings have also been observed on Martian spherical specimens identified as basidiomycetes (Figure 52, 56-60; Joseph 2021).

Gray spheroidal-cement-like concretions embedded in wavy-cement-calcium-like substrate have been observed in Eagle Crater (Bell et al. 2004; Squyres et al. 2004; Herkenhoff et al. 2004) and described as "harder than surrounding rock" (Squyres et al. 2004). The Opportunity team proposed that these gray spheroids had undergone "cementation" and had somehow became embedded in these waves of "cement" (Herkenhoff et al. 2004). What this "cementation" consist of was never determined by the Opportunity team other than to point out that these spheres and "cement" had a composition distinctly different from the underlying substrate (Herkenhoff et al. 2004).

Oxalate builds up on the external surface of the organism and infiltrates soil, sandstone and limestone crust, and dissolves Fe and other minerals, which in turn provide nutrients to the entire community of organisms (Chen et al. 2000 Freidmann 1982; Johnston & Vestal 1993; Weed & Norton 1991; Hen & Gong 1995) including, possibly, the algae symbiote; and which may promote photosynthesis. And it may form a calcium-oxlate "cement" particularly when exposed to a prolonged dry surface conditions and environmental extremes--such as would be encountered on iron-rich Mars.

It is unproven but reasonable to assume that Martian lichens and fungal puffballs (basidiomycetes) also produce oxalate/whewellite which may "cement" surrounding surfaces. In response to long periods devoid of moisture, it is possible that not just the substrate but the iron- and oxalate/ whewellite saturated lichen/puffballs may die, become harder than rock and fossilized. This would account for the gray spheroidal-cement-like concretions embedded in wavy-cement-like substrates that have been described as harder than rock (Figures 56-60). These are not unexplainable anomalies but additional evidence of life on Mars.

Figure 52: Sol 257: Evidence of what may be leprose, crustose, or the secretion of calcium oxalate "cement."

Figure 53: Terrestrial crustose lichen embedded in Whewellite calcium oxalate “cement.”

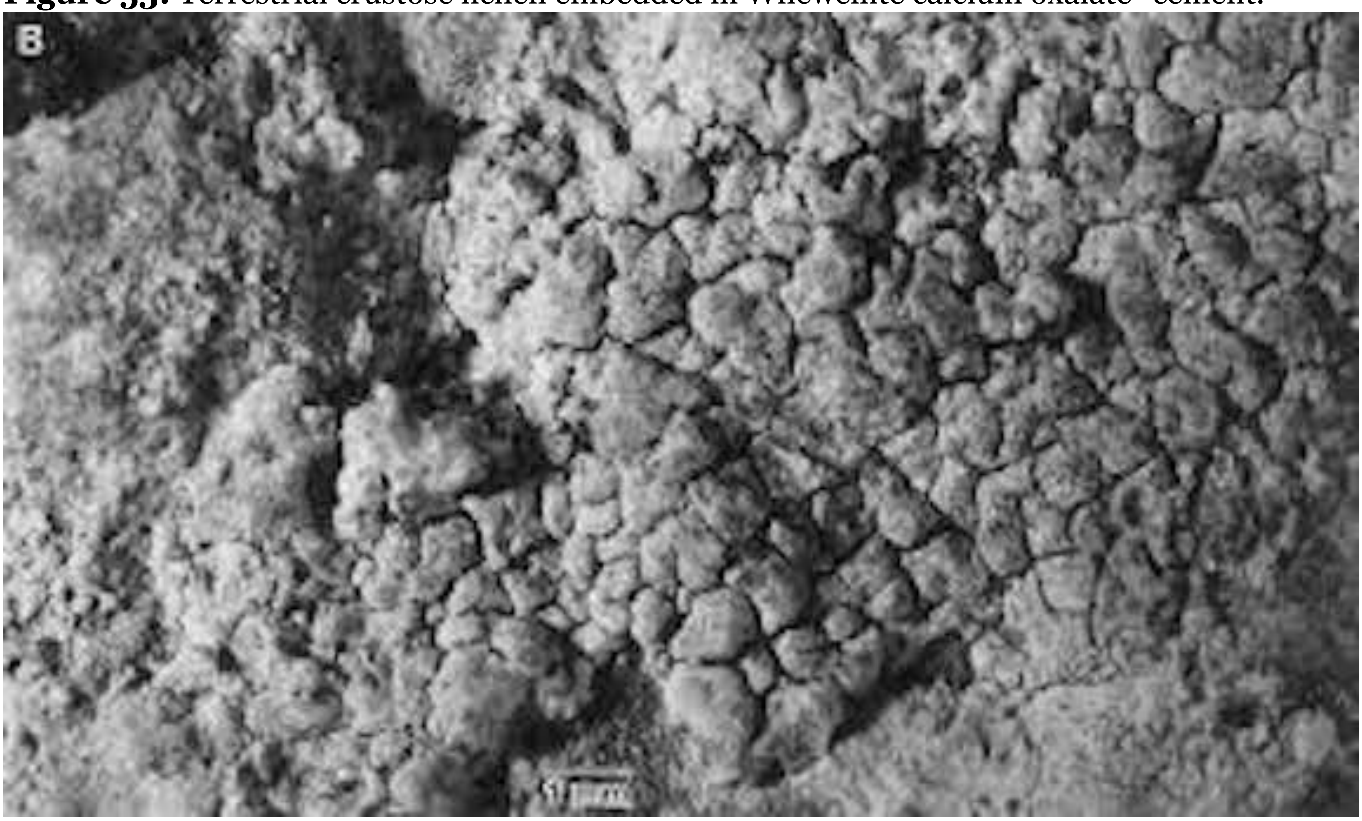


Figure 54: Whewellite-Rich Rock, Southwest Texas (from Jon Russ, et al. 1999).

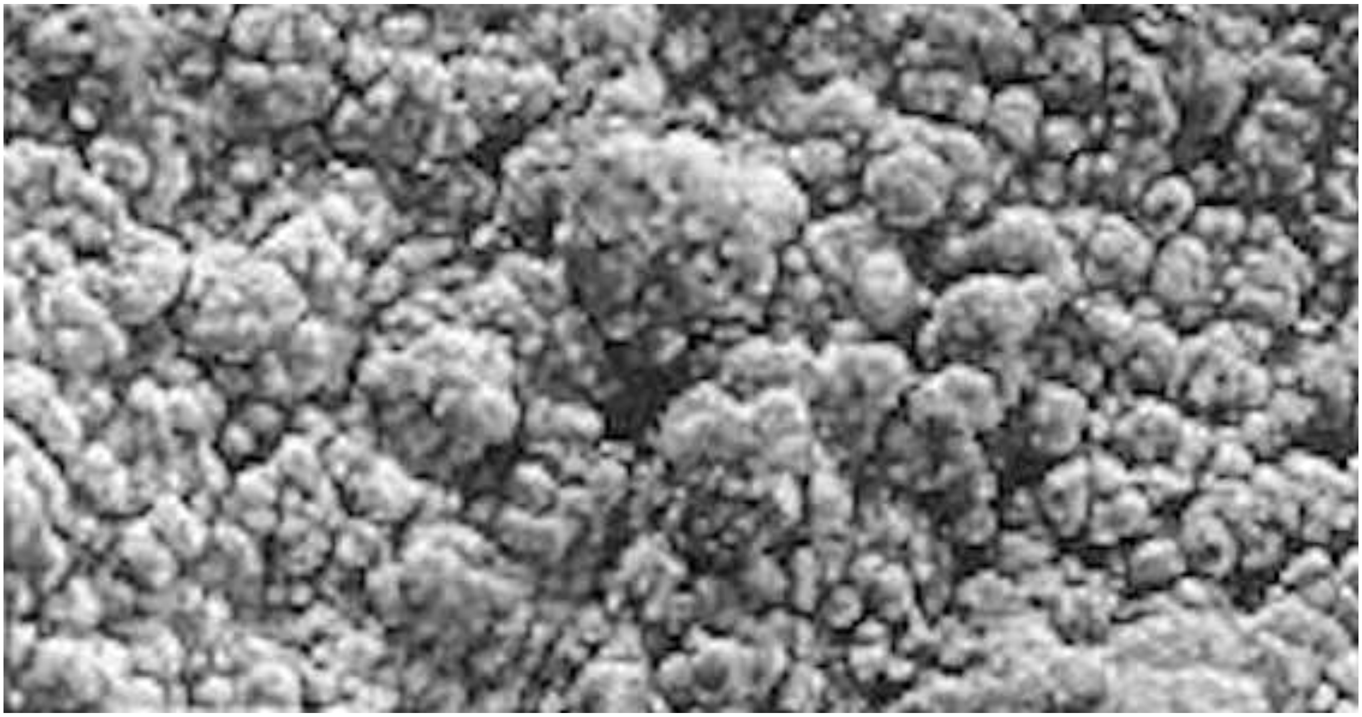


Figure 55: Whewellite-Rich Rock, Southwest Texas (from Jon Russ, et al. 1999).

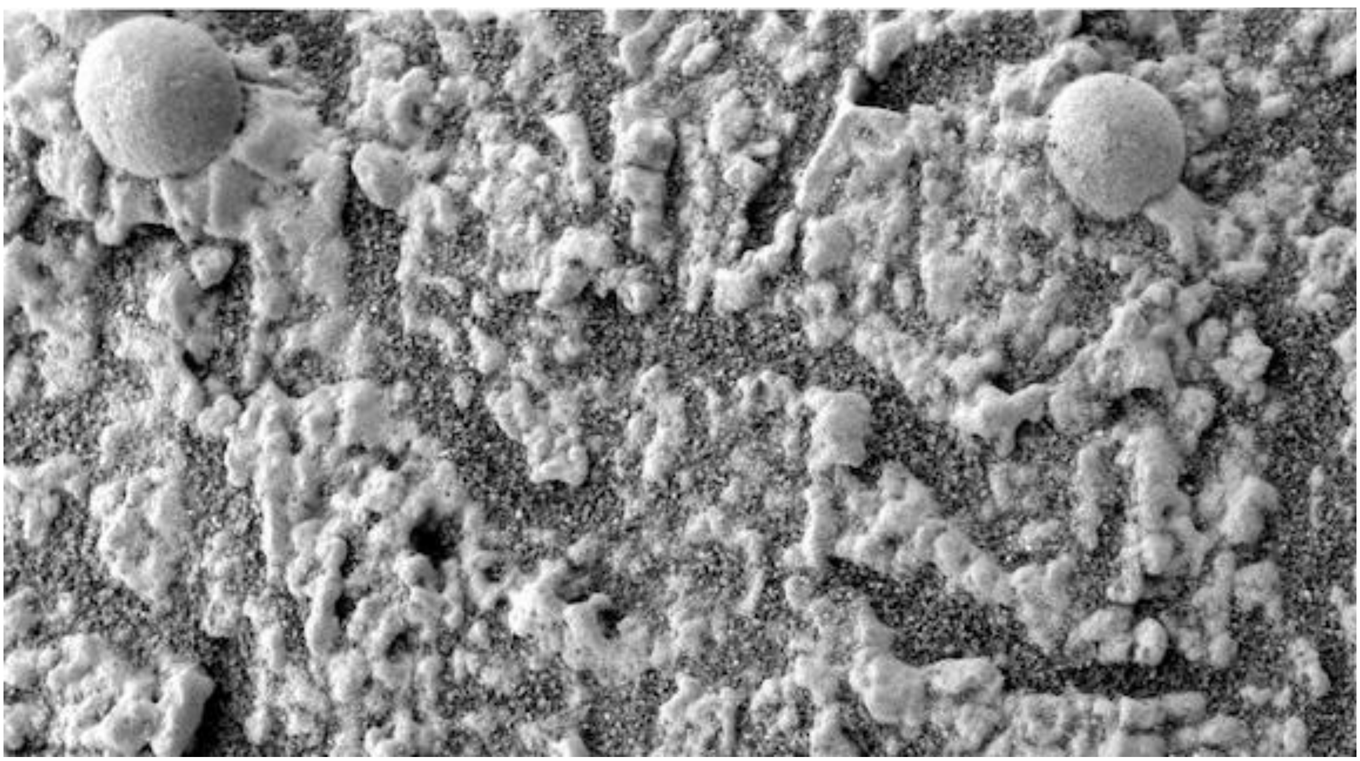


Figure 56: Sol 29. Martian organisms embedded in calcium-oxalate-like "cement."

Figure 57: Sol 39. Martian organisms embedded in calcium-oxalate-like "cement."

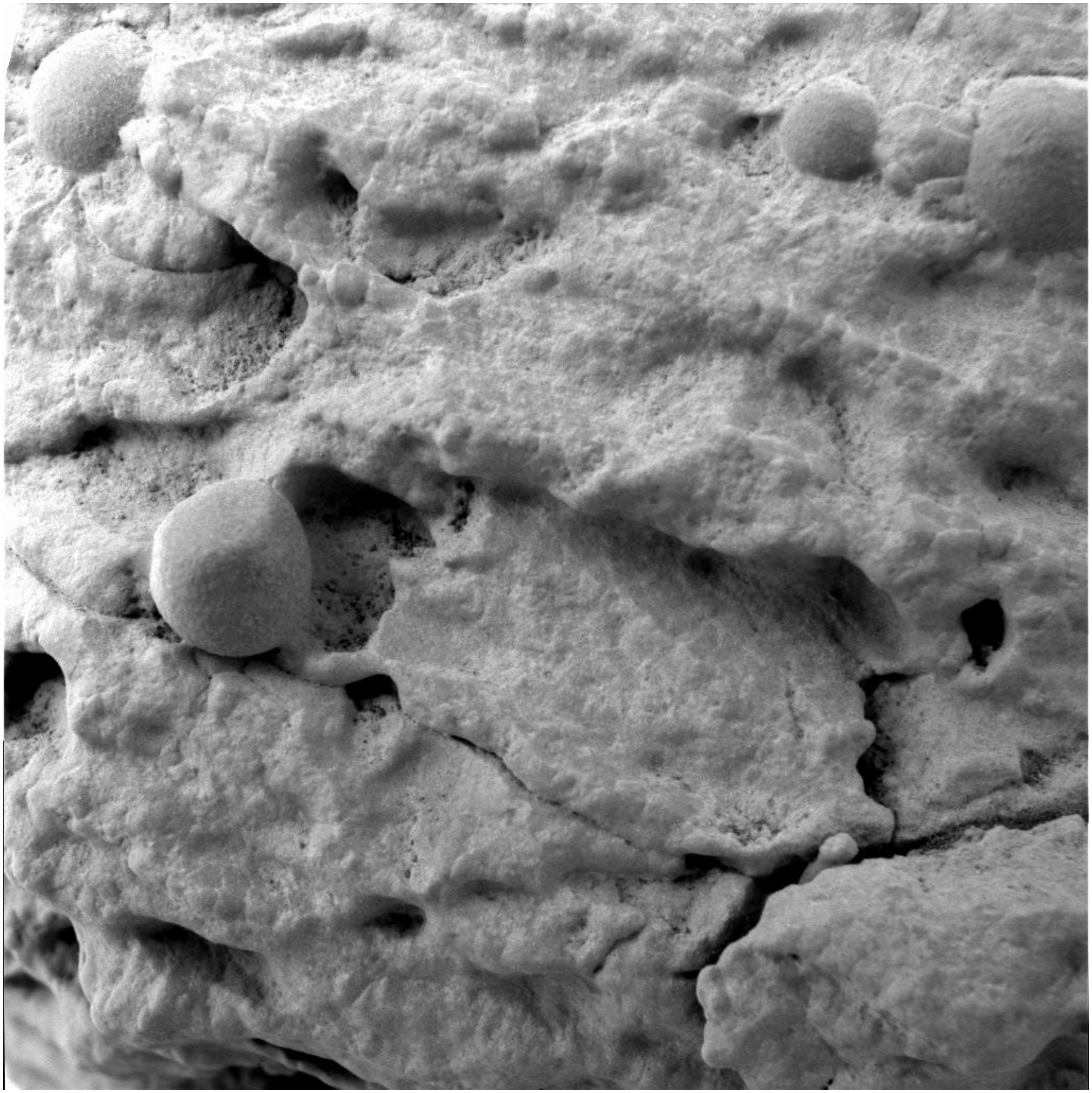


Figure 58: Sol 39. Martian organisms embedded in calcium-oxalate-like "cement."

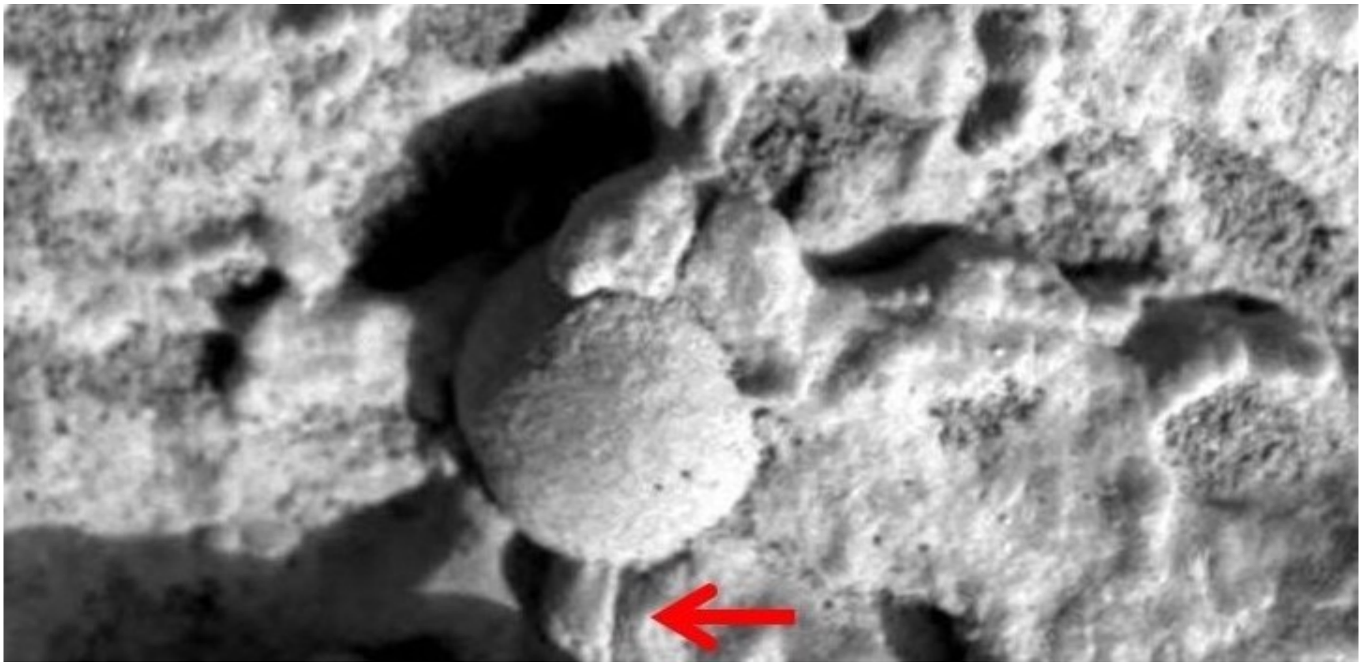


Figure 59: Sol 41. Martian organism embedded in calcium-oxalate-like “cement.”

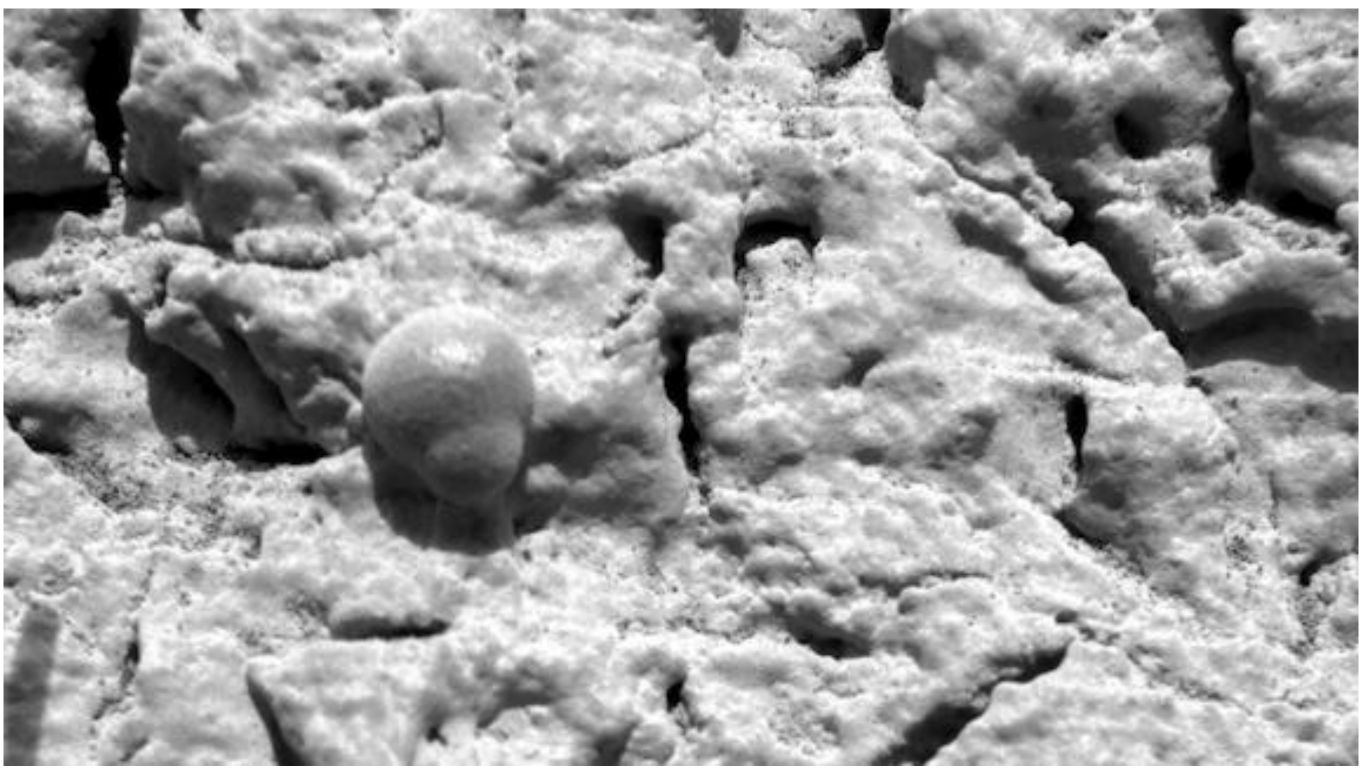


Figure 60: Sol 28. Martian organism embedded in calcium-oxalate-like “cement.”

III. BIOLOGY OF THE RADIATED IRON-RICH RED PLANET

11. Overwhelming and Conclusive Evidence of Life on Mars

The Evidence for life on Mars is pervasive and includes **(1)** fossilized stromatolites, microbial mats, tube worms, metazoans, and calcareous algae (Baucon et al 2020; Bianciardi et al 2014; Joseph 2014a; Joseph et al 2020d,e,g); Kazmierczak 2016, 2020; Noffke 2015; Rabb, 2018; Rizzo et al. 2020; Ruff & Farmer 2016; Small 2015); **(2)** biological residue discovered in Martian meteorites (Thomas-Keprta, et al. 2009; McKay et al. 2009); **(3)** living organisms including algae, fungi, and lichens (Dass 2017, Joseph 2014a 2016; Joseph et al. 2019, Joseph et al 2020a,b; Krupa 2017; Levin et al. 1978; Levin & Straat 2016; Rabb 2018, Small 2015); **(4)** biological activity detected in Martian soil samples (Levin & Straat 1976, 1977, 2016); **(5)** the consensus of 70 experts who agreed fungi were growing on Mars (Joseph 2016); **(6)** over a dozen puffballs that increased in size and emerged from beneath the soil in just three to seven days (Joseph et al. 2019, 2020a,b,c); **(7)** spheres and stemmed-mushrooms which emerged in old tire tracks formed by the rover Opportunity (Joseph et al. 2021); **(8)** massive black araneiforms that emerge in the Spring, grow rapidly, and then rapidly wane in the Autumn and Winter only to re-emerge the following Spring; and which most likely represents the growth of massive colonies of black fungi, lichens, algae, methanogens, and sulfur reducing organisms (Ganti et al. 2003; Ness, 2001; Joseph et al. 2020e, 2021; Kereszturi et al. 2012); **(9)** sequential images of black fungal bacterial growth on the rovers (Joseph et al. 2019s, 2020a, 2021); **(10)** sequential photos documenting fungal growth, multiplication, shape-shifting, disappearance, and movement to new locations (Joseph et al. 2021); **(11)** the continual replenishment and Spring/Summer increases in atmospheric methane and oxygen which parallels the biological production of oxygen and methane on Earth (Joseph et al. 2019, 2020a,b,c); **(12)** and vast colonies of lichens attached by hollow stems to rocks and topped by bulbous caps oriented skyward and which are nearly identical to photosynthesizing lichens on Earth (Joseph et al. 2019, 2020a,b,c).

As noted, it is well documented that terrestrial fungi, algae, and lichens can survive prolonged exposure to Mars-like environment. For example, De la Torre Noetzel and colleagues (2017) also exposed the lichen *Xanthoria elegans* to simulated Mars-analogue conditions for 1.5 years including direct exposure to ultraviolet (UV) irradiation, cosmic radiation, temperatures and vacuum conditions. It was found that the lichen photobiont (algae) showed an average viability rate of 71%, whereas 84% of the lichen mycobiont (fungi) survived--although they were adapted to and evolved on Earth. Moreover, 50-80% of alga and 60-90% of the fungus symbiote demonstrated normal functioning (Brandt et al.

2015). This included the ability to engage in photosynthetic activity post-exposure to these harsh environments with minimal impairment (Meesen et al. 2014).

Given these high rates of survival among organisms that evolved on Earth, it is reasonable to assume Martian organisms would not just survive but long ago evolved the ability to utilize the iron-rich radiation intense environment of the Red Planet so as to enable them to flourish. As will be detailed in the following sections, Martian organisms need not have evolved unique characteristics alien to Earth but only to adapt their cellular biology to take advantage of prevailing conditions.

12. Biology of the Iron Red Planet

Spectroscopic data from surface and orbital missions have indicated the presence of ferric (Fe^{3+}) iron across numerous mineral phases throughout the surface of Mars, including ferric oxides, iron oxides, magnetite, and crystalline hematite (Arvidson et al., 1989; Bibring and Langevin, 2008; Bru¨ckner et al., 2008; Christensen et al., 2001, 2008; Klingelho¨fer et al., 2004; Morris et al., 2006; Poulet et al., 2007; Ruff et al., 2008). Hydrated mineral phases have also been observed including sulfate (Klingelho¨fer et al., 2004; Gendrin et al., 2005; Milliken et al., 2008) which plays a significant role in the biological reduction of iron via iron-sulfur (FeS) proteins and metabolic enzymes (Conorton et al. 2017; Kobayashi and Nishizawa 2012). Iron oxides provide metabolic energy for iron-cycling organisms, including algae, lichens, and fungi (Conorton et al. 2017; Wang & Pantopoulos 2011); species which oxidize numerous organics and minerals thereby reducing ferric iron (Aisen et al. 2001; Lloyd, 2003). Ferric iron is the terminal electron acceptor for numerous organisms (Lloyd, 2003; Aisen et al. 2001).

Terrestrial organisms require iron, the metabolism of which, in plants, lichens, algae, plankton and diatoms, promotes the formation of chlorophyll and oxygen respiration photosynthesis (Sunda & Huntsman, 2015; Gevais et al. 2002; Conorton et al. 2017; Briat et al. 1995, 2015; Aisen et al. 2001) and enhances their tolerance to environmental extremes (De Conti et al. 2020). Almost all cells employ iron as a cofactor for oxygen transport, energy metabolism and DNA synthesis (Aisen et al. 2001; Briat et al. 1995; Conorton et al. 2017; Kobayashi & Nishizawa 2012). The chemistry and redox reactivity of iron makes it ideal for binding proteins and oxygen, and for electron transfer and the mediation of numerous catalytic reactions (Aisen et al. 2001; Kobayashi & Nishizawa 2012). Thus, the iron-rich low oxygen red planet is an environment in which a variety of organisms may flourish and dwell. Moreover, in low oxygen environments (such as Mars), high levels of iron can readily shuttle between oxidized ferric (Fe^{3+}) and reduced ferrous (Fe^{2+}) without any disruption of cellular redox equilibrium or negative reaction to oxidative stress (cf Galaris & Pantopoulos 2008; Wang & Pantopoulos 2011).

In fungi and lichens, iron enters via the mycelia and hyphae and is transported to the inner membranes and outward outer cortex. Lichens are mineral rich. The detection of "iron" in any form, on the surface of Mars, may be a biosignature of life.

Mars is mineral, metal, and iron-rich (Boynton et al., 2008; Bru¨ckner et al., 2008) and upon oxidation, the primary product is ferric (Fe^{3+}) iron and which is found in volcanic rock and numerous minerals including Fe(II)-bearing basaltic rocks and pyroxenes (Arvidson et al., 1989; Bibring and Langevin, 2008; Christensen et al., 2001). These different mineral phases are not due solely to oxidation, but weathering (Bibring and Langevin, 2008; Christensen et al., 2008); including biological weathering (Budel et al, 2004: Chen et al. 2000; Johnston & Vestal 1993; Hen & Gong 1995). Biologically, Fe^{2+} is utilized for reducing and may be oxidized to Fe^{3+} which is utilized for chelating (Kobayashi & Nishizawa 2012). Thus Fe^{2+} and Fe^{3+} are interactive and complimentary and enhance the viability of terrestrial and Martian organisms.

13. Iron, Hematite, Lichens & Oxalate

Oxalate acids infiltrate soil, sandstone and limestone crust, and dissolves Fe and other minerals, which provide nutrients to the entire community of organisms (Chen et al. 2000 Freidmann 1982; Johnston & Vestal 1993; Weed & Norton 1991; Hen & Gong 1995). Mineralization of oxalate also releases free aqueous metals, which precipitate as Fe and Mn oxides (Johnston & Vestal 1993; Ugolingi 1986). Lichen acids have polar groups (COOH, CHO, and OH) that induces water-soluble-metal complex formation (Ugolingi 1986). Hence, oxalate complexes are soluble, will become hydrated, and may leak deeper into the rock or into the surrounding soil, and may be carried upward and deposited on the surface of the rock, via capillary action, when water is depleted (Johnston & Vestal 1993). In consequence, Fe, A1, and Mn oxides, as well as hematite may be carried outward and accumulate at around these lichen-dominated rocks and soil (Johnston & Vestal 1989; Weed & Norton, 1991; Hen & Gong 1995).

High concentrations of iron is a lichen characteristic (Bajpai et al. 2009; Hauck et al. 2007). Many species feed on iron. It can be predicted that the lichens and fungi observed on the iron-rich red planet likely have a greater uptake of iron as compared to terrestrial species. Hence, on Mars, spectral signatures associated with various metals, oxides and minerals may reflect the high metal/mineral content of Martian organisms.

14. Martian Metal Biosignatures: Hematite & Lichen/Fungal Biochemical Mineral Iron Uptake

Lichens via the secretion of oxalate acids dissolve minerals and metals. Like a variety of plants (Connorton et al. 2017; Parajuli & Chettri 2020) they uptake and store iron, hematite and Fe^{2+} and Fe^{3+} ions (Backor & Loppi, 2009; Backer & Fahselr 2008; Kobayashi & Nishizawa 2012; Puckett et al. 1973; Marie et al. 2016). In fungi and lichens, iron enters via the mycelia-hyphae and is transported to the inner membranes and the outer cortex of the mycobiont cell walls where it may be bound and stored within or on the surface of the endodermis, epidermis, exciple and epithecium (Backor & Loppi, 2009; Collins and Farrar, 1978; Kasama et al. 2003). However, the mycobiont (fungus) and its hyphae, which makes up approximately 90 % of total lichen biomass, accumulates most of these heavy metals (Backor & Loppi, 2009) which may then be distributed to the photobiont.

Fe^{2+} and Fe^{3+} ions are employed by the photobiont's (algae's) extracellular tissues for the generation of melanin, chrophyll and photosynthesis (Backer & Fahselr 2008; Connorton et al. 2017; Hauck et al. 2009; Kobayashi & Nishizawa 2012; Mehra & Farago 1994; Kasama et al. 2003). Iron and other metals are essential for algal, fungal and lichen metabolism which is why lichens often colonize iron-rich rocks and metal saturated environments (Beck 1999; Purvis & Halls, 1996).

Lichens have a high capacity for metal and mineral deposition, and the concentration of Fe and other metals appears to directly correspondence to the amount of metal in colonized sites (Brodo, 1973; Looney et al., 1985; Lange and Ziegler, 1963; Pandey & Upreti 2000). Lichens may become metal-rich reservoirs (Singh et al. 2013). Lichens are not only metal rich, but are excellent biological indicators signifying the presence of iron, magnetite, and hematite in soil and rock (Paukov et al. 2015; Marie et al. 2016) and within and upon their cellular walls.

Given the iron-rich conditions of Mars, this raises the possibility that Martian lichen and fungi may be supersaturated with iron. Hence, the detection of iron and spectral signatures assumed to indicate hematite would also be an indicator of the presence of lichens and associated bio-communities including fungi and algae; especially on Mars. Moreover, high concentration of iron, coupled with the secretion of calcium-oxalate "cement" might also make some of these Martian organisms much harder, stronger, and durable, and reducing flexibility as compared to terrestrial species. Once they die, the high iron content, plus calcium-cement, may contribute to fossilization; and as such some of those attached to rocks may remain intact and anchored to their substrate even after they die.

15. Red Planet Radiation, Iron & Melanin

Mars with its obviously oxidized iron-red surface appears to be an iron-electron receptor unlimited world with widespread readily available iron and sulfate electron donors. Mars is thus perfectly suitable for melanin and oxygen producing photosynthesizing organisms in a high CO_2 environment. Ferric (Fe^{3+}) (and ferrous Fe^{2+}) iron is widespread across the surface (Arvidson et al., 1989; Boynton et al., 2008; Bru¨ckner et al., 2008; Christensen et al., 2001, 2008; Bibring and Langevin, 2008); and ferric iron is the terminal electron acceptor for numerous organisms (Lloyd, 2003; Aisen et al. 2001).

Lichens, algae, fungi, and numerous species of iron-reducing microbes flourish in Fe^{2+}, crystalline-Fe^{3+} and hematite (Fe^2O^3) rich environments (Cornell and Schwertmann, 1996; Roden and Zachara, 1996). These include Shewanella (Kosta and Nealson, 1995)--a gram-negative, proteobacteria--that grows and feeds on hematite and respires on a variety of organic electron acceptors found in hematite (Bosea et al. 2009; Fredrickson et al. 2008, Gralnick & Hau 2007; Lowy et al. 2006).

The surface of Mars is a radiation intense environment. Lichens are symbiotic organisms consisting of an algae and fungus. Fungi thrive in and are attracted to radiation intense environments (Becket et al. 2008; Dadachova et al. 2007; Tugay et al. 2006; Wember & Zhdanova 2001).

Mars is an iron-rich planet. Via iron uptake the terrestrial fungi-lichen consortium synthesizes and produces melanins (Kasama et al. 2003) which provide a defense against UV radiation and other environmental stressors (Dadachova et al. 2007). Fe content is higher in melanized than in non-melanized species (Fortuna et al. 2017) It has been documented that the lower cortex of the lichen is heavily melanized and has high levels of Fe, and when deprived of the cortex there follows a sharp and significant decline in Fe and melanization (Fortuna et al. 2017).

There is a direct association between high levels of iron and melanization. Thus iron-rich Mars provides an environment that promotes melanization. Melanin protects lichens and fungi from radiation damage (Mirchink et al. 1972; Nosanchuk & Casadevall 2003; Saleh et al. 1988) and environmental extremes and low temperatures (Robinson 2001). This iron-melanin relationship also enables fungi to harness radiation which may be utilized as a source of "food" and metabolic energy (Dadachova et al. 2007). The same relationship would likely prevail on Mars.

16. Melanin, Photosynthesis, Radiation Intense Martian Environments

It is well established that melanized organisms are the dominating species in a variety of extreme environments (Dighton et al. 2008; Robinson 2001; Wember & Zhdanova 2001) including soils saturated with radionuclides (Zhdanova et al. 2004). Simple eukaryotes including melanized fungi can withstand radiation doses up to 1.7×10^4 Gy (Saleh et al. 1988). This is well below Martian ground level radiation which has been estimated to range from "0.67 millisieverts per day" (Hassler et al. 2013) to 200 nm (Acuña et al., 1998)--well within the tolerance levels of a variety of prokaryotes (Moseley & Mattingly 1971; Ito et al. 1983) and eukaryotes including fungi (Dadachova et al. 2007; Novikova 2009; Tugay et al. 2006; Zhdanova et al. 1991, 2004) and lichens (De la Torre Noetzel et al. 2017; De la Torre Noetzel & Garcia 2020; Novikova et al. 2016). Melanin not only promotes survival, but photosynthesis in a variety of plants as well as lichens and algae.

It has also been repeatedly demonstrated that terrestrial lichens and fungi easily survive thermophysical Mars-like environments that simulate the atmospheric pressure, high CO_2 concentration, low temperatures, limited water availability, and reduced light of Mars (de Vera et al. 2010, 2014; Brandt et al. 2015; Onofri et al. 2012). For example, terrestrial lichens exposed to 22 day of Mars-like conditions not only remain viable but engaged in photosynthetic activity (de Vera et al. 2010; see also Onofri et al. 2012; de la Torre Noetzel et al., 2018). Likewise, the fungal and algae symbiotes that comprise the lichen consortium also survived; and if provided minimal shelter will rapidly adapt physiologically by increasing photosynthetic activity (de Vera et al. 2014). Those fully exposed to Mars surface simulation and Mars-like UV radiation with wavelengths >200 nm and Mars-like atmosphere also remained viable (89% of mycobionts and 79% if the photobionts) and regained 99% of their photosynthetic capabilities (Brandt et al. 2015) even when provided minimal water (Billi et al., 2011; Onofri et al., 2012; de Vera et al., 2014; de la Torre Noetzel et al., 2018). However, with long term 18-month exposure, terrestrial algae cells may begin to shrink in size (de la Torre Noetzel & Garcia 2020). It must be emphasized: these are organisms that evolved on and are adapted to terrestrial conditions, but which nevertheless survived Mars-like conditions. Certainly organisms that evolved on Mars would have enhanced survival capabilities far in excess to those possessed by terrestrial organisms.

Terrestrial fungi, lichens, and prokaryotes remain viable even after long-term direct exposure to space, and to gamma and solar UV radiation (Horneck et al. 2002; McLean & McLean 2010; Nicholson et al. 2000; Novikova et al 2016; Onofri et al. 2012; Sato et al. 2011; Tugay et al. 2006; Sancho et al. 2007; Raggio et al. 2011). Despite helium and iron ions at doses up to 2 kGy, X-rays at doses up to 5 kGy and γ rays at doses from 6 to 113 kGy these organisms retain their ability to engage in photosynthesis (De la Torre Noetzel et al. 2017). Even if their DNA is damaged by radiation above their tolerance levels, these genes are quickly replaced due to a redundancy of genes with repair functions (White et al. 1999).

Fungi, lichens and numerous species of microbe are attracted to and thrive in highly radioactive environments (Becket et al. 2008; Dadachova et al. 2007; Tugay et al. 2006; Wember & Zhdanova 2001). Fungi flourish on the outskirts and along the walls of the damaged highly radioactive Chernobyl nuclear power plant (Dighton et al. 2008; Zhdanova et al. 2004). Novikova et al. (2016) and Vesper et al. (2008) have also reported that fungi are invigorated and grow rapidly within the International Space Station as a consequence of the heightened radiation levels. In laboratory and field experiments, it has been documented that melanized fungi not only grew towards soil particles contaminated with radionuclides, but engulf and possibly consume these particles (Zhdanova et al. 1991; 2002).

Figure 61: Radioactive Fungi from Chernobyl

Ionizing radiation enhances the bioelectric properties of melanin and the growth of melanized microorganisms (Dadachova et al. 2007). For example, the capacity of irradiated melanin to reduce NADH increases 4-fold and significantly increases electron-transfer and growth rate as compared to non-irradiated melanin and non-melanized cells, even when deprived of nutrients (Dadachova et al. 2007).

Melanins absorb all wave lengths of UV and visible light (Nicolaus 1968; Rikkinen, 1995;

Huneck and Yoshimura, 1996), and in conjunction with other biological pigments (e.g. chlorophyll) convert electromagnetic-photonic energy into biochemical energy necessary for photosynthesis (Nicolaus 1968; Rikkinen, 1995; Huneck and Yoshimura, 1996). As noted, vast colonies of Martian specimens, with long stems attached to rocks and oriented skyward and topped with bulbous caps have been observed on Mars (Joseph et al. 2020a,b,c). Those upon rock and the surface were also initially described as pigmented purple, orange and yellow (Soderblom et al. 2004), the same as innumerable photosynthesizing species on Earth--but on Mars likely enhanced due to iron-related melanin. Therefore, it has been proposed those attached to rocks are engaged in photosynthesis thus accounting for the seasonal increases and continual replenishment of atmospheric oxygen (Joseph et al. 2020a,b).

Lichens come in a variety of colors--including blue, purple, orange and yellow--and it is believed different pigments are related to differential metal uptake (Engstrom et al. 1980; Hauck et al. 2009). Metal-induced pigmentations also protect against or serve to absorb and utilize solar radiation (Bjerke and Dahl, 2002; Nybakken et al., 2004; Hauck et al., 2007). The spheres of Mars have also been described as having a variety of colors, including and especially purple, orange and yellow (Soderblom et al. 2004) as well blue and blueish-green (Joseph et al. 2021)--colors that are never associated with terrestrial hematite, but pigmented photosynthesizing organisms.

It is believed that stable free radicals in melanin function as “radioprotectors” and prevent high-energy electrons from entering a cell, and/or act to absorb radiation energy which is converted to metabolic energy that is utilized by the cell (Dadachova et al. 2007) thereby stimulating cellular growth and proliferation (Conter et al. 1986; Croute et al. 1982). Dadachova et al. (2007) have reported that when exposed to radiation 500 times higher than background levels fungal cells grew rapidly and proliferated. Tugay and colleagues (2006) and Zhdanova et al. (1991, 2004) exposed micro-fungi and fungi to pure or mixed radiation (137 Cs, 123 Te, 109 Cd, 121 Sn), gamma irradiation (121 Sn) 200-400 Gy, and mixed gamma and beta radiation (137 Cs) (100-150 Gy (equivalent to an electron dose of 300-500 Gy), and found that 60% of fungal strains exhibited positive radiotropism, significant growth, and enhanced spoor production. Furthermore, these and other species rapidly adapt to abnormally high radiation levels and exhibited enhanced tissue and cellular regeneration and growth --a property described as "radiostimulation," and "adiotropism" (Levin 2003; Tugay et al. 2006; Zhdanova et al 2004).

Based on their experimental results and a review of the relevant scientific literature Dadachova et al. (2007) proposed “that the ability of melanin to capture electromagnetic radiation combined with its remarkable oxidation-reduction properties may confer upon melanotic organisms the ability to harness radiation for metabolic energy." Thus, it appears that in conjunction with melanin, radiation serves as an energy source for metabolism (Dighton et al. 2008; Tugay et al. 2006) and as such, and in conjunction with iron, produces nutrients and pigments which would enable various organisms to thrive and flourish in the radiation intense extreme environments of Mars.

Green, yellow, orange, blue, and purple-pigmented lichens, fungi, and algae have been observed on Mars (Levin et al. 1978; Krupa 2017; Rabb 2018; Small, 2015; Joseph 2006, 2016, Joseph et al. 2021). Organisms that evolved on Mars would have adapted to and would be invigorated by the high levels of radiation and high concentrations of iron and other minerals and metals which would enhance melanization and photosynthesis. Minerals, metals, iron, radiation, would provide a source of nutrition and metabolic energy thereby contributing to pigmentation and enhancing the ability to survive and engage in photosynthesis on Mars.

Figure 62: NASA and the Mars Opportunity team describes the Martian spheres as purple, blue, orange and yellow (Soderblom et al. 2004): the colors of spherical fungi. Clockwise: Purple *calvatia cyathiformis* puffball. Yellow puffball *Bovista colorat*a. Orange Poison Puffball *Scleroderma citrinum*. Blue *Leratiomyces* puffballs. Orange puffball Calvatia *rubroflava/rugosa*.

Figure 63: Photographed by rover Opportunity. Vast fields of spherical specimens, many with stalks above the surface. The "greenish" color may indicate chlorophyll.

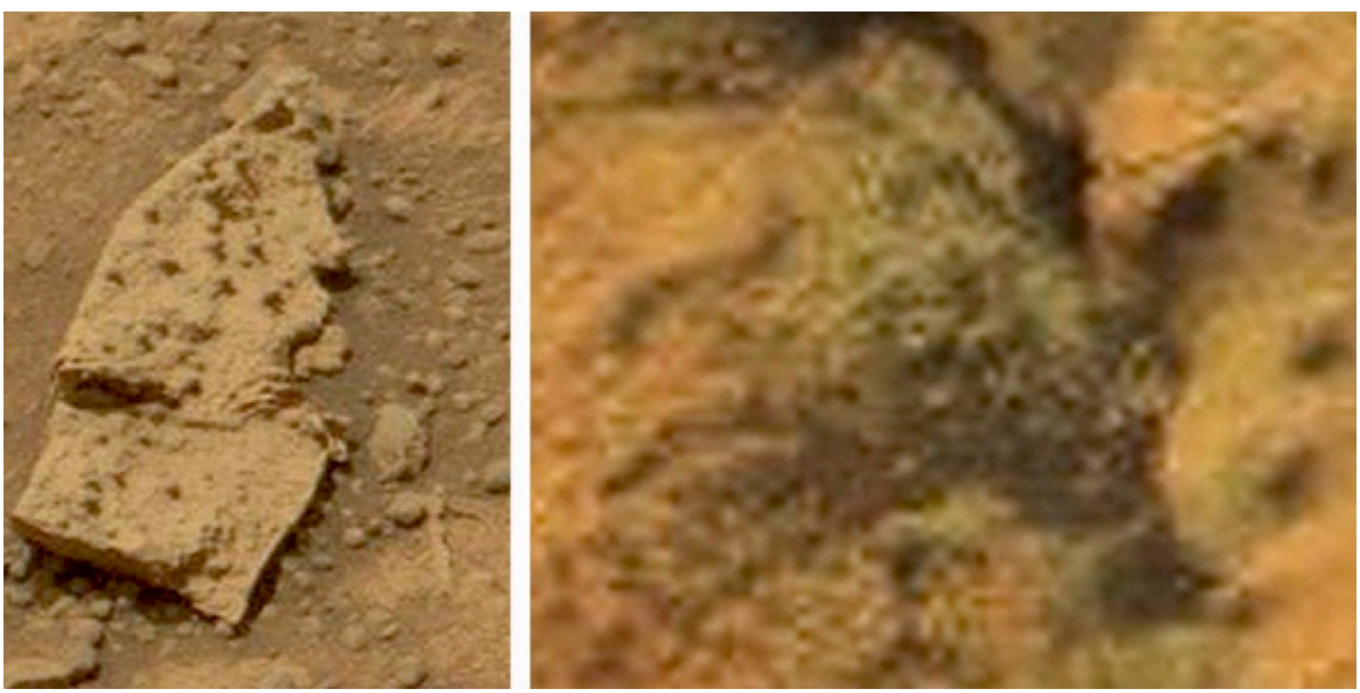


Figure 64: Photographed in Gale Crater **(Left)** Martian lichen/mushrooms and green algae. **(Right):** Sol 853. Martian green algae, lichens, dimpled-lichen-mushrooms, and oxygen air vents.

Figure 65: Sol: 85. Colonies of blue and purple Martian lichens attached by stems to rocks and blue puffballs upon the surface.

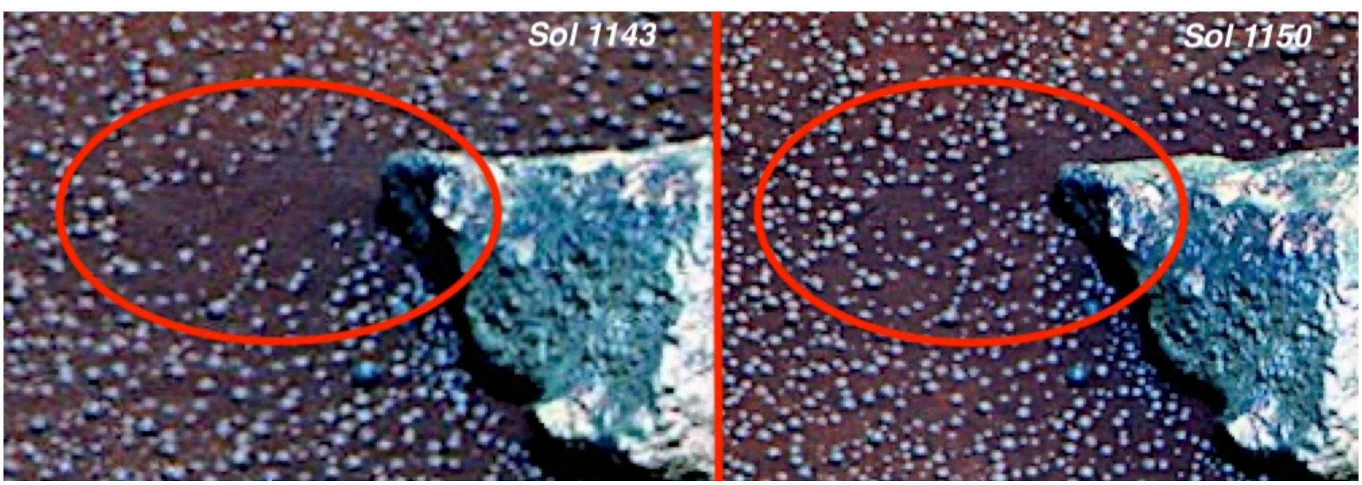


Figure 66: Sol 1143 documents area of soil devoid of spherical structures (circled in red). Seven days later, at least 18 purple spherical specimens have appeared in that same area.

17. Spores on Mars: Leprose, Crustose, and Embryonic Lichens/Fungus

Fungus exposed to high levels of radiation display enhanced spore production (Tugay et al. 2006; Zhdanova et al. (1991, 2004). Likewise, there is evidence that some Martian fungal puffballs have changed the crown of their sphere in preparation for spore production (Figures 67, 69-71) whereas in yet other photos fluffy white spore-like material litters the surrounding surface and within which have sprouted embryonic tubular and mushroom-like formation (Figures 72, 73; Joseph et al. 2021). Coupled with sequential photos showing growth, movement, and behavior (Joseph et al. 2021), evidence of spores and fungal embryos is additional evidence that life is reproducing and flourishing on the Red Planet.

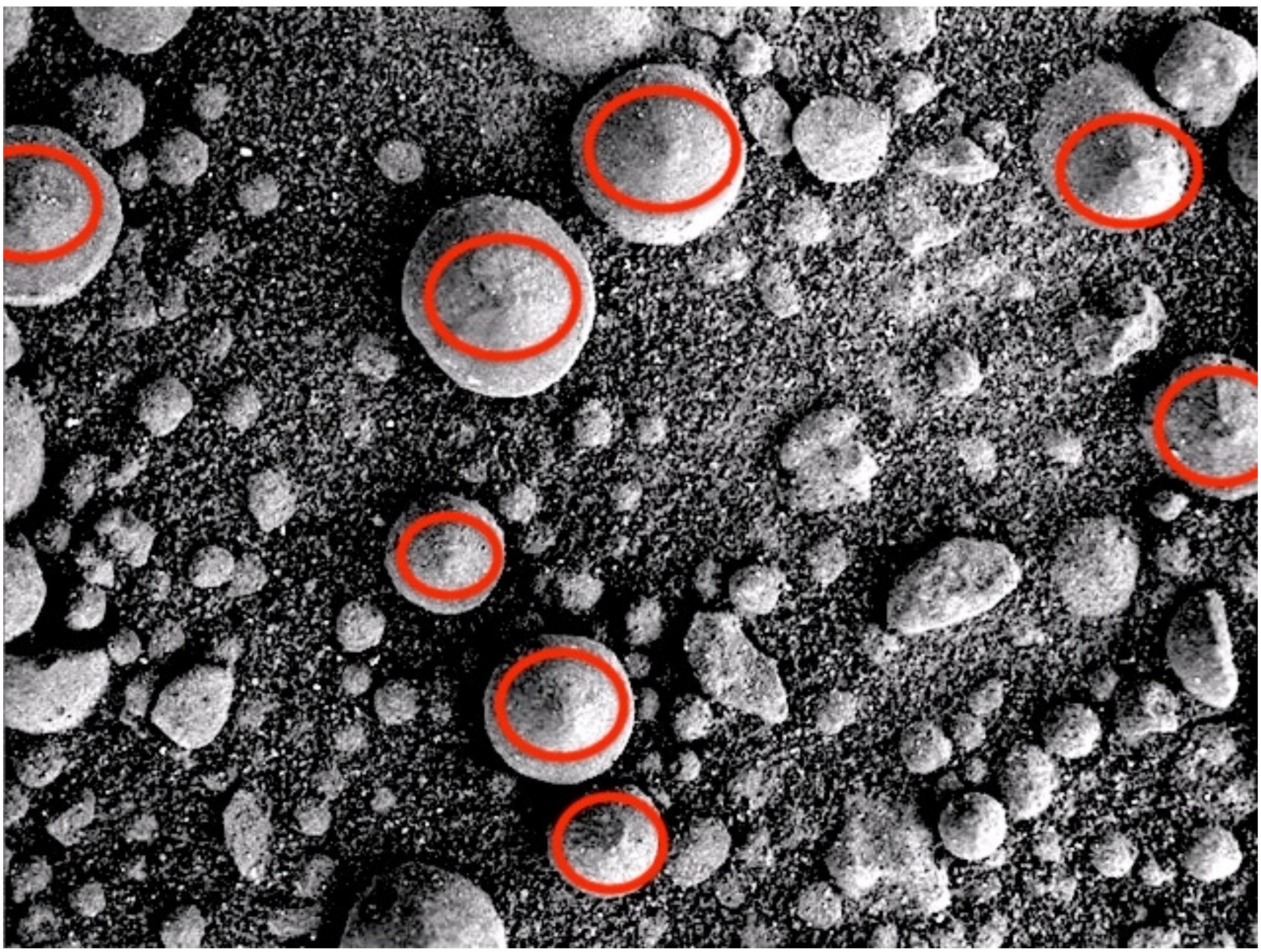


Figure 67: Martian mushrooms (puffballs) preparing to spore through their top cap. Note holes/apertures.

Figure 68: Terrestrial fungal puffballs) preparing to spore and sporing through their top cap.

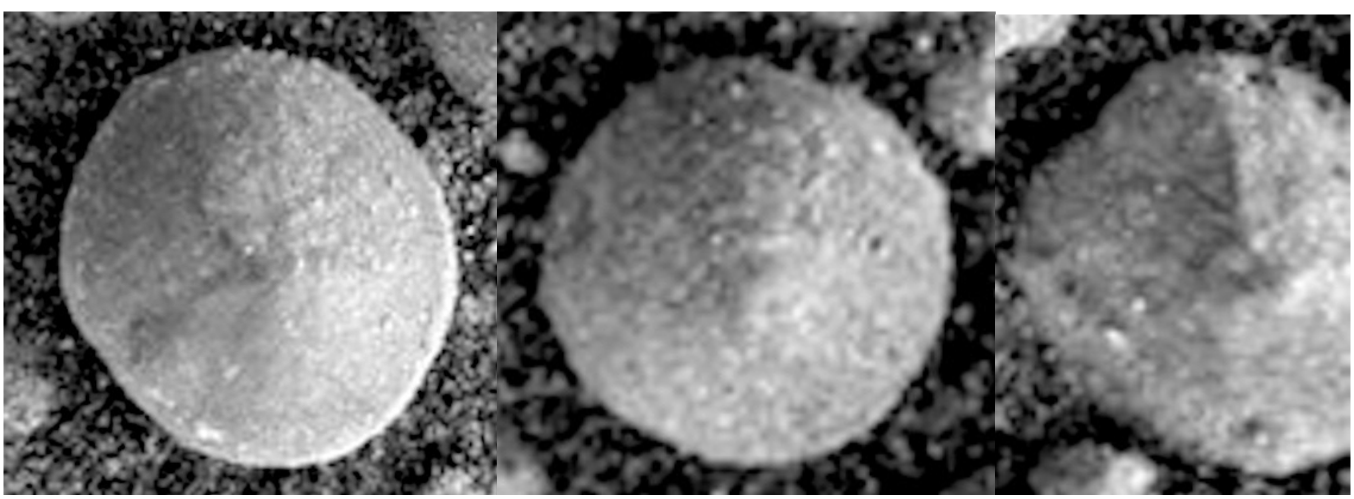


Figure 69: Martian mushrooms (puffballs) preparing to spore through their top cap. Note holes/apertures.

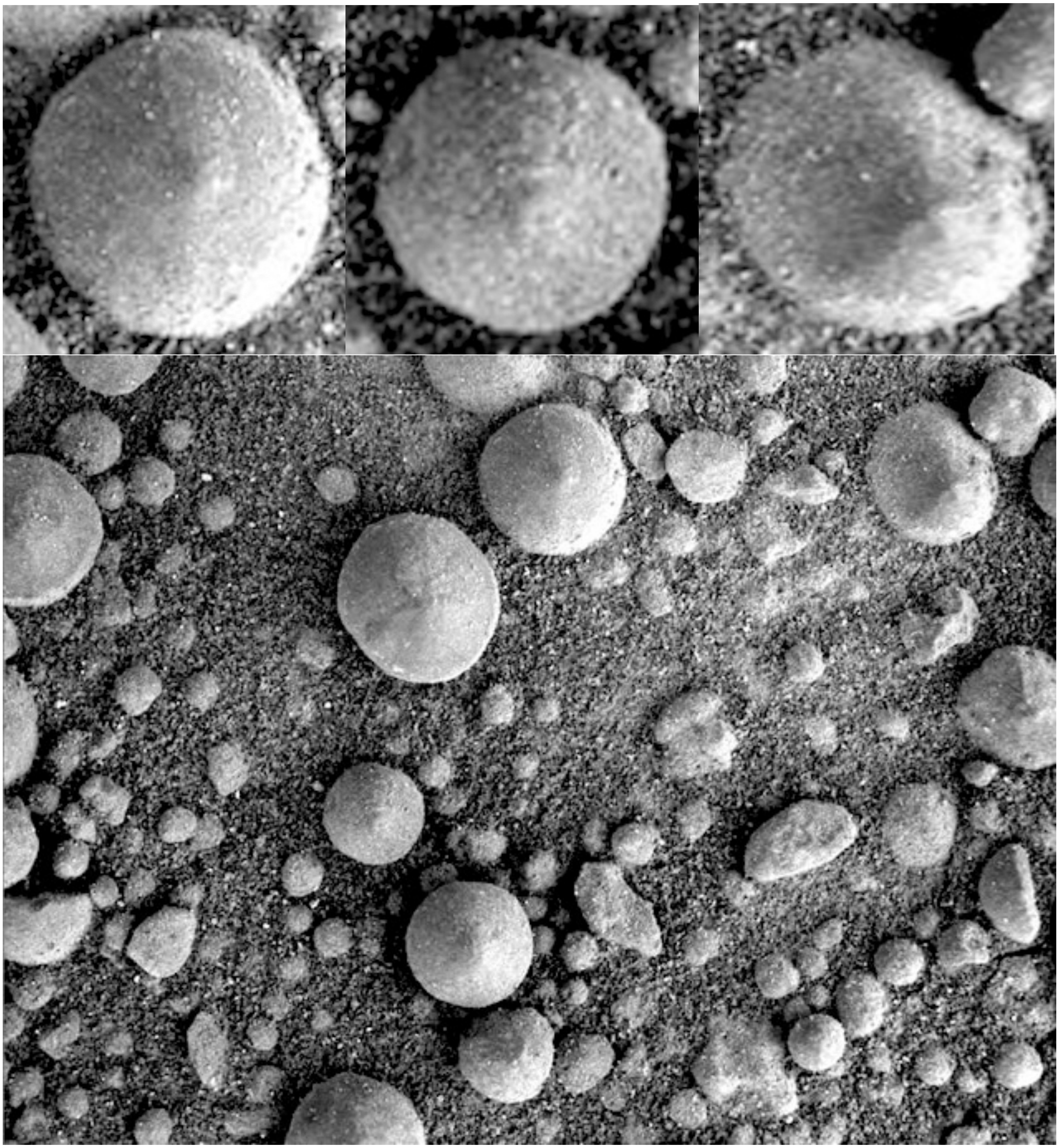


Figure 70: Martian mushrooms (puffballs) preparing to spore through their top cap. Note holes/apertures.

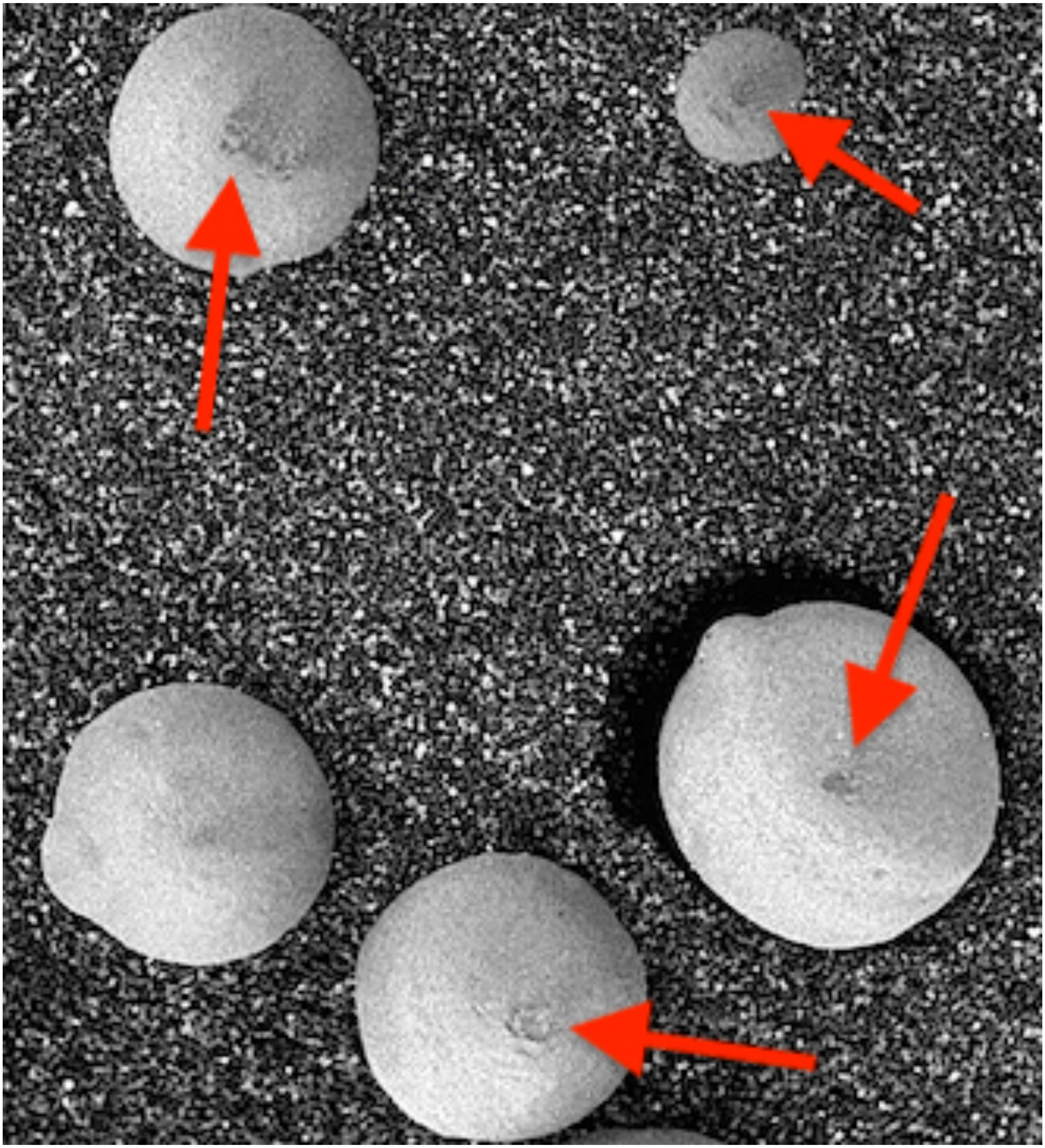


Figure 71: Martian mushrooms (puffballs) preparing to spore through their top cap. Note holes/apertures.

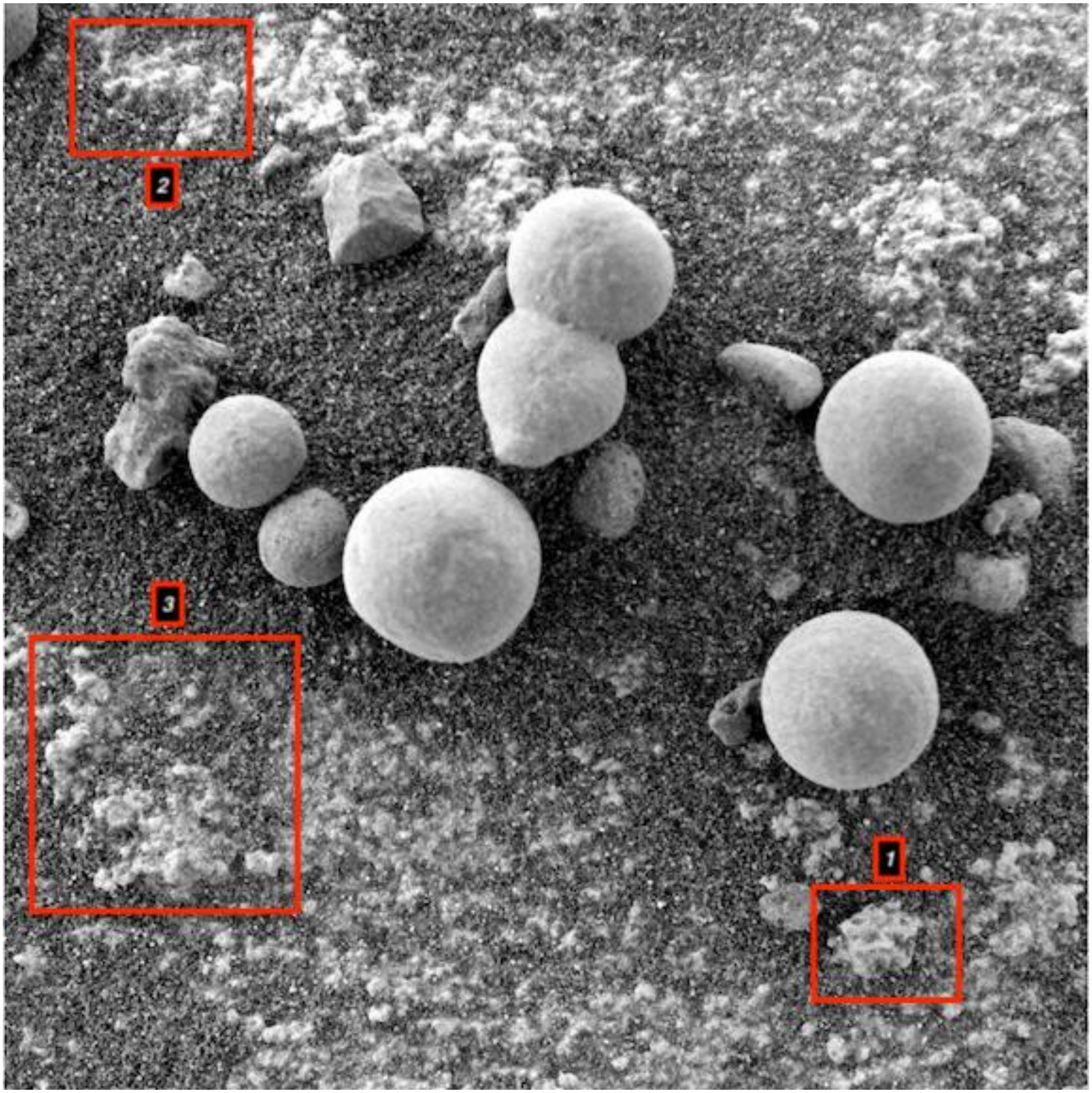


Figure 72: Martian mushrooms (puffballs) surrounded by fluffy white spores within which embryonic fungi are growing (see Figure 73).

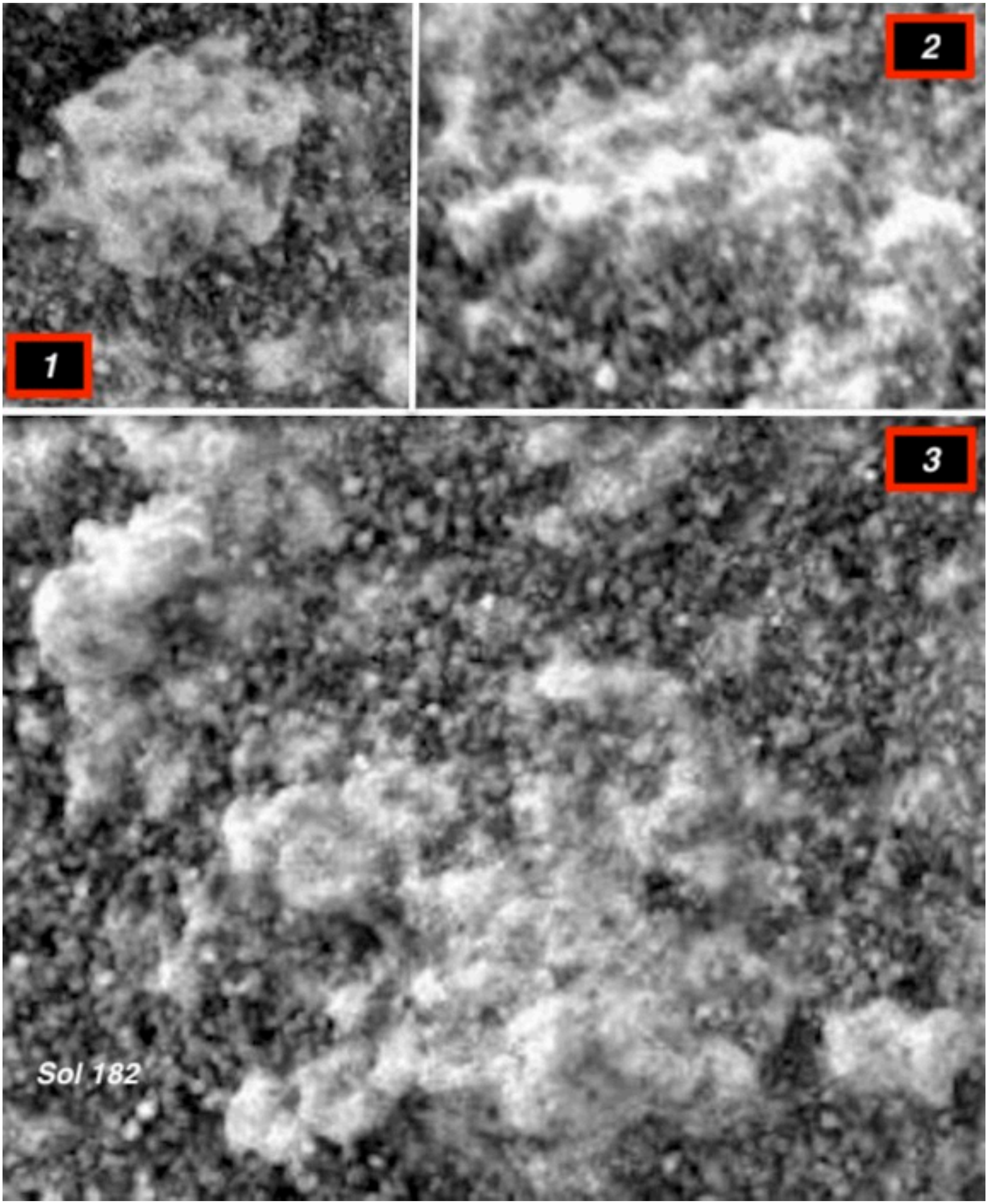


Figure 73: Embryonic fungi growing with spores surrounding Martian mushrooms (see Figure 72).

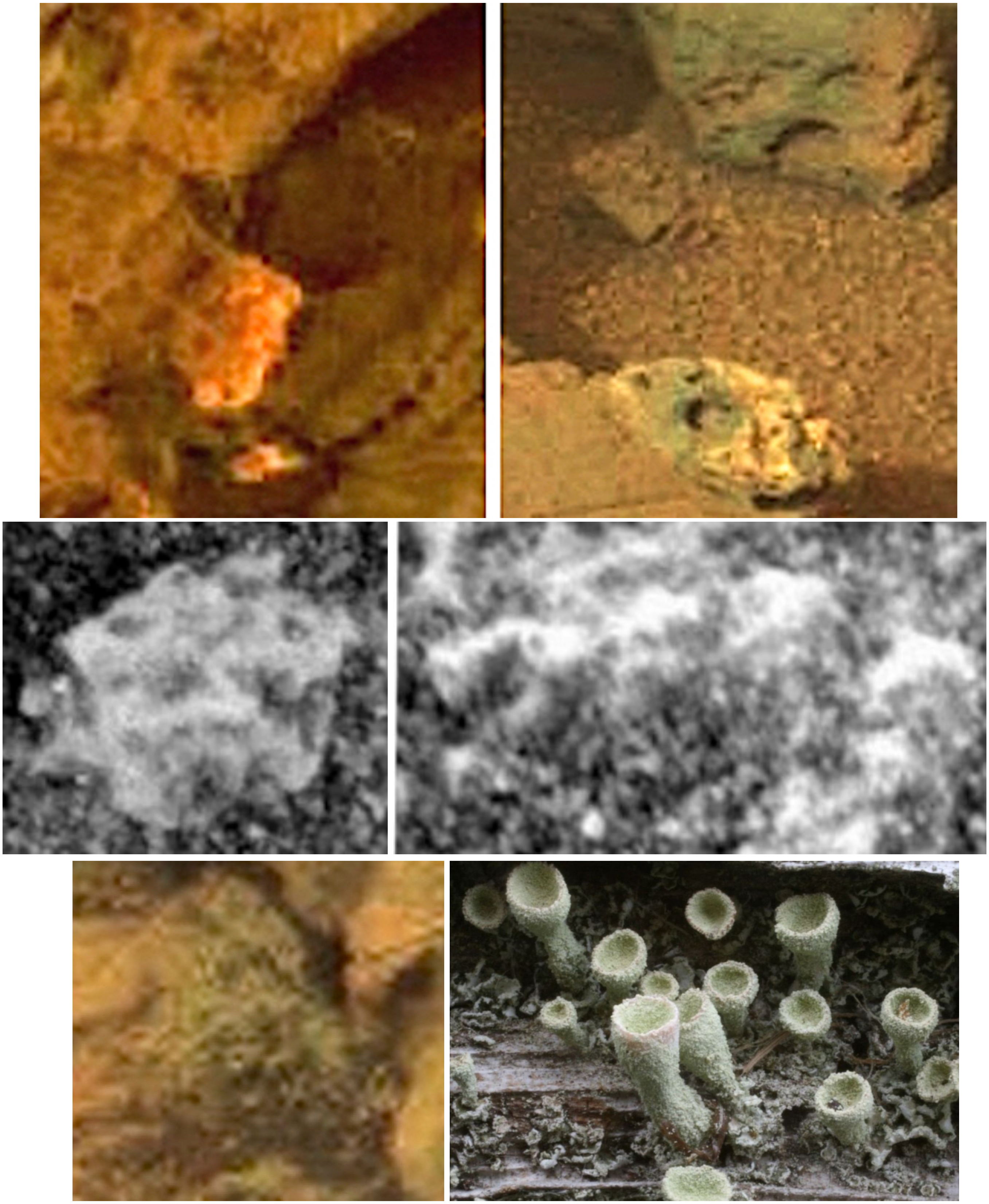


Figure 74: (**Top row**) Mars, Gale Crater, Fossilized Fungi (**Middle row**) Martian Embryonic fungi (**Left botto**m) Gale Crater, Mars, Green algae and tubular fungi (**Right bottom**) Terrestrial fungi, *cladonia-squamules* Photo credit: https://www.ukfungusday.co.uk/

IV. BIOLOGY OF HEMATITE

Mars is an ideal planet for organisms that flourish in an iron-rich, radiation intense, low oxygen environment (Joseph et al. 2019). Lichens, algae, fungi, and numerous species of iron-reducing microbes flourish in Fe^{2+}, crystalline-Fe^{3+} and hematite (Fe_2O_3) rich environments (Cornell and Schwertmann, 1996; Roden and Zachara, 1996) including Shewanella (Kosta and Nealson, 1995)--a gram-negative, proteobacteria-- that grows and feeds on hematite and respires on a variety of organic electron acceptors found in hematite (Bosea et al. 2009; Fredrickson et al. 2008, Gralnick & Hau 2007; Lowy et al. 2006).

Like their counterparts on Earth, Martian fungi, lichens, and algae would not just uptake substantial amounts of minerals and metals, including iron and hematite, but would likely become supersaturated with these metals which build up on their external cell walls. Therefore, these Martian organisms would be expected to reflect spectral signatures associated with various minerals, oxides and metals, including hematite; particularly as they would be concentrated on the outer cellular surfaces.

There is indirect evidence based on the analysis of spectra obtained from orbit, that grains of hematite may lay upon the surface of select regions of Mars. Rocks, pebbles and stone of varying sizes and shapes may contain or be covered with a thin layer of hematite. However, as to any hypothetical spherical concretions, their existence would require the cementing actions of various prokaryotes, lichens, and fungi which, on Earth, help form these concretions (Ayupova et al. 2016; Claeys 2006; Owocki et al. 2016). Even smaller fragments of hematite may indicate biology, as various organisms precipitate hematite by extracting energy from iron (Bosea et al. 2009; Fredrickson et al. 2008; Gralnick & Hau 2007) whereas "hematite" spheres of earth are infiltrated with microbiota and may be colonized by lichens. In addition, terrestrial hematite filaments and tubes are similar to structures produced by iron-oxidizing bacteria which suggests the former are fashioned by the latter (Ayupova et al 2016; Claeys 2006; Rajendrana et al. 2017). These "tubes" may serve as capillaries. In conjunction with the increased pressure of oxalate acids and their dissolving action on minerals and metals, these tubes and capillaries would drain away or draw outward soluable minerals and hematite particles to the outer surface thereby forming a thin layer atop and surrounding these concretions (Claeys 2006; Lowy et al. 2006).

Fungi also play a role in hematite formation (Ayupova et al. 2016, Claeys 2006; Owocki et al. 2016), the mineral substrates of which have been found "attached to fungal filaments, embedded in the fungal mycelium" (Claeys 2006). Fungi also secrete and precipitate soluble Fe and calcium oxalate (Gadd 1999; Graustein *et al.,* 1977; Verrecchia, 1990) which can dissolve and reorganize and shift the location of various metals, including hematite, including along their cellular surfaces.

Lichenized fungi may also "cement" these grains, minerals and metals together via the secretion of calcium (Clayes (2006). There is also a strong attachment of fungal hyphae to these minerals, such that "fungi engulf whole blocks of minerals in the hyphal network, irrespective of mineral surface topography" (Claeys 2006). The subsurface layers of spherical hematite contains numerous filaments with structures similar to fungal hyphae (Ayupova et al. 2016; Claeys 2006) wheres the outer surface may be colonized by lichens.

NASA (2009) and Squyres et al. (2004) have argued that Martian hematite was most likely created in boiling hot springs and hydrothermal vents billions of years ago. Likewise, numerous species of bacteria and archaea flourish in hot springs and hydrothermal vents including anaerobic hyperthermophiles, sulfate reducing bacteria and thermophilic archaebacteria (Gerday & Glansdorff 2007; Durvasula & Rao 2018; Robb et al. 2007).

As noted, these and other water-dwelling organisms will also "cement" sediment particles together, and via capillary action force soluble minerals and hematite particles to the outer surface of the resulting concretions (Claeys 2006; Lowy et al. 2006). In so doing they may cemented together a sphere covered with a thin layer of hematite. This would account for why so called terrestrial "hematite" spheres contain less than 2% hematite which is concentrated as a thin layer on the surface.

V. THE HEMATITE HOAX

18. The Spherical Hematite Hypothesis Refuted

In 1998, the spectral signature of "hematite" had been tentatively identified on the Martian surface as based on photographs utilizing color filters taken from space by NASA's Mars Global Surveyor spacecraft's infrared Thermal Emission Spectrometer (NASA 2009). The spectra was interpreted to represent what was believed to be fine or coarse grains of specularite (Fe_2O_3)--a crystalline hematite (Christensen et al. 2004; Morris et al. 2004; Squyres et al. 2004). On Earth fine and coarse grains of hematite form in iron-rich hydrothermal waters (Anthony et al. 2005; Morel 2013; Catlin & Moore, 2003; Kirkland et al 2004) with the assistance of a variety of microorganisms.

In 2004, the rover Opportunity's alpha proton x-ray spectrometer, upon examining outcrop in Eagle Crater, detected sulfur-related spectra. It was estimated the outcrop consists of 40% sulfur that was hypothesized to have been deposited and hydrated in salty/acidic water that streamed across the surface and which may have formed a shallow lake. The spectral signature of the mineral jarosite was also detected by the rover's Mossbauer spectrometer. Jarosite is a hydrated iron sulphate mineral that may form in acidic hydrothermal waters; and which are also the home of innumerable organisms.

NASA and the Opportunity team, however, did not expect to find the hundreds of thousands of purple, blue, orange and yellow spheres upon the surface or the vast colonies of lichen-mushroom-shaped specimens attached by stems to rocks. Hence, they did they have instruments capable of selectively examining these specimens. The instruments and tools at their disposal were not even mineral specific. Moreover, the temperature gages failed and the response functioning of their instruments continually changed "over the course of the mission," and this required ad hoc "instrument calibration" adjustments (Glotch and Bandford, 2006). Failure was not an option. Because of these malfunctions and as they lacked the tools to conduct a proper investigation, NASA and the Opportunity team began to speculate and draw conclusions based on inference, data manipulation, false colors, and panoramic images that included sand, soil, dust, and outcrops, reflected sunlight, albedo, unknown temperatures, and instruments that were not functioning properly; and then the presence of hematite was inferred (see methods as reported by Bell et al. 2004; Christensen et al. 2004; Glotch and Bandford, 2006; Klingelhöfer et al. 2004; Squyres et al. 2004) even though, as documented in this report, there was no resemblance to terrestrial hematite and vast colonies were attached to rocks by stems and oriented skyward. Not surprisingly, the methodology employed and their claims the spheres consist of hematite has been shown to be "contradictory," profoundly flawed, unconvincing (Joseph et al. 2020a,b; Lin 2016; Knauth et al. 2005; Small, 2015; Rabb, 2018) and "inappropriate" (Burt et al. 2005).

Hematite was never directly or positively detected in any of the spheres by the spectrometers. Although the Opportunity team observed specimens with lichen-like mushroom features jutting up from rocks within Eagle Crater (Bell et al. 2004; Squires et al. 2004), there was no attempt to determine if they consisted of hematite. Nevertheless, despite recognizing that the spheres upon the surface were a different color than hematite (Soderblom et al. 2004)--which is generally dark red (Anthony et al. 2005; Morel 2013)-- and were significantly smaller than terrestrial hematite, ranging in size from 0.6 to 6 mm in diameter (Herkenhoff et al., 2004) and uniformly round where terrestrial hematite has a variety of shapes, the Opportunity team assumed these spheres must be hematite. They arrived at this conclusion based on *inference* and the *interpretation* of panoramic images that included sand, soil, dust, and outcrops, and as based on generalized all-inclusive spectra recorded by the Opportunity's Mössbauer Spectrometer, Alpha Particle x-ray Spectrometer and Miniature Thermal Emission Spectrometer (Bell et al. 2004; Christensen et al. 2004; Klingelhöfer et al. 2004; Rieder et al. 2004; Squires et al. 2004); equipment that was not hematite specific.

Christensen and colleagues (2004), admitted they never examined any spheres but instead relied on panoramic images to determine "the mineral abundances and compositions of outcrops, rocks, and soils" via the "Miniature Thermal Emission Spectrometer (Mini-TES)." According to Christensen et al. (2004) they assumed the spheres are hematite based in part on the results from the Mini-TES which collected “infrared spectra” which was “combined with panoramic images and as based on thermophysical properties, atmospheric temperature profiles and atmospheric dust and ice opacities...” However, no ice was observed and the atmospheric temperature was unknown because the temperature sensors had failed! Christensen et al. (2004) also acknowledged their data was affected by "reduced spectral contrast" and was "likely contaminated" by sand, dust, and other materials, and which led them to "overestimate the hematite." As admitted by Glotch and Bandfied (2006), the data was a "poor fit" and did not match laboratory samples.

The spectral signatures were contaminated and confounded by numerous unknown and uncontrolled variables including reflected light from the Opportunity, jutting outcrops, and layers of obscuring dust and sand. It was impossible for the Opportunity's suite of spectral sampling instruments to obtain selective and accurate spectral signatures. All data collected included dust, dirt, sand, outcrops, large flat oblong rocks, surrounding matrix and soil, and were affected by reflected light and unknown atmospheric temperatures and variable solar radiance; and then the “data” was combined, adjusted, averaged, and then attributed to the spheres which were falsely claimed to contain hematite (see methods: Christensen et al. 2004; Klingelhöfer et al. 2004; Rieder et al. 2004). As admitted by Grotzinger et al. (2005): the spectra from rocks lying on the surface were "indistinguishable from that of the average spectral character of dust.”

The Opportunity team had no solid data. It was all guesswork and speculation.

Klingelhöfer and colleagues (2004) acknowledged that the "images obtained by the Microscopic Imager” were believed to "imply" hematite and were therefore "assigned to hematite" (Klingelhöfer et al. 2004). Furthermore, the possible presence of hematite was inferred based on the averaging of what were assumed to be high and low temperatures derived from outcrops and plains (Klingelhöfer et al. 2004)--when the temperature gages had failed (Glotch and Bandfield 2006).

Nor did they obtain spectra from any of the spheres, but from photos that included not spheres but flat oblong rocks which were then inexplicably mischaracterized as spheres (see Figure 6 in Bell et al. 2004). Moreover, Bell et al (2004) claimed the spheres contained hematite when their “results” were based on panoramic photographs depicting multiple features and was contaminated by solar radiance, atmospheric irradiance, surface temperature variations and albedo thus confounding the data.

Christensen et al. (2004) also admit that they removed spectra "by first deconvolving each spectrum with an end member library of 47 laboratory minerals and four scene spectra...and then subtracting" spectra until this "derived spectrum" could be interpreted to resemble "a laboratory hematite sample." Thus, the inferred presence of hematite was based on data manipulation and the selective elimination of spectral signals until arriving at a spectrum that was interpreted to be similar to the spectral signature of a sample of hematite photographed in a laboratory; the lighting and controlled conditions of which, of course, would be completely different from Eagle Crater or a natural terrestrial environment.

Although soils and outcrop matrixes of Eagle Crater likely contain considerable iron and jarosite (Bell et al. 2004; Christensen et al. (2004; Herkenhoff et al., 2004; Klingelhöfer et al. 2004; Rieder et al. 2004; Squyres et al. 2004), the fact is: no evidence of spherical hematite was found, the presence of iron was inferred to indicate hematite, and not one of the thousands of mushroom-shaped and lichen-like specimens were individually or selectively examined by Opportunity's suite of spectral sampling instruments for any evidence of hematite. Nevertheless, NASA and the Opportunity's team of investigators claimed the spheres consisted of hematite despite having no accurate data or hard evidence to support this assumption. In fact, Bell et al (2004) admitted the data is "not consistent" with solid hematite but jarosite and ferric iron and exhibited “crystalline ferric iron spectral signatures." Ferric iron is not hematite. The hematite claims are also refuted by subsequent studies conducted by the rover Curiosity and which detected only "minor" amounts of hematite in samples obtained from multiple locations (Treiman et al. 2016; Rampe et al. 2017; Yen et al. 2017).

NASA (2007) and the Opportunity teams’ claims are based on inference and “inappropriate” contradictory assumptions that should not have been published. Evidence of life is everywhere, but they had been so convinced by NASA’s incessant mantra “there is no life on Mars” they were unable to see what was right before their eyes. So they manipulated data and falsely claimed the spheres are hematite.

The “moqui marbles” (“hematite spheres”) of Utah have been proposed as analogs (Chan et al. 2004). These “marbles” come in all shapes and sizes and hematite is found only as a thin residue on the surface (Anthony et al. 2005; Chan & Perry 2002) whereas the subsurface is rife with life (Ayupova et al. 2016; Claeys 2006). Furthermore, the hematite “spheres” of Earth are generally dark red or black (Anthony et al. 2005) whereas the spheres of Mars were initially described as “yellow” “orange” and “purple” (Soderblom et al. 2004); pigments associated with photosynthesizing organisms including lichens and fungi which may appear purple, orange or yellow. Curiously, in later reports, the Martian spheres were described as pale white and their rainbow of colors were never mentioned again. Instead, the dull gray of the spheres embedded inside oxalate-calcium-like outcrop matrix became the standard color (Bell et al. 2004; Squires et al. 2004); the same color as terrestrial puffballs (Joseph 2016; Joseph et al. 2019; Joseph et al. 2020a,b).

The problem with claims about pale or white colored solid hematite spheres is they don't exist on Earth; unless machined by humans. Terrestrial hematite that are light or silver-or-pale-white in color are jagged, sharp-edged, crystalized (Figures 75) and do not have a round spherical shape (Anthony et al. 2005; Beske-Diehl and Li 1993; Grove et al. 2017). NASA (2009) therefore, resorts to a tautology and claims the white spheres of Mars consist of hematite because there are white spheres on Mars.

Figure 75: Terrestrial hematite that is silver-white or pale-white in color are jagged and/or sharp-edged, crystalized and do not have a round spherical shape. Pale or white colored hematite spheres do not exist unless hand- or machine tooled. NASA's claims about white spherical hematite on Mars is a hoax.

There is no factual evidence that the ground-level spheres, or the rock dwelling lichen with their long stems and bulbous tops consist of hematite (Joseph et al. 2019, 2020a,b). Claims to the otherwise are beset by contradictions, confounding uncontrolled variables, faulty and inadequate instrumentation, lack of factual data, and are refuted by the total absence of terrestrial analogs. This is why the claims published by the Opportunity team were immediately challenged as implausible, contradictory, not believable, and inappropriate (Burt et al. 2005; DiGregorio, 2004; Joseph, 2006, 2008; Knauth et al. 2005; Royer et al. 2008). The fact is: The spheres of Mars have no resemblance to terrestrial "hematite" spheres which are the wrong color and have a wide range of shapes. The spheres of Mars resemble colonies of photosynthesizing lichens atop rock, or fungal puffballs growing upon the surface.

Figure 76: Hematite spheres, Southern Utah.

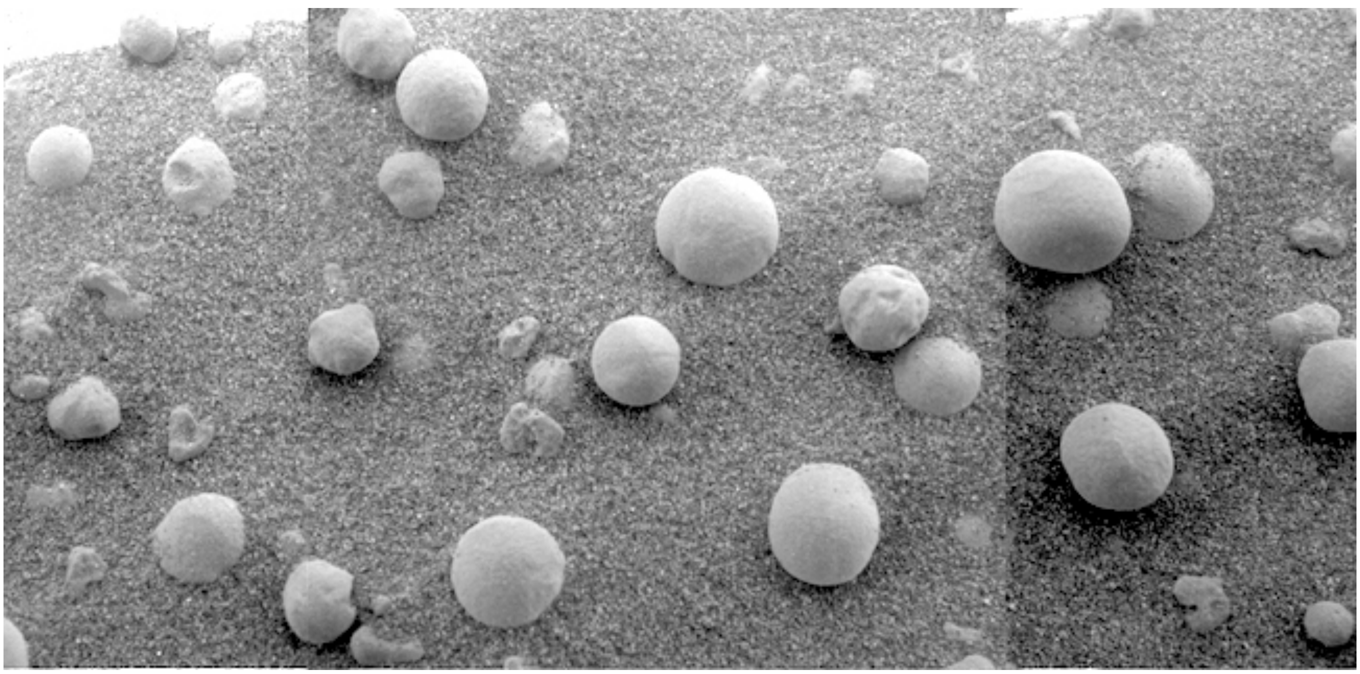
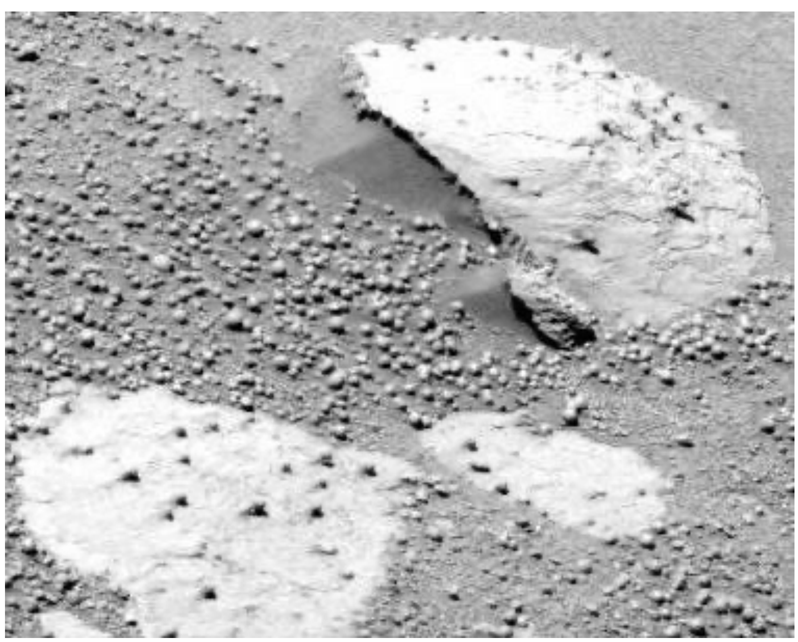
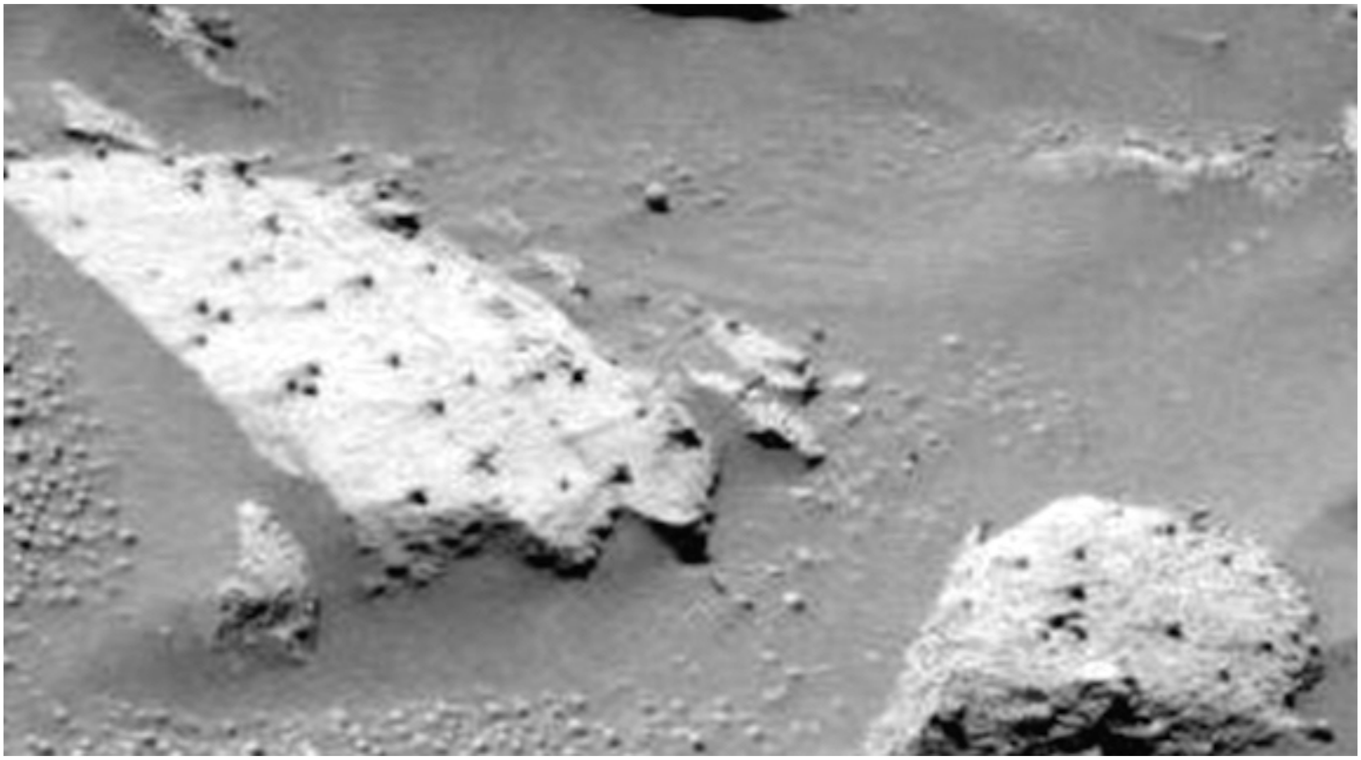
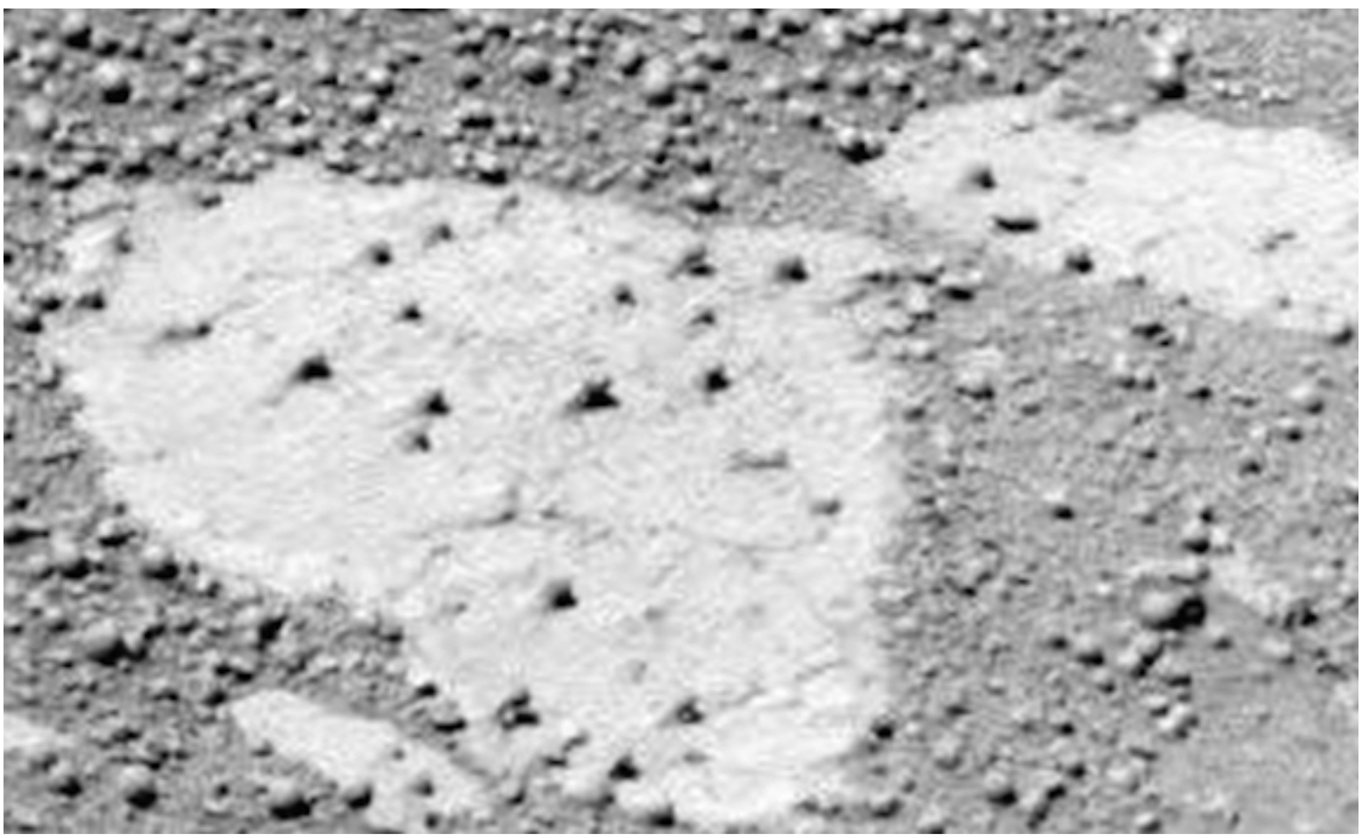


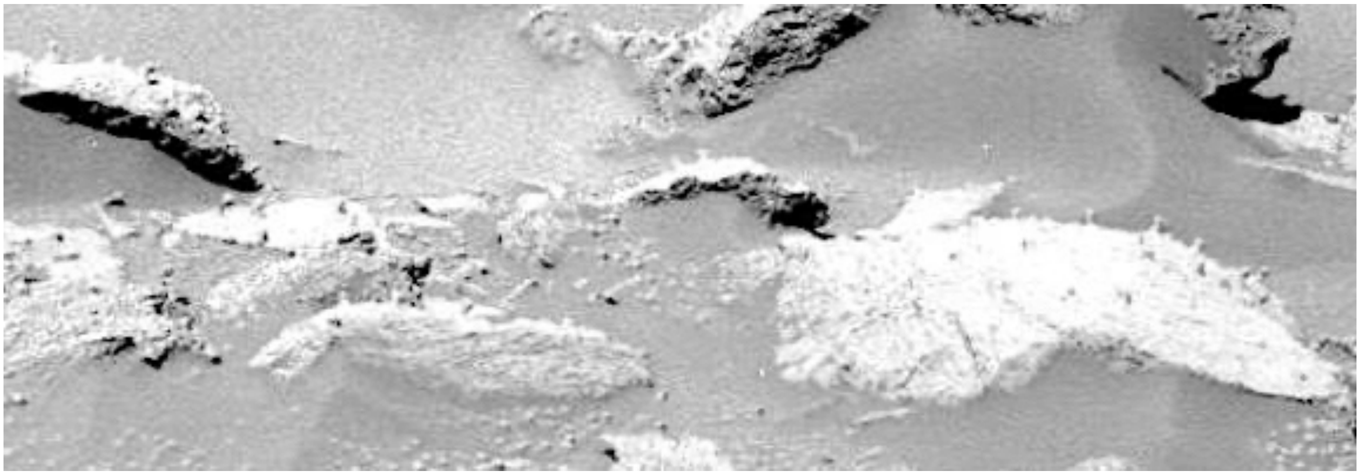
Figure 77: Martian fungal puffballs.

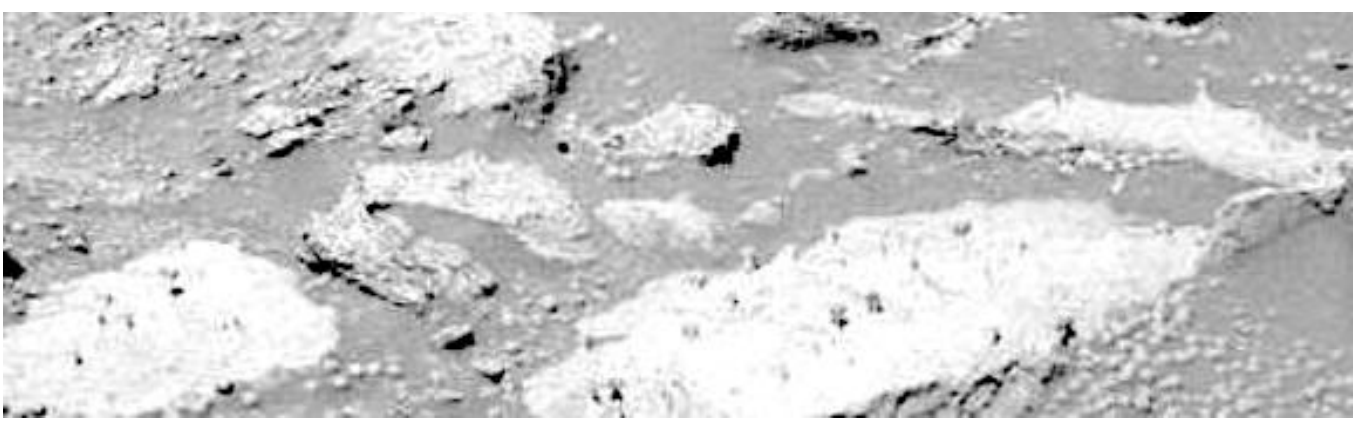
VI. VAST COLONIES OF LICHENS IN EAGLE CRATER

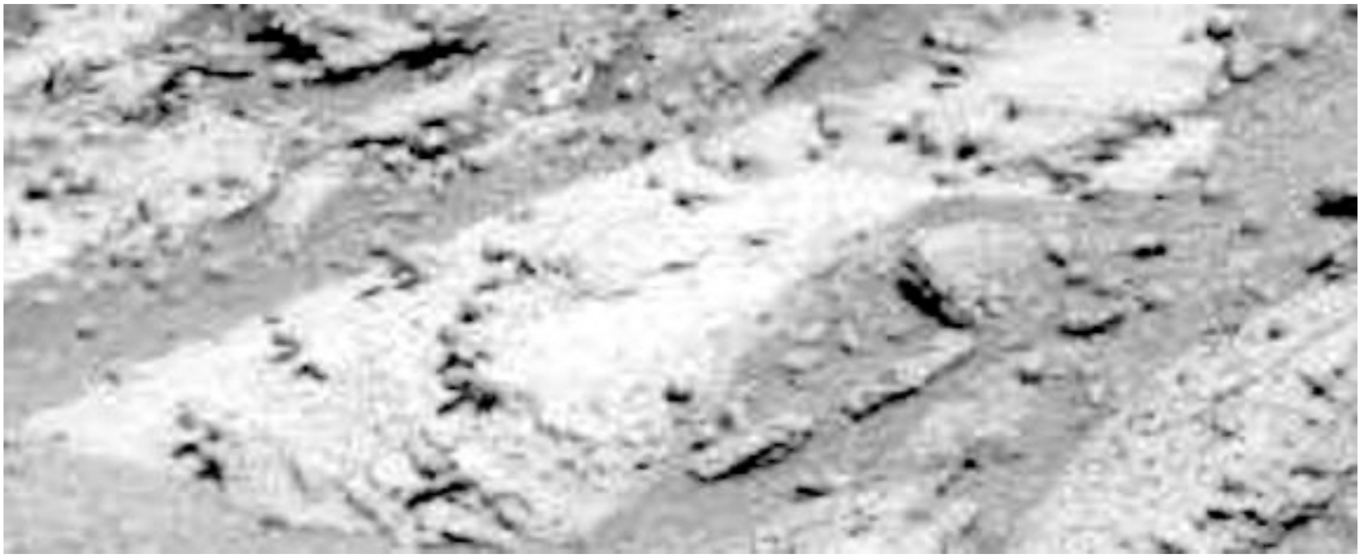












VII. NASA'S RELIGIOUS WAR AGAINST LIFE ON MARS

It is not the institution "NASA" which fabricated and generated the hematite hoax, but a well entrenched self-perpetuating religious group who first took power following the heyday of "Operation Paperclip" and so as to counterbalance and supervise nearly a thousand NAZI scientists who were put in charge of NASA's Space Program (Jacobsen 2014; Pyle & Pruden 2017). These NAZI slave-labor war criminals included high ranking NASA scientists SS-Sturmbannführer Werner Von Braun and Arthur Rudolph (Neufeld 2002, 2004; Hunt, 1985). The religious zealots supervising NASA's NAZIs immediately began hiring those who shared their religious convictions, recruiting entire congregations from their Temples of worship who were given positions of power and authority at NASA (Silverstein 2008; Joseph 2017). And this religious group took control of hiring, firing, the funding of research, and began to remake science so it conformed to their religious beliefs; and those beliefs required vehement opposition to the search for extraterrestrial life which they believed to be contrary to the teaching of the first book of Moses: Genesis (Greene, 2000, 2013; Jastrow 1978). To quote tribal leader and NASA administrator Robert Jastrow (1978): "Now we see how the astronomical evidence supports the Biblical view...the essential elements in the astronomical and Biblical accounts of Genesis are the same." And according to Dr. Phil Abelson, NASA consultant confidante and editor-in-chief of the journal Science: "The Bible says there is no life on other planets" (DiGregorio 1997). Thus, in 1971 when Mitchell and Ellis (1971) reported the discovery of 100 dormant microbes (*Streptococcus mitis*) inside a lunar camera retrieved from the moon, NASA tribal leader Dr. Leonard D. Jaffe stepped forward to discredit the discovery by claiming they were recent contaminants from a "dirty work bench" (Joseph 2016b).

Their next victim was Dr. Levin whose Viking Labeled release experiments NASA administrators vehemently opposed (DiGregorio 1997) because searching for life on Mars was "contrary to Torah" (Greene, 2000, 2013) and contrary to the teaching of "the Bible" (DiGregorio 1997). Dr. Levin reports he attended a meeting with 20 NASA administrator including Dr. John Olive and Dr. Phil Abelson, when the discussion turned to religion. Abelson began shouting "The Bible tells us there is no life on Mars" --a view that was endorsed by NASA administrators. Nor surprisingly, when the Mars Viking LR experiment produced positive results and thus evidence of life on Mars, the same administrators immediately denounced the results as "false positives" (DiGregorio 1997).

Dr. Levin was not the first or the last to be victimized by this religious cabal. In 1961 and over the following two years, three brilliant scientists, George Claus, Bartholomew Nagy, and Nobel Laureate Harold Urey, reported biological residue and an assortment of fossilized bacteria, including algae and cyanobacteria, in the Orgueil meteor (Claus & Nagy 1961; Nagy et al. 1963). The discovery led to world wide publicity followed by a campaign of threats, harassment, intimidation, slander and defamation by NASA scientists and administrators who dispersed funds to successfully defame and discredit these scientists (NASA Grant NsG-366; Anders & Fitch 1962; Fitch & Anders 1963). When Dr. Urey refused to recant, NASA and its agents denounced him as a "fraud" who "deliberately contaminated" the meteors and had perpetrated a “hoax" (NASA Grant NsG-366; Fitch & Anders 1963; Joseph 2017).

Dr. Harold Urey’s pioneering work on isotopes won him the Noble Prize in chemistry in 1934. In the 1950s he and his former student, Stanley Miller, produced over 20 amino acids, the building blocks of life, in a now famous experiment designed to determine whether the presumed chemical conditions of Earth early in its history could initiate the genesis of life (Miller & Urey 1959). It didn’t matter that Urey was a world famous member of the “tribe.” No one is safe from NASA’s religious zealots.

Dr. David McKay and his team were so afraid of NASA administrators and their fellow NASA “scientists” that they labored in secret until announcing their discovery of nanofossils and biological residue in Martian meteorite ALH (Mckay et al. 1996). However, these same administrators then provided tens of millions of dollars in funding to impugn and discredit McKay’s discoveries.

Scientific journals have also fallen victim. Case in point: The Journal of Cosmology (JOC) had been founded in 2009 and in less than 2 years began generating tremendous media attention and published the works of over 1,000 scientists from almost every major university in the world--including the works of 40 scientists from NASA--with editions edited by Nobel Laureate Sir Roger Penrose of Oxford University, and two editions edited by NASA Senior Scientists including Dr. Joel Levine who held a press conference at NASA headquarters in February of 2011, praising JOC's exemplary editorial policies of rigorous peer review (Joseph 2017). However, two months later, in May of 2011, when NASA scientist, Richard Hoover, published in JOC evidence of extraterrestrial microfossils (Hoover 2011) --and which generated world-wide attention-- NASA’s religious cabal, led NASA's Chief Scientist Paul Hertz, demanded that JOC and Hoover retract the article or suffer severe consequences (Joseph 2017). JOC and Hoover refused. Hertz then began a defamatory campaign to discredit JOC which Hertz and others at NASA slandered and libeled; referring to JOC as a "joke" "not a real journal" and falsely claiming JOC "does not peer review" (Science Magazine 2011). Hertz, using the authority of NASA, maliciously destroyed JOC’s reputation because it published evidence that conflicted with the beliefs of NASA’s religious leadership. Even death threats are believed appropriate including warnings of “hanging Hoover" (Science Magazine 2011).

This self-perpetuating anti-science religious cabal have held power at NASA since its inception (Joseph 2017) and they and their allies and members of the news media have continued these defamatory slanderous and threatening attacks into the present. NASA chief scientist Dr. Velvl Greene reports he was warned by dozens of NASA personnel that searching for life on Mars was "contrary to Torah," and he "shouldn't be doing this kind of work... because it goes contrary to Torah... It’s forbidden by Jewish law...” and he admitted there are hundreds of “scientists” at NASA who hold these beliefs (Greene, 2000, 2013). NASA has awarded millions of dollars to religious groups, including "The Center of Theological Inquiry" for the explicit purpose of advising NASA on how to respond to reports of extraterrestrial life (Joseph 2017); and NASA’s top scientists consult with their religious leaders for advise on if they should or should not search for life on Mars (Greene, 2000, 2013).

It’s the history of science: Copernicus was so frightened of the public, and the scientific community, he refused to allow his master work to be published until after his death. Giordano Bruno was denounced by the scientific community, arrested, tortured and burned at the stake for teaching that stars were suns, like our own, and there was life on other planets. Galileo was threatened with death and forced to recant. Nobel Prize winner Urey was hounded and threatened by NASA for discovering microfossils in meteors. Hoover was threatened with death

New, paradigm shifting discoveries have always been opposed by the howling mobs and the status quo who, with their torches and pitchforks come lumbering forth, hooting and grunting in fear, seeking to destroy what frightens them and what they don’t understand.

Be it science or religion, the status quo always protects the faith.

19. The Spirit of God & Life On Mars

It has been said: "Religion is the science of worshipping god." The discovery of life on Mars is not incompatible with belief in God. Only those who think they speak for god believe the evidence is incompatible and contrary to the teaching of their Lord.

There are a variety of religions and "holy" books accepted as divinely inspired. However, the "religious objections" to life on Mars are generally held only by those who hold to “orthodox” “Western” religious beliefs, and these zealots include those at NASA who believe the search for life on Mars is "contrary to the Bible" "contrary to Torah" and a violation of various religious laws. These "religious fanatics" speak out of ignorance. A close reading of their “Bible” makes it obvious that life is everywhere.

Not every worship the same “god” or “gods.” But most might agree that all things come from

"God" and all things return to "God." The cosmos, this universe, a single molecule, atom, particle, alternate dimensions, the future and the past, are manifestations of "god" (the quantum continuum).

In the opening passages of the beautiful poetry of Genesis, we are told: “The Earth was formless and void and darkness was over the face of the deep, and the spirit of god hovered over the waters" (Genesis 1:2). What is the "spirit of god" if not "life"? Is not the entire universe a manifestation of the "spirit of god?" Then: even before Earth was formed and was only a "void," life--the spirit of god--was everywhere... and wherever there is water, there is life: the spirit of god hovering over the waters.

Water is the most common molecule in the universe--"the face of the deep." The universe is "wet" and water-ice clinging to dust particles permeate space; and there are oceans of water splashing upon the shores of innumerable worlds--including Mars of long ago. Why wouldn't the spirit of god have hovered over all the waters of this cosmos?

"God" did not create one planet or one solar system or one galaxy. God created innumerable life forms that dwell on this planet. There are billions of people speaking thousands of different of "tongues" and dialects, and hundreds of millions who worship and sing the praises of "god" in their own unique way. And there are innumerable worlds in the heavens above... All these planets, myriad life forms, and those who worship and sing the praises of this “holy spirit” are a cosmic symphony of life, a celestial orchestra playing the songs of life in the eyes and ears of god.

Only Earth has life? One planet out of an infinity of worlds? An orchestra consisting of only one instrument that plays only a single note? Why would god "create" such an orchestra? Why would god create only one living planet? Does a television or radio have only one channel? Why would "god" create life on one planet and then stop?

All of life on Earth, in the universe, is a manifestation of the symphony of life that glorifies "god" --from which all things come and all things return. Of course there is life on Mars. The evidence is obvious. The “spirit of god” is not limited to Earth but is limitless and encompasses the entire cosmos.

I am not a religious person. These discoveries of life on Mars are based on science. But for a religious person this evidence should be seen as further proof that Life, the Spirit of God is everywhere.

VIII. CONCLUSIONS: EVIDENCE OF LIFE ON MARS

This author does not argue with the likelihood that hematite grains and crystals are to be found on Mars. However, lichens and fungi also dissolve, biologically weather and precipitate hematite and high concentrations of iron is a lichen characteristic (Bajpai et al. 2009; Hauck et al. 2007). Many species feed on iron and hematite which in turn can induce changes in pigmentation and increase melanin production which protects against radiation which is used as a nutrient. On Mars, it is likely that lichen and fungi may become supersaturated with iron and hematite. Hence, on Mars, spectral signatures associated with various metals, oxides and minerals may reflect the high metal/mineral content of Martian organisms.

However, as documented in this report there is no evidence to support the "inappropriate" claims that the spheres of Mars are hematite which have the wrong color size and shape. The Martian spheres resemble puffballs and lichens in almost all respects, even growing out of the ground and shedding spores within which embryonic fungi begin to grow.

The claims about hematite spheres on Mars are a hoax; a consequence of NASA's power of authority to enforce conformity of thought and its anti-science refusal to even consider the possibility of life on Mars. NASA has refused to equip any of the rovers with life detection technology, refuses to search for life, refuses to examine any specimens for life, and refuses to acknowledge any evidence for life, and has destroyed the careers of many scientists for "heresy." Coupled with the dire professional consequences of disobedience, the pressure to conform was so powerful that NASA scientists and the Opportunity team were unable to see what was right before their eyes. The evidence conflicted with everything they had been taught to believe and thus they missed the opportunity to make one of the greatest discoveries in the history of science: There is life on Mars. Instead, following the dictates of NASA which demands uniformity of thought, they ignored the evidence, falsely claimed to have discovered Martian hematite spheres and published what should have never passed peer review.

NASA cannot be trusted. Case in point: In addition to the hoax, NASA destroyed or has hid all but 300 of the over 10,000 photos from the Phoenix mission and has refused this author's Freedom of Information Act demands for access. NASA destroyed or hid over 1000 photos from the Curiosity mission. NASA adds layers of noise to photos and thick layers of false colors to obscure details. When NASA unexpectedly photographs obvious evidence of life they turn off the camera and move the rovers to a different location. Why is that? For the same reason they perpetrated the hematite hoax and what may be the most horrific fraud in the history of science.

The evidence for life is obvious. In our last report: "*Fungi on Mars? Evidence of Growth and Behavior from Sequential Images*" we documented the following:

Massive Black Formations Grow Every Spring: Far north and south of the equator, with the coming of Spring and the release of meltwater, huge dark / black formations appear, then grow larger--up to 300 meters, and then blacker, and with the coming of Autumn, they disappear. The following Spring, the exact same patterns emerge. Moreover, the patterns of growth are identical over thousands of meters in one location, but assume a different pattern (all identical) in a far distant location. Thus, we have repeating patterns coupled with waxing then waning--and this is consistent with biology: black fungi, black algae, black mould, black lichens--which are nourished by melt water, and become pigmented, then become dormant in Autumn.

NASA's explanation? Melting carbon dioxide! Carbon dioxide is a translucent white, not black, and when it melts, it becomes a gas, it does not spread across the surface

Black Fungi/Bacteria Growing On The Rovers: Evidence that black fungi and bacteria are growing on the rovers.

White Fungal Masses Growing On The Rover: After photographing a white fungal mass alongside a rock, the rover became contaminated with what appears to be identical white fungal masses.

White Fungal Masses Growing In Rock Shelters / Crevices: We presented sequential images of these white masses that look like fungus--they grow lager, they multiply, they move to different locations with tendrils leading the way, and they disappear.

Vast Colonies Of Lichens On Rocks: These specimens have long hollow stems, bulbous caps, they arch skyward, they look like vast colonies of thousands of lichens engaging in photosynthesis. Something is producing and replenishing Martian oxygen every spring and summer--a pattern identical to biological fluctuations on Earth.

Fungal Puffballs Growing On The Ground: We present evidence of dozens of mushroom-shaped spheres that grow out of the ground and that hundreds grow atop old rover tracks.

Growth of Mycelium & Calcium Carbonate Oxalate: Fungal and lichen mycelium / hyphae growing on the surface, sometimes rising up and over obstacles, and covered with masses of calcium carbonate oxalate which increases in mass and density.

Spores & Embryonic Mushrooms: Fungal puffballs that shed white fluffy spores within which grows embryonic fungi.

Growth, Movement, Multiplication: These are the hallmarks of life.

CONCLUSIONS: THERE IS LIFE ON MARS

There is now conclusive evidence for current and past life on Mars, including: positive findings from the two biology experiments conducted during the Viking Mission; biological residue discovered in several Martian meteorites; microstructures resembling thrombolites; macrostructures nearly identical to concentric domical stromatolites and microbial mats; fossils that resemble tube worms Ediacarans and metazoans; green algae; fungi that grow and multiply or wax and wane or move to different locations; bacteria and fungi growing on the rovers; fungal puffballs growing out of the ground and increasing in size; vast complex arctic colonies which emerge and grow hundreds of meters during the Spring and wane and disappear every Autumn; seasonal fluctuations and Spring/Summer increases in methane and oxygen which parallels the biological fluctuation of oxygen and methane on Earth; and vast colonies of hollow stemmed lichens attached to rocks and oriented skyward and likely engaged in photosynthesis and producing and replenishing the oxygen atmosphere of Mars.

The evidence is obvious and in total must be considered conclusive: There is life on Mars.

PRIMARY SOURCES

Joseph, R. (2016). A High Probability of Life on Mars, The Consensus of 70 Experts, Cosmology, 25, 1-25.

Joseph, R., Dass RS, Rizzo V, Bianciardi G. (2019). Evidence of life on Mars. Journal of Astrobiology and Space Science Reviews. 1: 40-81.

Joseph, R. G., N. S. Duxbury, G. J. Kidron, C.H. Gibson, R. Schild, (2020a) Mars: Life, Subglacial Oceans, Abiogenic Photosynthesis, Seasonal Increases and Replenishment of Atmospheric Oxygen, Open Astronomy, 2020, 29, 1, 189-209

Joseph RG, Armstrong RA, Kidron GJ, Schild R (2020b) Life on Mars: Colonies of photosynthesizing mushrooms in Eagle Crater? The hematite hypothesis refuted. Journal of Astrobiology and Space Science Reviews 5: 88-126.

Joseph R., Panchon, O., Gibson, C. H., Schild, R. (2020c). Seeding the Solar System with Life: Mars, Venus, Earth, Moon, Protoplanets. Open Astronomy, 29, 1.

Joseph RJ, Graham L, Büdel B, Jung P, Kidron GJ, Latif K, Armstrong RA, Mansour HA, Ray JG, Ramis GJP, Consorti L, Rizzo V, Gibson CH, Schild R (2020d) Mars: algae, lichens, fossils, minerals, microbial mats and stromatolites in Gale crater. J. Astrobiology and Space Science Reviews 3: 40-111.

Joseph, R., Planchon, O., Duxbury, N.S., Latif, K., Kidron, G.J., Consorti, L., Armstrong, R. A., Gibson, C. H., Schild, R., (2020e) Oceans, Lakes and Stromatolites on Mars, Advances in Astronomy, 2020, doi.org/10.1155/2020/6959532

Joseph RG, Armstrong RA, Latif K, Elewa, A.M.T., Gibson CH, Schild R (2020f) Metazoans on Mars? Statistical quantitative morphological analysis of fossil-like features in Gale crater. J Cosmology, 29: 440-475.

Joseph R. G., R. A. Armstrong, Konrad Wołowski, Giora J. Kidron, C. H. Gibson, Rudolph Schild, (2020g) Arctic Life on Mars? Araneiforms ("Spiders" "Trees"), Subglacial Lakes, Geysers, Mud Volcanoes, Dormancy and the Subsurface Biome, J. Astrobiology & Space Science Research, 2020, 6, 77-161

Joseph, R., et al. (2021) Fungi on Mars? Evidence of Growth and Behavior From Sequential Images. Astrobiology Research Report, 5/1/2021, ResearchGate.net https://www.researchgate.net/publication/351252619 https://www.researchgate.net/publication/351252619

REFERENCES

Acun˜a, M.H., et al. (1998). Magnetic field and plasma observations at Mars: initial results of the Mars Global Surveyor mission. Science 279, 1676–1680.

Adey W. R. (1993). Biological Effects of Electromagnetic Fields. Journal of Cellular Biochemistry 51:410-416.

Alain, K., et al. (2006). Microbiological investigation of methane- and hydrocarbon-discharging mud volcanoes in the Carpathian Mountains, Romania Environmental Microbiology (2006) 8(4), 574–590

Ali, D. et al. (2007). Life in the mud volcanoes. In Proceedings of the XVII EANA workshop on Astrobiology, Turku, Finland, 22–24 October 2007.

Aisen P., et al (2001). Chemistry and biology of eukaryotic iron metabolism, Int. J. Biochem. Cell Biol., 2001, 33 940-959

Alshits LK, Kulikov NV, Shevchenko VA, Yushkov PI. 1981. Changes in radiosensitivity of pea seeds affected by low level radiation. Radiobiol 21:459-463.

Anantharaman, K. et al. (2016). Thousands of microbial genomes shed light on interconnected biogeochemical processes in an aquifer system. Nat. Commun. 7, 13219 (2016).

Anders, E. and F. W. Fitch (1962), Search for Organized Elements in Carbonaceous Chondrites. Science, 138, pp. 1392-1399

Armstrong RA. (2013). Development of areolae and growth of the peripheral prothallus in the crustose lichen Rhizocarpon geographicum: an image analysis study. Symbiosis 60: 7-15.

Ascaso, C., et al. (1982). The weathering of calcareous rocks by lichen. Pedobiologia 24, 219–229.

Asch, S.E. (1951). Effects of group pressure on the modification and distortion of judgments. In H. Guetzkow (Ed.), Groups, leadership and men(pp. 177–190). Pittsburgh, PA:Carnegie Press.

Asch, S. E. (1952). Effects of group pressure on the modification and distortion of judgements. In G. E. Swanson, T. M. Newcomb & E. L. Hartley (Eds.), Readings in social psychology (2nd ed., pp. 2–11). New York:NY Holt.

Asch, S.E. (1955). Opinions and social pressure. Scientific American, 193, 35–35.

Asch S. E. (1956). Studies of independence and conformity: I. A minority of one against a unanimous majority. Psychological Monographs, 70, 1-70.

Armstrong RA, Bradwell T (2010) The use of lichen growth rings in lichenometry: some preliminary findings. Geografiska Annaler 92A: 141-147

Bachereau, F., Asta, J. (1997) Effects of solar ultraviolet radiation at high altitudes on the physiology and biochemistry of a terricolous lichen (Cetraria islandica (L.) Ach.). Symbiosis 23: 197–217.

Backer, M., Fahselr' D. (2008). Lichen photobionts and metal toxicity, Symbiosis, 46, 1-10

Backor, M., Loppi, S. (2009). Interactions of lichens with heavy metals, Biologia Plantarum 53 (2): 214-222.

Basset C.AL. (1993). Beneficial effects of electromagnetic fields. J Cell Biochem 31:387-393.

Baucon A, De Carvalho CN, Felletti F, Cabella R (2020). Ichnofossils, cracks or crystals? A test for biogenicity of stick-like structures from Vera Rubin Ridge, Mars. Geosciences 10: 39.

Beck, A. (1999). Photobiont inventory of a lichen community growing on heavy-metal-rich rock. Lichenologist 31: 501-510.

Becker RO. (1984). Electromagnetic controls over biological growth processes. Journal of Bioelectricity 3:105-118.

Becker RO, Sparado JA. (1972). Electrical stimulation of partial limb regeneration in mammals. Bull NY Acad Med 48:627- 641.

Becket, K. et al. (2008). Stress Tolerance in Lichens. In Lichen Biology (T, H. Nash III Ed) Cambridge University Press.

Beech, M., Comte, M., Coulson. I (2018). Lithopanspermia – The Terrestrial Input During the Past 550 Million Years, American Journal of Astronomy and Astrophysics, 7(1): 81-90.

Bell, J. F., et al., (2004). Pancam Multispectral Imaging Results from the Opportunity Rover at Meridiani Planum. Science 306, 1703-1709.

Beske-Diehl, S., Li, H. (1993). Magnetic properties of hematite in lava flows from Iceland: Response to hydrothermal alteration, JGR Solid Earth, 98, 403-417

Bianciardi G, Rizzo V, Castasano N (2014) Opportunity Rover's image analysis: Microbialites on Mars? Int J Aeron Space Sci 15: 419-433.

Bierson, C., et al. (2016). Stratigraphy and evolution of the buried CO2 depositin the Martian south polar cap. Geophysical Research Letters: 43, 4172-4179.

Bjerke JW, Dahl T. (2002) Distribution patterns of usnic acid-producing lichens along local radiation gradients in West Greenland, Nova Hedwigia, 75 487-506

Bothe, H. (2019). The Cyanobacterium Chroococcidiopsis and Its Potential for Life on Mars, Journal of Astrobiology and Space Science Reviews, 2, 398-412.

Briat, J-F., et al. (1995)Cellular and molecular aspects of iron metabolism in plants Biology of the cell, 84, 69-81, 1995

Brodo IM. (1973). Substrate ecology. In: Ahmadjian V, Hale ME, editors. The lichens. New York: Academic Press, 1973: 401-441.

Büdel, B., Weber, B., Kühl, M., Pfanz, H., Sültemeyer, D., and Wessels, D.C.J. (2004). Reshaping of sandstone surfaces by cryptoendolithic cyanobacteria: bioalkalisation causes chemical weathering in arid landscapes. Geobiology 2: 261-268

Burt, D.M., Knauth, L.P., Woletz, K. H. (2005). Origin Of Layered Rocks, Salts, And Spherules At The Opportunity Landing Site On Mars: No Flowing Or Standing Water Evident Or Required. Lunar and Planetary Science XXXVI (2005).

Camacho, A., et al. (2017). Photoferrotrophy: Remains of an Ancient Photosynthesis in Modern Environments, Front. Microbiol., 21

Catling, D. C., Moore, J. M. (2003). The nature of coarse-grained crystalline hematite and its implications for the early environment of Mars, Icarus, 165, 277-300.

Chan, M. A., & Parry, W. T., (2002) Rainbow of Rocks. Mysteries of Sandstone Colors and Concretions in Colorado Plateau Canyon Country, Public Information Series 77 Utah Geological Survey

Chan, M. A., Breitler, B., Parry, W.T., Ormo, J. & Komatsu, G. A. (2004). Possible terrestrial analogue for haematite concretions on Mars. Nature 429, 731-734.

Chen, J., et al. (2000). Weathering of rocks induced by lichen colonization — a review, Catena, 39, 2, 121-1146.

Christensen, P. R., Ruff, S. W., (2004). Formation of the hematite-bearing unit in Meridiani Planum: Evidence for deposition in standing water, JGR Planets, 109, E8 2004.

Christensen, P. R. et al., (2004). Mineralogy at Meridiani Planum from the Mini-TES Experiment on the Opportunity RoverScience 306, 1733-1739.

Claus, G., Nagy, B. (1961) A Microbiological Examination of Some Carbonaceous Chondrites. Nature 192, 594 - 596.

Collins, C.R. and Farrar, J.F. 1978. Structural resistance to mass transfer in the lichen Xanthoria parietina. New Phytologist 81: 71- 83.

Coonorton, J.M., et al. (2017). Iron homeostasis in plants – a brief overview, Metallomics. 2017 Jul 1; 9(7): 813–823.

Conter A, Dupouy D, Delteil C, Planel H (1986) Influence of very low doses of ionizing radiation on Synechococcus lividus metabolism during the initial growth phase. Arch Microbiol. 144: 286–290.

Cornell, R.M., Schwertmann, U., 1996. The Iron Oxides: Structure, Properties, Reactions, Occurrences and Uses. VCH, Cambridge.

Croute F, Soleilhavoup JP, Vidal S, Dupouy D, Planel H (1982) Paramecium tetraurelia growth simulation under low-level chronic irradiation. Investigations of a possible mechanism. Rad. Res. 92: 560–567.

Crowe, S. A., Døssing, L. N., Beukes, N. J., Bau, M., Kruger, S. J., Frei, R., et al. (2013). Atmospheric oxygenation three billion years ago. Nature 501, 535–539. doi: 10.1038/nature12426

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.

Dapremont, A.M., Wray, J. J. (2020). Igneous or Mud Volcanism on Mars? The Case Study of Hephaestus Fossae, JGR Planets,

Dass, R.S. (2017). The high probability of life on Mars: A brief review of the evidence. Cosmology 27.

Davaud, E., Girardclos, S., (2001). Recent freshwater ooids and oncoids from western Lake Geneva (Switzerland).: indications of a common organically mediated origin. Journal of Sedimentary Research, 71: 423–429.

De Conti , L., et al. (2020). Iron fertilization to enhance tolerance mechanisms to copper toxicity of ryegrass plants used as cover crop in vineyards, Chemosphere, 243, March.

Deering,R. A., et al. (1972) Independence of Propagation Ability and Developmental Processes in Irradiated Cellular Slime-moulds, International Journal of Radiation Biology and Related Studies in Physics, Chemistry and Medicine, 21:3, 235-245, DOI: 10.1080/09553007214550271

de la Torre Noetzel, R. et al. (2017). Survival of lichens on the ISS-II: ultrastructural and morphological changes of Circinaria gyrosa after space and Mars-like conditions EANA2017: 17th European Astrobiology Conference, 14-17 August, 2017 in Aarhus, Denmark.

de la Torre, R., et al. (2017). The Effect of High-Dose Ionizing Radiation on the Astrobiological Model Lichen Circinaria gyrosaAstrobiologyVol. 17, No. 2, 2017

de la Torre Noetzel, R., et al. (2019). Lichen Vitality After a Space Flight on Board the EXPOSE-R2 Facility Outside the International Space Station: Results of the Biology and Mars Experiment, AstrobiologyVol. 20,

de la Torre Noetzel, R., et al. (2020). Lichen Vitality After a Space Flight on Board the EXPOSE-R2 Facility Outside the International Space Station: Results of the Biology and Mars Experiment, Astrobiology, 20.

de la Torre Noetzel, R., García, M.V.O. (2020). Lichen Vitality After a Space Flight on Board the EXPOSE-R2 Facility Outside the International Space Station: Results of the Biology and Mars Experiment, Astrobiology, 20, No.

De Conti L., et al. (2020). Iron fertilization to enhance tolerance mechanisms to copper toxicity of ryegrass plants used as cover crop in vineyards, Chemosphere, 243, March, 125298

Del Monte, M., Sabbioni, C., and Zappia, G. (1987). The origin of calcium oxalates on historical buildings, monuments and natural outcrops. The Science of the Total Environment 67, 17–39.

de Vera, J-P., et al. (2010). Survival Potential and Photosynthetic Activity of Lichens Under Mars-Like Conditions: A Laboratory Study , Astrobiology, 10, 2.

De Vera, J.-P. (2012). Lichens as survivors in space and on Mars. Fungal Ecology, 5, 472-479.

De Vera, J. -P. et al. (2014). Results on the survival of cryptobiotic cyanobacteria samples after exposure to Mars-like environmental conditions, International Journal of Astrobiology, 13, 35-44.

De Vera J-P, Alawi M, Backhaus T, Baqué M, Billi D, Böttger U, et al. (2019). Limits of Life and the Habitability of Mars: The ESA Space Experiment BIOMEX on the ISS. Astrobiol. 19(2):145–157.

Dighton, J, Tatyana Tugay, T., ZhdanovaN., (2008) Fungi and ionizing radiation from radionuclides, FEMS Microbiol Lett 281, 109-120.

DiGregorio, B. E. (2004). Accretionary lapilli, tektites, or concretions: the ubiquitous spherules of Meridiani Planum", Proc. SPIE 5555, Instruments, Methods, and Missions for Astrobiology VIII, (1 November); https://doi.org/10.1117/12.563673

DiGregorio, B. (2018). Ichnological evidence for bioturbation in an ancient lake at Vera Rubin Ridge, Gale Crater, Mars. In Proceedings of the 3rd International Convention on Geosciences and Remote Sensing, 19 20 October 2018, Ottawa, ON, Canada, 2018; pp. 1–7.

Dufour, L. (1891) Puffball mushrooms 1891Atlas des Champignons,

Dundas C., M., Byrne S., McEwen AS. (2015). Modeling the development of Martian sublimation thermokarst landforms. Icarus 262, 154–169.

Eberl, D. D. (2021). Particle Size Distribution Evidence that Iron-Rich Martian Blueberries Were Precipitated from Solution. In preparation.

Engstrom GW, McDorman DJ, Maroney MJ. (1980). Iron chelating capability of physcion, a yellow pigment from Aspergillus ruber., Journal of Agricultural and Food Chemistry, 28, 1139-1141

Fitch, F., H. P. Schwarcz and E. Anders (1962), 'Organized elements' in carbonaceous chondrites. Nature, 193, pp. 1123-1125

Foss, F. J.; Putzig, N. E.; Campbell, B. A.; Phillips, R. J. (2017). 3D imaging of Mars' polar ice caps using orbital radar data". The Leading Edge. 36 (1): 43–57.

Freeman SE, Freeman LA, Giorli G, Haas AF (2018) Photosynthesis by marine algae produces sound, contributing to the daytime soundscape on coral reefs. PLoS ONE 13(10): e0201766).

Frei, R., Crowe, S. A., Bau, M., Polat, A., Fowle, D. A., and Døssing, L. N. (2016). Oxidative elemental cycling under the low O2 Eoarchean atmosphere. Sci. Rep. 6:21058. doi: 10.1038/srep21058s

Frey-Wyssling, A. (1981). Crystallography of the two hydrates of crystalline calcium oxalate in plants. American Journal of Botany 68, 130–141.

Freidmann, E.I. (1982) Endolithic microorganisms in the Antarctic cold desert. Science 215: 1045-1053

Friedmann, E.I, Hua M, Ocampo-Friedmann R (1988) Cryptoendolithic lichen and cyanobacteria communities of the Ross Desert, Antarctica. Polarforschung 58:251–259

Gadd, G. M., (1999). Fungal Production of Citric and Oxalic Acid: Importance in Metal Speciation, Physiology and Biogeochemical ProcessesAdvances in Microbial Physiology, 1999, 41, 47-92

Galaris D., Pantopoulos K. (2008). Oxidative stress and iron homeostasis: mechanistic and health aspects, Crit. Rev. Clin. Lab. Sci., 45, 1-23

Gánti, T., Horváth, A., Bérczi, S. et al. (2003). Dark Dune Spots: Possible Biomarkers on Mars?. Orig Life Evol Biosph 33, 515–557.

Geller, H. A, (2014) Evidence of life n Mars or Just another case of Pareidolia, Comology, 17, 33-36.

Gervais, F., et al. (2002). Changes in primary productivity and chlorophyll a in response to iron fertilization in the Southern Polar Frontal Zone, Limnology and Oceanography, 47, 5, 1324-1335.

Glasauer S.M.,Gadd G.M. (2013) Metals and Metalloids, Transformation by Microorganisms. In: Reference Module in Earth Systems and Environmental Sciences, 2013.

Glotch, T. D., Bandfield, J. L. (2006). Determination and interpretation of surface and atmospheric Miniature Thermal Emission Spectrometer spectralend-members at the Meridiani Planum landing site, Journal of Geophysical Research, VOL. 111, E12S06, doi:10.1029/2005JE002671.

Goyal R, Seaward MRD. (1981) Metal uptake in terricolous lichens I. Metal localization within the thallus. New Phytol 1981; 89: 631-645.

Goyal R, Seaward MRD, (1982). Metal uptake in terricolous lichens II, Effects on the morphology of Peltigera canina and Peltigera rufescens. New Phytol 1982; 90: 73-844

Graustein, W. C., Cromack, K., and Sollins, P. (1977). Calcium oxalate: Occurrence in soils and effect on nutrient and geochemical cycles. Science 198, 1252–1254.

Greene, V. (2000, 2013). Jewish Science. The Rebbe and the Scientist: Looking for Life on Mars, http://jemedia.org/email/newsletter/My_Encounter/11-9-13.pdf, https://www.chabad.org/therebbe/article_cdo/aid/2436891/jewish/The-Rebbe-and-the-Scientist-Looking-for-Life-on-Mars.htm

Grove, C., Jerram, D. A., Gluyas, J. G., Brown, R. J. (2017). Sandstone Diagenesis in Sediment–lava Sequences: Exceptional Examples of Volcanically Driven Diagenetic Compartmentalization in Dune Valley, Huab Outliers, Nw Namibia, Journal of Sedimentary Research, 87, 1314-1335

Grube, M., Hawksworth, D.L. (2007) Trouble with lichen: the re-evaluation and re-interpretation of thallus form and fruit body types in the molecular era. Mycol. Res. 111: 1116–1132.

Gupta, R. S. (2013). Molecular markers for photosynthetic bacteria and insights into the origin and spread of photosynthesis, in Advances in Botanical Research, Vol. 66, ed. J. Thomas Beatty (Cambridge, MA: Academic Press), 37–66.

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica, 4, 9.

Hansen, C.J et al. (2010). "HiRISE observations of gas sublimation-driven activity in Mars' southern polar regions: I. Erosion of the surface". Icarus. 205 (1): 283–295.

Hauck M, Dulamsuren Ch, Mühlenberg M. (2007) Lichen diversity on steppe slopes in the northern Mongolian mountain taiga and its dependence on microclimate, Flora, 2007, 202, 530-546.

Hauck, M., et al. (2009) Dissociation and metal-binding characteristics of yellow lichen substances suggest a relationship with site preferences of lichens, Annals of Botany, 103, 13–22

Hashimoto, Y, Yanagisawa, K. (1970). Effect of Radiation on the Spore Germination of the Cellular Slime mould Dictyostelium discoideum , Radiat Res (1970) 44 (3): 649–659.

Hassler, D, M., et al. (2013) Mars' Surface Radiation Environment Measured with the Mars Rover. Science, doi: 10.1126/science.1244797

He, H., et al. (2014). Physiological and ecological significance of biomineralization in plants. Trends in Plant Science 19:166-174.

Hen, J., Gong, Z. T. (1995). Role of lichens in weathering and soil-forming processes in Fildes Peninsula, Antarctic. Pedosphere. 5(4): 305-314.

Horneck, G. Mileikowsky, C., Melosh, H. J., Wilson, J. W. Cucinotta F. A., Gladman, B. (2002). Viable Transfer of Microorganisms in the solar system and beyond, In G. Horneck & C. Baumstark-Khan. Astrobiology, Springer.

Hoover, R (2011). Fossils of Cyanobacteria in CI1 Carbonaceous Meteorites, Journal of Cosmology, 2011, Vol 13.

Huneck S. (1999). The significance of lichens and theirmetabolites, Naturwissenschaften, 1999, 86. 559-570.

Huneck S, Yoshimura I. (1996). Identification of lichen substances, Berlin Springer.

Hunt, L. (1985). "US Coverup of Nazi Scientists". Bulletin of the Atomic Scientists. 2 (8): 16–24.

Ito, H, Watanabe H, Takeshia M. & Iizuka H (1983). Isolation and identification of radiation-resistant cocci belonging to the genus Deinococcus from sewage sludges and animal feeds. Agric". Biol. Chem. 47: 1239-47. doi:10.1271/bbb1961.47.1239.

Jastrow, R. (1978), God and the Astronomers, W.W. Norton and Co., 1978.

Jenkins, G. S., (2001) High-obliquity simulations for the Archean Earth: Implications for climatic conditions on early Mars, JGR Planets, 106, 32903-32913

Johnston, D. T., Wolfe-Simon, F., Pearson, A., and Knoll, A. H. (2009). Anoxygenic photosynthesis modulated Proterozoic oxygen and sustained Earth's middle age. Proc. Nat. Acad. Sci. U.S.A. 106, 16925–16929. doi: 10.1073/pnas.0909248106

Johnston CG, Vestal JR (1986) Does iron inhibit cryptoendolithic microbial communities? Ant J U.S. 21:225–226.

Johnston, C. G., Vestal, J. R. (1993). Biogeochemistry of Oxalate in the Antarctic Cryptoendolithic Lichen-Dominated Community, Microb Ecol 25:305-319

Joseph, R. (2006) Martian Mushrooms? BrainMind.com/MartianMushrooms.html

Joseph, R. (2008) Life on Mars: NASA. Evidence of Past Life on the Red Planet. youtube.com/watch?v=Wj4Q1hPRoDs

Joseph, R. (2014a). Evidence for Life on Mars: Moisture, Algae, Fungi, Martian Mushrooms, Lichens. 2005-2014. Cosmology, Vol 16. http://cosmology.com/LifeOnMars100.html

Joseph, R. (2014b). Answer to Geller and NASA et al: Self-Deception, Conformity of Thought, Delusional Pareidolia Cosmology, v 17, 37-39, 2014

Joseph, R. (2016). A High Probability of Life on Mars, The Consensus of 70 Experts, Cosmology, 25, 1-25.

Joseph, R. (2016b). The Truth About the Moon Microbes. Cosmology, January 12. http://cosmology.com/MoonMicrobes.html

Joseph, R. (2017). The Religious Wars Against Extraterrestrial Life, Cosmology, April 25, http://cosmology.com/ReligionExtraterrestrialLife.html

Joseph, R., Dass RS, Rizzo V, Bianciardi G. (2019). Evidence of life on Mars. Journal of Astrobiology and Space Science Reviews. 1: 40-81.

Joseph, R. G., N. S. Duxbury, G. J. Kidron, C.H. Gibson, R. Schild, (2020a) Mars: Life, Subglacial Oceans, Abiogenic Photosynthesis, Seasonal Increases and Replenishment of Atmospheric Oxygen, Open Astronomy, 2020, 29, 1, 189-209

Joseph RG, Armstrong RA, Kidron GJ, Schild R (2020b) Life on Mars: Colonies of photosynthesizing mushrooms in Eagle Crater? The hematite hypothesis refuted. Journal of Astrobiology and Space Science Reviews 5: 88-126.

Joseph R., R. A. Armstrong, Konrad Wołowski, Giora J. Kidron, C. H. Gibson, Rudolph Schild, (2020c) Arctic Life on Mars? Araneiforms ("Spiders" "Trees"), Subglacial Lakes, Geysers, Mud Volcanoes, Dormancy and the Subsurface Biome, J. Astrobiology & Space Science Research, 2020, 6, 77-161

Joseph R., Panchon, O., Gibson, C. H., Schild, R. (2020d). Seeding the Solar System with Life: Mars, Venus, Earth, Moon, Protoplanets. Open Astronomy, 29, 1.

Joseph RJ, Graham L, Büdel B, Jung P, Kidron GJ, Latif K, Armstrong RA, Mansour HA, Ray JG, Ramis GJP, Consorti L, Rizzo V, Gibson CH, Schild R (2020e) Mars: algae, lichens, fossils, minerals, microbial mats and stromatolites in Gale crater. J. Astrobiology and Space Science Reviews 3: 40-111.

Joseph, R., Planchon, O., Duxbury, N.S., Latif, K., Kidron, G.J., Consorti, L., Armstrong, R. A., Gibson, C. H., Schild, R., (2020f) Oceans, Lakes and Stromatolites on Mars, Advances in Astronomy, 2020, doi.org/10.1155/2020/6959532

Joseph RG, Armstrong RA, Latif K, Elewa, A.M.T., Gibson CH, Schild R (2020g) Metazoans on Mars? Statistical quantitative morphological analysis of fossil-like features in Gale crater. J Cosmology, 29: 440-475.

Joseph R., Panchon, O., Schild, R. (2020h). Seeding the Solar System with Life: Mars, Venus, Earth, Moon, Protoplanets. Open Astronomy, 29, 1.

Jung, P., Baumann, K., Lehnert, L. W., Samolov, E., Achilles, S., Schermer, M., Karsten, U. (2019). Desert breath—How fog promotes a novel type of soil biocenosis, forming the coastal Atacama Desert's living skin. Geobiology, 18, 113-124.

Kaźmierczak, J., (2016). Ancient Martian biomorphs from the rim of Endeavour Crater: similarities with fossil terrestrial microalgae. In book: Paleontology, Stratigraphy, Astrobiology, in commemoration of 80th anniversary of A. Yu. Rozanov, Publisher: Borissiak Paleontological Institute RAS, Moscow, Editor: S.V. Rozhnov, pp. 229-242.

Kaźmierczak, J., (2020) Conceivable Microalgae -like Ancient Martian Fossils and Terran Analogues:MER Opportunity Heritage. Astrobiol Outreach 8: 167. DOI: 10.4172/2332-2519.1000167.

Kendall, B., Reinhard, C. T., Lyons, T. W., Kaufman, A. J., Poulton, S. W., and Anbar, A. D. (2010). Pervasive oxygenation along late Archaean ocean margins. Nat. Geosci. 3, 647–652. doi: 10.1038/ngeo942

Kereszturi Á., Bérczi S., Horváth A., Pócs T., Sik A., Eörs S. (2012) The Astrobiological Potential of Polar Dunes on Mars. In: Hanslmeier A., Kempe S., Seckbach J. (eds) Life on Earth and other Planetary Bodies. Cellular Origin, Life in Extreme Habitats and Astrobiology, vol 24. Springer, Dordrecht.

Kharecha, P., Kasting, J. F., and Siefert, J. (2005). A coupled atmospheric-ecosystem model of the early Archean Earth. Geobiology 3, 53–76. doi: 10.1111/j.1472-4669.2005.00049.x

Kidron, G. J., Zohar, M. (2014). Wind speed determines the transition from biocrust-stabilized to active dunes, Aeolian Research, 15, 261-267.\

Kidron, G. J., Ying, W., Starinksy, A., Herzberg, M. (2017). Drought effect on biocrust resilience: High-speed winds result in crust burial and crust rupture and flaking, Science of The Total Environment, 579. 848-859, Doi: 10.1016/j.scitotenv.2016.11.016.

Kieffer, H., Christensen, P. & Titus, T. (2006). CO2 jets formed by sublimation beneath translucent slab ice in Mars' seasonal south polar ice cap. Nature 442, 793–796.

Kirkland,L.E. et al. (2004) Adifferent perspective for the Mars rover‘ Opportunity' site: Fine-grained, consolidated hematite and hematite coatings, Geophysical Research Letters, 315.

Klingelho¨fer, G. (2004). Jarosite and Hematite at Meridiani Planum from Opportunity's Mössbauer Spectrometer, Science 306, 1740-1745.

Knauth, L., Burt, D. & Wohletz, K. (2005). Impact origin of sediments at the Opportunity landing site on Mars. Nature 438, 1123–1128.

Kobayashi T., Nishizawa N. K. (2012). Annu. Rev. Plant Biol. 2012;63:131–152.

Kosta, J.E., Nealson, K.H., (1995). Dissolution and reduction of magnetite by bacteria. Environmental Science and Technology 29, 2535–2540.

Komatsu, G., et al., (2016). Small edifice features in Chryse Planitia, Mars: assessment of a mud volcano hypothesis. Icarus 268, 56–75.

Krupa, T. A. (2017). Flowing water with a photosynthetic life form in Gusav Crater on Mars, Lunar and Planetary Society, XLVIII

Kumar, P.S. et al. (2019). Recent seismicity in Valles Marineris, Mars: Insights from young faults, landslides, boulder falls and possible mud volcanoes, Earth and Planetary Science Letters, 505, 51-64.

Lalonde, S. V., and Konhauser, K. O. (2015). Benthic perspective on Earth’s oldest evidence for oxygenic photosynthesis. Proc. Natl. Acad. Sci. U.S.A. 112, 995–1000. doi: 10.1073/pnas.1415718112

Lange OL, Ziegler H. (1963). Der Shwermetallgehalt von Flechten aus dem Acarosporetum sinopicae auf Erzhlackenhalden des Harzes. Mitt flor-soziol Arbeits Gemeinsch 1963; 10: 156.

Leontyev D. V. Does the long-time warming affect the diversity of Myxomycetes in arctic soils? / D. V. Leontyev // Актуальні питання біотехнології та природокористування : матеріали IV наук.-практ. конф. (м. Харків, 9 листоп. 2016 р.) / Харк. держ. зоовет. акад., ф-т біотехнол. та природокористув. - Харків, 2016. - С. 28-30.

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

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

Levin, G.V., Straat, P.A., and Benton, W.D. (1978). Color and Feature Changes at Mars Viking Lander Site. J. Theor. Biol., 75: 381-390.

Levin, G.V., Straat, P.A. (2016). The Case for Extant Life on Mars and its Possible Detection by the Viking Labeled Release Experiment. Astrobiology 16 (10): 798 - 810, doi:10.1089/ast.2015.1464

Levin, G.V., Straat, P. A. (2018). Comments on the June 7, 2018, NASA News Release and Papers, Astrobiology, 18(7) 841-842.

Levin, M. (2003). Review: Bioelectromagnetics in Morphogenesis. Bioelectromagnetics 24:295-315.

Llirós, M., García–Armisen, T., Darchambeau, F., Morana, C., Triadó–Margarit, X., Inceoğlu, Ö, et al. (2015). Pelagic photoferrotrophy iron cycling in a modern ferruginous basin. Sci. Rep. 5:13803. doi: 10.1038/srep13803

Lin, L. (2016) Putative Martian Microbes Formed Plentiful Ooids on Mars, Astrobiol Outreach 2016, 4:1

Looney JHH, Kershaw KA, Nieboer E, Webber C, Stesko PI. (1985). The distribution of uranium and companion elements in lichen heath associated with undisturbed uranium deposits in the anadian Arctic. In: Brown DH, editor. Lichen Physiology and Cell Biology. New York: Plenum Press, 1985.: 193-209.

Lovett, R. A. (2000). 'Spiders' Channel Mars Polar Ice Cap". Science. 289 (5486): 1853a–4a.

Lutzoni, F., Pagel M. and Reeb, V. (2001) Major fungal lineages are derived from lichen symbiotic ancestors. Nature 411: 937–940.

NASA (2016). Possible Development Stages of Martian 'Spiders' https://www.nasa.gov/image-feature/jpl/pia21258/possible-development-stages-of-martian-spiders/

Maffei, M. E. (2014). Magnetic field effects on plant growth, development, and evolution (2014). Front. Plant Sci., 04.

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. In, Instruments and Methods for Astrobiology and Planetary Missions, 7441, 744102.

McLean, R.J.C., McLean, M. A. C. (2010). Microbial survival mechanisms and the interplanetary transfer of life through space. Journal of Cosmology, 7, 1802-1820.

McLennan, S. M. et al. (2014). Elemental Geochemistry of Sedimentary Rocks at Yellowknife Bay, 558 Gale Crater, Mars, Science, 343(6169). 1244734, doi:10.1126/science.1244734

Mehra, A. and Farago, M. E. 1994. Metal ions and plant nutrition. In: Plants and Chemical Elements - Biogeochemistry, Uptake. Tolerance and Toxicity, M.E. Farago, ed., VCH, Weinheim, pp. 32-36.

Miller, S. L. & Urey, H. C. (1959). Organic Compound Synthesis on the Primitive Earth. Science. 130 (3370): 245–51.

Mirchink TG, Kashkina GB, Abaturov ID (1972) Resistance of fungi with different pigments to radiation. Mikrobiologiia 41: 83–86.

Mitchell, F. J., & Ellis, W. L. (1971). Surveyor III: Bacterium isolated from lunar retrieved TV camera. In A.A. Levinson (ed.). Proceedings of the second lunar science conference. MIT Press, Cambridge.

Möhlmann, D., Kereszturi, A. (2010). "Viscous liquid film flow on dune slopes of Mars". Icarus. 207 (2): 654.

Moment GB. 1949. On the relation between growth in length, the formation of new segments, and electric potential in an earthworm. J Exp Zool 112:1-12.

Morris, R. V. et al, (2004). A First Look at the Mineralogy and Geochemistry of the MER-B Landing Site in Meridiani Planum, 35th Lunar and Planetary Science Conference, March 15-19, League City, Texas, abstract no.2179

Moseley BE, & Mattingly A (1971). Repair of irradiated transforming deoxyribonucleic acid in wild type and a radiation- sensitive mutant of Micrococcus radiodurans". J. Bacteriol. 105 (3): 976-83. PMC 248526 Freely accessible. PMID 4929286.

Mulleavy, P.,. Evans, T. E. (1982). Radiation Biology of the Myxomycetes, Chapter 7. Cell Bioog of Physriu,m and Didymium, VOl. II. Academic Press.

Nachon, M., et al. (2014). Calcium sulfate veins characterized by ChemCam/Curiosity at Gale crater, 575 Mars, J. Geophys. Res. Planets, 119(9). 2013JE004588, doi:10.1002/2013JE004588.

Nagy, B., Claus, G., Hennessy, D, J., (1962), Organic Particles embedded in Minerals in the Orgueil and Ivuna Carbonaceous Chondrites. Nature 193, 1129 - 1133.

Nagy, B., Fredriksson, K., Kudynowkski, J., Carlson, L. (1963), Ultra-violet Spectra of Organized Elements. Nature 200, 565 - 566.

Nagy, B., Fredriksson, K., Urey, C., Claus, G., Anderson, C. A., Percy, J. (1963). Electron Probe Microanalysis of Organized Elements in the Orgueil Meteorite, Nature 198, 121 - 125.

Ness, P.K. (2001). Spider-Ravine Models and Plant-like Features on Mars – Possible Geophysical and Biogeophysical Modes of Origin, Journal of the British Interplanetary Society (JBIS). 55: 85–108.

Neufeld, M. J. (2002). Wernher von Braun, the SS, and Concentration Camp Labor: Questions of Moral, Political, and Criminal Responsibility". German Studies Review. 25 (1): 63–65.

Neufeld, M. J. (2003). The Guided Missile and the Third Reich: Pennemünde and the Forging of a Technological Revolution". In Renneberg, Monika; Walker, Mark (eds.). Science, Technology, and National Socialism. Cambridge University Press. pp. 51–71

Nicolaus, RA (1968) Melanins. Hermann, Paris.

Nicholson, W.L., et al. (2012). Growth of Carnobacterium spp. from permafrost under low pressure, temperature, and anoxic atmosphere has implications for Earth microbes on Mars. PNAS. https://doi.org/10.1073/pnas.1209793110.

Niemann, H. et al. (2006). Microbial methane turnover at mud volcanoes of the Gulf of Cadiz, Geochimica et Cosmochimica Acta 70 (2006) 5336–5355.

Noffke, N. (2015). Ancient Sedimentary Structures in the < 3.7b Ga Gillespie Lake Member, Mars, That Compare in macroscopic Morphology, Spatial associations, and Temporal Succession with Terrestrial Microbialites. Astrobiology 15(2).: 1- 24.

Nordhagen, R. (1928). Die Vegetation und Flora des Sylenegebietes. I. die Vegetation. Skr Nor Vidensk Akad Oslo 1: 1-612.

Norlund LI, Baron C., Warren, LA (2010). Jarosite formation by an AMD sulphide-oxidizing environmental enrichment: Implications for biomarkers on Mars, Chemical Geo 275, 235-242.

Nosanchuk, JD, Casadevall A (2003) The contribution of melanin to microbial pathogenesis. Cell. Microbiol. 5: 203–223.

Novikova, N (2009) Mirobiological research on board 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://roomeu.com/article/long-term-spaceflight-and-microbiological-safety-issues.

Novozhilov Yuri K. Schnittler Martin Zemlianskaia Innav. Fefelov Konstantin A. (2000). Biodiversity of plasmodial slime moulds (Myxogastria): measurement and interpretation, Protistology, 2000.

Nybakken L, Solhaug KA, Bilger W, Gauslaa Y. (2004). The lichens Xanthoria elegans and Cetraria islandica maintain a high protection against UV-B radiation in Arctic habitats, Oecologia, 140, 211-216

Occhipinti, A., De Santis, A., and Maffei, M. E. (2014). Magnetoreception: an unavoidable step for plant evolution? Trends Plant Sci. 19, 1-4. doi: 10.1016/j.tplants.2013.10.007

Onofri, S., R. de la Torre, J-P de Vera, et al. (2012) Survival of rock-colonizing organisms after 1.5 years in outer space." Astrobiology. 2012;12:508-516.

Onofri, S., et al (2018). Survival, DNA, and Ultrastructural Integrity of a Cryptoendolithic Antarctic

Fungus in Mars and Lunar Rock Analogues Exposed Outside the International Space. Astrobiology, 19, 2.

Palmieri et al. (2019) Oxalic acid, a molecule at the crossroads of bacterial-fungal interactions,Advances in Applied Microbiology,106, 49-77

Pandey, V., Upreti, D.K. (2000). Determination Of Heavy Metals In Lichens Growing On Different Ecological Habitats In Schirmacher Oasis, East Antarctica, Seventeenth Indian Expedition to Antarctica, Scientific Report 2000 Department of Ocean Development. Technical Publication No. 15, PP 203-209

Pankowski1, A., McMinn, A. (2020) Iron availability regulates growth, photosynthesis, and production of ferredoxin and flavodoxin in Antarctic sea ice diatoms, Aquatic Biology, 4, January

Parajuli, I., & Chettri, M. (2020). Bioaccumulation of Iron in Plants and Their Possibilities as a Tool for Exploration of Hematite Ores. Amrit Research Journal, 1(1), 1-12

Parnell J, McMahon S, Boyce A. 2018. Demonstrating deep biosphere activity in the geological record of lake sediments, on Earth and Mars. Int. J Astrobio 17, 380–385.

Paukov A. G. et al (2015). Heavy metal uptake by chemically distinct lichens from Aspicilia spp. growing on ultramafic rocks, Australian Journal of Botany 63(2) 111-118

Petersen, J. H. (2013). The Kingdom of Fungi. Princeton University Press.

Phillips, R., et al. (2011). Massive CO2 ice deposits sequestered in the south polar layered deposits of Mars. Science: 332, 638-841.

Pilorget, C. (2011). Dark spots and cold jets in the polar regions of Mars: New clues from a thermal model of surface CO2 ice" (PDF). Icarus. 213 (1): 131.

Plait, P. (2012). Category: Pareidolia. Discover Magazine, February 2014, http://blogs.discovermagazine.com/badastronomy/category/pareidolia/

Pondrelli, M. et al. (2011). Mud volcanoes in the geologic record of Mars: The case of Firsoff crater. Earth Planet. Sci. Lett. 304, 511–519.

Portyankina, G. et al. (2020). How Martian araneiforms get their shapes: morphological analysis and diffusion-limited aggregation model for polar surface erosion IcarusVolume 342, 15 May 2020, 113217.

Poulton, S. W., Canfield, D. E. (2011). Ferruginous conditions: a dominant feature of the ocean through Earth’s history. Elements 7, 107–112. doi: 10.2113/gselements.7.2.10

Pozzobon, R. et al. (2019). Fluids mobilization in Arabia Terra, Mars: Depth of pressurized reservoir from mounds self-similar clustering, Icarus, 321, 2019, 938-959

Prieto-Ballesteros, Olga; Fernández-Remolar, DC; Rodríguez-Manfredi, JA; Selsis, F; Manrubia, SC (2006). Spiders: Water-Driven Erosive Structures in the Southern Hemisphere of Mars". Astrobiology. 6 (4): 651–667.

Probst, A.J., Ladd, B., Jarett, J.K. et al. (2018). Differential depth distribution of microbial function and putative symbionts through sediment-hosted aquifers in the deep terrestrial subsurface. Nat Microbiol 3, 328–336

Puckett, K. J., (1973) The Uptake of Metal Ions by Lichens: A Modified Ion-Exchange ProcessThe New Phytologist, 72, No. 2 329-342

Purvis, O.W., Halls, C., (1996). A review of lichens of metalliferous rocks. Lichenologist, v. 28, 571-601

Rabb, H. (2015). Life on Mars – Visual investigations. https://www.scribd.com/doc/288386718/Life- on-Mars-Visual-Investigation.

Rabb, H. (2018). Life on Mars, Astrobiology Society, SoCIA, University of Nevada, Reno, USA. April 14, 2018.

Raggio J, Pintado A, Ascaso C, De La Torre R, De Los Ríos A, Wierzchos J, Horneck G, Sancho

LG (2011). Whole lichen thalli survive exposure to space conditions: results of Lithopanspermia experiment with Aspicilia fruticulosa. Astrobiology. 2011 May;11(4):281-92. doi: 10.1089/ast.2010.0588.

Rakoczy, L. (1998) Plasmodial Pigmentation of the Acellular Slime Mould Physarum Polycephalum in Relation to the Irradiation Period Pol. J. Environ. Stud. 1998;7(6):337–342 .

Rapina, W. P et al. (2016). Hydration state of calcium sulfates in Gale crater, Mars: Identification of bassanite veins, Earth and Planetary Science Letters, 452, 197-205.

Rebriev, Y.A. et al. (2020). An Annotated Key to the Bovista (Lycoperdaceae, Basidiomycota) Species in Russia. Phytotaxa. 464(1); 1–28. DOI: 10.11646/phytotaxa.464.1.1

Remizovschi, A., et al. (2018). BiologicalaAnd Geological Traits Of Terrestrial Mud Volcanoes – A Review, Analele Universităţii din Oradea, Fascicula Biologie Review Tom. XXV, Issue: 2, 2018, pp. 102-114

Rieder, R., et al., (2004). Chemistry of Rocks and Soils at Meridiani Planum from the Alpha Particle X-ray SpectrometerScience 306, 1746-1749.

Rikkinen J. (1995). What's behind the pretty colours? A study on the photobiology of lichens, Bryobrothera, 1995, 4, 1-239

Rizzo V (2020) Why should geological criteria used on Earth not be valid also for Mars? Seeking indications for stromatolites at the macro-scale in extinct Martian lakes. International Journal of Astrobiology -- :1-12.

Rizzo V, Armstrong RA, Hua H, Cantasano N, Nicolò T, Bianciardi G. (2021) Life on Mars: clues, evidence or proof? In: Solar Planets and Exoplanets, IntechOpen, Article 95531.DOI:http:// dx.doi.org/ 10.5772/intechopen.95531

Rizzo, V., Cantasano, N. (2009). Possible organosedimentary structures on Mars. International Journal of Astrobiology 8 (4).: 267-280.

Rizzo V, Cantasano N. (2016). Structural parallels between terrestrial microbialites and Martian sediments: are all cases of 'Pareidolia' International Journal of AstrobiologyVolume 16 Issue 4.

Roberts, P., & Evans S. (2011). The book of Fungi. University of Chicago Press.

Robinson CH (2001) Cold adaptation in Arctic and Antarctic fungi. New phytologist 151: 341–353.

Roden, E.E., Zachara, J.M., (1996). Microbial reduction of crystalline iron(III) oxides: influence of oxide surface area and potential for cell growth. Environmental Science and Technology 30, 1618–1628

Rowan, P. (2016). Is NASA Running Away From Life on Mars? The Republican, August 3. https:// www.masslive.com/living/2016/08/is_nasa_running_away_from_life_on_mars.html

Royer, D. et al. (2008), The Mars spherule size distribution and the impact hypothesis. Lunar and Planetary Science Conference (No. XXXIX or 39), Abstract #1013. https://www.lpi.usra.edu/meetings/ lpsc2008/pdf/1013.pdf

Ruffi, W., Farmer, J.D., (2016). Silica deposits on Mars with features resemblinghot spring biosignatures at El Tatio in Chile. Nature Communications, 7: 13554, DOI: 10.1038/Ncomms13554.

Russ, J., Palma, R.L., Loyd, D. H., Boutton, T. W., Coy, M.A. (1996). Origin of the Whewellite-Rich Rock Crust in the Lower Pecos Region of Southwest Texas and Its Significance to Paleoclimate Reconstructions. Quaternary Research 46, 27–36.

Russ, J., Palma, R. L., Loyd, D. H., Farwell, D. W., Edwards H. G. M. (1995). Analysis of the rock accretions in the Lower Pecos region of southwest Texas. Geoarchaeology 10, 43–63.

Russ, J., et al. (1999) The Nature of a Whewellite-Rich Rock Crust Associated with Pictographs in Southwestern Texas, Studies in Conservation, 44, 91-103.

Russ, J., et al. (1996). Origin of the Whewellite-Rich Rock Crust in the Lower Pecos Region of Southwest Texas and Its Significance to Paleoclimate Reconstructions Quaternary Research, 46, 27–36

Saleh, Y. G., M. S. Mayo, and D. G, Ahearn (1988) Resistance of some common fungi to gamma irradiation." Appl. Environm. Microbiol. 1988, 54: 2134-2135.

Sancho L. G., de la Torre, R., Horneck, G., Ascaso, C. , de los Rios, A. Pintado,A., Wierzchos, J.,Schuster, M. (2007). Lichens Survive in Space: Results from the 2005 LICHENS Experiment Astrobiology. 7, 443-454.

Satoh, K, Y, Nishiyama, T. Yamazaki, T. Sugita, Y. Tsukii, K. Takatori, Y. Benno, and K. Makimura. "Microbe-I (2011) Fungal biota analyses of the Japanese experimental module KIBO of the International Space Station before launch and after being in orbit for about 460 days." Microbiol Immunol. 2011 Dec;55(12):823-9. doi: 10.1111/j.1348-0421.2011.00386.x.

Schulze-Makuch, D. Irwin, L.N., Lips, J.H., LeMone, D., Dohm, J.M., Farien, A. G. (2005) Scenarios for the evolution of life on Mars, Journal of Geophysical Research: Planets, 110, E12.

Science Magazine (2011), Bugs in space? Forget it. http://www.sciencemag.org/news/2011/03/bugs- space-forget-it

Schneider, A. (1987) A text-book of general lichenology, Willard N. Clute & Co

Seal, SN., Sen, SP (1970). The photosynthetic production of oxalic acid in Oxalis corniculata, Plant and Cell Physiology, 11, 119-128.

Silverstein, A. The West Temple (Cleveland, Ohio) Records. 1910-2008, http://collections.americanjewisharchives.org/ms/ms0784/ms0784.html, and http://www.thewesttemple.com/about-us/our-history3

Singh, S.M., Sharma, J., Gawas-Sakhalkar, P. et al. (2013). Atmospheric deposition studies of heavy metals in Arctic by comparative analysis of lichens and cryoconite. Environ Monit Assess 185, 1367–1376 (2013). https://doi.org/10.1007/s10661-012-2638-5

Skinner, J.A., Jr.; Adriano, M. (2009). Martian mud volcanism: Terrestrial analogs and implications for formational scenarios. Mar. Pet. Geol. 26, 1866–1878.

Small, L.W. (2015). On debris flows and mineral veins: Where surface life resides on Mars. https://www.scribd.com/doc/284247475/On-Debris-Flows-eBook.

Soderblomet. L.A. al. (2004). Soils of Eagle Crater and Meridian Planum at the Opportunity Rover Landing Site" (PDF). Science. 306 (5702): 1723–1726. Bibcode:2004Sci...306.1723S. doi:10.1126/science.1105127. PMID 15576606.

Song, J. F., Qi, H. Y., Cui, X. Y., & Peng, H. M. (2011). Effects of Organic Acids on Chlorophyll Contents and Photosynthesis of Fraxinus mandshurica Seedlings. Advanced Materials Research, 393–395, 713–716.

Squires, S. W., et al. (2004). In Situ Evidence for an Ancient Aqueous Environment at Meridiani Planum, Mars" (PDF). Science. 306 (5702): 1709–1714. Bibcode:2004Sci...306.1709S. doi: 10.1126/science.1104559. PMID 15576604.

Sterflinger, K (2006). Black Yeasts and Meristematic Fungi: Ecology, Diversity and Identification. In Rosa, Carlos; Gábor, Péter (eds.). Biodiversity and Ecophysiology of Yeasts. The Yeast Handbook. pp. 501–14. doi:10.1007/3-540-30985-3_20. ISBN 978-3-540-26100-1.

Stromberg, J.M., et al (2014).The persistence of a chlorophyll spectral biosignature from Martian evaporite and spring analogues under Mars-like conditions, International Journal of Astrobiology, 13 (3). pp. 203-223. ISSN 1473-5504.

Stromberg, J.M., et al (2019). Biosignature detection by Mars rover equivalent instruments in samples from the CanMars Mars Sample Return Analogue Deployment, Planetary and Space Science, https://doi.org/10.1016/j.pss.2019.06.007.

Sunda, W.G., Huntsman, S. A. (2015). High iron requirement for growth, photosynthesis, and low-light acclimation in the coastal cyanobacterium Synechococcus bacillarisFront. Microbiol., 18 June 2015

Takahashi, A., et al. (1972) Mutation frequency of Dictyostelium discoideum spores exposed to the space environment, Biological Sciences in Space 11.

Takeshi, K., et al., (2003), Accumulation Mechanisms of Uranium, Copper and Iron by Lichen Trapelia involuta, In Biomineralization (BIOM2001): formation, diversity, evolution and application, Proceedings of the 8th International Symposium on Biomineralization, Tokai Univ. Press, Kanagawa, 2003, 298-301

Terzi, M. (1961). The comparative analysis of inactviating efficiency of radiation on different organisms. Nature, 191, 461-463.

Terzi, M. (1965) Radiosensitivity and genetic complexity, J. Theoretical Biology, 8, 233-243.

Thomas-Keprta, K. L., et al. (2009). Origins of magnetite nanocrystals in Martian meteorite ALH84001. Geochimica et Cosmochimica Acta, 73, 6631-6677.

Thomas, P., W. Calvin, B. Cantor, R. Haberle, P. James, S. Lee. (2016). Mass balance of Mars' residual south polar cap from CTX images and other data Icarus: 268, 118–130.

Tooulakou, G. et al. (2016) Alarm Photosynthesis: Calcium Oxalate Crystals as an Internal CO2 Source in Plants, Plant Physiology, https://doi.org/10.1104/pp.16.00111

Tugay, T. Zhdanova, N.N., Zheltonozhsky, V., Sadovnikov, L., Dighton, J. (2006). The influence of ionizing radiation on spore germination and emergent hyphal growth response reactions of microfungi, Mycologia, 98(4), 521-527.

Ugolingi FC (1986) Processes and rates of weathering in cold and polar desert environments. In: Colmant SM, Dethier DP (eds) Rates of chemical weathering of rocks and minerals. Academic Press, Inc., Orlando, pp 193–235

Verrecchia, E. P. (1990). Litho-diagenetic implications of the calcium oxalate-carbonate biogeochemical cycle in semiarid calcretes, Nazareth, Israel. Geomicrobiology Journal 8, 87–99.

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

Wang, J., Pantopoulos, K. (2011). Regulation of cellular iron metabolism, J., Biochem. 434 (3): 365–381.

Weed R, Norton SA (1991) Siliceous crusts, quartz rinds, and biotic weathering of sandstones in the cold desert of Antarctica. In: Berthelin J (ed) Diversity of environmental biogeochemistry. (Developments in geochemistry, vol. 6) Elsevier, Amsterdam, pp 327–339

Wember VV, Zhdanova NN (2001) Peculiarities of linear growth of the melanin-containing fungi Cladosporium sphaerospermum Penz. and Alternaria alternata (Fr.) Keissler. Mikrobiol. Z. 63: 3–12.

White, O. et al. (1999) Genome Sequence of the Radioresistant Bacterium Deinococcus radiodurans R1, Science, 286, 1571-1577.

Wrede, C. et al. (2012). Aerobic and anaerobic methane oxidation in terrestrial mud volcanoes in the Northern Apennines. Sediment. Geol. 263–264, 210–219.

Zakharova,K., et al. (2014). Protein patterns of black fungi under simulated Mars-like conditions. Scientific Reports, 4, 5114.

Zhdanova NN, Lashko TN, Vasiliveskaya AI, Bosisyuk LG, Sinyavskaya OI, Gavrilyuk VI, Muzalev PN. (1991). Interaction of soil micromycetes with 'hot' particles in the model system. Microbiol J 53:9-17.

Zhdanova, N. N., T. Tugay, J. Dighton, V. Zheltonozhsky and P McDermott, (2004) Ionizing radiation attracts soil fungi." Mycol Res. 2004, 108: 1089-1096.

Zhuravskaya AN, Kershengoltz BM, Kuriluk TT, Shcherbakova TT. (1995). Enzymological mechanisms of plant adaptation to the conditions of higher natural radiation background. Rad Biol Radioecol 35:249-355.