Fossils on Mars: A Brief Review of the Evidence

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Abstract

The discovery and statistical analysis of fossils on Mars is reviewed. Fossilized formations similar to tube worms, and Ediacarans and Metazoans have been reported. The possibility these organisms evolved from algae that constructed stromatolites early in the history of Mars is discussed in the context of extinction using Earth as an analog.

Key Words: Mars, Fossils, Ediacarans, Metazoans, Acritarchs, Evolution, Extinction.

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1. Fossils on Mars

Some members of NASA's Opportunity and Curiosity rover crews have reported that Mars maintained a habitable environment for unknown periods of time (Ehlmann et al. 2011; Squyres & Knoll 2006; Vago et al. 2017) and prokaryotes and eukaryotes could have evolved (Squyres et al. 2005) and may have become fossilized (Grotzinger et al. 2014, 2015). In 2018, Barry DiGregorio, upon examining photographs of Gale Crater sediments, by the rover Curiosity's microscopic imager, observed enigmatic dark toned tubular features on at least five rocks near the top edge of Vera Rubin Ridge, all in close proximity to each other and are the first of their kind to be observed on Mars. Although these tubular formations have all the characteristics of terrestrial trace fossil burrows (DiGregorio 2018; Joseph et al. 2020a,b) the Curiosity rover team dismissed these as "sticks" and "gypsum crystals" that sometimes form when high concentrations of salts are exposed to water, as in an evaporating lake (reviewed by DiGregorio 2018). Unfortunately, the rover team, as is characteristic, failed to investigate and the Curiosity's Chemcam and the APXS were not employed to obtain usable data and the rover was moved to another location.

Baucon et al. (2020), although admitting the possibility of crystalization also pointed out that crystals and related geological processes do not share many of the morphological and topological features of the Vera Rubin Ridge tubes. In order to test for biogenicity and if these tubes are product of lifesubstrate interactions, Baucon et al (2020) performed a comparative analysis employing "Image J" image analysis software and examined the width, length and angle of these and similar non-biological terrestrial formations. They report they were unable to detect any grain-size differences between the tubular structures and the host rock but noted that contact with the host rock is sharp and well-defined and the colors are different, indicating they are separate and not coextensive as might be expected if formation is due to weathering. They also determined that the morphology closely resembles the horizontal burrows such as *Helminthoidichnites* and *Planolites*. However, they also observed fragmented polygonal cross-sections that may not be compatible with or adaptive for burrowing behavior.

On the other hand, Baucon et al. (2020) noted that several of these tubular structures do not geometrically interact with each other whereas others are coalescing and intersecting that is typical of many burrowing organisms, i.e. orientating and turning in response to other organisms or stimuli as is typical of ichnofossils. Given that Gale Crater is believed to be a series of lakes that periodically fill with water, Baucon et al (2020) also argued that this geological context is typical for the formation of ichnofossils on Earth. Nevertheless, Baucon et al (2020) concluded that their analysis is inconclusive and refer to these specimens as "sticks."

Because Gale Crater consists of a number ancient Martian lakes that periodically filled with water and was conducive to the proliferation and fossilization of a wide range of organisms a team of thirteen experts examined over 3,000 photographs from NASA's rover Curiosity Gale Crater image depository in search of fossils and living organisms (Joseph et al. 2020a). This team identified and provided photographs of specimens similar or identical to green algae, cyanobacteria, lichens, fungi, concentric domical stromatolites and mat-forming organisms. They also discovered an assemblage of diverse life-like specimens that resemble fossilized or trace fossils of various terrestrial organisms including tube worms, burrowing and tunneling organisms, *Foraminfera*, Ediacarans and early Cambrian metazoans and fauna that first appeared during the Ordovician (e.g. *Calymene callicephala, Flexicalymene meeki, Homotelus bromidensis, Isotelus sp., Pseudogygites canadensis, Streptelasma sp.*) as well as fossilized siliceous filamentous sponges--a veritable "Burgess Shale" treasure trove of what may be fossilized organisms that dwelled on Mars as long ago as 1 billion years and as recently as 500 million years ago if we employ evolution on Earth as an analog. Joseph et al. (2020a) also found fossilized specimens similar to the "tube worms" "ichnofossils" (Figure 1) the latter of which were first identified by DiGregorio (2018).

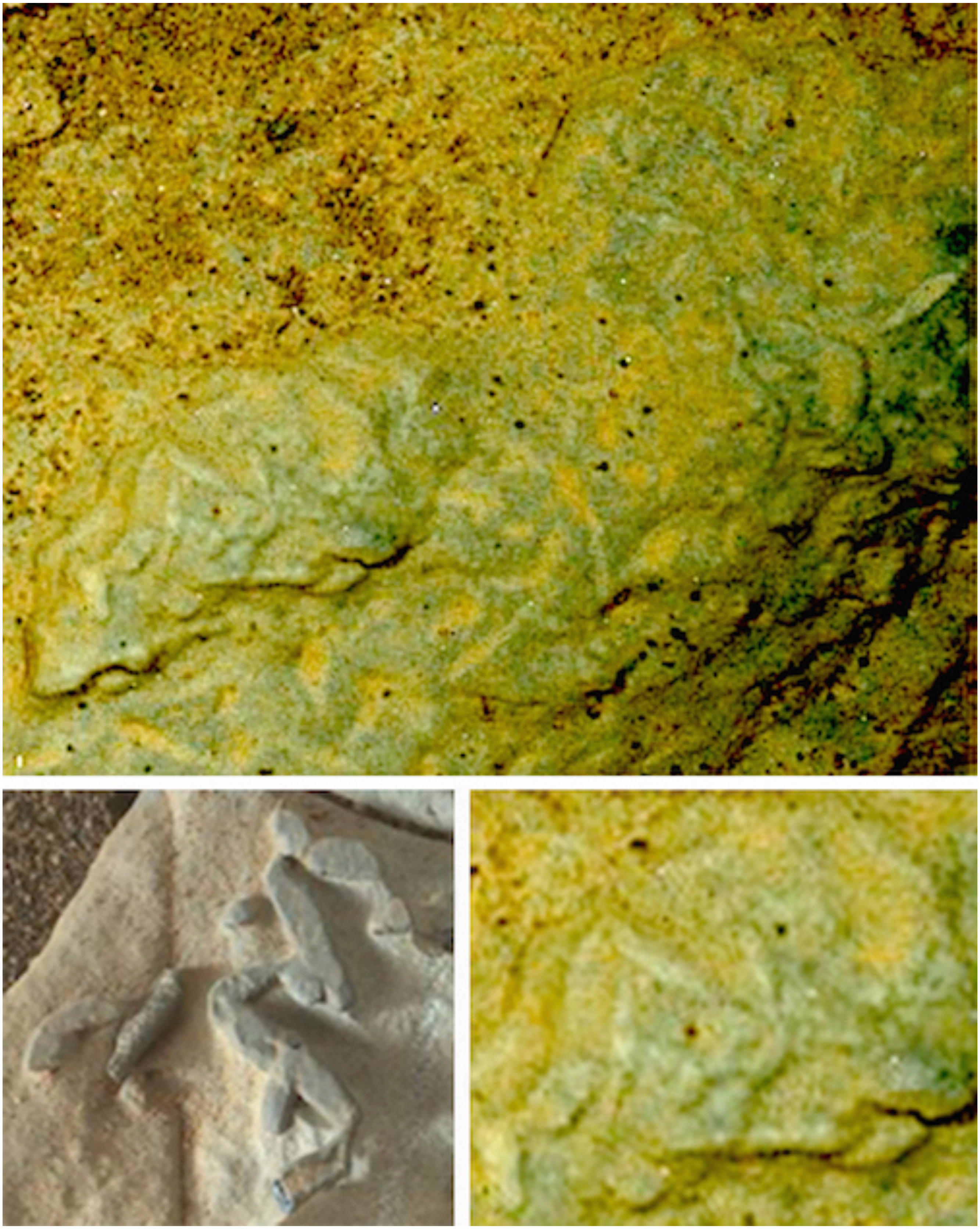

Figure 1. (Top) Sol 869: Specimens resembling mineralized fossils of tubular worms and metazoans, approximately 1 to 2 mm in length. (Bottom Left): Sol 1905 ("ichnofossils") compared with Sol 869 (bottom right). Reprinted from Joseph et al. (2020a).

Figure 2. (Top) Sol 809. (Bottom) Sol 809. Similar specimens in two different locations, photographed alongside tubular, curved, and other fossil-like structures which resemble a variety of metazoans. Reproduced from Joseph et al. 2020a.

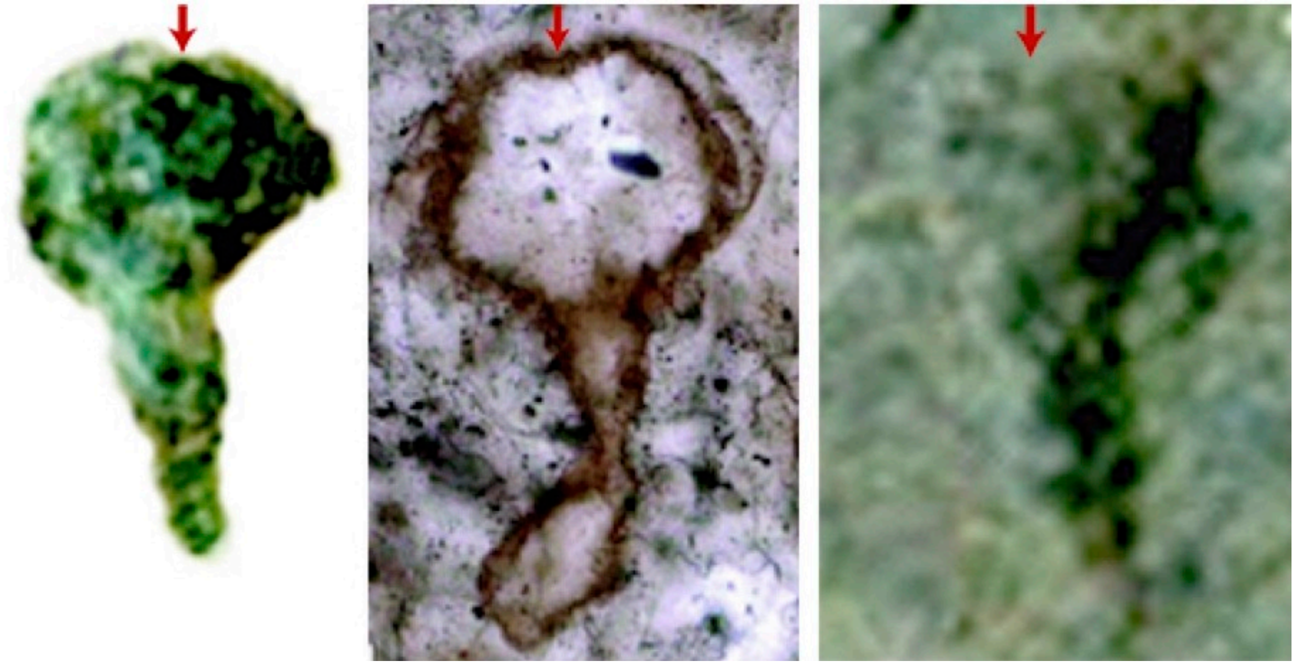

Figure 3. (Left) Sol 809. (Center) Terrestrial *Namacalathus*. (Right) Sol 869. Arrows indicate what may be open apertures. From Joseph et al. 2020b.

Because several of the adjacent “fossilized” specimens were nearly identical to each other, including those with an ice-cream-cone shape (similar to "*Namacalathus*" and "Lophophorates") and others having an ovoid-proboscis-shape coupled with zipper-like appendages on the outer-body similar to "Kimberella" an additional search was conducted and photographs of specimens in the same general vicinity examined. Dozens of formations that resemble "*Namacalathus*," "Lophophorates," and "Kimberella," were observed (Joseph et al. 2020b).

For purposes of comparative morphological and statistical analysis an abiotic image search was also conducted by Joseph et al. 2020b), using key words including: pseudofossils and Namacalathus, or "Lophophorates," or "Kimberella," or "tube worm." With the exception of the pseudo-tube worms no abiogenic formations, even remotely similar to these Martian specimens were found. Employing ImageJ software, nine of those metazoan-like ("ice-cream-cone" shaped) specimens that morphologically resemble "Namacalathus" and "Lophophorates," six (ovoid-proboscis-shaped) specimens resembling the Ediacaran "Kimberella," and three specimens resembling priapulids / "tube worms" were subjected to a computerized quantitative morphological analysis comparing these specimens with analog fossils from Earth. Based on morphology, distinct physical characteristics, and complex comparative analysis, the findings support the hypothesis that formations observed in the dried lake beds of Gale Crater, bear a significant resemblance to fossils from Earth that have been identified as Ediacarans and metazoans

(Figures 2,3). These specimens are statistically indistinguishable, and thus nearly statistically identical on all measures to "Namacalathus," "Kimberella" and trace fossils of "tube worms" (priapulids) and statistically similar to Lophophorates on some but not all measures of morphology.

2. Algae, Thrombolites, Stromatolites

These findings of DiGregorio (2018) Baucon et al. (2020), Joseph et al., (2020a,b) are consistent with evidence ancient Mars and Gale Crater offered a habitable environment where eukaryotes may have evolved and became fossilized. For example, even as early as the 1970s scientists were predicting fossils and fossilized stromatolites could be found on Mars (Sagan & Mullen 1977; Tewari 1998; Walter 1988). These predictions have been confirmed by reports of microbiolites dated 3.7 bya (Noffke 2015), thrombolites of unknown age (Rizzo & Cantasano 2009, 2015; Bianciardi et al. 2014, 2015; Ruff & Farmer 2016), and domical concentric stromatolites (Joseph et al. 2020a,b). Algae are the primary producers of microbiolites, thrombolites and stromatolites, and scientists have also reported evidence of fossilized algae and acritarchs (Kaźmierczak 2016, 2020; Joseph et al. 2020a; Rizzo et al. 2021) and what may be green algae alive on the surface (Joseph 2014; Joseph et al.2021; Krupa, 2017; Latif et al. 2021).

In addition to recent fossil-like specimens resembling Ediacarans and metazoans, concentric domical stromatolites identical to those in Lake Thetis, Australia, have been tentatively identified in Gale Crater (Joseph et al. 2020a,c); a series of ancient lakes marked by fluvial valleys and water pathways. It is believed Gale crater has repeatedly filled with water that would have sustained a variety of species and promoted their evolutionary development (reviewed in DiGregorio 2018; Joseph et al. 2020b,d).

3. Evolution, Extinction

Indirect evidence based on geochemical analysis (Macey et al. 2020), and findings from Martian meteorite ALH 84001 (McKay et al. 1996. 2009;Thomas-Keprta et al. 2009), suggest that microbial life was proliferating on Mars between 3 bya to 4.2 bya.

Using Earth as an analog, there is no reason to believe life on Mars would have become completely extinct. Despite five major catastrophic extinction events and multiple episodes of extinction (Elewa & Joseph 2009), life on Earth has alway rebounded, adapted, and evolved. It is impossible to completely eradicated life even in NASA clean rooms, with innumerable organisms surviving extensive efforts to sterilize equipment (reviewed by Joseph et al. 2019). It can be predicted, therefore, that like Earth, life on Mars, even when subject to extinction events, would have survived, rebounded, adapted and evolved (Elewa & Joseph 2009) eventually reaching stages of development parallelling Earth (Joseph et al. 2020b,d), though it is also possible “evolution” progressed more rapidly or more slowly on Mars.

Naturally, once Mars lost its magnetic field and protective layers of ozone and surface oceans lakes and rivers, there would have been a mass extinction and evolution would have taken a trajectory unlike that of Earth. Therefore, following a massive extinction, it is possible that surviving organisms including complex eukaryotes may have adapted to these drastically altered conditions and evolved accordingly, Perhaps they dwell in Martian caves, crevices, beneath and within rocks and soil. To speculate, perhaps some of these organisms eat fungi, algae, lichens and perhaps each other; and this may explain why sequential images sometimes show fungi-like organisms that disappear (Joseph et al. 2021).

It has been hypothesized that Martian lichens, fungi and algae utilize iron and radiation as nutrients (Joseph 2021). However, some the metazoan-like Martian fossils appear to be encased in a shell (Joseph et al. 2020b). Therefore, to speculate, these putative Martian metazoans, if they did not become extinct, may have evolved a brain and a crustacean/anthropod-shell-like exoskeleton that would protect them from radiation when they venture from their shelters in search of food or mates (Joseph, personal communication). These would not be ocean dwellers, but cold-desert dwellers and might resemble terrestrial crabs, woodlice or spider-crabs (Joseph 2008; 2016). As of this writing, there is no convincing evidence that complex eukaryotic (or crab-like) organisms dwell on Mars, but if they did, it could be predicted they may spend much of their life cycle in a dormant state, hidden in their burrows, beneath rock shelters, or in caves.

4. Conclusions

It is impossible to make precise determinations as to the identity or exact nature of these fossil-like specimens. There is as yet no consensus and it is not known with absolute certainty if there is and was life on Mars and if these early Martian life forms evolved or were deposited on Mars (or Earth) by meteors, comets, or other celestial mechanisms that enabled life to travel to and from the inner planets (Joseph et al. 2020d). Although the increasing body of evidence favors those who believe there is and was life on Mars, and life evolved and became fossilized, as of this writing, it is not possible for this author to offer a conclusive affirmation in favor of this hypothesis.

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