Forms Resembling Sponges or Corals at Gale Crater, Mars: Evidence of Fossilised Life or Mineralogy?

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ABSTRACT

Forms resembling sponges or coral were photographed in Gale crater, Mars by the Curiosity rover 'Mars Hand Lens Imager' (MAHLI) on sol 3396 that may represent the result of either mineralization or be evidence of fossilisation. At least seven individual structures were observed showing various degrees of fragmentation, but the most complete specimen was approximately 1.3 cm across and consisted of apparently branched 'tubes' attached to the substratum at a single point. At higher magnification, a reticulate surface texture and possible pores were apparent; findings consistent with a biological origin. Although a mineral accretion or concretion cannot be ruled out, it is more probable that the structures represent the fossilised remains of a type of sponge or coral, the former being the more likely. In the early life of Gale crater, these putative sponges may have lived at the bottom of a shallow, saline lake, subsequently becoming preserved in deposits of sand or silt, and then were gradually exposed over long periods of time.

Key words: Curiosity rover, Gale crater, Sponge, Coral, Mineralogy

1. Introduction

Forms resembling sponges or coral were photographed in Gale crater, Mars by the Curiosity rover 'Mars Hand Lens Imager' (MAHLI) on sol 3396. In a press release (NASA March 01, 2022), it was suggested that the structures resulted "when minerals carried by water cemented the rock". A possible analogue of such a process could be the formation of stalagmites which form in limestone caves and 'grow' upward due to the accumulation of hydrated and dissolved sediments, minerals and calcium carbonate dripping down from above (Fairchild and Baker 2012; Hicks 1950). As there is no evidence that these forms developed in a cave, this explanation is unlikely. It is also not likely that the structure consists of lava tubes as there is no evidence of volcanic activity or lava in the surrounding areas of Gale crater.

By contrast, in the past, Gale crater may have periodically contained volumes of water including lakes, rivers and streams (Grotzinger et al. 2015; Le Deit et al. 2016; Thomson et al. 2011) and today, has all the characteristics of a series of dried lakes (Grotzinger et al. 2014) that may be periodically replenished with water (Rampe et al. 2020). Chemical and geological analyses obtained by Curiosity in Gale crater suggest a fluvial-lacustrine sequence of fine-grained sedimentary rocks containing both clay and hydrated minerals, which were likely to have been deposited originally inside a lake of approximately neutral pH (Grotzinger et al. 2014). These deposits were then subjected to two further more acidic phases and contain many of the elements necessary for life including H, O, S, C, N, P, as well as Fe, Mg and Mn (Grotzinger et al. 2014). The presence of these elements supports the hypothesis that Gale crater could have possessed a wide ranging ecosystem based on chemolithoautotrophy.

Hence, Gale crater may have been habitable in the past and evidence for a wide variety of organisms has been published. Elongated tubular specimens resembling tube worms have been reported not only in Gale crater (Armstrong 2021; Joseph et al. 2021a) but on the floor of Endurance crater adjacent to specimens resembling crustaceans and holes and vents in the surface that may be the remnants of hydrothermal vents (Joseph 2021a). Possible fossils also include microbialites (Bianciardi et al. 2014, 2015; Small 2015; Noffke 2015; Rabb 2018); domical stromatolites (Joseph et al. 2020a; Latif et al. 2021; Elewa 2021), calcareous algae (Rizzo et al. 2020, Bianciardi et al. 2021); and structures resembling sponges, tube worms, crustaceans, and organisms including *Namacalathus*, the Lophophorates, and *Kimberella* (Joseph et al. 2020b, 2021a, 2021b).

In addition, Gale crater formations resembling layered stromatolites and tabulata coral have also been reported (Joseph et al. 2022). Observations of what may be living and fossilized algae, cyanobacteria, tube worms, crustaceans, microbial mats, stromatolites, coral and hydrothermal vents in the equatorial regions of Mars, strongly supports the hypothesis that the enigmatic forms and adjacent formations photographed on sol 3396 may be the fossilized remnants of coral, sponges, or colonies of marine organisms that long ago flourished in the lakes of Gale crater.

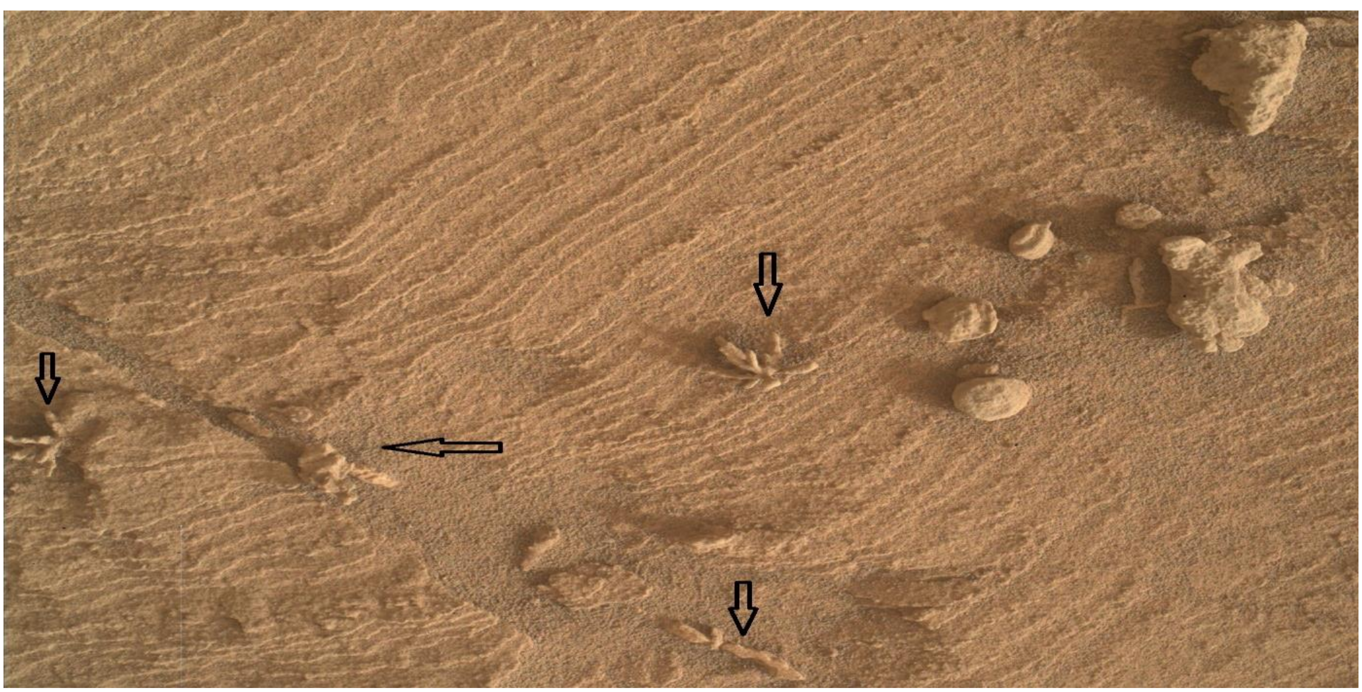

Figure 1. The general environment of the specimens photographed by Curiosity's MAHLI on sol 3396 (3396MH0001900011200997C00_DXXX). At least four specimens can be identified (arrows). Note the apparent 'ripple marks' running across the substratum from top left to bottom right. (NASA/JPL – Caltech).

Figure 2. Overall view of the best preserved specimen photographed in Gale crater by the rover Curiosity (sol 3396, MAHLI) (3396MH0001760011201019C00_DXXX). Note the tubular branches attached by a single point to the substratum, the variation in width of the tubes, and the slightly rounded or flattened tips (NASA/JPL – Caltech).

2. Physical Description & Examination

At least seven individual specimens were observed photographed on sol 3396. Figure 1 shows the general environment of four of the specimens exhibiting various degrees of fragmentation. The specimens are attached to an eroding sandy substratum with frequent 'ripple marks' suggesting ancient water movement. The most complete specimen (Fig 2) is approximately 1.3 cm across (estimated from the motor count), and apparently consists of a series of interconnected 'flask-shaped' branched tubes attached to the sediment by a central holdfast. The 'tube-like' processes are narrower at the base before expanding and terminating in a rounded or flattened top. At higher magnification (Fig 3), the surface of the 'tubes' appears to have a reticulate texture punctuated by possible holes or pores. In addition, some of the specimens (Fig 4) appear to have evidence of holes at the tips of the tubes.

3. Interpretation

3.1 Mineralogy: It is possible that the specimens represent exclusively the results of mineralogy and especially the precipitation of minerals from water without the presence of a biogenic component. Complex morphologies which 'grow' in an upward or downward direction can be formed in caves as the result of the dripping of calcium-rich water, i.e., stalactites and stalagmites (Hicks 1950) but this type of accretion is an unlikely explanation as the current specimens appear to have formed in relation to a sedimentary sandy substratum showing evidence of ancient water movements.

Another possibility is that the specimens are the mineral 'fulgurite' which is formed when lightning strikes and melts sand, the subsequent cooling fusing the sand particles together to form complex shapes. A further possibility is that the specimens are concretions formed as a mineral deposit within the sedimentary rocks of Gale crater. Such concretions are usually harder and more resistant to weathering than the parent rock. Concretions are usually spherical or ovoid, however, but more complex shapes are possible. Nevertheless, it is unlikely that these processes alone would result in a population of branched specimens attached to the substratum by a central point and with such a close resemblance to living organisms.

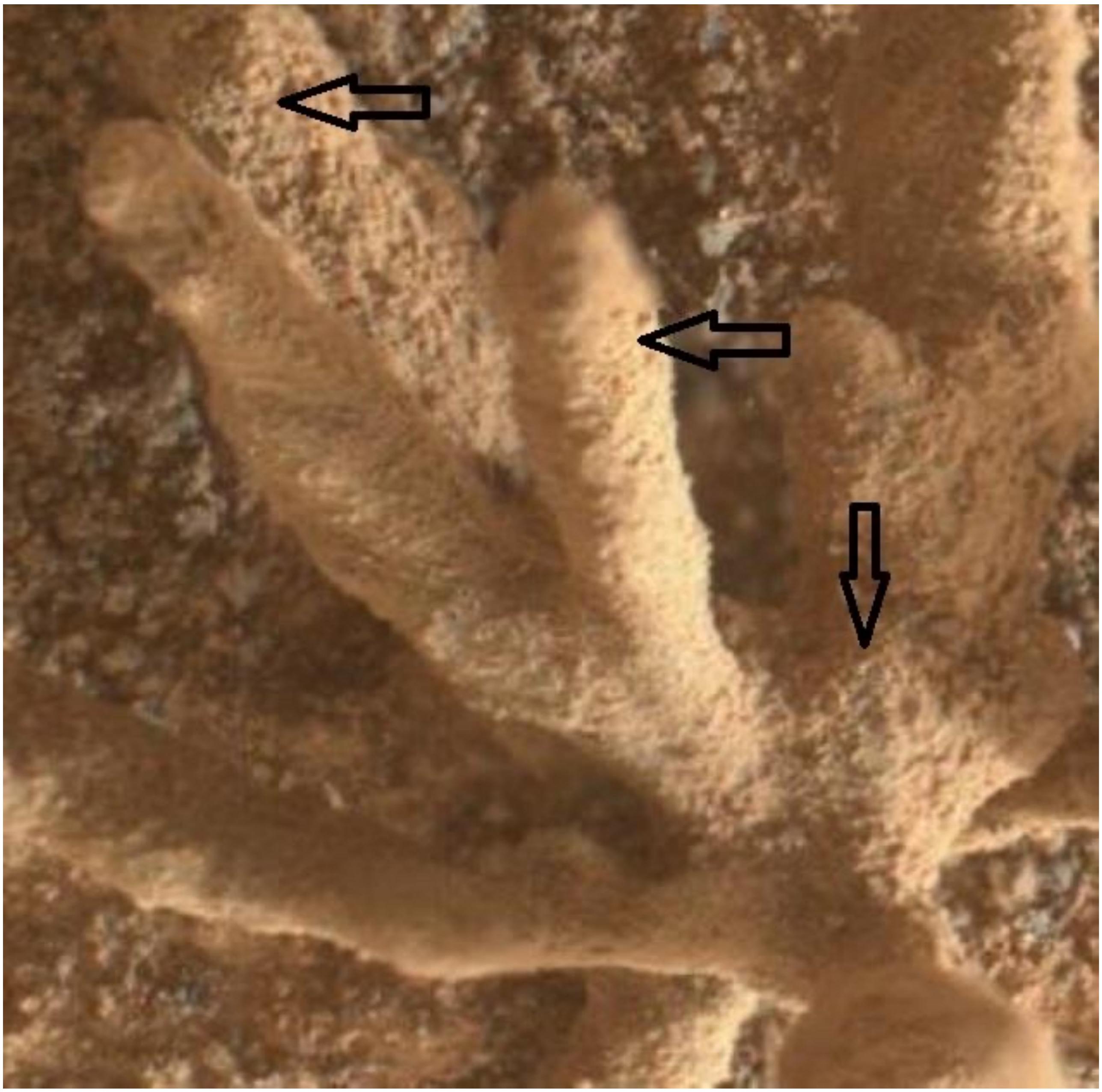

Figure 3. Close up of the specimen (3396MH0001760011201019C00_DXXX). Note the reticulate pattern of striations on the surface of the tubes and at the base and evidence of possible pores ('porocytes') (arrows).

3.2 Amino acids: It is possible that the forms are the result of the self-assembly of complex biomolecules but are not directly the consequence of a living organism. For example, shock processed amino acids tend to form complex agglomerative structures due to impact-induced shock heating and subsequent cooling (Singh et al. 2020). Such processes could also have resulted ultimately in the self-assembly of life on Earth and also on other planetary bodies such as Mars (Singh et al. 2020).

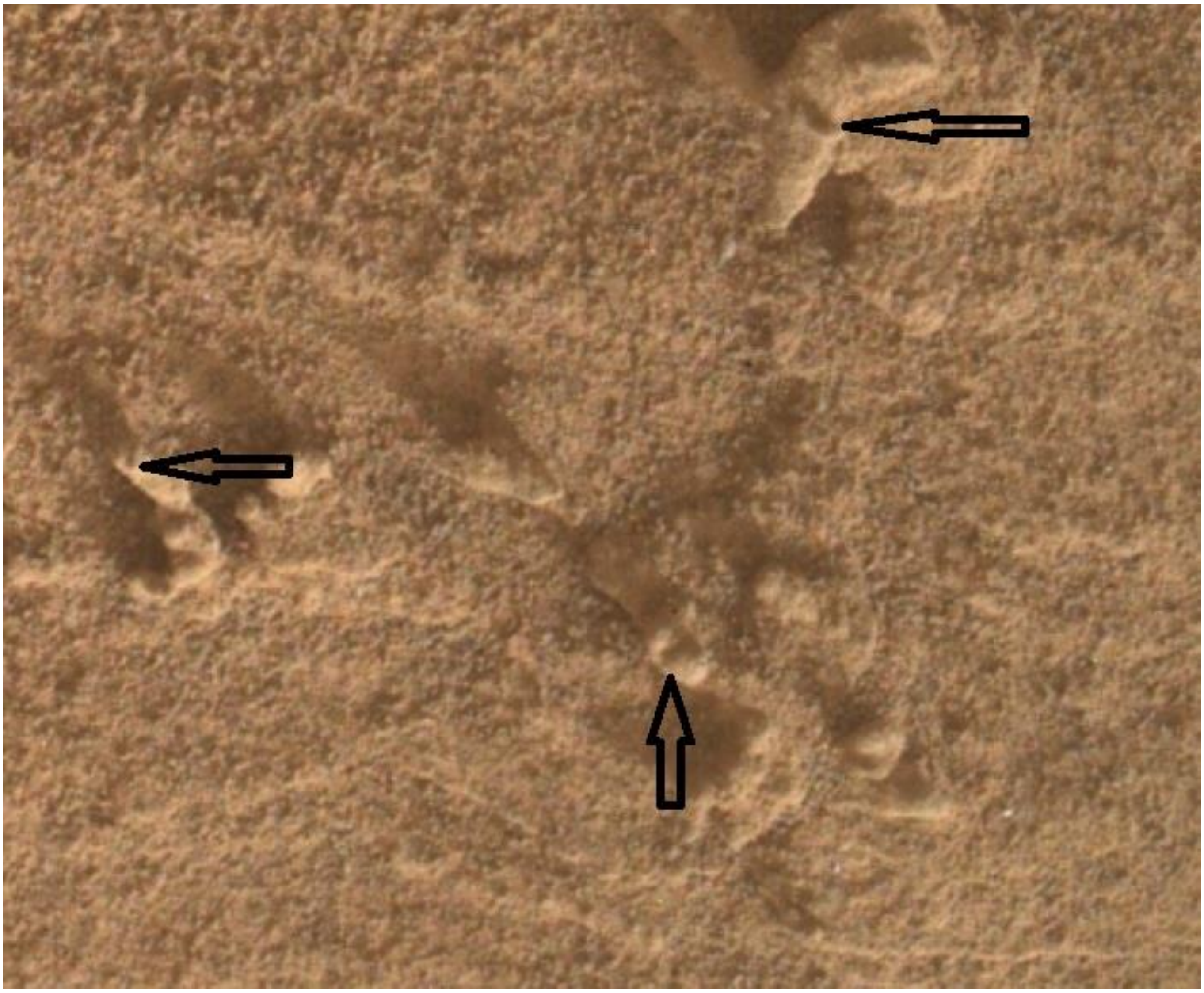

Figure 4. Three further specimens photographed on sol 3396 (3396MH0001900011200957C00_DXXX) showing possible oscula (arrows) at the tips of the 'tubes' (NASA/JPL – Caltech).

3.3 Algae**:** Some features of the specimens suggest the possibility that a biological entity may have been involved in the construction of the specimen. Morphological and morphometric analyses of the 'rice grains', detected in Gale crater on sols 809 and 880 at the 'Mojave' site in the lacustrine Murray Formation have been attributed to pseudomorphic crystals of sulfate (Martin et al. 2017). This evidence suggest they are not morphologically similar to gypsum, jarosite, or feldspar crystals, but show a high shape affinity to the Euglenoids (Rizzo et al. 2021). One possibility is that the specimens are small accretionary structures formed in shallow water by trapping, binding, and cementation of sand grains by cyanobacteria, i.e., a type of small stromatolite. Another possibility is that the specimen is a calcified green alga such as a member of the Dasycladales (Huang and Lu 2006). For example, *Dasycladus vermicularis* (Scopoli) Krasser, is an olive-green, erect, unbranched, club shaped, slightly calcified alga. However, the present specimen is branched, has a different 'tube' morphology compared with Dasycladia, and appears to be significantly more calcified than an alga.

***3.4 Lichens*: **Lichens are regarded as 'extremophiles' and able to survive in some of the most inhospitable terrestrial habitats (Armstrong 2017). As a consequence, they have been identified as potential inhabitants of Mars (Armstrong 2019; Joseph et al. 2020b).

If extremophile lichens exist on Mars, they would be subjected to a considerably more hostile environment than the most extreme on Earth; the probable lack of sufficient liquid water over most of the surface and limited supplies of nitrogen and other nutrients being particular problems. Nevertheless, many images of putative lichen-like features have been photographed by Martian rovers, especially by Spirit, Opportunity, and Curiosity (Joseph et al. 2020a). Hence, the specimen in question could represent a branched fruticose-type lichen attached to the substratum at a central point, terrestrial lichens of the genera *Usnea*, *Ramalina*, and *Evernia* being possible analogues.

Many lichens can use atmospheric water vapour (Lange and Kilian 1985) and hence, some desert lichens take advantage of occasional periods of fog (Kappen 1988; Kidron and Kronenfeld 2021, 2022). Such lichens often have a large surface area to trap moisture and hence, have a fruticose, pendulous, or tufted growth form. Such adaptations are also seen in some essentially crustose species, e.g., *Caloplaca corallinoides* (Tuck.) Hulting, which adopt a pulvinate, branched, or coralloid form which may superficially resemble the specimens observed in Gale crater. However, the specimen lacks many obvious lichen-like features familiar in terrestrial lichens such as reproductive apothecia, isidia, or soredia.

3.5 Sponges: Studies have postulated that metazoans that have been fossilized in Gale Crater (Joseph et al. 2020b). In addition, tube-like structures resembling the cases of terrestrial tube worms (Joseph et al. 2021b; Armstrong 2021) have been reported.

The most immediate terrestrial analogues of the present specimens which suggest themselves are the sponges (Phylum Porifera). Sponges are regarded as the most primitive of all the animal groups and may have originated in the Precambrian period on Earth, although this is debated (Antcliffe et al. 2014). Sponges range in size from 1 cm to 2 m and are very varied in color (De Haas and Knorr 1966). They are attached to the substratum and form a crust, clump, or small tree-like structure growing either individually, in colonies, or on branched 'stems'. In calm waters, sponges often grow into a branched form similar to the current specimens but in surf they form simple clumps. In its simplest form, the sponge comprises a tube, sealed at the bottom and open at the top ('osculum'), the walls being perforated by several closable pores ('porocytes') (Fig 5). Sponges draw in water through the system of pores to extract nutrients, the water being expelled through the osculum at the tip of each tube. The morphology of the current specimens suggests a sponge as does the reticulate texture over parts of the surface and the possible porocytes (Fig 3) and oscula (Fig 4). In addition, the incorporation of calcium or silica into the body of the sponge could have ensured its survival essentially 'fossilized' *in situ* in sand or silt.

3.5 Corals: The specimen could also be a type of coral (e.g. Phylum Cnidaria, class Anthozoa). Corals are composed of reef-forming 'polyps' and are more evolutionarily advanced than the sponges (De Haas and Knorr 1966) with rare fossils on Earth recorded from the Cambrian until the Ordovician periods; after which they become more widespread (Pratt et al. 2001). Polyps are mostly fixed in location and occur as solitary individuals or in colonies; with or without a strengthening skeleton of calcium carbonate. Their body is cylindrical with tentacles arranged around a 'mouth'. Structures that resemble corals have been tentatively identified in Gale Crater (Joseph et al. 2022). Although some corals have a reticulate surface, several features of the morphology of the specimens in question more closely resemble a sponge than a coral.

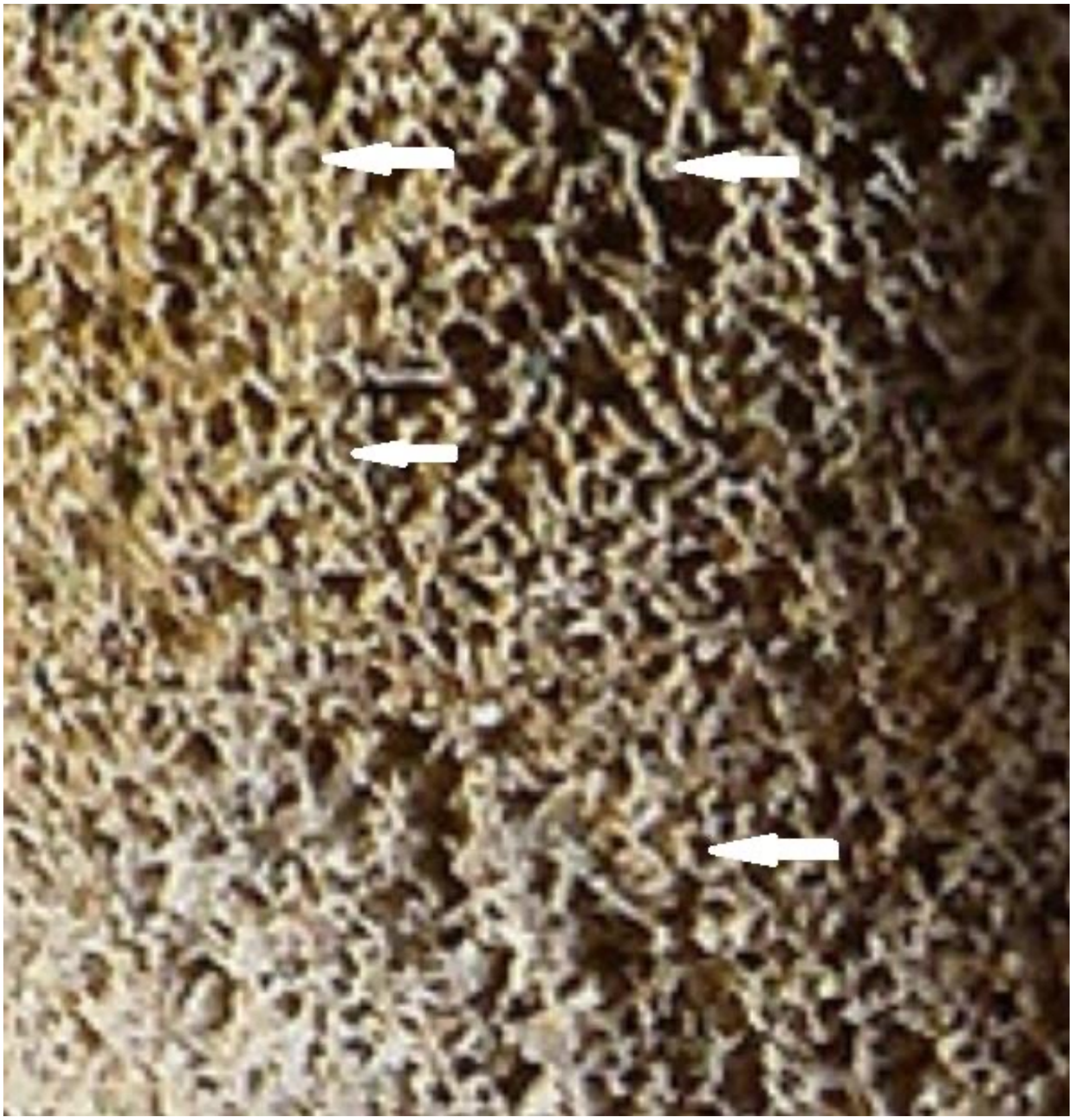

Figure 5. Close-up image of the surface of a typical terrestrial sponge. Note the reticulate pattern of striations over the surface and the small pores: 'porocytes'. (Image by R. Armstrong).

6. Conclusion

This article describes a number of unusual specimens photographed by the rover Curiosity MAHLI in Gale crater on sol 3396. The most complete specimen was approximately 1.3 cm across, consisting of apparently a series of tubes branching from a central holdfast. At higher magnification, pores, a reticulate surface texture, and possible opercula were apparent. Although complex deposits formed by accretion are unlikely, mineral concretions formed within the sedimentary rocks of Gale crater cannot be ruled out. Nevertheless, it is more probably that the structures represent the remains of a type of sponge or coral, the former being more likely given the morphology of the specimens and their relative evolutionary ages and complexity. On Earth, peripheral areas of deep sea vents are often inhabited by a variety of organisms distinct from those living close to the vent chimneys, varieties of sponges being particularly characteristic (Georgieva et al. 2020). These sponges utilise organic matter produced at the vent as well as being associated with putative chemosynthetic gammaproteonic bacteria as symbionts and which produce a variety of carbon and nitrogen based compounds (Georgieva et al. 2020). Although evidence of such vents have not been found in Gale crater, Joseph et al. (2021a) found numerous holes in the surface in Endurance crater which could be collapsed hydrothermal vents with associated tubular structures representing possible fossil tube worms. Hence, the cluster of forms resembling sponges in Gale crater could be the remnant of a population which lived in the vicinity of an ancient hydrothermal vent, and may have become preserved in deposits of sand or silt, and then gradually became exposed over long periods of time.

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