

Cocoons, Fungi, Nematodes, Rhizoids, Annelids, Eggs, Arthropoda in Gale Crater, Mars?

R. Gabriel Joseph^{1*}, N. Chandra Wickramasinghe², Richard A. Armstrong³, David Duvall⁴, Rudolph Schild⁵

¹Astrobiology Research Center, CA, USA

²University of Buckingham, Buckingham, UK

³Dept. of Vision Sciences, Aston University, Birmingham, UK.

⁴Dept. of Zoology, Oklahoma State University, OK

⁵Center for Astrophysics, Harvard-Smithsonian, Cambridge, MA

*Corresponding author: R. Gabriel Joseph, E-mail: RhawnJoseph@gmail.com

ABSTRACT

White and dark gray oblong-ovoid cocoon-egg-like forms (“cocoon-eggs”), less than a mm in diameter, many with a single hole in one end, and some with unidentifiable specimens protruding from (exiting or entering) these holes, were photographed on mudstone in Gale Crater, Mars, on Sol 1302. If biological some of these cocoon-eggs may be frozen, fossilized or have already “hatched” or undergone metamorphosis. Specimens resembling segmented and tubular worms and rhizoids and those with multiple appendages (Arthropoda) were also photographed on these and other substrates on Mars, including on Sols 130, 132, 302, 551, 553, 808, 809, 868, 906, 1280, 1921, in Gale Crater. Many Sol 1302 “cocoon-eggs” are embedded in substrate that appears to consist entirely of a coral-stromatolite-like mass of worm- and larvae-like forms; and similar worm and segmented larvae forms appear in the interior of three semi-transparent ovoid structures. Embedded in the soil surrounding these “cocoon-eggs” are numerous concave patches reminiscent of dried “egg-yolk,” cocoon remnants or fungus, and that may represent the final stage of “cocoon” collapse and disintegration; or they are fungal in origin. Some of the segmented and tubular worm-like forms may include rhizoids and tubular fungi. Ovoids with open apertures may be evidence of fungal sporing. The possibility that fungus and diverse species and their “cocoon” share the same substrate is supported by what appears to be cyanobacteria, worms, *insecta* (arthropoda), and stalks topped by ovoids or ovoid-shaped microbialite-like sediment. Fungi, lichens, cyanobacteria, stromatolites and arthropoda have been previously reported in other areas of Gale Crater, whereas fungal “puffballs” and specimens attached to rocks with stalks and topped with mushroom-like caps have been observed in Meridiani Planum. The possibility these specimens are abiogenic cannot be ruled out. The evidence, in our view, arguably supports the hypotheses that various organisms colonized Mars in the ancient or recent past.

Keywords

Life on Mars
Fossils on Mars
Worms on Mars
Annelids
Nematodes
Insects
Cocoons
Eggs
Larvae
Fungus
Fungi

WORMS, COCOON-EGGS, FUNGI IN GALE CRATER

Ovoid and oblong egg-shaped forms, less than a mm in size, white to dark gray in color, in close proximity to one another, and similar to worm and insect eggs and cocoons (“cocoon-eggs”) and some resembling segmented pupae have been

photographed by the rover Curiosity, in Gale Crater, on Sol 1031 and 0132, the latter of which are featured in this report (Figures 2-35). If biological these “cocoon-eggs” may have been frozen and/or fossilized in the ancient past and many may be in various stages of dehydration or deterioration having “hatched” their contents. It is unlikely in our view that these

Research Article

oblong- ovoids are small pebbles as dozens of “cocoon-eggs” have a small or large hole at one end (Figures 2, 8-11). In many specimens *something* (identity unknown) also appears to be protruding from (exiting or entering) these anterior located holes (Figures 2, 8-10); features --including a dented appearance-- also shared with terrestrial worm eggs/cocoons (Figures 46-48).

Multiple curled and elongated worm-like forms can be discerned within the interior of two semi- translucent “cocoon-eggs” (Figure 30) whereas in the interior of another two, single segmented-pupae- like forms almost the size of the entire oblong-ovoid structure may be present (Figure 14). In addition, several specimens on the surface resemble segmented pupae (Figure 6).

Numerous cocoon-eggs photographed on Sol 1032 are also embedded in substrate that appears to consist entirely of a coral-microbialite-like mass of coiled and worm-like forms (Figures 3, 8, 11, 13, 28, 30-32) whereas smooth and segmented tubular specimens have been photographed in this and other Gale Crater locations on Sols 130, 132, 302, 551, 553, 808, 809, 868, 906, 1280, 1921, as reported here and in other reports [1-5]; including specimens that appear to have multiple appendages and resemble *insecta* (Arthropoda) [6-7] whereas others are similar to ovoid-shaped lichenized-fungi topped with a single hole and which may be sporing. Moreover, some of the specimens resemble dead or fossilized puffballs with stems attached.

If any of these specimens are alive, frozen, fossilized, or abiogenic, is unknown. Extraction is required.

DIVERSE EXPERT OPINIONS

Twenty experts, sixteen specializing in insect and worm biology were consulted and of those who replied: eight agreed these ovoid forms are similar to worm eggs and/or cocoons; two favored insect eggs or cocoons; two identified what may be pupae (thereby accounting for metamorphosis in shape, Figure 6, 14); one pointed out a white-worm-millipede-like specimen with what may be multiple “legs” (Figure 6); seven of the total suggested these specimens are either fossilized or quite old. In addition, one expert stated he had no idea what they are, one suggested pebbles weathered by water but could not explain the holes at one end or why many are located on the sides and slopes beneath the mound, and two suggested that some specimens may include fungal or lichen fruiting bodies. (*Personal Communications to R. Joseph, R. Schild*). The experts in insect and worm biology were not initially informed the specimens were photographed on Mars.

“COCOONS” FUNGI” AND DIVERSE ORGANISMS?

The coloration and overall morphology of some of the “cocoon-eggs” differ from the others; and this is typical of eggs produced by some species of worm, insect, and fish (Figures 46-48). Many of the Gale Crater “cocoon-eggs” are dented or dark in color, some are dark and white others completely white; also typical of many terrestrial species. A single hole in one end is also typical of most ovoid specimens regardless of color. Perhaps the color transitions maybe related to dehydration, maturity, metamorphosis, sun bleaching. This diversity is also characteristic of the eggs produced by a single or multiple organisms belonging to the same species (Figures 46-48) .

It is also possible that the mound of soil photographed on Sol 132 hosted a variety of egg-laying and cocoon-forming organisms as well as tubular fungi and basidiomycota puffballs as reported in other areas of Mars and Gale Crater [1-2, 8-12] and an assemblage not uncommon in terrestrial soil. For example, specimens resembling worms (Figures 1, 6-7, 12-18, 30-33) worm-like forms with multiple tiny millipede-like legs (Figure 6), and ovoid spider-like forms with multiple tentacles (Figures 34-35) were all photographed in the same mound of soil; and in other areas of Gale Crater (Figures 36-41) [2,6-7].

Surrounding these “cocoon-eggs” photographed on Sol 1032-- including those that appear to be broken or decomposing-- are numerous concave patches gray to yellowish in color and reminiscent of dried “egg-yolk” cocoon remnants or fungus (Figures 4, 20-21, 24, 27-29). It is unknown if these concave patches represent the final stage of “egg-cocoon” metamorphosis, collapse and disintegration; if they are the consequence of predation; or if they are fungal in origin and the remnants of fungal puffballs that have died and deteriorated after sporing. The possibility that fungi and the “cocoon-eggs” share the same substrate--as photographed on Sol 1032-- is supported by what appears to be stalks protruding upward from holes in the soil topped by ovoids or ovoid-sediment (Figures 8-9, 22-26). Those ovoids with stalks are relatively few in number, sometimes interlocked, and do not resemble the “cocoon-eggs.

To speculate: if these Sol 1032 specimens are biological, perhaps they represent a mutualistic, symbiotic or predatory relationship among diverse organisms including cyanobacteria, worms, insects, pupae, fungi and lichens, the ancestors of whom long ago evolved and adapted to the extreme environments of Mars.

The hypothesis that multiple organisms have colonized Mars in the recent or ancient past is supported by discoveries of forms that strongly resemble algae, lichens, tube worms,

crustaceans and other multi-tentacled specimens on Mars [1, 9-17]; fossilized structures that resemble a vast array of marine invertebrates [18-19]; trace fossils of rock-boring organisms [19-20]; an ovoid specimen that emerged from a hole as revealed by sequential photos and two similar specimens that appear to be consuming prey [6], as well as fungi that grow out of the ground, increase in size and number, and move and change shape and location and some of which have a single anterior placed hole and appear to be sporing [10].

ABIOTIC EXPLANATIONS

There is no absolute proof that any of the specimens presented in this or other reports are alive, frozen or fossilized whereas it is certainly possible that some of the “worm-like” specimens presented here are abiogenic. For example, these elongated forms may consist of compacted soil and sand, perhaps formed via receding bodies of water leaving waves of elongated fluidized concretions in their wake and which later dried and broke apart and were scattered by wind.

These elongated forms may also consist of strands of mud that upon drying formed unusual elevated concentric and eccentric tubular layers and patterns. Perhaps water-sediment-mineral interactions formed complex concentric and twisting linear shapes, creating elevated cylinders and pipes due to the flow of subsurface fluids or fluidized sediment. As Gale Crater has repeatedly filled with water which then receded, these scenarios are plausible. Hence, without extraction, genetic analysis, and detailed examination it is impossible to completely rule out abiogenic scenarios.

It is possible some of the ovoids are pebbles that have been weathered and rounded and smoothed by rushing water in the ancient lake beds of Gale Crater. In several photos it also appears that bedrock wraps around the ovoids, and this could have occurred in response to rapidly receding waters such that the purported “pebbles” sank into the drying mud. However, some of that surrounding sediment resembles corals which are biological, whereas numerous ovoids are attached beneath the sloping mound and if pebbles are defying gravity and any abiotic explanation of how they were placed in these upside-down locations.

ADDITIONAL EVIDENCE OF BIOLOGY

As can be seen in the following photos and figures, contrary to any abiogenic explanation is the fact many of the tubular forms are segmented (similar to annelids and rhizoids), and others smooth and have open apertures at one end (similar to nematodes and tubular fungi). If these are “worms: the aperture may serve as a “mouth” for the filter feeding, scavenging or predation.

If abiogenic there should be numerous holes along the length, not just at one end. Hence, it is not likely these “cocoon-eggs” are pebbles that have been water weathered and then sank into the mud including substrate that is above the specimen and on downward-inward sloping substrate. Then there is the “hole” and unknown *something* that is entering or exiting these holes. The “pebble” possibility is thus refuted.

If not “egg-cocons” the other only reasonable explanation is that these ovoids may be the fruiting bodies of lichenized fungi whereas the segmented filaments may be rhizoids and filamentous cyanobacteria; impressions that support the hypothesis that multiple species colonized this sediment which may include microbialites. Consider, for example the specimens resembling cyanobacteria. Then there are those that appear to possess multiple appendages photographed on Sol 1032 and in other areas of Mars. Similar to soil samples of Earth it is reasonable to suppose that these and other organisms have colonized the same substrate.

Is it possible that all or most of specimens presented in the following photos and Figures are abiogenic? We believe the answer is “no.”

Do many of the specimens clearly resemble “cocoon-eggs,” “worms” and fungi? Yes. Are they alive, frozen, fossilized? The answer is unknown.

Do some of the specimens resemble *insecta*? Yes. What are they? Unknown.

Can we, in every instance, precisely identify or differentiate which specimens are “eggs” or “cocoon,” or those which are fungi and lichen fruiting bodies, or “worms” vs rhizoids and tubular fungi? Not without extraction, genetic analysis and microscopies examination.

A SAMPLE OF SPECIMENS FROM GALE CRATER

We have presented a sample of terrestrial eggs and cocoons produced by a worm, insect, and fish, for comparative purposes. Note that the eggs and cocoons produced by a single organism can differ in color, size, and shape, and collapsed indentations are typical (Figures 45-46).

Some of the Gale Crater, Mars photographs presented here lack an ideal resolution, but are included for illustrative purpose. Fortunately, the specimens in the majority of photographs are clearly visible thanks, in part, to Fotor image enhancement software which enabled the authors to magnify these images, and alter color and contrast to sharpen detail. Unless otherwise indicated all specimens were photographed in Gale Crater.

Research Article

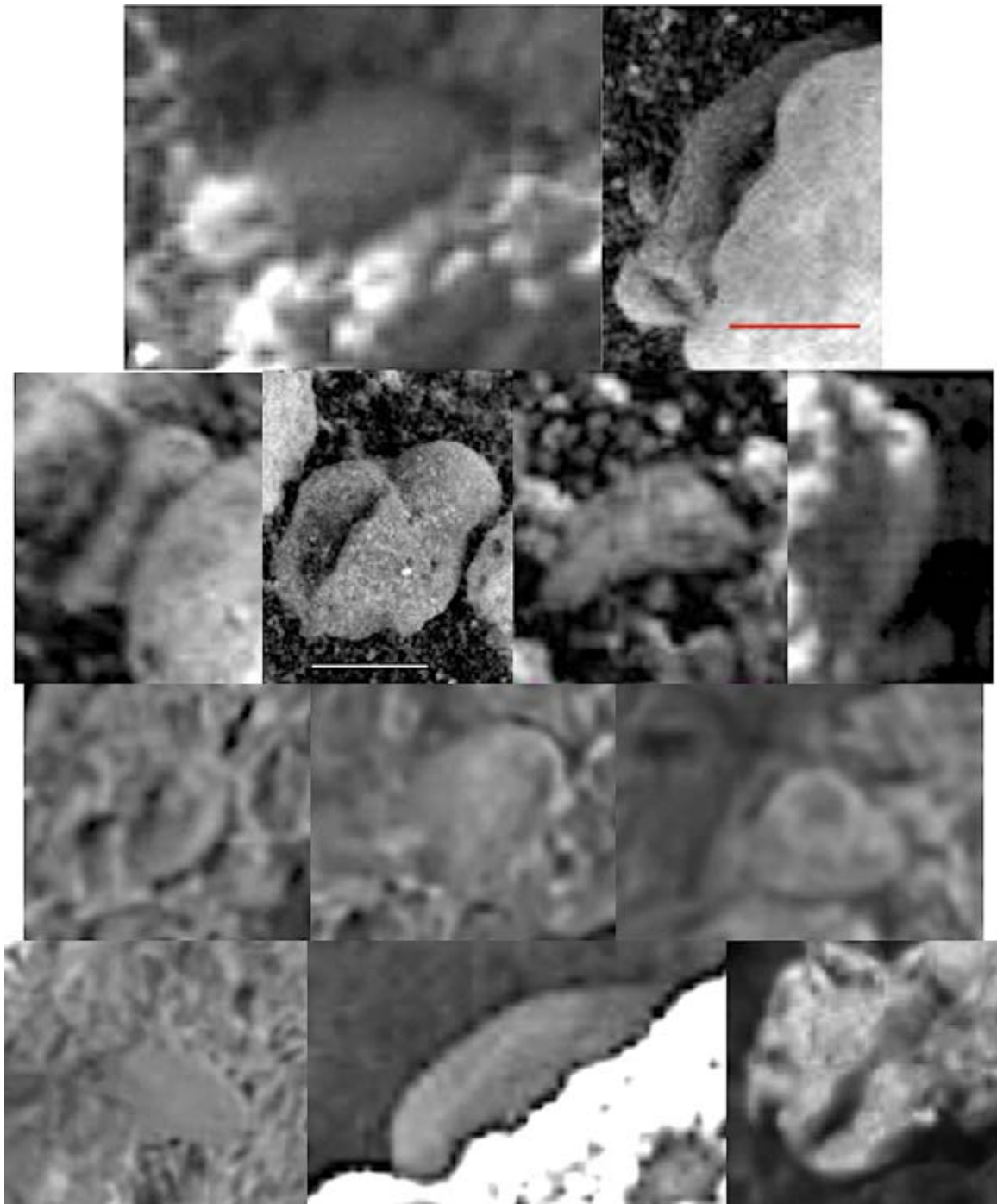
Because of depth of field and angle and distance from the camera the inclusion of “scale bars” would be deceptive and misleading. The graphic scale in mastcam images cannot be obtained from information NASA makes available.

We estimate that the size of the majority of these specimens range from 1 mm to 5 mm, though, admittedly, their actual

length, width, and diameter are unknown.

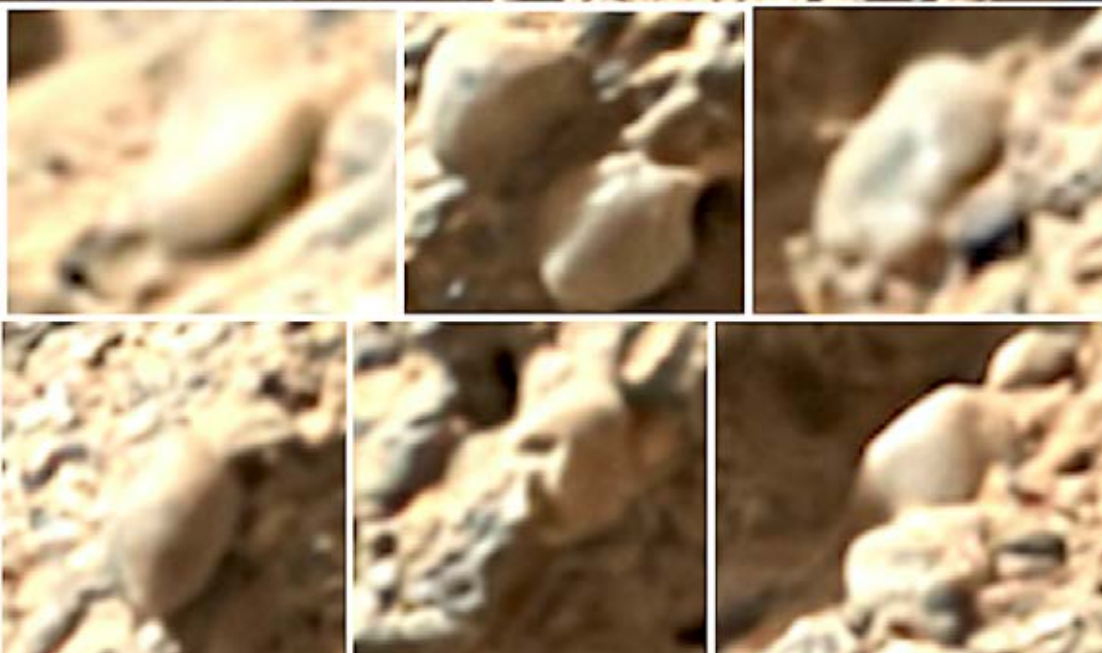
The following should be viewed as just a sample of the “egg-cocoon” and worm-like specimens observed in Gale Crater.

A SAMPLE OF WORM-LIKE SPECIMENS PHOTOGRAPHED ON MARS



Figures 1: A sample of worm-like specimens photographed by NASA, on Mars. Specimens are approximately 1-4 mm in length (scale bars).

FROZEN/FOSSILIZED COCOONS, WORMS, INSECTS? PHOTOGRAPHED IN GALE CRATER ON SOL 1032MH0001700000400209R00_DXXX



Figures 2: Ovoid structures with dented shapes similar to earth worm eggs and cocoons (see Figures 46-48).

Research Article



Figure 3: Ovoid structures resembling worm eggs and cocoons. The dented shape of these specimens and diverse colors are typical of worm eggs (see Figures 46-48).



Figure 4: Ovoid structures resembling worm eggs and cocoons. Note yellowish concave patches that resemble dried egg yolk and cocoon remnants. The dented shapes and diverse colors of these specimens are typical of worm eggs (see Figures 46-48).

Research Article



Figure 5: A worm egg-cocoon? Note greenish-forms that may be exiting a hole at the anterior- right of the specimen. The dented shape is typical of worm eggs (see Figures 46-48).

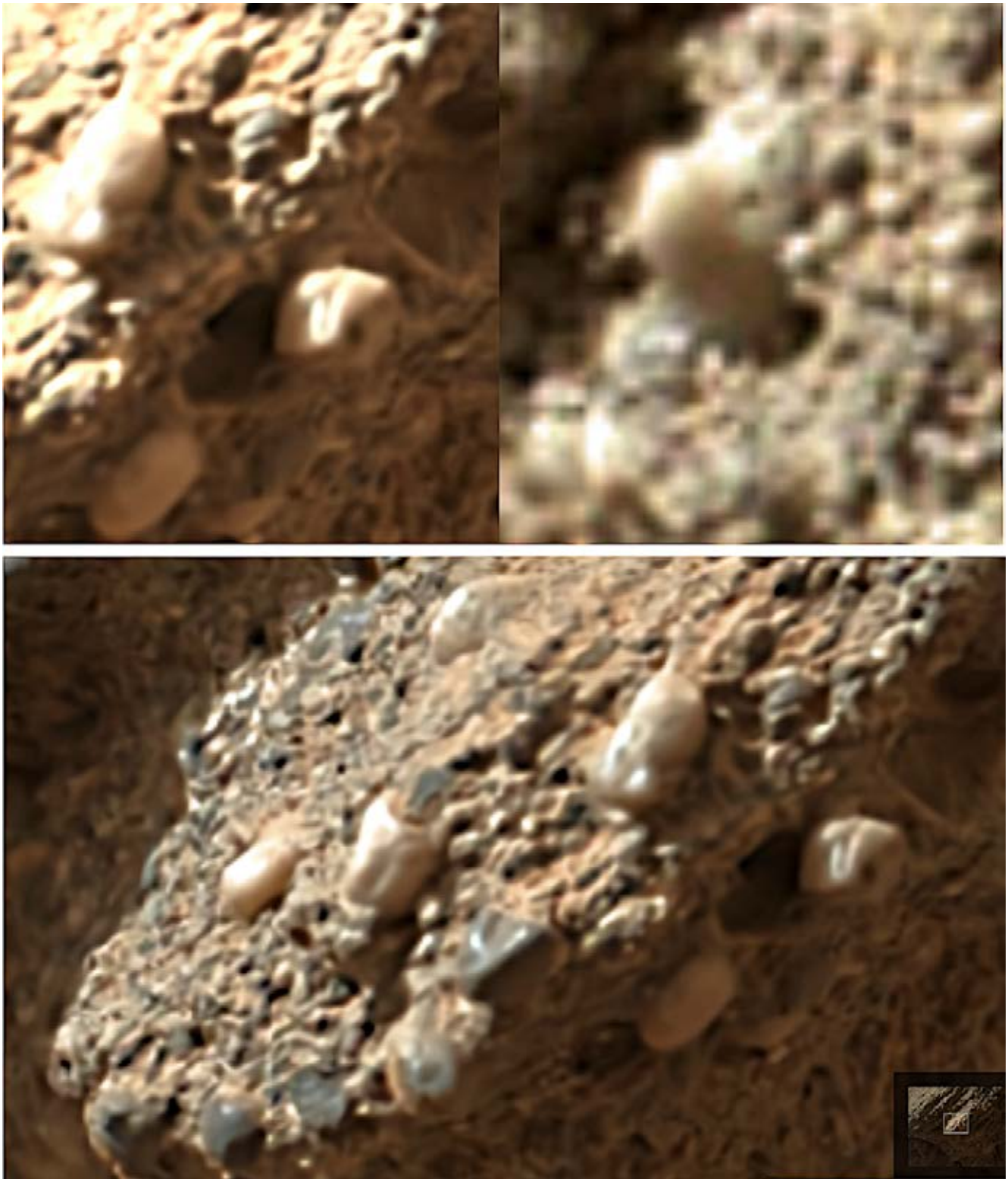


Figures 6: (Top) Segmented millipede-like specimen with what appear to be multiple legs. (Bottom) Pupae?

Research Article

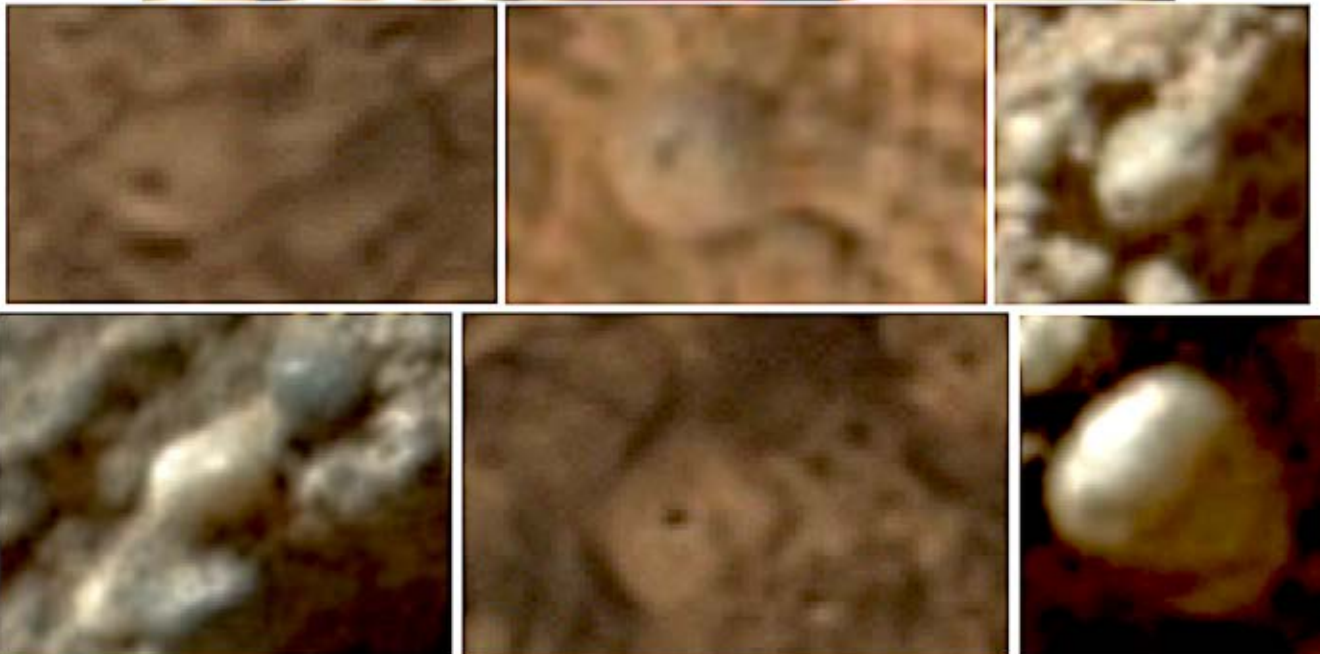


Figure 7: Segmented “worms” (top left and top center) and open tubular forms (bottom center). (Top center) a broken “egg” with segmented worms or fungal puffball and rhizoids? Impossible to differentiate without extraction, genetic analysis and microscopic examination.



Figures 8: Ovoid specimens, some with hole at one end, one (bottom center) with something entering or exiting the hole, one (Upper right) with a stalk protruding from a hole in the sediment. Note coral-microbialite-like worm-matrix.

Research Article

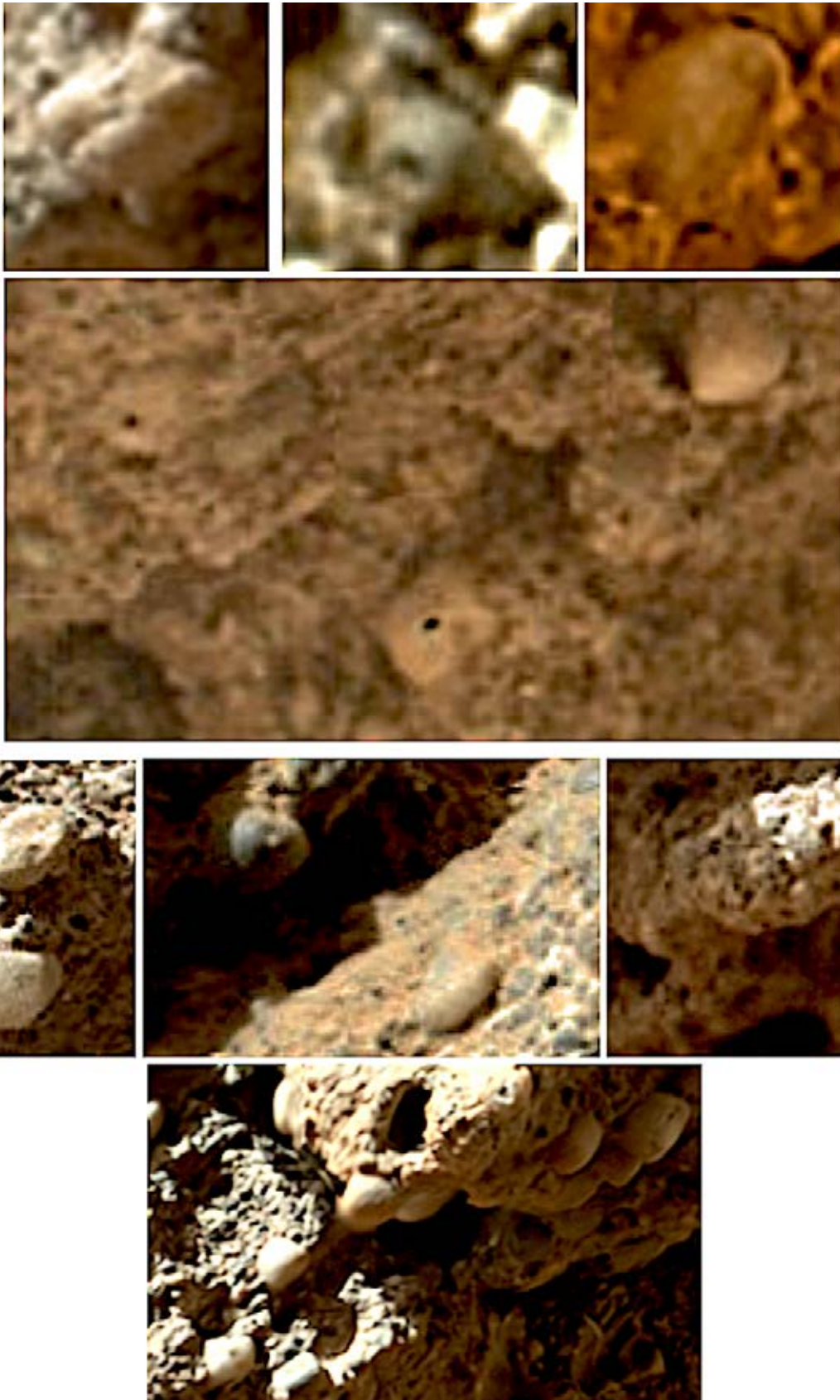


Figures 9: Ovoid specimens, some with holes at one end, including (bottom right) a coiled worm-like form.

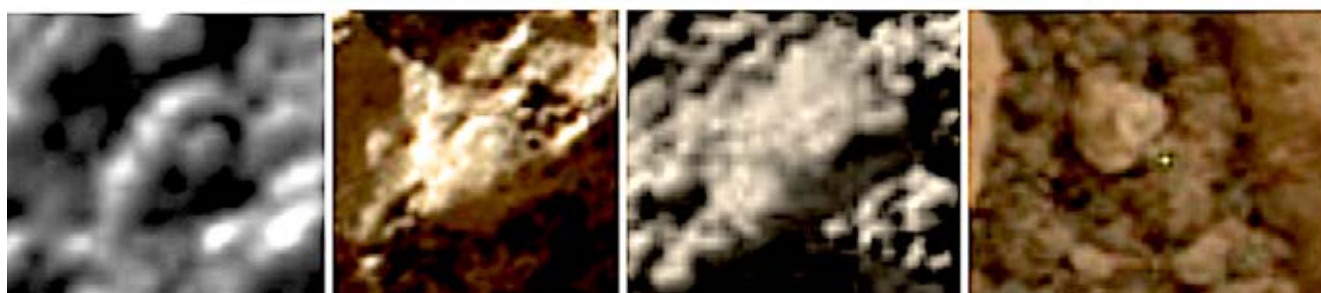
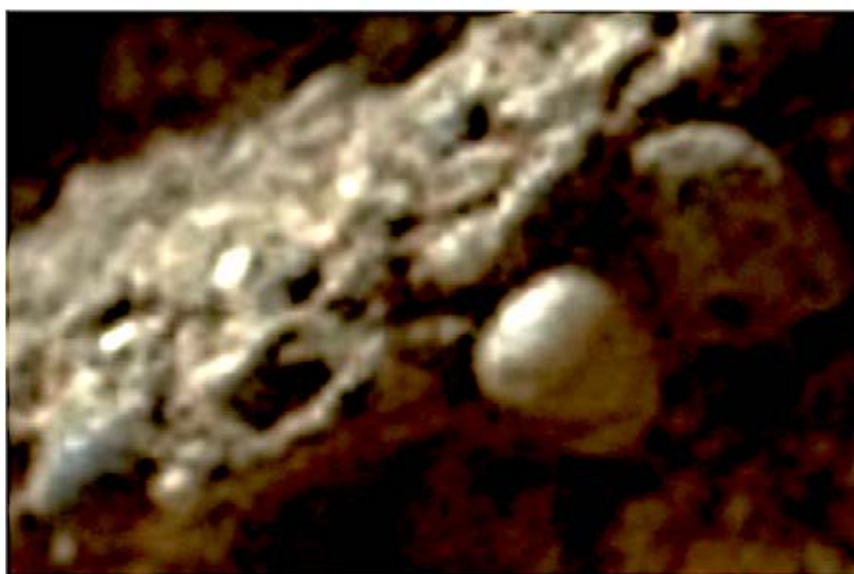
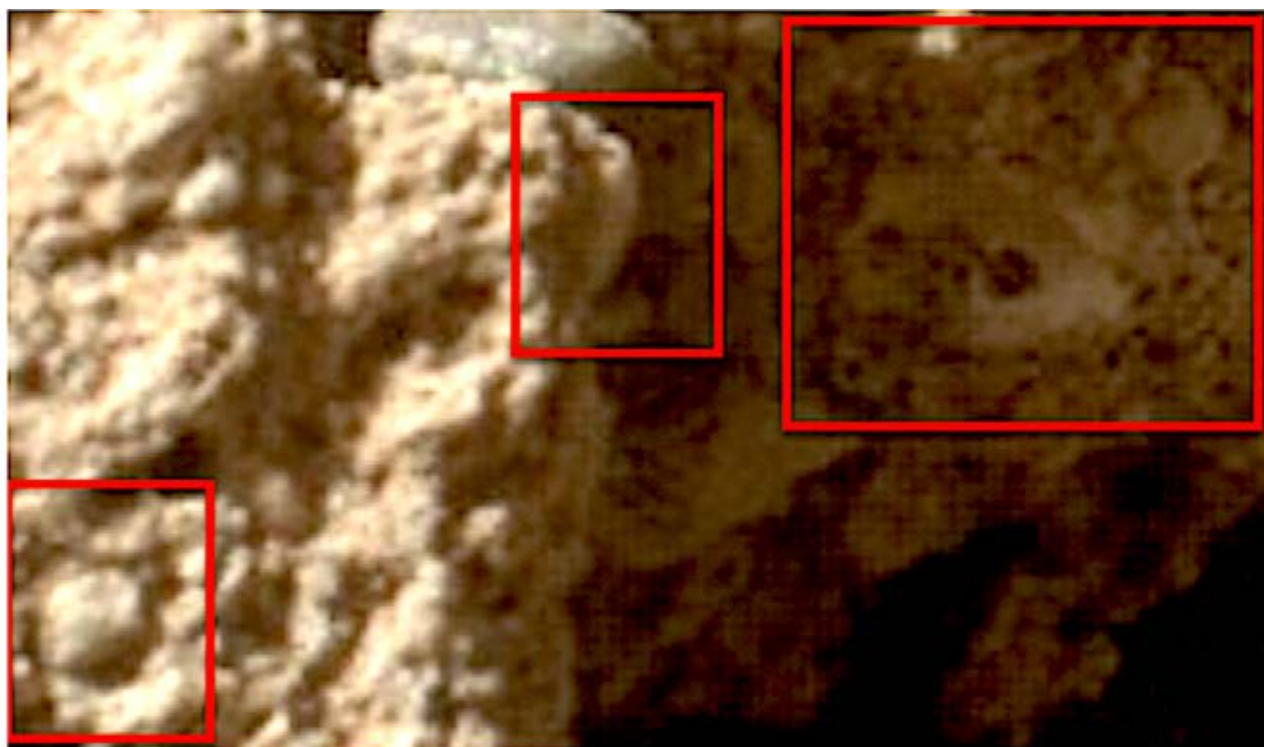


Figures 10: Ovoid specimens with holes at one end. If not “eggs” then possibly fungal fruiting bodies that have spored [36].

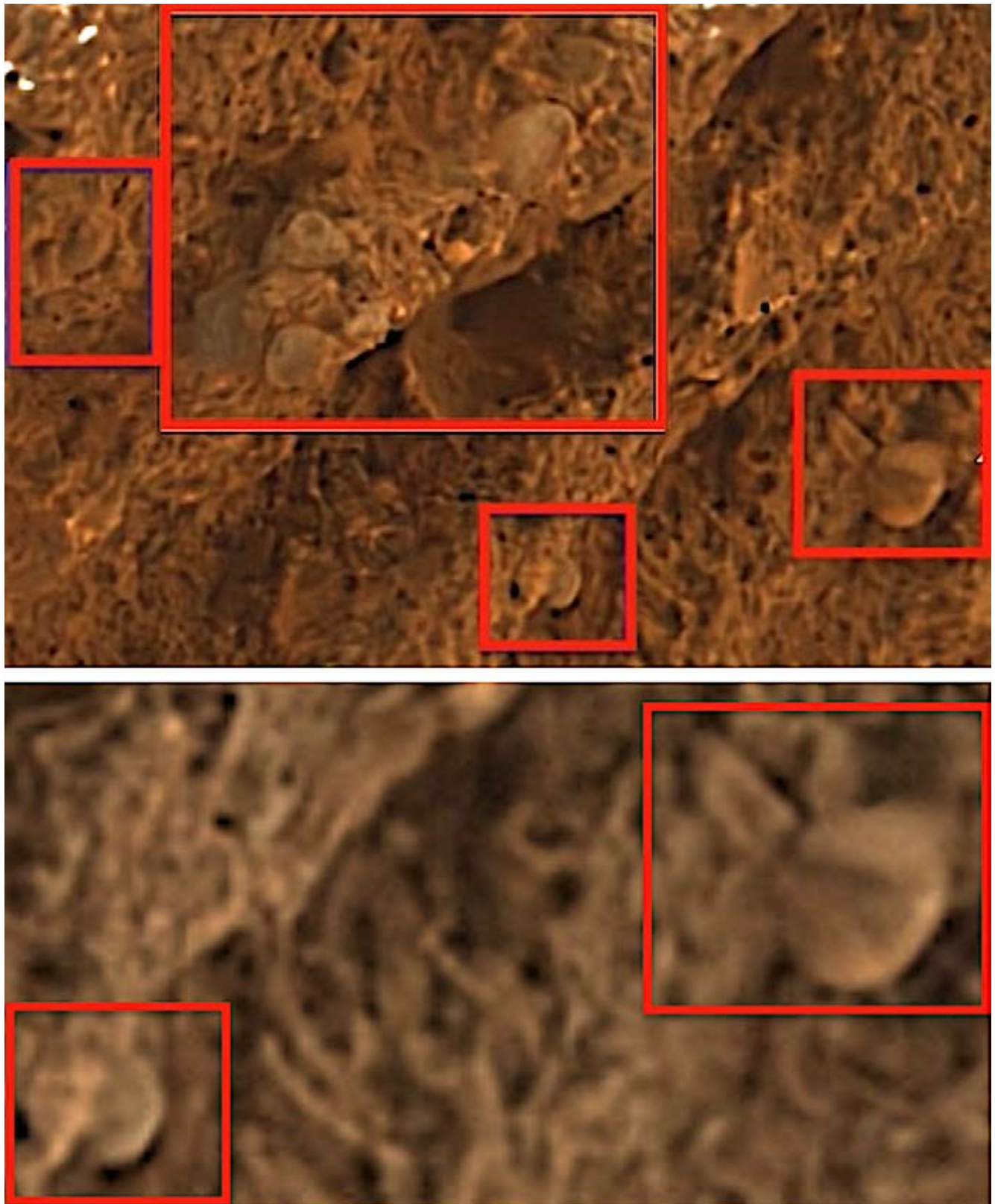
Research Article



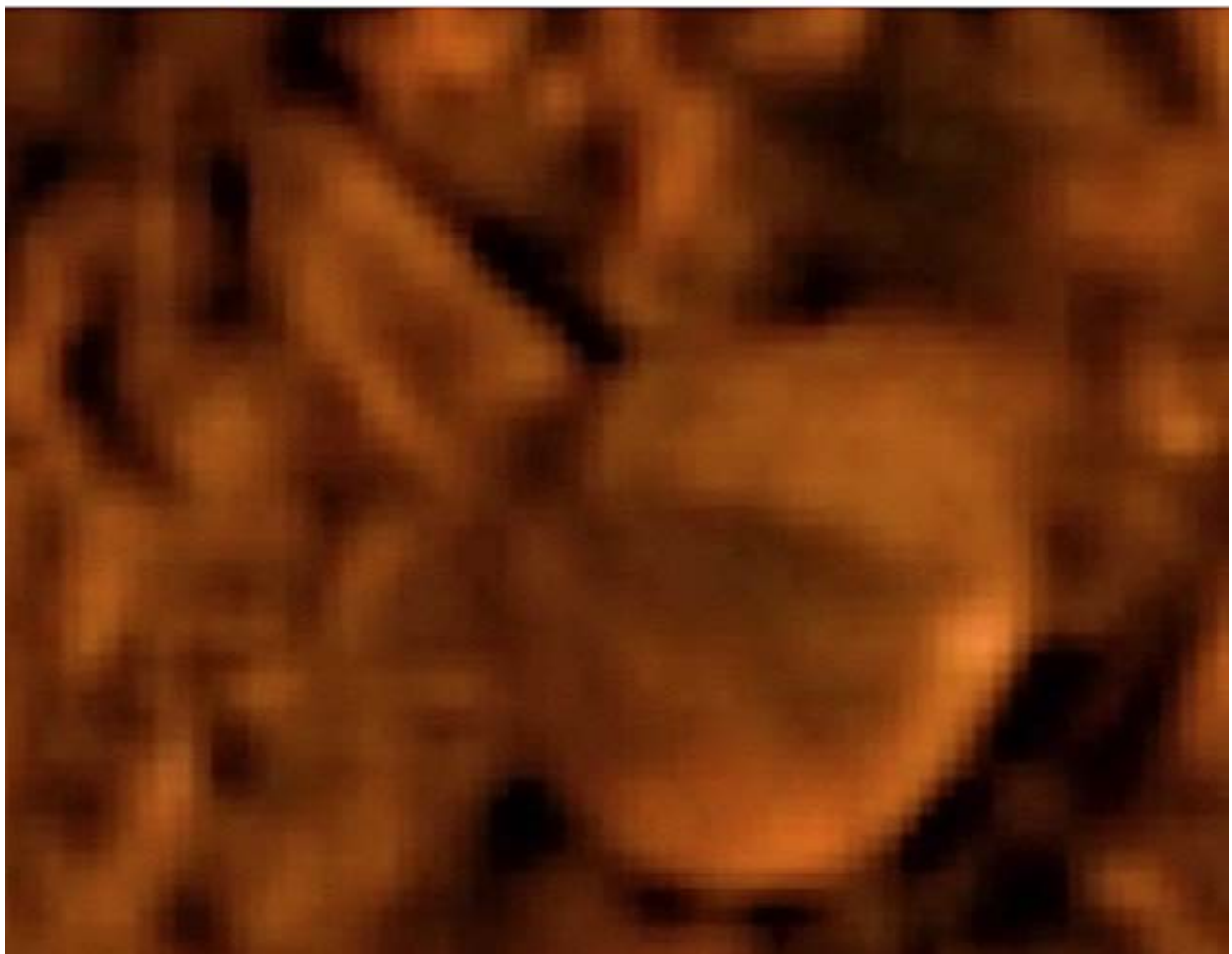
Figures 11: Ovoid specimens, most with holes at one end.



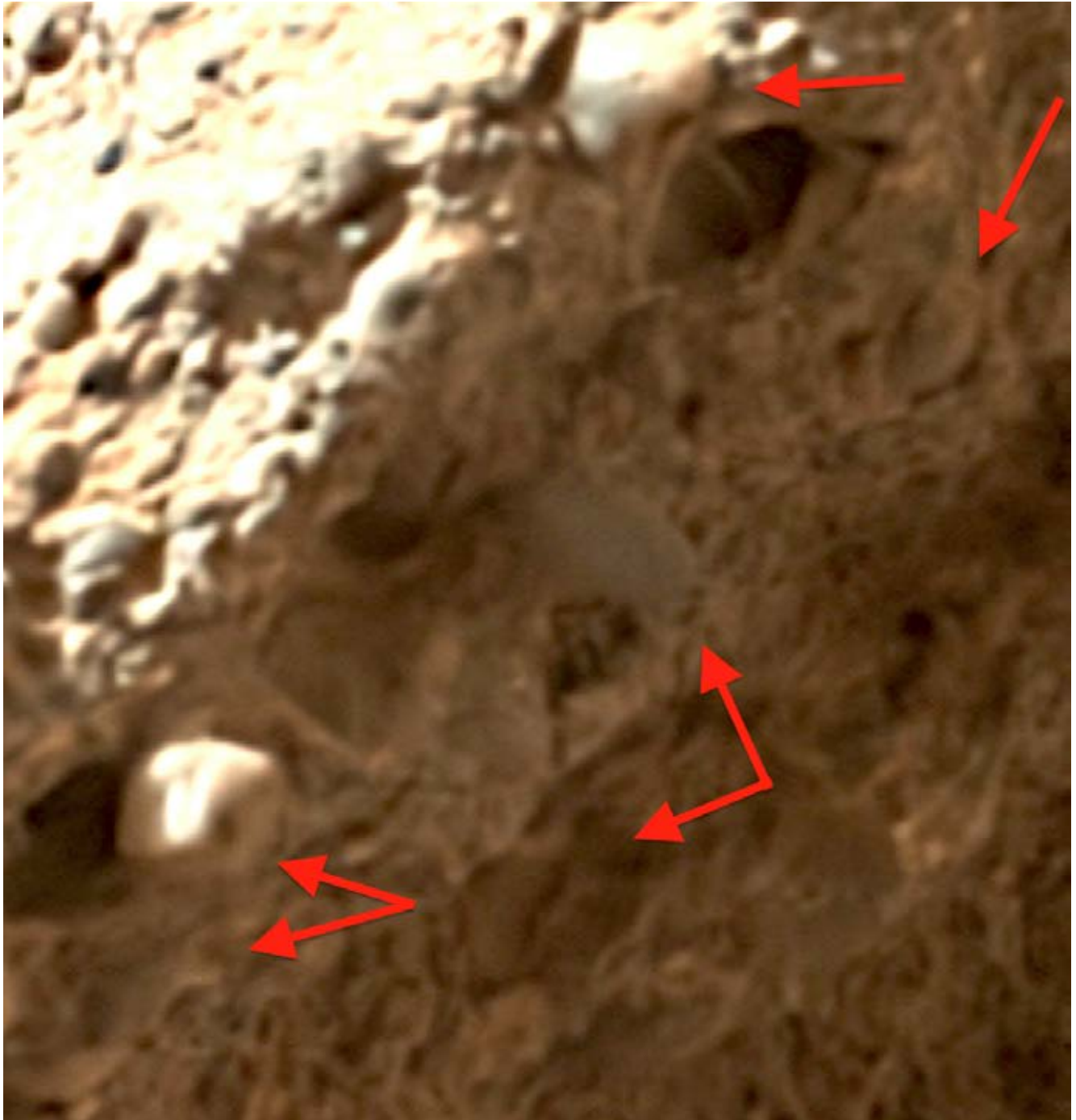
Figures 12: Open tubular and coiled worm-like specimens.



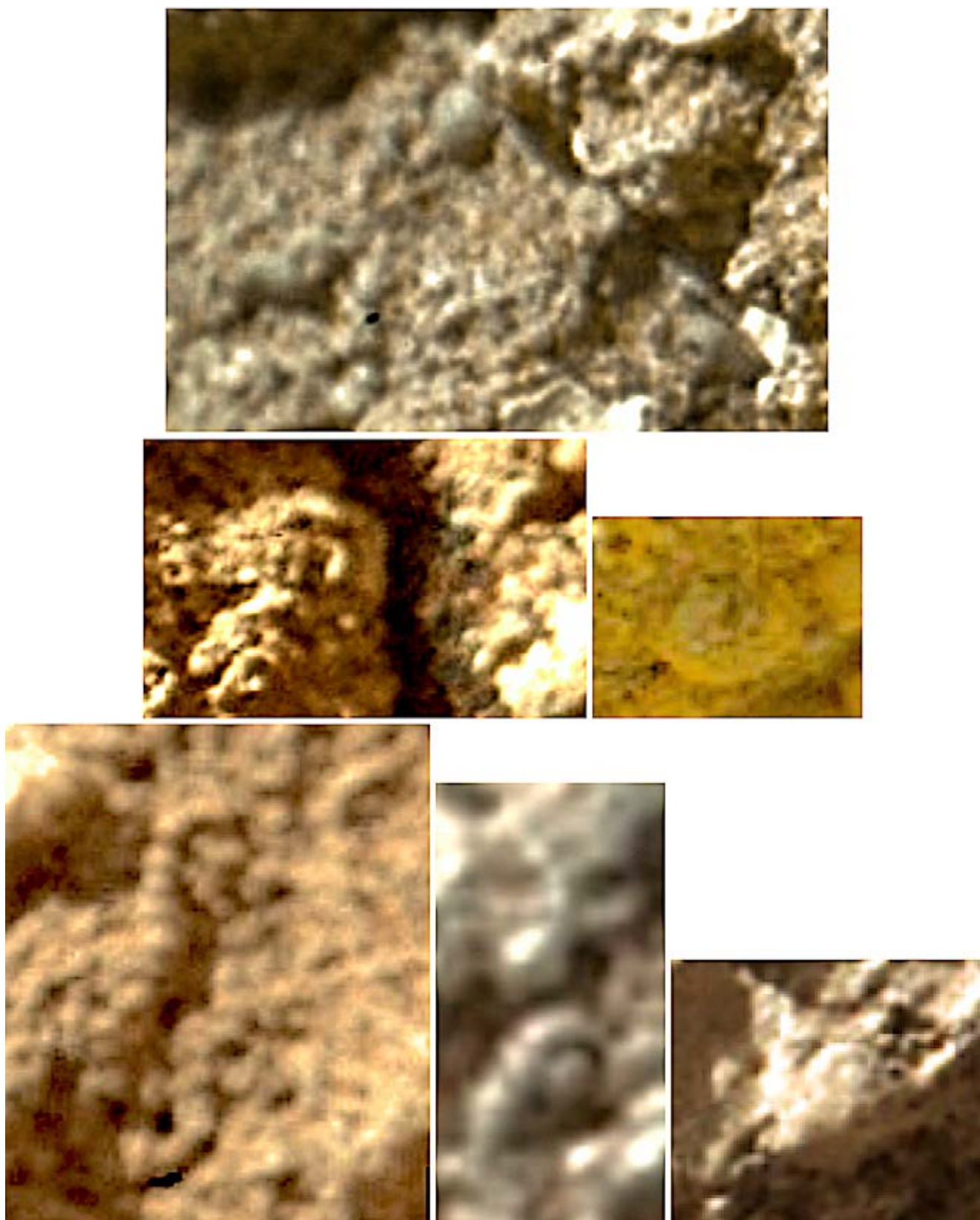
Figures 13: Open tubular worm-like specimens and (bottom) possible pupae within cocoons.



Figures 14: Possible pupae within cocoons. Not segmentation of forms.



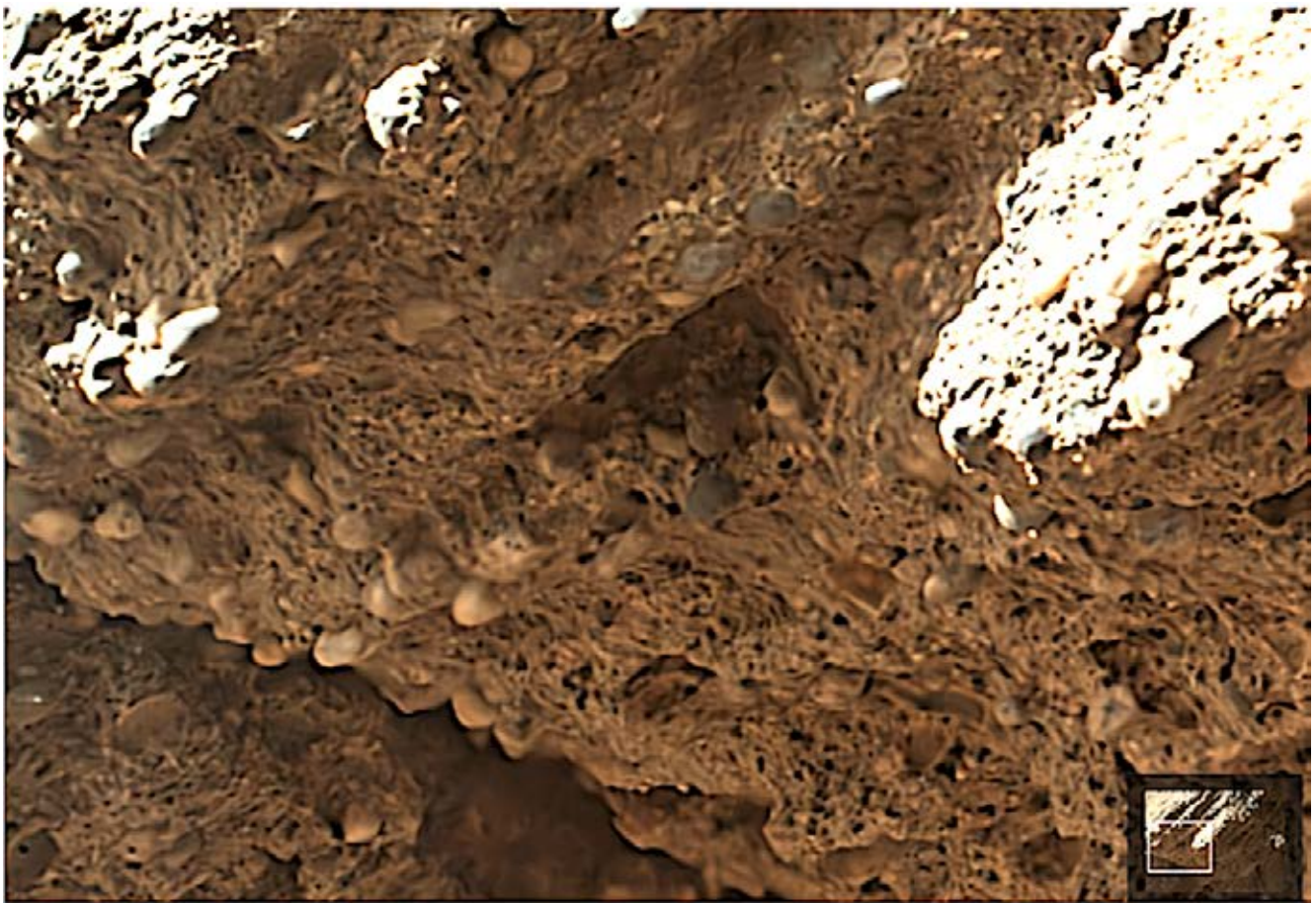
Figures 15: (Lower left) Worm egg? (Middle and Top Right) Open tubular worms? Note stromatolite- microbialite-like sediment.



Figures 16: A variety of worm-like forms and those resembling a giant cyanobacteria (lower left).

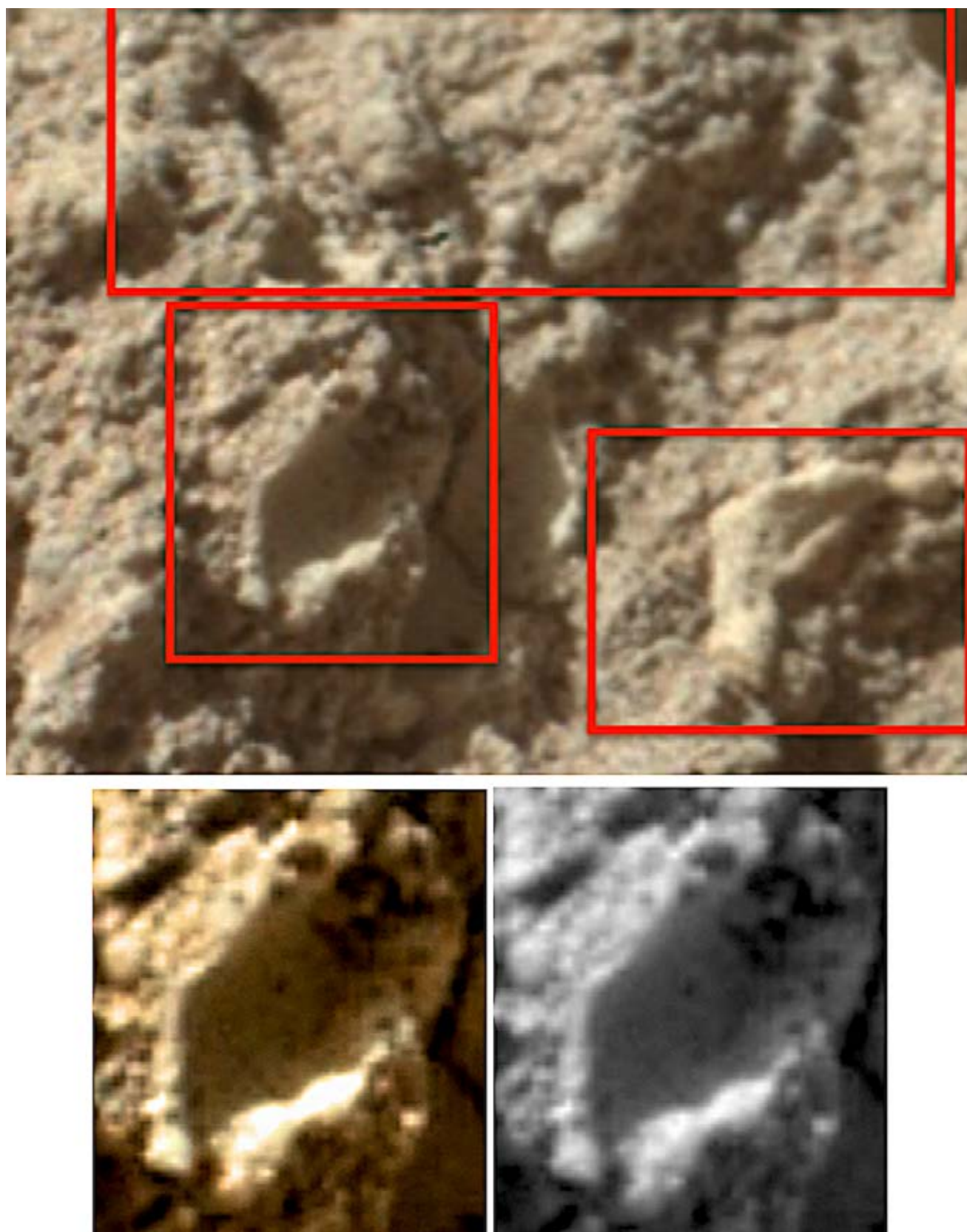


Figures 17: Open tubular worm-like forms resembling nematodes.



Figures 18: Ovoid cocoon-eggs and worm-like forms in a coral-worm-like matrix.

Research Article



Figures 19: Fossilized tubular and segmented worms? (Bottom) Open tubular specimens is embedded in the egg-yolk-like matrix, supporting the hypothesis this substance is the remnants of a worm egg-cocoon. Conversely, this concave substance may be fungi.

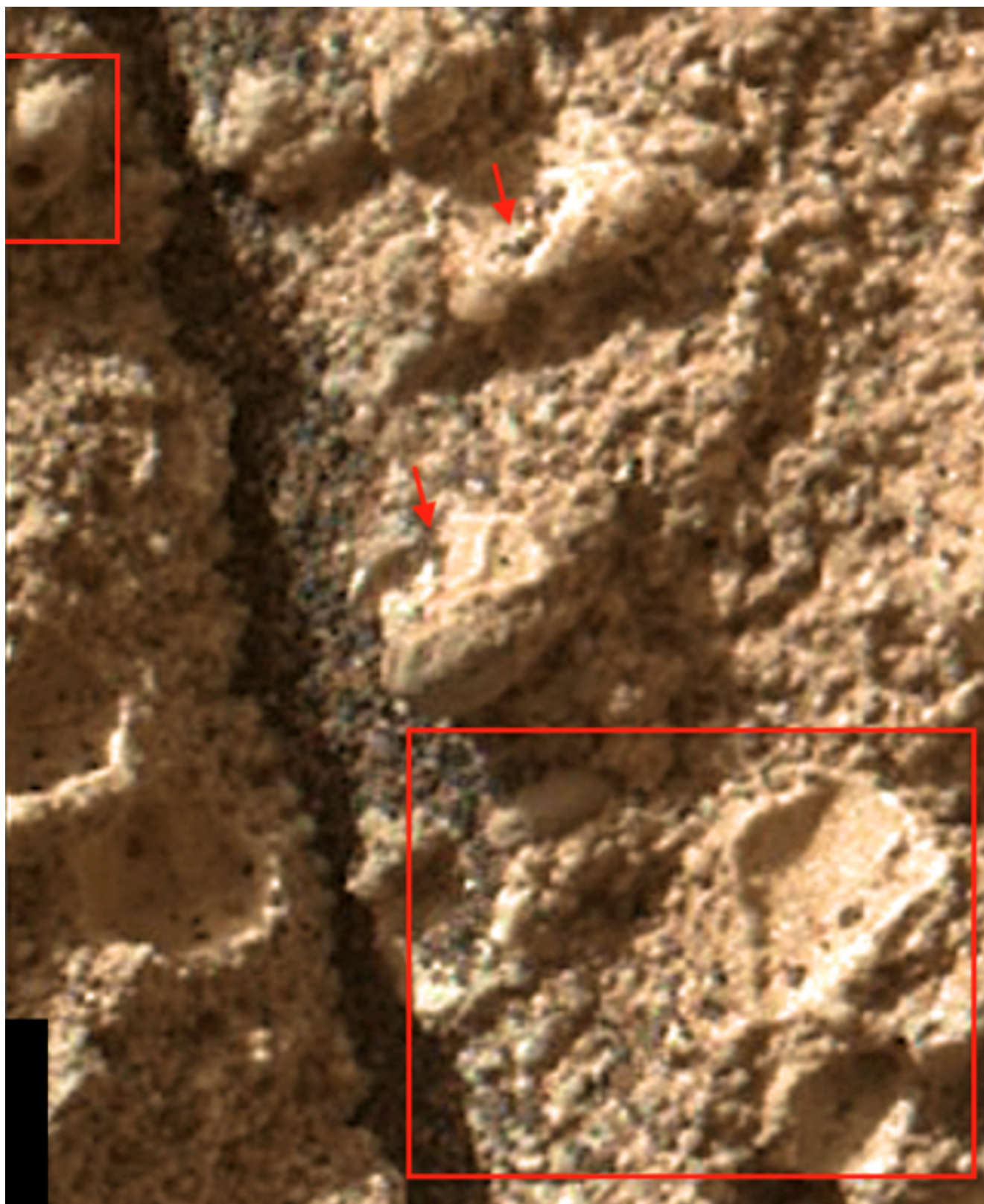


Figure 20: Worms? Broken “eggs”? Concave dried egg-yolk or cocoon remnants. Dead and deteriorating fungal puffballs?



Figure 21: Worms? Remnants of cocoons? Concave dried egg-yolk formations vs fungi?

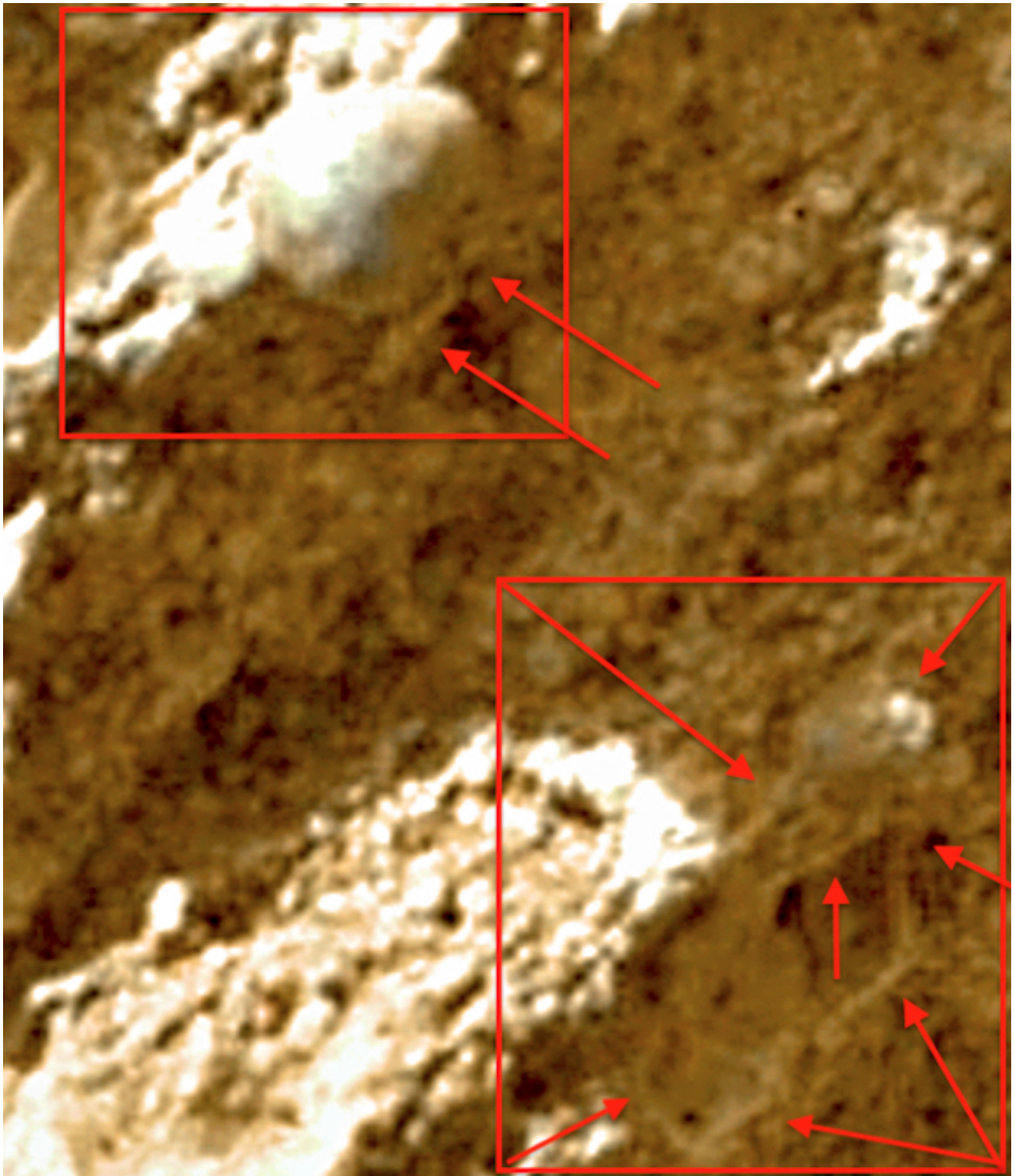


Figure 22: Fossilized “eggs” with protruding (exiting) fossilized “worms” (bottom right) and worms in “egg-yolk” matrix? Or (top left) fungal puffball with stem?



Figure 23: Fossilized and broken “eggs” with protruding (exiting) fossilized “worms”? Or fossilized fungal puffballs with stalks and rhizoids?

SOL 1032 SPECIMENS RESEMBLING COCOON REMNANTS AND FUNGI WITH STALKS?



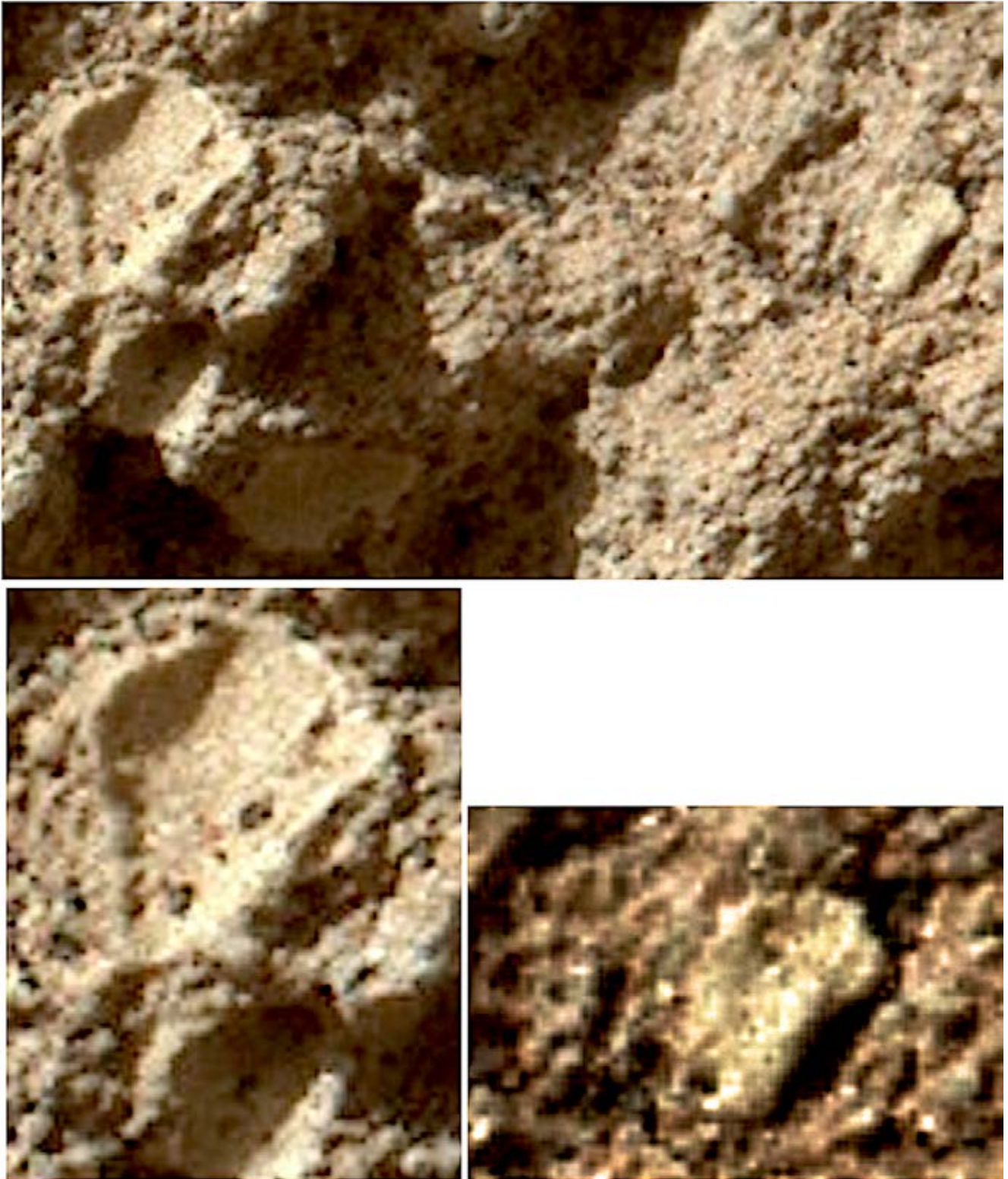
Figure 24: Concave “cocoon-yolks?” Fungus? Note three-four ovoid structures with stalk.



Figure 25: Structures with stalks embedded in a microbialite-like sediment.



Figure 26: Worms? Rhizoids? Fungal puffballs? (Lower left) ovoid flowering specimen with center hole and stalk.



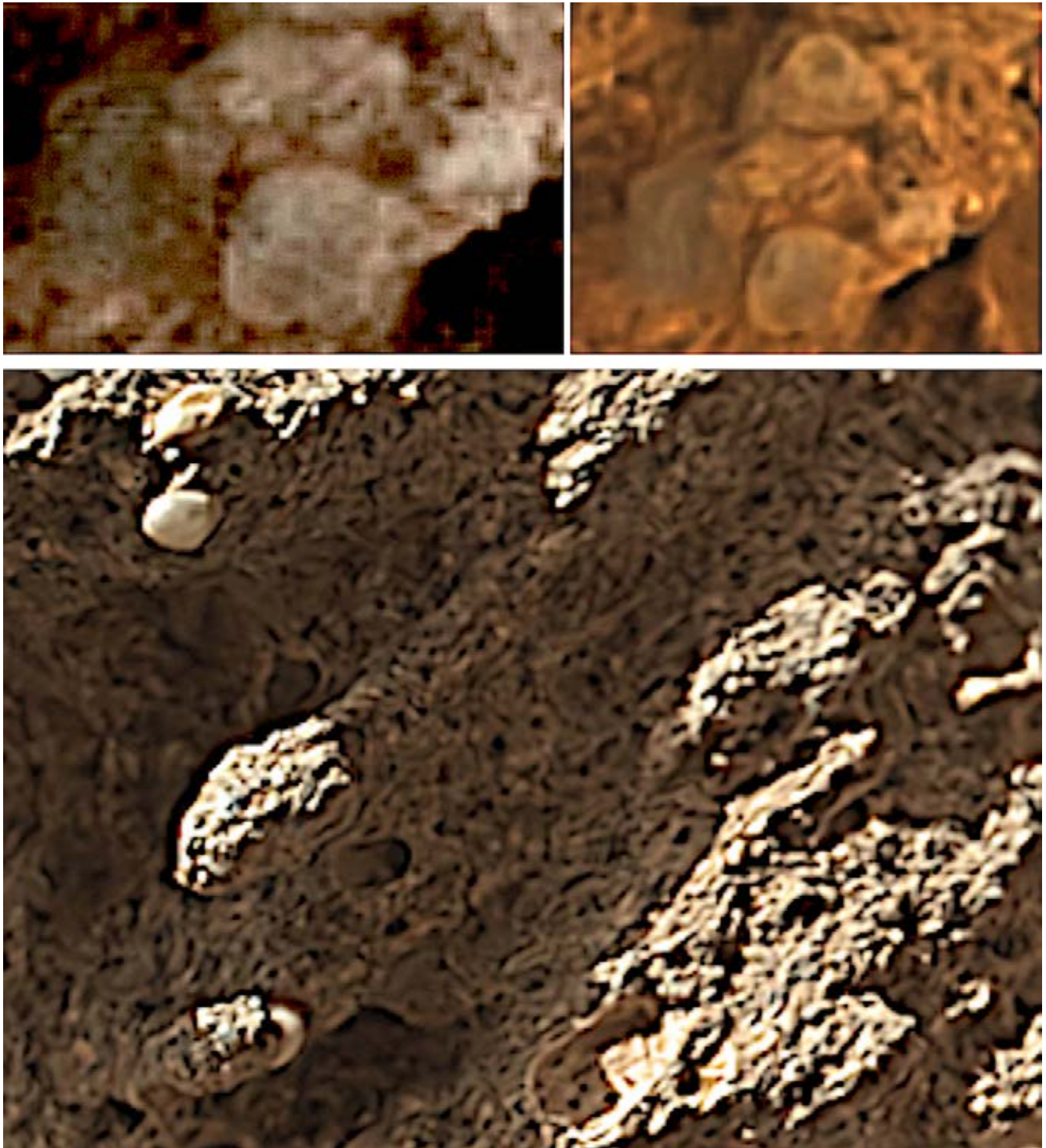
Figures 27: Remnants of cocoon-eggs that have hatched or undergone metamorphosis? Or the remnants of a fungal puffball after sporing? Note forms similar to cyanobacteria on the left side and bottom of figure to the bottom left).



Figure 28: Remnants of cocoon-eggs that have hatched or undergone metamorphosis. Sediment resembles a coral-matrix.



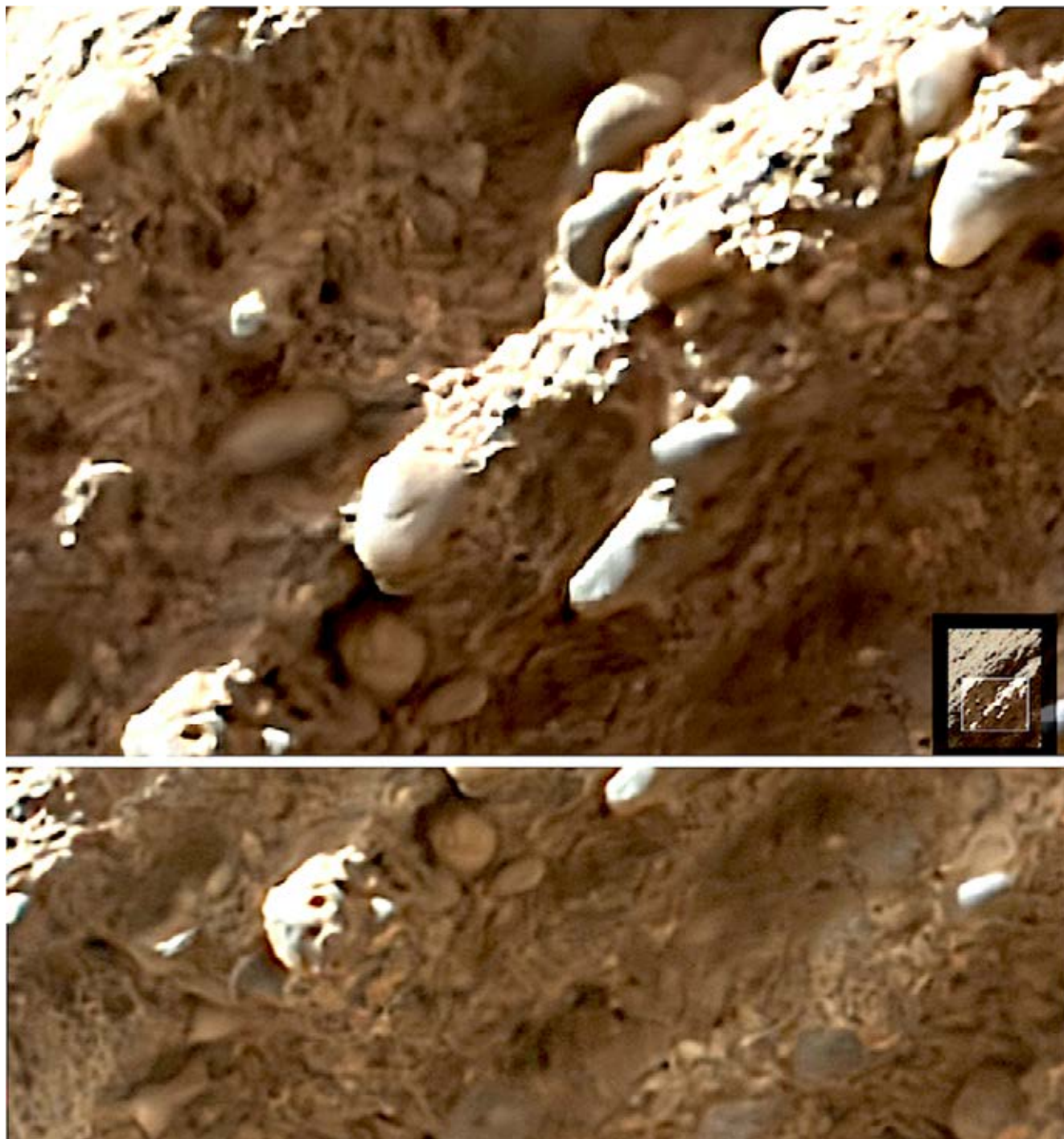
Figure 29: Egg-cocoons and “egg-yolks”? Dried concave fungus?

SOL 1032 SPECIMENS WITH WORM-LARVAE AND EMBEDDED IN TUBULAR MATRIX

Figures 30: (Upper left) coiled forms within and on the surface of ovoid. (Upper right) Worm- like forms in brownish matrix. (Bottom) Egg-cocoons in coral-honey-comb worm-like matrix.



Figure 31: Egg-cocoons in a coral-worm-like matrix.



Figures 32: Egg-cocoons in a coral-microbialite-worm-like matrix.



Figure 33: (Left) Coiled worm-like forms.

SPECIMENS RESEMBLING INSECTA WITH MULTIPLE APPENDAGES

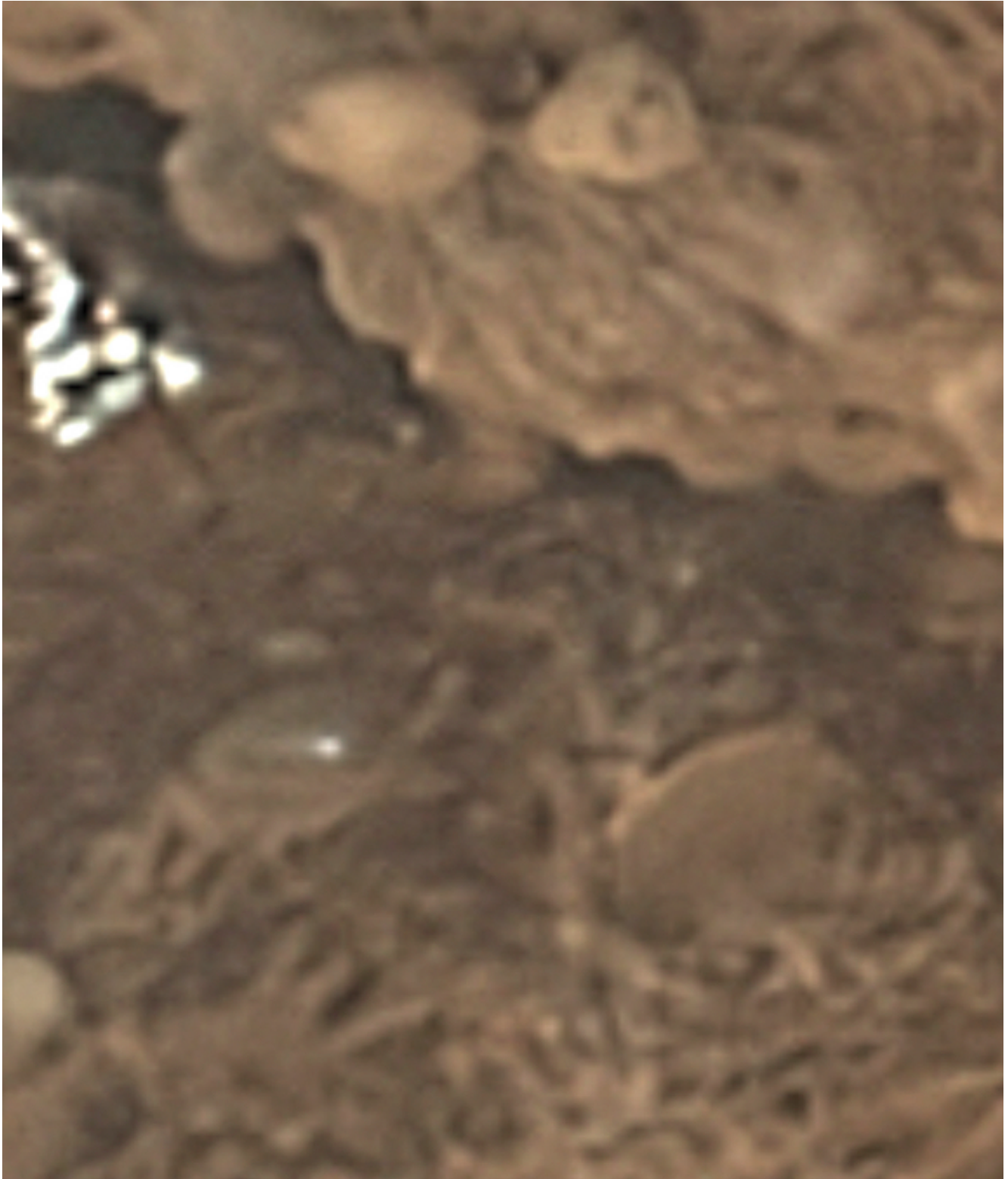
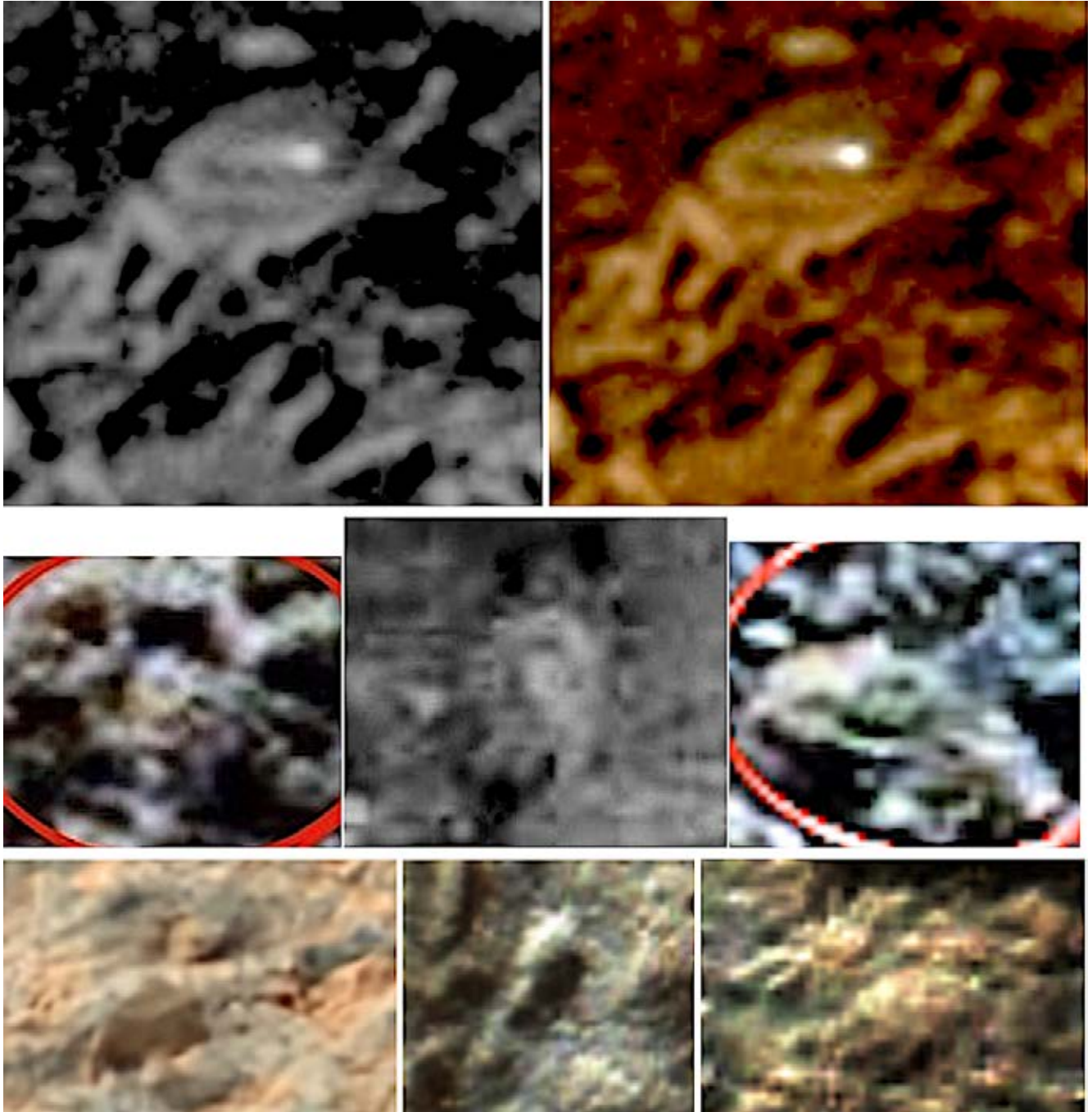


Figure 34: Sol 1302. (Bottom left). Ovoid specimen with multiple appendages? (see Figure 35).

Research Article



Figures 35: (Top Sol 1302) Ovoid specimen with multiple appendages? Note how light is reflected from the ovoid; suggestive of chitlin. (Middle) Specimens with multiple appendages have been photographed in other areas of Gale Crater and that are clearly distinct from surrounding substrate [7] (Bottom) Sol 132, Sol 905, photographed in Gale Crater [2].

FOSSIL WORMS AND/OR CALCAREOUS TUBES IN GALE CRATER

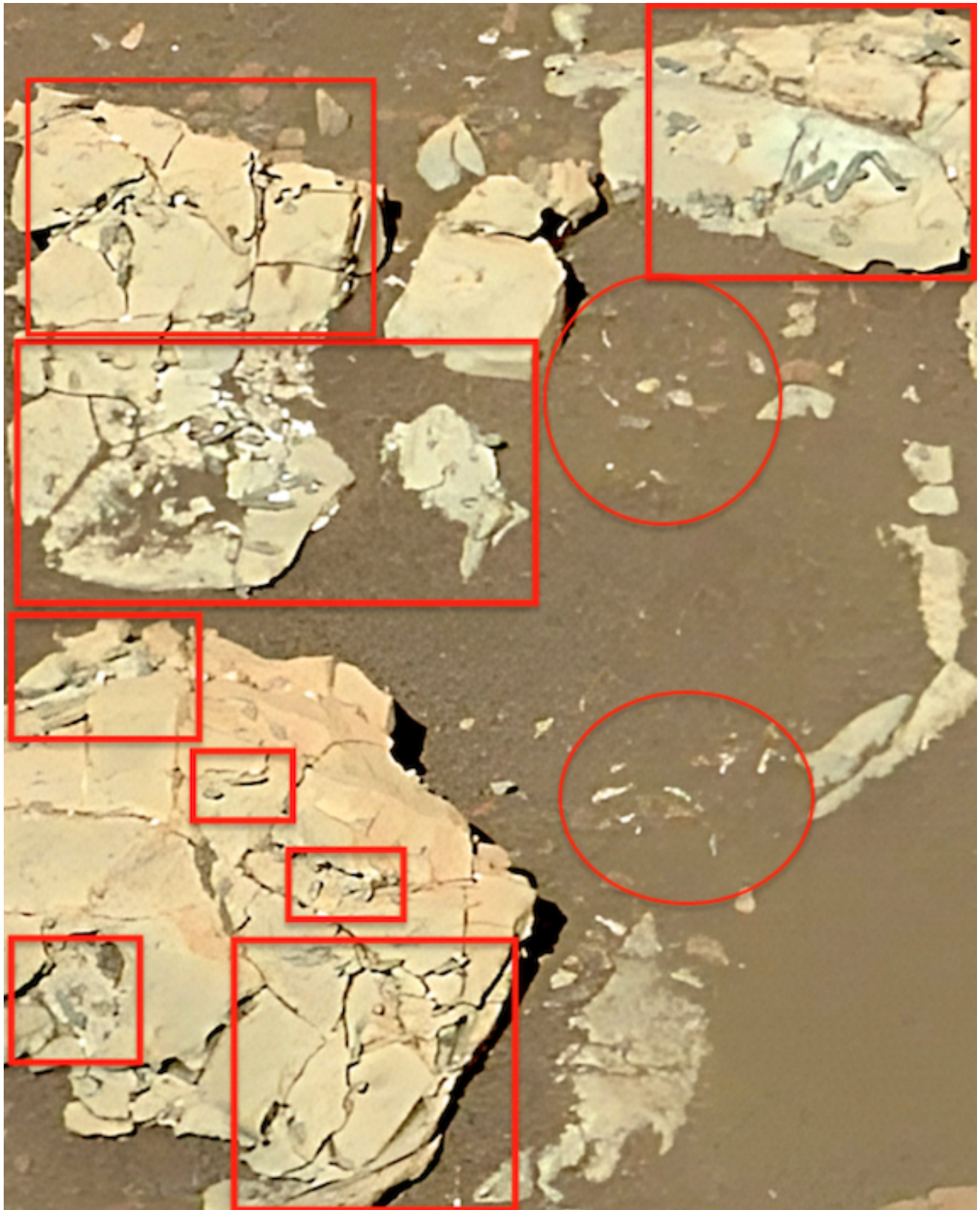
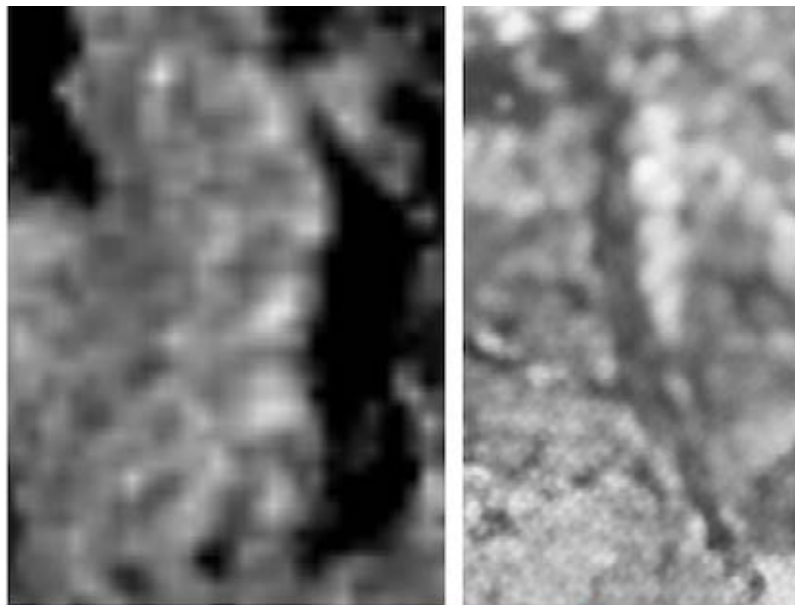


Figure 36: Numerous tubular specimens photographed on Sol 1921, Gale Crater.

Research Article



Figures 37: Fossilized impressions of segmented worm-like forms photographed on Sol 553, Gale Crater.

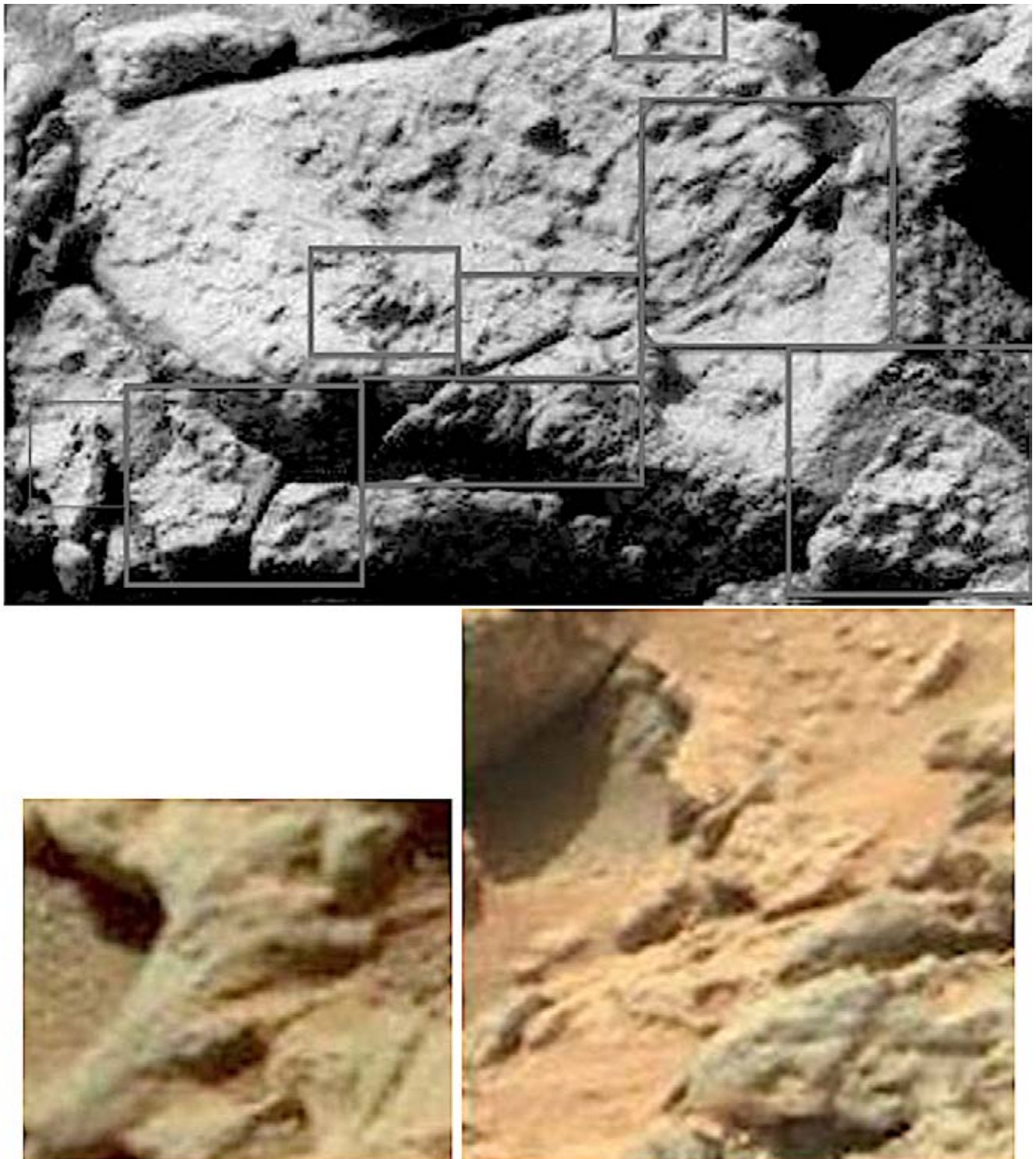


Figures 38: Fossilized impressions of worm-like forms photographed on Sol 808-809 (Top) and Sol 130 (Bottom) in Gale Crater.

Research Article

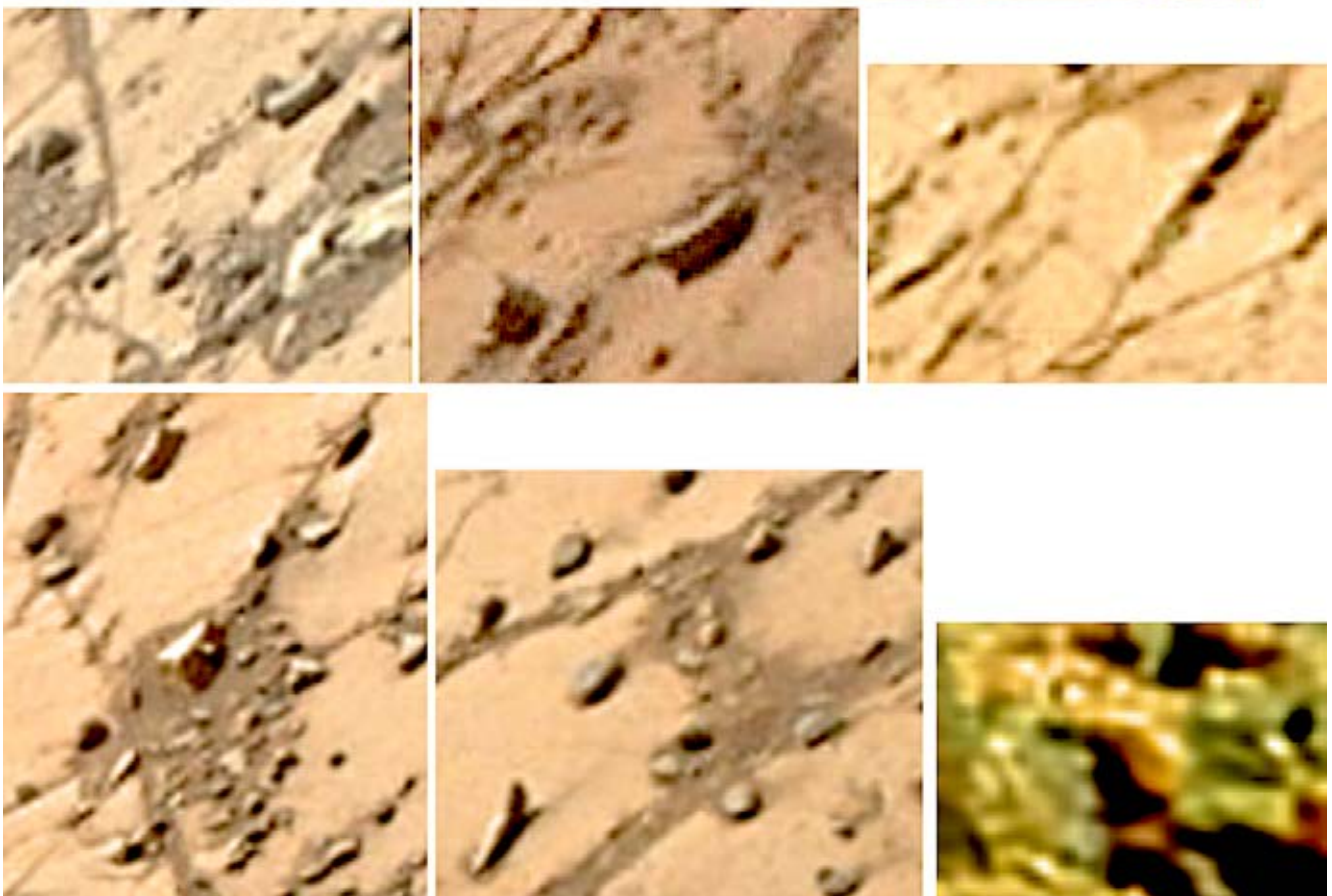


Figures 39: Fossilized impressions of worm-like forms photographed on Sol 906 in Gale Crater.



Figures 40: Fossilized impressions of worm-like forms photographed on Sol 906 (Top) Sol 1280 (Second Row Left) and Sol 302 (Second Row Right and Bottom) in Gale Crater.

Research Article



Figures 41: Fossilized impressions of worm-like forms photographed on Sol 302 (Top) Sol 868 (Bottom two rows), in Gale Crater.

DISCUSSION

As documented in this report, curled, smooth, segmented, and elongated tubular forms similar to annelids, nematodes, rhizoids and tubular and conical fungi have been photographed in numerous locations throughout the ancient lake beds of Gale Crater. Some of these worm-like specimens have a large open orifice at one end that may serve as a “mouth” for filtering feeding or predation as is characteristic of nematodes.

Several worm-like forms have an open circular pouch on the dorsal (superior) surface (Figures 37-38), in the general vicinity of where the cocoon forming and egg-storing clitellum girdles the bodies of earthworms (annelids). If these open pouches serve the same function as the clitellum is unknown. It must be stressed, however, that some of these segmented forms may be rhizoids and those with open apertures may be tubular fungi (Figure 42).



Figure 42: Example of segmented tubular-worm like forms, possibly including cyanobacteria and fungal- lichen-rhizoids, photographed by Viking 1 in Chrys Planitia [20]. These and other tubular worm-like forms are commonplace in various regions of Mars [1-2, 12, 19, 23]. Algae and lichens are likely growing on the boulder [20].

Research Article

In other previous reports elongated tubular specimens photographed in Gale Crater have been interpreted as ichnofossils of burrowing worms [1, 3-5]. This interpretation was subsequently rejected by a NASA-controlled journal [21] which also failed to review or acknowledge the comparative statistical and quantitative morphological evidence that favors a biological interpretation [3-5, 22].

Tubular forms, interpreted as “tube worms” and “tube worm casings” as well as specimens resembling crustaceans and mass groupings of coiled worm-like forms have also been photographed in the dried lake-beds of Endeavor Crater. There were photographed adjacent to holes and upon soil and matrix the chemistry and mineralogy of which is consistent with an ancient lake or inland sea heated by thermal vents [3, 17, 22].

In addition, masses of what resemble small coiled worms have been photographed within bore holes in the surface of rocks in Jezero Crater which long ago hosted an inland sea [19]. These holes appear to have been fashioned by rock-boring marine organisms. Large segmented and smooth-skinned tubular forms have also been photographed in Utopia Planitia and

Chryse Planitia, during the Mars- Viking mission (Figure 42); however, if these are actual worms or fungal-lichen rhizoids could not be determined [20]. Likewise, some of the specimens presented here also resemble fungal puffballs, lichens, rhizoids and some of the those with holes at one end are similar to fungal fruiting bodies [36].

In support of the “worm” hypothesis, numerous oblong and ovoid egg-shaped forms similar to worm- and insect- eggs and cocoons have also been photographed on Sol 1031 and 0132, the latter of which have been featured in this report. Many have a hole at one end which varies in size, and in a few specimens *something* appears to be exiting or entering these openings. Some “egg cocoons” also resemble pupae, whereas others that are semi-transparent appear to contain segments pupae and coiled tubular forms within.

In addition, numerous cocoon-eggs photographed on Sol 1032 are embedded in substrate that appears to consist entirely of a mass of coiled and worm- and cyanobacteria-like forms embedded in a coral-stromatolites matrix. Figure 43, for example resembles a biologically constructed hive.



Figure 43: Sol 1032. Microbialite-like formation reminiscent of a “hive” surrounded by “cocoon-eggs” and/or fungal puffballs embedded within the matrix or that grow outward from it. Could something be living in that hole? Might it have biologically fashioned its surroundings and is producing these “cocoon- eggs”? If not “eggs” then the only other reasonable explanation is fungus (e.g., fungal puffballs) in relationship with microbialite-constructing cyanobacteria. That numerous species, including worms, algae, fungi might share the same substrate is typical of soil samples from Earth.

The “egg cocoons” are not uniform in appearance, some appearing dented, shriveled, wrinkled, or partially collapsed, and which may be due to freezing, dehydration, fossilization, and/or age and the hatching of young, or because they were produced by different species. Moreover, not all are white, as some are white and dark, and others very dark in color and many regardless of shape or color have single hole at one end. However, this lack of uniformity, the concave dents, and differences in color are also characteristic of a single hatch of eggs produced by single organisms belonging to numerous species of worm, insect and fish (Figures 45-46).

Surrounding these “cocoon-eggs” photographed on Sol 1032--including those that appear to be broken or decomposing-- are numerous concave patches that may consist of dried “egg-yolk,” remnants of cocoons, or fungus. Perhaps these patches are what remains following the final stage of “egg-cocoon” metamorphosis and/or collapse and disintegration following hatching. It is also possible these patches are fungal in origin; and if fungal or “yolk” perhaps they are all that’s left after predation or death following hatchings or fungal sporing.

The possibility some of these ovoids include fungi is supported by what appears to be stalks protruding upward from holes in the soil topped by ovoids or ovoid-shaped microbialite-like sediment: a possible indication of a mutualistic relationship with cyanobacteria. Large cyanobacteria have been reported here, and algae, fungi and stromatolites have been previously reported in Gale Crater, whereas fungal “puffballs” and oval-fungal-lichen-like specimens attached to rocks with stems have been observed in Meridiani Planum [8-9, 11-12].

Specimens resembling *insecta* have been photographed on Sol 1032 and other areas of Gale Crater (Figures 34-35, 41). In earlier reports multi-tentacled forms have also been observed in the dried lake beds of Gale Crater [2, 7] whereas those resembling

crustaceans have been photographed in Endeavor Crater which long ago hosted lake waters heated by hydrothermal vents [22]. One Gale Crater ovoid specimen--with what appear to be forward-facing eyes--was photographed in a hole and the next day (Figure 44) was photographed several centimeters outside the hole whereas another specimen (Figure 45) appears to be consuming something [6].

To speculate: if the diverse and numerous Gale Crater specimens presented in this report are biological, perhaps they represent a mutualistic, symbiotic or predatory relationship among a variety of organisms including cyanobacteria, worms, insects, fungi and lichens whose ancestors have evolved and adapted to the extreme environments of Mars; and most of which spend much of their lives beneath the soil in crevices, holes, caves and caverns.

It is also reasonable to ask: if these are living organism (e.g. *insecta*), might those capable of doing so hide within holes or retreat beneath the soil in response to the approach of the rover? Might they emerge if the rover remained stationary and unmoving for several days and if prey became available (Figures 44-45)?

If these elongated forms are in fact worms, then it would be expected they would spend almost their entire lives beneath the soil. Those on the surface, if alive, might become frozen and unmoving when temperatures drop, or they might die and become fossilized. If frozen or fossilized this would explain why so many have been photographed on the surface. If dormant, then, it could be predicted that given favorable conditions they may become metabolically and physically active. Unfortunately, it is impossible to determine which “worms” are biological vs abiogenic concretions of dried mud and soil based on these photos. Identification would require extraction and genetic analysis.



Figure 44: Left/Sol 888: The hole in the crevice is occluded by something. Worm-like specimens are to the right of the hole. **Right/Sol 889:** The following day (one day later) a life-like specimen with eye-like orifices appears on the ledge in front of the hole that is no longer occluded. It is evident that the entrance to the hole now appears to be empty and shadows from the specimen are to its right and not behind it [6]. One of the worm-like forms is also no longer visible. Photographed in Gale Crater.

Research Article



Figure 45: ML0022190050204146E01_DXXX Ovoid specimen with forward facing “eyes” and possibly feeding on a worm-like specimens. Note reflection of sunlight off the surface of the specimen and which may be indicative of the reflective properties of chitin and/or the upper layers of cuticle [6]. Photographed in Gale Crater.

WHY SPECIMENS ARE SIMILAR TO THOSE FROM EARTH? EXTRATERRESTRIAL INTERPLANETARY ORIGINS

That these and other life-like forms are similar to those of Earth, despite the fact that the current environments of these planets are so dissimilar could be the basis of a cautionary objection: Wouldn't it be reasonable to assume, given the “alien” nature of Mars, that life on the Red Planet would have evolved into forms completely alien to Earth? The answers to this objection may include the following:

- (1) Life on primordial Earth and Mars may have originated on other more ancient worlds [23-26], and these forms of life, including viruses, contained in their genomes the same foundation genes [23, 27-29]: the “genetic seeds” from which arose and evolved similar forms of life on both planets.
- (2) Subsequently life may have been repeatedly transferred between these two planets for the last 4 billion years, a function of tons of life-bearing soil and rock and volumes of water ejected and splashed into space following the impact of meteors, asteroids and comets [2, 15, 26, 30].
- (3) Its been reported that insect larvae and eggs from marine organisms develop and reproduce normally after 7 to

13 months exposure to space outside the ISS and could survive on Mars [31]. It is also well established that over 40 species including bacteria, fungi, lichens, algae, plants, insects, crustaceans, and marine organisms, including daphnia embryos, diapausing larvae of dipterans, and eggs of cyprinodont fish, of fairy shrimps, tadpole shrimps, copepods and ostracods, can also survive outside the ISS and in Mars-like environments despite long term exposure to gamma, microwave and ultraviolet radiation and a wide range of high and low temperatures [32]. Nematodes not only survive in space following a catastrophic explosion hundreds of miles above Earth, but also the subsequent crash to the surface of this planet. In total, these findings, coupled with life-like morphology, supports the hypothesis that the specimens presented here may include fungi, lichens, cyanobacteria, “worms” “*insecta*” and cocoon-building egg-laying organisms that may have been deposited on either or both planets following interplanetary transfer; organisms that subsequently evolved and adapted to life on Mars.

- (4) Mars does not have a stabilizing moon which causes periods of extreme axial obliquity [18, 33]. When axial tilt periodically exceeds 40 degrees, temperatures and atmospheric pressure rise and surface and subsurface and polar ice melts and release large bodies of melt water that form rivers, lakes, oceans and inland seas

that stabilize and endure for hundreds of thousands or millions of years [18, 34-35]. Hence, there are episodes in which the Red Planet may become Earth-like. Therefore, during periods of high obliquity life may have flourished in the oceans of Mars; and these organisms may include those deposited on Mars following interplanetary transfer. When axial tilt declines below a critical tipping point these waters rapidly recede and then freeze, resulting in mass extinctions. In consequence only those dwelling beneath the soil would survive, whereas surface dwellers would freeze or become fossilized [2, 18]. This scenario would also explain the coral-like matrix depicted in Sol 1032.

- (5) Currently, Mars has at best, a very weak magnetic field such that the surface is bombarded by cosmic, gamma, and UV rays. At ground level, in the equatorial and southern hemisphere there is a protective, albeit weak, magnetic field that could provide protection for species that have evolved and adapted to this environment. Moreover, just as the obliquity of Mars is cyclic and waxes and wanes up to 80 degrees, it is possible that the “internal dynamo” and magnetic field of Mars also waxes and wanes and is currently at a minimum. Therefore, during periods of Red Planet high obliquity its “internal dynamo” may also become increasingly active, thereby producing a protective magnetosphere that would assist in preventing the solar winds from blowing the Martian atmosphere into space as well as protecting surface life from cosmic, gamma and UV rays.
- (6) As a consequence of a common source of life, repeated instances of interplanetary transfer of life, and repeated episode in which both planets are Earth-like (due to extreme obliquity), it can be predicted that similar forms of life may evolve and periodically flourish on both worlds, only to suffer mass extinctions when the axial tilt of Mars declines below a critical tipping point.
- (7) Given these limiting parameters, periodic catastrophic conditions, lack of evidence that vertebrates evolved, it is possible that current and past life on Mars might be limited to bacteria, algae, fungus, lichens and other simple eukaryotes, including metazoan invertebrates as previously reported [1-20] and as exemplified by the putative worms and *insecta* presented in this and other reports.
- (8) These scenarios do not preclude the possibility that numerous species were never completely eradicated via mass extinction events. Some Martian organisms and

their eggs, may have remained dormant and survived beneath the soil and/or have adapted to low obliquity conditions, perhaps even feeding upon high levels of radiation as is typical of many species of fungi.

CONCLUSIONS

Presented in this report are numerous forms in Gale Crater, Mars, that resemble worms, *insecta*, worm-insect eggs and cocoons, as well as tubular fungi, fungal puffballs, fruiting bodies, rhizoids, and cyanobacteria. That different species colonized the same substrate is typical of sediments on Earth.

It is highly unlikely, that the “cocoon-eggs” are pebbles that have been smoothed and weathered by the waters of the ancient lakes of Gale Crater. Why they have holes at one end is difficult to explain as abiotic, but could represent fungal fruiting bodies that have produced spores as identified in yet other areas of Mars [36]. Without extraction and detailed examination, it is impossible to completely rule out abiogenic scenarios or differentiate between species that bear gross similarities.

The diversity and morphological similarities between life on Earth and Mars are to be expected if life on Mars and Earth have a common origin and/or if life was repeatedly transferred between planets contained within volumes of water and mountains of debris ricocheted into space following bolide impact. Indeed, viruses, prokaryotes, and simple eukaryotes may commonly fall from space [23, 37-38] and Mars and Earth should be similarly contaminated.

If insect eggs, and other small biological entities were delivered to Earth via bolide impacts, as arguably may have happened in the Cambrian explosion [29,39], it would be difficult to rule out the possibility of similar introductions to our neighboring planet Mars at a time when life-favorable conditions may have probably prevailed; and/or that interplanetary transfer contributed to a “Cambrian Explosion” on both planets [2, 30].

It is thus noteworthy that some of the cyanobacteria, fungi, and worm-like and cocoon-like structures presented in this paper bear a resemblance to putative fossilized specimens discovered in meteorites as discussed by Wainwright and Wickramasinghe [24]. It has also been reported that cyanobacteria, fungi, lichens, seeds, worms, *insecta*, crustaceans, and their eggs survive long term exposure to space outside the ISS, and in Mars-like environments, and could survive interplanetary transfer to Mars [15, 26, 31-32].

If biological--and if deposited following interplanetary transfer--the ancestors of these putative organisms and their eggs may have evolved and thrived during periods of extreme axial obliquity when temperatures and atmospheric pressures were higher and oceans, lakes, and rivers flowed and remained

Research Article

stabilized on Mars [18-20]. High obliquity may also have a positive enhancing influences on the Martian internal dynamo and magnetosphere which would then provide enhanced protection against radiation to surface dwelling organisms and preserving the atmosphere against the effects of solar winds. Once axial tilting declined, these waters may have suddenly receded and the planet's internal dynamo may have slowed nearly to a halt, resulting in a mass extinction such that only those that could adapt and/or those living beneath the soil survived.

It is impossible to rule out all abiogenic scenarios, or to precisely identify and differentiate between putative organisms based on photographs. However, we believe that many of the specimens presented in this report may be alive or represent the fossilized or frozen remnants of various egg-laying and cocoon-constructing organisms, as well as cyanobacteria, lichens, fungi, corals and worms that colonized Gale Crater and its lakes in the ancient past.

CONFLICT OF INTEREST

The authors declare no conflict of interest associated with this research.

REFERENCES

1. Joseph, R. Graham, L., Budel, B., Jung, P., Kidron, G. J., Latif, K., Armstrong, R. A., Mansour, H. A., Ray, J. G., Ramos, G.J.P., Consorti, L., Rizzo, V., Gibson, C.H., Schild, R. "Mars: Algae, Lichens, Fossils, Minerals, Microbial Mats and Stromatolites, in Gale Crater." *Journal of Astrobiology and Space Science Reviews*, 3 (2020): 40-111, ISSN 2642-228X, DOI: 10.37720/jassr.03082020
2. Joseph, R. G., Rizzo, V., Gibson, C.H., del Gaudio, R., Sumanarathna, A. R., Ray, J.G., Elewa, A. M. T., Bianciardi, G., Duvall, D., Wickramasinghe, C., Schild, R. "Fossils on Mars: A "Cambrian Explosion" "Burgess Shale" in the Ancient Lake Beds of Gale Crater?" *Journal of Astrophysics & Aerospace Technology* (2023).
3. Armstrong, R. A. "Statistical Analysis of 'Tube-Like' Structures on Mars Photographed by Curiosity and Opportunity and Comparisons with Terrestrial Analogues," *Journal of Astrobiology*, 10 (2021): 11-20,
4. DiGregorio, B. "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 (2018): 1-7.
5. Baucon, A. et al. "Ichnofossils, Cracks or Crystals? A Test for Biogenicity of Stick-Like Structures from Vera Rubin Ridge, Mars." *Geoscience*, 10 (2020): 39.
6. Joseph, R. "The Eyes of Mars: Evidence of Complex ("Animalia") Life on Mars?" *The Journal of Cosmology*, 32, (2022): 144-158
7. Joseph, R.G., Armstrong, R.A., Duvall, D. "Spiders on Mars: Gale Crater, Cyanobacteria, Stromatolites, Fungus, Mineral-Soil Concretions." *Journal of Cosmology*, Vol 31 (2022): 44-74.
8. Dass, R.S. "The high probability of life on Mars: A brief review of the evidence." *Cosmology*, 27, (2017).
9. Armstrong, R. A. "Martian Spheroids: Statistical Comparisons With Terrestrial Hematite ("Moqui Balls") and Lichen Dibaecis Baeomyces," *Journal of Astrobiology*, 7 (2021): 15-23
10. Joseph, R. et al. "Fungi on Mars? Evidence of Growth and Behavior From Sequential Images," *Journal of Cosmology*, May, 2021, 29, (2021): 480-550
11. Joseph, R., "Lichens on Mars vs the Hematite Hoax. Why Life Flourishes on the Radiation- Iron- Rich Red Planet." *The Journal of Cosmology*, 30 (2021): 1-102.
12. Joseph, R. "Evidence for Life on Mars: Moisture, Algae, Fungi, Martian Mushrooms, Lichens. 2005-2014. *Cosmology*, 16 (2014).
13. Armstrong, R.A. "Forms Resembling Sponges or Corals at Gale Crater, Mars: Evidence of Fossilised Life or Mineralogy?" *Journal of Astrobiology*, Vol 13, (2022): 4-12.
14. Latiff, K., Ray, J.G., Planchon, O. "Algae on Mars: A summary of the evidence." *Journal of Astrobiology*, 7 (2021): 22-28.
15. Joseph, R., Dass, R., Rizzo, V., Cantasano, N., Bianciardi, G. "Evidence of Life on Mars," *Journal of Astrobiology and Space Science Reviews*, 1 (2019): 40-81.
16. Elewa, A.M.T. "Fossils on Mars: A Brief Review of the Evidence," *Journal of Astrobiology*, Vol 7 (2021): 29-37
17. Sumanarathna, A. R., et al. "Tube Worm-Like Structures, Hematite, and Hydrothermal Vents on Mars: Support for, and Opposition to Joseph et al." *Journal of Astrobiology*, 10 (2021): 38-62.
18. Joseph, R., Gibson C, Wolowski, K, Bianciardi G, Kidron GJ, Armstrong RA, del Gaudio R, Sumanarathna AR, Cantasano N, Duvall D, Schild R. "Evolution of life in the oceans of Mars? Episodes of global warming, flooding, rivers, lakes, and chaotic orbital obliquity." *Journal of Astrobiology*, 13 (2022): 14-126, 2022 10.13140/RG.2.2.19993.90727
19. Joseph, R. Armstrong, R. "Mollusks on Mars! Rock-Boring Marine Life in Jazero Crater: A Comparative Quantitative Morphological Analysis." *Journal of Cosmology*. 32 (2022).
20. Schild, R., Joseph, R. G. "Life on Mars Discovered by NASA's Viking Landers: Lichens, Algae, Moss, Microbial Mats, Vesicular Trace Fossils in Utopia Planitia and Chryse Planitia," *Journal of Cosmology*, 32 (2022): 44-115
21. Genise, J. F. "Martian stick-like structures are not trace fossils: a new protocol for testing ichnogenicity synthesized from paleosol ichnology," *International Journal of Astrobiology*, 20 (2021): 5.
22. Joseph, R., Armstrong, R. A., Duvall, D., Schild, R. E. "Tube Worms, Hydrothermal Vents, Life On Mars? A Comparative Morphological Analysis," *Journal of Astrobiology*, 8 (2021): 14-126.
23. Hoyle, F., Wickramasinghe, N.C. "Evolution from Space," J.M. Dent, London. (1984).

24. Wainwright, M., Wickramasinghe, C., "Life comes from space: The decisive evidence World Scientific. Singapore and London (2022)
25. Arrhenius, S. "Worlds in the Making. Harper & Brothers, New York. (1908).
26. Joseph R., Planchon, O., Gibson, C. H., Schild, R. "Seeding the Solar System with Life: Mars, Venus, Earth, Moon, Protoplanets." Open Astronomy, 29 (2020): 1.
27. Joseph, R. "Viruses, Bacteria, Archae, Eukaryotes, and the Evolution of Life," Journal of Cosmology, 1 (2009): 150-200.
28. Wickramasinghe, C., Tokoro, G., Slijepcevic, P. "Cosmic Viruses: Grand Blueprint of Life in the Universe," Journal of Astrobiology, 11 (2022): 45-51.
29. Joseph, R. "Astrobiology, the Origins of Life, and the Death of Darwinism." University Press California. (2000).
30. Joseph, R., & Duvall, D. "Mars, Comets, and the Cambrian Explosion: The Interplanetary Transfer of Life," The Journal of Cosmology, 30 (2021): 158-206.
31. Orlov, O.I., et al. "Planetary Protection Challenges In Space Exploration Missions And Ways Of Their Resolution With Account Of Russian Exobiology Experiments," Reviews in Human Space Exploration, 44 (2017).
32. Alekseev, V.R.; Hwang, J.-S.; Levinskikh, M.A. "Effect of Space Flight Factor on Dormant Stages in Aquatic Organisms: A Review of International Space Station and Terrestrial Experiments." Life 12 (2022): 47. <https://doi.org/10.3390/life12010047>
33. Ward, W. R. "Large-Scale Variations in the Obliquity of Mars." Science, 181 (1973): 4096.
34. Head, J.W., Mustard, J.F., Kreslavsky, M.A., Milliken, R.E., Marchant, D.R. "Recent ice ages on Mars." Nature 426 (2003): 797–802.3
35. Clifford, S. M. "Introduction: Dynamic Mars, Recent and Current Landscape Evolution of the Red Planet," edited by Soare, R, J, et al, Elsevier (2018).
36. Joseph, R., Kidron, G.J., Armstrong, R.A. "Mars: Evidence of Fungus, Spores, and Reproductive Behavior," Journal of Astrobiology, 11 (2022): 52-85,
37. Wickramasinghe, C., Nimalasuriya, A., Wainwright, M and Tokoro, G. "Microbiomes: A Possible Space Component?" Astrobiology and Outreach, 3 (2015): 1000139.
38. Wainwright, M., Wickramasinghe, N.C., Tokoro, G. "Neopanspermia – Evidence That Life Continuously Arrives at the Earth from Space," Advances in Astrophysics 6 (2021).
39. Steele, E. J., et al. "Cause of Cambrian Explosion - Terrestrial or Cosmic?" Progress in Biophysics and Molecular Biology 136 (2018): 3-23.

Citation: Joseph RG, Wickramasinghe NC, Armstrong RA, Duvall D, Schild R (2023) Cocoons, Fungi, Nematodes, Rhizoids, Annelids, Eggs, Arthropoda in Gale Crater, Mars? Appl Cell Biol, 11(1), 2023 [1-51]

SUPPLEMENT: WORM, INSECT, FISH EGGS / COCOONS FROM EARTH



Figures 46: Worm eggs. Courtesy of Muhammad Roil bin Bilad, Nurul Huda, Jumardi Roslan, and colleagues.



Figures 47: Worm eggs-cocoons and insect cocoon (middle).



Figures 48: Worm eggs-cocoons (top). Fish eggs (bottom).