Arthropods on Mars?

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ABSTRACT

As presented in this report numerous fossils like forms resembling a variety of marine arthropods including crustaceans, sea spiders, scorpions, arachnids, nematodes, annelids, tube worms, sea snakes, *Kimberlla, Namacalathus, Lophotrochozoa*, armored trilobites and millipedes have been found in Gale Crater (on Sols 302, 553, 753, 781, 809, 869, 880, 905, 1032), and (annelids, tube worms, crustaceans) in Meridiani Planum both of which have hosted rivers, lakes, and inland seas. Similar specimens are mixed within a variety of divergent fossil-like forms and are also found on distant sediment and mud stone. All specimens are distinct from underlying substrate and there are no obvious patterns or repetitions typically produced by erosion or weathering. Although without extraction and direct examination it is impossible to precisely determine the identity of all these specimens, the same problems bedevil identification of Burgess Shale fossils some of which are presented in this report for comparative analysis. The discoveries presented here and in other reports supports the theory that metazoans and other marine organisms evolved in the lakes, oceans and inland seas of Mars.

Key Words: Metazoans, Cambrian Explosion, Ediacaran, Fossils, Algae, Evolution, Trilobites

I. INTRODUCTION

1. Arthropods on Mars?

The ancient lake beds of Gale Crater, which has likely repeatedly hosted lakes, rivers and a vast inland sea [1-2], have proven to be a veritable treasure trove of "Burgess Shale" fossil-like forms resembling a vast array of marine metazoans that first evolved during the Cambrian Eras on Earth, including arthropods with multiple appendages [2-8]. Examination of a small area at the bottom of the ancient lake bed of Gale Crater photographed on Sol 905 and swept clean of overlying dust, dirt, sand, algae, and organic debris by the rover Curiosity, has revealed, as reported here for the first time, formations that resemble what could be described as the Martian equivalent of armored and tri-segmented trilobites. As presented in this report fossil-like forms resembling arthropod marine biota--including crustaceans, sea spiders, scorpions, arachnids, nematodes, annelids, tube worms, sea snakes, *Kimberlla, Namacalathus Lophotrochozoa*, and millipedes--have been photographed in various locations of Gale Crater on Sols 302, 553, 753, 781, 809, 869, 880, 905, 1032, whereas fossil-like crustaceans and tube worms have been found in Meridiani Planum which, like Gale Crater, hosted large bodies of water in the ancient past [2]. For comparative purposes photographs of fossilized Cambrian Era fauna discovered in the Burgess Shale are provided.

It's not likely these putative Martian arthropods are abiogenic as they are within a few cm of one another, and are distinct from the underlying substrate and have different orientations and diameters and are devoid of repetitive or other patterns typically due to wind, rain, erosion, and weathering. Moreover, most are adjacent to and mixed within a vast assemblage of fossil-like specimens that resemble a variety of marine organisms [7-8] including arachnida and crustaceans and which have also been photographed in Gusev Crater and Meridiani Planum (respectively) as presented here (Figures 1-5, 7-13, 15-19).

An examination of three putative Martian trilobites indicates the presence of three lobes, a jointed body encased in jointed spiny armor, a snout, pleopods (feet), and pygidial spines/tails that are of varying lengths (Figures 28, 30, 32) similar to Huntonia trilobites (Figure 29). The presence of a mouth and eyes cannot be discerned but are evident in other fossilized forms (e.g. Figures 2-4, 42-46). Many of the arthropods / arachnida have multiple appendages (Figures 7-19, 15-16). Specimens identified as putative sea spiders, scorpions, arachnids, nematodes, annelids, tube worms, *Kimberlla, Namacalathus Lophotrochozoa*, millipedes and sea snakes, resemble their counterparts from Earth.

Given depth of field and distance from the camera specimen size can't be determined. It is estimated these putative arthropods range from 2 to 5 mm in length and diameter which is smaller than the average size of terrestrial arthropods. In other reports, putative Martian organisms and their fossils have been found to be typically smaller than their counterparts on Earth [3,5-6] with notable exceptions: cyanobacteria, fungi, and lichens [9-14].

Why the difference in overall size but not the morphology and gross appearance of putative Martian arthropods reported here? It is possible that the gravity of Mars, being approximately 62% less than on Earth, coupled with differences in concentrations of atmospheric gasses, exposure to cosmic radiation, available nutrients, etc., may have a differential influence on size. At this juncture there are no definitive answers and we can only speculate.

Photographs of specimens were enlarged, sharpened, contrast added, and in some instances natural embedded colors were enhanced via Fotor software. These photos were not tinted or altered other than via enhancing color and image resolution. Note the layered green terrain surrounding an area brushed clean by NASA's Curiosity brush instrument whereas the central area is devoid of color (Sol 905; Figures 27). Green may be the natural color of the unswept terrain and possibly indicative of algae. Also in Figure 33 are buried masses of what resemble dead organisms outside the central area cleaned of debris--in the ridges/crests between rover-brush-troughs--but still covered over in organic detritus that has built up over unknown years of time. Therefore, it can be surmised that the "fossils" that are clearly visible, are only those that were not swept away by the brush instrument (e.g Figures 27, 29).

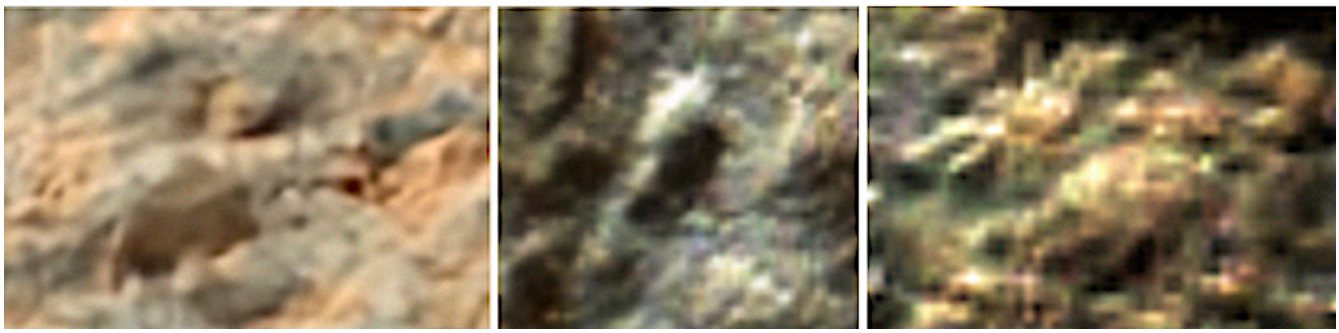
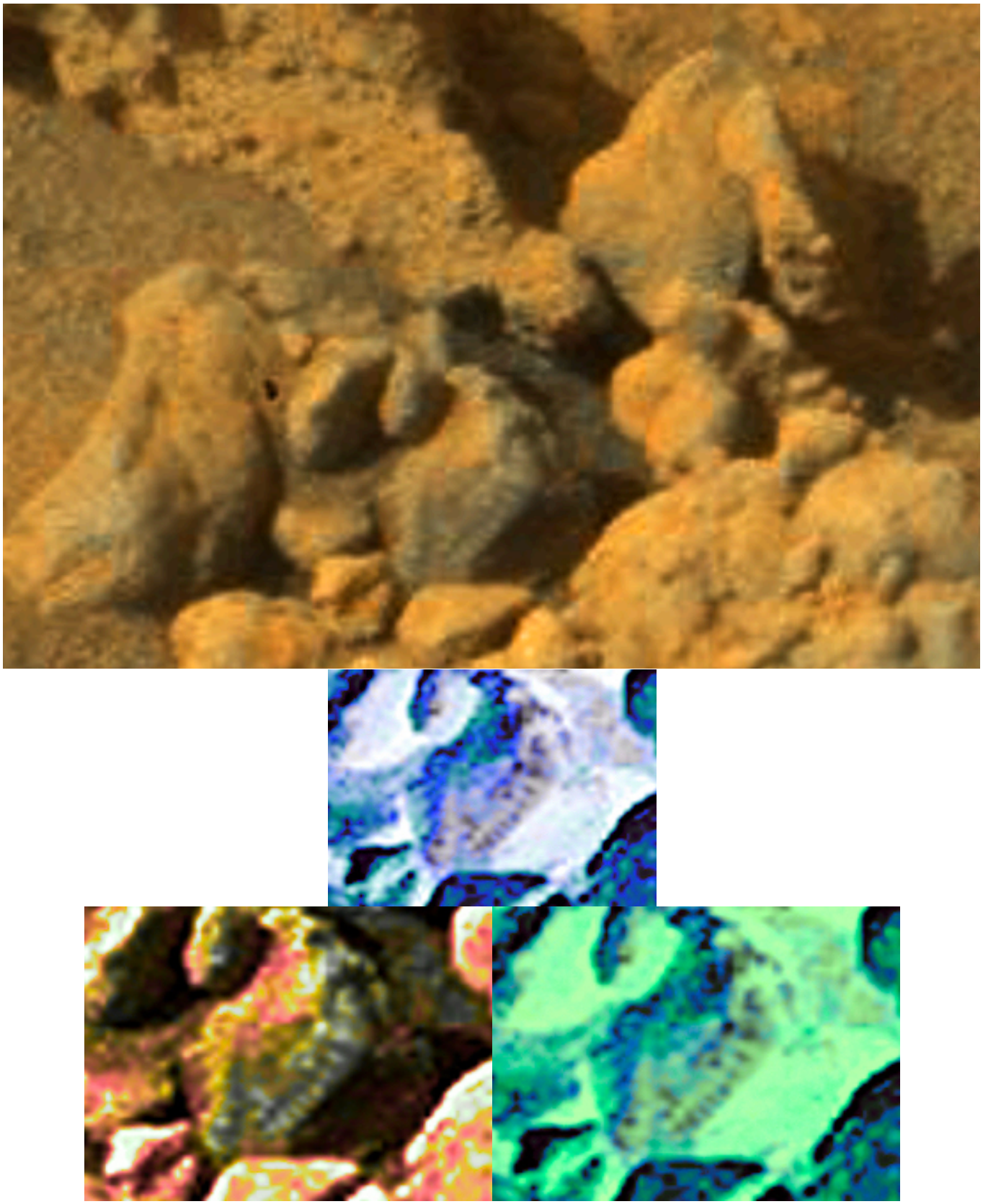
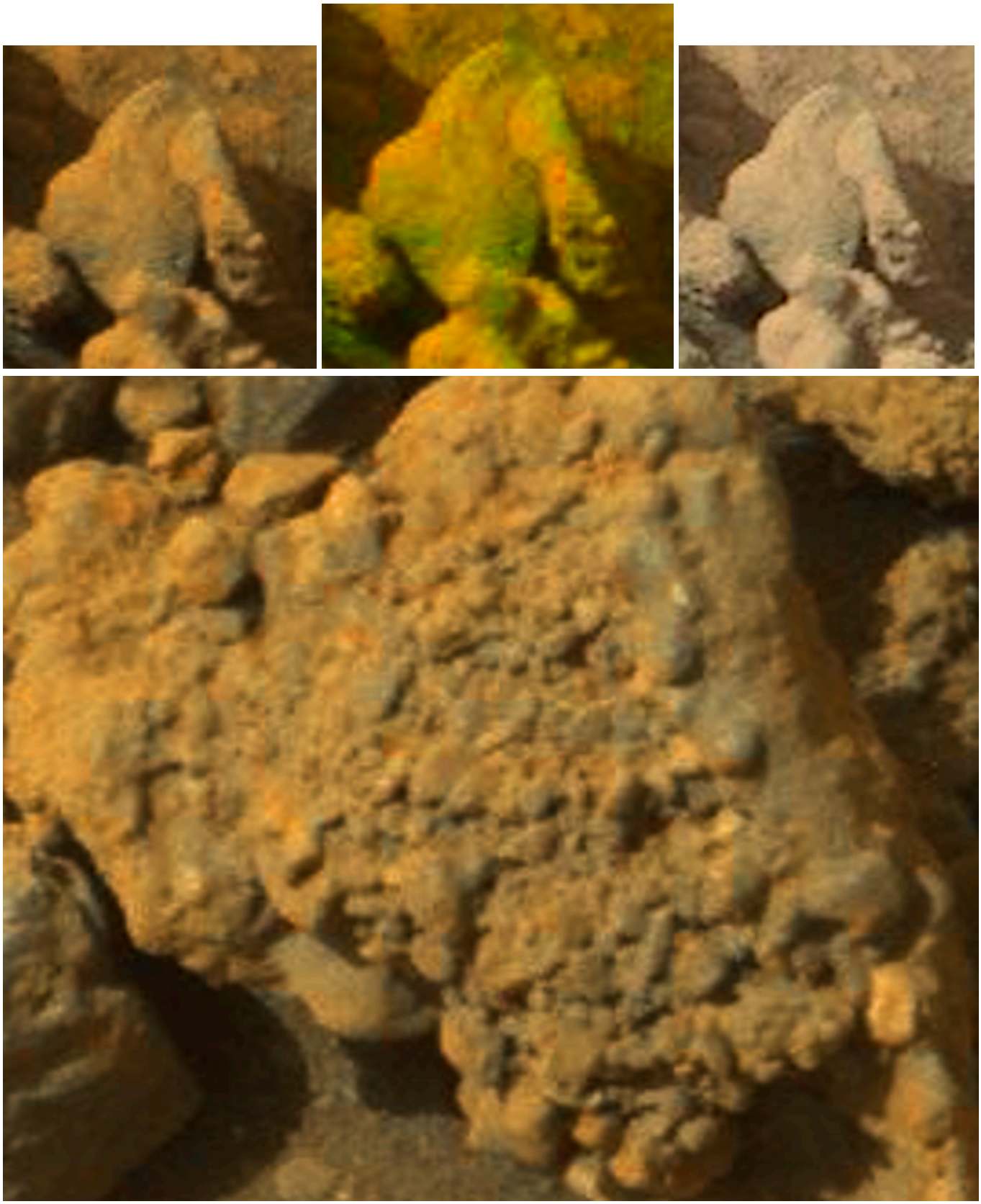


Figure 1. Sea spiders, arachnids, scorpions? Photographed in Gale Crater. Reproduced from [8].

Figure 2. Nematodes, annelids, tube worms, sea snakes, *Kimberlla,* millipedes and a relatively large specimens that resembles a "diamond" headed snake? Photographed in Gale Crater. 0753MR0032350020403675E01_DXXX



Figures3. Photographed in Gale Crater. 20753MR0032350020403675E01_DXXX



Figures 4. Photographed in Gale Crater. 20753MR0032350020403675E01_DXXX

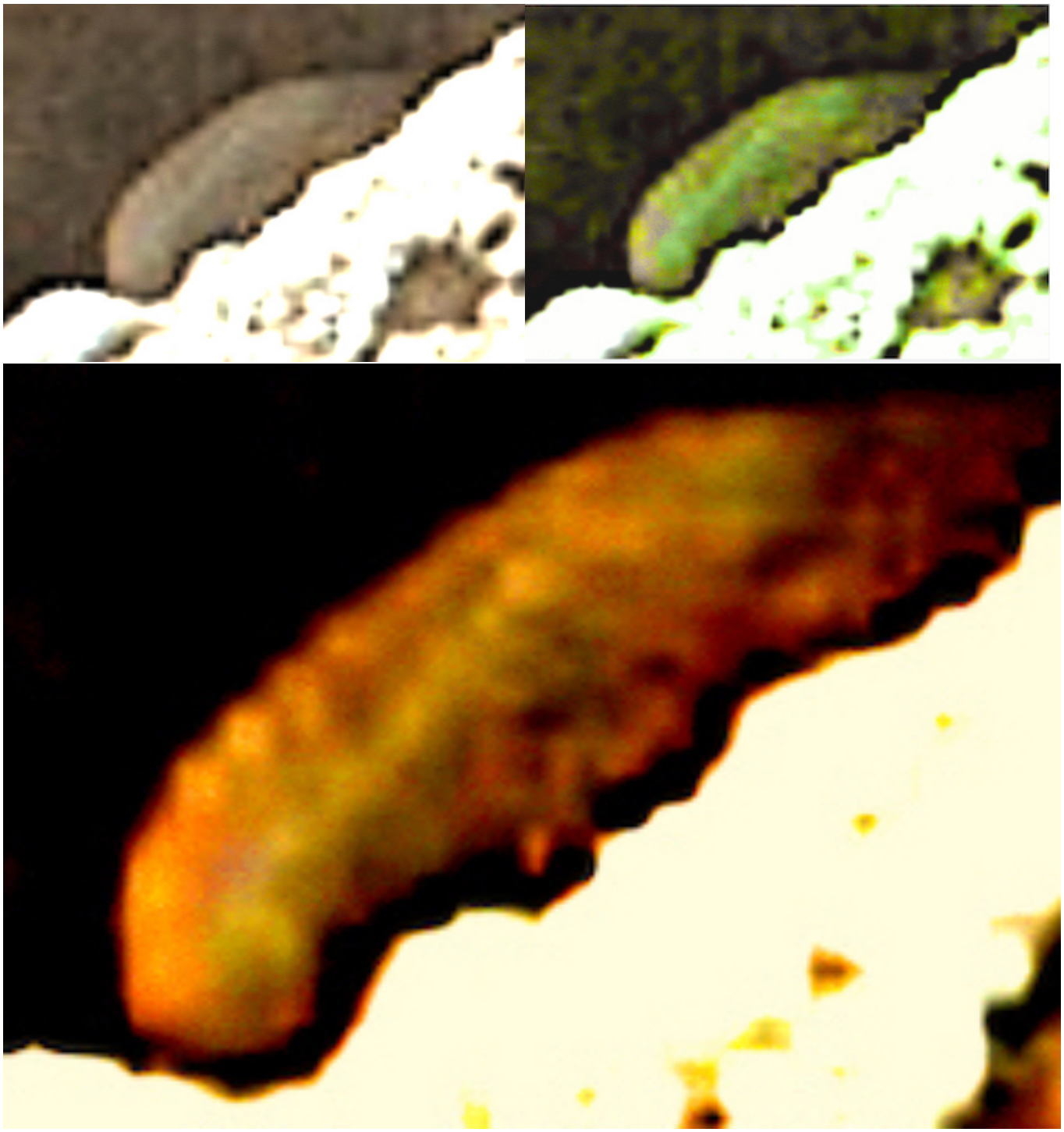


Figure 5. Semi-translucent millipede-like organism. Photographed in Gale Crater on Sol 0553

Figure 6. Burgess shale fossils. From C. D. Walcott, Cambrian Geology and Paleontology, 1912, Smithsonian, WDC.

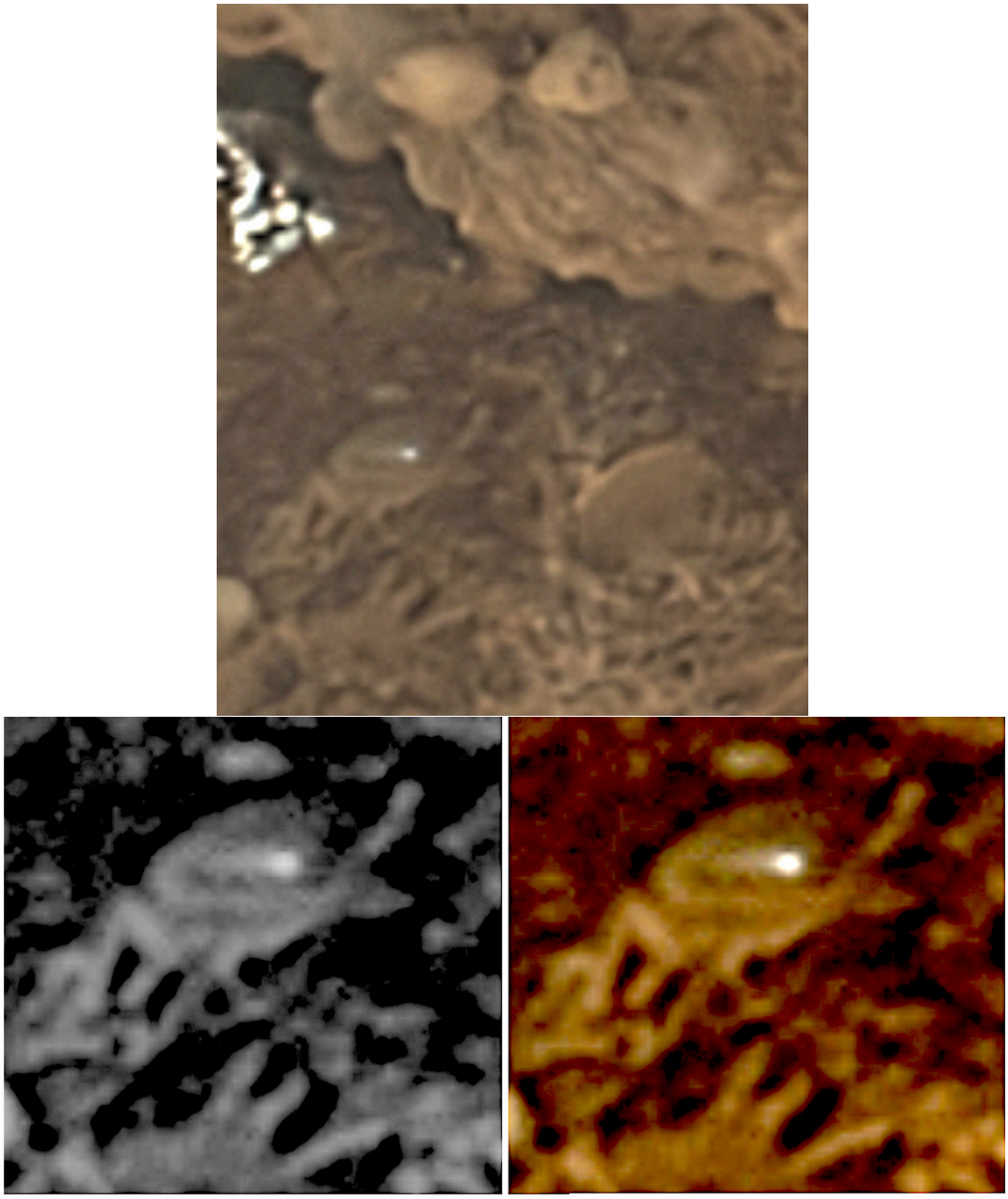


Figure 7. Gale Crater arachnoid / crustacean? 1032MH0001700000400209R00_DXXX

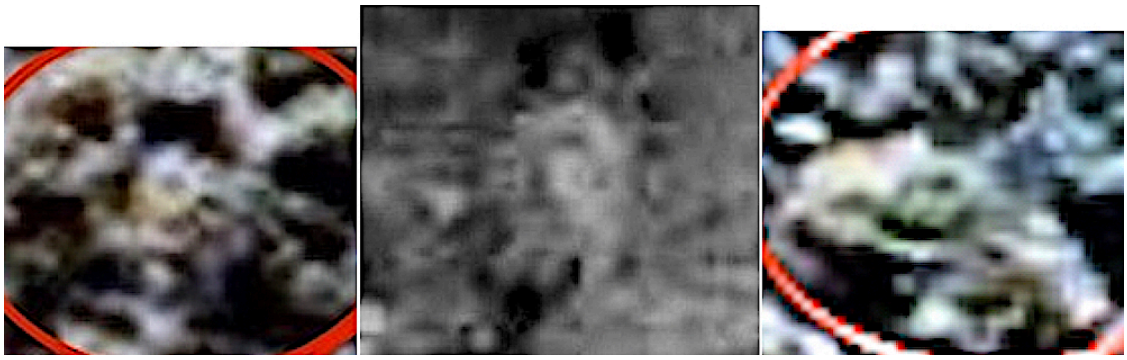


Figure 8. Photographed by the rover Curiosity in Gale Crater. Reproduced from [8].

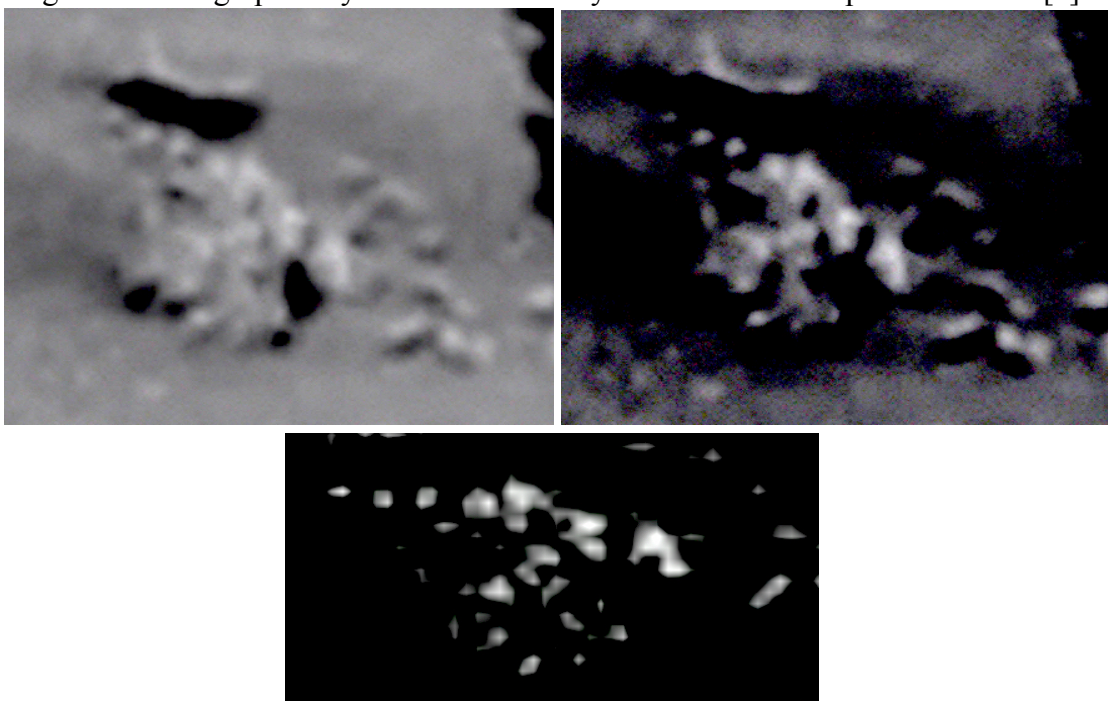


Figure 9. Photographed by the rover Sprit in Gusev Crater. 4822P169153230EFFAAB2P2417L7M1

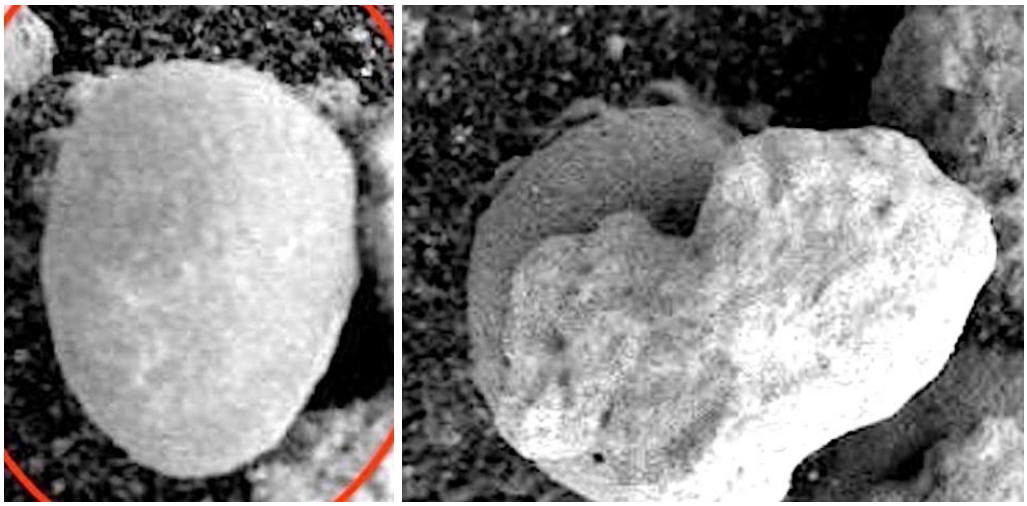


Figure 10. Crustaceans with pleopods? Photographed in Meridiana Planum by the rover Opportunity [29-30]. 1M145850365EFF3505P2977M2M1

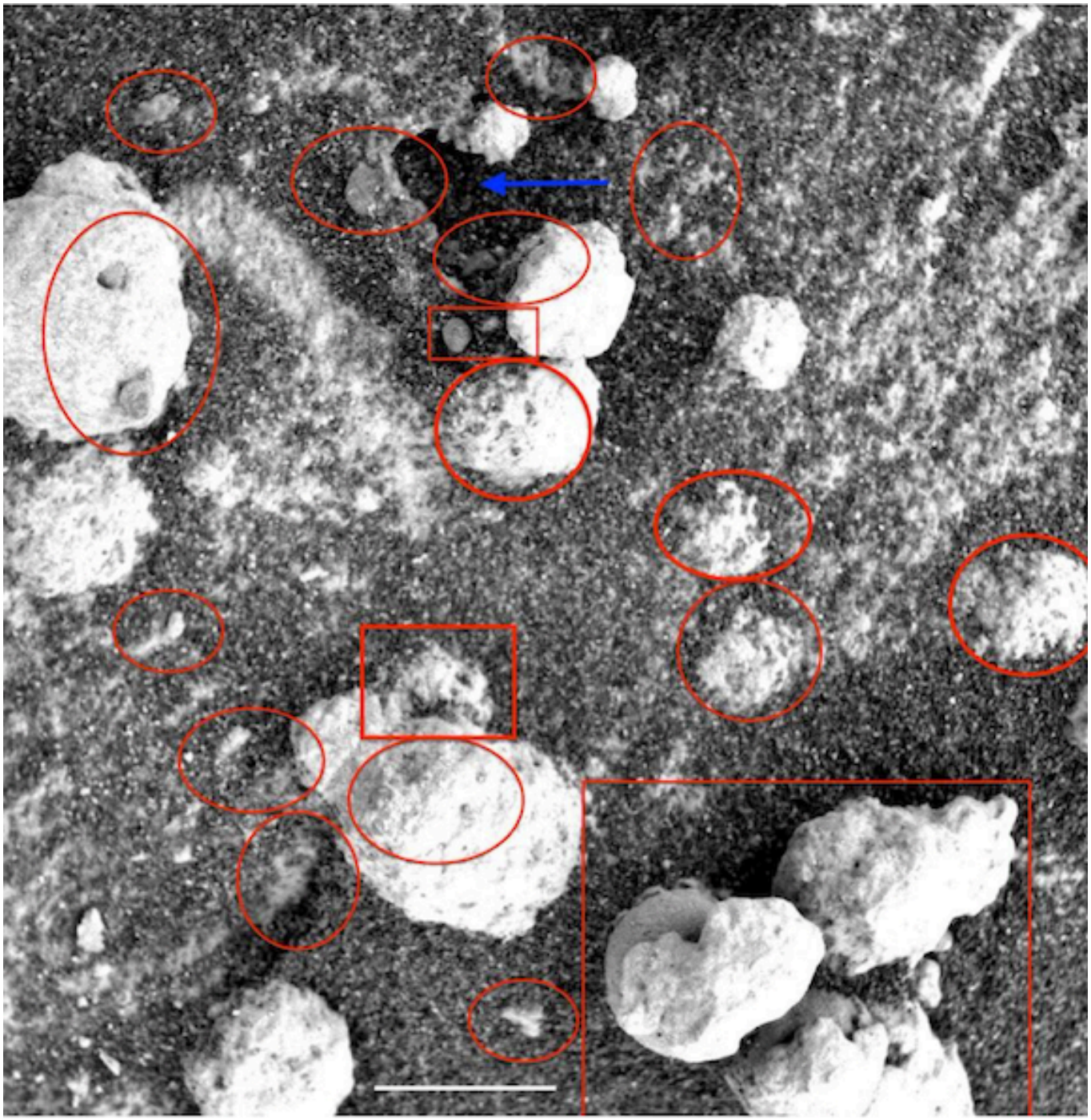
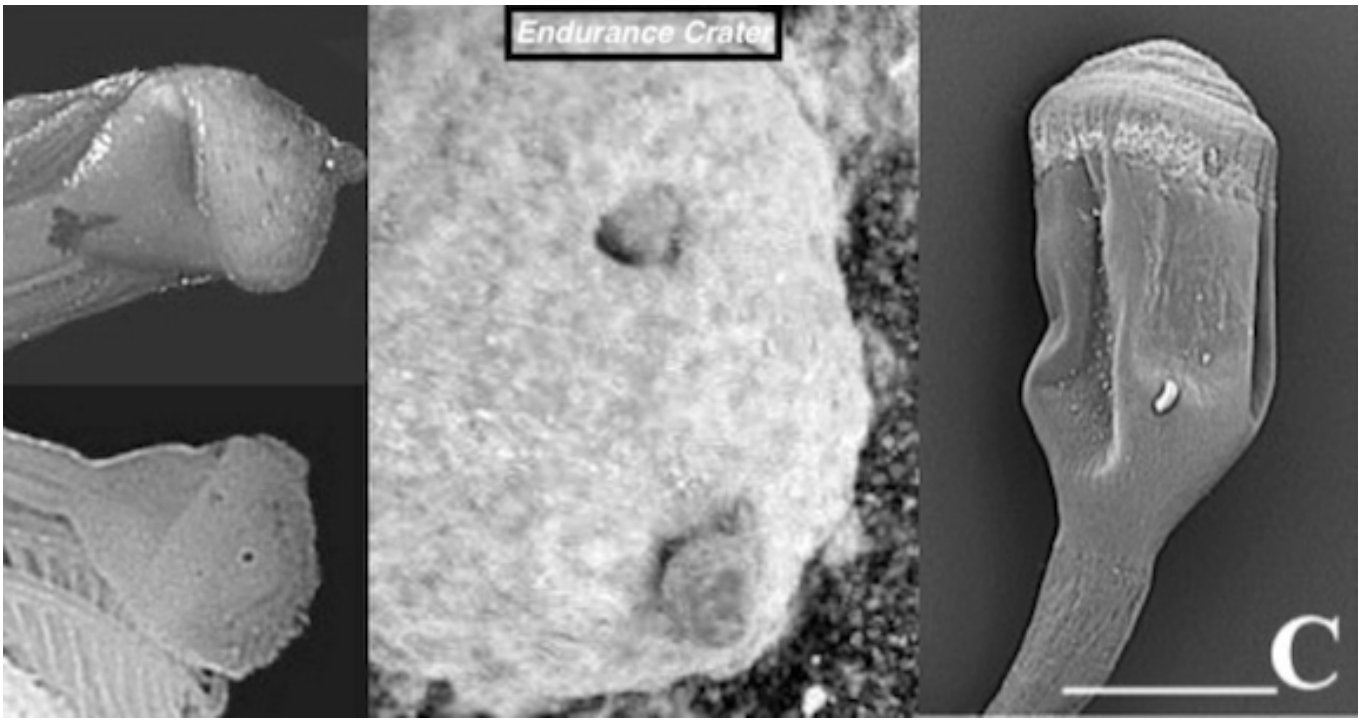


Figure 11. Blue arrow points to a hole/vent. Specimens resembling tube worms and worm tubes upon the surface, and "worms" protruding from small holes in the white matrix which may consist of anhydrite which in turn is associated with the chimneys of active and collapsed hydrothermal vents and their surroundings [29-30]. Note oval specimens in the lower right with what appear to be pleopods. ___ 5 mm



Figures 12. Tube worm operculum and collars (Right/Left) Terrestrial Tube Worms (Annelida, Serpulidae) C. *Pseudochitinopoma amirantensis.* Operculum, —300 μm, (Middle) Mars, Endurance Crater, Tube Worms? Reproduced from [29-30]

Figures 13 Mars, Endurance Crater, Tube Worms? Note operculum and collars. Reproduced from [29-30].

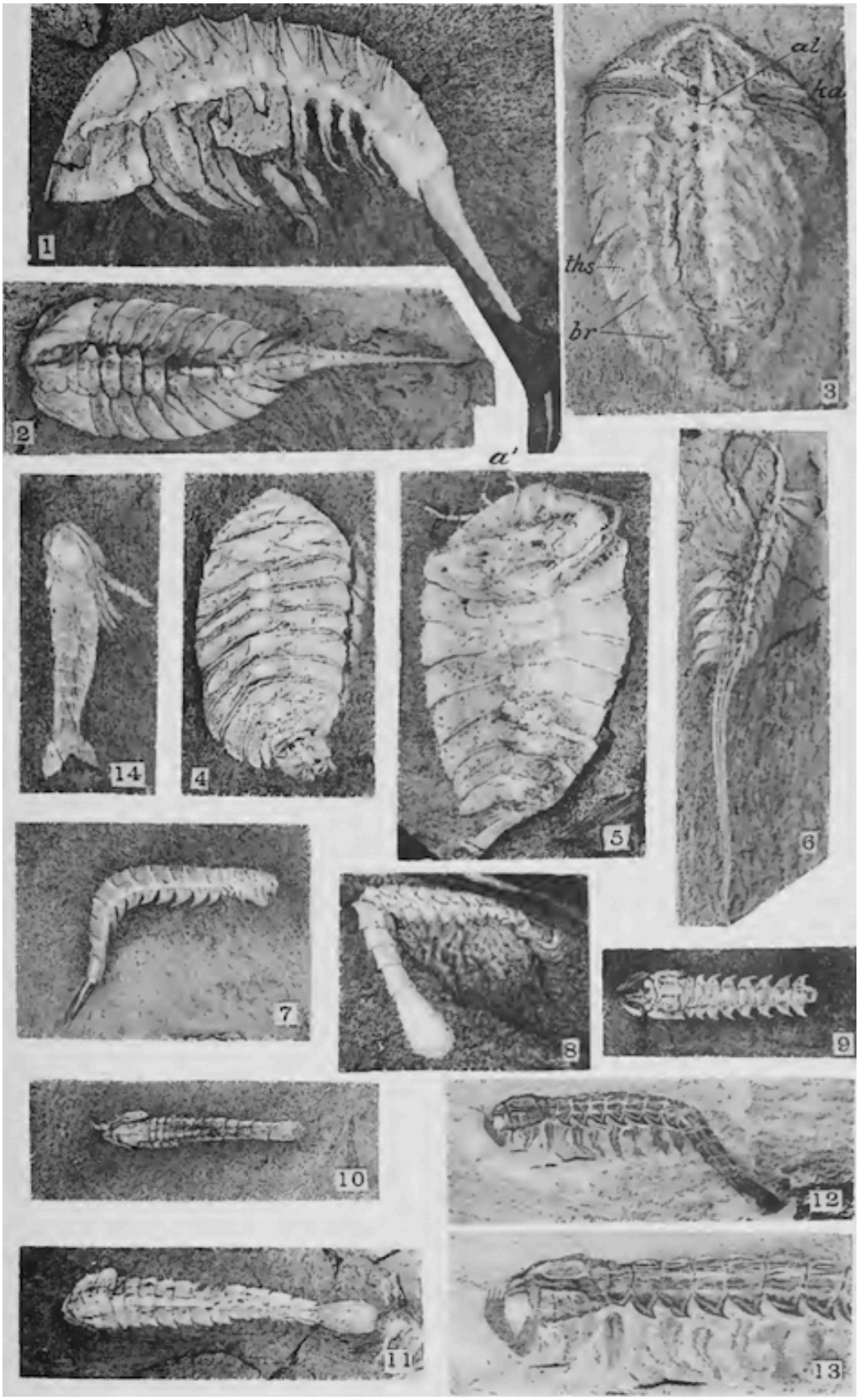


Figure 14. Burgess shale fossils. From C. D. Walcott, Cambrian Geology and Paleontology, 1912, Smithsonian, WDC.

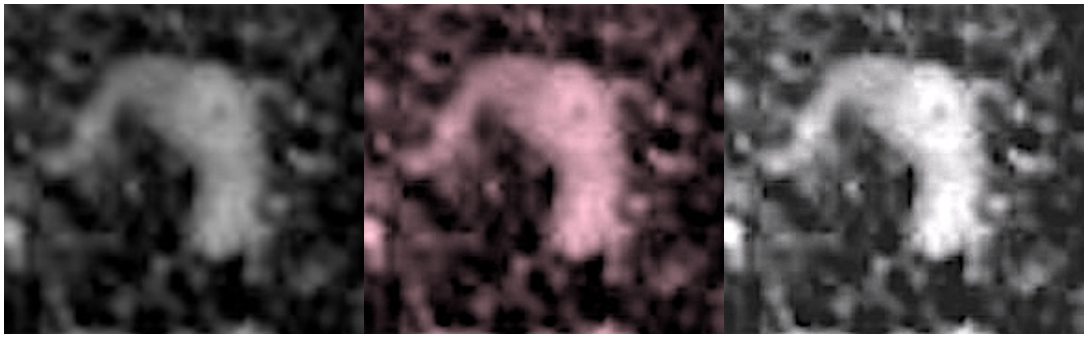


Figure 15. Arthropod? Photographed in Meridiani Planum by the rover Opportunity [29-30]. 1M145850779EFF3505P2977M2M1

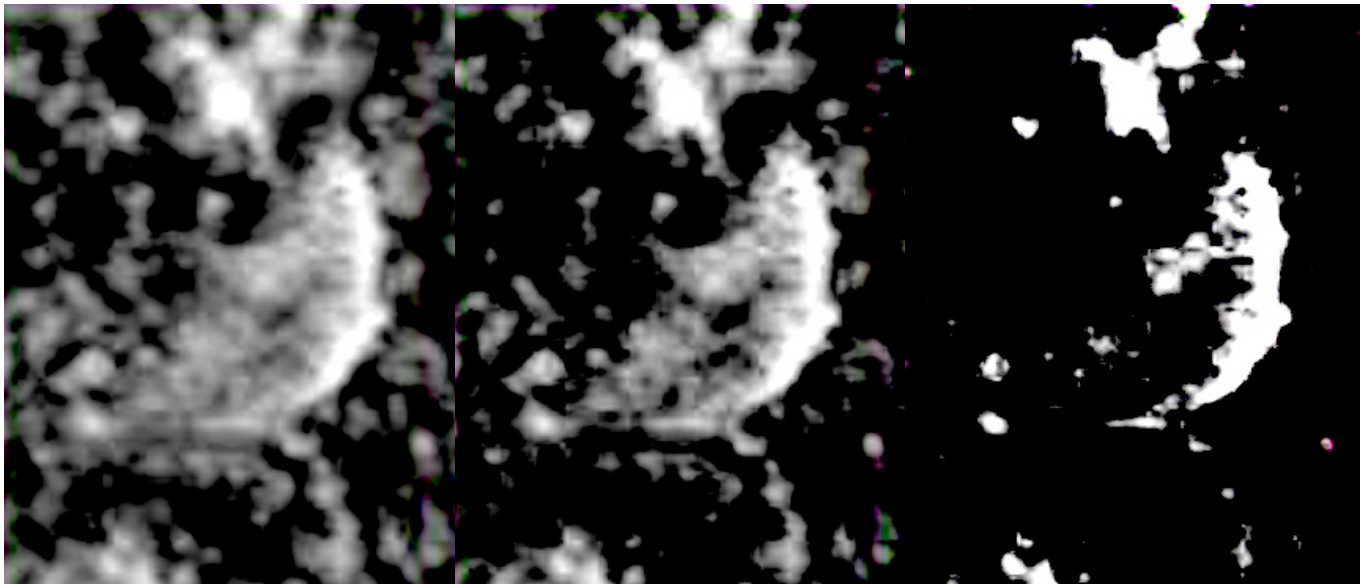


Figure 16. Crustacean / shrimp? Photographed in Meridiani Planum by the rover Opportunity [29-30]. 1M145850365EFF3505P2977M2M1 1M143896318EFF3336P2957M2M1

Figure 17. (Left) Gale Crater. Sol 1921. (Right). Photographed in Meridiani Planum by the rover Opportunity [29-30]. 1M145850153EFF3505P2977M2M1

Figure 18. Sol 753. Fossils and possibly living organisms: crustaceans, sea spiders, scorpions, nematodes, annelids, tube worms, *Kimberlla,* millipedes. 0753MR0032350010403674E01_DXXX

Figures 19. An assemblage of Gale Crater forms resembling millipedes, annelids, and nematodes.

Figures 20. Segmented worm-like tubular forms oriented in different directions including upwards on a mound of soil in Gale Crater. 0302MR0012570170203809E01_DXXX

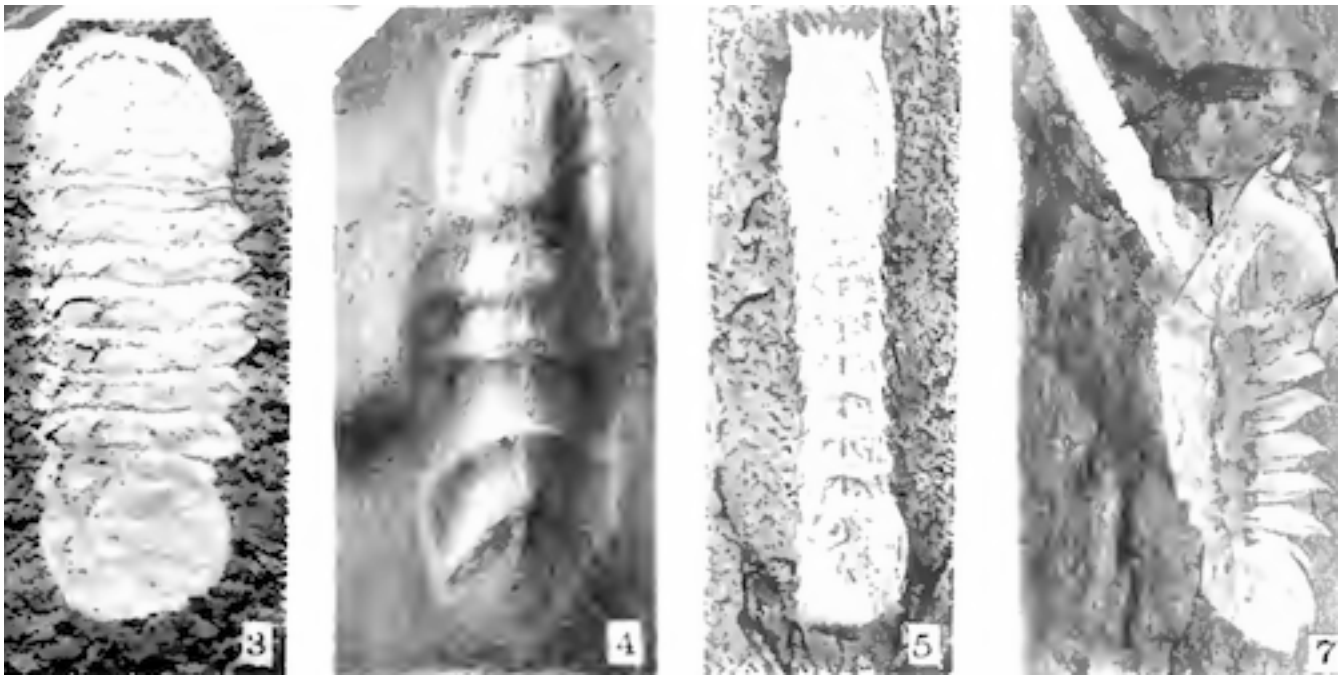
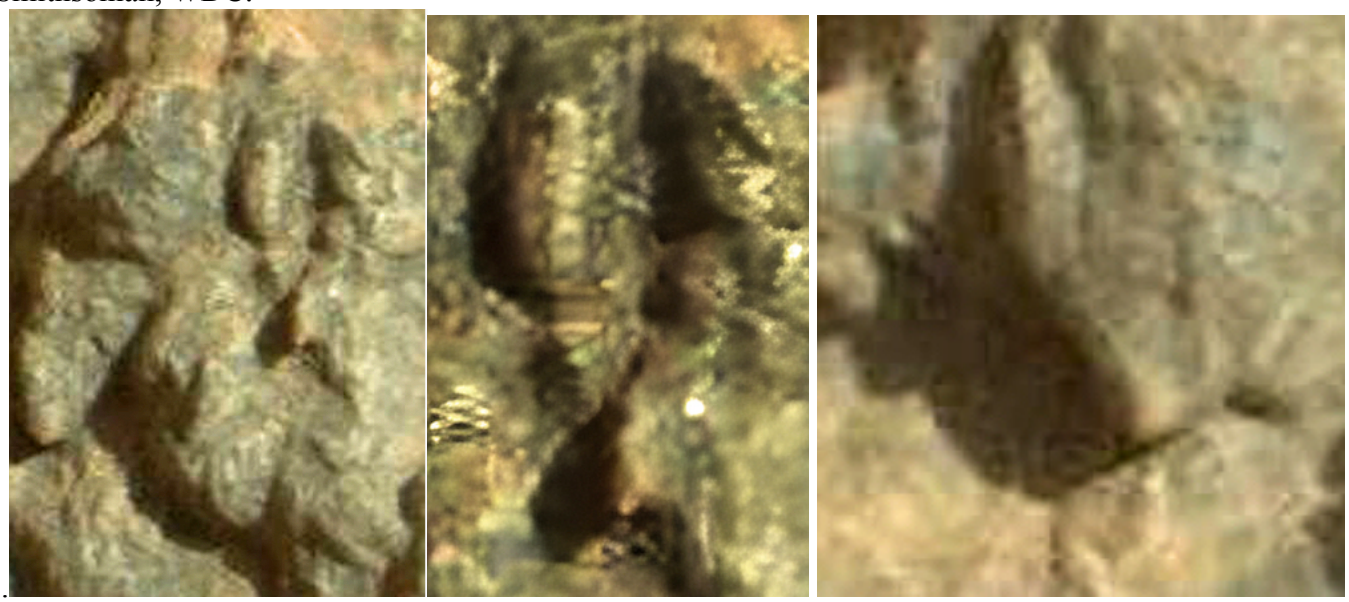
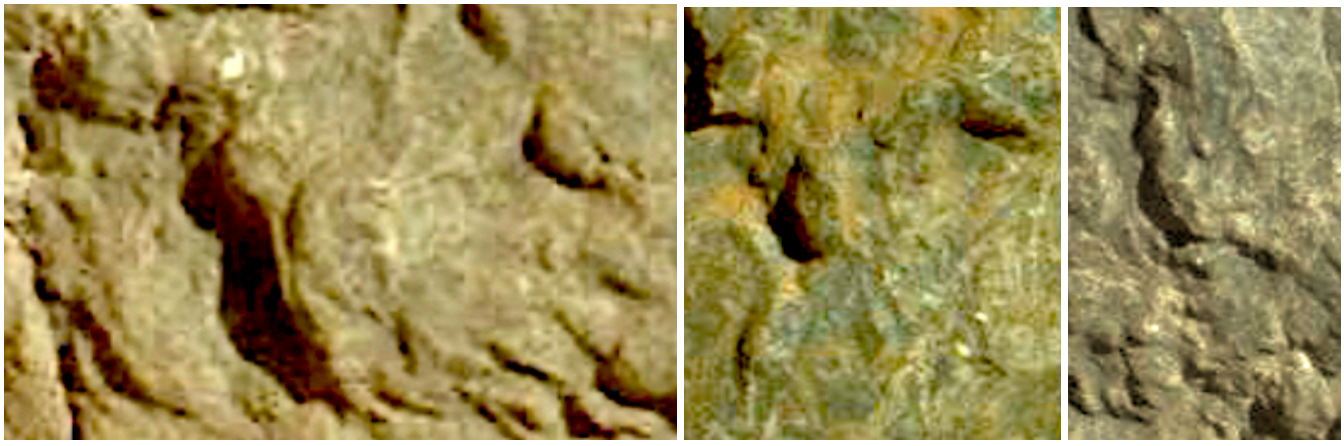


Figure 21. Burgess shale fossils. From C. D. Walcott, Cambrian Geology and Paleontology, 1912, Smithsonian, WDC.

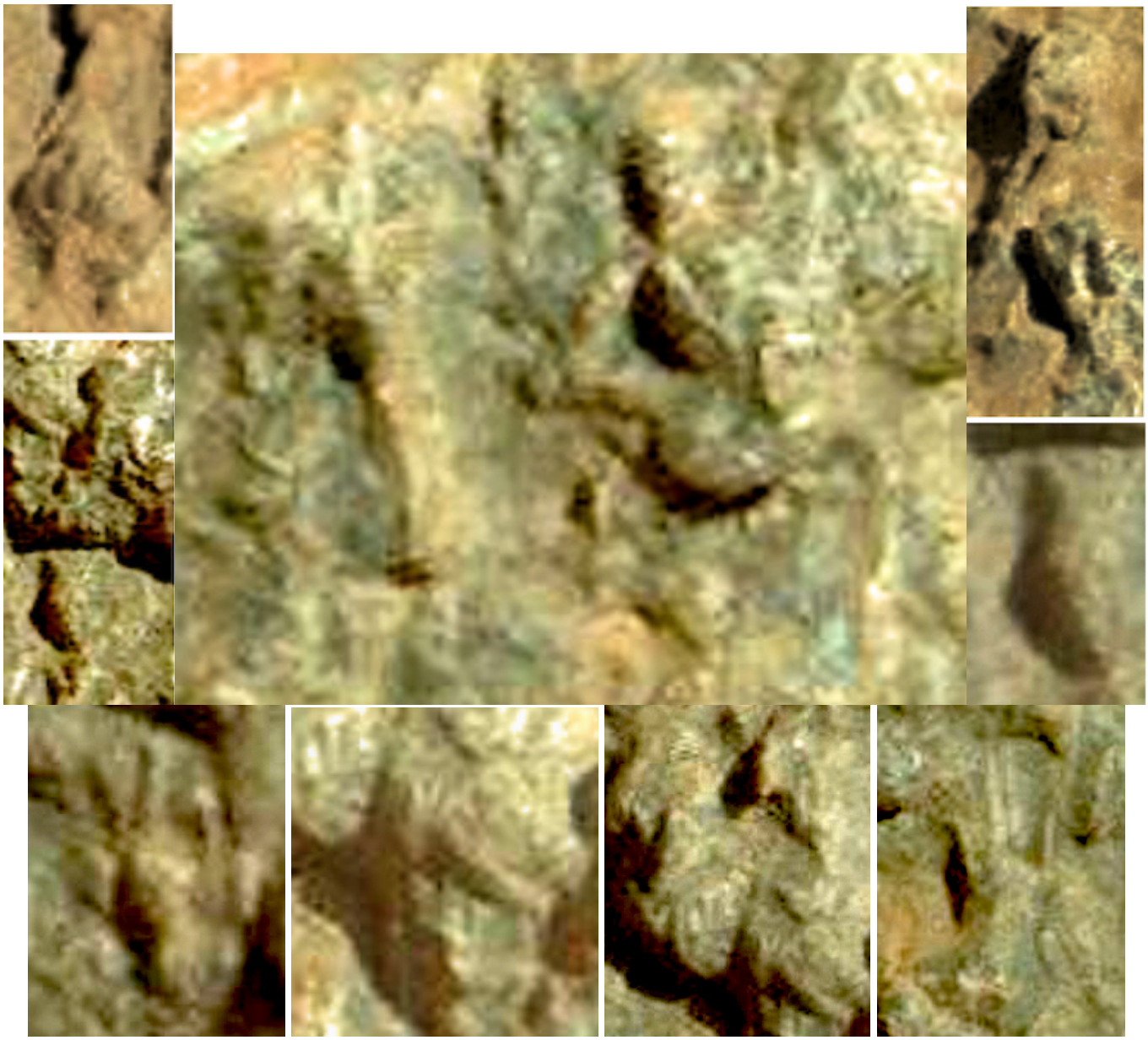


Figures 22. Segmented fossilized worms photographed in Gale Crater. 0553MR0022370010303889E01_DXXX

Figure 23. Sol 553. An assemblage of fossils like forms ranging from 1-5 mm in size: nematodes, annelids, *Kimberlla, Namacalathus, Lophotrochozoa*, millipedes and other marine organisms? Photographed in Gale Crater.



Figures 24. Sol 0553. An assemblage of fossils like forms ranging from 1-5 mm in size: Nematodes, annelids, *Namacalathus, Lophotrochozoa*, millipedes and other marine organisms? Photographed in Gale Crater.



Figures 25. Sol 0553. An assemblage of fossils like forms ranging from 1-5 mm in size: Scorpions, nematodes, annelids, *Kimberlla, etc.* Photographed in Gale Crater

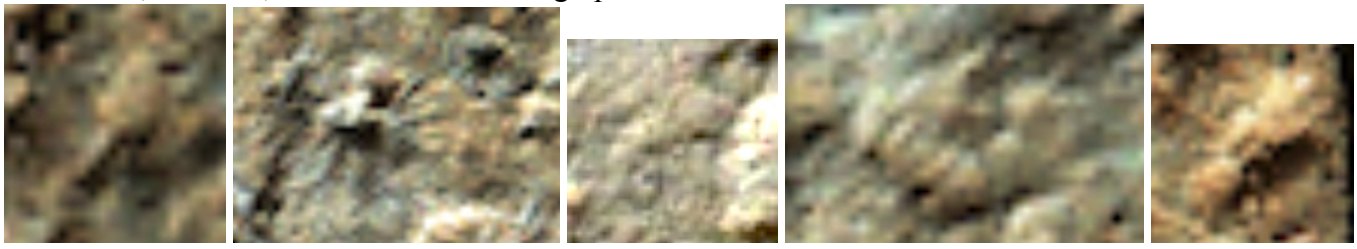


Figure 26. Sol 0905. An assemblage of fossils like forms ranging from 1-5 mm in size. Photographed in Gale Crater

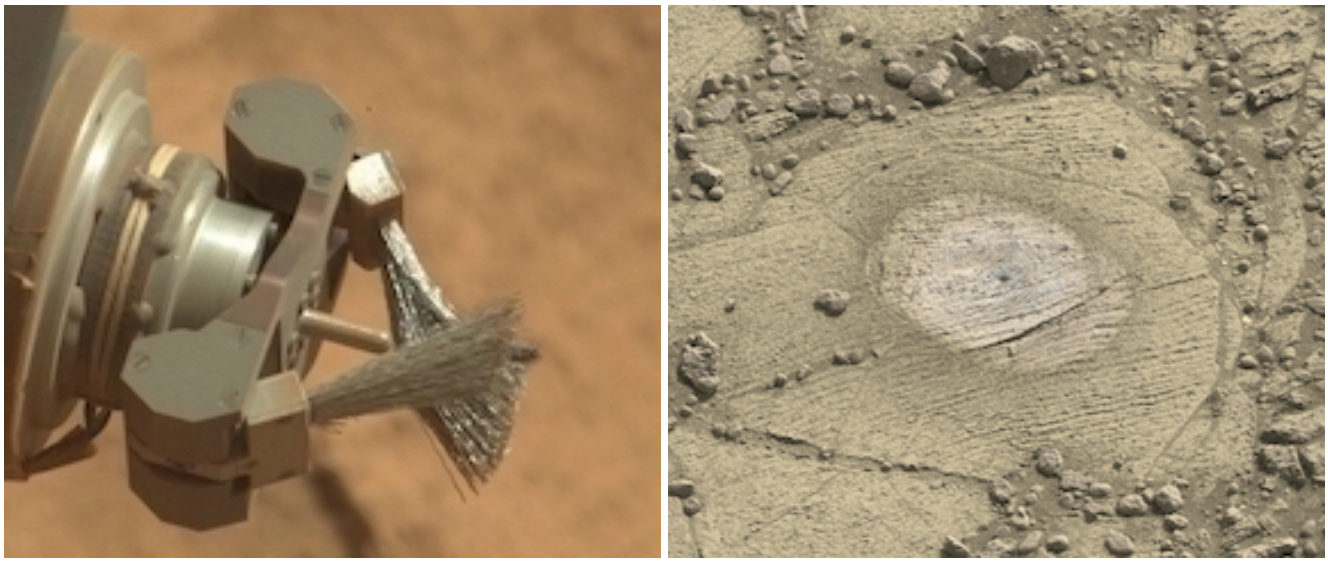


Figure 27. (Left) The rover Curiosity Brush instrument. (Right). Approximately 15 cm section of the floor of Gale Crater, after dust, dirt, and organic debris had been swept away. The green color was not added and the photo was not tinted but was embedded in the color spectrum of the original NASA photo was filtered and saturated. The green may be representative of green algae or cyanobacteria (blue-green algae). Note extensive water pathways. 0905MH0001930000302862R00_DXXX

Figure28. (Top) Photographed in Gale Crater, on Sol 905. (Bottom) Fossil trilobites.

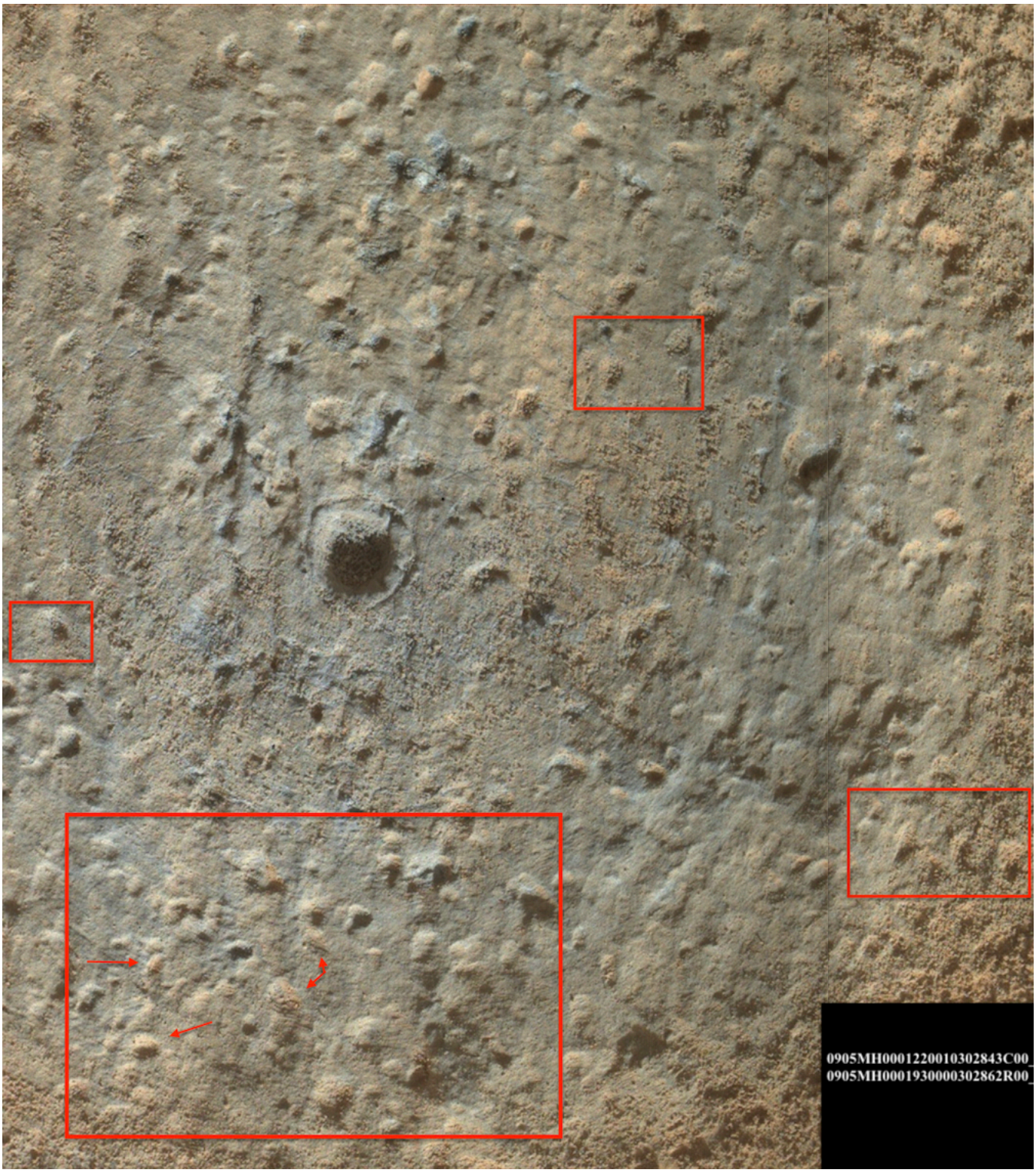
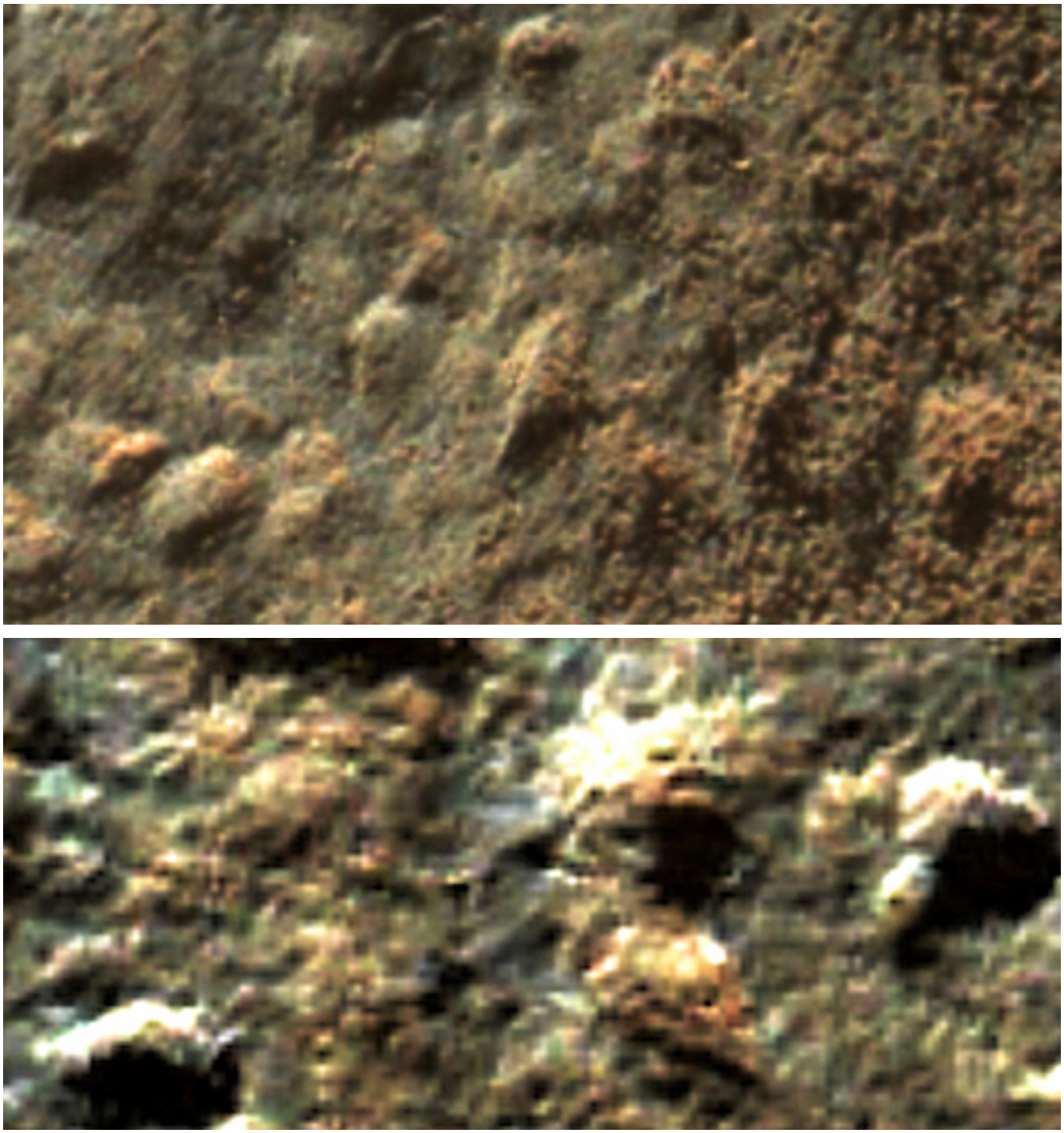


Figure 29. Sol 0905. An assemblage of fossil-like forms uncovered by the brush instrument employed by NASA's rover Curiosity. Specimens in red boxes include those that have triple (tri) body parts that appear to be armored and could be likened to a Martian arthropods that resemble trilobites.



Figures 30. 0905MH00019300003028 62R00_DXXX. Note numerous fossil-like forms including those with multiple legs and appendages including a sea spider / crustacean upper left bottom figure). Two, possibly three specimens resembling trilobite arthropods can be observed in total.

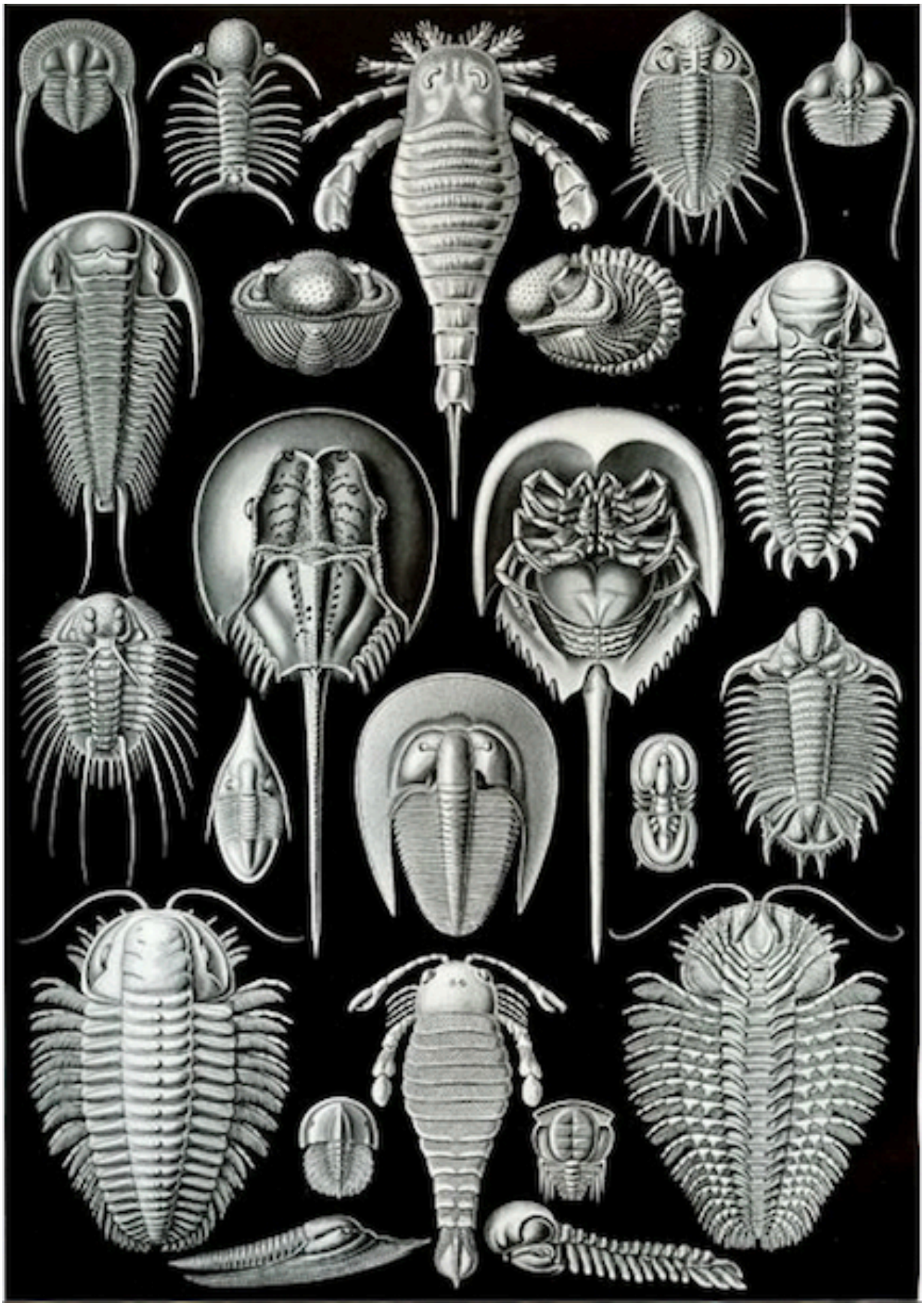


Figure 31. Trilobites. Drawings by Ernst Haeckel, from Kunstformen der Natur (1904).

Figure 32. 0905MH0001930000302862R00_DXXX. Note numerous fossil-like forms including two, specimens resembling armored trilobites / arthropods.

Figure 33. 0905MH0001930000302862R00_DXXX. A portion of the floor of Gale Crater, after debris had been swept away (right side). Note numerous fossil-like forms. The green embedded in the original NASA photo may be indicative of green algae or cyanobacteria (blue-green algae). Note the three thin soil layers: the upper most layer to the left, a lower layer in the middle, and the lowest layer to the right. Each revealed "layer" reveals masses of organisms buried and embedded in organic detritus.

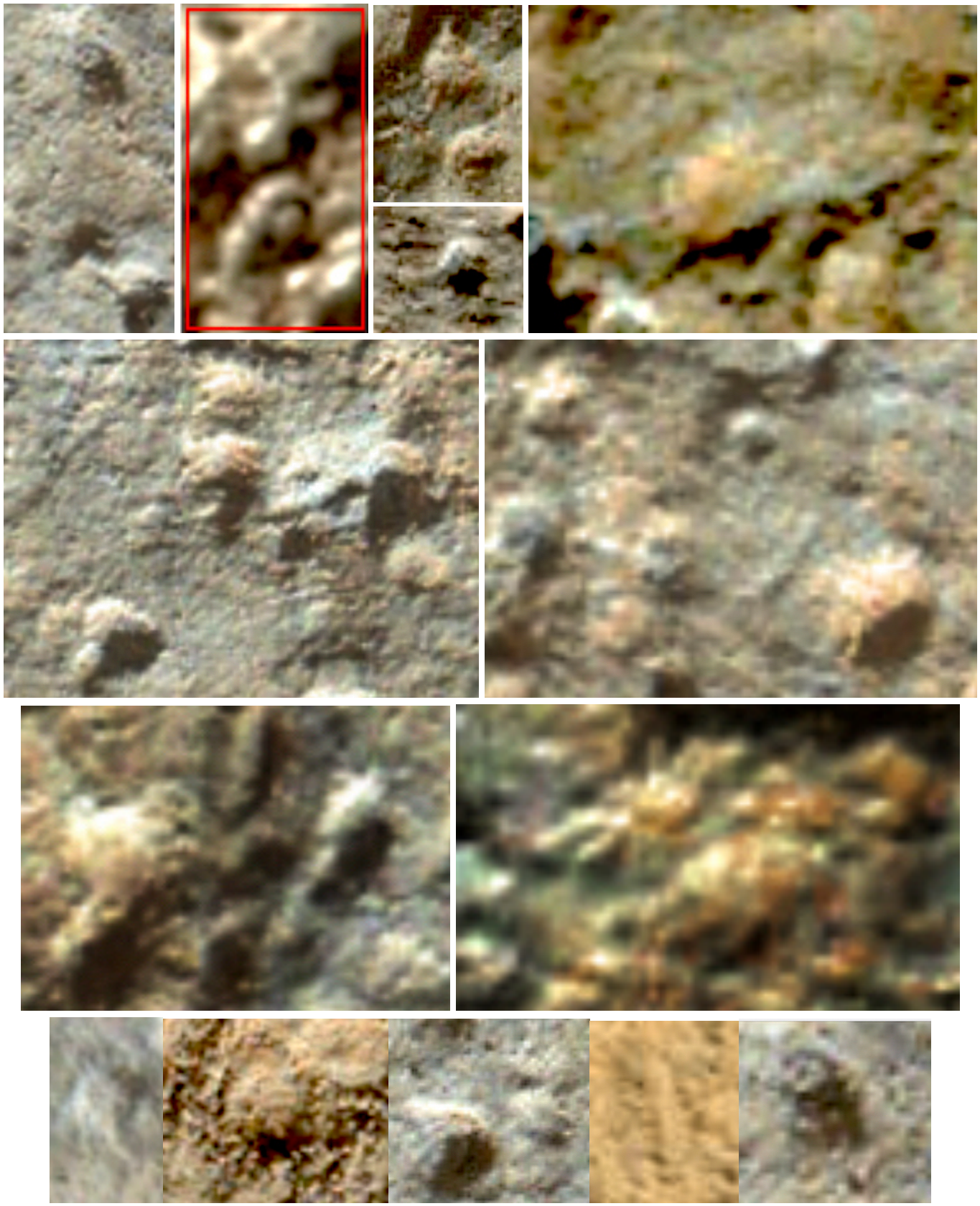


Figure 34. Sol 905. Sea spiders, crustaceans, scorpions, snails, shelly forms, etc. Reproduced from [8].

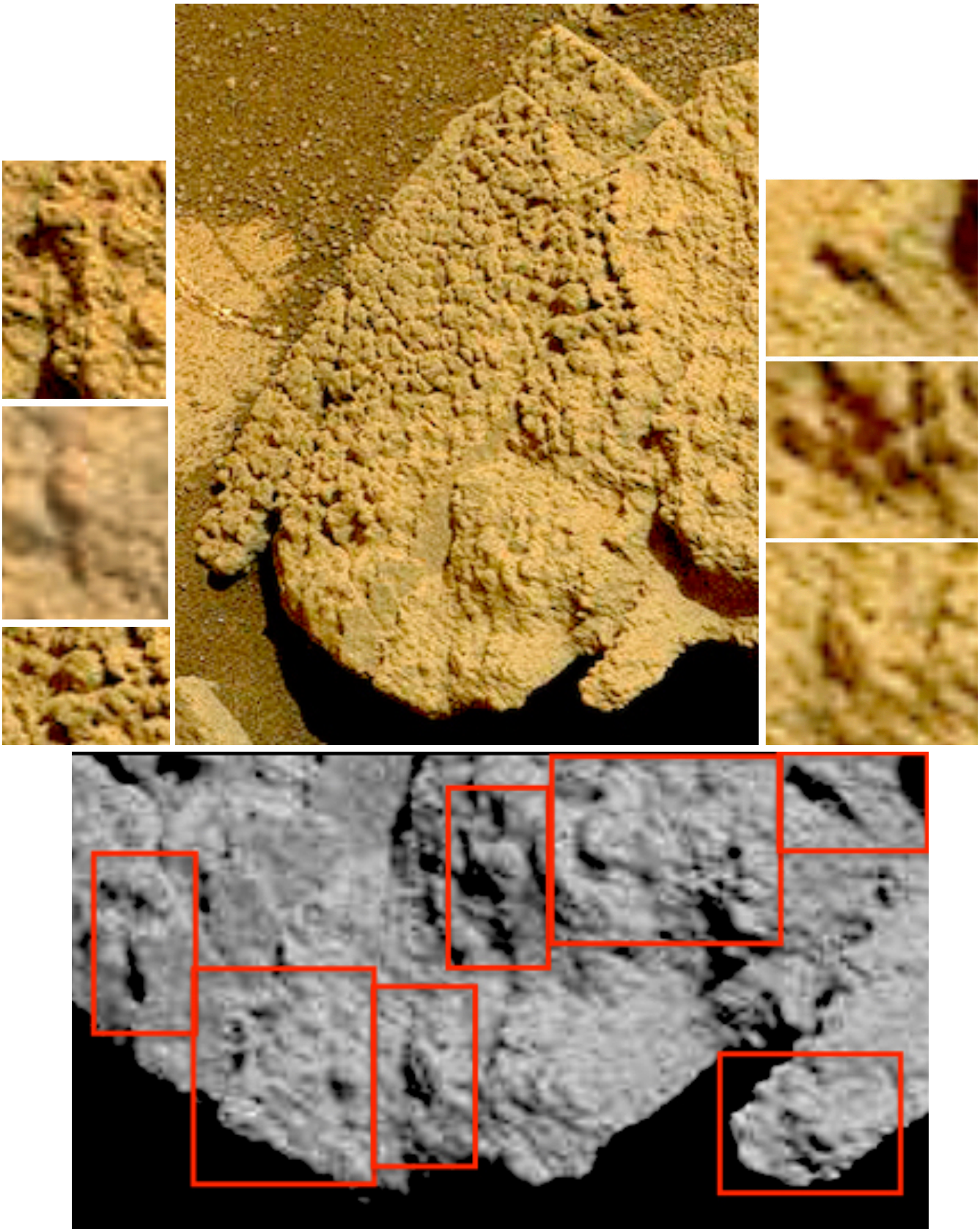


Figure 35. An assembly of fossil-like forms. Gale Crater. 0781MR0034100010404109E01_DXXX-1

Figure 36. Sol 809. An assemblage of fossil-like forms that resemble segmented worms, and several "*Kimberella,*" and "ice-cream-cone-shaped" specimens (809MH0001710000300846R00_DXXX)

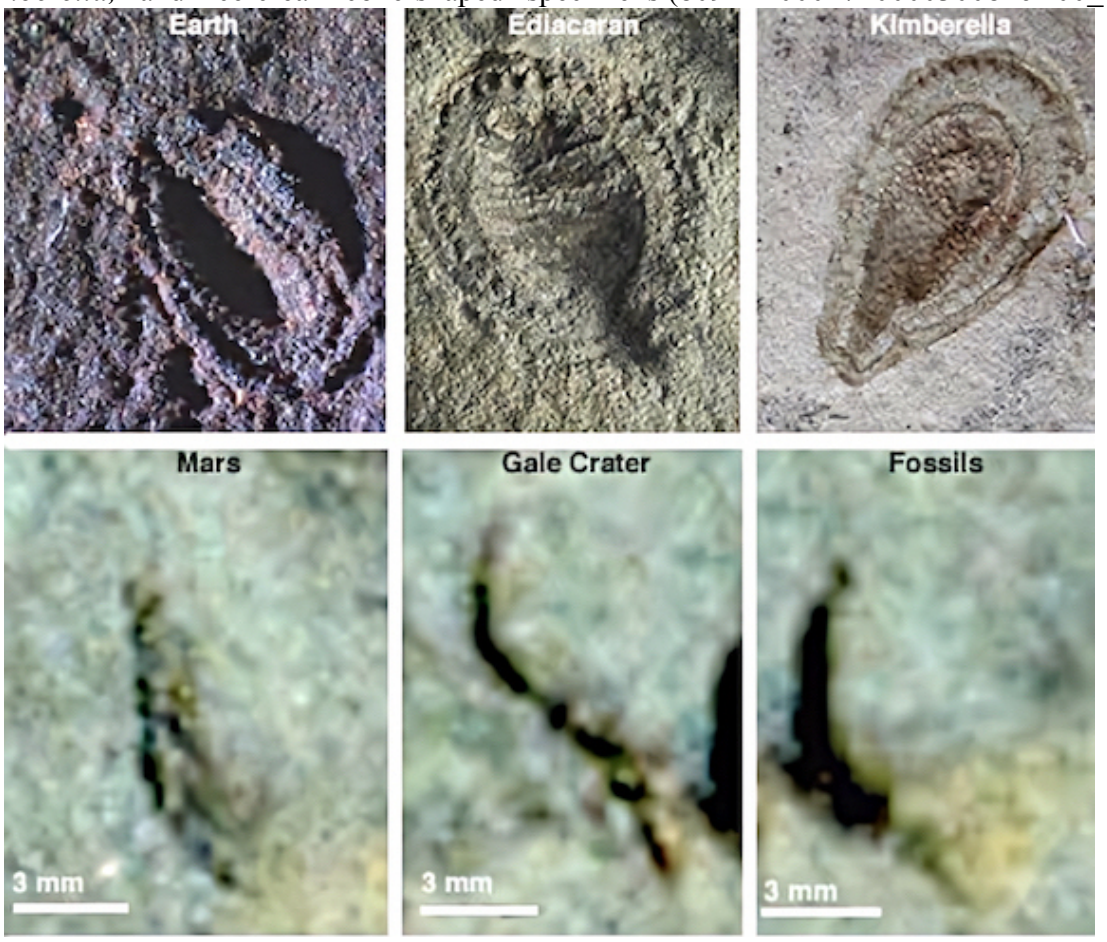


Figure 37. Sol 809. "*Kimberella,*" from Earth and Mars

Figures 38. An assemblage of fossil-like forms that resemble nematodes, “shelly” organisms, "*Kimberella,*" *Namacalathus, Lophotrochozoa,* and other marine species. Sol. 0880MH0004620000302350R00_DXXX

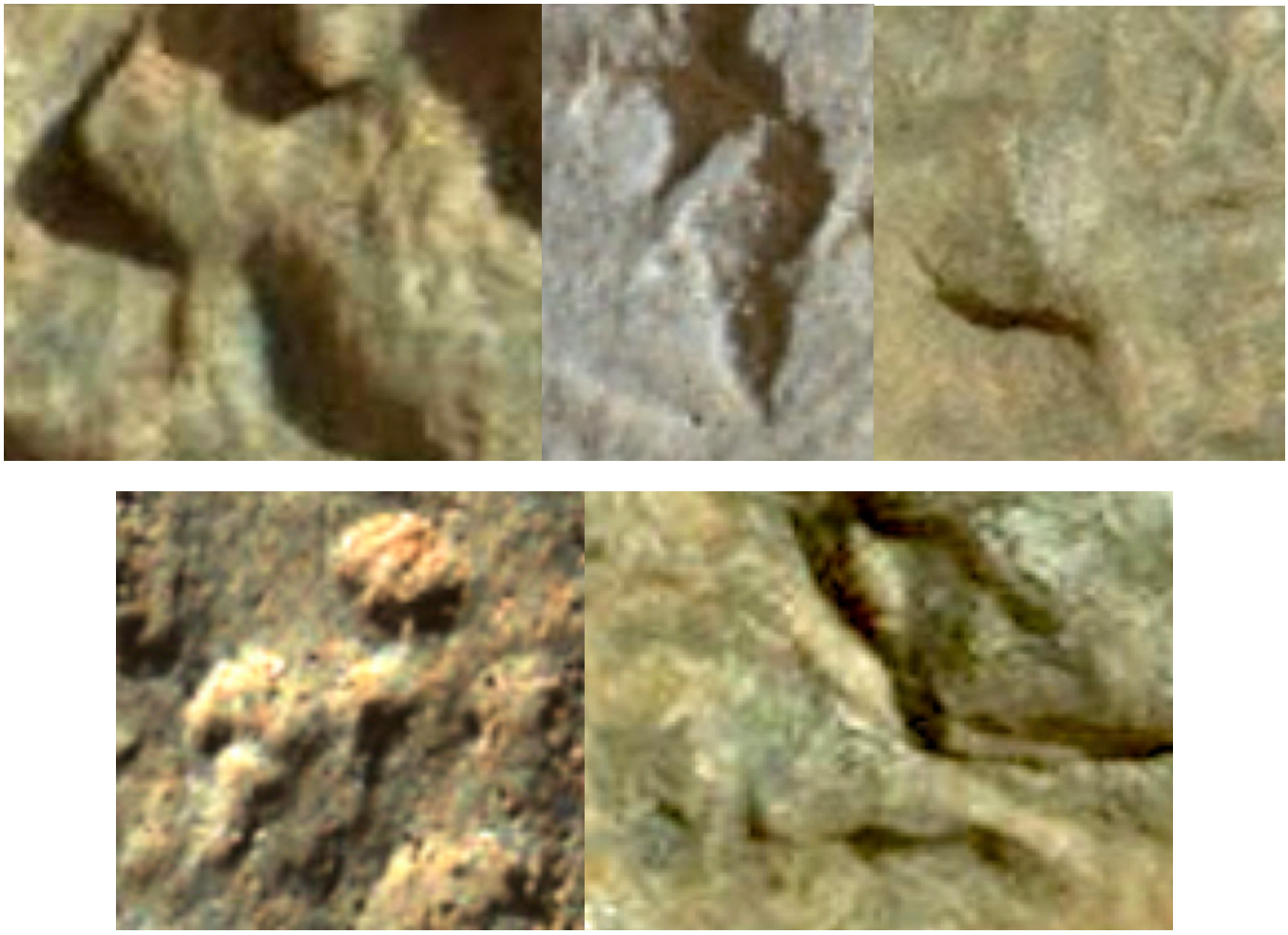
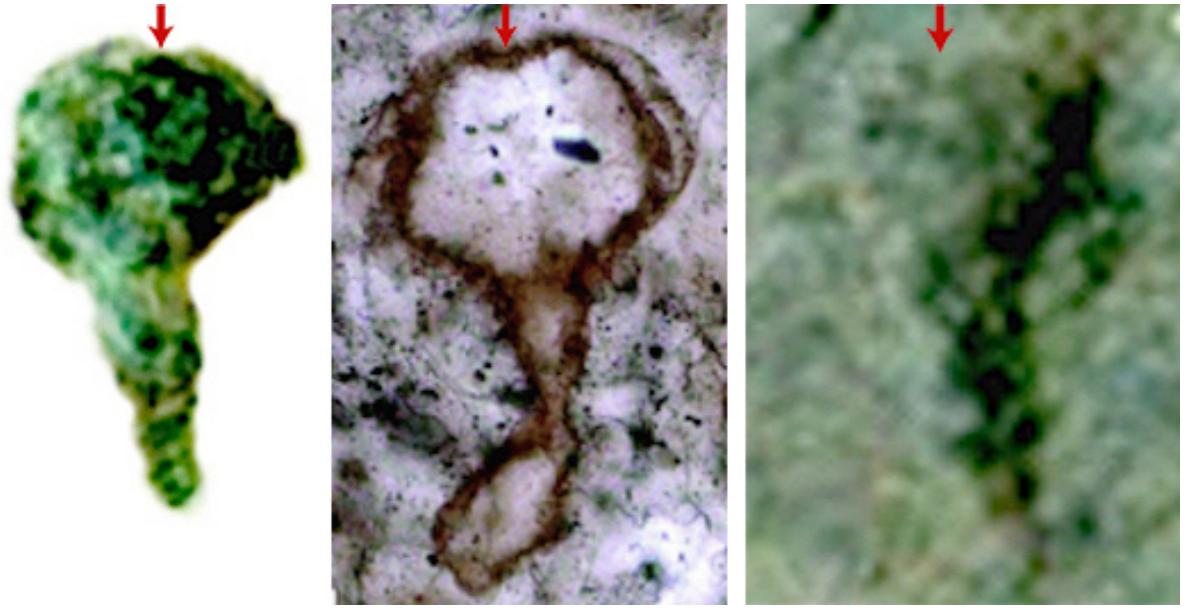
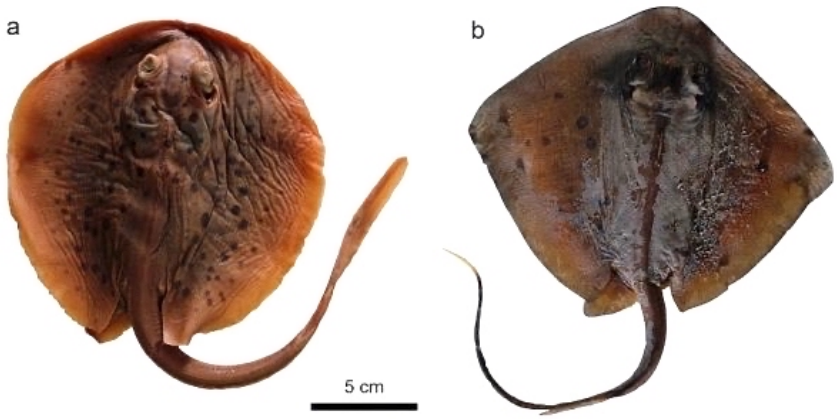


Figure 39. Sol 0552. *Namacalathus, Lophotrochozoa,* and other organisms. Gale Crater.



Figures 40. (**Mars left**): Gale Crater. Sol 809. (**Earth center**): *Namacalathus*. (**Mars right**): Gale Crater Sol 869. Arrows indicate open apertures for filter feeding.

Figures 41. Sol 880. Gale Crater, An assemblage of fossil-like structures one of which resemble an elasmobranch, but could be one organism atop another. 0880MH0004620000302350R00_DXXX



Figures 42. a) Taeniura lymma; b) Neotrygon sp. From a collection at the Institute of Paleontology of the University of Vienna. CREDIT: Giuseppe Marramà

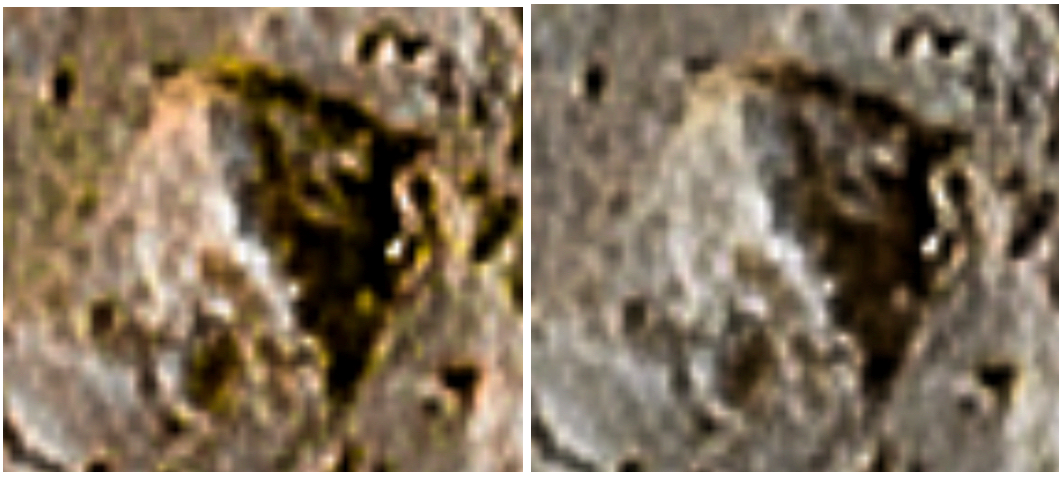


Figure 43. Sol 0880. Gale Crater specimen that may represent an elasmobranch with tail, or two different organisms, one on top of the other.

Figure 44. 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 chitlin and/or the upper layers of cuticle. Photographed in Gale Crater.

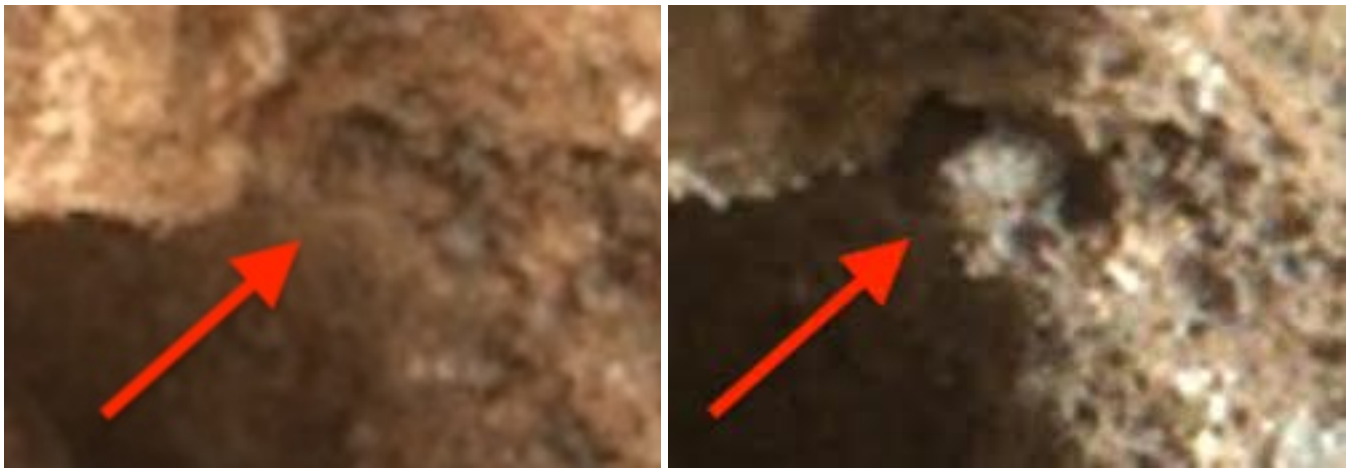


Figure 45: Mars. Gale Crater **Left/Sol 888:** The hole is occluded by something within the hole. **Right/Sol 889:** The following day (one day later) a life-like specimen appears on the ledge in front of the hole that is no longer occluded and is empty. To speculate: the specimen is live and had been occluding the entrance to the hole and then emerged, via what could be interpreted as pleopods and pareiopods, and leaving an empty hole behind it.

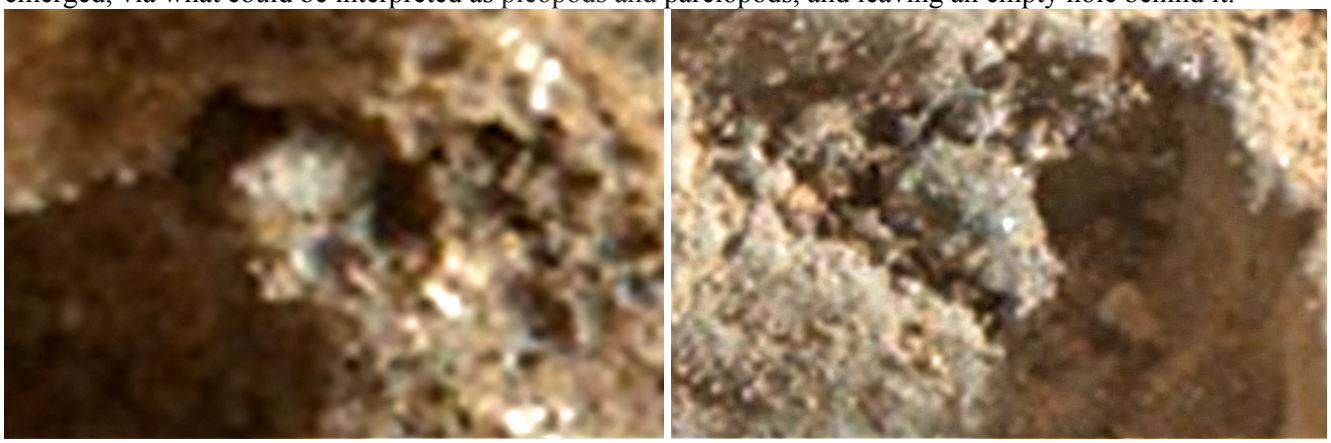


Figure 46: Mars. Gale Crater (Sol 889): Two spheroidal specimens in rock crevices with what could be pleopod and pareiopod appendages and two forward facing orifices that could be interpreted as "eyes." If these are living organisms or anomalous life-like mineral-soil concretions is unknown (0889MH0002270000302739R00_DXXX).

II. DISCUSSION

2. Martian Arthropods

In recent reports a vast assemblage of fossil like specimens have been identified not just in Gale Crater but other areas of Mars, including forms resembling fossilized metazoan invertebrates that first evolved during the Cambrian Eras on Earth [1-8, 28-30, 33-35]. It has been proposed that Gale Crater represents a veritable "Burgess Shale" and that Mars experienced a Cambrian Explosion of life [7] followed by a mass extinction [8]. In support of that theory, presented here are specimens that resemble the fossilized remains of arthropods, trilobites, arachnida, shrimp, crabs, sea spiders, scorpions, arachnids, millipedes, centipedes, nematodes, annelids, *namacalathus, lophotrochozoa, Kimberella,* sea snakes, and numerous other putative Martian metazoans similar in morphology to those that evolved, on Earth, during the Ediacaran and Cambrian epochs on Earth.

These fossil-like forms were photographed in Meridiani Planum and Gale Crater. Although many are obvious and recognizable, not all arthropod-like specimens are easily identified due to photo quality and as there are no obvious terrestrial analogs. Those who have studied the Burgess shale have met with the same problem: although recognized as arthropods, many specimens, despite being well preserved, could not be identified or assigned to any of the well-known groups [31-32]. Moreover, those Cambrian era fauna that were the most alien in appearance quickly became extinct [31].

Not only are many of the Burgess shale forms alien and bizarre, but the ancestry even of those easily recognized is controversial and unresolved. One group of scientists have proposed that arthropods are polyphyletic and do not share a common ancestor but that trilobites and the three groups of "arthropods" (Crustacea: shrimp, crabs; Chelicerata: sea spiders, arachnids; Myriapoda: millipedes, centipedes) evolved separately from different early Cambrian and Ediacaran and pre-Ediacaran fauna; and are similar only because of "convergent evolution." Yet other groups of scientists argue that arthropods are monophyletic and share a common ancestor. Obviously, it would be impossible, at this juncture, to determine the evolutionary heritage and ancestry of the Martian specimens presented in this report other than to note a life-like appearance and morphological similarities to their putative counterparts on Earth.

Several of the fossils forms presented resemble armored trilobites. The trilobites of Earth date from the early Cambrian era but became extinct at the end of the Permian era 250 million years ago [31-32, 36-40]. They are quite variable in appearance and size and are believed to consist of over 20,000 different species including filter feeders, scavengers, and predators which colonized a variety of niches including on land [37, 39-40]. Typically they are heavily armored, posses numerous pleopods, have large heads equipped with eyes, snout and mouth, and are believed to shed their armor as they grow. Many have tails and many do not. Primarily they are marine organisms and their fossil remains have been found throughout the world in association with fossilized brachiopods, crinoids, and corals [36-40].

Many of the substrates on which Martian fossils have been observed resemble corals colonized by a wide variety of organisms--which is typical of the corals of Earth. Great coral reefs have been tentatively identified in the dried oceans beds of Mars [2]. In addition, trace fossils of rock-boring marine organisms (mollusks, bivalves) have been photographed in Jezero Crater, Utopia Planitia and Chryse Planitia [23,33]. Specimens similar to crustaceans equipped with pleopods (for movement and scavenging) have also been photographed in the dried lake beds of Endeavor Crater adjacent to fossilized forms similar to tube worms and worm tubes and next to holes and a surface that has the chemistry and mineralogy of and may have served as hydrothermal vents [5, 28-30]. Putative Martian corals, trace fossils of what may be mollusks and bivalves that flourished along the shores of the sea, tube worms, and a vast assemblage of fossil-like marine-dwelling arthropods [2, 28-30, 33-35] are mutually supportive evidence favoring the theory that life flourished in the oceans, lakes and seas of Mars.

3. Oceans of Mars: Arthropod Habitats

The putative arthropods presented in this report flourished in the sea and have been found in association with fossil-like forms resembling crinoids, corals, and more complex organisms similar to shrimp, sea spiders, scorpions, arachnids, nematodes, annelids, tube worms, sea snakes, and millipedes. Similar discoveries have been previously reported [2-8].

The emerging consensus is that Mars has been repeatedly flooded with oceans of water, a consequence of the planet's extreme chaotic obliquity (axial tilting) that wanes and waxes up to and beyond 80◦ thereby increasing global temperatures and atmospheric pressures that cause the melting of the polar ice caps, permafrost, and surface and subsurface glaciers. In consequence titanic volumes of flood water sweep across the surface creating oceans, lakes, rivers, and inland seas that stabilized and have endured for hundreds of thousands and millions of years, only to recede, seep beneath the soil, and freeze forming surface and subsurface glaciers and the polar ice caps when obliquity declined below a critical tipping point [2, 41-44]. The last period of extreme axial obliquity may have came to a close 400,000 to 110,000 years ago [42-43]; and causing the oceans, lakes and inland seas of Mars to rapidly recede and refreeze and leaving in their wake evidence of microbialites, stromatolites, and fossilized algae, acritarchs, foraminifera, sponges, tube worms, crustaceans, reef-building corals, bivalves, and those resembling Cambrian Era metazoan invertebrates [2-8, 18-19, 23, 28-35] as reported here.

III. CONCLUSIONS

A vast array of fossil-like forms have been discovered in Gale Crater and other areas of Mars that likely repeatedly hosted rivers, lakes, and inland seas during periods of high obliquity which caused temperature and atmospheric pressure to rise and resulting in floods of meltwater. Because of increased atmospheric pressure the resulting lakes, rivers and oceans remained stable and endured for perhaps tens of millions of years before receding and freezing in parallel with the waning of obliquity that may also have had an impact on the magnetosphere of Mars. A mass extinction was the consequence and numerous species died and some became fossilized [8]. As reported here, these putative fossils include those that resemble shrimp, crustaceans, scorpions, sea spiders, arachnids, millipedes, nematodes, annelids, trilobites and sea snakes.

All these specimens were photographed among a vast array that resemble a variety of marine metazoan invertebrates of different sizes and that are oriented in a variety of directions and clearly distinct and of a different composition than the underlying substrate. The lack of any patterns indicative of weathering and erosion is also consistent with a biological explanation. Without extraction and direct examination, however, it is impossible to precisely determine the identity of many of the specimens so far discovered [2, 7-8]. Nevertheless, because these organisms evolved and adapted to the unique environment of Mars they should not be expected to be identical to their "cousins" on Earth.

Admittedly, the interpretations presented here are based purely on morphology and not all specimens are easily identifiable. Likewise those who have studied the Burgess shale have been unable to identify or assign to any known groups many of the fossils discovered despite being well preserved [31-32]. Many of these Cambrian organisms were extremely bizarre in appearance and quickly became extinct leaving no descendants and are devoid of modern analogs. However, just as Burgess Shale fossils are surrounded by the remains of other marine organisms that could be easily identified, many of the fossil-like Martian specimens are also similar to life that flourished during the Cambrian Era when trilobites and other arthropods are believed to have first evolved.

In conclusion, coupled with the evidence so far published [2-8, 18-19, 23, 28-30, 33-35] the numerous fossils of what clearly resemble a diverse and wide variety of marine fauna supports the theory that metazoan arthropods long ago evolved in the lakes, oceans and inland seas of Mars.

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