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Arthropods on Mars: Fossil Evidence of Life

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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 Meridiani Planum both of which have hosted rivers, lakes, and inland seas. Similar specimens are mixed within a variety of divergent fossillike 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.

Keywords: Metazoans, Cambrian Explosion, Ediacaran, Fossils, Algae, Evolution, Trilobites

INTRODUCTION

Arthropods on Mars?

The ancient lake beds of Gale Crater, which has likely repeatedly hosted lakes, rivers and a vast inland sea, 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. 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. For comparative purposes photographs of fossilized Cambrian Era fauna discovered in the Burgess Shale are provided [1].

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 including arachnida and crustaceans and which have also been photographed in Gusev Crater and Meridiani Planum (respectively) as presented here (Figures 10-13, 17) [2].

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 4-7) similar to Huntonia trilobites. The presence of a mouth and eyes cannot be discerned. All the arthropods/arachnida has multiple appendages (Figures 10-13, 17). Specimens identified as putative sea spiders, scorpions, arachnids, nematodes, annelids, tube worms, Kimberlla, Namacalathus Lophotrochozoa, millipedes and sea snakes, resemble their counterparts from Earth [3].

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 with notable exceptions: cyanobacteria, fungi, and lichens [4].

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 [5].

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 1-2). Green may be the natural color of the unswept terrain and possibly indicative of algae [6].

Also in Figure 2 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 (Figures 1-7).

Figure 1. (Left) 0905MH0001930000302862R00_DXXX Approximately 15 cm section of dirt and organic debris had been swept away by the rover Curiosity's brush instrument. The green was embedded in the color spectrum of the original NASA photo and may be cyanobacteria. Note extensive water pathways. (Right) A sample of the buried fossil life like specimens located in the central and adjacent partially covered areas that had not been completely swept away by the brush instrument. Many specimens clearly resemble their counterparts on Earth, whereas some are similar to the "alien" and strange looking Cambrian era marine fossils located in the Burgess Shale.

Figure 2. 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 that reveals masses of organisms buried and embedded in organic detritus.

Martian arthropod/Trilobite fossils?

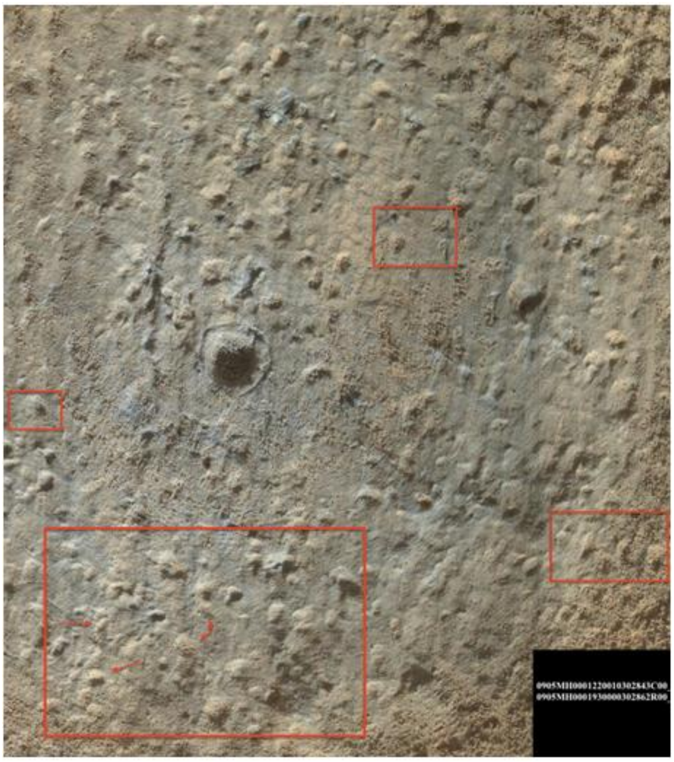

Figure 3. Sol 0905. An assemblage of dozens of fossil-like forms uncovered by the brush instrument employed by NASA's rover Curiosity. These putative fossils include arachnids, nematodes, annelids, Kimberlla, Namacalathus, Lophotrochozoa, and, in red boxes, those that have triple (tri) body parts that appear to be armored and could be likened to a Martian trilobites.

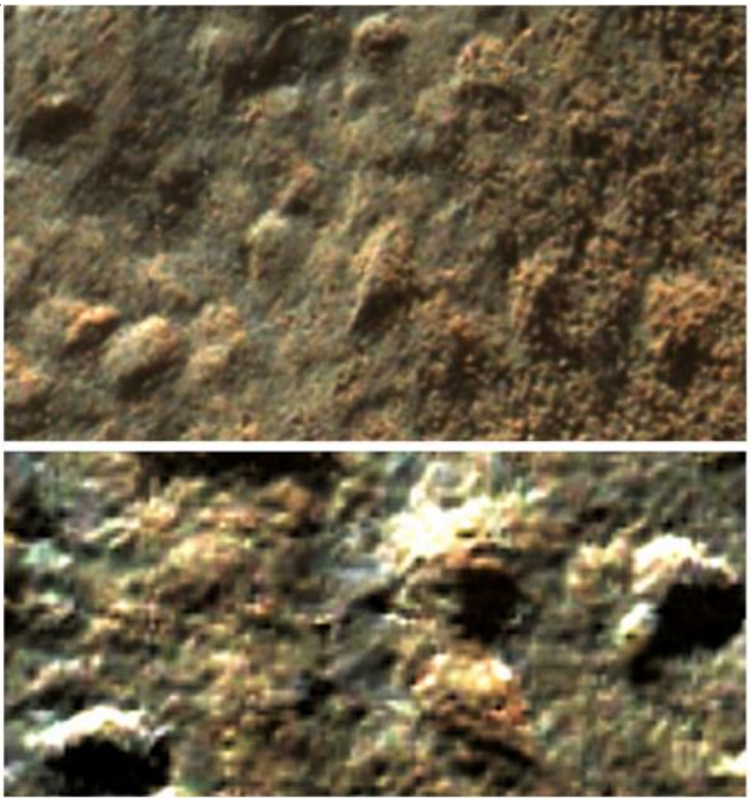

Figure 4. 0905MH0001930000302862R00_DXXX. Note numerous fossil-like forms including those with multiple legs and appendages including a sea spider and armored crustacean upper left bottom figure). Two, possibly three specimens resembling trilobite arthropods can be observed.

Figure 5. 0905MH0001930000302862R00_DXXX. Note numerous fossil-like forms including two, specimens resembling armored trilobites/arthropods.

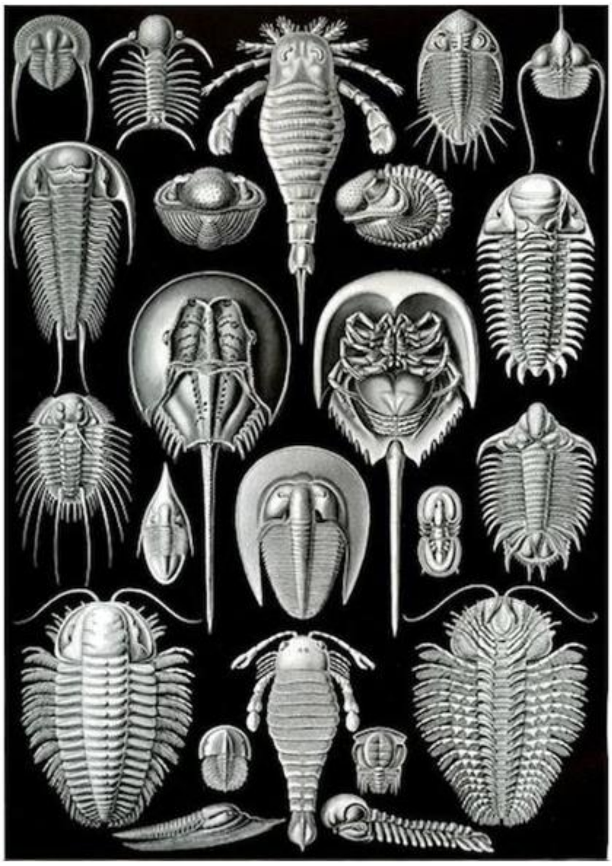

Figure 6. Trilobites. Drawings by Ernst Haeckel, from Kunstformen der Natur (1904).

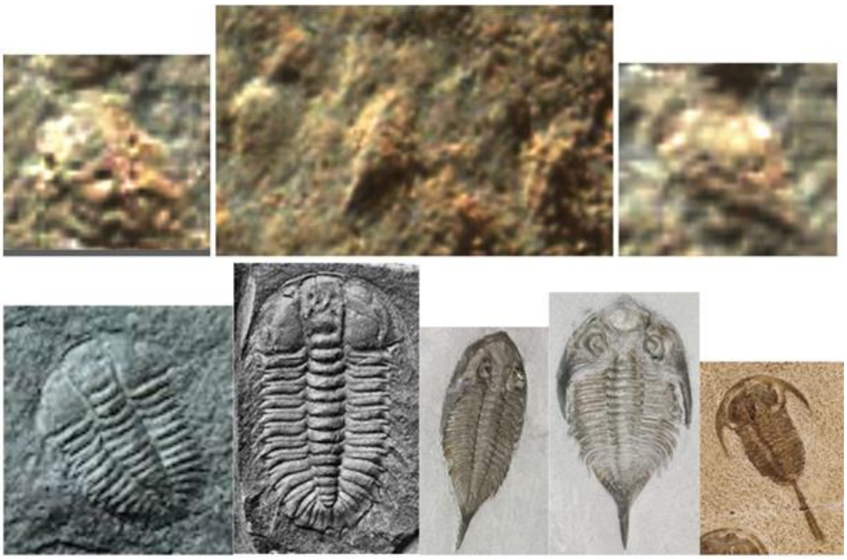

Figure 7. (Top) Photographed in Gale Crater, on Sol 905. (Bottom) Fossil trilobites.

Martian Arthropods?

Arthropods are bilaterally symmetrical, have an exoskeleton consisting of cuticle made of chitin, a segmented body, and paired jointed appendages. They pass through many stages of moulting as they grow: the outer exoskeleton is shed and repeatedly replaced [7]. They have compound eyes and a nervous system which forms pairs of ganglia. Almost all arthropods lay eggs and eggs and cocoons have been observed in several mounds of soil in Gale Crater [8-12].

There are four major groups of arthropods. Specimens resembling all four groups have been observed on Mars, examples of which are presented in this report as follows 1, Trilobita (Figures 3-4, 6). 2, Crustacea: shrimp, crabs (Figures 11, 13). 3, Chelicerata: sea spiders, scorpions, arachnids (Figures 9-10, 17). 4, Myriapoda: millipedes, centipedes (Figures 8-40).

It is noteworthy that the earliest fossil crustaceans (including fossil shrimp) date from the Cambrian era about 510 million years ago. Forms resembling shrimp and other crustaceans have also been photographed on Mars in an ancient sea bed in Meridiani Planum adjacent to what may be the remnants of tube worms and hydrothermal vents [13].

Admittedly, not all these Martian specimens are easily identified however, the same problem has plagued paleontologist studying the "Burgess shale" which is a vast depository for Cambrian Era fauna. Based on this evidence, in total, it has been proposed that Mars experienced a Cambrian Explosion similar to Earth; but which was then followed by a mass extinction [14-19].

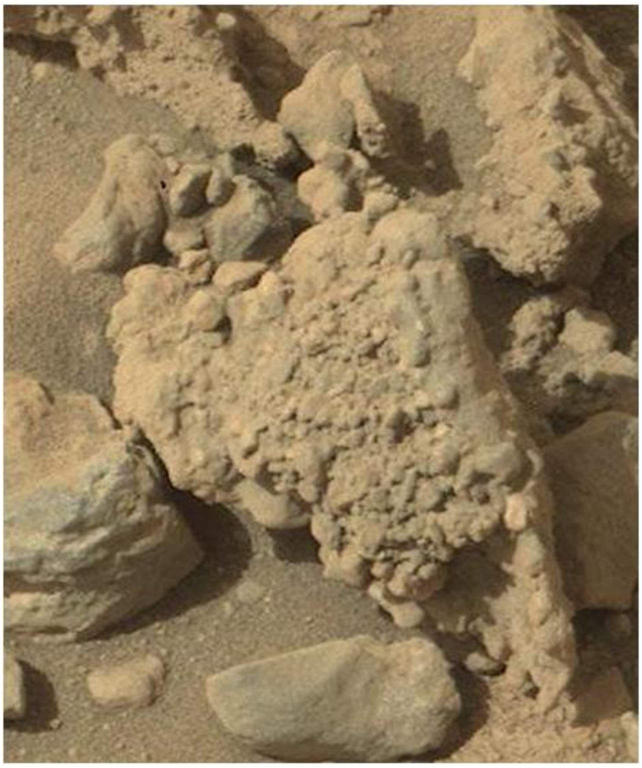

Figure 8. Nematodes, annelids, tube worms, sea snakes, kimberlla, millipedes and a relatively large specimens that resembles a "diamond" headed snake. Photographed in Gale Crater. 0753MR0032350020403675E01_DXXX

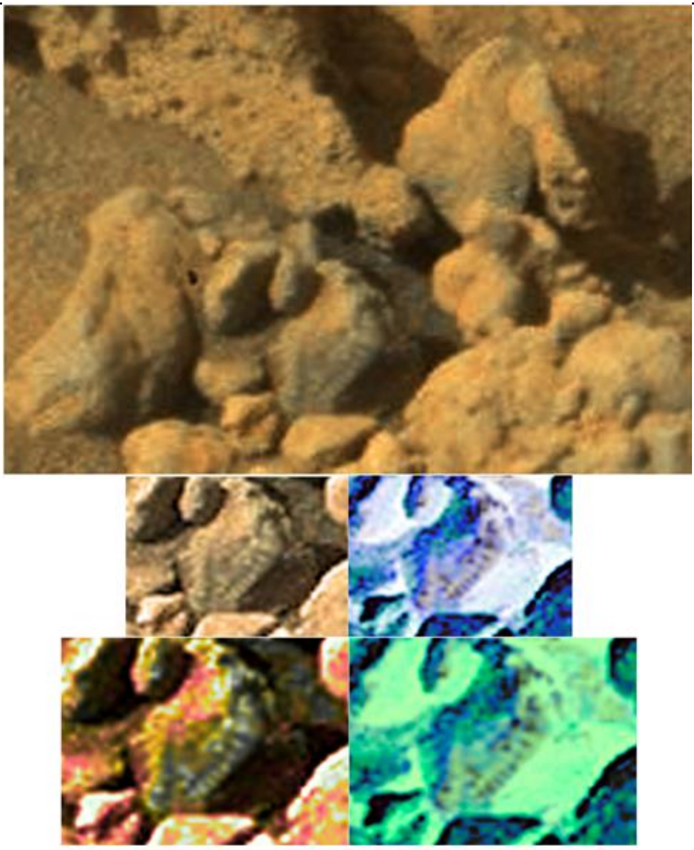

Figure 9. Photographed in Gale Crater. 20753MR0032350020403675E01_DXXX.

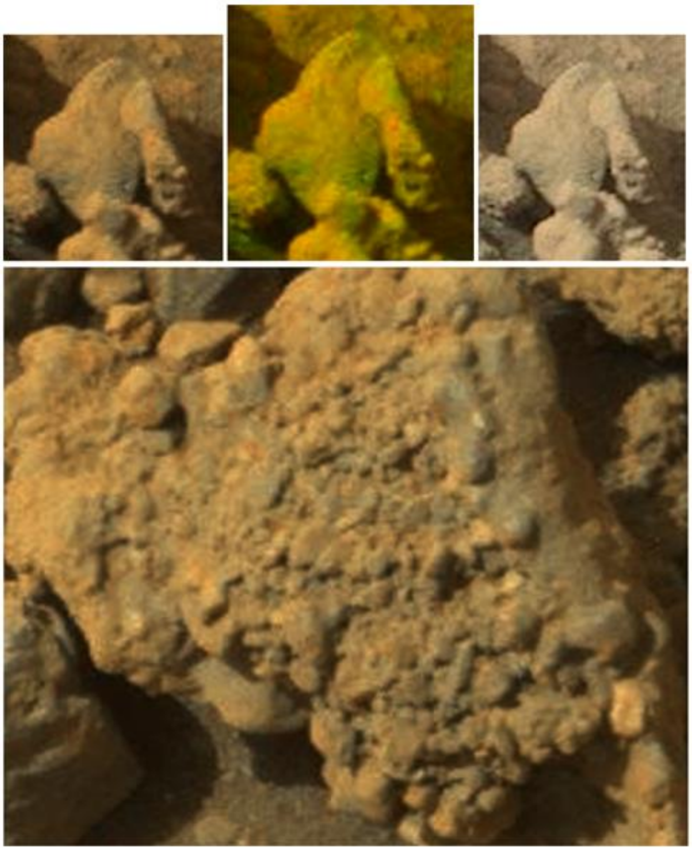

Figure 10. Photographed in Gale Crater. 20753MR0032350020403675E01_DXXX.

Figure 11. Semi-translucent millipede like organism. Photographed in Gale Crater on Sol 0553.

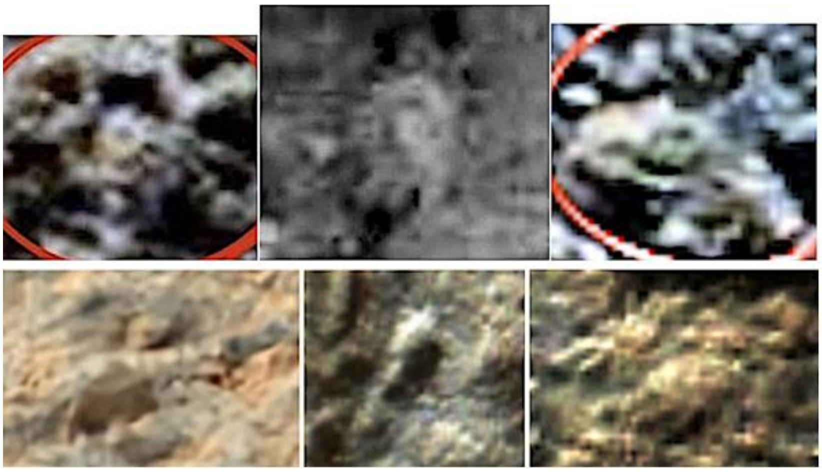

Figure 12. Sea spiders, arachnids, scorpions, and crustaceans. Photographed in Gale Crater.

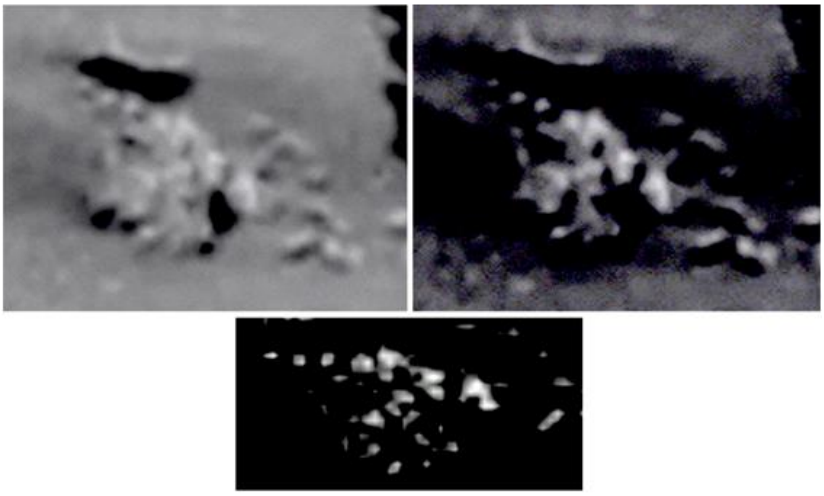

Figure 13. Photographed by the rover Sprit in Gusev Crater. 4822P169153230EFFAAB2P2417L7M1.

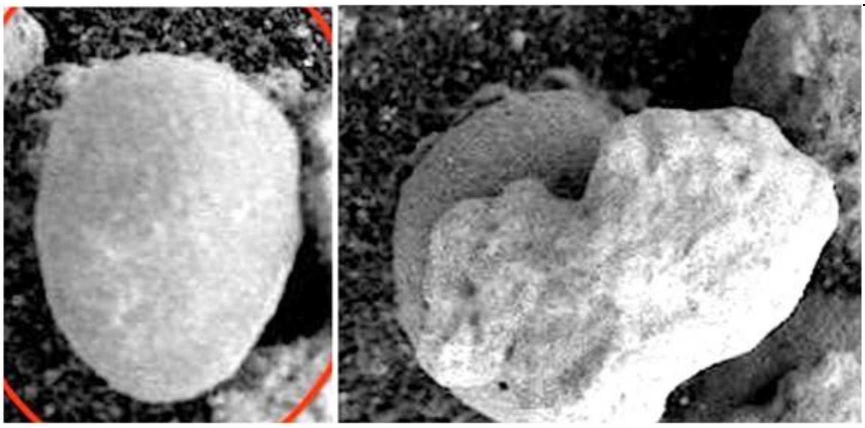

Figure 14. Crustaceans with pleopods? Photographed in Meridiana Planum by the rover opportunity. 1M145850365EFF3505P2977M2M1.

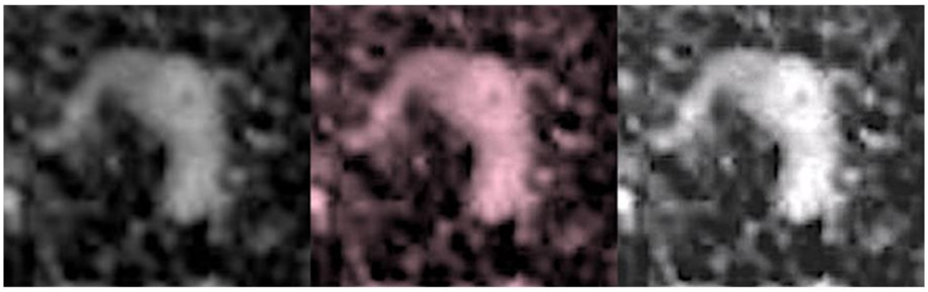

Figure 15. Arthropod? Photographed in Meridiani Planum by the rover opportunity. 1M145850779EFF3505P2977M2M1.

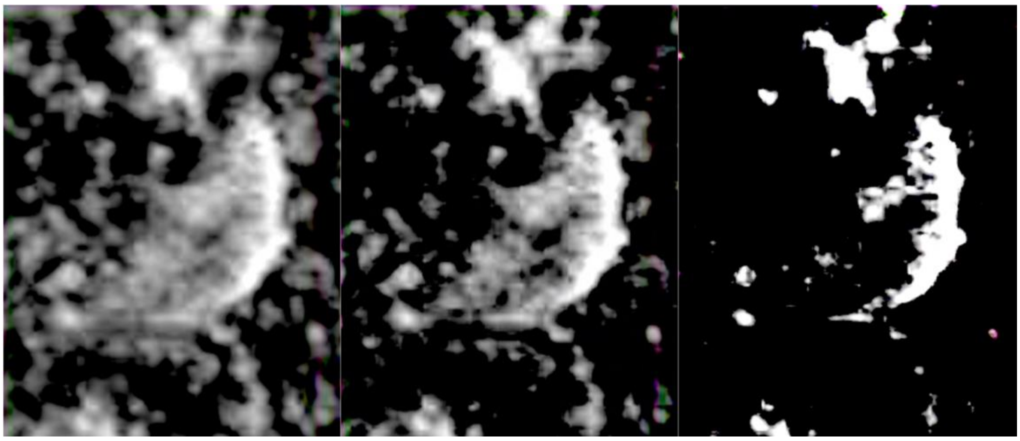

Figure 16. Crustacean/shrimp? Photographed in meridiani planum by the rover opportunity. 1M145850365EFF3505P2977M2M1 1M143896318EFF3336P2957M2M1.

Figure 17. (Left) Gale Crater. Sol 1921. (Right). Photographed in meridiani planum by the rover opportunity. 1M145850153EFF3505P2977M2M1.

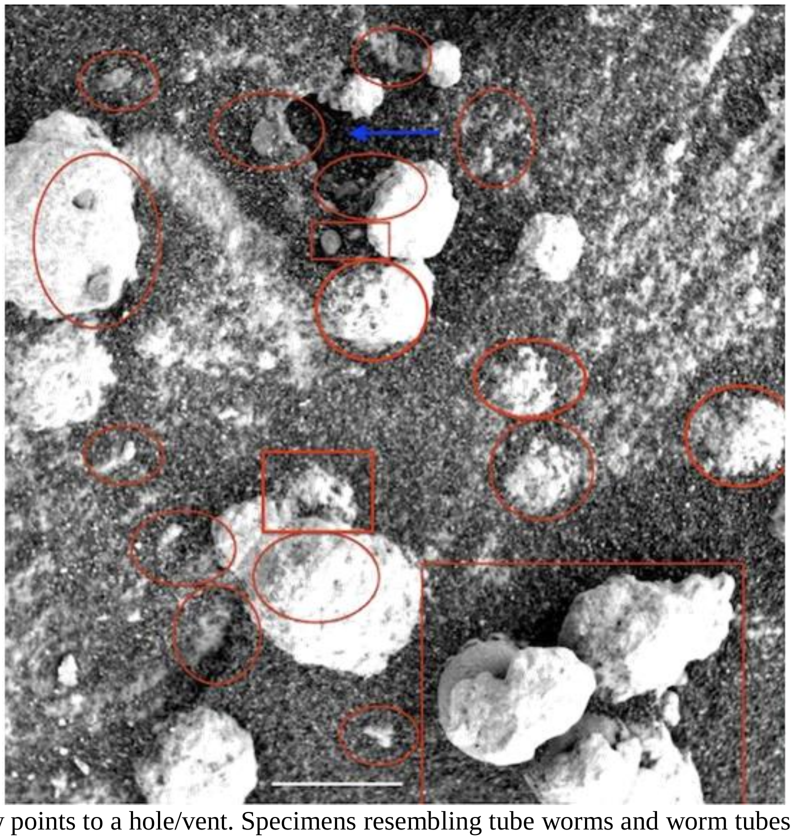

Figure 18. Blue arrow points to a hole/vent. Specimens resembling tube worms and worm tubes upon the surface, and "worms" protruding from small holes in the white matrix which may consist of anhydrite which in turn is associated with the chimneys of active and collapsed hydrothermal vents and their surroundings. Note oval specimens in the lower right with what appear to be pleopods.

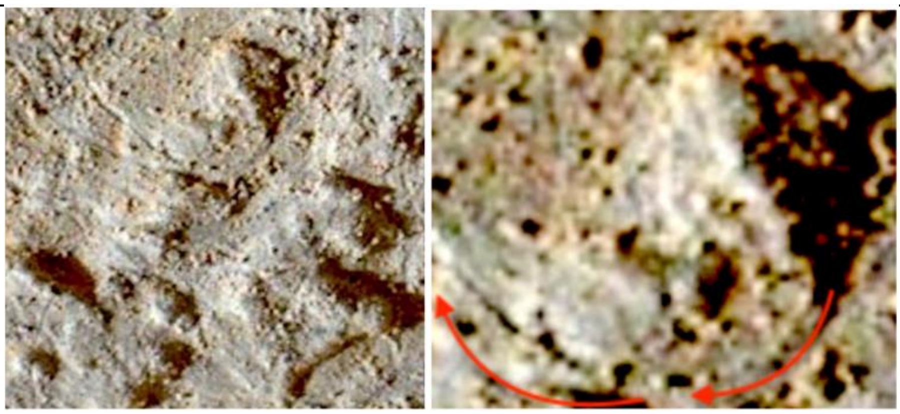

Figure 19. Sol 880. Gale Crater, An assemblage of fossil-like structures one of which resemble an elasmobranch, but could be one organism atop another. 0880MH0004620000302350R00_DXXX.

Figure 20. a) Taeniura lymma; b) Neotrygon sp. From a collection at the institute of paleontology of the university of vienna. CREDIT: Giuseppe Marrama.

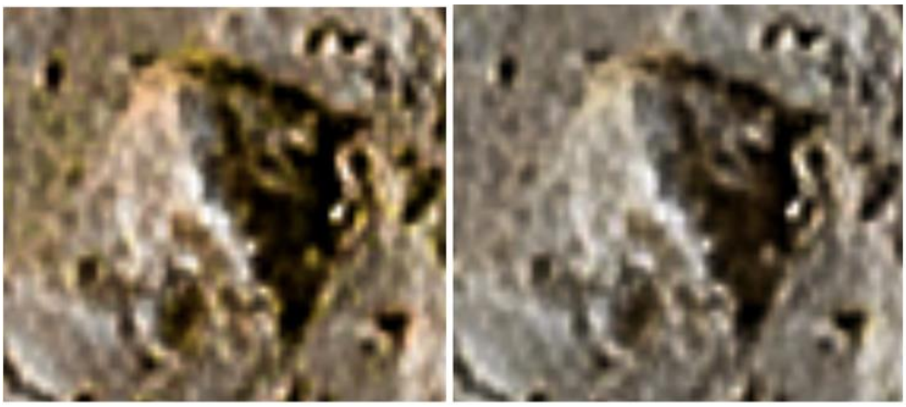

Figure 21. Sol 0880. Gale Crater specimen that may represent an elasmobranch with tail, or two different organisms, one on top of the other.

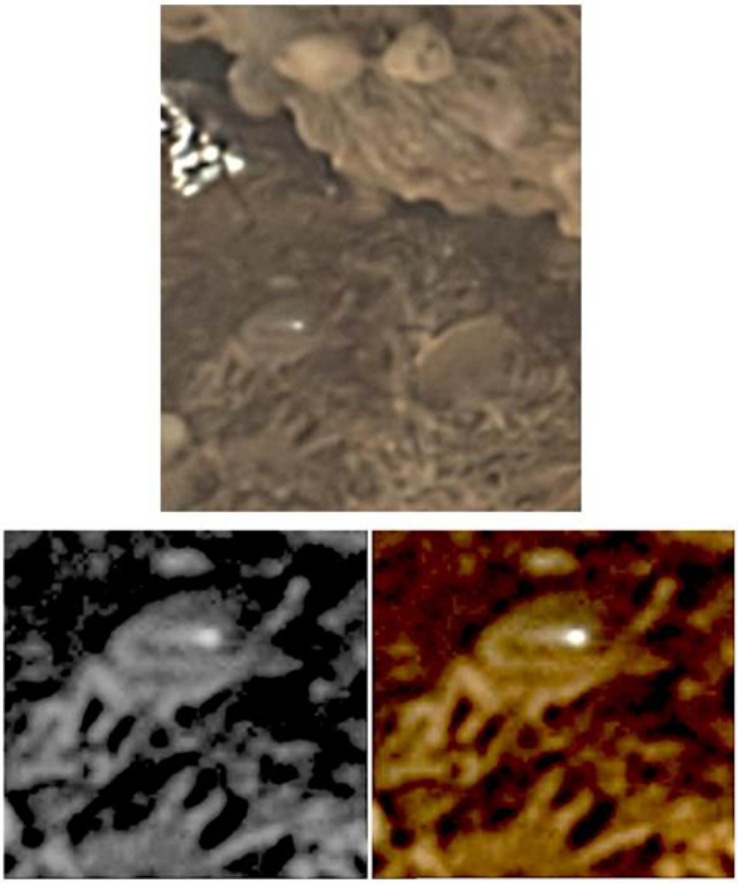

Figure 22. Gale Crater arachnoid/crustacean? 1032MH0001700000400209R00_DXXX.

Burgess shale arthropods

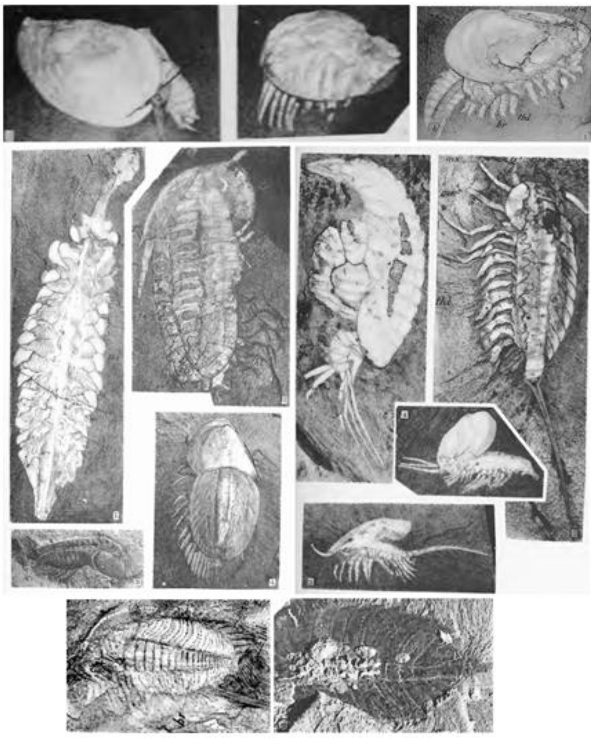

Figure 23. Burgess shale fossils. From C. D. Walcott, Cambrian Geology and Paleontology, 1912, Smithsonian, WDC.

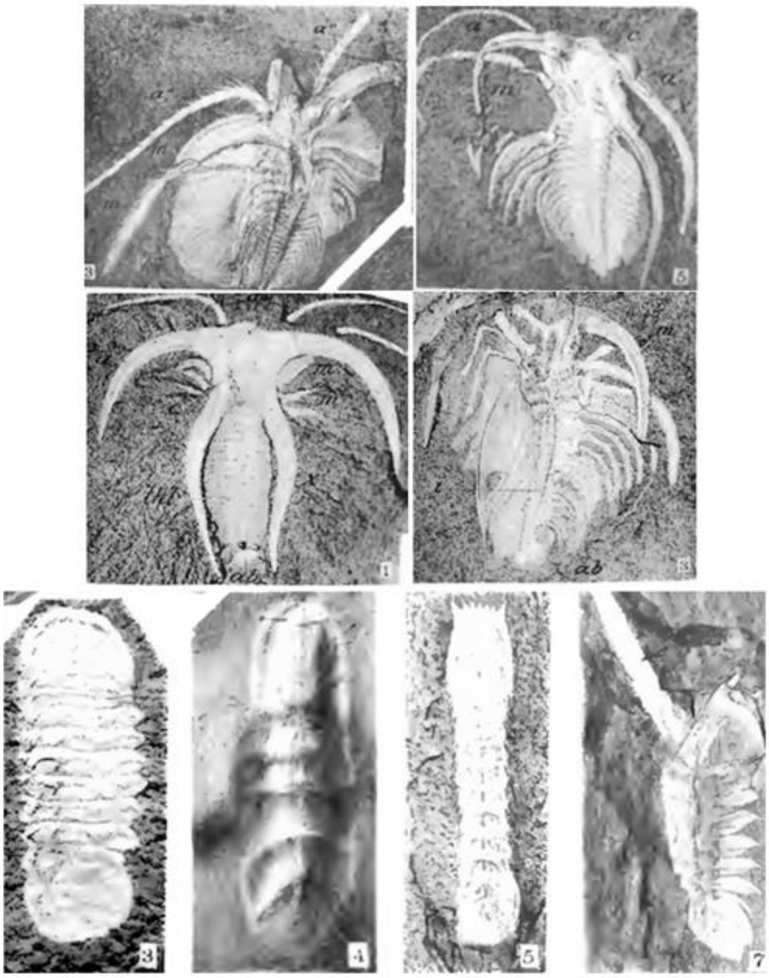

Figure 24. Burgess shale fossils. From C. D. Walcott, Cambrian Geology and Paleontology, 1912, Smithsonian, WDC.

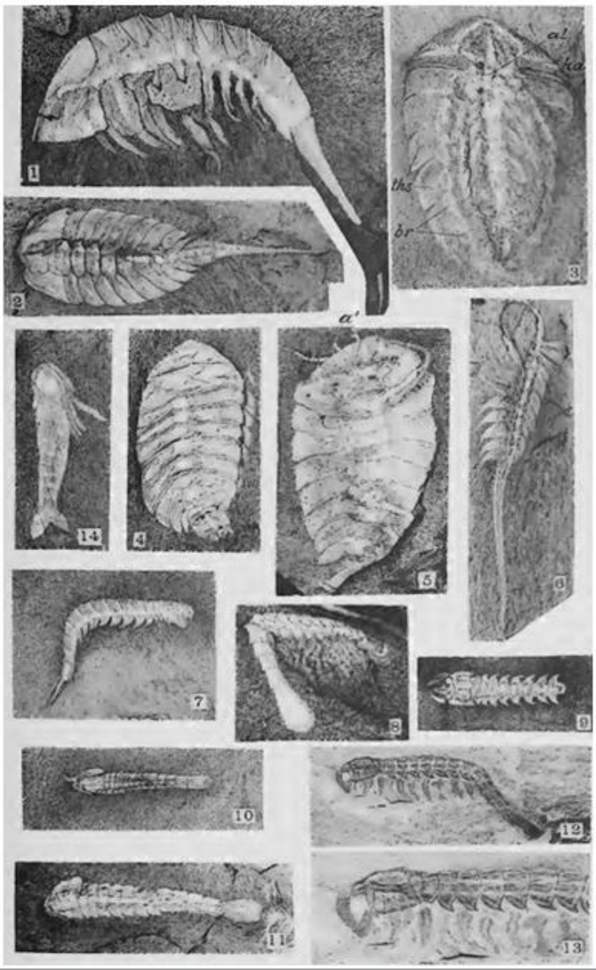

Figure 25. Burgess shale fossils. From C. D. Walcott, Cambrian Geology and Paleontology, 1912, Smithsonian, WDC.

A burgess shale on mars

Figure 26. 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.

Figure 27. 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.

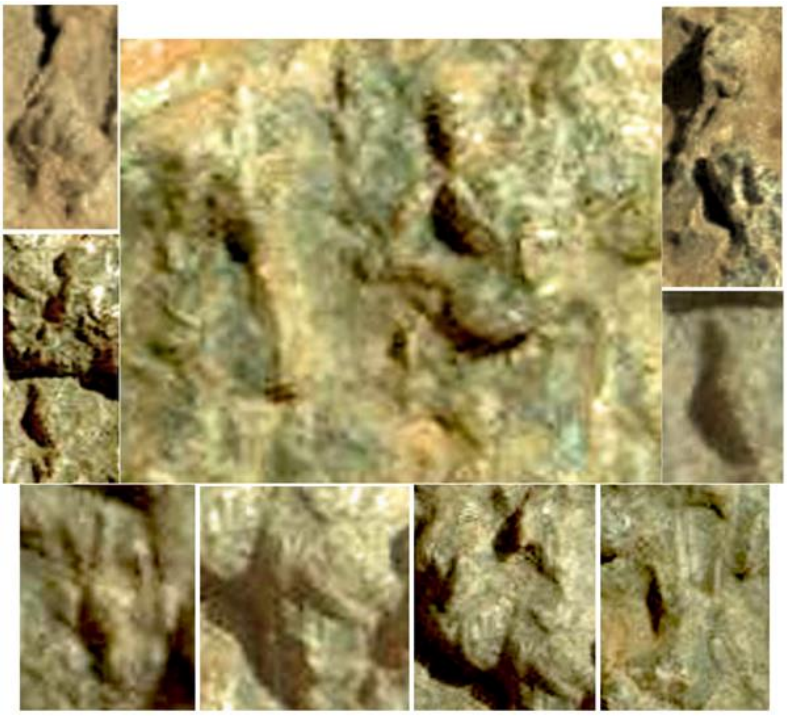

Figure 28. Sol 0553. An assemblage of fossils like forms ranging from 1-5 mm in size: Scorpions, nematodes, annelids, Kimberlla, etc. Photographed in Gale Crater.

Figure 29. Sol 0905. An assemblage of fossils like forms ranging from 1-5 mm in size. Photographed in gale crater.

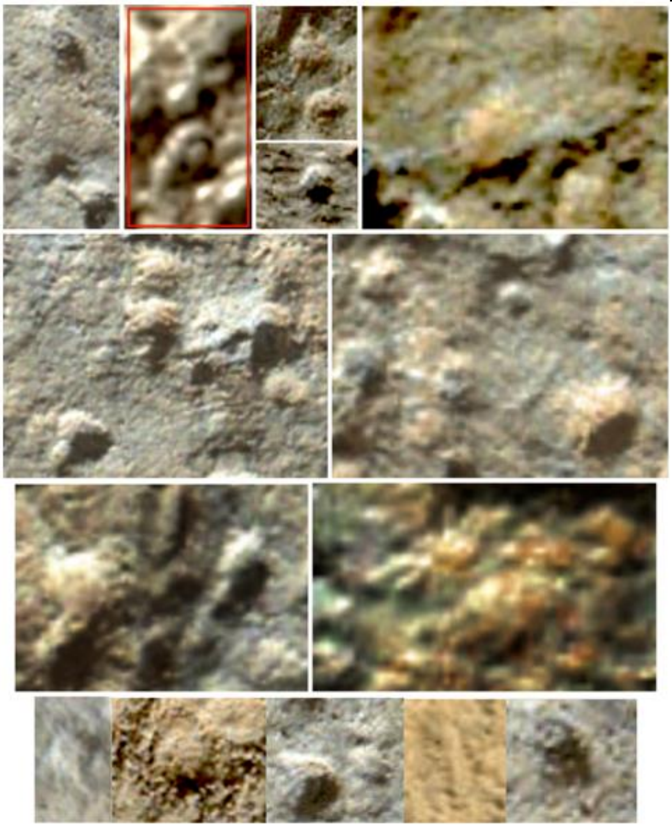

Figure 30. Sol 905. Sea spiders, crustaceans, scorpions, snails, shelly forms, etc.

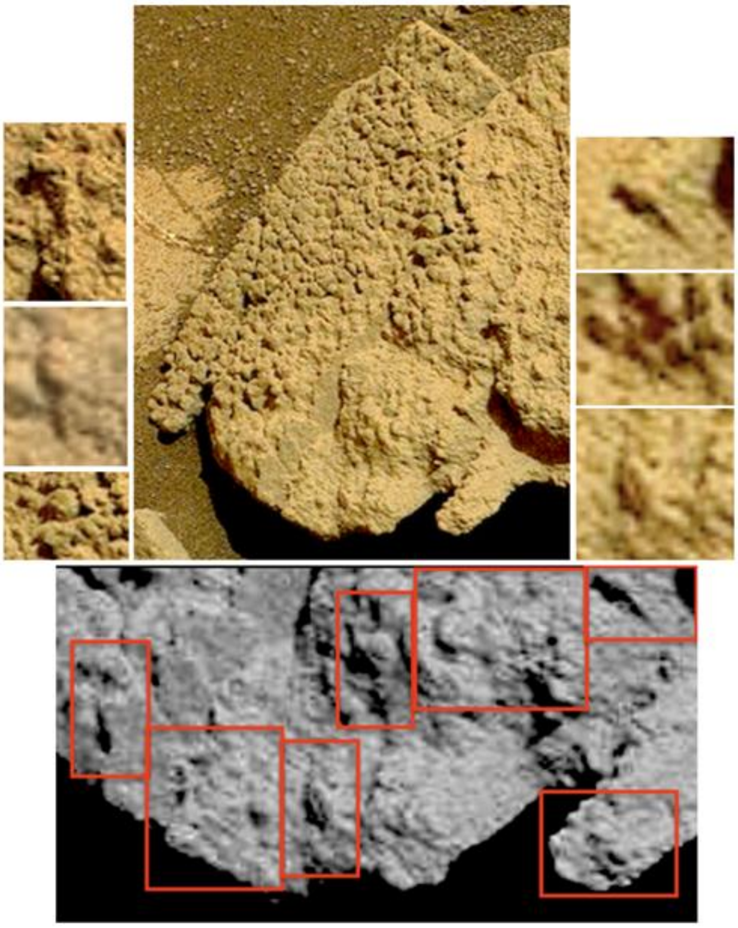

Figure 31. An assembly of fossil-like forms. Gale Crater. 0781MR0034100010404109E01_DXXX-1.

Figure 32. Sol 809. An assemblage of fossil-like forms that resemble segmented worms, and several "Kimberella," and "ice cream cone shaped" specimens (809MH0001710000300846R00_DXXX).

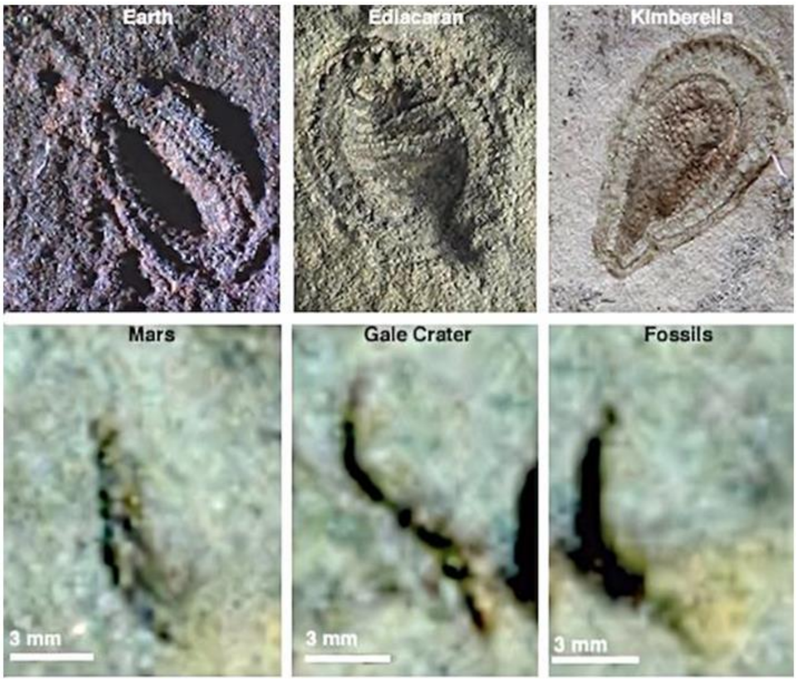

Figure 33. Sol 809. "Kimberella," from Earth and Mars.

Figure 34. An assemblage of fossil-like forms that resemble nematodes, “shelly” organisms, "Kimberella,” Namacalathus, Lophotrochozoa, and other marine species. Sol. 0880MH0004620000302350R00_DXXX.

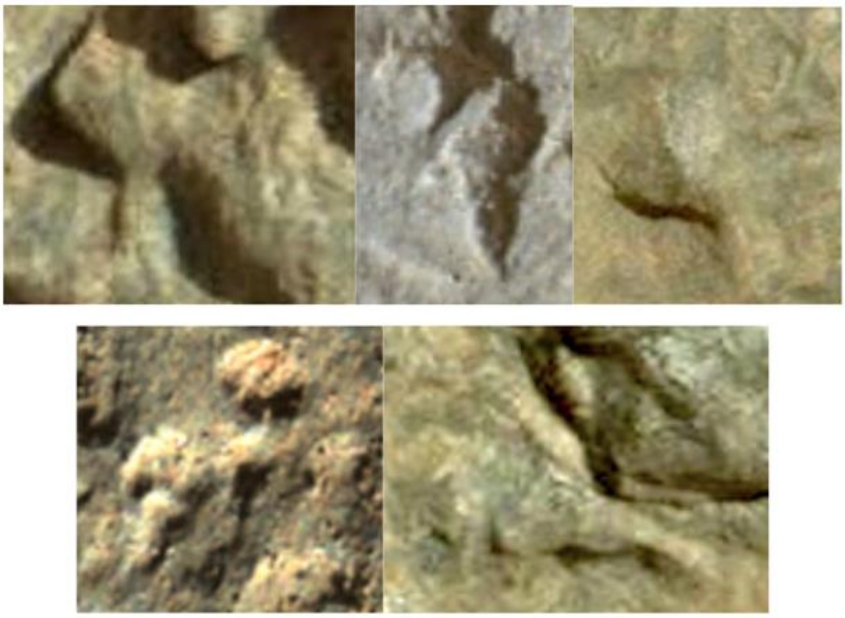

Figure 35. Sol 0552. Namacalathus, Lophotrochozoa, and other organisms. Gale Crater.

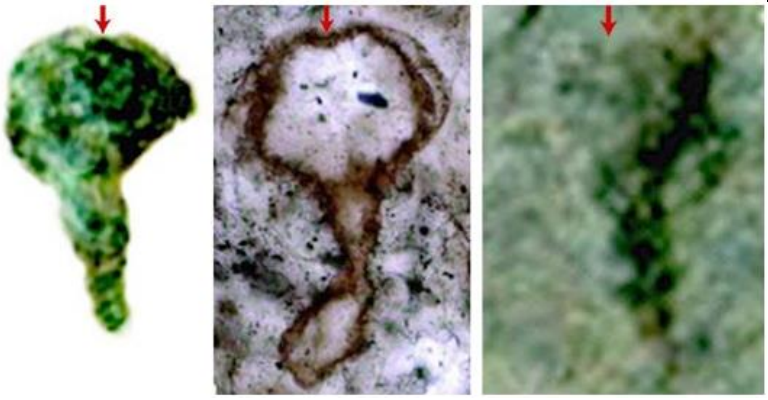

Figure 36. (Mars left): Gale Crater. Sol 809. (Earth center): Namacalathus. (Mars right): Gale Crater Sol 869. Arrows indicate open apertures for filter feeding.

Figure 37. Sol 753. Fossils and possibly living organisms: crustaceans, sea spiders, scorpions, nematodes, annelids, tube worms, Kimberlla, millipedes. 0753MR0032350010403674E01_DXXX.

Figure 38. An assemblage of Gale Crater forms resembling millipedes, annelids, and nematodes.

Figure 39. Segmented worm-like tubular forms oriented in different directions including upwards on a mound of soil in Gale Crater. 0302MR0012570170203809E01_DXXX.

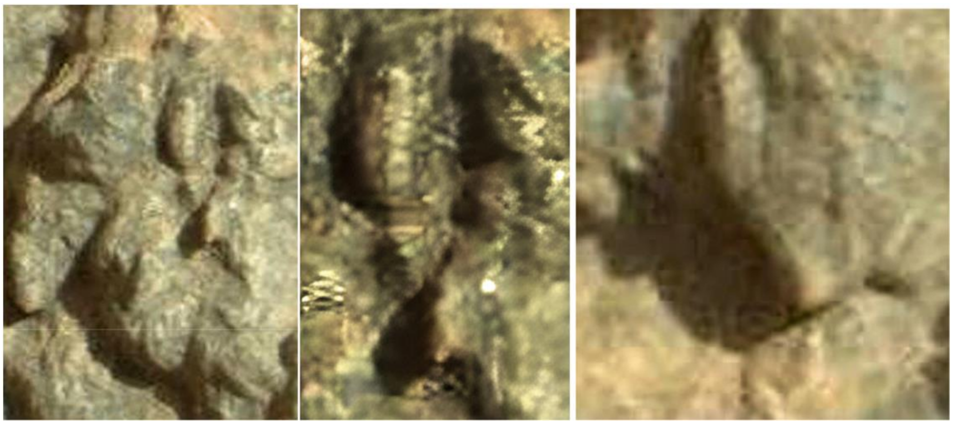

Figure 40. Segmented fossilized worms photographed in Gale Crater. 0553MR0022370010303889E01_DXXX.

DISCUSSION

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. It has been proposed that Gale Crater represents veritable "Burgess Shale" and that Mars experienced a cambrian explosion of life followed by a mass extinction [20]. 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 [21].

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 any 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. Moreover, those cambrian era fauna that were the most alien in appearance quickly became extinct.

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. 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. Typically they are heavily armored, possess 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 [22].

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. In addition, trace fossils of rock boring marine organisms (mollusks, bivalves) have been photographed in Jezero Crater, Utopia Planitia and Chryse Planitia. 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. 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 are mutually supportive evidence favoring the theory that life flourished in the oceans, lakes and seas of Mars [23].

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.

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. The last period of extreme axial obliquity may have come to a close 400,000 to 110,000 years ago; 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 as reported here [24].

CONCLUSION

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. 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. 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. 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 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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