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Case Series

Conceivable Microalgae-like Ancient Martian Fossils and Terran Analogues:MER Opportunity Heritage

Jozef Kazmierczak*

Department of Paleobiology, Polish Academy of Sciences, Warszawa, Poland

ABSTRACT

The finding of life on Mars, existing now or in the past, will certainly be one of the greatest adventures in the history of mankind. Further arguments are provided, strengthening an earlier claim, that among mineral bodies (dubbed "newberries"), imaged by the MER Opportunity in deposits of Late Noachian age (~3.8 to 3.6 Ga) exposed at the rim of Endeavour Crater (Matijevic Formation) objects occur that resemble fossils of Terran unicellular and colonial microalgae. The previously claimed algal affinities of these fossil objects is now supported by examples of "newberries" showing the presence of internal structures highly similar to daughter colonie characteristic for Terran volvocalean algae and cell-like objects enclosing objects reminiscent of chloroplasts characteristic for modern and fossil unicellular green and yellow green algae. A fluffy layer of stagnant water body is postulated as sedimentary environment promoting early post mortem silicification (Fe^{3+} smectite) of the microalgae-like biota.

Keywords: Martian life; Noachian; microfossils; microalgae; Rover (MER-B) Opportunity; Endeavour Crater; Mars

HIGHLIGHTS

- New observations are provided in support of previous claims suggesting the presence of possible microalgae-like objects (biomorphs) in Late Noachian deposits at the rim of Endeavour Crater imaged 2012/2013 by MER, Opportunity.
- A model is proposed explaining the origin of the Fe-smectite mineralized microalgae-like objects as product of early post-mortem degradation anddiagenesis of bloom plankton in a fluffy boundary layer of stagnant water body.
- Indicated is the significance of the Late Noachian microalgae-like fossils from the Endeavour Crater for the search of similar microfossils by the upcoming 2020 NASA and ESA robotic missions.

INTRODUCTION

In 2016 two new Martian robotic (rover) missions have been announced by NASA and ESA for 2020 [1,2]. As main targets for both missions findings of traces of ancient life on Mars have been declared https://www.nationalgeographic.com/news/2016/10/alien- fossils-nasa-exploring-mars-2020-space-science/

A definite selection of landing sites and of most effective and reliable instruments (payload) to fulfill this purpose is just completed (NASA: Jezero Crater, and ESA: Oxia Planum). In the shadow of technical and scientific preparations for both these missionsthe initial results of a study on ancient (late Noachian/early Hesperian) Martian mineral objects, imaged in 2012/2013 by NASA Opportunity rover (MER-B) at the rim of Endeavour Crater, as possible biomorphs, were published [3]. These objects were originally by NASA experts dubbed "newberries" to differentiate them from earlier by Opportunity on Meridiani planum discovered spherical structures named by the same experts "blueberries" [4-7]. In comparison with Endeavour "newberries", the Meridiani Planum spherical objects are characterized by homogenous structure and much higher, comparing with "newberries", content of iron. The interpretation of "blueberries" as micro-concretions originated in water-loaded sediment was almost equivocally accepted whereas the origin of the "newberries" remained and is still a matter of considerable controversy [5,8]. The main reason why paleobiological studies on the "newberries" from the rim of Endeavour crater have been undertaken was the well-documented origin of these structures in an aqueous environment [5]. Already atfirst glance, basing on long-time micropaleontological and geomicrobiological experience, it was clear that some of the "newberries" are strikingly similar to

Correspondence to: Jozef Kazmierczak, Department of Paleobiology, Polish Academy of Sciences, Warszawa, Poland, E-mail: jkaz@twarda.pan.pl

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somepeculiar Terran microfossils known as acritarchs, calcispheres, and mazuelloids [3]. Particularly the Late Devonian calcispheres, decently preserved with organic parts,sampled from core of a deep borehole Sosnowiec IG-1 (Upper Silesia, SouthernPoland), have revealed these structures as early post mortem mineralized colonial and unicellular green microalgae (Chlorophyta) [9-12]. These comparative studies showedthat there are enough arguments for claiming some of the Endeavour "newberries" as structures analogous to some of the calcispheres and acritarchs (Figures 1 and 2) and to declare several of the "newberries" as biomorphs, i.e. possibly biologically originated objects [3].

It is notable that NASA experts found easily explainable as non-biological objects themultitude of spherules ("blueberries") imaged by Opportunity just at the beginning of its long route over Meridiani Planum to Endeavour Crater. As basis for such identification they used much larger concretions rich in the mineral hematite deposited by water saturating the bedrock [6,7] similar to those described and compared earlier with the martian nodules [13-15] and newly [16] from Jurassic Navajo Sandstone (Utah) and Cretaceous Djadohta Formation of southern Mongolia. Such iron oxideconcretions were interpreted as sedimentary structures representing diagenetic records of groundwater flow and water-rock interactions. These evidently concretionary and morphologically undifferentiated bodies are texturally rather homogenous and sharply different from the morphologically diversified Matijevic Fm biomorphs.

The reason for a lack of focus in the experts imagination, when faced with the images of the Endeavour Crater "newberries", is understandable. First, the experts had apparently no access to reliable comparative material, and second, they seemingly overlooked the existence of papers [10,11,17-19], which could be helpful in explaining the nature and morphological diversity of the "newberries" as fossils of possibly early post mortem mineralized microalgae. The purpose of the present report is therefore to illustrate and discuss several further decent examples of the Endeavour Crater "newberries" that may indeed represent Martian remains of biological objects similar to ancient and modern Terran microfossils affined clearly with microalgae [3] similarly as to other recently described Terran microfossils [20-25]. All these findings permit now replace the previous term "biomorphs", cautiously proposed for the Noachian Martian objects [3] with the term "microalgae-like fossils" which will be used further in the text.

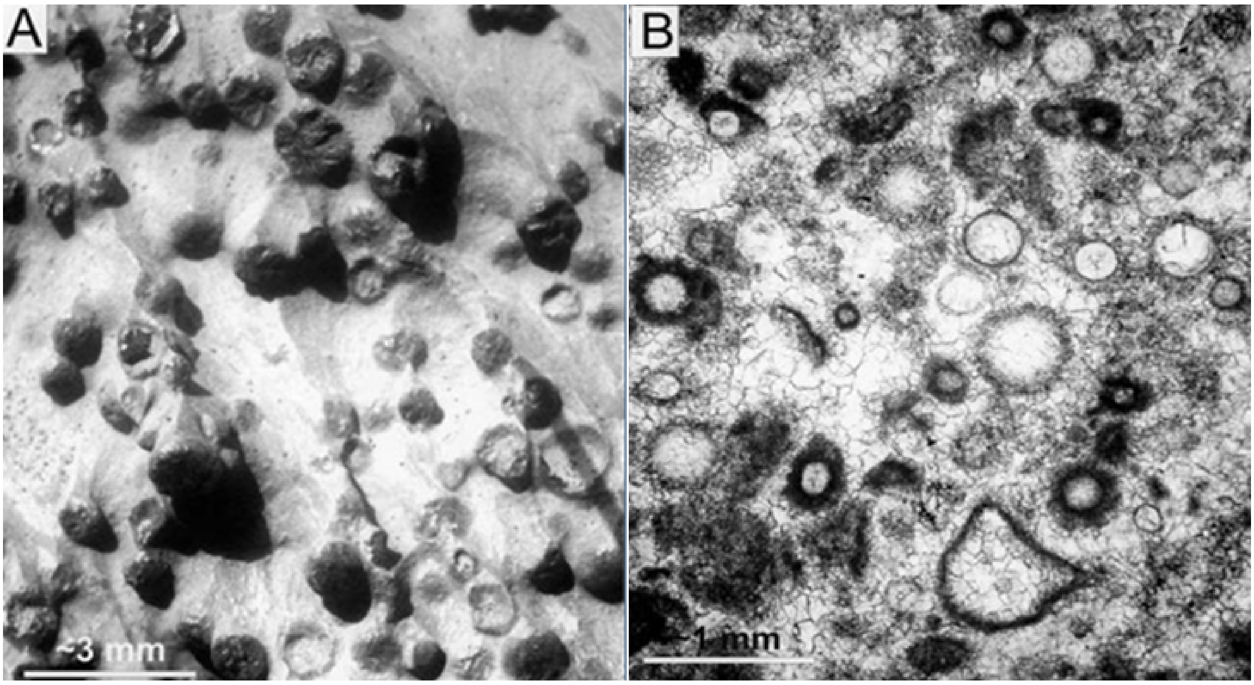

Figure 1: Comparison of Martian (Noachian) 'newberries' photographed by MER Opportunity Micro Imager (MI) at the rim of Endeavour Crater with analogous early post mortem calcified Late Devonian microalgae. (A) Accumulation of Martian 'newberries' shown on magnified part of the photograph taken by Opportunity from weathered rock surface on sol 3247 at Kirkwood outcrop, Cape York. [Credit: NASA/JPL-Caltech/Univ. of Arizona]. (B) Transmitted plain light photomicrograph of accumulation of Late Devonian early post mortem calcified microalgae; petrographic thin-section, Sosnowiec IG-1 borehole, core depth 2389-2395 m, Upper Silesia, Poland. The diameters of the Martian 'newberries' approximately 1 to 3 mm; the scale bar for (B) -200 μm

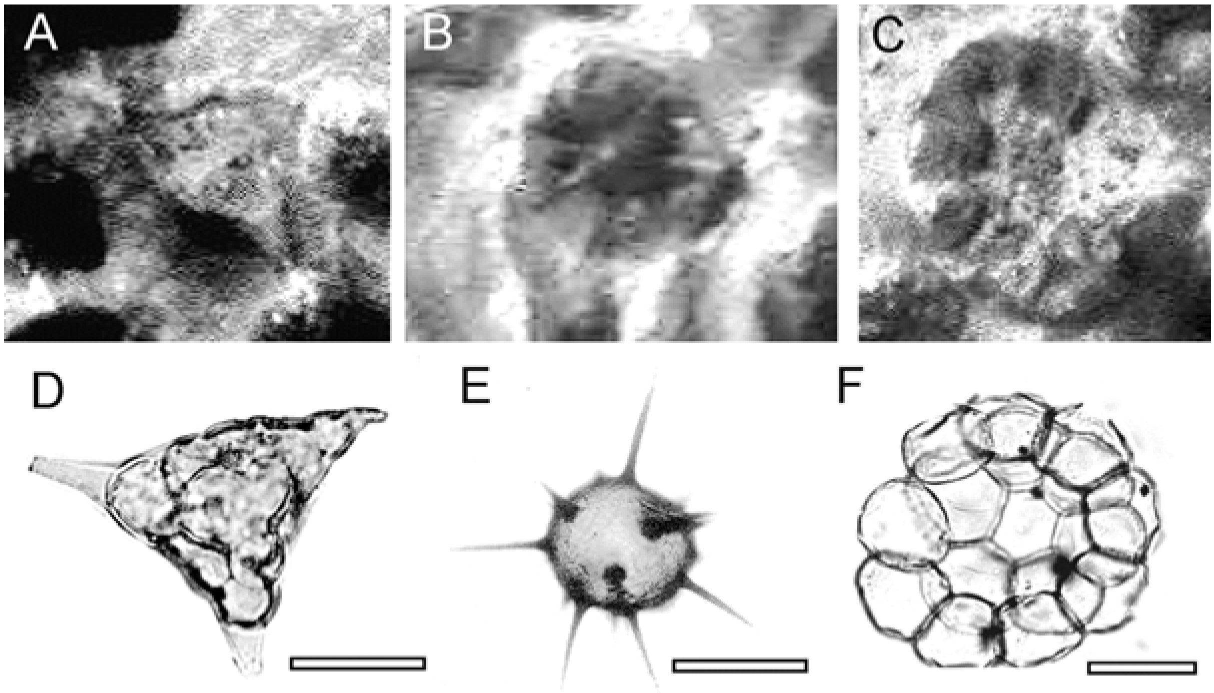

Figure 2: Selected Martian (Noachian) 'newberries' photographed by MER Opportunity micro imager (MI) at the rim of Endeavour Crater and comparison with Terran fossil microalgae. (A) Image of a Martian acanthomorph object compared in (D) with supposed Terran analog, a tri-star-shaped Silurian acritarch microalga Veryhachium (Zalesie Nowe, Holy Cross Mountains, central Poland). (B) Spiny Martian specimen and (E) supposed Terran analog, an Ordovician acritarch microalga Baltisphaeridium mochtiense [26]. (C) Spherical Martian object composed of globoid units resembling colony of Cretaceous chlorophycean alga Palambages morulosa [27] shown in (F). All Martian objects from weathered rock surface at Kirkwood outcrop, Big Nickel locality, Cape York [Credit: NASA/JPL-Caltech/Univ. of Arizona]. (A) and (C) taken on sol 3247, (B) taken on sol 3250. Scales equal: for A, B and C ~1.5 to 2 mm; for D 30 μm; for E 60 μm; for F 25 μm.

As a basis for previous claim of biological nature of some of the "newberries" imaged by Opportunity Micro Imager (MI) at the rim of Endeavour Crater, only a few examples had been chosen [3]. They have been selected to show three different morphologies from the large population of "newberries" imaged on sols 3064, 3247, and 3250, or occurring as individual bodies dispersed rarely in the rock matrix on sols 3094 and 3305. Figures 1 and 2 are showing comparison of the Endeavour Crater objects with Terran marine microfossils of different geological age. Whereas in the 2016 report [3] the comparison of Martian and Terran specimens was based entirely on Devonian microfossils photographed in transmitted light in petrographic thin sections, the Terran analogs shown here in Figure 2 represent three dimensional views of Ordovician, Silurian and Cretaceous common microfossils obtained by chemical maceration of the parent cherty rocks. These examples alone represent actually the clue of the bio-aspects of the Endeavour objects which, in the light of the present knowledge, are rather difficult to be interpreted as abiologically originated structures.

RESULTS

New observations on Noachian microfossil like objects. Two new cases of Late Noachian (Matijevic Fm) structures, which in our opinion are crucially supportive for the presence of biological objects in deposits cropping out at the rim of Endeavour Crater, are the specimens presented below (Figure 3).

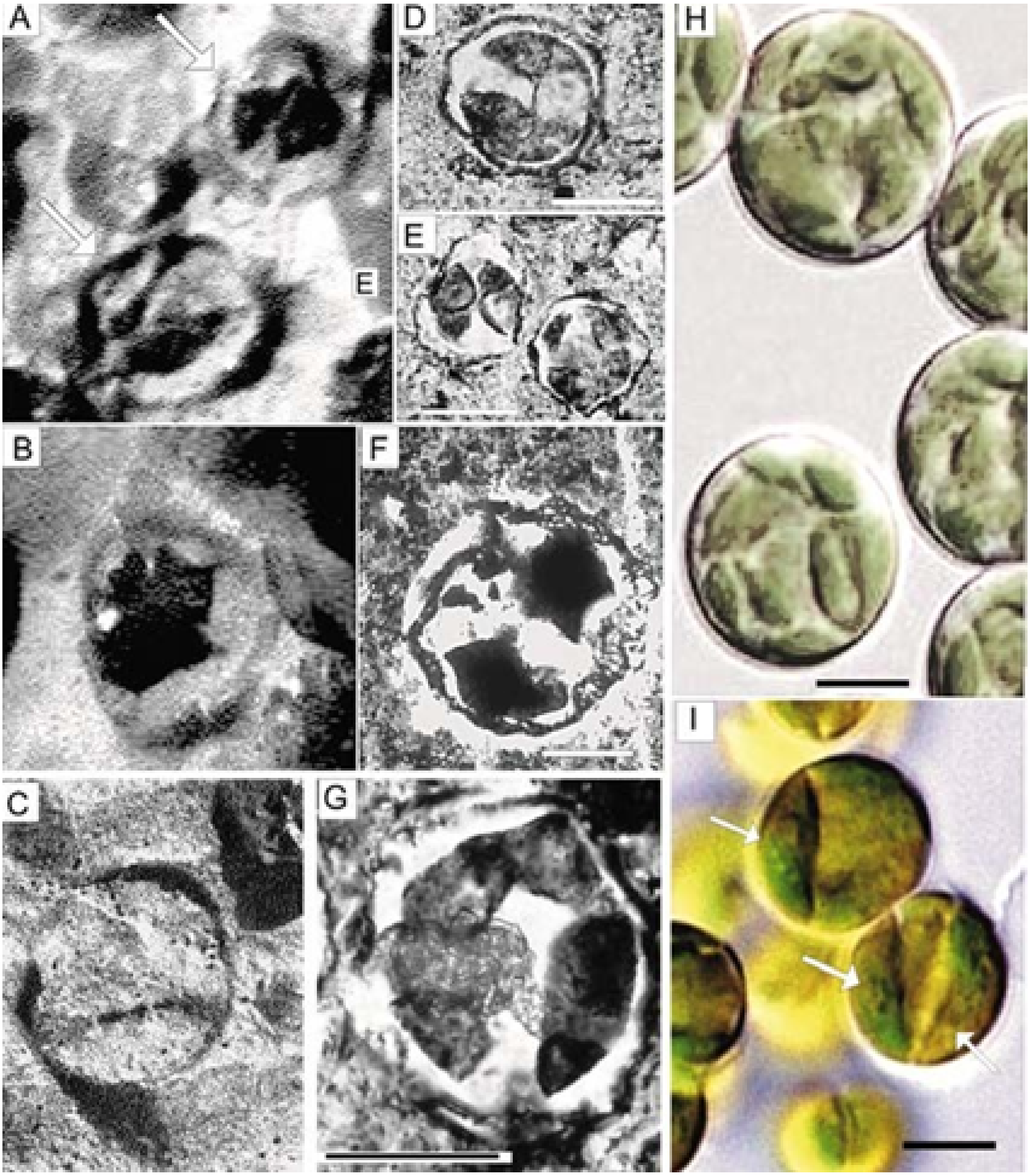

Figure 3: Martian (Noachian) microfossil-like objects ("newberries") from the rim of Endeavour Crater compared with Terran fossil and modern analogs. (A), (B), (C) Examples of subequatorial cross sections of three spheroid "newberries" imaged by MER Opportunity micro imager (MI) on sol 3247 on weathered rim of Endeavour Crater (Kirkwood outcrop, Cape York). Note the distinctly delineated walls of the naturally exposed spheroids and the dark subangular to ovoid structures in their interiors [Credit: NASA/JPL-Caltech/Univ. of Arizona]. (D, (E), (F), (G) Micrographs of equatorial thin sections (transmitted light) of carbonaceous walls of spheroid Early Silurian microalgae (Cymatiosphaera-like acritarch) with internal structures reminiscent of those visible in the specimens of "newberries" shown in (A) to (C). They are interpretable as remains of chloroplasts (Bardzkie Mountains, Sudetes, southwestern Poland). (H) For comparison optical micrograph of modern unicellular xanthophycean microalga with subangular and ovoid chloroplasts similar to the internal structures of the Martian and Silurian objects illustrated in this figure [**http://protist.i.hosei.ac.jp/PDB/Images/Heterokontophyta/Botrydiopsis/sp_03.html**] (I) Large parietal chloroplasts (arrowed) in modern unicellular chlorophycean algae from the genus Lobosphaeropsis; note similarity with Martian specimen shown in (C) this figure [from 31]. The diameter of Martian objects in (A) to (C) ~2 mm. Scales for others equal: for (D) to (G) 20 μ m, for (H) and (I) 10 μ m.

Case 1

Observation

Three spheroid "newberries" were imaged by Opportunity micro imager (MI) on sol 3247 on weathered rim of Endeavour Crater (Kirkwood outcrop, Cape York). All three specimens are exposed by weathering (?wind corrosion) in near equatorial sections. They show distinctly delineated walls, smooth on outer and inner side, that are built of very fine grained mineral (clay-like?) material (Figures 3A-3C). The walls are firm, and only occasionally pierced by a few irregularly distributed pores. The characteristic feature of the three specimens is the presence of sub angular to ovoid massive platy structures of various size in their interiors. The platy structures in Figures 3A and 3B are much darker (in reflected light), and almost black, when compared with the light gray walls of the spheroids and the surrounding fine grained sediment (matrix).

Comparison

These spheroid "newberries" are easily comparable with some cellularly preserved fossils of modern representatives of Terran microalgae, particularly with those classified to green algae (Chlorophyta). Such a conclusive comparison is possible due to presence in the Martian forms of the above mentioned internal platy structures which are directly comparable with internal structures known as chloroplasts that occur in cells of all modern green algae. According to scholar definition, chloroplasts are algal and plant cells organelles that carry out photosynthesis. Due to high concentration of chlorophyll they convert light energy to organic molecules used by algae or plants as food. Chloroplasts are believed to have evolved from cyanobacteria that have been once endosymbiotically engulfed by early eukaryotic cells. New chloroplasts are originating through binary or multiple fission which is typical for bacterial reproduction [28].

In Figures 3D-3G examples of carbonaceous fossils of spheroid cells of Silurian acritarch microalgae are shown (in thin sections) with internal structures highly similar to those from the Martian specimens shown in A to C. All these Silurian structures are easily interpretable as remains of fossilized chloroplasts particularly when compared with images of chloroplasts from modern green microalgae (Figures 3H and 3I; for excellently illustrated chloroplast morphologies, see e.g. [29-31]. It should be mentioned that preservation (fossilization) of intracellular structures (organelles, reproductive bodies and other intracellular structures) is a rare but well-known phenomenon described from various groups of fossil microalgae, protists and even prokaryotes [12, 32-41]. For the dark color of the chloroplast-like structures from the Martian cells (photographed in incidental light) responsible presumably is an in vivo enrichment of chloroplasts in metals. Had they been, as photosynthetic pigments in modern chloroplasts (in particular chlorophylls) are, enriched in Mg, Zn, Mn, Fe, and Cu [e.g. 42-43], their dark coloration could have indicate a retain in a fossil state the metal-staining effect of their photosynthetic apparatus [44].

The dark shiny stain of the internal structures of some of the naturally weathered 'newberries' may also be compared with the tiny black crusts composed of mixture of manganese, iron oxide, hydroxide and clay minerals that are forming from biofilms on desert rocks exposed for very long time to eolian erosion (corrosion) by very fine dust (rock varnish) [45].

Case 2

Observation

Considered are two specimens of Late Noachian (Matijevic Fm) microfossil-like mineral bodies imaged by Opportunity micro-imager at Kirkwood outcrop (Cape York) from weathered rock surface. The image of the first was taken on sol 3064 (Figure 4A), and the second on sol 3247 (Figure 4B). Both specimens are near-equatorially sectioned well delineated spherical mineral objects with distinct granular walls composed of not well recognizable closely adhering granular bodies. The external surface of the spheres is almost smooth, the internal rather corrugated enveloping slightly plunged internal space. The characteristic feature of both specimens is the presence in the internal spaces (chambers) sections of three to four, more or less distinctly visible, hollow spherical bodies with walls built of granular material. These almost equally sized internal bodies occupy nearly the whole internal space in both examined specimens.

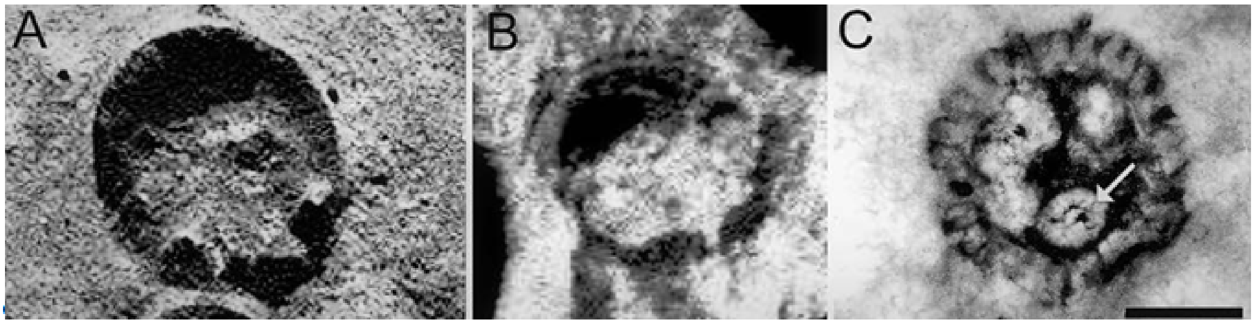

Figure 4: Martian (Noachian) microfossil-like objects from the rim of Endeavour Crater compared with a Terran Devonian analog. (A), (B) Images of well-delineated spherical mineral bodies taken at Kirkwood outcrop (Cape York) by Opportunity Microscopic Imager from weathered (naturally macerated) rock surface on sols 3064 (A) and 3247 (B). Both specimens are sub-equatorially sectioned and show well-delineated (i.e., weathering resistant) walls extending above rock matrix, and plunged internal chamber filled with hollow globular bodies of similarly granular wall structure [Credit NASA/JPL-Caltech /Univ of Arizona]. (C) For comparison, micrograph of sub-equatorial thin section (transmitted light) of a specimen of Late Devonian (Upper Silesia, southern Poland) volvocalean alga Eovolvox silesiensis [from 9] enclosing remnants of five daughter colonies (one arrowed) preserved in a degraded parent colony. The Martian specimens are approximately 1.5 to 2 mm in diameter, the scale for (C) equals 40 μ m.

Comparison

These spherical Noachian bodies are essentially similar, if not identical, with spherical compound structures shown in our previous report and compared directly with Late Devonian colonial volvocalean algae [3]. Such an affinity was proposed on the basis of similarities in morphological organization of the Martian structures with the Devonian microalgae, a suggestion strengthen in one case by the presence in the Martian form of internal hollow spherical object interpreted as remain of daughter colony [3]. Production of daughter colonies inside parental colonies in vegetative reproduction cycle is a unique feature of some colonial volvocaleans permitting unmistakably their classification as representatives of this group of green algae. It was however also clear during preparation of the first report that finding of only one specimen of Martian volvocalean-like structure with traces of purported singular daughter structure was by far not satisfactory to claim with certainty such a bio-affinity. Although among the studied Devonian colonial volvocaleans there are many with only singular daughter colonies (Figure 5), forms with several daughters also occur, like in the colony shown in Figure 4C see also [9,10]. Comparing the size and mode of distribution of the Devonian daughter colonies imaged in Figure 4C with the Noachian spherical hollow internal bodies illustrated in Figure 4 A and B, there is little doubt of the similarity of all these structures.

Additional examples of Noachian microalgae-like fossils and Terran analogues

In order to strengthen the previous claim [3] suggesting microalgae-like nature of selected newberries from the rim of Endeavour Crater (Matijevic Fm) further example of Martian biogenic structures from the same strata are presented below. Images of Martian objects resembling fossil Terran colonial volvocalean algae showing a spectrum of preservation phenomena are particularly usable for such a comparison.

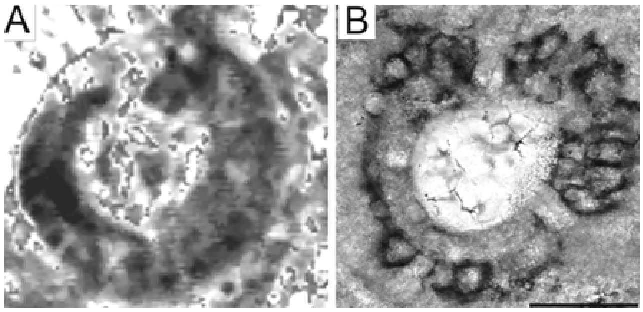

Figure 5: Martian (Noachian) microfossil-like object from the rim of Endeavour Crater compared with Terran Devonian analogs. (A) Opportunity Microscopic Imager photograph taken on sol 3094 at Whitewater Lake rock outcrop, Cape York. The image shows sub-equatorially sectioned spherical object exposed from the rock by the Rock Abrasion Tool (RAT). The object, approximately 1.5 mm in diameter, has well-delineated external and internal shape, and is composed of tightly adhering sub-globular to sub angular units enveloping a central chamber [Credit NASA/JPL-Caltech /Univ. of Arizona]. (B) For comparison, micrograph of sub-equatorial thin section (transmitted light) of a specimen of Late Devonian (Upper Silesia, southern Poland) colonial volvocalean alga showing colony organization similar to that visible in the Martian object. Noteworthy is the large singular daughter colony in the Devonian specimen tightly adhering the parent colony. Scale for (B) equals 100 μ m.

In Figure 5A, a Noachian newberry specimen is shown which in the report [3], Figure 5C was interpreted as an analog of the Late Devonian volvocalean microalga Eovolvox. Both structures were described as sub-equatorially sectioned hollow spherical objects. The example of the here shown Eovolvox specimen with large daughter colony closely adhering to mother colony (Figure 5B) permits suggestion that the Noachian form in Figure 5A may also represent remains of such a double ("sphere in sphere") colony (Figure 6).

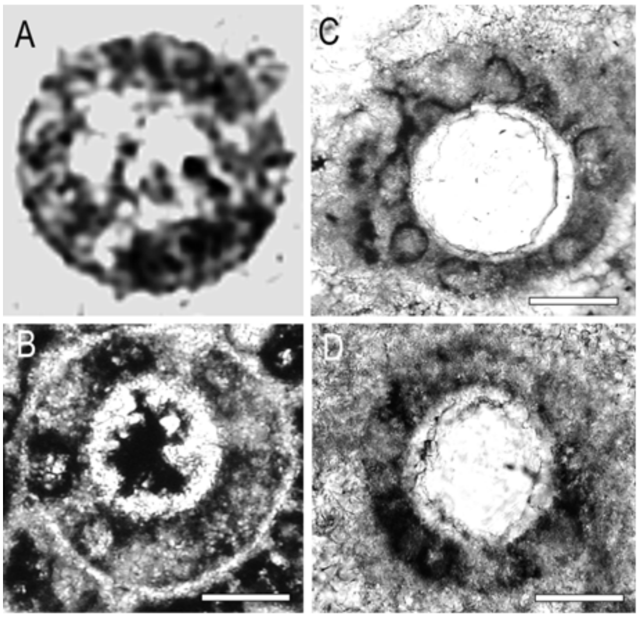

Figure 6: Martian (Noachian) microfossil-like object compared with Terran Devonian analogs. (A) Image of Martian spherical object taken by Opportunity Microscopic Imager on sol 3305 at Espérance rock outcrop, Cape York [Credit: NASA/JPL-Caltech/Univ. of Arizona]. This well-delineated and slightly degraded spherical body which was exposed by the Rock Abrasion Tool (RAT) is in part comprised of a peripheral layer of adhering globular units enveloping a central chamber. (B), (C), (D) For comparison, micrographs (transmitted light) of subequatorial thin sections of Terran post mortem calcified colonial specimens of volvocalean alga Eovolvox silesiensis from subsurface Late Devonian limestone of Upper Silesia (Southern Poland). Similarly as the Martian microfossil, the Devonian colonies are composed of peripherally arranged cells enveloping central chambers; noteworthy is the varying degradation of the Devonian colonies which strongly resemble the mode of preservation of the Martian object. The diameter of the Martian structure is ~2 mm, the scales for (B), (C) and (D) equal 100 μ m.

For increasing the number of Late Devonian volvocalean colonies, suggested by [3] as analogs for the Noachian biomorph (1M421595695EFFBY08P2955M2M3) imaged with Opportunity Micro Imager on sol 3305 (Figure 6A), three additional images of Eovolvox are illustrated in Figures 6B-6D. They are explicitly showing the spectrum of cells and colonies preservations: from such with spectacularly preserved shapes, through those with indistinctly visible cell shapes, to almost unrecognizable cells. The similarity of the Noachian object to fossils of these Devonian microalgae is striking and unmistakably pointing similarities of their degradation history (Figure 7).

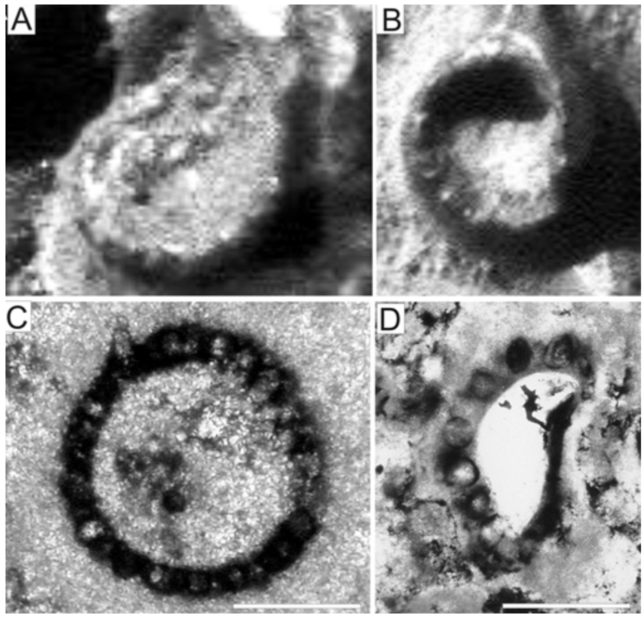

Figure 7: Martian (Noachian) microfossil-like object from the rim of Endeavour Crater compared with Terrestrial Devonian analogs. (A) and (B) MER Opportunity Microscopic Imager photographs taken on sols 3250 (A) and 3251 (B) at Kirkwood outcrop(Cape York) from weathered rock surface. Both images represent subequatorial sections of weathering exposed spherical objects composed, as the object illustrated in Figure 5A, of degraded peripheral layer of tightly adhering subglobular units enveloping a central chamber which in (A) enclose a few similarly subglobular units and in (B) is empty. (C) and (D) For comparison, micrographs of subequatorial sections of two specimens of Late Devonian (Upper Silesia, southern Poland) volvocalean algae to show incomplete preservation of cells comprising the colonies similar to globular units forming the Martian objects. [Credit for (A) and (B): NASA/JPL-Caltech/Univ. of Arizona]. Scale for (C) equals 100 μ m.

Two new examples of Noachian colonial volvocalean-like objects, exposed by weathering from Endeavour Crater rim (Matijevic Fm), are illustrated in Figures 7A and 7B. These sub-equatorially sectioned spherical objects of clear affinity with other previously described Noachian volvocalean-like fossils are showing partial degradation, distortion and asymmetrical deformation of individual cells and cell layers forming the colonies. Similar preservation phenomena are visible in sub-equatorial sections of colonies of Late Devonian volvocaleans illustrated for comparison (Figures 7C and 7D).

Remarks on mineralogy, depositional environment and taphonomy of the Noachian microalgae-like fossils

Not much information has been gained by Opportunity instruments concerning the depositional environment of Matijevic formation, the only pre-impact rocks examined at the rim of Endeavour Crater [46-48]. The spectrometric data inferred earlier from Mars Reconnaissance Orbiter (MRO) showed that they are in large part composed of phyllosilicates (ferric smectites implying formation in an aqueous environment of circum-neutral pH [5,49]. As Opportunity reached the area of Cape York with the outcrops of Matijevic formation rocks, the

Mössbauer spectrometer was no more functioning, and the mineralogical data obtained, beside those from spectral information collected by Mars Reconnaissance Orbiter, were limited to that supplied by the Alpha Particle X-ray Spectrometer (APXS) and Pancam (VNIR) spectra.

The Matijevic formation rocks have been extensively described by [5,46-48]. The matrix consists of very fine-grained clastic material of basaltic origin with various amounts of the ~2-4 mm-sized spherules. The local accumulations of the spherules form small, discontinuous ridges [48]. The spherules are mostly hollow, partially filled or solid, rather irregularly distributed in the matrix, and with weak indication of reworking. They are showing various resistance to weathering.

The Matijevic formation is interpreted as presumably pre-impact regional deposit of fine fall of volcanic eruption or distant impact. The matrix is high in SiO_2, P_2O_5 and Ni, and low in K_2O, TiO_2, and SO_3, while the spherules-rich targets are very high in SiO_2, high in Ni, low SO_3 and very low in P_2O_5, CaO and TiO_2 [48]. The chemical composition of the spherules is not much different from the spherule-rich matrix. Such compositional similarity may indicate accretionary origin of the newberries from volcanic ash clouds [5]. Otherwise much greater compositional differences between spherules and matrix should be expected for objects originated from impact-generated ash clouds or for concretionary bodies.

Basing on Rock Abrasion Tool (RAT)-determined specific grind energy, it has been concluded [5] that the newberries are harder than the embedding matrix, and that their shells are more resistant than their interiors. The APXS results over newberry-rich targets indicate a mild enrichment of Fe and decreases in Ca, Al, and Mn relative to the Matijevic fm matrix. The increase in ferric iron mineral crystallinity of probably the newberry shells and interiors relative to the matrix is consistent with the concretionary origin hypothesis [46]. Accretionary lapilli are described as consisting of the same composition as surrounding materials [50,51]. Finally, the subtle spectral differences between the RAT cuttings of abraded newberries relative to their RAT-brushed and wind-abraded surfaces provide evidence of more oxidized materials within their shells or interiors. This was interpreted as being more consisted with a diagenetic (i.e., concretionary) origin of these bodies (Figure 8) [46].

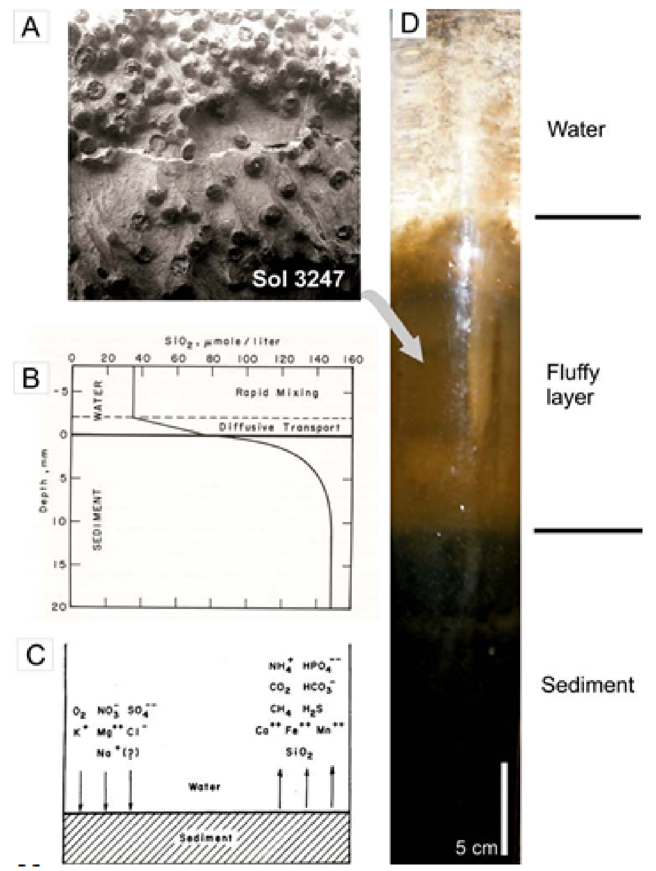

Figure 8: (A) Depositional environment suggested as plausible model for the origin of the Late Noachian microalgae-like fossils imaged by MER Opportunity from the Matijevic Formation at the rim of Endeavour Crater. (B and C) Basing on observations of chemical gradients characterizing sediment-water interface (benthic boundary layer) in many Earth's standing basins, it can be assumed that mineralization with silicate minerals of a settled post-bloom biomass of Noachian microalgae was enhanced in a viscous fluffy layer similar to that visible in (D) in a core sample taken from the bottom (water depth 64 m) in the quasi-marine Satonda Crater lake, Indonesia [52]. (D) Courtesy of Prof. Stephan Kempe, Technical University Darmstadt; (B) and (C) from [53].

As support for the idea of diagenetic origin of the "newberries", it would be interesting to evaluate a bit closer the conditions needed for precipitation of Fe^{3+} smectites in the Noachian wet environment. Phyllosilicates of the smectite group detected in Noachian and early Hesperian terrains on Mars can be interpreted to form under neutral to alkaline conditions [54]. When interpreted as early post mortem mineralized microalgae, the characterized shortly above microfossils of the Matijevic Fm can be explained as final products of processes occurring in water environment rich in chemical components and physical conditions necessary for authigenic formation of Fe silicates. Accepting Matijevic Fm sediments as deposits of stagnant (? lacustrine) water body, we may envisage the preservational environment for post bloom microalgae as a well-developed viscous fluffy layer (Figure 8D) at the sediment/water interface. For examples of fluffy layers in modern seas and lakes see e.g. [55-59]. Fluffy and other benthic boundary layers, beside increased concentration of particulate and fluid organic matter, are usually highly enriched in most chemical components [53] (Figure 8B, C) needed to initiate there precipitation of a variety of mineral phases, with phyllosilicates inclusively [60].

Authigenic phyllosilicates are known to enhance fossilization and preservational potential of soft bodied organisms [35,61-69]. Unanswered remains, however, the question concerning the oxic conditions during the formation of the Fe^{3+} smectite envelops on the Matijevic Fm microalgae. Observations in natural environments and in laboratory experiments showed that Fe-rich smectites may form in a broad spectrum of environmental oxygenation and therefore are not good indicators of the redox regime of their formation environment [70].

SUMMARY OF ARGUMENTS AND CONCLUSIONS

Beside the above presented comparative morphological observations, following sedimentary and taphonomic arguments are supporting biological nature of the above showed algal-like microfossils from the Matijevic formation:

The supposed microfossils and the surrounding matrix have different mineralogy what contradicts observations gathered from large number of volcanic lapilli and impact microtectites accumulations whose mineralogy is always identical with that of the matrix [50,51].

The distinct morphological diversity and well-defined shapes of the Matijevic Fm microalgal fossils differs from typically monotonous composition of rather irregular lumpy morphologies characterizing microlapilli and microtectites accumulated from massive ash fallout [51,71,72].

The varying lateral distribution density of the Matijevic Fm microfossils, which occur often in variously sized groups or clusters (but also as dispersed individuals), is reminding irregular deposits of post-bloom microalgae settled often on the bottom in the form of variously degraded macroflocs and macroaggregates [73-80].

Plastic deformations visible in some newberries and the differentiated, often asymmetrical degradation of individual specimens, is a phenomenon not observed in microlapilli or microtectites, but is typical for ancient early postmortem degraded and mineralized (calcified or phosphatized) microalgae [9-11,19].

Accepting at least part of the Noachian Matijevic Fm " newberries " as early post mortem with ferric smectite mineralized remains of post bloom microalgae, a stagnant lacustrine water body with relatively thick fluffy layer promoting mineralization and preservation of such decaying objects is suggested as most plausible sedimentary environment.

The morphological similarity of the Noachian Matijevic Fm microalgae-like fossils to some common Terran Paleozoic and modern microalgae might be suggestive for Martian provenance of the latter. Such interplanetary transport could have most probably happened during the time of the Late Heavy Bombardment (~4.1-3.8 Ga) a time corresponding with the Terran Paleoarchean era. Findings of Terran Early Archean aqueous deposits with remains of fossil microalgae morphologically analogous to those from Matijevic Fm could have been the best proof for such a hypothesis.

If what is written above is true, then the recent guides and advices [81-85] for researchers looking for ancient Martian life during the upcoming NASA and ESA 2020 missions could be, somewhat sarcastic, commented, that the main goal of these missions to find Noachian microalgae-like fossils-was already achieved by MER Opportunity on September 6, 2012 (Martian sol 3064), when it photographed and sent to Earth the first images of the "newberries" from Matijevic Fm. Nevertheless best success wishes are addressed to the upcoming 2020 missions focused on search for Noachian fossils, to find also those reminiscent of the microalgae-like objects found by MER Opportunity at the rim of Endeavour Crater.

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