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Interactive Comment

Interactive comment on "Comets, carbonaceous meteorites, and the origin of the biosphere" *by* R. B. Hoover

R. B. Hoover

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Reply to Klyce Interactive Comment on "Comets, carbonaceous meteorites, and the origin of the biosphere"

I would like to thank the reviewer for the comments on the manuscript. I am now preparing a revised version to re-structure the manuscript in accordance with the requests of the Referee. This revised manuscript will contain additional images and EDS spectral data of living cyanobacteria and the biomorphic microstructures that I am interpret as indigenous microfossils in Orgueil CI1 and Murchison CM2 meteorites. The complex and highly differentiated forms that have been found embedded in freshly fractured interior surfaces of these meteorites exhibit very recognizable morphological characteristics, sizes, and the distinctive specialized cells for nitrogen fixation (heterocysts) and reproductive stages (motile trichome segments or hormogonia, akinetes, and spores) as well as ecologically consistent microbial assemblages and consortia that are very well known to microbiologists and phycologists familiar with the filamentous Cyanobacteria (Cyanophyta under the Botanical code). These features include well-defined cylindrical or tapered filaments with the trichomes (uniseriate or multiseriate) that are sometimes encased within an external EPS sheath that may be either thick or thin and laminated or unlaminated.

In situations like that shown in Fig. 4, the empty hollow sheath that remains behind after the exit of the motile trichome can be seen and in other areas it appears as a collapsed sheath. The extracellular polysaccharide (EPS) layer on the hormogonia may be sufficiently thin to allow delineation of the cross-walls to be seen clearly enough to permit the shape and size of the internal cells to be estimated. In some cases the microfossils found in-situ in the meteorites are so well preserved that distinctive ultra-microstructures (e.g. fimbriae) can be seen at very high magnifications. These results are being prepared for other papers to be submitted to other peer-reviewed Journals. The images presented in this manuscript show clear evidence of specialized cells, life cycles and reproductive stages (e.g. heterocysts, akinetes and separation of short segments of trichomes that have emerged from the sheath). The array of diverse microstructures found (sometimes seen in the same field of view and in immediate proximity to each other) are entirely consistent with the known morphological characteristics and life cycle habits of the genera and species of well studied cyanobacteria and for this reason these forms are interpreted to represent morphotype of these microorganisms.

There are no known abiotic processes that have ever been shown to mimic such an extensive suite of recognizable biogenic features and therefore these forms are interpreted as the microfossils of microorganisms that grew on the parent body of the meteorite. The detection of rich assemblages of the mineralized remains of these filamentous microfossils with well known features of cyanobacterial mats provides suggests that pools of liquid water must have existed for some period of time on the parent body in order to permit the growth and formation of the mat structure. If the parent body

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was a low mass object such as a water containing asteroid or comet, then a gravity vector must have been produced, possibly from the spin of the parent body, to produce the sediment/water interface that would be needed for the formation of mat-like assemblages as seen in Fig. 6.

Furthermore, the mineralized remains of these microfossils have been found embedded in the rock matrix and are clearly indigenous. EDAX elemental analyses and 2D x-ray maps reveal that they exhibit chemical properties that link them to biogenic forms (e.g., biogenic elements such as C, O, S, and P) as well as to the mineral meteorite matrix (e.g. Fe, Ni, Si) in which they are found. However, many of them exhibit elemental distributions are distinctively different (lacking in N and with anomalous C/O ratios) from recent living cyanobacteria or cryopreserved microorganisms that are found in ancient ice or permafrost). The C/O ratios are similar to that found in bituminous coal and the carbonized remains of Proterozoic microfossils that Dr. Rozanov and I have found preserved in the Devonian graphites of Botogol, Russia.

Regarding the problem of contamination, I am entirely convinced that these forms found in freshly fractured interior surfaces of the carbonaceous meteorites are valid indigenous biogenic forms that clearly cannot be logically dismissed as recent (i.e. post-arrival) contaminants. During the past 38 years, I have worked with many distinctly recognizable microfossils (e.g., diatoms, radiolaria, silicoflagellates, forams, and acritarchs). In the Astrobiology Laboratory at NASA/NSSTC, we routinely work with a wide variety of living anaerobic and aerobic microbial extremophiles (bacteria, archaea and cyanobacteria) and I have employed rigorous microbiological techniques and methods to prevent contamination and developed methods to recognize contamination when it is present.

Since, I was very well aware that all prior reports of the detection of microfossils in meteorites have been dismissed as either coating artifacts or surface contaminants (e.g. pollen grains, etc.) extreme care was taken to make certain that these types of problems would be avoided. It is still widely accepted in the scientific community that the carbonaceous meteorites are extensively contaminated with pollen. However, during this study over an entire decade of research, I have not yet encountered a single recognizable pollen grain in any of the carbonaceous meteorites.

The Environmental Scanning Electron Microscope was used with freshly fractured, uncoated, interior surfaces to protect from surface contaminants and coating artifacts. Contaminants can easily be introduced via the tools, containers, sieves, acids and liquids employed during the cleaning and microfossil extraction processes. Contamination from these effects clearly posed great problems to the early researchers seeking to extract the "acid-resistant microfossils" from meteorites and archaean and Proterozoic Earth rocks. The powerful tools of the Environmental and Field Emission Scanning Electron Microscopes made it possible to effectively search for microfossils in-situ without ever subjecting the meteorites to any contact with acids or any other liquid.

The final comment of the reviewer requests an explanation for why the scientific establishment seems to ignore this evidence for microfossils in meteorites. Perhaps it is because these results are still not extremely widely known and publications such as this will help make this information more widely available. The prior reports of evidence for microfossils in meteorites have been strongly criticized by the scientific community. The initial evidence provided by of George Claus and Bartholomew Nagy has been generally dismissed as resulting from "Pollen Contaminants." This interpretation of their results is absolutely not supportable by the scientific literature. Although they did publish one image of a form that was clearly a pollen grain contaminant, the vast majority of the spherical "organized element" forms they found was most certainly indigenous to the meteorites and were not pollen contaminants. This was initially shown in the work of Rossignol-Strick and Barghoorn (1971) as described in the manuscript. Furthermore, I have found many spherical forms that are similar in size and configuration to many of the "organized elements." These bodies were found in-situ in several carbonaceous meteorites (e.g., Orgueil, Murray, Nogoya, Tagish Lake, and Murchison) during the research carried out at NASA/NSSTC since 1997. Spherical acritarch-like forms (some with apparent pylomes and processes) were found during independent studies carried out at NASA/MSFC and by Dr. Rozanov at the Paleontological Institute of the Russian Academy of Sciences in the Vendian (Lower Cambrian) black shales of Altay-Sayan as well as in the Orgueil and DAG 749 CO3meteorite (Hoover et al., 1999) and these quite possibly represent microfossils. It is also absolutely clear that there are large numbers of much more simple spherical forms (many of which are similar in size and morphology to some of the "organized elements") and minute "nanobacteria-like" bodies present in the carbonaceous meteorites. It is by no means certain that either the "nanobacteria" or the larger "organized element"-like forms found in meteorites represent valid microfossils. While it is true that there are many biological entities (e.g., coccoidal bacteria, cyanobacteria, and algae) that are similar in size, size range, and morphology to these forms, there are also many abiotic mimics in the same size range with simple spherical morphology. Although they could be biological, they may also be abiotic and caution has led us to carefully photograph and document these forms for latter study but at this point it is impossible to draw any solid conclusions regarding their biogenicity.

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