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Biogeosciences Discussions

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

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In large parts the manuscript is a review about various aspects of astrobiology. It deals with terrestrial life in extreme conditions, some general statements of the origin of life and a introduction into comets with respect to there delivery of water and pre-biotic compounds to Earth. The author develops a scenario in which organisms can survive during the perihelion approach of a comet in wet pockets inside the comet nucleus.

The author applied Field Emission Scanning Microscopy to investigated CI and CM carbonaceous chondrites which are among the most primitive available material. He claims the detection of indigenous microfossils based on the surface morphology of structures on fresh broken surfaces of the Murchinson (CM) and Orgueil (CI) meteorite.

I have major concerns about the manuscript as it does not fulfill the formal requirements of a scientific publication. The manuscript is quite unfocused. The text has to be

structured, and introduction, results and discussion have to be separated more clearly. The author claimed the detection of indigenous microfossils in carbonaceous chondrites. Such a finding would be of outstanding importance and can not be introduced through the backdoor into scientific literature in review character. Only morphological similarities are presented as an argument that the investigated structures actually represent fossilized bacteria-like organism. The author did not consider an abiotic origin, which would be the most straightforward explanation, as the investigated structures are composed of Mg and S. It is confusing, that the author argues that the lack of bio-indicators document a fossilization process, and hence concluded that the investigated structures represent extraterrestrial microfossils. The presented arguments **do not** justify the detection of fossilized remains of extraterrestrial life.

At least major revisions of the manuscript are necessarily required. The author has to decide if the manuscript will be a strictly theoretical article about life in comets or if the main intention is to report the detection of extraterrestrial microfossils in carbonaceous chondrites. In case the author want to write about the detection of microfossils in carbonaceous chondrites further investigation are absolutely necessary. At least some arguments have to be presented that the investigated structures are not of abiotic origin but represent the remains of living organisms. Such a manuscript should focus on the identification of microfossils. Redundant passages have to be removed. A petrologic and geochemical introduction of the investigated meteorites should be added. If the author intends to write a theoretical article about life in comets the following comments should be considered.

The author assumes that carbonaceous chondrites represent fragments of comets. This is a controversially discussed theory. The author has to mention the different opinions of the scientific community accordingly.

The author proposed a scenario in which water may be present and organism might survive in a comet nucleus during its perihelion passage. It has to clarify, if he means survival or origin of life. If he means surviving, it has to be discussed how the comet got

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"infected" with life. If he means originating the environmental conditions in the parent body which led (in his opinion) to the origin/evolution of life have to be discussed.

The dynamical lifetime of comets is in the order of 10^7 years, and their physical lifetime (distance from sun <2.5 AU) is only in the range of 10^3 years (Levison and Duncan 1997, Icarus, 127). Thus, an origin/evolution of organisms would be restricted to only a few thousand years (integral of the time near perihelion) in which the comet (surface) is heated to high temperatures by solar insulation. For a given area of a comet nucleus a total of a few thousand years is an optimistic upper limit. The comet is shrinking during every perihelion passage, and the temperature profile is affected accordingly for a given area. The scenario invoked by the author would imply an fast origin/evolution of organisms in a laterally strongly restricted and thermally highly variable environment. As the chemical composition of CI chondrites are considered representative for the solar nebular any significant elemental redistribution can be excluded. Thus, everything necessary for the evolution of life had to be in place.

Another logic consequence of the authors hypothesis is a co-evolution of life on at least three different parent bodies (Earth, and the parent bodys of Murchinson and Orgueil), as the Murchinson and Orgueil meteoroid was on an highly eccentric orbit only for the last few million years. The time span between origin of the solar system and accretion of cometary material ($\sim$4.56 Ga ago) and the time in which these material acquired an eccentric orbit (few million years ago) it is at very low temperatures!!!. The author has to discuss the implications, that at least three different morphotypes of aerobic and photosynthetic terrestrial organisms can be found in an environment like inside carbonaceous chondrites. It has to be mentioned that aerobic organisms appear late in the evolution of life on Earth, and the first terrestrial organisms considered oxygen poisonous.

The identification of microfossils based only on morphological arguments is questionable. Especially as the manuscript offers only information concerning surface morphology and not internal structures. After investigating structures resembling remark-

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ably preserved bacterial and cyanobacterial microfossils from ∼3.5 billion-year-old terrestrial sediments Brasier et al (Nature 416, 2002) concluded: *"Ancient filamentous structures should not be accepted as being of biological origin until all possibilities of their non-biological origin have been exhausted".* In the reviewed manuscript a non-biological origin of the investigated structures is not considered by the author.

The author described the treatment of the investigated samples and how he tried to avoid terrestrial contamination. However, the investigated meteorites reside on Earth for a considerable long time of 142 and 37 years for Orgueil and Murchinson meteorite respectively. Meteorites are subject to weathering and contamination even during curation. Therefore, a contamination of meteorites with terrestrial organics can not be excluded. The most straightforward explanation for organisms which look similar to terrestrial ones is that these organisms actually are of terrestrial origin. In the introduction the author emphasizes that terrestrial life can be found in nearly all environments on Earth. Thus, a contamination with terrestrial organism of meteorites partly composed out of organic matter is highly likely. The author may like to point out that the nearest source of pristine meteorite samples of carbonaceous chondrites is on the surface of Moon.

These are some major concerns about the hypothesis of life in comets which should be addressed by the author. Furthermore I have some comments to certain sections of the manuscript.

P. 27, line 22: *"Excellent candidates for suitable environments..."*. In planetary bodies as Mars or the moons Io and Europa temperatures of deep crustal rocks can be assumed to remain constant for a considerable long time as they are heated by internal sources or tidal forces. The nucleus of comets does not fit into this listing as only its surface is heated by solar insulation and temperature is highly variable.

P.28, line 16: *"The ability of microorganisms to remain viable in..."*. Again the nuclei of comets does not fit into the listing together with ice caps on Mars and icy moon of

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Jupiter and Saturn. Additionally, high vacuum and extreme cold environments are not *"ideal sites"* to search for potentially viable microorganism.

P. 28, line 21 *"Gas hydrates..."*. Reference missing

P. 31, line 25: *"Comets are among the most interesting and important bodies in the solar system.."*. This is a personal opinion of the author, and most people would think in this context of Earth, Moon and Sun.

P. 32, line. 6: *"dominant paradigm..."*, Not a good expression. The cited references are rather old and during this time only limited data of comets was available.

P. 32, line 11: Describe the significant differences (with respect to the manuscript) between *"dirty snowballs"* and *"icy mudballs"*.

P. 33, line 2: Reference missing

P. 33, line 3: Reference missing

P. 33, line 21: Reference missing

P. 33, line 25: *"The deuterium enrichment of seawater..."*.It remains unclear why a two times lower deuterium contend of seawater compared those of comets indicates a cometary origin. Please clarify and/or give according references.

P. 35, line 15-19: Reference missing

P. 36, line 13-20: References missing????

P. 37, line 22: The deep impact experiment ejected large amount of dust *"too many to have been pulverized by the impact..."*. This argues in favor for a comet being compoed of loose sediments and not cemented ones.

P. 37, line 25: What is the reason to mention the grain size and composition of the Orgueil meteorite? Geological materials formed by different processes can have similar grain size. Who measured the grain size and composition of the Orgueil meteorite? If

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this are results of the authors work it has to be moved to the section results.

P. 38, line 7: As the gravity of the comets is very low (escape velocity of only a few m/s) also weakly consolidated sediments can form surfaces with a considerable relief. This has to be discussed. Additionally, if the comet would be mantled by a rigid crust large fragments are expected to be ejected from near the crater rim.

P. 38, line 16: *"Hoover et al. (1986, 2001, 2004a, 2004c) have suggested that pockets and pools of..."*. Where do the microorganism came from? Captured by the comet (i.e. during passage of a planetary atmosphere) or evolution of life inside these pockets? Is there sufficient time for the origin of life in such pockets?

P. 39, line 13: *"This suggests..."*. Please change from comets and meteorites to comets and asteroids. It should be mentioned that the geological record on Earth is limited to $\sim$3.8 Gyr.

P. 39, line 14: *"Evidence for indigenous mineralized remains..."*. The conclusions of the current manuscript can not be presented in the introduction as a given fact.

P. 41, line 18-27: CI chondrites are broadly accepted to represent the most primitive available material of the solar system. Hence, no significant elemental redistribution can be detected and aqueous activity on the parent body is, thus, strongly limited.

P. 42, line 1: Please mention that the results of McKay 1996 are not broadly accepted and shortly mention according publications which investigated ALH 84001.

Paragraph 5.3 and 5.4: General statements, results and interpretation are badly mixed up. Result has to be presented separately without any interpretation. The author identified structures of a given morphology and composition. In the discussion it had to be argued if these structures are of biotic or abiotic origin. Generally, I think it is problematic to use names of terrestrial organism to describe morphological structures of extraterrestrial origin. Redundant information including conclusions of other author distract the reader from the hard facts and should be omitted in the section results.

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P. 47, line 7: *"Since a 16s rRNA sequence could not be carried out..."*. A biological origin of the investigated structures could not be determined by the method.

P. 17, line 19: *"The total absence of nitrogen and phosphorus..."*. The chemical composition of the investigated structures indicate an abiotic origin. It is essential that this possibility is discussed in a manuscript were the detection of extraterrestrial microfossils is claimed. Additionally it has to be stated explicit that a biological origin of the structures is deduced only by surface morphology and not by internal structures.

Figure 5: The EDS spectrum of Figure A should be presented too. What is the detection limit for carbonate and phosphor in the measurements?

Figure 5: shows the investigated structures, which are interpreted by the author to represent *"well-preserved and mineralized remains of microfossils..."*.

Interactive comment on Biogeosciences Discussions, 3, 23, 2006.