Biogeosciences Discussions, 3, S81–S88, 2006
www.biogeosciences.net/bgd/3/S81/
European Geosciences Union

Biogeosciences
Discussions

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

R. B. Hoover

Received and published: 23 March 2006

Reply to Comments by J. Toporski regarding the manuscript "Comets, carbonaceous meteorites, and the origin of the biosphere"

I thank Dr. Toporski for taking the time to review this manuscript and providing these comments, which help me to recognize other areas that should be explained more thoroughly in the revised text. Science continues to advance as new knowledge is accumulated and it is important that the results and ideas presented must be able to withstand critical challenges in order for their validity to be tested. Dr. Torposki has raised a number of issues in this review and I am happy to have this opportunity to discuss them. For science to advance it is necessary for it to be able to revise views, even if they are widely held and have long been generally accepted by the scientific community, when new data is obtained that shows them to be invalid.

Pg. S23, Par. 1. Although it has long been held that comet nuclei are sufficiently

Full Screen / Esc

Print Version

Interactive Discussion

Discussion Paper

porous that water ice changes directly from the solid to the gaseous state when the temperature of the icy nucleus exceeds the 200 K sublimation temperature of ice in a vacuum. Since it is generally accepted that life requires liquid water, the scientific community has generally adopted the view that microbial life could not exist on comets. However, the results obtained by high resolution imaging and IR spectrometry of the nuclei of a number of comets by spacecraft (comet P/Halley by Vega 1, Vega 2, Giotto; comet Borrelly by Deep Space 1; comet 81P/Wild 2 by Stardust; and comet 9P/Tempel 1 by Deep Impact) have revealed structural features, chemical compositions and temperatures that are dramatically different than what was expected by the world's leading authorities on cometary nuclei. Deep Impact produced movies showing flaring and geyser-like jets erupting from the nucleus of Tempel 1 even though the comet was at 1.5 AU. Sunshine et al. (2006) have just published data showing evidence for water ice at the surface of the comet. The images reveal sharply higher albedo in large regions (total area 0.5 km2) where chunks of the black crust may have blown off and temperatures of the surface that range from a high of 330 K (57 C) to a low of 280 ś8 K (-1 C to 7 C) which is the temperature at which the phase transition occurs from ice to liquid water. Water geysers have also been observed from Saturn's tiny moon Enceladus. All of these results provide evidence for the existence of liquid water on comets as they near perihelion, which is one of the major points of this manuscript. The is important evidence in support of one of the primary thesis of this manuscript, because if comets are capable of supporting microbial life then their role in the formation of the Earth's biosphere may have been much greater than is currently accepted and widely held view of the endogenous origin of life on Earth may in fact be invalid.

Pg. S23, Par. 2. The reviewer objects to the interpretation of Fig. 1.c. as cyanobacteria from the 3.5 km depth of the Vostok ice core and argues that this is not "known to be the preferred habitat for this group of organisms" and suggests, "dust fibres would show similar morphologies and size ranges." The reviewer also wonders why the interested reader should trust this interpretation. This is a fair question and perhaps additional text is needed to explain. The research on the deep Vostok ice material was carried out in collaboration with Dr. Sabit Abyzov, the pioneer of the study of ice-entrapped microbiota in the ancient layers of the Antarctic glacier. The interior core samples that were studied had previously prepared by him using the sterile technique to extract the central part of the ice core and as he has previously described (Abyzov, 1993). The samples were hand carried by him to the Astrobiology lab at NASA/MSFC and fractured under a sterile hood and the interior ice was then immediately placed on a flame sterilized polished aluminum stub mounted on ESEM cold stage. The temperature of the cold stage was then raised and the microorganisms trapped within the ice were observed and studied as the water melted away from them. Therefore, I know that these specimens were indeed contained within the deep ice cores and they are indigenous rather than recent laboratory contaminants. Therefore the forms from the deepest layers of the core are almost 400,000 years in age. “Dust fibres” such as lint, cotton fibrils from clothing, etc. are common in the modern environment but would not have been an expected contaminant on the Central Antarctic Ice Sheet several hundred thousand years ago. However, there is no reason to suggest that cyanobacteria would not have been as common in the snow and ice of central Antarctica then as they are now. Cyanobacteria are the predominant biota of the cold polar environments and the central Antarctic Ice Sheet. They are the primary colonizers of glacial moraines after ice sheets retreat and they play a primary role in carbon and nitrogen fixation of polar desert soils (Vincent, 2000). They are the primary photoautotrophs and microbial biomass dominants in lake sediments with species of Lyngbya, Plectonema, Phormidium, Calothrix and Oscillatoria and they frequently form thick mats under perennially ice-covered lakes (Vincent, 1988). I have personally collected cyanobacteria and diatoms that were growing in thin films of liquid water surrounding dark sun heated rocks in the Thiel Mountains of Antarctica when the surface air temperature was -40 C. I did not suggest in the manuscript that the cyanobacteria and diatoms shown in this figure were carrying out active metabolism while in the deep Vostok ice but rather that they were present in the ice. We have previously published in the peer-reviewed scientific literature evidence for cyanobacteria and diatoms entrapped in the Deep Antarctic ice cores and this paper (Abyzov et al., 2004) is referenced in the manuscript (Pg. 32, line 27. In Fig. 1.c. the filaments have broken and cells can be seen to have emerged from the fractures in the filaments. In light of this comment, I will consider include an additional figure showing the appearance of filaments and cells of the living cyanobacterium Plectonema wollei that I collected in Lake Guntersville, AL and which I have maintained in culture in the NASA/NSSTC Astrobiology laboratory.

My interpretation of the filamentous forms (shown in Fig. 1 from the deep ice at Vostok and in Figs. 4, 5, and 6 from the Orgueil and Murchison meteorites) as morphotypes of cyanobacteria has been heavily guided by a careful study of the extensive literature on this wonderful group of microorganisms. Cyanobacteria. During the past 8 years, I have had the opportunity to work on a variety of microbial extremophiles with Dr. Elena Pikuta and this work has resulted in the description of several new species in the peer-reviewed Journals, Extremophiles and the International Journal of Systematic and Evolutionary Microbiology. On some occasions the early phases of that work was first presented and published in the SPIE volumes as well. My understanding of living and fossil cyanobacteria and microbial extremophiles has benefited tremendously from the many helpful discussions with my friends and colleagues.

Abyzov, S.: Microorganisms in the Antarctic Ice, in: Antarctic Microbiology, (E. Imre Friedmann, editor), Wiley-Liss, New York, pp. 265-295, 1993.

Abyzov, S. S., Hoover, R. B., Imura, S., Mitskevich, I. N., Naganuma, T., Poglazova, M. N., and Ivanov, M. V.: Use of different methods for discovery of ice-entrapped microorganisms in ancient layers of the Antarctic glacier, Advances in Space Research, Cospar 33, 1222-1230, 2004.

Vincent, W. F.: Cyanobacteria Dominance in the Polar Regions, in: The Ecology of Cyanobacteria. Their Diversity in Time and Space. (B. A. Whitton and M. Potts, editors), Klewer Academic Publishers, Dordrecht, The Netherlands, pp. 321-340, 2000.

Vincent, W. F.: Microbial Ecosystems of Antarctica, Cambridge University Press, Cam-

bridge, pp. 1-304, 1988.

Pg. S24, Par. 2. The reviewer suggests that the form shown in Figure 2 "shows all the features of a mineral grain and suggests that a valid alternative interpretation is that it in "an exotic mineral." I strongly disagree. Chemistry plays the paramount role in the identification of any species of mineral. Gold is a noble and there is a very limited group of mineral species that contain this element. There are some 50 species of gold minerals known, many of them are Gold-Tellurium complexes like Calaverite (AuTe2), Bilibinskite (PbCuAu3Te2), or Nagyagite (Pb5Au(Te,Sb) 4 S5-8). Gold also occurs in minerals with silver, bismuth, or antimony and sulfur. There are only two known mineral species that contain both gold and oxygen (Auroantimonate, AuSbO3) and an unnamed hydroxide of gold and antimony Au2SbO2 (OH4). However, there has never been found on Earth a species of gold mineral, which contains gold with either Uranium, or with Carbon, or with Phosphorus. For this reason, I cannot in good conscience suggest that this is some kind previously unknown "exotic mineral." Bioaccumulation and bioleaching of both gold and uranium is a well known to microbiologists and it is used extensively for the extraction of gold from low-grade ores in the process known as biomining. I referred to the form, as an "exotic microorganism" because I do not know what genus or species it is and I am not even sure that it belongs is a prokaryote. I will consider adding an image of a recognizable prosthecate bacterium (Caulobacter sp.) that has also bioaccumulated gold.

Pg. S24, Par. 3

There does exist hard data in support of the newly obtained evidence for water on comets as has been previously described. It is not a "logic leap" to assert that if there is liquid water, biogenic elements, and a source of energy microbial growth can take place. That is the way it works everywhere on Earth. If we were to discover that life exists on earth but nowhere else in the Cosmos that would be a most astonishing result. Nowhere in the manuscript do I assert that the consequence of possible microbial life on comets is the origin of life on Earth. It could well be that the microbiota that are found in the carbonaceous meteorite grew on the parent body (water bearing comet or asteroid) but yet arrived on the parent body as a result of an impact ejection process lifting viable microbiota from Earth and placing them into a debris field where they were later accreted by the parent body.

Pg. S 25, Par. 1. I am aware of the potential problem of microbial contamination. I have already described in the peer-reviewed literature a fungi contaminated sample of Murchison that was received from the Field Museum. It was possible to determine that the sample was contaminated with recent fungi by the elemental composition of the fungal hyphae and by their behavior in the FESEM beam. I sent this sample to Dr. Andrew Steele while he was working with David McKay and specifically told him that it contained a known recent fungal contaminant.

In the revised manuscript, I will provide more information about this problem and to the methods that can be used to differentiate recent contaminants from indigenous microstructures. I will also add a section on biogenic elements, biominerals, minerals of the carbonaceous meteorites. I have studied abiotic and naturally occurring epsomite samples of fibrous and crystalline epsomite from Spain, the United Kingdom (provided by the Museum of Natural History, Paris) and New York (provided by the W. M. Keck Earth Science Mineral Engineering Museum, Reno) as well as freshly collected native Epsomite from Poison Lake, Washington, USA. However, just as with the gold situation, epsomite is a mineral species that contains only Mg, S, and O. Actually, the magnesium sulfate in the Orgueil meteorite can change to different hydration states (and therefore dfferent mineral species) as a result of exposure to atmospheric moisture. This effect can defrade the mineralized remains after they are exposed unless great care is taken to keep them in vacuum or in a dessicator.

There is only one mineral species known that contains Mg, S, O, S, and P. It is the very rare mineral:

Borickyite: (Ca, Mg)(Fe,Al) 4 (PO4)2OH8.4-5H20

This mineral also contains calcium and higher levels of Aluminum. The EDS analysis indicated that these elements absent in the Orgueil filament and consequently this exotic mineral is excluded as a possible candidate to explain these mineralized remains in the Orgueil meteorite.

High resolution images ESEM and FESEM data is presented in this paper in which for the detailed morphology and elemental composition as determined by Energy Dispersive X-ray Spectroscopy analysis of a complex suite of biomorphic microstructures that I have found embedded in freshly fractured interior surfaces of the Orgueil and Murchison carbonaceous meteorites and which I interpret as indigenous microfossils. I have discussed these images and EDS spectral data of the biomorphic microstructures that I am interpreting as microfossils in detail with a number of noted meteoriticists, cosmochemists, and mineralogists and am indebted to them for their helpful comments and suggestions. These include mineralogists at the Keck Museum in Reno, Nevada, Dr. Claude Perron and co-workers at the Museum of Natural History in Paris and Academician Eric Galimov and co-workers at the Vernadsky Institute in Moscow. I have also discussed the Orgueil and Murchison forms with Paleontologists (Alexei Rozanov, Elena Zhegallo, and Galina Ushatinskaya at the Institute of Paleontology in Moscow) and with microbiologists with extensive at knowledge in the fields of microbial extremophiles and cyanobacteria (Academician Georgi Zavarzin, Academician Michael Ivanov, and Ludmilla Gerasimenko of the Institute of Microbiology, Moscow); Rosemarie Rippka Herdman of the Pasteur Institute, Paris, Richard Castenholz of the University of Oregon, and Ann St. Amand, President of Phycotech, Inc.). These individuals all have great knowledge of cyanobacteria they have helped to educate me on the important features concerning the taxonomy and characteristics of cyanobacteria. Furthermore, they have never indicated that they doubt that these complex forms represent the remains of cyanobacteria and other filamentous forms that are known to be prokaryotic mat community components or the degraded remains of polysaccharide sheaths of filamentous prokaryotes. It is very important to note that just as diatoms can be identified to genus and species on the basis of the size and morphological characteristics of the frustule alone, so too can the cyanobacteria be keyed to the family, genus, and species level on the basis of the morphology and structural characteristics of the cells, filaments, sheath, trichomes, and specialized cells. Phycologists do this on a daily basis and do not require (and very rarely use) the molecular methods (such as 16S rDNA gene sequences) to carry out the identification of the organism. Good scientific practice must always be the objective study of natural phenomena unimpeded by preconceived notions and dogma. Hence, their study does constitute a valid area of scientific research in the multidisciplinary field of Astrobiology.

These biomorphic microstructures do exist in the carbonaceous meteorite and they can be found by anyone who conducts a careful search. I would be pleased to invite the referee (or the any of the Editors or other reviewers) to come to the Astrobiology Laboratory at the NASA Marshall Space Flight Center and I will fracture fresh samples of the Orgueil and Murchison meteorites. The new samples will be examined in the FESEM to demonstrate the existence of these biomorphic microstructures that are found embedded in freshly fractured the rock matrix and which have elemental compositions that are inconsistent with known minerals and consistent with mineralized biogenic forms.

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