Biogeosciences Discuss., 11, C8706–C8709, 2015
www.biogeosciences-discuss.net/11/C8706/2015/

Biogeosciences
Discussions
Open Access

Interactive comment on "Fossilized bioelectric wire – the trace fossil *Trichichnus*" *by* M. Kędzierski et al.

M. Kędzierski et al.

mariusz.kedzierski@uj.edu.pl

Received and published: 12 February 2015

We are grateful to Referee #2 for remarks which stimulated us to clarify some of our ideas. Referee #2 claimed that trace fossil Trichichnus "[...] might or might not be interpreted as remains of Thioploca filaments and indications of framboids that might or might not have been colonized by nanowire forming bacteria.", and continues [...] the hypothesis proposing the function of the structure as electric wires is not supported by the data. Though nothing in the data set contradicts the idea, my point is that idea is not needed to explain the Trichichnus fossil scientifically." Indeed, we do not need to explain Trichichnus as an electric wire. We consider this trace fossil as a remnant of the Thioploca-like bacterial mat. Such starting point entails further considerations that brought us to (bio)geobattery idea. Actually, there are two important points of our

manuscript, partly time-related, listed and discussed below:

1) Thioploca-like bacteria as possible Trichichnus trace maker None of the known organisms can produce Trichichnus-like spatial structure visible in our CT scanner pictures, except for large sulphur bacteria constructing a long and dense mat with vertical filaments reaching the Trichichnus dimension. Therefore, we narrowed our interpretation to Thioploca-like bacteria. At the present stage, the interpretation of Thioploca-like bacteria as the Trichichnus trace maker is based only on a rough comparison of 3D pictures.The similarity is striking and in our opinion this is the best explanation of origin of this trace fossil. In addition, Thioploca-like bacteria link different chemical zones in the sediment what is important when the potential of Trichichnus to facilitate an electron transfer is regarded. As referee #2 says "[..] the interpretation of the Trichichnus fossil as remains of Thioploca sheets might be a convenient alternative to the classical interpretation [..]".

2) transformation of Thioploca-like sheaths into Trichichnus, including their bacterial consortia and iron sulfide infilling, which could serve as "bioelectric cables". Trichichnus is a unique place where several bioelectric processes can be met, both these related to strictly biogenic processes and those which combine bacteria and minerals. The filamentous forms of the family Beggiatoacea (comprising Thioploca spp.) were just pointed out as the main direct competitors to cable bacteria (see Nielsen and Risgaard-Petersen, 2015) In addition, Thioploca's sheaths are inhabited by consortia of different bacteria (Kojima et al., 2006; Teske et al., 2009) or even protists (Buck et al., 2013). Positive hybridization with probe CoSRB385 points out that these consortia are related to members of deltaproteobacterial family Desulfobactereaceae, in competitive hybridization with almost identical (single mismatch) probe InSRB385 designed for families Desulfobulbaceae (Malkin & Meysman, 2015) and Desulfovibrionaceae (Teske et al., 2009). Close relationship between Thioploca and iron sulfides is observed already at the early stages of bacterial mat formation. Studies of Thioploca spp. from the Bay of Conception showed that filaments of the short-cell morphotype disappear

from sheaths during autumn/winter time and these empty sheaths are stained with iron sulfide (Schulz et al. 2000; we add this paper to references). A complex electroactive biofilm, interconnecting bacterial cells and iron sulfide surfaces (see refs. in the manuscript), can form the long-distance wires reaching further than it has been documented, so far. Pyrite (iron disulfide) framboids which typically infill the Trichichnus trace maker can extent electron transfer into later stages of diagenesis (a model described in the last chapter of the manuscript), when the metal semiconductor (pyrite wire in this case) crosses over the redox boundary, and fulfills the geobattery idea. Sulfur in iron sulfide framboids results from bacterial (typically Desulfovibrio desulfuricans) sulfate reduction, is sometimes modified by bacterial sulfur oxidation.

Referee #2 expects us to tone down the Trichichnus-biogeobattery idea because we do not have a substantial evidence. However, the idea is always a good starting point. There are not many or, better to say, there are practically no examples of palaeogeobatteries. In our paper, we present a potential ancient place where several bioprocesses related to electron transfer in sediment could proceed. Number of evidence for such processes, both in the field and laboratory investigations, has been growing significantly for last few years. Development of new technologies, e.g. multipurpose electrodes which combine reactive measurements with electrical geophysical measurements (Zhang et al., 2010) opens new frontiers in monitoring microbial processes in sediments. We believe that our idea enhances special attention to Thioploca's endobionts in respect of their electron exchange along the cell-to-mineral wires. The fossilized filamentous sulphur oxidizing bacteria operating at the oxic-anoxic interface are reported even from the Palaeoproterozic (e.g., Hiatt et al., 2015). However, we should be aware that discovery of fossilized "wires" that operated in sediment alone can be difficult. Since a "cable bacteria" trigger a rapid oxygenation of the sediment, they also allow a bioturbating macrofauna to colonize the bottom in the next step and to destroy them mechanically (e.g., Malkin et al., 2014). It seems that Trichichnus is the only record of bioelectrical processes in the fossil state due to deep-tier occurrence of the Thioploca sheaths far below range of most bioturbating organisms, i.e., at the

depth of 20–30 cm.

The sentence (p. 17715, l. 19-20) "Regarding Thioploca sulphur bacteria it is interesting to note that bacterial species Desulfitobacterium frappier is capable of both reducing [...]" is rephraseed into "It is interesting to note that other sulphur bacteria species Desulfitobacterium frappier is capable of both reducing [...]".

References:

Hiatt, E.E., Pufahl, P.K. & Edwards, C.T., 2015. Sedimentary phosphate and associated fossil bacteria in a Paleoproterozoic tidal flat in the 1.85 Ga Michigamme Formation Michigan, USA. Sedimentary Geology, 319: 24–39.

Malkin, S., Rao, A.M.F., Seitaj, D., Vasquez-Cardenas, D., Zetsche, E.-M., Hidalgo-Martinez, S., Boschker, H.T.S. & Meysman, F.J.R., 2014. Natural occurrence of microbial sulphur oxidation by long-range electron transport in the seafloor. The ISME Journal, 8: 1843-1854.

Malkin, S.Y. & Meysman, F.J.R., 2015. Rapid redox signal transmission by "cable bacteria" beneath a photosynthetic biofilm. Applied and Environmental Microbiology, 81: 1-9.

Nielsen, L. & Risgaard-Petersen, N., 2015. Rethinking sediment biogeochemistry after the discovery of electric currents. Annual Review of Marine Sciences, 7: 21.1–21.18.

Schulz, H.N., Strotmann B., Gallardo, V.A. & Jorgensen, B.B., 2000. Population study of the filamentous sulfur bacteria Thioploca spp. off the Bay of Concepcion, Chile. Marine Ecology Progress Series, 200: 117–126.

Zhang, C., Ntarlagiannis, D., Slater, L., Doherty, R. 2010. Monitoring microbial sulfate reduction in porous media using multi-purpose electrodes. Journal of Geophysical Research: Biogeosciences, 115: G00G09, doi:10.1029/2009JG001157

Interactive comment on Biogeosciences Discuss., 11, 17707, 2014.