

## ***Interactive comment on “Biogeochemical Impact of Cable Bacteria on Coastal Black Sea Sediment” by Martijn Hermans et al.***

**Martijn Hermans et al.**

m.hermans@uu.nl

Received and published: 2 October 2020

The study documents the effect of cable bacteria on sediment geochemistry in repacked sediment cores on sediment collected from the Black Sea. The findings support current paradigms in the cable bacteria literature. This is a nice case study that has been well presented and written up. The dominance of cable bacteria in the oxygen budget is an interesting finding. There is also some additional data on element mapping that sheds further light on the effect of cable bacteria on sediment geochemistry at different sites. I only have a few relatively minor comments and suggestions for improvement.

Reply: We thank Anonymous Referee #1 for reviewing our paper and the insightful and

C1

constructive feedback. Please find our replies to each comment below.

Comment #1 The authors used the classic sediment repacking method to start a cable growth cycle. What effect might homogenisation have had on the final findings? For example, would siderite be likely to be so close to the surface under normal circumstances.

Reply: The homogenisation likely did not have a significant effect on our final findings. Homogenisation of the sediment is essential to obtain proper replicate cores, and is known to induce growth of cable bacteria. While some of the FeS and siderite might have oxidised during sieving, homogenising and repacking, this does not affect the conclusions of our experiment. There is still ample FeS and siderite present in our sediment cores at the start of the experiment, and our time-series indicate that both FeS and siderite were dissolved by cable bacteria activity over time. Both FeS and siderite are frequently observed in marine surface sediments (e.g. Sulu-Gambari et al. 2016).

Comment #2 Line 163 – no need to say ‘bottom water’ just water samples?

Reply: Here, we specifically use the term bottom water samples, since it refers to the overlying water in the cores. Water samples could also refer to other things, such as water column or pore water samples. Therefore, we think it is best to use the term bottom water samples, to avoid potential confusion.

Comment #3 Line 172 – please elaborate a little on exactly what you mean by salt corrections.

Reply: Freeze-drying removes the water from samples. However, the salt stays behind in the dried sediment. Hence, the weight of the freeze-dried sediment used for the sequential extractions needs to be corrected for this salt content if we wish to calculate elemental/mineral concentrations, such as Fe oxide and metal bound P contents per gram of sediment. Without the salt correction the absolute elemental/mineral con-

C2

centrations would be underestimated. Hence, we subtract the weight of the salt from the freeze-dried sediment to calculate the 'real' weight of the dry sediment. We will explain this in a bit more detail in our methods: "After freeze-drying, the salt from seawater stays behind in the solid-phase fraction. To determine the actual weight of the dry sediment, it is necessary to subtract the weight of the salt from the total weight of freeze-dried sediment."

Comment #4 Line 205 – could you add a sentence on how the embedding was achieved?

Reply: The resin embedding process will be described in more detail: "On day 47, an undisturbed core (first 5 cm of surface sediment) was sampled for epoxy resin embedding for high-resolution elemental mapping (Jilbert et al. 2008; Jilbert and Slomp 2013). Sediment was carefully pushed upwards from the experimental core into a shorter (7 cm length; 1 cm diameter) mini core. This mini sub-core was then transferred to an acetone bath in a argon-filled glovebox and subsequently embedded with Spurr's epoxy resin as described in Jilbert et al. (2008). After curing, the epoxy-embedded core was split vertically using a rock saw."

Comment #5 Line 210 onwards – consider adding this to methods.

Reply: The methods used to obtain these elemental maps from the epoxy resin embedded surface sediments from the Gulf of Finland and Lake Grevelingen are described in detail in the other studies cited (Sulu-Gambari et al. 2016; Sulu-Gambari et al. 2018; Hermans et al. Submitted). Therefore, we prefer not to describe the sampling process of those resin embedded cores in section 2.4 of our methodology.

Comment #6 also Line 261 – Only Ca and Si fluxes are presented, I couldn't see them?

Reply: These Ca and Si fluxes are presented in Fig. S10 and Table S4 in the Supplementary Information, see line No. 480 in the manuscript.

Comment #7 Line 384 not clear what you mean here, please elaborate.

C3

Reply: We have used Fick's law for the calculation of the diffusive fluxes, which does not take the effect of the electric field generated by cable bacteria on the diffusion potential into account. The Nernst-Planck equation, however, extends Fick's law, because solutes can also be moved with respect to the fluid by electrostatic forces. In the revised version, we will explain this in greater detail including the effect on the SO<sub>4</sub><sup>2-</sup> flux.

Comment #8 Line 415 – could it be that the nitrate is just denitrified? Also on this point, it seems that not flux measurements were made for nitrate. It seems likely that some nitrate is released to the water. It might be worth a brief discussion of a few scenarios here. All the nitrate is released to the water column, all the nitrate is denitrified by sediment bacteria and all the nitrate is denitrified by cable bacteria.

Reply: Unfortunately, we do not have data for NO<sub>3</sub><sup>-</sup>. The problem of the abovementioned scenarios is that, if we would include the role of other groups of bacteria, and the potential release of NO<sub>3</sub><sup>-</sup> to the water column, the mass balance for O<sub>2</sub> would have an even greater mismatch. When looking at the stoichiometry of NO<sub>3</sub><sup>-</sup> by cable bacteria and the conversion of N to N<sub>2</sub>, we cannot close the budget fully that way. We will modify the text to explain this in more detail: "These findings can be explained, however, if we assume that at least part of the NO<sub>3</sub><sup>-</sup> that is being formed near the sediment-water interface is also used for the metabolic activity of cable bacteria. It has been shown that cable bacteria can couple the oxidation of 2S to NO<sub>3</sub><sup>-</sup> in the absence of O<sub>2</sub> (Marzocchi et al. 2014). Our data suggest that this process may also occur in sediments where O<sub>2</sub> is present in concert with NO<sub>3</sub><sup>-</sup> near the sediment-water interface. However, we cannot exclude release of NO<sub>3</sub><sup>-</sup> to the water column or denitrification by other bacteria in the sediment."

Comment #9 Line 485 – very interesting!

Reply: Thank you, this potential niche for vivianite formation is indeed an interesting finding.

C4

Comment #10 Line 522 – not obvious to me from Fig 8A, it is interesting, can you make this clearer?

Reply: We will make this more explicit in the text: “While the Fe oxide layer is clearly enriched in P, we also observed a second layer enriched in P very close to the sediment-water interface (Fig. 8A). This layer is located above the Fe oxide layer, and in this layer P is strongly correlated with Ca.”

Comment #11 Line 546 I agree this is likely driven by cables, but how is this different from a straight reaction diffusion scenario (given ubiquity of cables, such a scenario does seem unlikely though). I think this idea needs a little more development and explanation as to how it might actually be applied.

Reply: Focusing of Fe and Mn oxides and associated P can indeed also occur in sediments overlain by oxic waters, where no cable bacteria are active. However, as demonstrated by our experiment (and various other studies (e.g. Risgaard-Petersen et al. 2012; Rao et al. 2016), in sediment populated by active cable bacteria, the upward fluxes of Fe<sup>2+</sup> and Mn<sup>2+</sup> are higher due to the dissolution of FeS, Fe- and Mn carbonates. This allows strong focusing of Fe and Mn oxides in a thin layer within a relatively short time frame. We will add the following section in our manuscript: “Focussing of Fe and Mn oxides in the surface sediment is not exclusively tied to the activity of cable bacteria, and can also occur in the absence of cable bacteria. However, the upward fluxes of Fe<sup>2+</sup> and Mn<sup>2+</sup> in sediments populated by cable bacteria are higher due to active dissolution of Fe and Mn minerals at depth (e.g. Risgaard-Petersen et al. 2012; Rao et al. 2016). Hence, within the same time period following an environmental perturbation (such as a transition to oxic bottom waters after a period of anoxia or mixing of the sediment), more Fe<sup>2+</sup> and Mn<sup>2+</sup> can oxidise upon contact with O<sub>2</sub> near the sediment-water interface and thus stronger enrichments of Fe and Mn minerals will be observed. Therefore, focussing of Fe and Mn oxides in subsurface sediments is likely more prominent and stronger in sediments populated by active cable bacteria compared to sediments where no cable bacteria are active under such conditions.”

C5

Comment #12 Figure 3 not clear how this was generated. Based on the pictures?

Reply: The depth intervals of the oxic, suboxic and anoxic zone are based on the micro-electrode data. We will make it more explicit in the caption of Fig. 3.: “Time-series of the development of the oxic zone (orange), suboxic zone (light grey) and the anoxic/sulphidic zone (dark grey) in the sediment. These zones were calculated from 3 replicate microelectrode depth profiles retrieved from two different cores.”

#### References

Hermans, M., Astudillo Pascual, M., Behrends, T., Lenstra, W. K., Conley, D. J., and Slomp, C. P. (Submitted). Coupled dynamics of iron, manganese and phosphorus in brackish coastal sediments populated by cable bacteria.

Jilbert, T., de Lange, G., and Reichart, G. J. (2008). Fluid displacive resin embedding of laminated sediments: preserving trace metals for high-resolution paleoclimate investigations. *Limnology and Oceanography: Methods* 6: 16-22.

Jilbert, T., and Slomp, C. P. (2013). Iron and manganese shuttles control the formation of authigenic phosphorus minerals in the euxinic basins of the Baltic Sea. *Geochimica et Cosmochimica Acta* 107: 155-169.

Marzocchi, U. and others (2014). Electric coupling between distant nitrate reduction and sulfide oxidation in marine sediment. *The ISME journal* 8: 1682-1690.

Rao, A. M., Malkin, S. Y., Hidalgo-Martinez, S., and Meysman, F. J. (2016). The impact of electrogenic sulfide oxidation on elemental cycling and solute fluxes in coastal sediment. *Geochimica et Cosmochimica Acta* 172: 265-286.

Risgaard-Petersen, N., Revil, A., Meister, P., and Nielsen, L. P. (2012). Sulfur, iron-, and calcium cycling associated with natural electric currents running through marine sediment. *Geochimica et Cosmochimica Acta* 92: 1-13.

Sulu-Gambari, F. and others (2018). Phosphorus cycling and burial in sediments of a

C6

seasonally hypoxic Marine Basin. *Estuaries and Coasts* 41: 921-939.

Sulu-Gambari, F., Seitaj, D., Behrends, T., Banerjee, D., Meysman, F. J., and Slomp, C. P. (2016). Impact of cable bacteria on sedimentary iron and manganese dynamics in a seasonally-hypoxic marine basin. *Geochimica et Cosmochimica Acta* 192: 49-69.

---

Interactive comment on *Biogeosciences Discuss.*, <https://doi.org/10.5194/bg-2020-292>, 2020.