Final author comments

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M. Reinholdsson and I. Snowball

Answers to RC C707: Anonymous Referee #1, 2 April 2014 (referee comments in *italic*)

The combination of selected data sets from very different sites and environmental conditions weakens the presentation.

We agree that the comparison with the Fe_R from the coastal site in the Archipelago Sea, Finland, is from different environmental conditions, but they were the best data available to us. This comparison can be removed.

An in-depth discussion on possible diagenetic impact on the preserved greigite is completely missing.

As we have stated in the manuscript "the calculated fluxes should perhaps be interpreted as reflecting the amount of magnetosomal greigite that has survived deposition and burial. The initial production might have been more since magnetosomes can be degraded during transport through the water column, for example in the acid vacuoles of grazing protozoa." We understand that the referee is concerned about what happens to the greigite during and after burial. We can also add a discussion about possible diagenetic impacts where the amount of Fe_R limits the amount of iron that is sulphidised in Baltic Sea sediments (Boesen and Postma, 1988; Sternbeck and Sohlenius, 1997). Whether iron mono-sulphides (FeS) or pyrite is formed is controlled by the sulphate concentration. The low salinities in the Baltic Sea cause sulphate starvation and the accumulation of iron mono-sulphides rather than pyrite in the Bornholm Basin. The Gotland Basin has higher sulphate concentrations due to the production of H_2S, but is still characterised as a moderate sulphate depleted area (Boesen and Postma, 1988). Therefore, the magnetosomal greigite might be preserved to a higher degree due to the possible sulphate starvation. Diagenetic greigite (not magnetosomal) is often preserved due to sulphate starvation and arrest (incomplete) of the pyritisation process. We can also emphasize that oxygenation of hypoxic/anoxic environments can cause the oxidation of greigite near the sediment surface layer.

Neretin et al. (2004) stated that pyrite could be formed through prolonged exposure of iron-containing minerals to dissolved sulphide. Since pyrite exists in Littorina Sea sediments (Sternbeck and Sohlenius, 1997) this could affect our samples. At the same time the organic membrane surrounding the magnetofossils might act as a coating and help preserve the magnetofossils to a higher degree. Reinholdsson et al. (2013) did not observe any evidence of significant alteration of the nanometre-sized greigite magnetofossils even though they had been buried for several thousands of years. One would expect pyritisation to lead to a reduction in magnetosomal greigite grain size, with subsequent loss of the ability to retain magnetic remanence below the single-domain to superparamagnetic grain-size boundary, which would be accompanied by significant frequency dependency of the magnetic susceptibility. Our data do not suggest that any post-depositional pyritisation of the magnetofossil greigite has taken place.

LOI may be used for stratigraphy correlation purposes, as mostly done in the present communication, but should not for flux estimates for organic matter.

LOI is frequently used as a quantitative measure for TOC (Heiri et al., 2001), and there is a high degree of correlation between LOI and organic carbon measured in duplicate sub-samples (Dean, 1974). LOI and total organic carbon (TOC) have high correlation coefficients both for LL19 (R^2=0.92) and F80 (R^2=0.81). Furthermore, only patterns of LOI and the LOI flux, and no absolute values are used in the discussion about the possible organic matter influence. Additionally, the low salinity of the Baltic Sea causes a low concentration of calcareous fossils, and the possible addition of carbonate to the LOI measurement should not be a major problem in Baltic Sea sediment samples.

The Fe_R flux reported for the near-coastal site cannot be taken as a realistic reference.

We agree with the referee and will remove the comparison from the manuscript.

It looks as if the used number of references was selected not to cover all known aspects about controlling factors for MTB abundances and activities in freshwater-brackish sediments.

We have tried to include the controlling factors that seem most important regarding the data presented and have cited the review papers that we are aware of and have access to. There are many suggested, but not necessarily proved (hence 'known') controlling factors for MTB growth and abundances and to include them all in our manuscript would be unrealistic. If we were to do so, our report of an innovative geophysical approach to quantifying the amount of a biomineralized mineral that is extremely sensitive to oxidation in a laboratory, would become a review about the ecological factors that determine the abundance and activity of magnetotactic bacteria, which was not the purpose of the study.

The question remains, if magnetosome greigite is a product of pelagic or benthic microbial activity.

We do not know if the production is pelagic or benthic. Our manuscript focusses on a geological archive of preserved magnetofossils. Clearly, we must emphasize that we have not conducted a study about the ecology of magnetotactic bacteria, but about a method that could be used to detect their magnetofossils in geological archives. Our treatment of the data presented by Reinholdsson et al. (2013) and the new data is placed into a chronostratigraphic framework and it does illustrate how relatively small amounts of an element can be converted by bacteria into a form that is easily detected and quantified by geophysical measurements (possibly at lower limits where other chemical/mineralogical methods would fail to detect at all). Current hypothesis/models used to explain the production of magnetosomes places the origin within the water column. We would make this statement clearer in a revised manuscript, with suggestions for work that could be done by microbiologists to sort out the location of production.

Answers to RC C1658: I. Vasiliev, 16 May 2014 (referee comments in *italic*)

The submission to Biogeosciences is a bit too much based on their previous results.

The present manuscript submitted to BGD includes new rock magnetic data and LOI data from site LZGB2, and Fe_T data from station F80. Most important, however, is that the manuscript submitted to BGD applies the age-model described by Lougheed et al. (2012), which is used to calculate the fluxes. The EPSL paper had a completely different focus, which was not chronology and fluxes could not be calculated at the time the EPSL paper was written and submitted. The EPSL paper (Reinholdsson et al., 2013) concluded that the mineral magnetic enhancements of laminated sapropels in the deeper basins of the Baltic Sea was due to greigite magnetofossils. This paper was the first to confirm that greigite magnetosomes were capable of determining the magnetic properties of buried sediments. This discovery was the focus of that paper, which relied on a detailed series of rock magnetic experiments, the development of a method to extract the low concentrations of magnetosomes for TEM studies and elemental analyses. We do not see any problem with applying the equations of Lascu et al. (2010) to already published data.

Boesen, C., and Postma, D., 1988, Pyrite formation in anoxic environments of the Baltic: American Journal of Science, v. 288, no. 6, p. 575-603.

Dean, W. E., 1974, Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition; comparison with other methods: Journal of Sedimentary Research, v. 44, no. 1, p. 242-248.

Heiri, O., Lotter, A. F., and Lemcke, G., 2001, Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results: J. Paleolimnol., v. 25, no. 1, p. 101-110.

Lascu, I., Banerjee, S. K., and Berquo, T. S., 2010, Quantifying the concentration of ferrimagnetic particles in sediments using rock magnetic methods: Geochem. Geophys. Geosyst. , v. 11.

Lougheed, B. C., Snowball, I., Moros, M., Kabel, K., Muscheler, R., Virtasalo, J. J., and Wacker, L., 2012, Using an independent geochronology based on palaeomagnetic secular variation (PSV) and atmospheric Pb deposition to date Baltic Sea sediments and infer ^{14}C reservoir age: Quat. Sci. Rev., v. 42, p. 43-58.

Neretin, L. N., Bottcher, M. E., Jorgensen, B. B., Volkov, II, Luschen, H., and Hilgenfeldt, K., 2004, Pyritization processes and greigite formation in the advancing sulfidization front in the Upper Pleistocene sediments of the Black Sea: Geochimica Et Cosmochimica Acta, v. 68, no. 9, p. 2081-2093.

Reinholdsson, M., Snowball, I., Zillen, L., Lenz, C., and Conley, D. J., 2013, Magnetic enhancement of Baltic Sea sapropels by greigite magnetofossils: Earth Planet. Sci. Lett., v. 366, p. 137-150.

Sternbeck, J., and Sohlenius, G., 1997, Authigenic sulfide and carbonate mineral formation in Holocene sediments of the Baltic Sea: Chemical Geology, v. 135, no. 1-2, p. 55-73.