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Biogeosciences
Discussions

Interactive comment on "Pleistocene sediment offloading and the global sulfur cycle" *by* S. Markovic et al.

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Please see supplement for formatted response.

Comments by Anonymous Referee #2

The manuscript by Marcovich et al. describes how quaternary sea level fluctuations have affected the oceanic sulfur budget through massive movement of sediment off the shelf. They use sulfur isotopic records from two IODP drill cores from the Eastern Equatorial Pacific. The study is very well written and relatively easy to understand, even for someone who is not completely familiar with this research area. It is a valuable addition to our understanding of the sulfur cycle.

We thank the referee for her/his support of the study.

There are a few minor points that I would like to see discussed in a bit more detail or changed to improve clarity. 1) Page 1214, line 5ff: Sediment offloading will also introduce pyrite and OM into the abyssal box, but it will not be counted, because it is already accounted for in the shelf box. While I agree that you should not count things twice, I wonder how much of the pyrite that is moved from the shelf into the abyss will be oxidized because oxygen penetration depths in abyssal sediments are usually much greater.

This is indeed a valid point which we immediately incorporated upon reading the comment. Physical reworking of sediment promotes pyrite oxidation (Calmels et al., 2007). Therefore, if sediment transfer is slow and includes physical erosion, suspension and deposition, we would expect that pyrite is already oxidized before sediments reach abyssal plain. In case of instant sediment transfer (i.e., gravity flows) we would expect that pyrite is oxidized in situ after deposition. While we cannot quantify the proportion of pyrite oxidized in this manner we note that abyssal plains along continental margins are dotted with the evidence of this sediment transfer which is generally thought to occur during glaciations (Weaver et al., 2000; Piper and Normark, 2009; Meiburg and Kneller, 2010). After emplacement, molecular oxygen diffuses into sediments and oxidizes organic matter and sulfides (Colley et al., 1984; Cowie et al., 1995; Thomson et al., 1998; Robinson, 2001). The process will continue until diffusive supply of oxygen is interrupted either through deposition of pelagic sediment or another turbidite layer. Depending on the sediment accumulation rates and turbidite frequency in particular region, oxidation can last a few thousand to >10 kyrs (Cowie et al., 1995; Thomson et al., 1998; De Lange, 1998; Robinson, 2001).

The language in the revised paper is now changed to recognize this as one of the possible pathways of shelf pyrite oxidation. We thank the reviewer for this suggestion.

2) Page 1216, line 11: Please check spelling of "environments"

Done.

3) Page 1221, line 9: What do you mean by "moderately sensitive"? This is a phrase that can mean almost anything.

This is a very good point. Thank you for drawing our attention to this ambiguity. We have changed the language and we now use: “The model output is affected by the initial size of pyrite shelf sub-reservoir (Fig. 5).“

4) Page 1223, line 3ff: If there is a connection between build up of oceanic DIC from pyrite oxidation and jumps in atmospheric CO2, would it be possible to show them? This is an interesting aspect and your arguments are compelling, but I would like to see something like a "smoking gun". Can you prepare a graph that shows this relationship?

Thank you for your comment. At this point, using our sulfur cycle model and ïĄď34S data we can only calculate DIC input as a result of the imbalance between pyrite weathering (input flux) and pyrite burial (sink). Figure 1A shows temporal changes of DIC input for base model scenario assuming initial fluxes at steady state values. The cumulative DIC input over the past 3Myr is shown on Fig. 1B.

Due to complex behavior of different carbonate species in atmosphere-seawater system we cannot delineate the impact of excess DIC (Figure 1) on atmospheric CO2 concentration. This would require a carbon isotope mass balance model which connects competing effects of weathering, organic matter burial and decomposition, carbonate burial and dissolution. Since this is well beyond the scope of this paper we changed the language in the last section of discussion and dropped the sentence that suggested the direct link between sulfide oxidation and the long term Pleistocene CO2 variations. We hope, however, that this research will stimulate discussion that in turn will lead to more thorough understanding of the role sulfide oxidation played in modulating inorganic carbon budget during Pleistocene.

5) Graphs A1 to A4: The graphs are nice, but in order to make a direct comparison between the different model runs I would rather like to see them as a single panel with 4 sub-graphs instead of 4 separate figures. Plotting them all into one graph will not

work as they are too similar.

This is a great idea! We have merged Figures A1-A4.

References:

Calmels, D., Gaillardet, J., Brenot, A., and France-Lanord, C.: Sustained sulfide oxidation by physical erosion processes in the Mackenzie River basin: Climatic perspectives, Geology, 35, 1003-1006, 10.1130/g24132a.1, 2007.

Colley, S., Thomson, J., Wilson, T. R. . and Higgs, N. .: Post-depositional migration of elements during diagenesis in brown clay and turbidite sequences in the North East Atlantic, Geochim. Cosmochim. Acta, 48, 1223–1235, doi:10.1016/0016-7037(84)90057-7, 1984.

Cowie and G: Elemental and major biochemical changes across an oxidation front in a relict turbidite: An oxygen effect, Geochim. Cosmochim. Acta, 59, 33–46, doi:10.1016/00167-0379(40)0329K-, 1995.

Hu, X. and Cai, W. J.: An assessment of ocean margin anaerobic processes on oceanic alkalinity budget, Global Biogeochem. Cycles, 25, doi:10.1029/2010GB003859, 2011.

De Lange, G. J.: 33. Oxic vs. anoxic diagenetic alteration of turbidite sediments in the Madeira Abyssal Plain, eastern North Atlantic, in Weaver, Schmincke, Firth and Duffileld (Eds.): Proceedings of the Ocean Drilling Program, Scientific Results, vol. 157, pp. 573–579., 1998.

Meiburg, E. and Kneller, B.: Turbidity Currents and Their Deposits, Annu. Rev. Fluid Mech., 42, 135–156, doi:10.1146/annurev-fluid-121108-145618, 2010.

Piper, D. J. W. and Normark, W. R.: Processes That Initiate Turbidity Currents and Their Influence on Turbidites: A Marine Geology Perspective, J. Sediment. Res., 79, 347–362, doi:10.2110/jsr.2009.046, 2009.

Robinson, S. G.: Early diagenesis in an organic-rich turbidite and pelagic clay sequence from the Cape Verde Abyssal Plain, NE Atlantic: Magnetic and geochemical signals, Sediment. Geol., 143, 91–123, doi:10.1016/S0037-0738(00)00187-1, 2001.

Sun, X. and Turchyn, A. V.: Significant contribution of authigenic carbonate to marine carbon burial, Nat. Geosci., 8, 201–204, doi:10.1038/ngeo2070, 2014.

Thomson, J., Jarvis, I., Green, D. R. H. and Green, D.: Oxidation fronts in Madeira abyssal plain turbidites: Persistence of early diagenetic trace-element enrichments during burial, site 950, in Weaver, Schmincke, Firth and Duffileld (Eds.): Proceedings of the Ocean Drilling Program, Scientific Results, vol. 157, pp. 559–571, Ocean Drilling Program. [online] Available from: http://cat.inist.fr/?aModele=afficheN&cpsidt=2439726 (Accessed 20 March 2015), 1998.

Torres, M. a, West, a J. and Li, G.: Sulphide oxidation and carbonate dissolution as a source of CO2 over geological timescales., Nature, 507, 346–9, doi:10.1038/nature13030, 2014.

Weaver, P. P. E., Wynn, R. B., Kenyon, N. H. and Evans, J.: Continental margin sedimentation, with special reference to the north-east Atlantic margin, Sedimentology, 47, 239–256, doi:10.1046/j.1365-3091.2000.0470s1239.x, 2000.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/12/C932/2015/bgd-12-C932-2015-supplement.pdf

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Interactive comment on Biogeosciences Discuss., 12, 1205, 2015.

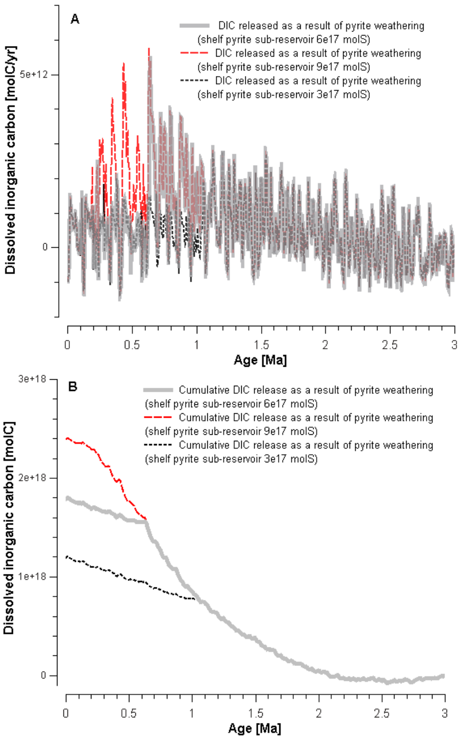

Fig. 1. Figure 1. DIC release as a result of pyrite weathering. (a) The temporal change of DIC input calculated from the balance between pyrite weathering and pyrite burial. Note that weathering of pyrite rel