

Interactive comment on “A geochemical modelling study of the evolution of the chemical composition of seawater linked to a global glaciation: implications for life sustainability” by G. Le Hir et al.

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Comment for F. Corsetti (reviewer 1) Regarding the model results and data. Indeed the model is just a simplified system representing the complex Earth system. The objective of this modelling exercise is to test the geochemical impact of a hard snowball. Indeed the model cannot account for all the processes, particularly because it's a global ocean model, while all the data come from specific environments. Therefore the model estimations can help to interpret data, but we are not claiming that the model is producing geological data. We are going to include few sentences about this in the revised ms.

(1) p1846 Since we use a 0-dimensional geochemical model, the ice-sheet dynamic

is not modelled. Hence, we use several assumptions to represent the environmental modifications due to a snowball event. One of them is the shut down of the weathering fluxes when the snowball glaciation is achieved.

(2) p1847-1848 Before the glaciation, the quasi absence of gradient represents the small O₂ concentration difference between the deep and surface ocean. Since the ocean becomes very poorly enriched in O₂ (9 $\mu\text{mol/kg}$) we use the term quasi-anoxic, therefore the deep ocean is not strictly anoxic. This will be fixed in the revised version. With respect to the BIFs precipitation, indeed it is usually assumed that the BIFs are formed after the glaciation itself. However Young (Young, 2002) shows that a part of BIFs is deposited inside the diamictites. Hence, if the first two conditions occur without the last, we cannot explain the BIFs position observed in the Rapitan diamictites sequence. To form BIFs during the glaciation, we propose (according to our modelling results) that the surface ocean atmosphere remains lowly enriched in O₂, but sufficiently to precipitate iron oxides. However, this issue is still open, and requires a more insightful modelling of the ocean chemistry, including the sulphur and iron cycles. This is beyond the scope of this preliminary study, but certainly has to be accounted for in the next future.

(3) p 1851. Indeed several mechanisms are proposed to explain the cap carbonate occurrence. The Shields paper (Shield, 2005) will be cited in the revised ms.

(4) p1854. A large range of glaciation duration have been proposed, from less than 1Ma (Jacobsen and Kaufman, 1999) up to 33Ma (Condon et al., 2005; Zhou et al., 2004). 5 Ma, as mentioned by the reviewer, lies inside the range of possibilities. Here we chose the extreme case wherein the glaciation duration equals 30Ma, because high CO₂ levels are required to melt the snowball (Pierrehumbert, 2004). A shorter duration implies solid Earth degassing overcoming geological constraints (Cogné and Humler 2004). However, a 5 Ma glaciation remains a likely solution if processes helping at melting the ice (dust for instance) occur. It should be noted that if the duration becomes shorter, the environmental changes will be less intense, as the reviewer suggests. This

can be mentioned in the revised text.

Comment for A. Ridgwell (reviewer 3)

The A. Ridgwell et al paper published in Sciences (Ridgwell et al., 2003) will be referred in the revised ms. Since the authors have effectively discussed the carbonate precipitation during the deglaciation, we are also going to correct the sentence at the beginning of the section 2, including the suggestion of a very short transition between the glacial and post-glacial.

(1) Oxygen ratio into the atmosphere and biological productivity 10 % of the present day value is obtained by reducing the photosynthetic biological productivity, a reasonable assumption for Neoproterozoic times (no widespread land plants, less oxygen producer in the ocean). The marine biological productivity is reduced to 1.5% of its present day production to reach 0.021bar of pO₂ in the atmosphere. Recent papers exploring the second oxygenic event (Canfield et al., 2007; Fike et al., 2006) show that the Neoproterozoic atmosphere remained poorly oxygenated until this second oxygenic event, although the level is not well known. According these papers, this event has affected the Proterozoic atmosphere between 630 and 542Ma. Catling and Claire (Catling and Claire, 2005) suggest O₂ level between 10 and 50 % of the present day level, 50 % being the terminal Proterozoic level.

(2) p1841 Precambrian Life on continents Indeed life was present on lands, even in the Paleoproterozoic, but restricted to wet environments (lakes, rivers) (Gutzmer and Beukes, 1998), mainly as microbial mats. The impact of this on the biogeochemical cycle is not well known. It appears that fully developed weathering profiles existed in the Paleoproterozoic (Beukes et al., 2002). But the vascular plants, with true impact on weathering (Berner, 2004) only developed during the Devonian (Eifelian and Givetian stages, (Stein et al., 2007)).

(3) p1844 Phosphor rate The phosphorus removal is linked to the dissolved oxygen level according to the formalism of Van Cappelen and Ingall (VanCappellen and Ingall,

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1996) for the burial of organic matter. Additional removal comes from the adsorption on hydrothermal plume particles (Wallmann, 2003). This flux is made proportional to the phosphate concentration of the deep waters, which is a first order kinetics. When the glaciation begins the source of PO_4 is cut off (continental apatite), therefore its level drops to until 0 very quickly after the glaciation onset because of short reaction time relative to hydrothermal uptake (200 000 yrs).

(4) p1845 Radiative convective model We have used a Radiative convective model to build our relationship linking the pCO_2 as a function of the Temperature. The model is adapted from the ClimT project and is available in open source from the Chicago University website. <http://mathsci.ucd.ie/~rca/climt/> CliMT is developed by Rodrigo Caballero, with contributions from Jonathan Mitchell and Mike Steder. It initiated as a project of the Climate Systems Center at the Department of the Geophysical Sciences, University of Chicago, with funding from NSF Information Technology Research grant ATM-0121028.

(5) p1849 pH and carbonate dissolution This was a misprint. Indeed the carbonate dissolution occurs when the omega goes down 1, not when the pH is acidic. The sentence will be changed accordingly.

(6) p1852 the deglaciation timing The post-snowball climatic conditions are far from the present day one. We are presently exploring this with a 3D GCM. We agree with the reviewer that the Pleistocene glaciations are not good analog for what happens in the Neoproterozoic. We think that the best method to solve this problem is to use an Ice-Sheet Model coupled with a climatic model. Considering the importance of this problem, we wish to perform such simulations in brief delay.

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