Line by Line changes in the manuscript after review

Lines refers the "Maron et al_review.pdf" file.

Line 48: added reference to Reggiani et al. (2005) which is a fundamental paper about the pelagic sedimentation in the Lagonegro Basin.

Line 54: added reference to Reggiani et al. (2005) which is about the siliceous sedimentation in the Scisti Silicei Fm.

Line 56: species name *Misikella posthernsteini* now in italics.

Line 58: species name *Proparvicingula moniliformis* now in italics.

Line 74: added sentence "… in controlled atmosphere (argon) …".

Line 135: added the missing reference to a peak in magnetic susceptibility at ~48 m.

Figure 2: added the position of the greigite-bearing samples along the stratigraphic log, shown as red squares.

Lines 140-144: corrected the reference to panel letters in Figure 2. Added the reference to the greigite-bearing samples now marked in Figure 2.

Figure 3: added samples from the lower part of the section, as requested by Reviewer #1.

Figure 5: added further samples from the lower part of the section, as required by Reviewer #1.

Lines 183-194: added a description of the magnetite components MAG-1 and MAG-2 identified after IRM unmixing. The paragraph is: "The unmixing of IRM acquisition curves reveals at least two low coercivity components that can be attributed to magnetite (MAG-1 and MAG-2; Fig. 5, Tab. 1) and a high coercivity component that can be attributed to hematite (Fig. 5, Tab. 1). The dispersion parameter (DP; Tab. 1), defined as the standard deviation of the coercivity distribution (Egli, 2004), can be used to discriminate roughly the detrital component of magnetite from the authigenic (i.e., biogenic) component. Usually, detrital magnetite has a larger DP than biogenic magnetite (Egli, 2004), although a threshold between detrital and biogenic is hard to define. Our preliminary interpretation of the two components considers MAG-1 as detrital (larger DP) and MAG-2 as biogenic (smaller DP) (Fig. 5). The presence of biogenic magnetite is also suggested by the central ridge visible in FORC diagrams, in particular around the NRB (e.g., sample PA+55 at 45.45 m; Supplementary Fig. A2). The averaged FORC diagram in Figure S4 show a well-defined central ridge dominated by low coercivity phases (Supplementary Fig. A3), possibly due to soft biogenic magnetite (Roberts et al., 2014). The samples containing greigite (Fig. 4) do not seem to be strictly related to high concentration of magnetite, except in the upper part of the section, in the lower Rhaetian (Fig. 2)."

Line 203: corrected the reference to appendix A4.

Table 1: corrected table content adding the new samples shown in Figure 5.

Lines 275-276: corrected the words "long term" into "long-term".

Figure 9: added the magnetic susceptibility curve χ as suggested by Reviewer #1.

Line 284: added the reference to panel E in Figure 9: "… E. magnetic susceptibility (χ) curve …".

Line 289: corrected the word "peak" in the more correct word "decrease".

Lines 290-292: added the sentence: "… and to an increase in magnetic susceptibility (χ; Fig. 9E). Possible explanations of the susceptibility increase at the NRB could be the production of authigenic magnetite in particular conditions of scarce oxygenation, as also suggested by the presence of Fe-sulfides (greigite) in this interval (as described in paragraph 4.1.2)."

Lines 327-329: added the sentence: "The uplift of the Cimmerian belt could have contributed establishing a monsoonal-type climate in the western Tethys, enhancing seasonal runoff and silicate weathering of mafic rocks (Onoue et al., 2018).".

Line 337: added the sentence: "… , (where mafic lithologies are documented, such as the Permian basalts of the Central Alborz; Delavari et al., 2016), …".

Lines 339-342: added the sentence: "Moreover, the development of an extensional system in Central Alborz of Iran during Late Triassic led to the emplacement of alkaline volcanism with the formation of the Triassic alkaline basaltic rocks (TABR) of the Kamarbon area, which overly the Carnian massive dolomites and are beneath the Norian-Rhaetian sandstones of the Shemshak Formation (Doroozi et al., 2018).".

Line 355: added the references to Goddéris et al. (2008) and Schaller et al. (2015).

Lines 358-359: added the reference to Goddéris et al. (2008).

Lines 364-365: added the sentence: "Further investigations (geochemical and rock magnetic) are required to expand the record of the weathering in the Rhaetian to unravel the meaning of this short-term increase of hematite.".

Line 378: added the reference to Goddéris et al. (2008).

Lines 380-382: removed a sentence about a negative peak in $\delta^{13}C_{org}$ since is not pertinent to this part.

Figure A2: added a new Figure A2 in Appendix A showing FORC diagrams. We also added the relative caption.

Figure A3: added a new Figure A3 in Appendix A showing coercivity data from FORC diagrams. We also added the relative caption.

Figure A4: old Figure A2 becomes Figure A4. Caption has been corrected to fit the new figure numbering.

Lines 413-415: added the "Acknowledgments" paragraph.

Lines 468-473: added references to Delavari et al. (2016) and Doorozi et al. (2018).

Lines 485-488: added references to Egli (2004) and Egli (2013).

Lines 497-498: added reference to Harrison and Feinberg (2008).

Lines 502-504: added reference to Goddéris et al. (2008).

Lines 611-613: added reference to Reggiani et al. (2005).

Replies to reviewers:

REVIEWER 1

Dear Anonimous Referee #1,

thank you for your valuable comments and suggestions. In this Author's comment are reported your comments followed by our replies.

This article deals with climatic perturbations in the Late Triassic (Late Norian – Early Rhaetian) using a combination of magnetic and geochemical parameters on the sedimentary Pignola Abriola section from southern Italy to determine long-term weathering trends. Variability in hematite occurrence along the section, interpreted as enhanced subaerial oxidation of iron minerals, support previous long-term increase in rock weathering in the Middle Norian already triggered with $^{87}Sr/^{86}S$ data from Sicily. The authors preferably link both the enhanced weathering trend and the subsequent decrease to the multiphase Cimmerian orogeny though weathering of silicate rocks entering the equatorial belt due to the northward displacement of Pangea may have also play a role. Decrease in the hematite content approaching the Norian Rhaetian Boundary (NRB) is followed by more instabilities in the signal whose origin remain to be determined.

The paper is well written and clearly presented. The dataset and the careful work clearly accomplished with the magnetic properties and major element data clearly deserve publication with minor revisions, even if some clarifications need to be brought.

[My main concern is that the interpretations only focuses on the correlation of the hematite content derived from the IRM acquisition curves while less attention is payed to the signal carried by the susceptibility curves that also includes the 'magnetite' content for which interpretations are somehow lacking. The unmixing of IRM acquisition curves exhibits two components of magnetite: what are they?]

- *We are including into the revised version of the manuscript that we will be submit an interpretation of the magnetite components obtained from IRM unmixing. MAG1 component generally has a wide coercivity distribution that is compatible with detrital magnetite, while MAG2 has a much narrower distribution that could be interpreted as authigenic magnetite, possibly of microbial origin. We added a brief discussion in paragraph 4.1.2 about the magnetite components shown by IRM unmixing. The unmixing of IRM acquisition curves reveals at least two low coercivity components that can be attributed to magnetite (MAG-1 and MAG-2 as reported in Figure 5 and Table 1) and a high coercivity component that can be attributed to hematite. Both magnetite and hematite in Pignola-Abriola are interpreted as mainly of detrital origin, as also suggested by the inclination flattening of 0.6 as calculated* *for Pignola-Abriola by Maron et al. (2015) using the E/I method of Tauxe and Kent (2004). An authigenic origin, possibly biogenic, of part of the magnetite fraction cannot be excluded. The detrital component can be discriminated from the biogenic magnetite component using the dispersion parameter (DP), defined by Egli (2004) as the standard deviation of the coercivity distribution obtained from IRM unmixing. The detrital magnetite has generally a larger DP than the biogenic magnetite (Egli, 2004), although a discrete threshold is hard to place. Our preliminary interpretation of the two components considers MAG-1 as detrital (larger DP) and MAG-2 as biogenic (smaller DP). We also introduced a description of a series of FORC diagrams, now placed in the appendix, that corroborate the hypothesis of the presence of biogenic magnetite.*

[Also, why displaying susceptibility versus temperature curves from samples between 40 m and 48 m (around the NRB) where hematite contribution is mostly low while most of the interpretation of the record concerns the increasing weathering trend on the 0-20 m and the subsequent decrease up to 35 m? A susceptibility versus temperature curve of the relevant hematite rich lithologies would have been pertinent and/or low temperature curves may have better evidenced the presence of hematite. Note that to a lesser extent the same comments (concerning relevant example of hematite rich lithologies) apply for the Fig 5 IRM unmixing curves displayed than span between 33 m and 54.5 m.]

- *Thank you for this comment. We modified the figures of the upcoming revised manuscript. About the thermal susceptibility curves in Figure 3, we added samples from the lower part of the section. Unfortunately, we cannot rely on data from samples below 30 m since we do not have enough material from this part of the section to be used for thermomagnetic analysis. In Figure 5 we now consider a wider range of samples, covering the interval where the perturbation in the hematite content is evident.*

[It might also have been interesting to place on the stratigraphy and magnetic parameters the 12 samples containing greigite (Are they dispatched all along the section or more around the NRB for example?) or maybe just to discuss in the text on one example the influence on the magnetic parameters….]

- *The greigite-bearing samples are mostly located in the lower part of the section, and generally are not influencing the other magnetic parameters. In most of the greigite-bearing samples, magnetite carries most of the magnetic remanence (≥ 60%), except for a group of samples between 15 m and 21 m where hematite is more abundant. A possible explanation for the presence of an association of greigite and magnetite is the development of anoxic/dysoxic conditions and the consequent production of Fe-sulfides and biogenic magnetite (magnetotactic bacteria thrives in poorly oxygenated environments). This is now discussed in the 4.1.2 paragraph of the upcoming revised manuscript.*

[The susceptibility record versus age should be included in Figure 10. Its comparison with the δ^{13}C curve cannot be achieved in the paper since the susceptibility curve is not displayed with the age model. The paper could benefit of possible correlations between these two curves.]

- *Thank you for your comment. We added the susceptibility record in Figure 9 since it is where the main geochemical and rock magnetism parameters are compared. We discussed the comparison with the δ13Corg curve in the manuscript. From this comparison we can observe that the transient peak in weathering occurs at the NRB after a major negative excursion of δ13Corg and to an increase in magnetic susceptibility (χ). The negative peak of δ13Corg and the correspondent high levels of susceptibility observable close to the NRB are* *correlated to a very low amount of hematite. A similar episode is observable, although less pronounced and more rapid, in the lowermost Rhaetian. A possible explanation of the susceptibility increase at the NRB could be the production/preservation of authigenic (biogenic?) magnetite in particular conditions of scarce oxygenation (dysoxia?), as also suggested by the presence of some greigite-bearing samples in the lowermost Rhaetian.*

[Concerning the interpretation, if the multiphase Cimmerian orogeny might indeed be a good candidate for explaining the increase of detrital Hematite content and the evolution of the geochemical parameters, the interpretation for the 5 My chemical weathering could be improved. For example possible candidates for the 'onset and demise of mafic lithologies' associated with the Cimmerian orogeny that could be relevant for the interpretation are lacking and should be proposed even if the record of the orogeny is complex to support this interpretation that otherwise remains too speculative.]

- *Evidence of mafic rocks related to Cimmerian orogen is shown in paragraph 6.2 of the manuscript (Bashgumbaz Complex of Pamir; Nilüfer unit of Turkey), in particular between line 328 and line 342. The Bashgumbaz Complex is a portion of a large mafic-ultramafic nappe exposed in the Pamir region of Tajikistan, consisting of a low-grade metamorphic association with mainly gabbros and serpentinized harburgites and secondary quartzdiorites and plagiogranite, with the presence of basaltic and rhyolitic volcanites (Zanchetta et al. 2018). Originally a volcanic arc in a supra-subduction setting, it has been later underthrust and then obducted during Cimmerian orogeny in the late Triassic. The Nilüfer unit is an intercalation of metabasite, marble and phyllite (Okay et al. 2002). The metabasic rocks of the Nilüfer unit are made of mafic tuffs, pillow lavas and pyroclastic rocks. During Cimmerian orogeny the Nilüfer unit has been deformed and undergone blueschist and greenschist metamorphism. The Cimmerian orogeny led to the exhumation of these mafic rocks that were successively weathered. A possible cause of the rapid decrease of pCO2 in the Sevatian could also be the northward movement of Pangea as suggested by Goddéris et al. (2008) and by Schaller et al. (2015). This latter option cannot be excluded. However, we have no knowledge of particular concentrations of silicatic-mafic rocks in the core of Pangea that could have weathered during equatorial transit. In our opinion, the exhumation of mafic rocks during the Cimmerian orogeny represents a more valid explanation as evidence of these rocks have indeed been found. An alternative to this interpretation could be the weathering of fresh basaltic lavas from a large igneous province. The only known LIP across the Norian/Rhaetian is the Angayucham in North America. However, both its and drift history relative to the equator are poorly known. We expanded the discussion about the contribution of the weathering of the Cimmerian orogen in the increase of the hematite content. In particular, we better explain the role of the Cimmerian belt in driving the climate of the western Tethys by establishing a monsoonal-type environment.*

[Finally, if the complex record around and mostly after the NRB deserve future research plans to be explained why not indicating earlier in the paper that this part of the record still need more investigations or propose some lines of further research that could help unravelling its signification?]

- *We indicate in the revised interpretation the investigations that we think are needed to unravel the meaning of the increase of hematite in the lower Rhaetian.*

[Specific comments on the text & Figures :

Methods :

Line 75 : Why not putting here that the Curie experiments were performed in a controlled atmosphere ?]

- *We added few words to describe how we performed the experiment in a controlled atmosphere (in this case, argon).*

[Results :

Line 154 : What about the Peaks around 48 m?]

- *Thank you for noticing this. We added a reference to the peak of susceptibility at 48 m to this sentence.*

[Figures :

Fig 2 : Please label the Legend with accurate case corresponding to the curves displayed (A, B, C, ….). Suppress from left to right.]

- *We modified the caption according to your suggestion.*

[Fig 7 : The $\delta^{13}C$ curve is not on the Fig please remove from the legend.]

- *Thank you for noticing this typo in the caption. We removed the reference to the $\delta^{13}C_{org}$ curve.*

[Fig 9 - 10: I would have appreciate to have the susceptibility curve also displayed versus age on these Figures. The signal seems more complex around the NRB and would benefit from a correlation with the $\delta^{13}C$.]

- *We added the susceptibility curve to Figure 9 to facilitate the comparison with other rock magnetic and geochemical parameters. We would prefer to not add the susceptibility curve to Figure 10, as this is a synthetic figure which is mainly focused on the main proxies of weathering, which are the hematite content, the pCO_2 and the $^{87}Sr/^{86}Sr$ ratio, and is meant to facilitate the interpretation of the weathering phase of the Norian-Rhaetian.*

References in this reply:

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Okay, A.I., Monod, O., and Monié, P.: Triassic blueschists and eclogites from northwest Turkey: vestiges of the Paleo-Tethyan subduction, Lithos, 64, 155-178, doi:10.1016/S0024-4937(02)00200-1, 2002.

Schaller, M.F., Wright, J.D., and Kent, D.V.: A 30 Myr record of Late Triassic atmospheric $p\mathrm{CO}_2$ variation reflects a fundamental control of the carbon cycle by changes in continental weathering, Geol. Soc. Am. Bull., 127, 661-671, doi:10.1130/B31107.1, 2015.

Tauxe, L., and Kent, D.V.: A simplified statistical model for the geomagnetic field and the detection of shallow bias in paleomagnetic inclinations: Was the ancient magnetic field dipolar? In Channel, J.E.T., Kent, D.V., Lowrie, W., and Meert J.G. (Ed.), Timescales of the Paleomagnetic field. AGU, Geoph. Monog. Series, 145, 101–115, doi:10.1029/145GM08, 2004.

Zanchetta, S., Worthington, J., Angiolini, L., Leven, E.J., Villa, I.M., and Zanchi, A.: The Bashgumbaz Complex (Tajikistan): Arc obduction in the Cimmerian orogeny of the Pamir, Gondwana Res., 57, 170-190, doi:10.1016/j.gr.2018.01.009, 2018.

Dear Anonimous Referee #1,

after checking the previous reply to your comments, we realized there was a mistake in the reply to this comment:

Also, why displaying susceptibility versus temperature curves from samples between 40 m and 48 m (around the NRB) where hematite contribution is mostly low while most of the interpretation of the record concerns the increasing weathering trend on the 0-20 m and the subsequent decrease up to 35 m? A susceptibility versus temperature curve of the relevant hematite rich lithologies would have been pertinent and/or low temperature curves may have better evidenced the presence of hematite. Note that to a lesser extent the same comments (concerning relevant example of hematite rich lithologies) apply for the Fig 5 IRM unmixing curves displayed than span between 33 m and 54.5 m.

We previously replied to this comment that "we cannot rely on data from samples below 30 m since we do not have enough material from this part of the section to be used for thermomagnetic analysis". This is actually a wrong sentence we retained from a previous version of the replies document we prepared before submission of our final replies. We actually have some samples from the lowermost part of the section, below 30 m and we integrated them in Figure 3. We apologize for this mistake.

REVIEWER 2

Dear authors,

First of all, I'd like to apologize for the dramatic delay in the review process, which was largely due to my inability to find a second reviewer. I have therefore decided to rely on a single review, which was carried out by a specialist. I believe that this review is of very high quality, and I invite you to respond to it in detail. At this stage, I consider your contribution publishable, subject to a moderate review.

That said, I have also taken the decision to attempt to revise the manuscript. Unfortunately, I am unable to evaluate the data acquisition and analysis part of this article, as I am not a specialist in these matters. I have therefore focused on the discussion and conclusion sections.

In these two parts of the article, the authors describe accurately and correctly the operation of the Walker et al. (1981) planetary thermostat. I insist on this point, because the combination of the need to maintain a quasi-equilibrium between carbon inputs and outputs on the one hand, and the observation of variations in climate and CO2 content on the other, is often poorly understood and explained. This is not the case here.

On line 332, the authors describe very precisely the results obtained by Goddéris et al. (2008, Earth Planet. Sci. Lett.) concerning the potential impact of the northward shift of Pangea towards the Norian-Rhetian transition, and the resulting activation of continental surface weathering. But the reference is not cited. Far be it from me to engage in self-promotion, but I think the reference should appear.

- *Dear Prof. Goddéris, thank you for your comment and for pointing out this missing reference to us. We added the reference to Goddéris et al. (2008) to line 332 and also where we refer to the northward drift of Pangea.*