

Interactive comment on “Early Jurassic climate and atmospheric CO₂ concentration in the Sichuan paleobasin, Southwest China” by Xianghui Li et al.

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Dear Prof. Dan Breecker,

We thank for your constructive comments and questions. Below are the replies.

—My concerns are primarily related to the new pCO₂ determinations made. First, luminescent calcite (lines 141 and 142) is probably not a good material to use for paleoCO₂ determinations because luminescent pedogenic carbonate is thought to form under anoxic conditions, associated with water-saturation when there is a poor connection between soil pore spaces and the atmosphere (Mintz, J. S., Driese, S. G.,

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Breecker, D. O., & Ludvigson, G. A. (2011). Influence of changing hydrology on pedogenic calcite precipitation in Vertisols, Dance Bayou, Brazoria County, Texas, USA: implications for estimating paleoatmospheric pCO₂ (Journal of Sedimentary Research, 81(6), 394-400.). The paleosol carbonates studied here might be ‘weakly’ luminescent, but it is hard to tell without any quantification/standardization. It is also possible that there are other factors that influence luminescence. But all of this needs to be discussed so readers can evaluate the selection of materials. I will say, however, that the careful petrography and drilling of dense micritic zones is a plus.

We thank for the valuable comment and providing the reference.

Mintz et al. (2011) provides a good example that hydrology influences the luminescence of calcretes, that we now cite and use to refine our discussion of the luminescent quality and justification for sampling the Jurassic calcretes we present in this paper.

All of the samples studied were screened for cathodoluminescence (CL), and only a few are shown in the manuscript. The samples shown have the brightest luminescence of all of the studied samples, and they were chosen because the quality of the images is much better. Most are calcites and dull to non-luminescent, with little (~ 5-10%) light orange or brownish red luminescence. The luminescence is almost certainly due to a relatively high Mn/Fe ratio, and we expect that seasonally the soils may have been water logged and disoxic.

More importantly, the key to distinguish the pedogenic calcretes from other geneses is the identification of both field occurrence and micro-texture. Our field and microscopic observations demonstrate that the calcretes have typical pedogenic features. The ginger-like calcretes are discrete within the Bk horizons, and do not form linear/tabular limestone. Slickensides and vertical rhizoliths can be often / sometimes seen in paleosols. Petrographically, we see that predominant micritic calcites occupy the dense areas of the calcretes (Fig. 2). Some calcretes have areas that were cracked and filled by secondary / diagenetic spar-calcites, that were avoided when micro-sampling.

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Based on field and petrographic observations, we drilled powder samples for stable isotope analysis in dense micritic zones as the referee suggested. Thus, the carbon isotope value of carbonates can be used to estimate pCO₂.

In the new figure 2, we inserted the scanned photos of the thin-sections and marked the cathodoluminescent and drilling dense areas and added plane light photos (Fig 2c and 2d), which roughly correspond to the CL image positions. We also added sentences in the text (3.2) to make notes on the observation results of petrography and CL images (new lines 137-145).

— I am concerned that the CO₂ changes the authors interpret here may not be statistically significant changes. This is impossible to evaluate without uncertainty quantification. The authors do consider the effect of using different input values for the pCO₂ calculation, but my guess is that they have nonetheless largely underestimated the error associated with their approach. For instance, the authors calculate δ¹³C_r values from δ¹³C values of OM measured in different locations (across the globe) from the carbonate nodules. What magnitude of uncertainty might this introduce? Furthermore, δ¹³Ca is calculated from δ¹³C_r. Given the effects of CO₂ and water stress on δ¹³C values of C₃ plants, this approach is associated with substantial uncertainty that is not addressed in this manuscript. The authors recognize that there is uncertainty associated with the value of S(z). However, their consideration of S(z) = 2000 and 2500 ppmV is not an accurate representation of the uncertainty. I suggest error propagation that includes uncertainty associated with each input to the equation on line 159 and the results shown as error bars on each CO₂ determination.

Following the suggestion, we have made the error propagation for the pCO₂ results with procedures and formulas by Breecker (2013) and Breecker and Retallack (2014), and also considered parameters from Zhang et al. (2018). We have added the errors in figure 8d and a paragraph of uncertainty assessment in the end of the subsection 4.3 (new lines 244-250).

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It is noted that parameters of temperature, δ¹³C_r, δ¹³Ca, δ¹³C_s, and S(z), remain the same as the calculation of pCO₂ in the supplementary Table S4 in order to be consistent. We did not use variable temperatures and S(z) because the clumped isotopes analyses is currently not available in China. Additionally, and the depth (m) to the Bk is not known due to the disappearance or erosion of the top boundaries of the observed paleosols, thus making our S(z) values minimum estimates. 2°C, 0.15‰, 0.1‰, and 0.1‰ are selected for the standard errors of temperature, δ¹³C_c, δ¹³C_{om}, δ¹³Ca, and 788 ppmV is adopted for the standard error of soil carbonate transfer function with S(z) as suggested by Breecker and Retallack (2014). For details please see Table S5.

Results of error propagation show that the largest source of the uncertainty is the S(z) standard error 766 ppmV of modern soil carbonate (Breecker and Retallack, 2014). The second largest source of error is the S(z) value selection. Details of these errors are now discussed in a new paragraph in text (new lines 254-250, subsection 4.3). Other errors such as those for temperature, δ¹³C_r, δ¹³Ca, δ¹³C_s, exert far less to the uncertainty of pCO₂ estimates.

— The descriptions of the sediments and paleosols reported here will be useful. I'm not sure I would call these Aridisols, though, because redoximorphic features are prominent (at least in some of the soils, e.g., Fig 3 a,b,c). Are you sure these are not Vertisols? Are there wedge-shaped peds? The authors mention abundant slickensides- a feature common in Vertisols.

We thank the reviewer for asking this question. There is much confusion from the literature with multiple classifications, and discussions of features such as slickensides that do seem to suggest more moisture. The aridisol (calcisol and gypsisol) and vertisol are distinguished with clay-heave structure by Retallack (1993, 1998, 2001). For calcisols, a high ratio of clay can produce clay-heave and slickenside structures due to hydrological changes. Additionally, some angular, subangular, and platy peds are common in the calcisols, but few are wedge-shaped. We concur with the reviewer that the Jurassic soils we have studied are likely vertisols.

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Please also see the two figures herein named of Figs. 1 and 2, which are actually Figs. 2 and 8 in text, respectively.

Thank you for attention!

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C5

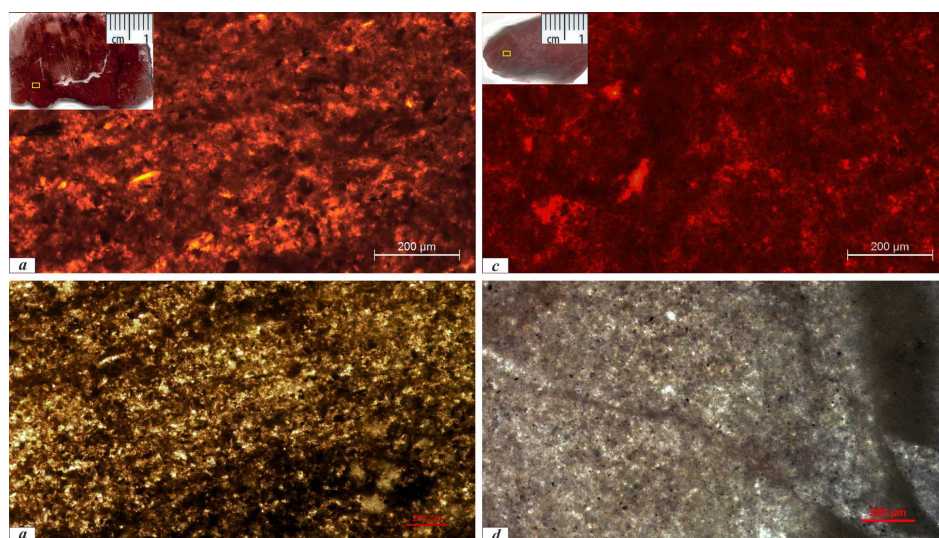


Fig. 1.

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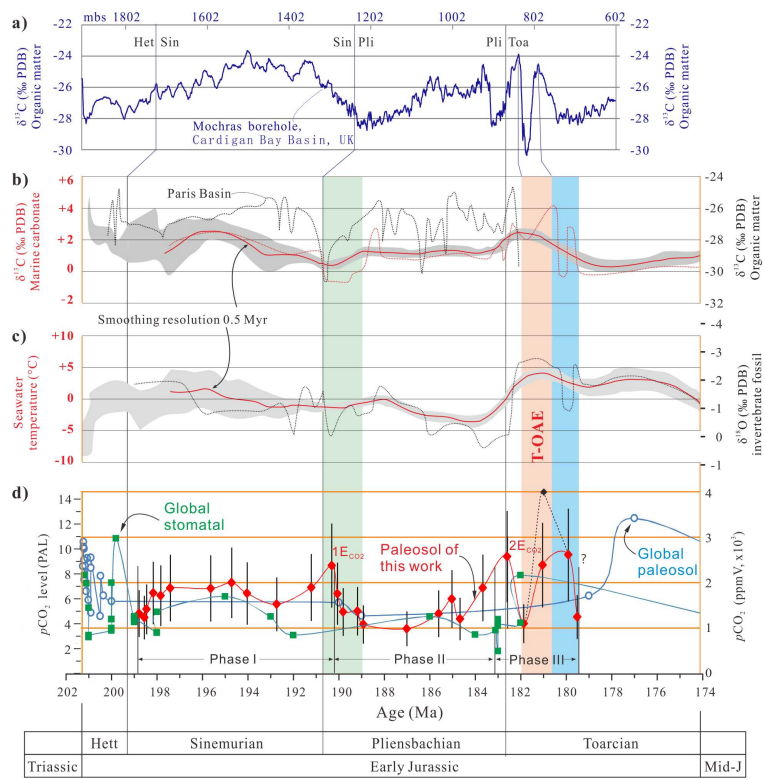


Fig. 2.