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Climate of the Past
Discussions

Interactive comment on "Aptian-Albian clumped isotopes from northwest China: Cool temperatures, variable atmospheric $p\mathrm{CO}_2$ and regional shifts in hydrologic cycle" *by* Dustin T. Harper et al.

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General Response to Reviewer Commentary

First, the authors of the manuscript entitled "Aptian-Albian clumped isotopes from northwest China: Cool temperatures, variable atmospheric pCO2 and regional shifts in hydrologic cycle" would like to thank the three reviewers for providing focused critical evaluations of our work. Below, we directly address the reviewer's comments and include the original reviewer commentary. Original reviewer comments are labeled

"RC1", "RC2" and "RC3". We intend on largely following the advice and comments of reviewers. In our responses, we layout specific planned revisions for the next draft submission. We are confident that we can address the reviewer's concerns with only these few, minor revisions to the manuscript. We look forward to hearing the editor's decision for the next stage of the manuscript.

Response to Review 1 (Anonymous)

RC1: The manuscript entitled as "Aptian-Albian clumped isotopes from northwest China: Cool temperatures, variable atmospheric pCO2 and regional shifts in hydrologic cy- cle" by Dustin T. Harper et al., present new results of pedogenic carbonate stable isotopes (δ13C, δ18O and Δ47) from the lower mid-Cretaceous (Aptian-Albian) Xiagou and Zhonggou formations, Yujingzi Basin of NW China. Authors estimate the MAT using Δ47 of carbon ad oxygen isotopic values and the MAP using CALMAG of mu- drocks, further calculate the pCO2 using MAP and δ13C of pedogenic carbonates with other parameters, and discuss the carbon and hydrologic cycles for the interval of the Aptian-Albian. This work is a new progress of the land quantitive paleoclimate in North China, even in East Asia. It would provide clues and references for the climatic re- construction of the greenhouse Cretaceous period. However, more data and evidence need to further enhance and refine, and some issues have to solve.

Geological data to complement. Though figure 1 shows the locations of samples in outcrop, it does not have any geological significances. It does not exhibit any stratigraphic sequences with sample horizons. In my opinion, it is important that sampling locations are plotted in a geological sketch. And it is advised that a sampling log is added.

Author Response: Much of the geologic data and sampling information for the study site was initially described in Suarez et al. (2018). We have also included supplemental tables in the present study detailing sample lithology and samples identified as paleosol B-horizons. However, to address the reviewer's concern for lack of stratigraphic and geologic data, we opt to include additional supplemental figures in the next draft submission which will include lithostratigraphic columns with sampling locations, and images of sampled carbonate nodules, nodule features and sedimentary structures interpreted to represent pedogenesis (slickensides, ped structure etc.).

RC1: Data age. Authors used the organic stable carbon isotope chemostratigraphic records for the site (Suarez et al., 2018) to have the studied strata age-controlled. Albeit more than 400 organic stable carbon isotopes were correlated and suggested the Aptian-Albian in Suarez et al. (2018), it is not assured and persuaded due to lack of precise age reference-point and age-index fossils. This is a common issue and problem of the land materials for paleoclimatic analysis. It is cautious to make the precise correlation for the terrestrial strata and samples.

Author Response: While we agree chemostratigraphic correlation can be complicated by local influences over global variations in carbon cycle, we argue that Suarez et al. (2018) provide convincing evidence that our study sections span the "C10" carbon isotope high after Menegatti et al. (1998) and Bralower et al. (1999). Variations in δ13C of organic C from the same sample collection utilized in this study have been correlated to globally representative records of carbon cycle variations.

Further, this is not the only age constraint for the Xinminpu Group. Samples from localities to the South of the Yujingzi basin have been identified as Xinminpu Group and measured for radiometric dates. These dates range from 123 $\pm$2.6 Ma to 113.7 $\pm$1.8 Ma (Kuang et al., 2013; Li et al., 2013).

Additionally, a recent study (Zheng et al., 2021) establishes regional ages through bio- and chronostratigraphy. This study reviews available age controls for the Lower Cretaceous in NW China and places the organic carbon isotope records of Suarez et al. (2018) (i.e., our study sections) within the chronostratigraphic framework of the region. Now that this paper has been published, we will include more details of the biostratigraphy and chronostratigraphy which better establish the age control of our

study site in the next draft submission.

RC1: Field description of paleosols. It is key to make sure the observed horizons are real paleosols, i.e. authors claimed the paleosols a kind of vertisol. I do not see the details of the paleosols even though authors have done analyses of CL and microfacies for the calcareous nodules. Shape, size, content, and occurrence of nodules can provide us reference for paleosols. Color, structures, and ped types can give us some information about the paleosols. Other more, vertisols are a kind of paleosols we do not easily observe and distinguish in practice in field recognition. Detailed notation of evidence seems necessary for the classification of the vertisol.

Author Response: Much of this information was established in Suarez et al. (2018) for the study sections, and for this study we avoided redundancies with respect to detailed outcrop and paleosol descriptions. However, we understand the importance of establishing the sampled paleosols as vertisols to interpretation of our results. Following this reviewer's comment, the authors have decided to include an additional supplemental figure (also described above) which will include strat columns with descriptive observations of pedogenic structures and images of hand samples. Additionally, we plan to update our field map based on this review and review 2. This site map will show the region with localities of geologic and paleontologic interest as well as select outcrop images which show, for example, mukkara cracks and other evidence supporting our classification.

RC1: Drilling samples for clumped isotopes. It is a good job for the clumped isotope. But it is also a problem to take powder samples from the calcretes. This is because we only need <0.1 mg for the common C-O analyses of carbonates, but we have to take over 5mg for clumped isotope analysis. It is difficult to take so much from a calcretes sample according to much experience. So, how to get the enough quantity of the powder sample may need to expain.

Author Response: Our pedogenic carbonate nodules were cm to multi-cm in scale, providing ample carbonate material for sampling. The reviewer makes a good point in that it is important that the clumped isotope material that is sampled should maintain uniform δ13C and δ18O values. To ensure this, we measured multiple "spot" samples for δ13C and δ18O for each nodule, and only sampled material for clumped isotopes from areas with uniform δ13C and δ18O in a given sample. The average δ13C and δ18O values were then compared with the values obtained during the clumped isotope measurement as an indication of successful sampling. We argue that this strategy has been clearly outlined in the manuscript. In addition, the new supplemental figure will show the sizes of typical carbonate nodules sampled so that readers can have a better sense for the material sampled.

RC1: Low temperature and low pCO2 in the Aptian-Albian. As we know from lots paleoceanographic and paleoclimatic achievements, the mid-Cretaceous is the hottest interval in the Phanerozoic. So, the conclusion from the authors that a low temperature had been in the Aptian-Albian may need to further examine except for the short "cold snap". It may be paradox that low temperature is consistent with low pCO2 in the Aptian-Albian in Northwest China. This is because the pCO2 is almost global in nature, but the temperature in a basin, North China, was probably local record to great degree on land. Actually, we know the Cretaceous climate was not homogeneous in China.

Author Response: The coauthors humbly disagree that the scientific community has concluded that the mid-Cretaceous was the hottest interval of the Phanerozoic. Taken as a whole, yes, the Cretaceous Period was one of the warmest intervals, but this paper and many others investigate a more detailed climate record. At the stage level, many would argue that the hottest interval occurred during the Late Cretaceous near the Cenomanian-Turonian boundary (Bice et al., 2006; Hay et al., 2017). Certainly, we know that the Cretaceous was generally a warm interval (Hay et al., 2017), but a large number of publications which examine shorter-term climate variations indicate relative cool conditions at the Aptian-Albian, but also other stages such as the Valanginian (see for example, Mutterlose et al., 2009; Rodriguez-Lopez 2016; Bottini et al., 2015;

Heimhofer et al., 2008; Millan et al., 2014; Vickers et al., 2019). Undoubtedly, there were large variations in the carbon cycle during this time evidenced by ocean anoxic events and variable δ13C in global archives, suggesting these variations were global in nature (Menegatti et al., 1998; Bralower et al., 1999). Indeed, previous work on mid-Cretaceous climate suggests relatively cool temperatures over a large swath of latitude in Asia (Amiot et al., 2011).

We agree that surface temperatures on Earth are not homogeneous, including over a large land mass such as Asia. Also, we agree that our temperature record reflects a local signal. Atmospheric pCO2 is certainly a global signal when we compare atmospheric CO2 mixing times with the temporal resolution of our record. However, shifts in pCO2 are clearly linked with shifts in land surface temperatures over many intervals (e.g., Bice et al., 2006; Pagani et al., 2005; Hay et al., 2017). In the manuscript we have discussed the local versus global nature of our records, both in terms of topography and with respect to latitude, fairly extensively in the discussion section 4.3 "Latitudinal gradients of temperature and meteoric water δ18O for the Aptian-Albian". In this section, our temperature record was placed within a global context using latitudinal temperature profile figures (Figure 7).

Indeed, one large take-away from this work is that Cretaceous climate was not homogenous neither spatially (see discussion and figures on latitudinal temperature distribution) nor temporally. Variations were clearly occurring in terms of climate and the carbon cycle, evidenced by: 1. Shifts in global records of carbonate δ13C (Menegatti et al. 1998; Bralower et al. 1999; Suarez et al., 2018) 2. Multi-million year records of variable atmospheric pCO2 including ours and those of Bice et al. (2006) and Wang et al. (2014). 3. Mid-Cretaceous records of temperature (terrestrial and marine; for example, Bice et al., 2006; Amiot et al., 2011; O'Brien et al., 2017; this study)

RC1: Some references are not regularly lined in text. For examples, references cited in Lines 55, 269, etc. are neither listed in the sequence of publishing time nor of surname letter.

Author Response: Thank you for pointing this out. We plan to address this in the next draft submission.

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