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## Reply on RC1

Andre Baldermann et al.

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Author comment on "Palaeo-environmental evolution of Central Asia during the Cenozoic: new insights from the continental sedimentary archive of the Valley of Lakes (Mongolia)" by Andre Baldermann et al., Clim. Past Discuss.,  
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## Review of paper Preprint cp-2021-32: "Palaeo-environmental evolution of Central Asia during the Cenozoic: New insights from the continental sedimentary archive of the Valley of Lakes (Mongolia)" by Baldermann et al.

In the below text we comment on all of the reviewer comments and outline our point by point responses, demonstrating our ability to address all substantial comments.

### RC1: Anonymous Reviewer

#### General comments

The valley of lakes in Mongolia is certainly a key area for investigating Cenozoic mammal evolution and climate changes in Central Asia. It is significance to reconstruct the paleoclimate evolution history during late Eocene to early Miocene based on sedimentological, petrographic, mineralogical and geochemical signatures recorded in a sedimentary succession in the valley of lakes in Mongolia. In this study, Baldermann et al. extended the existing mineralogical and (isotope) geochemical dataset reported in Richoze et al. (2017) to constrain provenance, paleoenvironmental conditions and post-depositional alteration history of the Eocene-Miocene sedimentary succession. Their reconstruction provides good data support for refining the evolution of hydroclimate and weathering conditions in Central Asia in the early Cenozoic. However, there are still some main issues that need further discussion.

We thank the reviewer for the overall positive evaluation of our work. Below, we comment on the specific comments provided by the reviewer and demonstrate how we will revise the text of the manuscript accordingly.

#### Specific comments

1) The chronological framework for sedimentary succession is the basis of paleoclimate reconstruction. In this study, authors thought that authigenic “hairy” illite minerals were formed during coupled petrogenesis and precipitation from hydrothermal fluids originating from major basalt flow events, and illite crystallization ages in sedimentary succession were used to establish the chronological framework in this study. Noticeable, the age of basalt I is ~31.5 Ma at ~40-45m (as shown in Figure 2), which is much younger than illite crystallization age (34.2 Ma) at ~35 m. Authigenic illite crystallization ages possibly are ages when sedimentary strata were affected by hydrothermal fluids, should not be the ages when the sedimentary strata were deposited. Therefore, it should be careful to use the illite crystallization ages to establish the chronological framework of sedimentary succession. Detailed magnetostratigraphic work in the valley of lakes in Mongolia had been done by Sun and Windley (2015). It is suggested to consider their established magnetostratigraphic age framework in this study.

We fully agree with the reviewer. Illitization post-dates the deposition of the sedimentary strata of the Valley of Lakes, and was likely associated with petrogenesis and the major basalt flow events. We state this in section 5.3: “The polytype analysis and K-Ar age dating reveal these illitic phases have been precipitated between 34.2 and 25.2 Ma (Fig. 5), which (within uncertainty) is well within the documented intrusion ages of the basalt I group (32.4-29.1 Ma) and basalt II group (28.7-24.9 Ma) (Daxner-Höck et al., 2017) and closely matches the biozonation reported in Harzhauser et al. (2017).” We therefore agree with the reviewer that the lowermost illite age (34.2 Ma) is slightly younger than the intrusion ages of the basalt I group (32.4-29.1 Ma), but still within the analytical uncertainty of K/Ar age dating. Indeed, the biozonation of Harzhauser et al. (2017) is based on the radiometric and magnetostratigraphic dating of the sections by Höck et al. (1999) and Sun and Windley (2015). Harzhauser et al. (2017) explicitly state in their Introduction: “The radiometric and magnetostratigraphic dating of the sections by Höck et al. (1999) and Sun and Windley (2015) suggests an early Rupelian age for Zone A (33.9 Ma to □31.5 Ma), a late Rupelian age for Zone B (□31.5 Ma to □28.1 Ma), a nearly Chattian age for Zone C (□28.1 Ma to □25.6 Ma), a mid-Chattian age for Zone C1 (□25.6 Ma to □24.0 Ma), a latest Chattian age for Zone C1-D (□24.0 Ma to □23.0 Ma) and an Aquitanian age for Zone D (□23.0 Ma to □21.0 Ma).” As our chronological framework is based on the biozonation of Harzhauser et al. (2017), the magnetostratigraphic work of Sun and Windley (2015) is directly accounted for. For clarification, we will add the precise boundaries of the biozones A to D in the geological framework section and also provide these boundaries in Figure 8, together with the illite formation ages. In summary, the global and regional climatic trends seen in the Valley of Lakes sediments (Figure 8) are supported by a well-established chronological framework.

2) As mentioned in this paper, the depositional setting was characterized by an ephemeral braided river system draining prograding alluvial fans, with episodes of lake, playa or open steppe sedimentation. It means that the sedimentary facies in the study area have been changed many times during late Eocene to early Miocene. The chemical weathering index may change with different sedimentary facies. Therefore, it is suggested that sedimentary facies should be added to the Figure 8.

In section 2, we refer to published literature that addresses in detail the changes observed in the sedimentary facies across the different sections of the Valley of Lakes: “Further details about the local nomenclature, the investigated profiles, profile correlation and lithostratigraphic relationships are provided in Harzhauser et al. (2017), Daxner-Höck et al. (2017) and Richoz et al. (2017).” We don’t find it necessary to repeat these findings here. Nevertheless, Richoz et al. (2017) have concluded that the overall sedimentation system has not changed much in the considered timeframe, a feature confirmed in this study. Moreover, our novel K-Ar datings of the detrital illite fraction as well as our

discrimination function analysis indicate no significant changes in sediment provenance occurred from the late Eocene to the early Miocene. Alike, we propose an about constant detrital silicate influx with a relative contribution of  $\sim > 95\%$  from the Burdhol zone and  $\sim < 5\%$  from the Baidrag zone. Thus, the chemical weathering index records changes in the weathering conditions of the source rock areas rather than changes in the sedimentary facies. We will add a sentence in section 5.1. stating this.

3) The scatter in the  $\delta^{18}\text{O}$  isotope composition of the soil carbonates in the upper Eocene was attributed to playa lake sedimentation (as shown in Figure 8), but there was no petrographic-sedimentological evidence for sediment deposition in a lake or playa environment. Why is there such a paradox?

We will modify the sentence as follows for clarification: "In contrast to Badamgarav (1993) and Daxner-Höck et al. (2017), we found no petrographic-sedimentological evidence for lake or playa sedimentation in the upper Eocene strata, which we attribute to the different sample types considered: While Badamgarav (1993) and Daxner-Höck et al. (2017) have identified efflorescent salt crusts composed of halite, tepees and polygonal structures in some layers, no such sedimentary structures were observed in the paleosol horizons of the same age. However, the scatter in the  $\delta^{18}\text{O}$  isotopic composition of the soil carbonates, which has been attributed to varying amounts of evaporation (Richoz et al., 2017), is consistent with a playa lake setting."

4) The  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  profiles showed that significant aridification occurred between  $\sim 62\text{--}92\text{ m}$  (maybe  $\sim 30\text{--}24\text{ Ma}$ ) in the valley of lakes, and the aridity weakened above  $\sim 95\text{ m}$  (after  $\sim 24\text{ Ma}$ ). The change trend in chemical weathering indexes were not consistent with  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  profiles. In the range of  $50\text{--}85\text{ m}$  (maybe  $\sim 31\text{--}26\text{ Ma}$ ), chemical weathering indexes fluctuated frequently, but generally decreased; they increased significantly at  $\sim 26\text{ Ma}$ , and maintained relatively stable high values during the early Miocene. What causes the difference between isotope data and chemical weathering indexes? Sedimentary facies? Post diagenesis? Basalt flow events? Or regional tectonic activities? Noticeable, without the precise chronological framework, it is not significant to make one-to-one correspondence between the fluctuations of chemical weathering indexes and global climate events.

As indicated in our response to comment 1) we are confident that the chronological framework we use is correct. We agree with the reviewer that the weathering indices scatter to some degree but they are basically inversely correlated to the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  profiles (cf. dashed orange lines in Fig. 8). This is because variations in the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  profiles are consistent "with inverse shifts seen in the chemical weathering indices (dashed orange lines in Fig. 8), i.e., periods with increased precipitation coincide with higher chemical weathering indices and vice versa." Thus, the palaeo-climatic conditions in the Valley of Lakes and in the adjacent areas were the driving factor for the observed hydroclimate and weathering trends. Changes in sedimentary facies, diagenesis, basalt flow events or regional tectonic activities are negligible as the trends we see are based on a stable sediment provenance and pristine soil carbonate isotope signals. We will add a statement in section 5.5. stating this.

## Technical corrections

1) The formation names marked in Figure 6 are wrong, please check it carefully. e.g. a) Tsagaan Ovoo formation should be Loh Formation. c) Loh should be Tsagaan

The formation names marked in Figure 6 are correct but we will change sub-figures a) and c) in order to bring the formations in stratigraphic order.

Sun, J.M.& Windley, B.F. (2015). Onset of aridification by 34 Ma across the Eocene-Oligocene transition in Central Asia. *Geology*, 43(11), 1015-1018.