Reviewer comments are displayed in blue italic

Dear Denis-Didier Rousseau,

Thank you very much for your assessment of the manuscript. We have now assessed the review by William Lukens, who we would like to thank for his careful considerations.

Reviewer Lukens:

I have carefully read the manuscript and supplemental data sets submitted by Prof. Meijers and coauthors. The goal of this paper is to present a new, large data set of stable carbon isotope analyses performed on carbonates from late Miocene to Holocene sites in Anatolia. By combining their analyses with previously published carbonate d13C data, as well as published paleoclimate estimates from the region, the authors demonstrate secular changes and restructuring of paleofloral communities since ~10 Ma.

Overall, the paper is very well written and presents a compelling and interesting data set. The strengths of the work are that the data are both numerous and have well constrained age estimates. The geographic and tectonic setting differs greatly compared to most studies that evaluate C3-C4 transitions and turnovers – this study focuses on a region that only (geologically) recently shifted to a Mediterranean style climate. One would hypothesize that a late Miocene C4 expansion, approximately coincident with similar shifts in eastern Africa and central to eastern Asia, would then trend back to C3 dominance with the change rainfall seasonality. This is in broadly what the data show, but with interesting added nuance in timing and variation.

My only real concern is the interpretation and vetting of the origin of the carbonates. The manuscript rightfully focuses on the large-scale structure of the data set and how it fits within a broad, regional to global picture of paleoclimate and paleovegetation (appropriate for this journal and this style of paper). However, there has been great progress in the study of paleosols (paleopedology) since the 1980s-1990s, during which many of the original works documenting d13C-based shifts and "C4 expansion" were first published. We now recognize that carbonates in continental strata can superficially appear to be "pedogenic" but in fact may be palustrine, diagenetic, pedogenic, or any combination thereof. Some of the authors of this study previously published very good work focused on the clearly lacustrine carbonates of this region (Meijers et al., 2020, https://doi.org/10.1130/GES02135.1). However, there is a spectrum of palustrine to pedogenic carbonates that can be a bit of a nightmare to disentangle. In my perspective, the best way to address these concerns is to focus on the paleosols at some of the sites in much greater detail, with both field and micromorphological observations to test that the "pedogenic" carbonates are associated with other (non-carbonate) features of paleosols (e.g., soil structure, clay fabrics, redoximorphic mottling, etc.). Perhaps this is underway?

We agree that distinguishing between pedogenic, palustrine, and diagenetic carbonates in continental settings is not always straightforward, and that carbonates may form along a continuum of processes. In this study, carbonate samples were classified based on field descriptions and lithological context, which identify them as predominantly pedogenic or soil-related carbonates. However, we acknowledge that some degree of ambiguity may remain, and that a subset of samples could reflect mixed origins.

That said, near-surface carbonate formation will be affected by soil type and formation depth, which are in turn controlled by climate conditions. As a consequence of climatic variability on the time scales considered, we assume that some of the within-outcrop variability of δ^{13}C values in Fig. 2 may, in addition to fluctuating components of C_3 and C_4 vegetation, be resulting from transient environmental conditions.

Importantly, however, the observed long-term shifts in δ^{13}C values, specifically the distinction between values from ca. 7.2 Ma to 4.9 Ma and those after ca. 3.9 Ma (Fig. 2), represents a consistent pattern across multiple sites and stratigraphic intervals. While we cannot entirely exclude some influence of mixed carbonate origins, the magnitude and consistency of this temporal trend suggest that our main conclusions are robust.

There is one supplemental figure (Fig. S1) that shows some examples of the sampled carbonates in outcrop. Figure S1e shows a potential paleosol based on color variations. However, boxes c and f show zones that clearly retain cm- to dm-scale bedding, which would not be expected to occur in a soil profile that was mature enough to host sizeable carbonates of pedogenic origin. Simply put, pedogenic carbonates require much longer durations to form than the time it takes to convert primary bedding to soil structure. The morphologies shown in Fig. S1 may be more akin to palustrine carbonates, which my colleagues and I have puzzled over in areas such as the Meade Basin of Kansas, USA (e.g., Lukens et al., 2019, https://doi.org/10.2110/jsr.2019.24). The rhizoliths or "taproots" could also be precipitations along burrows, which are often overlooked. Interpreting photosynthetic pathways from carbonate d13C analyses requires that a carbonate sample had formed in equilibrium with plant-respired CO2 in a subsoil horizon; there are countless other ways to produce variable d13C values across the range observed in this study (e.g., the lacustrine data in Meijers et al., 2020).

The Reviewer specifically addresses three examples of sampled carbonates in Fig. S1. Two (e and f) of three examples are from subsections within locality Orta Tepe South. As the Reviewer notes, subsection 12C-032-038 in Fig. S1e displays color variations typical for paleosols, whereas he qualifies subsection 12C-039-043 in Fig. 1f as potentially atypical for a paleosol. We acknowledge that some of these carbonate occurrences may reflect a spectrum of formation processes, including pedogenic and palustrine influences. We would like to point out, however, that samples from both subsections at Orta Tepe South yield near-identical ranges of δ^{13}C and δ^{18}O values (see Table S1), which suggests formation under similar environmental conditions and supports a consistent interpretation of the isotopic signal.

I encourage the authors to consider follow-up work that would more critically assess the origin of these samples, for example by documenting paleosol horizons in more detail. Micromorphological evaluationwould also add to a more compelling case, by parsing d13C data by crystal phases and associations. I acknowledge that the authors defend the veracity of their data by referring to recently published clumped isotope analyses, but those data still may not preclude a palustrine origin for some of the samples.
We thank the Reviewer for this constructive suggestion and agree that a detailed classification of near-surface carbonates in the region (including systematic documentation of paleosol horizons and micromorphological analyses) could put valuable additional constraints on carbonate origins. We will consider these approaches in future studies.

Overall this is excellent, exciting work and a pleasure to read, and I look forward to future considerations of the nuances behind the origin of this very useful paleoenvironmental archives.
The thank the Reviewer for their kind words.

We updated the timing of the onset of the C_3-C_4 transition in South Asia (lines 261-262), to incorporate the chronostratigraphic reassessment of Tauxe and Feakins (2020), which we regret was omitted in earlier versions. The study constrains the onset of the transition to between 7.8 Ma and 7.2 Ma, refining the broader interval (8.0 to 4.7 Ma; Behrensmeyer et al., 2007; Quade and Cerling, 1995).

Sincerely,

Maud Meijers

On behalf of the authors