Comments by the reviewer are *italicized*; our responses are in indented, normal font.

Comments by Jon Smith

The manuscript is well written, well organized and would be of interest to many geoscientist, but If the authors are not able to address these concerns, I think it will be very skeptically received. While I did not get a chance to fully review the manuscript, I did identify some very concerning issues regarding the vintage and accuracy of the geologic background information and the field methods and assumptions with respect to how rock samples were selected in the field. Despite my tardy reply, I list my concerns below.

> We thank Dr. Smith for his thorough and helpful review and, in particular, the references to newer literature. Dr. Smith's comments have helped improve our overall description of the stratigraphy and we also address in detail (both here in the review and also in the manuscript) why the carbonates we sampled are almost certainly Miocene (and in most cases late Miocene) in age.

Line 50 - References to the overall and specific geology composition of the Ogalla are very dated, which isn't necessarily a problem except that it not consulting more recent studies likely led to the additional lithostratigraphic concerns listed below. The authors should carefully read the more recent papers specifically addressing the lithofacies and calcrete stratigraphy of the Ogallala such as:
Joeckel, R.M., Wooden Jr, S.R., Korus, J.T., and Garbisch, J.O., 2014, Architecture, heterogeneity, and origin of late Miocene fluvial deposits hosting the most important aquifer in the Great Plains, USA: Sedimentary Geology, v. 311, p. 75-95.
Smith, J.J., and Platt, B.F., 2023, Reconstructing late Miocene depositional environments in the central High Plains, USA: Lithofacies and architectural elements of the Ogallala Formation: Sedimentary Geology, v. 443, p. 106303.
Korus, J., and Joeckel, R.M., 2023, Telescopic Megafans on the High Plains, USA Were Signal Buffers in a Major Source-To-Sink System: The Sedimentary Record, v. 21.

> We have now incorporated all of these references into the manuscript (Joeckel et al. 2014 was previously referenced).

Line 52 - The concept of the Ogallala ''cap rock'' referring to a regionally persistent and ledge-forming terminal petrocalcic horizon is not supported by more recent stratigraphic studies (Swineford et al. 1958; Diffendal 1982; Gustavson and Winkler 1988; and Joeckel et al. 2014). Instead, these studies show that carbonate-cemented paleosols and petrocalcic horizons are present in numerous stratigraphic positions in Ogallala deposits. I understand that there is a very prominent calcrete at the contact between the Ogallala and the Blackwater Draw Formation in TX, but this should not be interpreted to represent a regionally persistent marker bed throughout the expanse of the Ogallala as was previously assumed (prior to the 2000s). See References above and Ludvigson et al. (2009), Review of the stratigraphy of the Ogallala Formation and revision of Neogene ("Tertiary") nomenclature in Kansas.

> We have changed the wording here to indicate that the "cap-rock" is a regional distinctive

feature limited largely to the southern High Plains. We do not mean to imply anything regarding its genesis here; rather, we only wish to note that it is a regionally distinctive geomorphic feature (see also changes to lines 68-70).

Line 68 - see earlier comment, while I agree Ogallala exposures are typically well indurated by carbonate, I would hesitate to refer to this characterstic as "its caprock", as its not a single bed.

We have modified this sentence to denote that the many calcic-rich units help to create the characteristic escarpments of the High Plains.

Figure 1- giving the circles and squares different colors might help to distinguish them a bit better.

Great idea! We've modified the colors to help distinguish them.

Line 175 – Some very interesting papers have recently been published on just this topic, see Korus, J., and Joeckel, R.M., 2023, Telescopic Megafans on the High Plains, USA Were Signal Buffers in a Major Source-To-Sink System: The Sedimentary Record, v. 21.

We have now incorporated this reference throughout the manuscript.

Line 182 – Additional publications with specific volcanic age data from Ogallala ash bed should be cited:
Swisher, C. C. III, 1992, 40Ar/39Ar dating and its application to the calibration of the North American land mammal ages [Ph.D. thesis]: Berkeley, University of California, 239 p.
Smith, J.J., Turner, E., Moller, A., Joeckel, R.M., and Otto, R.E., 2018, First U-Pb zircon ages for late Miocene Ashfall Konservat-Lagerstatte and Grove Lake ashes from eastern Great Plains, USA: Plos One, v. 13.

Now added.

Line 192 - This may be the case in some areas, but it is not a consistant feature. Calcretes are present in many Ogallala outcrops regardless of stratigraphic position as it is most like a result of exposure case hardening. See Joeckel et al. 2014 and Smith and Platt 2023 for more on modern interpretation of "cap rock".

We have now modified this sentence to note that this is a feature only observed in the southern High Plains. We do not disagree that, north of Texas and New Mexico, caliches may result from case-hardening (though see arguments in our responses below about why the isotopic evidence suggests that this may not the case). Rather, in Texas and New Mexico another explanation for the caprock—which fits with the available field observations (Gustavson, 1996; Gustavson and Winkler, 1988)—is provided by Brock and Buck (2009), who posit that the Stage VI caliches that are typical of the southern High Plains result from extended landscape stability and continuous carbonate dissolution/precipitation (note though that Brock and Buck (2009) conduct their study on a different caprock in northwest Arizona).

Line 205 – "on the assumption that the caprock formed simultaneously across the Great Plains." –

we know this is incorrect. See references above.

We have modified this sentence. While our original intention was simply to note that previous authors (not us) have relied upon such a method to provide temporal constraints, we realize the wording was confusing. We have now modified the sentence to note that certain Ogallala outcrops (particularly in New Mexico, where they are disconnected from the escarpment) have only ever been "dated" using geomorphic or lithologic correlations across hundreds of kilometers (Frye et al., 1982).

Line 211 – See Smith and Platt (2023) for more on unconformities and the thorny issue of Ogallala calcretes…

Line 226 - The authors need to provide more information on their samples and sampling methods. There are many carbonate morphologies in the Ogallala, and its becoming increasingly clear most are not coincident with paleosol formation. The pics in Fig. 2 helps, but is also concerning. Carbonate nodules and burrows may be authogenic, but I have some reservations about the pictured root casts and am very skeptical of the "cap rock" calcrete. We strongly suspect that many of these calcretes and calcrete morphologies are primarily carbonate precipitation due to case hardening of the exposed surface and not syndepositional. This is a vitally important issue because this may be the primary reason you are getting a consistently modern signal from your d18O; you may be sampling carbonates that precipitated essentially in response to recent exposure and under essentially modern conditions. I'm not stating that is the case, but its impossible for me to tell without being more specific in how and what you sampled.

We now include several sentences detailing the types of samples collected and our field and laboratory sampling methods. All sample types (for each sample) are listed in Table S1 (though this Table should be publicly available shortly, here is a link to access it prior to publication:
https://datadryad.org/stash/share/sY5SXxVH-Hfp104CZ4m-grrcnOh-RAdwdbCNrF1Avcg).

Because this comment questions perhaps the most critical assumption in our study (*i.e.*, that the sampled carbonates record late Miocene climate)—and, indeed, a critical assumption in nearly all paleoclimate studies that use stable isotopes—we also respond to it in detail here.

First, while Smith and Platt (2023) and Joeckel et al. (2014) provide compelling evidence that some of the carbonates in some sections of the Ogallala are not syndepositional, the isotopic data presented herein does not necessarily support this interpretation. In each individual section that we present, though we sampled a wide-variety of carbonate types (ie, rhizoliths, nodules, burrows, matrix, and caliche/cap-rock), the $\delta^{18}O$ is nearly identical between sample types. This is perhaps best seen in Figure 4b (and also Table 1) in our manuscript, where we plot the 1σ for each section's $\delta^{18}O$. The 1σ values are very low (*i.e.*, <1 ‰), which indicates that in most of our sections, the variety of sampled carbonates have very similar $\delta^{18}O$ values. In only three sections is the $1\sigma > 1$‰. The section with the largest 1σ (WC; Wildcat Bluff Nature Park outside Amarillo, TX) has only 3 samples. The topmost sample (the carbonate-cemented ash, dated by Cepeda and Perkins (2006)) is almost certainly altered, with $\delta^{18}O$ and $\delta^{13}C$ values distinctly different than nearly all other samples in the southern Great Plains (see Supplemental Table 1). The section with the second largest 1σ (ESP, from the Santa Fe Group in the Española basin) has a very wide $\delta^{18}O$ range, which has been the subject of further work by our research group (Bui et al., 2023; Spaur, 2022; Spaur et al., 2022) and is anyway outside the area of Ogallala deposition. This uniformity of $\delta^{18}O$ values in individual sections has been found by previous workers as well (Fox and Koch, 2004; Ludvigson et al., 2016). The fact that $\delta^{18}O$ is invariant in these sections suggests that all carbonates are forming from the same source waters. Thus, if rhizoliths, burrows, and nodules are original and formed syn-depositionally (as suggested by Joeckel et al. (2014)), then—from an isotopic perspective—the sampled caliches and caprock formed at the same time as the rhizoliths, burrows, and nodules.

Alternatively, climate could have been invariant (partly the hypothesis in our study) and all of these carbonates are simply recording modern meteoric water $\delta^{18}O$. However, here the $\delta^{13}C$ data strongly indicate that, for most of our sections, the carbonates that we sampled (though see note below regarding the sections in New Mexico) formed no later than the latest Miocene. In the Great Plains, there is a well-documented increase in carbonate $\delta^{13}C$ due to the spread of C4 grasslands after the Miocene (Fox and Koch, 2004, 2003). The appearance of C4 grasses leads to $\delta^{13}C$ values of approximately -2‰ (or even higher) by the Pleistocene. Nearly all of our Ogallala sections have mean $\delta^{13}C$ values < -6‰, indicating they formed in the late Miocene prior to the widespread dominance of C4 grasses. Indeed, some of the lowest mean $\delta^{13}C$ values are in the northern Great Plains. (We recognize that the $\delta^{13}C$ data were not available in the initial submission but they are now listed in Table 1 and publicly available via the Dryad link).

The only sections with $\delta^{13}C$ values > -6‰ occur in New Mexico. These sites have less precise age control than sites to the east in Texas and to the north. Most of these sites were originally studied by Frye et al. (1982), who correlated these sites to the Ogallala Formation based upon their geomorphic position and/or their lithology. We know of no studies (except the Masters thesis by Henry (2017)) that have followed up to constrain the age of deposition at these sites. At several of these sites, not only is the mean $\delta^{13}C$ > -6‰, but the $\delta^{13}C$ 1σ is relatively high, largely due to the fact that the caprock sometimes has a much higher $\delta^{13}C$ (in other cases, the caprock caliche has similar $\delta^{13}C$ values to the rest of the sampled carbonates). At these sites, then, the $\delta^{13}C$ may support the contention of Joeckel et al. (2014) and Smith and Platt (2023) that some of the sampled carbonates formed millions of years after deposition and/or that the caprock has a multi-genetic history (also found by Henry (2017)).

However, because we have no other independent age data for these sites (except for CP, studied by Henry (2017)), we are hesitant to exclude these data solely based on their $\delta^{13}C$ values and instead choose to include these data in our study. Further, there are also samples at many of these sites with low $\delta^{13}C$. Thus, we are hesitant to exclude these sections since, in many cases, these sites have carbonate samples that return $\delta^{13}C$ values indicative of formation during the late Miocene. Because there may have been landscape-scale variability in the abundance of C4 in the late Miocene (Lukens and Fox, 2022), it seems prudent to not exclude this data. We further note that excluding these data would not substantially alter the estimated mean $\delta^{18}O$ or modify the conclusions of this study.

Thus, we suggest that the largely invariant $\delta^{18}O$ in any given section indicates that all of the carbonates in any given section formed from the same meteoric water (or that climate has been relatively invariant since the late Miocene) and that the low $\delta^{13}C$ (low relative to modern soil carbonate $\delta^{13}C$) indicates that, in most of these sections, the carbonates must have formed prior to the spread of C4 grasses in the Pliocene. An interesting follow-up study would be to try and reconcile both the field observations of Joeckel et al. (2014) and Smith and Platt (2023) with the isotopic evidence for Miocene formation of carbonates from this study, particularly in the central and northern Great Plains. Additional work is also necessary to provide independent age estimates for many of the sites in New Mexico identified as the Ogallala Formation by Frye et al. (1982).

We have now included this reasoning in the manuscript in lines 504-554.

Line 317 – "this year"…. What year? 2016? Or an average of 1980-2016?

We have modified the text to note that these plots encompass all months of the year (ie, January through December), averaged over the timeframe of the HYSPLIT climate model data (*i.e.*, 1980-2016).

Line 421 – "also imprecision in the chronologies of the sections we sampled"… Not just the sections, but the sampled material itself, as in assuming the carbonate is in some respect syndepositional with the host sediments. I would be curious to see inter-area sampling differences. For example what is the variance in d18O between the 19 samples from the BV location? Are there patterns with respect to sample type (nodules that appear pedogenic vs calcrete vs rhizoliths)?

We address the point about chronology imprecision in the point above, but do note that, while our samples record late Miocene formation (ie, prior to the spread of C4 grasslands), within this epoch, samples may not have necessarily formed syn-depositionally.

The 1σ for the BV location is 0.45 ‰ and the full range is 1.8 ‰ (reported in Table 1). As mentioned above, there is very little variance in the isotope data from any given section. It is difficult to compare $\delta^{18}O$ of sample types across sections due to the fact that $\delta^{18}O$ varies by more than 10‰ from our southernmost to our northernmost sites. However, within each section, there is no pattern in $\delta^{18}O$ with respect to sample type.

Again, I apologize for not completing my review. I have few concerns about the results of the geochemical analyses. The methodology and output is well communicated, and I would not be surprised by their findings in the slightest; in fact they align very well with my most recent publication using paleosols and trace fossils to interpret climate conditions (Platt, B.F., and Smith, J.J., 2023. Late Miocene paleoecology and paleoclimate in the central High Plains of North America reconstructed from paleopedological, ichnological, and stable isotope analyses of the Ogallala Formation in western Kansas, USA. Evolving Earth, https://doi.org/10.1016/j.eve.2023.100019.) But frankly, I am extremely skeptical of their interpretations and conclusions due to the lack of communicating exactly what was sampled, how or why they suspect the sampled carbonate is ancient, and the authors out dated understanding of the regional geology. I was not able to complete *my review, so I will not make a final recommendation.*

> We hope our revisions have helped to address these concerns, and we also incorporated the Platt and Smith (2023) reference into the manuscript. We have modified the manuscript to incorporate newer sedimentological interpretations and have revised our descriptions of the litho-stratigraphy. Regarding the stable isotope analysis, our data do not suggest that there are carbonates within most of these sections that formed at a substantially different time than the other carbonates in these sections. This conclusion arises due to the small variance in $\delta^{18}O$ in each section (suggesting all carbonates are recording the same waters) and that the $\delta^{13}C$ is low and clearly formed prior to the well-documented spread of C4 grasses in the Great Plains (though note the additional independent chronology work that is needed in New Mexico). These observations indicate that the carbonates sampled and analyzed in our study do indeed record late Miocene climate.

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