Geochronology Discuss.,
https://doi.org/10.5194/gchron-2019-12-AC1, 2020

GChronD

Interactive comment

Interactive comment on "LA-ICPMS U-Pb geochronology of detrital zircon grains from the Coconino, Moenkopi, and Chinle Formations in the Petrified Forest National Park (Arizona)" *by* George Gehrels et al.

George Gehrels et al.

ggehrels@gmail.com

Received and published: 10 February 2020

Glenn Sharman (Referee) gsharman@uark.edu Received and published: 27 November 2019

==> Responses to reviewer comments inserted below

This manuscript by Gehrels et al. presents a new dataset of detrital zircon U-Pb dates from 29 samples collected during the Colorado Plateau Coring Project. The sample transect provides a detailed view of changing provenance and depositional

Printer-friendly version

Discussion paper

age through Permian-Triassic rocks that have been well-studied for their scientific importance related to the environmental, biologic, and tectonic evolution of the western United States. Beyond its value in providing greater context for this particular region and time, this manuscript more generally provides an excellent case study of how detrital zircon LA-ICP-MS data may be treated during maximum depositional age (MDA) analysis. I suspect that the authors' approach, which involves consideration of four different approaches to calculating the MDA of each sample and, will provide a useful example for others in the geologic community to follow. This study is somewhat unique in that detrital zircon LA-ICP-MS MDA calculations can be compared to existing chronologies (paleomag, CA-ID-TIMS of detrital zircon and volcanic cobbles) to assess the degree to which MDA calculations approximate the true depositional age. I found this manuscript to be well-written and illustrated. I have one major reservation about the authors' conclusions and several minor comments (see Summary Comments below).

I have also included line-by-line comments.

Specific Comments:

1. My biggest criticism of the conclusions of this manuscript is the inference that near depositional age zircon are air-fall in origin and older zircon are recycled. The authors repeatedly make this claim in the later part of the manuscript (e.g., Lines 700-701, 706-708, 718, 720, 740, 744-745, 765-766, 770-771, 820). However, relatively little attention was giving to substantiating this claim, besides merely stating that this is the preferred interpretation (Lines 679-681). A general comparison was made between grain size and contemporaneous zircon, yet when I view Fig. 13, I see several counter-examples (e.g., mudstone and siltstone that lack contemporaneous zircon and sandstone that has it). A simple plot of lag time (MDA minus model age) versus grain size would be helpful in evaluating this argument – I suspect that there will be a lot of scatter. I would be more convinced of this argument if morphology data were reported that showed young zircon to be euhedral and needle-like. More generally, the

authors seem to imply (perhaps unintentionally) that near-depositional age zircon must be exclusively air-fall in origin. However, examination of modern river detrital zircon age distributions reveals that very young zircon are found in fluvial sediment that drain regions with active volcanism. I see no reason why the Chinle rivers that emanated from the Cordilleran arc would not similarly carry young zircon in their bedloads. Note that I am not suggesting that air-fall zircon are not present or important (I suspect they are). But I don't think a strong argument has been presented that show that young zircon are exclusively airborne.

==> Response: These are great comments! Most are addressed below, where the same concerns are keyed to specific sections of the manuscript.

Not addressed below is the suggestion of plotting our maximum depositional ages on a lag-time plot. Our sense is that such a plot would not be of great benefit for two reasons:

First, given that two different age models are viable for a portion of the section, we would need to include two different offset plots. In contrast, when plotted by age, a single plot (Fig. 13) shows both age models, the maximum depositional ages, and the lag time (the difference between the two).

Second, using a lag-time plot would obscure one of the primary patterns of our data, which is that significant portions of the stratigraphy yield similar maximum depositional ages. For example, the eight samples from the Blue Mesa and lower Sonsela members that yield indistinguishable ages, which we interpret as evidence of recycling. This pattern shows up very clearly on an age plot (Fig. 13), but would be obscured on a lag-time plot – our max depo ages would appear to get older upsection, but this is only because the age model is getting younger. . ..

We also are unable to provide reliable information about morphology of the young grains, as most were plucked out from the mounts and dissolved for CA-TIMS geochronology. We tried to do this analysis with BSE images of the grains (before analysis), but the size/shape of the grains in the images has little bearing on the true size/shape of the grains. This because the mounts were polished down just a little so as to retain more material for the CA-TIMS analyses.

2. A relatively minor point relates to how the PDP y-axis scale was presented in figures with an x-axis scale change (e.g., Fig. 7-8). The authors state that they increase the y-axis by a factor of 10x for the plotted age distribution >240 Ma. Yet, I wonder if the PDP y-axis should be scaled relative to the width of the plot and the age range plotted, rather than using an arbitrary number? For example, if a figure has a 50:50 split between 0-300 Ma and 300-3300 Ma, then the optimal ratio of the older plot would be a 10x y-axis increase. But if that sample plot had a 33:67 split, then the necessary y-axis increase would be lower (5x). Following this practice should ensure that the area underneath the curve for each plot is consistent.

==> Response:

The reviewer's suggestion would result in a vertical exaggeration for Figure 7 of about 20x (rather than 10x). Although this would yield a more accurate portrayal of the proportion of old vs young ages, it would require a ~2x reduction in the height of the 190-240 Ma curves (to maintain spacing between the older curves). This would be unfortunate because the young portions of the curves are so important to the main conclusions of the study. Instead, 10x exaggeration is used to show the young curves in greater detail, and then, to address the issue of proportions, the percent of young grains is reported to the left of each curve. Figure 8 is a little more complicated because there are so few young grains in the lower three curves. 5x exaggeration is used for these three to enable showing the young age distributions in greater detail. Again the proportion of young vs old ages is shown with a percentage next to each curve.

Line-by-line comments:

Line 24: "Inductively Coupled Plasma" ??? ==> Revised to: ... Laser Ablation-Inductively Coupled Plasma Mass ...

Line 25: How many detrital zircon grains? ==> Revised to: . . . on 7,175 detrital zircon grains . . .

Line 57: “Formation and to” Line 79: How many grains total reported? ==> Revised to: . . . grains analyzed per sample (total of 7,175 analyses). . . .

Line 114: “yielded zircon U-Pb ages” – why the “/”? ==> Revised to: . . . yielded U-Pb (zircon) ages . . .

Lines 146-149: Suggest including reference to Marsh et al. (2019): Geosphere ==> Revised to: (Ramezani et al., 2011; Marsh et al., 2019; Rasmussen et al., 2019)

Lines 243-244: It’s not clear to me what is meant by “boundaries selected at the youngest and oldest gap in ages”. What constitutes a “gap”? I would prefer the method be spelled out sufficiently clearly that subsequent users could recreate it.

==> This is difficult to quantify given that the size of the "gap" (= step in the age distribution) is different for every data set. If there are many young analyses, ages within the youngest cluster might differ in increments of 0.1 m.y., in which case a gap would be identified as the first step of 0.3-0.5 m.y. If there are just a few analyses, with successive ages differing by 0.5 m.y., then a gap would be more like the first occurrence of a 1 or 2 m.y. step. Yes, this is highly subjective, which is why the preceding text emphasize that this is a weakness of the weighted mean method! Fortunately, this methodology does not have a significant impact on the final max depo ages given that three additional methods (with no assumptions about including/excluding ages) are also used - results for all four methods are reported in DR Table 6. For full transparency, readers are able to see exactly which ages have been included/excluded for the weighted mean calculation in DR Table 4, as the included ages are shown with red font.

Line 264-268: Coutts et al. (2019): Geoscience Frontiers demonstrated this well with a zircon standard as an example ==> Revised to: . . . For example, as described by Coutts et al. (2019), consider the analytical data . . .

Line 513: How large? (i.e., suggesting reporting percentage range) ==> The percent of young vs old grains for each sample is shown on Figure 7.

Line 524: It's unclear to me why a 1.44 Ga peak would be associated with the Ouachita orogeny – this age mode is not well represented in Fig. 3 ==> Agreed! Revised to . . . significant proportion of ∼1.44 Ga grains that most likely may have been incorporated during transport from the Ouachita orogenic highlands, or may signal increased input from the Ancestral Mogollon . . .

Line 527: There's a slight discrepancy between how sample names are reported in the text (e.g., 243-3) and how they are reported on the figures (243). Perhaps it would be better to use the same sample name throughout? My preference would be to include the dash, as this seems to convey a bit more information than just the number.

==> The full sample numbers (e.g., 243-3) are used wherever samples are described, e.g., in the text, in DR Tables 1 and 3, and in Appendix 1. Shortened sample numbers (e.g., 243) are used in the figures and the interpretive tables to improve readability...

Lines 578-579: This is a completely reasonable approach. That said, it may be worth incorporating the concepts recently discussed by Anderson (2019): Earth-Science Reviews. For example, it is possible that a certain degree of Pb loss occurs in zircon without unusually high U concentrations. Also, minor amounts of Pb loss in zircon does not necessarily result in a discordant analysis (depending on the age of the grain and degree of Pb loss).

==> Andersen et al. (2019) emphasize two main issues: the mechanics of common Pb correction, and the impact of common Pb correction and Pb loss on ages of Precambrian detrital zircons. Regarding common Pb correction, we spend considerable effort to ensure that our common Pb corrections are reliable. As described in detail in our analytical methods papers (published in 2006, 2008, 2014, 2015, and 2018), and briefly outlined in the methods section of this manuscript, we do the following: – conduct a pre-ablation pass on each grain to remove surficial common Pb – monitor 204 intensity of each analysis, and remove analyses that have unusually high 204 counts. We submit that this is a better approach than described by Andersen et al. (percent of 206 that is initial) , as it does not depend on age or Uconc. – continually monitor the 206/204 of zircon standards and NIST glasses during round-robin sessions to ensure that our measured values are similar to ID-TIMS values. – monitor the discordance of R33, a young secondary standard, during every session to ensure that common-Pb-corrected 206/238 ages are concordant. This tests for systematic issues with measuring 204 (Hg and Pb) during each session. – monitor 202Hg so that we can subtract 204Hg from the 204 signal, resulting in a reliable measurement of 204Pb for 206/204-based common Pb correction. – use gold traps to reduce Hg concentrations so that 204Pb can be measured more reliably. A citation to Andersen et al. (2019) has been added because they discuss some of these strategies. In terms of interpretation, the concepts presented by Andersen et al. (2019) are most relevant for Precambrian zircons, where discordance can be used to identify analyses compromised by Pb loss. For Precambrian ages, we follow their recommendations regarding appropriate settings for discordance filters, and also base interpretations on clusters of ages rather on individual ages that do not belong to clusters (e.g., Gehrels, 2014). Because Pb-loss always increases scatter, clustering analysis reduces the significance of ages that have been compromised by Pb loss. For young ages, as described in detail in the manuscript, we use patterns of age versus Uconc to assess the likelihood that ages belonging to the youngest cluster are compromised by Pb loss. Such patterns are used to highlight max depo ages that may be too young due to Pb loss, but are not used to filter analyses. As the reviewer notes, we just don't have an independent means of identifying/removing analyses that have been compromised by Pb loss!

==> Reference to Andersen et al. has been included on lines 269-270: . . . In addition to this statistical bias, the youngest single age will be even farther from the mean (true) age if it has been compromised by Pb loss (e.g., Andersen et al., 2019). . . .

Line 685: Is there reason to be think that air-fall zircon are typically >60um in size? Is

Printer-friendly version

Discussion paper

there morphological information from the zircon crystals themselves that suggest an air-fall versus transported (abraided) origin? ==> Nowhere have we suggested that air-fall zircons will be mostly >60 um. The issue is that for fine-grained strata, detrital grains will be mostly <60 um in size, so many of the >60 um zircons analyzed will be air-fall in origin. Our original text did not do a good job of describing these important relations – see revised text in the detailed explanation below. . ..

Line 690: The authors contend that near depositional-age zircon are air-fall and older zircon are transported. Yet, I see no evidence presented that rules out the possibility of near depositional-age zircon that are transported by primary erosion of contemporaneous volcanic rocks. For example, Malkowski et al. (in press): AJS report a sample with >90% zircon of age 0.5 Ma from a river that drains the Lassen Volcanic Field in northern California. Clearly near-depositional age zircon can be transported in rivers. My concern here is the authors are implying (perhaps unintentionally) that near-depositional age zircon is exclusively air-fall in origin (e.g., Lines 700-701, 706-708, 718, 720, 740, 744-745, 765-766, 770-771, 820) when no data is provided to substantiate this claim.

==> Of course the reviewer is correct about this! Our original text clearly did not do a good job of describing the observations that lead to interpreted connections between grain size and age offset. The key, as described briefly in the comment above and in detail below, is that depo-age zircons analyzed from fine-grained strata are mostly air-fall in origin because >60 um zircon grains are too large to be transported with fine-grained sediment. Our samples from fine-grained strata are probably loaded with young detrital grains, we just don't see them because we only analyze >60 um grains!

The reviewer correctly mentions that provenance (e.g., whether or not sediment was shed from an active magmatic arc) may be an important control on the relations between grain size and age offset. We did not put much emphasis on provenance in our original discussion, so this important factor has been emphasized in the revised text presented below.

Lines 697-703: A simple plot of interpreted lag time (i.e., youngest zircon age versus age model, shown in Fig. 13) versus sample grain size would be helpful in evaluating the significance of the relationship between sample grain size (sandstone vs siltstone vs mudstone) and abundance of young zircon. This relationship is somewhat shown on Fig. 13. A cursory examination suggests that both sandstone and mudstone samples yield contemporaneous MDA calculations, with at least one mudstone (261) and one siltstone (210) yielding MDAs that are too old.

==> A response to the suggestion of using a lag-time plot is provided above. Regarding exceptions to the interpreted relations between grain size and age offset, the reviewer is correct that some samples do not follow a simple pattern. These were not highlighted or explained in the original discussion, but are discussed below and in the revised text.

==> The three sets of comments above indicate that the original manuscript does not do a good job of explaining two fundamental aspects of our results, which are (1) the correlation between stratigraphic position, grain size, and convergence/divergence of the three chronologic records, and (2) the occurrence of three main clusters of LA-ICPMS ages. These patterns are shown on Figure 13, described on lines 673-676, and interpreted on lines 680-709. Confusion around these interpretations results at least in part from the original order of presentation, in which we first state our interpretations and then explore the observations that support them.

We propose to improve this discussion in the revised manuscript by first describing each of the critical observations concerning relations between stratigraphy, grain size, lab methods, and age offsets. We also add in a discussion of possible connections with provenance, which, as the reviewer suggests, are an important factor that we neglected to emphasize. We then use these observations to develop our preferred interpretations for the convergence/divergence of the chronometers and the clusters of ages.

Following are proposed revisions to section 9 that should address the reviewer concerns:

***** Our preferred maximum depositional ages for strata of the Chinle Formation range from ∼223.3 to ∼209.6 Ma, which is similar to the ∼227.6 to ∼209.9 Ma range of CA-TIMS ages (Fig. 13). All available U-Pb data therefore suggest that the analyzed Chinle Formation strata are Late Triassic, and probably Norian in age (Dickinson, 2018), given the assigned ages of ∼237 to ∼201.3 for Late Triassic time (Cohen et al., 2013) and ∼227 to ∼208.5 Ma (Cohen et al., 2013) or ∼205.7 Ma (Kent et al., 2017) for Norian time.

Figure 13 presents a comparison of our preferred maximum depositional ages, all available ID- and CA-TIMS ages [from Riggs et al. (2003), Heckert et al. (2009), Ramezani et al. (2011), Irmis et al. (2011), Atchley et al. (2013), Nordt et al., (2015), Kent et al. (2018), and Rasmussen et al. (2019)], and two age models that are based on magnetostratigraphic and CA-TIMS geochronologic information (Kent et al., 2019; Rasmussen et al., 2020). As shown on this figure, our LA-ICPMS MDA's reveal two first-order patterns. The first pattern is that the LA-ICPMS-based MDA's overlap with most CA-TIMS ages and both age models for most strata belonging to the Blue Mesa Member and Petrified Forest Member, but are significantly older for strata of the Sonsela Member. The second pattern is that most LA-ICPMS-based MDA's belong to three main clusters (∼222-219 Ma, ∼217-215 Ma, and ∼212-211 Ma), whereas the other chronologic records show a relatively simple pattern of upward younging (Fig. 13). The following discussion explores these two patterns – details of the magnetostratigraphic information, CA-TIMS data, and age models are discussed by Kent et al. (2018, 2019) and Rasmussen et al. (2020).

As shown on Figure 13, the LA-ICPMS-based MDA's presented herein overlap with the other chronometers for sequences which are dominated by fine-grained strata (e.g., Blue Mesa Member and Petrified Forest Member), but are several million years too old for sequences which are dominated by coarse-grained strata (Sonsela Member) (Fig. 13). This pattern appears to hold for member-scale stratigraphic units (e.g., strata from the Petrified Forest Member), although some individual samples clearly do not follow this pattern. For example, of the six samples from the Petrified Forest Member that yield maximum depositional ages which overlap with the other chronometers, four are mudstone-siltstone and two are sandstone. In the lower Sonsela Member, of the six samples that yield maximum depositional ages that predate the other chronometers, five are sandstone and one is siltstone. These exceptions suggest that the dominant lithic characteristics and depositional environment of a member (e.g., dominantly fine-grained floodplain deposits for the Petrified Forest Member versus dominantly coarse-grained channel deposits of the Sonsela Member [Woody, 2006]), are more important than the grain size of an individual horizon in controlling the recognition of near-depositional-age zircon grains.

The observed pattern that predominantly fine-grained strata of the Mesa Redondo, Blue Mesa, and Petrified Forest members yield reliable MDA's, whereas predominantly coarse-grained sandstones of the Sonsela Member do not, is surprising for two reasons. First, in terms of provenance (as described above), strata of the Mesa Redondo, Blue Mesa, and Petrified Forest members are interpreted to have been shed mainly from the Ouachita orogen, which lacks Triassic igneous rocks, whereas strata of the Sonsela Member were shed from the Cordilleran magmatic arc to the southwest, which contains abundant Permian and Triassic igneous rocks (Fig. 3). Second, as shown in the margins of Figures 7 and 8, Triassic zircon grains are significantly ($\sim$2x) more abundant in strata of the Sonsela Member than in underlying and overlying strata. Based on these two observations, one might expect that strata of the Sonsela Member would yield reliable MDA's, whereas strata from the Mesa Redondo Member, Blue Mesa Member, and Petrified Forest Member would not.

We suggest that these counter-intuitive relations result in large part from our analytical method of only analyzing zircon grains that are >60 um, combined with the maximum size of zircons that can be transported in fine-grained versus coarse-grained sediments. For coarse-grained sediment, >60 um zircon grains could include both transported (detrital) components that mostly predate deposition, as well as zircons that are air-fall in origin and approximately of depositional age. A MDA calculated from a mix of these grains would accordingly pre-date deposition. In contrast, Triassic zircon grains from fine-grained strata would tend to be mostly air-fall in origin given that the older, transported grains are too small to analyze. A MDA calculated from zircons that are primarily of air-fall origin would accordingly approach the true depositional age.

The relations described above suggest that convergence versus divergence of the chronologic records results from connections between depositional setting, grain size, provenance, and analytical methods, which together conspire to control the proportions of air-fall (near-depositional age) versus slightly older detrital zircon grains recognized in our samples. We suggest that the three chronometric records agree (to within $\sim$1 m.y.) for strata of the lower Blue Mesa Member and middle-upper Petrified Forest Member because of the availability of zircon grains of air-fall origin, which are near depositional age and both <60 um and >60 um in size, versus the scarcity of pre-depositional-age Triassic grains of sufficient size for analysis due to the lack of Triassic rocks in the source region (mainly the Ouachita orogen) and the small (<60 um) grain size of most sediment. In contrast, for the Sonsela Member, the LA-ICPMS MDA's are interpreted to pre-date the other chronologic records because the sediment was derived from the south, where abundant igneous rocks of Permian-Triassic age were exposed, and the grain size of the detrital (pre-depositional-age) zircons was sufficiently large that many would have been analyzed.

A test of this hypothesis is provided by MSWD values of the weighted means calculated for ages from samples belonging to the various stratigraphic units. As shown in DR Table 6, MSWD values for samples from dominantly fine-grained strata of the Mesa Redondo-Blue Mesa and Petrified Forest units are 1.7 and 1.3 (respectively), whereas coarser grained strata of the lower and upper Sonsela units yield higher MSWD values of 2.6 and 2.1 (respectively). These values are consistent with the interpretation that zircon grains in coarser-grained units have a greater range of ages than zircon grains in finer-grained units.

These interpreted connections may also provide an explanation for the patterns of offset of the CA-TIMS ages of Rasmussen et al. (2020) relative to the LA-ICPMS ages and magnetostratigraphic age models in the Sonsela Member (Fig. 13). For strata of the upper Sonsela Member, the CA-TIMS and magnetostratigraphic records converge because the methods of grain selection were apparently successful in identifying populations of syn-depositional age zircon grains. For strata of the lower Sonsela Member, however, these methods were unsuccessful in identifying a sufficient number of depositional-age zircon grains to determine a reliable MDA, presumably because of their low abundance relative to older transported grains.

The second main pattern exhibited by the three chronometers is that most of the LA-ICPMS-based MDA's belong to three main clusters (∼222-219 Ma, ∼217-215 Ma, and ∼212-211 Ma), whereas the other chronologic records show a relatively simple pattern of upward younging (Fig. 13). For the ∼222-219 Ma cluster, a plausible interpretation, following from the connections described above, is that ∼222-219 Ma zircon grains of air-fall origin accumulated in fine-grained strata of the lower Blue Mesa Member, and were then recycled from age-equivalent strata into predominantly coarser grained channel sands of the upper Blue Mesa Member and lower Sonsela Member. Grains from these same sources appear to have also been recycled into sandstone sample 131-2 of the lower Petrified Forest Member (Fig. 13). The ∼212-211 Ma cluster may have formed in a similar fashion, with initial accumulation of near-depositional-age air-fall zircons in mudstones of sample 116-1, followed by recycling of these grains from age-equivalent strata into coarser-grained strata of samples 104-3, 92-2, and 84-2 (Fig. 13).

The source of zircon grains that belong to the ∼217-215 Ma cluster is less obvious given the lack of recognized fine-grained strata dominated by zircons of this age (Fig. 13). One possibility is that ∼217-215 Ma grains were eroded from fine-grained strata exposed elsewhere [perhaps near Sonsela Buttes (Marsh et al., 2019) or near the Cordilleran magmatic arc] that are dominated by grains of this age. A second possibility is that fine-grained strata dominated by ∼217-215 Ma ages were originally present in the lower Sonsela Member, but were removed by erosion and recycled into strata of the upper Sonsela Member. Previous workers have suggested the existence of a hiatus or hiatuses (Ramezani et al., 2011) or an erosional event (Rasmussen et al., 2020) at approximately this stratigraphic level, as shown by the preferred age model of Rasmussen et al. (2020) on Figure 13. The occurrence of very different <240 Ma ages, >240 Ma ages, and U/Th values in samples 196-3 and 195-2 suggests that this shift in provenance, condensed section, or unconformity likely coincides with the proposed boundary between strata of the lower Sonsela Member and upper Sonsela Member. As discussed by Ramezani et al. (2011) and Rasmussen et al. (2020), the possibility of an unconformity or condensed section near this stratigraphic position has important implications for Chinle stratigraphy and fundamental Late Triassic biotic and climatic changes. It should be noted, however, that no stratigraphic evidence for such an unconformity was recognized in the CPCP core. *****

Lines 768-769: “equivalents or immediately”? ==> Not sure what the issue is here – text is ". . . lateral equivalents of immediately underlying . . ."

Lines 859-868: See summary comment above. This is a strong conclusion and theme throughout the later part of the manuscript, but is in my view not well documented by the data itself. ==> Agree that the original statement is not well supported – it lacks the critical information that these patterns hold for >60 um zircons! Following is an attempt to include this critical qualifier: Our results show that the most reliable information comes from sequences dominated by fine-grained clastic strata (mudstone and siltstone) given that these strata have a low abundance of pre-depositional-age zircon grains of the appropriate size (>60 μm diameter) for routine analysis by LA-ICPMS. Mudstone-siltstone samples may accordingly yield have a high proportion of >60 um zircon grains that are air-fall in origin (or only slightly reworked) and thereby record the age of deposition. In contrast, sedimentary sequences dominated by sandstone could well commonly yield abundant >60 um zircon grains that predate depositionhave been recycled from older sediments, thereby diluting syn-depositional-age zircon grains. Future attempts to determine depositional ages from fluvial strata should accordingly focus on sequences dominated by fine-grained strata, rather than sandstones, in spite of the challenges of extracting and analyzing the smaller zircon crystals.

Lines 1175-1176: Example of inconsistent use of sample names between text and figures (see also comment above) ==> See response above.

Lines 1183-1184: See summary comment above regarding how PDPs are scaled when an x-axis scale change is used. ==> See response above.

Lines 1203-1204: Unclear meaning in last sentence – possible typo? ==> Yes, there is a typo in this line. Should be: ". . . Stars represent MDS values for sets of examples, with the exception that sample 131 is not included with other Petrified Forest samples."

Figure comments:

Fig. 13 is missing very fine sand on the x-axis scale. (it goes from mud, silt, f ss, m ss, c ss, etc.). The jump from silt (upper limit of 65 um) and fine sand (lower limit of 125 um) is an important one. Is it possible to add vf sand to the plot? ==> Very Fine Sand has been added (with Fine Sand)

Miscellaneous comments: The sample coordinates (latitude, longitude) are missing from this manuscript, as far as I can. These should be included somewhere prior to publication. ==> All samples were collected from a drill core collected from the same position (35.085933° N, 109.795500° W, WGS84 datum). This has been added to the revised manuscript.

Interactive comment on Geochronology Discuss., https://doi.org/10.5194/gchron-2019-12, 2019.