Reviewer #1 (S. Burgess)

1.

Line 356 (and the first conclusion bullet): I think this section (and the paper) would benefit from inclusion of a date on Meishan bed 25 or 28, which bracket the P-T boundary in this section and were dated in Burgess et al (2014). Although the current work does utilize the ET2535 tracer, inter-laboratory bias might still be at a level above the internal precision quoted for many weighted mean dates, which may effect the agreement that now exists between the two studies. You assert that age agreement between the three different sections indicates interlab agreement at the 0.05% level, but I'd like to see that agreement tested directly – doing so would corroborate the synchronicity of the south China sections, and would eliminate any circularity in arguing that current agreement indicates no bias.

We agree that a date in Meishan Bed 25 or Bed 28 would strongly support our assertion of an inter-lab agreement at the 0.05% level between the Massachusetts Institute of Technology (MIT) and the University of Geneva (UNIGE). Unfortunately, samples from Meishan were not accessible. However, such an inter-laboratory comparison was carried out in a study of Schoene et al. (2010) about the end-Triassic mass extinction, dating the same volcanic unit (North Mountain Basalt; NMB-03-1; see their Fig. 1C) in the two EARTHTIME laboratories at MIT and UNIGE by using exactly the same analytical protocol, identical ET2535 tracer solution and Th/U correction. Their analyses of 13 single grains of the North Mountain Basalt from UNIGE and 19 analyses from MIT was statistically equivalent, yielding a weighted-mean $^{206}Pb/^{238}U$ date of 201.38 ± 0.02/0.22/0.31 Ma (internal uncertainties/with tracer calibration uncertainties/ with decay constant uncertainties) with a mean square weighted deviation (MSWD) of 1.2.

Schoene, B., Guex, J., Bartolini, A., Schaltegger, U., and Blackburn, T. J.: Correlating the end-Triassic mass extinction and flood basalt volcanism at the 100 ka level. Geology, 38, 387–390, doi:10.1130/g30683.1, 2010.

2.

Astrochronologic timescales also exist for the late Permian and early Triassic intervals in South China, some recently published with precision on par with the dates published here. Is it possible to integrate these datasets into the modeling approach used here? If so, would inclusion increase the precision to which section positions can be dated? If not, I'd be interested to see a short addition to the paper discussing the relationship of the timescale developed here with the astrochron timescale.

Since our study focus on a very short time interval around the PTB and most of the astrochronological studies are either based on long term 450-kyr eccentricity cycles or show discrepancy between the radioisotopic and astrochronologic timescale, we decided not to integrate these timescales into the Bchron modeling. But we agree that for longer time spans (i.e. the Early Triassic epoch) the astrochronological timescale might add some valuable information which can be factored into a combined modeling approach. Nevertheless, we added a small paragraph comparing the radioisotopic and the astrochronologic timescale around the boundary interval:

“6.5 Comparison of astrochronology

Sedimentary cycles driven by orbital forcing (100-kyr eccentricity cycles) were inferred by Peng et al. (2008) on the basis of Ce/La fluctuations in Dongpan. These cycles were also used by Feng and Algeo (2014) to calibrate their radiolarian extinction and survival intervals. The duration of these two intervals amounts to ~260 kyr (see their Fig. 5). For the same stratigraphic interval, our U-Pb ages (interval from DGP-16 to DGP-21) indicate a much shorter duration of max. 75 kyr. It is not clear if this chemical cyclicity might either represent precession instead of eccentricity cycles or rather a local signal of the sedimentary-chemical system. Huang et al. (2011) produced an astrochronological timescale across the PTB in China and Austria with an estimated duration of 700 kyr for the extinction interval. However, the extinction interval in their study is too long and ranges from the start of the Neogondolella meishanensis conodont zone to the base of the Isarcicella isarcica zone, defining a prolonged extinction interval stretching from the top of Bed 24e to the base of Bed 29 in Meishan. Wu et al. (2013) reported Milankovitch cycles from late Permian strata at Meishan and Shangsi, South China, indicating a 7.793 Myr duration for the Lopingian epoch based on 405-kyr orbital eccentricity cycles. Their inferred duration of 83 kyr for the extinction interval in Meishan between the base of Bed 25 and the top of Bed 28 is in good agreement with the radioisotopically-dated duration of 61 ± 48 kyr for the same interval (Burgess et al., 2014). This is consistent with the study of Li et al. (2016) whose astronomical-cycle tuning of spectral gamma-ray logs constrains the extinction interval in Meishan to less than 40% of a 100-kyr eccentricity cycle (i.e., <40 kyr).

Burgess, S.D., Bowring, S.A., and Shen, S.Z.: High-precision timeline for Earth’s most severe extinction. P. Natl. Acad. Sci. USA, 111, 3316–3321, doi:10.1073/pnas.1317692111, 2014.

Feng, Q.L., and Algeo, T.J.: Evolution of oceanic redox conditions during the Permo-Triassic transition: Evidence from deepwater radiolarian facies. Earth-Sci. Rev., 137, 34–51, doi:10.1016/j.earscirev.2013.12.003, 2014.

Huang, C., Tong, J., Hinnov, L., and Chen, Z.Q.: Did the great dying of life take 700 k.y.? Evidence from global astronomical correlation of the Permian-Triassic boundary interval. Geology, 39, 779–782, doi:10.1130/g32126.1, 2011.

Li, M., Ogg, J., Zhang, Y., Huang, C., Hinnov, L., Chen, Z.-Q., and Zou, Z.: Astronomical tuning of the end-Permian extinction and the Early Triassic Epoch of South China and Germany. Earth and Planetary Science Letters, 441, 10–25, doi:10.1016/j.epsl.2016.02.017, 2016.

Peng, X.F., Feng, Q.L., Li, Z.B., Meng, Y.Y.: High-resolution cyclostratigraphy of geochemical records from Permo-Triassic boundary section of Dongpan, southwestern Guangxi, South China. Sci. China Ser. D-Earth Sci., 51, 187–193, 2008.

Wu, H., Zhang, S., Hinnov, L. A., Jiang, G., Feng, Q., Li, H., and Yang, T.: Time-calibrated Milankovitch cycles for the late Permian. Nature Communications, 4:2452, doi:10.1038/ncomms3452, 2013.

3.

At Meishan, the boundary date is well defined because of bracketing dates (on beds 25 and 28) very close to the paleontologically-defined PTB. You show no dates above the boundary at Dongpan, and at Penglaitan your bracketing dates are at least 30 cm from the boundary, with one coming from a zircon-bearing sediment, not from a volcanic ash. Although sediment accumulation rate is high at these sections relative to Meishan, a *bracketing date close to the boundary would be helpful – I think this is another reason to date a bed from Meishan (specifically Bed 28).*

The reviewer missed ash bed DGP-21 in Dongpan, so that the PTB is also bracketed in this section by the two dated ash beds DGP-17 (251.956 ± 0.033 Ma; 2.7 m below PTB) and DGP-21 (251.953 ± 0.038 Ma; 0.1 m above PTB).
At Penglaitan, we can not exclude re-sedimentation of PEN-28 (252.062 ± 0.043 Ma; 0.3 m below PTB) which would be reflected by a slightly older deposition age, but under- and overlying true airfall ash beds PEN-70 (252.125 ± 0.069 Ma; 0.6 m below PTB) and PEN-22 (251.907 ± 0.033 Ma; 0.5 m above PTB) do not reveal any stratigraphical inconsistency. Additionally, both inferred dates of the PTB in Dongpan (251.938 ± 0.029 Ma) and in Penglaitan (251.982 ± 0.031 Ma) are identical and can not be distinguish from each other within the 30 ka uncertainty of its $^{206}Pb/^{238}U$ dates.

4.

This might be a result of my naïve understanding of the statistical method applied here, but are changes in lithology factored into the up/down-section projection of time? Can they be? I'd be interested to see how sediment accumulation rate changes in portions of the section that are entirely carbonate, or entirely clastic material, for example. Is any geochronologically bracketed interval characterized by a single lithology? It would be interesting to test whether the model is improved by accounting for lithology change.

Changes in the lithology are not considered by the age-depth model. However, as discussed in the review section of M. Schmitz the thickness of the dated volcanic horizons was removed and the lithostratigraphy of the modeled sections has been rescaled in order to create a more accurate model of the deposition rates of the background sedimentation. This is necessary since instantaneous event beds such as volcanic ashes and turbidite deposits (reflected here by volcanogenic sandstones) would bias the correct reconstruction of the sedimentation history. Unfortunately, all modeled sections feature a rather heterogeneous lithology of mixed carbonate and siliciclastic beds without any dated interval that is characterized by only a single lithology.

5.

This study is in large part a test application of the Bchron technique to "deep" time. There is clear age accord between the modeled PTB boundary dates generated in the Dongpan and Penglaitan sections, and likely coincidence of these with the Meishan section, which suggests utility of the Bchron method for the Permian and Triassic. As mentioned in the study, the carbon record from these sections does not allow for further correlation, and the astrochronologic timescale for the late Permian is not as well developed as that for the early Triassic. Thus, I wonder if the very early Triassic record, for which exists an accurate geochronologic and astrochronologic timescale and better chemostratigraphic correlation possibilities, might be a more robust interval on which to apply this model in the future.

We agree that this can be done in the future and added a part in the conclusions: ” The seemingly erratic Late Permian carbon isotope record in South China does not allow laterally reproducible inter-calibration with the newly obtained U-Pb dates. This stands in sharp contrast with the Early Triassic carbon isotope record which is of global significance (e.g., Galfetti et al., 2007), thus making the Early Triassic interval the ideal target of future studies that integrate chemostratigraphy, geochronology and astrochronology in a Bayesian age-depth modeling approach.”

Galfetti, T., Bucher, H., Ovtcharova, M., Schaltegger, U., Brayard, A., Brühwiler, T., Goudemand, N., Weissert, H., Hochuli, P.A., Cordey, F., and Guodun, K.: Timing of the Early Triassic carbon cycle perturbations inferred from new U–Pb ages and ammonoid biochronozones. Earth Planet. Sc. Lett., 258, 593–604, doi:10.1016/j.epsl.2007.04.023, 2007.

Line-specific comments:

Line 30: “has” to “have”

It has been corrected.

Line 37: I’d not say that “plume-induced” is universally accepted. Some prefer a model in which subduction of sediments is responsible for huge amounts of flux melting – not many, but some.

It has been changed to: “The most likely cause derives from the temporal coincidence with massive and short-lived volcanism of the Siberian Traps (e.g., Burgess and Bowring, 2015) that injected excessive amounts of volatiles (H_2O, CO_2, SO_2, H_2S) into the atmosphere.”

Line 39: I don’t think “deeply” is the correct word.

“Deeply” was erased.

Line 54: You might mention the reason that most geochronology isn’t precise enough to resolve biologic events – namely that these biologic events (i.e., extinction) occur on decamillennial timescales, and that most weighted-mean dates are characterized by uncertainty far in excess of this threshold.

Now changed to: ”Earliest U-Pb geochronological studies (e.g., Bowring et al., 1998; Mundil et al., 2004; Ovtcharova et al., 2006; Shen et al., 2011) do not reach decamillennial resolution, which is necessary to resolve biotic events such as extinction or recovery.

Line 63: I suggest stating that by "expanded" you mean higher sediment accumulation rate over the same duration, which results in a thicker, more expanded section.

Now changed to: "The aim of this work is 1) to date the PTB in two sedimentary sections that are continuous with a conformable PTB and with higher sediment accumulation rates over the same duration than in Meishan, using the highly precise and accurate dating technique of CA-ID-TIMS, and 2) to test the age consistency between the PTB as defined paleontologically in Meishan and as recognized by conformable formational boundaries in the deeper water sections, Dongpan and Penglaitan."

Line 68: Do you detect them or model them?

It has been changed to "model".

Line 181: You use a Th/U (magma) of 3.00 − 0.50 (1←). I'd appreciate a bit more explanation about why this value was chosen, and the sensitivity of dates to this parameter. E.g., what if 2 or 4 are used – I realize that the 2← uncertainty covers this range, but interpretation based on the dates may be different and warrants a brief discussion. Burgess et al (2014) use a value of 3, which enables comparison between datasets – is this why you use 3?

Now changed and discussed as follows: "All $^{206}Pb/^{238}U$ single grain ages have been corrected for initial ^{230}Th-^{238}U disequilibrium assuming Th/U_{magma} of 3.00 ± 0.50 (1σ). This should best reflect the Th/U of the whole rock and is identical to the Th/U_{magma} used by Burgess et al. (2014) for the Meishan ash beds, in order to provide an unbiased comparison of the Dongpan, Penglaitan and Meishan chronology. Th-corrected $^{206}Pb/^{238}U$ dates are on average 80 ka older than the equivalent uncorrected dates when applying this correction, but changes in the Th/U_{magma} have only minor effects on the deposition ages of the Dongpan and Penglaitan volcanic beds. Compared to the Th/U_{magma} of 3.00 ± 0.50 (1σ) used in this study, they would become max. 11 ka younger with Th/U_{magma} of 2.00 ± 0.50 (1σ) and max. 7 ka older with Th/U_{magma} of 4.00 ± 0.50 (1σ)."

Line 220: No need for "strongly"

"Strongly" was erased.

Line 305,6: Awkward sentence start

Now changed to: ”As discussed in the Method section, the Bayesian Bchron model leads to more realistic uncertainty estimates, producing an increased uncertainty of the model age with increasing distance from the stratigraphic position of a U-Pb dated sample.”

Line 332: ‘immediately” is not the correct word. I would prefer to see the stratigraphic depth of bed 25 below the boundary.

It has been changed to: ”The first geochronological studies in the GSSP Meishan D have been carried out on bed 25, which base starts 4 cm below the formational PTB, by U-Pb sensitive high-resolution ion microprobe (SHRIMP) analysis of zircons yielding a $^{206}Pb/^{238}U$ age of 251.2 ± 3.4 Ma (Claoué-Long et al., 1991) and by $^{40}Ar/^{39}Ar$ dating of sanidine at 249.91 ± 0.15 Ma (Renne et al., 1995).

Line 342: the sentence starting with “that” is awkwardly phrased.

The sentence was rephrased to: ”It was shown by Mundil et al. (2001) by confining data selection to single-crystal analyses of the same horizons, that the multi-grain approach might disguise complexity of zircon population ages which are caused by pervasive lead loss and inheritance.

Figure 1: Please put location of the Meishan section on figure.

The location of Meishan GSSP was added.