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Interactive comment on "Cross-continental age calibration of the Jurassic/Cretaceous boundary" *by* Luis Lena et al.

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General comments

The paper by Lena et al. reports six new U-Pb ages from ash beds around the biostratigraphically constrained Jurassic-Cretaceous boundary (JKB) from three sections in Argentina and Mexico and uses them to argue that the age of the system boundary is 140 Ma, more than 5 m.y. younger than in the most widely used recent geological time scales. This contribution is significant and timely, as the calibration of the JKB has remained uncertain due to a dearth of reliable numeric ages around it. As a related but different issue (unfortunately not clearly separated in the paper), this is also a 'hot topic' as the JKB is the last Phanerozoic system boundary without an accepted GSSP

definition.

The main strength of the paper is providing most welcome new U-Pb dates from the JKB interval and placing them in a multiple biostratigraphic framework. The dates are of high analytical quality and precision, obtained using cutting edge CA-ID-TIMS methods. However, I take several issues with the interpretation, and may suggest guidance for a revised version which could better avoid the pitfalls of confusing regional and global biostratigraphic correlation issues. Instead, a re-focused discussion should emphasize the obvious significance of the radioisotopic dates in highlighting problems and contradictions in biostratigraphy. Additional recommendations will lead to improvements in the structure of the paper, its language, and the presentation of figures. I recommend publication after revision.

Specific comments

The following points and issues require attention during the revision (listed largely in the order of appearing in the original version of the Discussion Paper).

The paper needs a proper "Geological and stratigraphic setting" chapter to augment and replace the "Studied areas" in the current version. Formation names, i.e. the bare bone lithostratigraphy should be complemented with brief characterization of basin evolution and depositional environments, to provide context for assessment of stratigraphic completeness and sedimentation rates in the section, the latter being crucial in the authors' arguments in comparing the JKB age of different sections. Care should be taken to ensure consistency in terminology and usage of biozones.

Much biostratigraphic information is presented both in the text and in Fig. 4. However, it is not clear to the reader what, if any of these is new here, what is taken unchanged from the references cited, and what is revised from published sources. Cases where there is controversy in either the zonal subdivision of sections or their correlation, based on ammonoids, calpionellids and ammonoids (e.g. between Riccardi 2015 and Vennari et al. 2014), and the stance of the authors should be more clearly stated. The reader might suspect that calcareous nannofossil occurrences are newly obtained as Supplementary Fig. 3 is promised to present them (p. 3, l. 26), but this figure is missing.

Details of reporting of the error and age interpretation would be better placed in the main text's Methods chapter rather than in the Supplementary Material. For the aimed global relevance in time scale studies, the most conservative error (i.e. that including the tracer calibration and decay constant errors) needs to be quoted and used for each U-Pb dates throughout the paper. This is typically still within $\pm$0.2 Ma, a commendable high precision.

The chapter "Results and discussion" needs to be split into two, allowing results to be clearly separated from the interpretation.

Even though it is widely accepted that magnetostratigraphy is very useful for global correlation in the JKB interval, projecting the magnetozones identified in the Arroyo Loncoche section in the Neuquén Basin (Iglesia Llanos et al. 2017) introduces additional confusion (p. 5, l. 1-9, Fig. 4) to the already complex web of stratigraphic correlation of the three studied sections. The new results from Las Loicas do not appear to be closely correlatable with Arroyo Loncoche, Fig. 4 reveals that the placement of the JKB is offset by nearly one ammonoid zone, being near the base or at the top of the Substeueroceras koeneni zone, respectively. It would suffice to say that magnetostratigraphy of the Las Loicas section will be desirable to enhance the utility of the newly obtained U-Pb ages and clarify contentious biostratigraphic correlation issues.

Discussion on the age of the JKB in the Mazatepec section includes an assumption on the FAD of a nannofossil taxon, Nannoconus steinmanni minor, not actually found in the section (p. 5, l. 31 – p. 6, l. 3). Such speculation is best avoided.

Beware of the lack of formal definition of base Tithonian. There is no agreed-upon GSSP decision yet, contrary to what is implied here (p. 6, l. 25). The attendant uncertainties of stage boundary placement and its correlation with the Andean sections

make the time scale calibration use of La Yasera U-Pb date more problematic than admitted here.

The discussion on the duration of the Tithonian is interesting but contains a factual error and misses some further opportunities. The Geological Time Scale 2016 (Ogg et al. 2016) is misquoted, it assigns 150.8 Ma to the base of Tithonian Stage and 145.5 Ma to the JKB, hence the duration of the Tithonian is 5.3 m.y., less in agreement with the 6.9 m.y. arrived at here. It would be useful to compare two other, independent duration estimates. The Pacific M sequence of magnetic anomalies has long featured in time scale calibration. The recent work of Malinverno et al. (2012) (the MHTC12 scale) suggests 6 m.y. for the Tithonian, i.e. between magnetochrons M22An and M19n2n. The cyclostratigraphic analysis of Kietzmann et al. (2015; not cited by Lena et al.) identifies 10 long eccentricity cycles for almost the entire Tithonian, starting with the Virgatosphinctes mendozanus zone dated here at La Yesera, hence a duration of c. 4 m.y. The discussion should emphasize that the duration favored here is longer these previous estimates using other methods and offer possible reasons to explain the difference, perhaps considering biostratigraphic correlation issues.

Perhaps my most important criticism and suggestion pertains to the projection of a sedimentation rate-based JKB from the Mexican Mazatepec section into Las Loicas in Argentina. The authors can make a much stronger case and build a more logical argument by projecting the actual U-Pb date, expressing the stratigraphic height from the age-model calculation as $\sim$28.5 m and note the mismatch in biostratigraphies. Reading from Fig. 4, beds of the same numeric age thus appear assigned to nannofossil zone NJK-B vs. high in NJK-D, to calpionellid Crassicollaria zone vs. Calpionella zone (and its third subzone, the Elliptica subzone, and ultimately to lower Berriasian vs. upper Tithonian at Las Loicas and at Mazatepec, respectively. The discussion could thus be refocused to use the newly obtained high-precision and high-resolution U-Pb age framework to highlight biostratigraphic correlation issues, most likely due to diachronous FAD-LADs of certain key taxa.

To strengthen the argument for potential problems in biostratigraphic correlation, the authors might comment on the discrepancy of ammonoid-based correlation, and striking differences of thickness of zones in different sections even within the Vaca Muerta Fm. (e.g. Argenticeras noduliferum zone: ∼27 m in Las Loicas vs. 5 m in La Yesera section).

It the "Global correlation" chapter, the suggestion of understanding the JKB as an interval (p. 8, l. 1-10) is conceptually flawed and needs to be rephrased. By definition, the JKB boundary (as any other chronostratigraphic boundary) is a time line. It does indeed carry an uncertainty of our numeric calibration but it cannot be equated with an actual time interval in which different "boundary events" took place.

Also in this final chapter, consider the significance of your argument for a significantly younger JKB together with Martinez et al. (2015) suggested age for the base Valanginian at 137 Ma. This would make for a shorter than previously understood Berriasian Stage of a ∼3 m.y. duration. This in turn contradicts with the astrochronology of Kietzmann et al. (2015), who identify more than 10 long eccentricity cycles in the Berriasian part of the Vaca Muerta Fm.

The statement in chapter "6. Data availability" suggests that some of the raw data will be withheld until completion of the thesis of the first author. Instead, all data should be made available at the publication of this paper. Understandable practice is not to release data in a thesis prior to publication, but there should be no reason to justify an embargo the other way around.

Fig. 1 is of inferior quality, on a base map published nearly 25 years ago, unnecessarily carrying a title and showing non-American sections not mentioned in the text.

Table S1 contains the essential data for the U-Pb geochronology, it should be placed in the main part of the paper. Fig. S is also worth transferring from the Supplementary Material to the main part. (However, its labeling needs re-coloring so it be legible in black and white print, panel C might be more informative to show the dated ash bed, D

needs labels, and the figure needs a caption.)

Additional reference cited above (not used in the original version): Kietzmann, D.A., Palma, R.M. and Iglesia Llanos, M.P., 2015. Cyclostratigraphy of an orbitally-driven Tithonian–Valanginian carbonate ramp succession, Southern Mendoza, Argentina: Implications for the Jurassic–Cretaceous boundary in the Neuquén Basin. Sedimentary Geology, 315: 29-46.

Technical corrections

The comments below also include several suggestions for better English language, style and word choice.

p. 1, l. 12 (and elsewhere): age → numeric age

elusive → difficult to determine

l. 16: display → contain

l. 21: one of the last major Phanerozoic stage boundaries → last Phanerozoic system boundary

l. 23: absolute → [delete, avoid "absolute age" altogether]

p. 2, l. 3: Calpionella alpina subzone (cf. l. 16) [ensure consistency in zonal names and terminology]

l. 17: selected → suggested

l. 21: Kamptneri → kamptneri

p. 3, l. 6: spans → exposes

l. 12: out of sequence numbering of figures (not as they appear in text)

l. 26: optical images → photomicrographs

p. 4, l. 3: The section → The Las Loicas section

l. 29: impose → may provide

p. 5, l. 2, 6: fossil density → abundance of fossils

p. 6, l 24: Tithonian

p. 9, l. 22: thank

p. 10, l. 3: Neuquén

p. 11, l. 11: [delete] February

p. 12, l. 6: Potosí [+spell out journal name]

l. 13: &amp [delete]

p. 14, l. 4: Episodes [delete the rest of name]

l. 14: Aguirre-Urreta

l. 22: [provide doi instead of URL]

References cited in text but not listed in reference list: Edwards, 1963 R Core Team, 2013

p. 15, l. 3: Distribution of continents → Global paleogeography

l. 9-15 (Fig. 3): Give stratigraphic horizon of occurrence (e.g. m from base) fo each specimen photographed

p. 16, Fig. 1: delete title, consider using different base map, do not show migrazion routes and sections not discussed in text

p. 17, Fig. 2: Barriasian → Berriasian

[J/K boundary interval – see comments about conceptual flaw here]

[fonts too small in the upper part, too large in the lower part]

p. 18, Fig. 3: [it is redundant to show taxon names here, it is customary to give them in the caption only]

p. 19, Fig. 4: [this is the key figure of the paper, already need to refer to in the Geological setting, so make it Fig. 2; A: show meters; put Las Loicas section to a separate panel B, making the others C and D; La Yesera: indicate placement of JKB; some lettering uses illegibly small font]

Supplementary Material

p. 1, l. 1: Ash beds were crushed → Samples were crushed

p. 3, part 5

Give weight of each sample so zircon yield can be assessed in this context.

Grains discarded as too old are erroneously quoted as $>\sim$150 Ma for each sample, provide true cut-off age of grains not included in age calculation.

5.3 (p. 4): Ash bed LL10 has n=6 grains in Fig. 2, four in text

5.4. Ash bed LL13: include date of discarded grains in Table S1 (really older than 450 Ma?)

5.5. “Due to its proximity to the Tordillo Fm.” [it is from the Tordillo Fm.]

inherited grains or detrital grains?

5.6. MZT-81 (p. 5): check this descriptions, there are errors here. four discarded grains (not five), the grain numbers are in error (belong to sample LL10)

Fig. S needs a caption and should be transferred to the main part of the paper. The labels of the figures need to be recolored so they be legible in black and white print as well.

Table TS.1 is essential to assess the U-Pb dates reported so it should be transferred to the main part of the paper

Sample LY5 in Table TS.1: why discard grain z67 and keep z10, when the first one is not older and its error is not larger? This and similar issues of only marginally different-aged grains undermine the credibility of unbiased and rigorous selection of grains for the age interpretation.

8.2 (p. 11), Table TS.2: Why is the age value of 2 m any different from the age of LL13 taken from this level?

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