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Reply to comments on: "Tethyan calpionellids in the Neuquén Basin (Argentine Andes), their significance in defining the Jurassic/Cretaceous boundary and pathways for Tethyan-Eastern Pacific connections" by Kietzmann & Iglesia Llanos

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ABSTRACT

The comments by Kietzmann & Iglesia Llanos (Comment on "Tethyan calpionellids in the Neuquén Basin (Argentine Andes), their significance in defining the Jurassic/Cretaceous boundary and pathways for Tethyan-Eastern Pacific connections" by R. López-Martínez, B. Aguirre-Urreta, M. Lescano, A. Concheyro, V. Vennari and V. Ramos) on our paper published in the Journal of South American Earth Sciences 78 (2017): 116-125, provide a worthy opportunity to further clarify our observations and interpretations regarding the importance of precise biostratigraphic studies in the definition of the Jurassic/Cretaceous boundary in the Argentine Andes. These include the calpionellids as primary markers, the classic and widespread nannofossils bioevents as secondary markers, together with a detailed ammonite zonation.

1. Introduction

The authors want to express their appreciation to the comments of Kietzmann and Iglesia Llanos (2017) because they give an excellent opportunity to discuss different methodologies, their precision, and the potential criteria for correlation of the Jurassic-Cretaceous Andean sequences with the Tethys. In order to analyze the comments, the authors will discuss the ammonite biostratigraphy and the new calpionellid records. On these bases, it will be very simple to evaluate the apparent discrepancies between different correlation schemes.

2. Ammonite biostratigraphy

This is the major point of discrepancy. As the cyclostratigraphic and magnetostratigraphic studies of Kietzmann et al. (2011b, 2015) and Iglesia Llanos et al. (2017) as well as the contributions of Kietzmann and Iglesia Llanos (2017) are tied to the Andean ammonite zonation and its correlation with the Tethys, the inconsistencies in the ammonite biostratigraphy immediately produce important disagreements in the results.

Previous studies by these authors are mostly based on the Arroyo Loncoche section of the Vaca Muerta Formation (see Fig. 1). In none of these studies there are stated how many ammonite levels were recorded and how many specimens were collected and studied. Besides, none of the ammonites have been described systematically, none have been illustrated, and there is no record of any repository where these fossils can be compared with published studies. Based on these premises their biostratigraphic results are questionable.

As for example Iglesia Llanos et al. (2017, p. 194) state that "The boundary between ammonite zones in Arroyo Loncoche was placed according to the first occurrence of the index species". However, the range chart with vertical distribution of the taxa (their Fig. 2) and the ammonite biozones does not follow this criterion. For instance, the base of the *Corongoceras alternans* zone is placed on the first occurrence of *Corongoceras* sp. and the index species is not even

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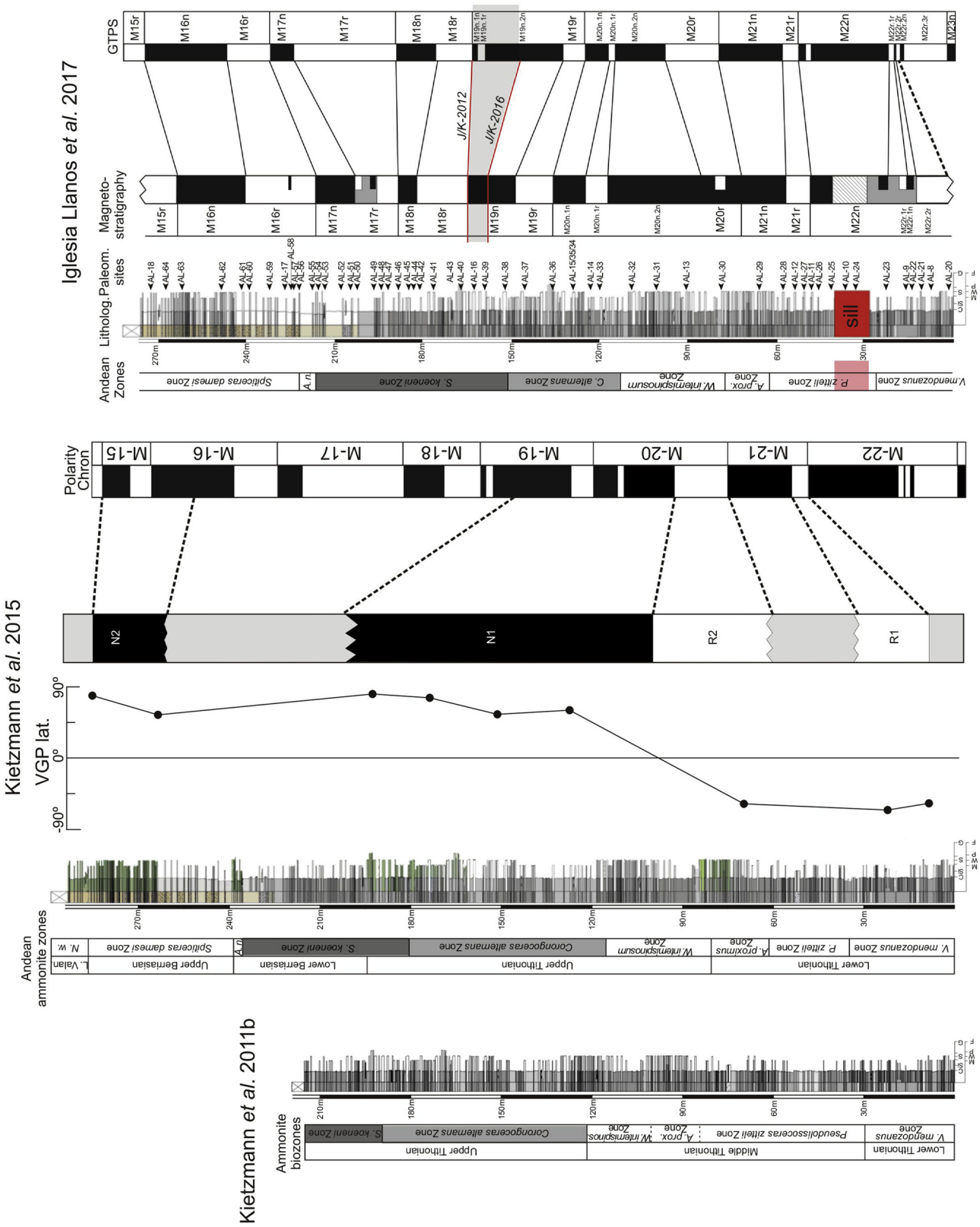

Fig. 1. Stratigraphic columns of the Arroyo Loncoche section of the Vaca Muerta Formation from Kietzmann et al. (2011b, 2015) and Iglesia Llanos et al. (2017). Note the discrepancy in the duration of the ammonite zones such as *Corongoceras alternans* and *Substeueroceras koeneni* (shaded in grey) and the mismatches in the different magnetostratigraphic scales.

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recorded in this section. It should be noted here that species of the genus *Corongoceras* in the Neuquén Basin are recorded not only in this biozone, but also in the older and younger biozones. Also, the base of the *Substeueroceras koeneni* zone is placed on the first occurrence of *Substeueroceras* sp. (at 150 m of the base of the section) while the index species appears higher (above 180 m). This more than 30 m discrepancy explains the different biozonation of the same section published by Kietzmann et al. (2011b, Fig. 3) where they placed the base of the *Substeueroceras koeneni* zone at 190 m of the base of the Arroyo Loncoche section. Striking variations in the thickness of other biozones of the same section in their papers are neither explained nor discussed (see comparison in our Fig. 1).

It is worth mentioning here that in none of the publications dealing with the Arroyo Loncoche section (Kietzmann et al., 2011b, 2014, 2015; Iglesia Llanos et al., 2017; Kietzmann, 2017; Ivanova and Kietzmann, 2017) the number and location of each fossiliferous level are shown.

Although Kietzmann and Iglesia Llanos in their comments state that the Loicas section studied by Vennari et al. (2014) and López Martínez et al. (2017) is of limited thickness, the reader is invited to compare their sections with the biostratigraphic range presented in both papers. Vennari et al. (2014) specified that their logging of the complete Las Loicas section contained on 54 fossiliferous levels with 450 ammonite specimens. In the detailed 75 m of section studied by López-Martínez et al. (2017, Fig. 1) they recorded 35 fossiliferous levels and studied 228 ammonites.

3. New calpionellid records

Regarding the calpionellids, the Berriasian Working Group has recently published (Wimbledon, 2017 on behalf of most of the BWG) the decision about using the base of the Alpina Subzone, Calpionella Zone, which is defined by the acme of the small and globular form of *Calpionella alpina* Lorenz, as the primary marker for the base of the Berriasian. It was also discussed within the BWG, but not officially published yet, that the main secondary markers will be magnetostratigraphy and nannofossils. Past decisions stated that a Berriasian GSSP should be defined in the Tethys, the largest geographical entity at that time. Thus, any new findings of primary markers in far reaching areas as the Andes are very much welcomed.

The data from Vennari et al. (2014) is supported by calcareous nannofossils, strengthening the correlation with the Tethyan area, and now by calpionellids (López-Martínez et al., 2017). It is worth to mention that in absence of calpionellids, the calcareous nannoplankton offers the most accurate way for the Jurassic/Cretaceous boundary determination (Wimbledon et al., 2011). The ammonite zones used by López-Martínez et al. (2017) are based on the work of Vennari et al. (2014) with some strong evidences of correlation with Tethyan areas provided by calcareous nannofossils and now by calpionellids, increasing their value.

Some calpionellid reports from the Neuquén Basin in Argentina (Fernández Carmona et al., 1996; 1998; Fernández Carmona and Riccardi, 1998; 1999; Kietzmann et al., 2011a; 2017 and López-Martínez et al., 2017) offer a new perspective for the correlation between Tethyan and Pacific domains including ammonites and other fossils groups.

Nonetheless, by now, there are only a few studies focused in the calpionellid distribution in the Neuquén Basin, and we consider normal the existence of some controversies. In this way, discussions are welcomed and expected and we are grateful to Kietzmann and Iglesia Llanos for their comments on our work.

Comments are stressed out in some discrepancies with previous published works by Kietzmann and Iglesia Llanos. Unfortunately, the data presented by these authors about the Jurassic/Cretaceous boundary are based on secondary proxies (cyclostratigraphy, magnetostratigraphy and calcareous dinocysts) "calibrated" with at least a controversial Andean ammonite biozonation.

4. Specific points

> *"In the section Comments of previous calpionellid records López-Martínez* et al. *questioned some previous age assignments. These authors point out that* Kietzmann et al. (2011a) *assigned a late Early Tithonian age for the Windhauseniceras internispinosum ammonite Zone which is in fact early Late Tithonian. Such difference in the age assignment responds simply to the changes introduced by* Riccardi et al. (2011) *with respect to* Riccardi (2008a, b) *in the biostratigraphic schemes (*Fig. 1*)".*

That is not strictly true. Riccardi (2008a, b) used a three-fold division of the Tithonian and assigned the *Windhauseniceras internispinosum* ammonite zone to the upper part of the middle Tithonian. Later on, Riccardi et al. (2011), still using a three-fold division of the Tithonian moved the *W.internispinosum* zone to the base of the upper Tithonian. In none of these works, a late Early Tithonian age was assigned to this biozone. So, Fig. 1 of the comments by Kietzmann and Iglesia Llanos is misleading, specially the left column where the authors use a bi-fold division of the Tithonian and also the right column quoting Riccardi (2015). This author clearly stated that "There is no attempt to deal here with the precise definition of the Jurassic-Cretaceous limit, and therefore the use of terms such as "Tithonian", "Berriasian", "Upper/Late Jurassic" and "Lower/Early Cretaceous" have been kept to a minimum and is usually adopted when quoting other sources" (Riccardi, 2015, p. 24). So, to make this point more clear we present here a Fig. 2 which shows the relevant intervals of the original figures of Riccardi (2008a, Figs. 8, 2008b and Fig. 7), Riccardi et al. (2011, table 1) and Riccardi (2015, Fig. 1).

> *"In the same discussion, López-Martínez* et al. *interpreted that* Kietzmann et al. (2011a) *reported the Boneti Subzone of the Chitinoidella Zone, based on the presence of the genus Chitinoidella close the J-K boundary. However, López-Martínez* et al. *do not mention that* Kietzmann et al. (2011a) *clearly stated that "the occurrence of large forms of Calpionella alpina Lorenz, Crassicollaria sp. and Tintinnopsella sp. in association with ammonites of the Late Tithonian (Corongoceras alternans and lowermost Substeueroceras koeneni Zones (*Fernández Carmona et al. 1996*) rule out the correlation of this level with the Chitinoidella Zone".*

It was not an interpretation, Kietzmann et al. (2011a) stated in 3rd paragraph: "The Jurassic-Cretaceous transition encloses the calpionellid-level, which contains Calpionellidea of the genus *Chitinoidella*. Finally, Berriasian beds (*Argentiniceras noduliferum* and *Spiticeras damesi* Ammonite Zones) contains abundant *Colomisphaera* sp., and some poorly preserved hyaline calpionellids."

> *"Anyway, the position of the Chitinoidella Zone alleged by López-Martínez* et al. *is different from that interpreted by Kietzmann (*Fig. 2a*), which makes it an interesting topic for further studies".*

By mistake, the position of the Chitinoidella Zone in López-Martínez et al. (2017) is miss located in their Fig. 4.

> *"López-Martínez* et al. *claim that the chronostratigraphic position of the Argentiniceras noduliferum ammonite Zone in* Kietzmann (2017) *is Lower Berriasian. However, this author interpreted the*

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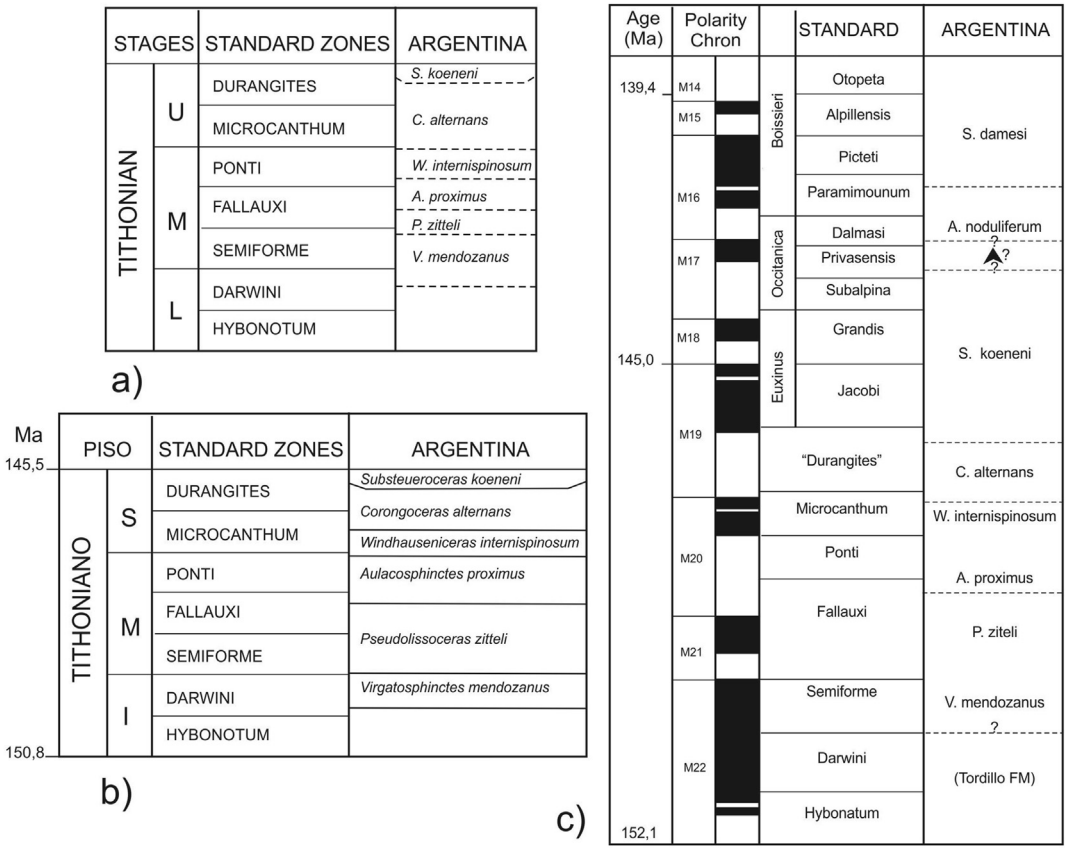

Fig. 2. Ammonite zonations of a) Riccardi (2008a, b), b) Riccardi et al. (2011) and c) Riccardi (2015). Note the three-fold division of the Tithonian (a and b) and the absence of stages in c). None of these zonations attribute the *Windhauseniceras internispinosum* zone to the late early Tithonian.

Argentiniceras noduliferum Zone as Upper Berriasian taking into consideration the biostratigraphy (Riccardi 2015), cyclostratigraphy (Kietzmann et al. 2011b, 2015) and magnetostratigraphy (Iglesia Llanos et al. 2017). The misinterpretation pointed out by López-Martínez et al. in the age of the Argentiniceras noduliferum Zone derives from confusing the age ranges assigned by Kietzmann (2017) to the calpionellids with those of the ammonite zone (Fig. 2a). In this respect, the author reported the younger chitinoidellids at the very base of the Argentiniceras noduliferum Zone, and thus the younger stratigraphic chitinoidellids record would be uppermost lower Berriasian, which does not imply that he interprets the Argentiniceras noduliferum Zone as Lower Berriasian."

Kietzmann (2017) placed the *Argentiniceras noduliferum* zone in the upper Berriasian (in his Figs. 2 and 3) but at least part of this zone in the uppermost lower Berriasian (Kietzmann, 2017, p. 154, 155, 159). Finally he stated that "the Andean *Argentiniceras noduliferum* ammonite Zone is correlated by ammonite biostratigraphy, cyclostratigraphy and magnetostratigraphy to the uppermost Occitanica-lowermost Boissieri Standard Zone (uppermost Early Berriasian to lowermost upper Berriasian)" (Kietzmann, 2017, p. 160).

Kietzmann et al. (2014, 2015) placed this ammonite zone in the early Berriasian. More recently, Ivanova and Kietzmann (2017, Figs. 8–10) placed the *Argentiniceras noduliferum* biozone in the middle Berriasian in the Arroyo Loncoche, Rio Seco del Altar and Tres Esquinas sections. These examples show the lack of precision in the definition of the biozone boundaries and the variable use of different subdivision (two-fold or three-fold) of the Berriasian stage.

"In the Discussion section, López-Martínez et al. *also commented on the paper by Iglesia Llanos et al. (2017). They pointed out that their calpionellid biozonation differs in age from the classic Tethyan standards, since the base of the Calpionella Zone is placed in the Late Tithonian instead of the base of Berriasian"*

López-Martínez et al. (2017) only mention the work of Iglesia Llanos as part of previous works of the Neuquén Basin and in fact, the biozonation differs from the Tethyan standards. As explained in the present comments, the use of an old chronostratigraphic chart (2012) justifies their wrong correlation.

"Cr. colomi, which López-Martínez allege that indicates the Colomi Subzone, has also been found in the Early Berriasian Alpina Subzone … This implies that the upper Crassicollaria Zone from López-Martínez et al. *could actually belong to the lower Calpionella Zone as well."*

This is a conceptual and methodological misunderstanding of Kietzmann and Iglesia Llanos. The assemblage composed of *Calpionella alpina*, *Crassicollaria parvula*, *Cr. colomi*, *Cr. brevis*, *Tintinnopsella remanei* and *T. carpathica* is typical from the late Tithonian Crassicollaria Zone while the acme of small and globular forms of *Calpionella alpina* defines the Alpina Subzone, Calpionella Zone (Remane, 1985, 1986; Lakova et al., 1999; Oloriz et al., 1995; Pop, 1996; Reháková and Michalík, 1997; Houša et al., 1999; Boughdiri

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et al., 2006; Andreini et al., 2007; Michalík and Reháková, 2011; Wimbledon et al., 2011, 2013 and others).

The presented assemblage cannot belong to Calpionella Zone because this zone is dominated by the small and globular form of *Calpionella alpina* and crassicollarians only appear subordinately. López-Martínez et al. (2017) clearly stated about the Alpina Subzone: "The assemblage is nearly monospecific, dominated by *Calpionella alpina* over scarce specimens of *Crassicollaria massutiniana*, *Tintinnopsella remanei* and *T. carpathica*." The confusion alleged by Kietzmann and Iglesia Llanos it is not possible because both biozones were clearly differentiated in Las Loicas section and are easy to detect in thin sections.

Another point against the argument of Kietzmann and Iglesia Llanos are the calcareous nannofossils bioevents that differentiate the Tithonian and Berriasian. This is clearly stated in López-Martínez et al. (2017): "… shows a coincidence between the FAD of *Nannoconus wintereri* with the uppermost calpionellid Crassicollaria Zone, Colomi Subzone and the FAD of *Nannoconus kamptneri minor* with the acme of *Calpionella alpina* (small and globular form)".

> *"López-Martínez* et al. *asserted to have found the "explosion" of Calpionella alpina in sample LL7. In order to demonstrate that this acme has in fact taken place, the study of more than one stratigraphic section with the corresponding statistics should be mandatory. This is a requisite to rule out that such "explosion" could have been the result of mechanical concentration.*

This is another conceptual mistake of Kietzmann and Iglesia Llanos. We explained before how to detect the Calpionella Zone. It is not necessary the study of more than one stratigraphic section to detect this acme as can be checked in a lot of published papers that comprise only one section (Reháková et al., 2009; Michalík et al., 2009; Benzaggagh et al., 2010; Krische et al., 2013; Wimbledon et al., 2013; Hoedemaeker et al., 2016; among others). The acme of *Calpionella alpina* is a global event in which the small and globular form of this species occupied niches opened by the extinction of crassicollarians (Reháková, 2000).

The statistics is not mandatory as they claim, as can be seen in several published papers, some of them even cited in their comment (Reháková et al., 1996, 2009; Grün and Blau, 1997; Boorová et al., 1999; Lakova et al., 1999; Platonov et al., 2014; among others).

The mechanical concentration is not defined by statistical analysis but from taphonomic studies. The analyzed samples show no evidence of calpionellid resedimentation or reworking.

> *"On the other hand, López-Martínez objected that* Kietzmann (2017) *reported some species found in the Tethys at older stratigraphic levels".*

We did not object, just mentioned this fact, because is in the conclusion of his paper "… particularly chitinoidellids that persists until the Early Berriasian" (Kietzmann, 2017, p. 162).

> *"Remarkably, López-Martínez* et al. *have not taken into account that there already exists a magnetostratigraphic study in the Loicas section performed by Iglesia Llanos in 2013 together with Aguirre-Urreta and Ramos that so far, has not been published".*

We do not use magnetostratigraphic data from the Loicas section performed by Iglesia Llanos because they are still unpublished. These data are insufficient at the present knowledge to be correlated with the magnetic standards. The authors do not recommend introducing possible miscorrelations by dealing with sparse data (see paleomagnetic correlations in Kietzmann et al., 2015 and Iglesia Llanos et al., 2017 in the Arroyo Loncoche section illustrated in our Fig. 1).

> *"Additionally, recent data published by* Ivanova and Kietzmann (2017) *suggest the correlation of the Argentiniceras noduliferum ammonite Zone with the uppermost part of Stomiosphaerina proxima and the lower part of Stomiosphera wanneri calcareous dinoflagellate Zones, which would indicate a Late Berriasian age".*

Some inconsistencies in Ivanova and Kietzmann (2017) do not allow this interpretation. Firstly, they place the *Argentiniceras noduliferum* biozone in the middle Berriasian in the Arroyo Loncoche, Rio Seco del Altar and Tres Esquinas sections (Figs. 8, 9 and 10). Secondly, in their Fig. 11 the Fortis and Proxima (calcareous dinoflagellates zones) were joined darkening the results in the temporal interval of interest. They also placed the FO of *Stomiosphaerina proxima* very near the base of *Argentiniceras noduliferum* ammonite zone. This FO is considered to occur near the Jurassic/Cretaceous boundary by Rehánek (1992) and accepted as late Tithonian by Reháková (2000) and Lakova et al. (1999). However, they assume this FO as middle Berriasian according to their ammonite biozonation. In that sense, their own primary data are more according with the biozonation of Vennari et al. (2014) than the one used by Kietzmann (2017).

5. Concluding remarks

At the moment there are two different biostratigraphic zonations with the Andean ammonites and their correlation with the Tethys. The correlation of the lower Tithonian ammonites zones between the Andes and the Tethys from Riccardi (2008a, b; 2015) and Riccardi et al. (2011) is coincident with the work of Vennari et al. (2014), Vennari (2016) and Aguirre-Urreta et al. (2014). However, this correlation is disputed by the new magnetostratigraphic results obtained in the Neuquén Basin (Iglesia Llanos et al., 2017).

The major discrepancy on the alternative ammonite zonations is related to the extension of the *Substeueroceras koeneni* zone in the Berriasian, and the age assigned to the overlying *Argentiniceras noduliferum* zone.

The main problem is that both magnetostratigraphy and orbital cyclostratigraphy are floating scales that need to be tied either to a detailed biostratigraphy or to precise absolute ages. The poor biostratigraphy based on ammonites, partially constrained by dinoflagellate cysts and calcisphaeres used by Iglesia Llanos et al. (2017), Kietzmann et al. (2015), Kietzmann (2017) and Ivanova and Kietzmann (2017) introduced some mismatches. For example, the duration of the different biozones had changed among their different studies without a rationale, and these inconsistencies are reflected in their final results. We want to remark that the early study of Kietzmann et al. (2011b) is closer to the work of Vennari et al. (2014) and subsequent papers.

There is no doubt that further studies under execution in the Andes will shed light to these differences tying a robust biostratigraphy with precise absolute ages where the floating scales will be properly anchored on.

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