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Article in Journal of South American Earth Sciences · June 2017
DOI: 10.1016/j.jsames.2017.06.007

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Tethyan calpionellids in the Neuquén Basin (Argentine Andes), their significance in defining the Jurassic/Cretaceous boundary and pathways for Tethyan-Eastern Pacific connections

Rafael López-Martínez a, Beatriz Aguirre-Urreta b, *, Marina Lescano b, Andrea Concheyro b, Verónica Vennari c, Victor A. Ramos b

a Laboratorio de Carbonatos y Procesos Kárticos, Instituto de Geología, Universidad Nacional Autónoma de México, México, DF, Mexico
b Instituto de Estudios Andinos Don Pablo Goeber, CONICET & Universidad de Buenos Aires, Ciudad Universitaria, Pabellón 2, 1428 Buenos Aires, Argentina
c Grupo vinculado al Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales (IANIGLA-CONICET), Museo de Historia Natural de San Rafael, Mendoza, Argentina

**Article history:**
Received 16 March 2017
Received in revised form 5 June 2017
Accepted 12 June 2017
Available online 13 June 2017

**Keywords:**
Calpionellid
Vaca Muerta Formation
Jurassic/Cretaceous boundary
Andean region
Hispanic Corridor
Paleobiogeography

**Abstract**

The study of calpionellid distribution in the well-documented Las Loicas section of the Vaca Muerta Formation in the Neuquén Basin, Argentine Andes, allows the recognition of the upper part of the Crassicollaria Zone and the lower part of Calpionella Zone across the Jurassic/Cretaceous boundary. The Calpionella Zone, Colomi Subzone (Upper Tithonian) is composed of Calpionella alpina Lorenz, Crassicollaria colomi Doben, Crassicollaria parvula Remane, Crassicollaria massutiniana (Colom), Crassicollaria brevis Remane, Tintinnopsella remanei (Borza) and Tintinnopsella carpathica (Murgeanu and Filipescu). The Calpionella Zone, Alpina Subzone (Lower Berriasian) is indicated by the explosion of the small and globular form of Calpionella alpina dominating over very scarce Crassicollaria massutiniana. The FAD of Nanoconus wintereri can be clearly correlated with the upper part of Crassicollaria Zone and the FAD of Nanoconus kamptneri minor with the Calpionella Zone. Additional studies are necessary to establish a more detailed calpionellid biozonation and its correlation with other fossil groups. The present work confirms similar calpionellid bioevents in westermmost Tethys (Cuba and Mexico) and the Andean region, strengthening the Paleo-Pacific-Tethyan connections through the Hispanic Corridor already known from other fossil groups.

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1. Introduction

The Jurassic/Cretaceous transition is currently a hot topic of discussion. At present, the accepted marker of the Tithonian/Berriasian boundary for the Berriasian Working Group (Wimbledon et al., 2011) is the base of the Calpionella Zone (Alpina Subzone), defined by the acme of small and globular Calpionella alpina Lorenz. The Calpionella Zone is easily recognized in the Tethys. Meanwhile the selection of a Global Boundary Stratotype Section and Point (GSSP) is still under debate. Calpionellids are pelagic microfossils of uncertain origin, which appeared in the late Tithonian and continued until the middle of the Early Cretaceous (Remane, 1985). They provide important correlation markers, especially in pelagic carbonates of the Tethys and have become accepted as the best late Tithonian to early Berriasian stratigraphic indicators.

Works in progress are trying to extend the discussion on that boundary far away from classical Tethyan areas such as the Boreal region (Hoedemaeker, 1991; Zakharov et al., 1997; Zakharov, 2003; Zakharov and Rogov, 2008), Andean Austral region (Vennari et al., 2014; Kietzmann et al., 2015; Iglesia Llanos et al., 2017), China (Wan et al., 2016) and California (Zakharov, 2015) among others. In that sense, the Neuquén Basin, located at the foothills of the Argentine Andes in western Gondwana is a key area, as there are clear exposures along hundreds of kilometers, expanded sections and an abundant fossil content. The most common fossils in the Tethyan-lower Valanginian Vaca Muerta Formation are ammonites, but belemnites, bivalves and other mollusks, brachiopods, and echinoids are also present (Riccardi et al., 2011; Aguirre-Urreta et al., 2011) while radiolarians and nannofossils are abundant as well (Ballent et al., 2011; Vennari and Pujana, 2017). Calpionellids...
have been scarcely recorded (Fernández Carmona et al., 1996; 1998; Fernández Carmona and Riccardi, 1998; 1999; Kietzmann et al., 2011; Kietzmann, 2017). Remane (1985) referring to the apparent absence of calpionellids in the Neuquén Basin noted that his "own repeated scrutiny of samples from Argentine Tithonian and Berriasian has also been unsuccessful".

Thus, the aims of this communication are three fold: to figure the hyaline calpionellids in a section exposing the Tithonian/Berriasian transition in the Neuquén Basin; to correlate their record with ammonites and nannofossils and to expand their paleogeographic distribution to the southern Hemisphere, far from their typical Tethyan occurrence.

2. Geological setting and fossil locality

The Neuquén Basin has a complex history mainly controlled by the changing tectonic setting of the western margin of Gondwana (Ramos and Folguera, 2005). It is one of the few South Hemisphere basins to have a good marine record from Early Jurassic to mid Early Cretaceous (Barremian) times. During that interval, the area constituted a retro-arc basin linked to the eastern margin of the Paleo-Pacific Ocean and its depositional evolution was controlled by a combination of eustasy and local tectonics (Legarreta and Gulisano, 1989). The Tithonian-lower Valanginian interval is represented by the Vaca Muerta Formation. This unit is mostly composed of black shales and mudstones with variable amount of interbedded ash-fall tuffs and limestones. Its deposition is related to a widespread marine transgression that started in the early Tithonian (Legarreta and Uliana, 1991). This work focuses in Las Loicas section exposed along a road that forks from national road 145, from Bardas Blancas to the international border at Pehuencue Pass in Mendoza Province. It is located near the Argentine-Chilean border, approximately 34 km west of Bardas Blancas (Fig. 1). The 217 m thick marine black shales and mudstones of the Vaca Muerta Formation in Las Loicas span from the upper lower Tithonian to the upper Berriasian, but our detailed analysis is restricted to the upper 75 m of the section where the J/K transition occurs as shown in Fig. 1. Ammonites were identified on the basis of abundant material collected in several field trips defining zones according to the classic ammonite biostratigraphy of the Andes. Calcareous nannofossil markers previously identified in the Tethys were recognized in the studied section, spanning the upper Tithonian to the lower Berriasian, with NJK zone and its NJK-A, NJK-B, NJK-C and NJK-D subzones confined to the studied interval (Vennari et al., 2014).

3. Comments on previous calpionellid records

There are very few previous records of calpionellids in the Neuquén Basin, and most of them are published in brief abstracts that note their presence in the Vaca Muerta Formation, though without taxonomic descriptions or illustrations. However, it is important to list them as they have been recently cited in discussions related to the Jurassic/Cretaceous transition in the Andes. Fernández Carmona et al. (1996, 1998) recorded the genera Calpionella Lorenz, Tiertinnospessa Colom and Crassicollaria Remane. Large forms of Calpionella alpina and Crassicollaria sp. were associated with late Tithonian ammonites of the Corongoceras alternans and the lower part of the Substeueroceras koeneni zones in two distinctive levels at the Arroyo Durazno locality in the High Andes of Mendoza. Fernández Carmona and Riccardi (1998) provided the first record of Chitinoidella Doben in Argentina from the Vaca Muerta Formation at the locality Río Seco de Altar, Mendoza. They also indicated that from the same levels there are middle-late Tithonian ammonites. Fernández Carmona and Riccardi (1999) reported the Alpina Zone from the Vaca Muerta Formation at the locality Chacay Melehue, Neuquén and the study area is within the Neuquén Basin in the Alta Cordillera Mendocina. The calpionellids were represented by small forms of Calpionella alpina and large forms of Tintinnospessa carpathica associated with abundant Nannoconus spp., Cadosina fusca Wanner and Colomisphaera Nowak (calcareous dinoflagellate cysts) and abundant radiolarian casts. According to these authors, the small forms of Calpionella alpina indicate the early Berriasian and were associated with the ammonite Pseudoslanfandoria australis (Burckhardt). It should be noted that Chacay Melehue is a classic locality of the Neuquén Embayment and is situated far away from the Alta Cordillera (High Andes) of Mendoza so it is not clear where the calpionellids came from, as in both areas there are outcrops of the Vaca Muerta Formation. Besides, if the small forms of Calpionella alpina are associated with Pseudoblanfandoria australis, their age should be late Berriasian as this endemic ammonite species is restricted to the Spicigeras damesi Zone of the late Berriasian (Leanza, 1945; Riccardi, 1988). Besides, large forms of Tintinnospessa carpathica point at least to middle Berriasian not early Berriasian as suggested.

Kietzmann et al. (2011) studied the Vaca Muerta Formation in two sections in southern Mendoza (Arroyo Loncoche and Río Seco de la Tosca) where they found chitinoidellids at the Jurassic/Cretaceous boundary. In the Arroyo Loncoche section the microgranular calpionellid level is located 3.2 m above the last bed with the ammonite Substeueroceras koeneni (Steuer) (late Tithonian) and 1.8 m below of the first occurrence of ammonites of the Spicigeras damesi Zone (late Berriasian). They assigned this level to the last-termost late Tithonian to early Berriasian. Besides, they also reported that the late early Tithonian (Windhauseniceras internispinosum ammonite zone) (sic, this zone is early late Tithonian) contained Chitinoidella sp. (Chitinoidella Zone) while upper Tithonian levels (Corongoceras alternans and Substeueroceras koeneni ammonite zones) recorded highly recrystallized indeterminate hyaline calpionellids. According to these authors, the Jurassic/Cretaceous transition presented the genus Chitinoidella and the Berriasian beds some poorly preserved hyaline calpionellids. This is an unusual long range for Chitinoidella Zone (Boneti Subzone), as this subzone indicates the lowermost upper Tithonian in the Tethys (Sallouhi et al., 2011).

More recently, Kietzmann (2017) studied the Vaca Muerta Formation where he described seven species of Chitinoidellidae ranging from the Virgatosphinctes mendozanus up to the Argentiniceras noduliferum Andean ammonite Zones in the Arroyo Loncoche and Río Seco de la Cara Cura sections, and four species of Calpionellidae recorded only in the Río Seco de la Cara Cura in the Corongoceras alternans ammonite Zone. He recognized the Chitinoidella and Crassicollaria standard Zones; the first one is correlated with the Virgatosphinctes mendozanus -Windhauseniceras internispinosum Andean ammonite Zones and the second enabled its correlation at least with the Corongoceras alternans ammonite Zone. Kietzmann (2017) claimed that, unlike in the Tethys where the chitinoidellids abound during the late early Tithonian until the late Tithonian (Fallauxi to Microcanthum ammonite Standard Zones) (Lakova and Petrova, 2013), in the Neuquén Basin they persist in the Argentiniceras noduliferum Andean ammonite Zone. This zone everywhere in his text is considered as uppermost lower Berriasian but in the sections depicted in his Figs. 3 and 4 it is drawn in the base of the upper Berriasian and the records of chitinoidellids only reach the upper Substeueroceras koeneni ammonite Zone (sample L 190) in the Río Seco de la Cara Cura and just up to the base of the Argentiniceras noduliferum ammonite Zone (sample L 190) in Arroyo Loncoche (Kietzmann, 2017).
4. Material and methods

As a first approach, eleven samples from the Vaca Muerta Formation encompassing the Jurassic/Cretaceous transition at Las Loicas section were analyzed in thin section for calpionellid determination. Only one sample (LLC 13) was sterile. To increase the probability of finding calpionellids suitable for determination, three different thin sections of each hand sample were selected in different orientations varying from parallel to transverse to the bedding. Those thin sections were analyzed following a grid of 500 × 500 μm to cover the entire surface. In the analyzed samples, calpionellids were scarce and poorly preserved. Recrystallization and absence of collar prevented the determination of several specimens.

The illustrated fossils are housed at the Paleontology Collections, University of Buenos Aires, under the acronyms BAFC-NP (nannofossils) and BAFC-LD (calpionellids).

5. Calpionellid assemblages

Two main calpionellid assemblages were recognized in the studied section of Las Loicas ranging from late Tithonian to early Berriasian in age.

Assemblage 1. Late Tithonian Crassicollaria Zone, Colomi Subzone. Samples LLC 1-LLC 6. Calpionella alpina is abundant and dominates over scarce Crassicollaria parvula, Cr. colomi, Cr. brevis, Tintinnopsella remanei and T. carpathica. The presence of Crassicollaria colomi and Cr. parvula suggests that this assemblage corresponds to the late Tithonian Crassicollaria Zone, Colomi Subzone. Nonetheless, this is a non-typical assemblage compared with that present in sections of the Mediterranean Tethys (Lakova et al., 1999; Andreini et al., 2007; Rehákova et al., 2011; Lakova and Petrova, 2013) but it is similar to records from Mexican and Cuban sections (Pszczółkowski and Myczynski, 2010; López-Martínez et al., 2013a, b; 2015) in which Tintinnopsella remanei is still present in the higher part of the
Crassicollaria Zone.

Assemblage 2. Early Berriasian Calpionella Zone, Alpina Subzone. Samples LLC 7–LLC 10. This assemblage is marked by the “explosion” of the small and spherical form of Calpionella alpina. This bioevent is recognized as marker of the Calpionella Zone, Alpina Subzone by several authors (Remane, 1985, 1986; Lakova, 1994; Olóriz et al., 1995; Pop, 1996; Reháková and Michalík, 1997; Houša et al., 1999; Boughdiri et al., 2006; Andreini et al., 2007; Michalík and Reháková, 2011; Wimbledon et al., 2011, 2013 and others) and it is currently regarded as the best primary marker candidate for the Jurassic/Cretaceous boundary (Wimbledon et al., 2011; Wimbledon, 2014). The assemblage is nearly monospecific, dominated by Calpionella alpina over scarce specimens of Crassicollaria massutiniana, Tintinnopsella remanei and T. carpathica.

The calpionellids from Las Loicas are shown in Fig. 2, and a species list is summarized below.

Calpionella alpina Lorenz (Fig. 2A–C). This species appears in all the studied samples in two distinct morphologies; the large form (Fig. 2A–B) typical for the late Tithonian assemblages and the small globular form typical for the early Berriasian (Fig. 2C). Both forms are easy to distinguish due to their size and morphology. Both morphotypes coexist in sample LLC 6 but the globular form is poorly represented: the acme of this form occurs in sample LLC 7. Calpionella alpina is a very well known species reported from numerous Tethyan sections.

Crassicollaria colomi Doben (Fig. 2D). Crassicollaria colomi is very scarce (only in sample LLC 1) and with bad preserved collar but the typical morphology with a small preoral shoulder can be observed. This species is well known from the Tethys and it is a new record for the Neuquén Basin.

Crassicollaria parvula Remane (Fig. 2E). Specimens attributable to Cr. parvula are scarce in the studied thin sections (LLC 1) and the species is difficult to separate from Cr. massutiniana due to the preservation of the collar. Nonetheless, in some specimens the typical sub parallel collar can be observed. This species is well known for the whole Tethys and it is a new record for the Neuquén Basin.

Crassicollaria massutiniana (Colom) (Fig. 2F). Typical forms of Cr.

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massutiniana appear in samples LLC 3, LLC 4, LLC 8 and LLC 9. Some specimens are well preserved and conserve the typical ring near the oral zone. This species is again recorded throughout the Tethys and it has recently been reported in the Neuquén Basin (Kietzmann, 2017).

Crassicollaria brevis Remane (Fig. 2G). This species appears in samples LLC 4, LLC 5, LLC 6 and LLC 7. Even with high recrystallization, morphological details like the small conical lorica with a well-developed outward collar allow its recognition. This species was widely reported in the Tethys is here recorded for the first time in the Neuquén Basin.

Tintinnopsella remanei (Borza) (Fig. 2H). Specimens assigned to T. remanei are frequent in samples LLC 3, LLC 4, LLC 5 and LLC 7 but it is not documented upwards. This species has been recorded throughout the Tethys in the Crassicollaria Zone but this is the first record from the Neuquén Basin.

Tintinnopsella carpatica (Murgeanu and Filipeiscu) (Fig. 2I). Only two specimens assignable to T. carpatica were identified in samples LLC 6 and LLC 7. The scarcity of this species does not allow the determination of morphological changes throughout the section. The specimen illustrated in Fig. 2I is small, 50 µm in height with a near conic aboral zone. Tintinnopsella carpatica has been recorded throughout the Tethyan domain.

6. Discussion

As few previous records of Calpionellidae in the Neuquén Basin were hardly described or illustrated, their vertical distribution remains in doubt. Riccardi (2015, p. 30) noted that the genus Chitinoidella was recorded for the first time in the Tithonian of Río Seco del Altar, Sierra de la Cara Curá, by Fernández Carmona and Riccardi (1998), and that the recorded species include Chitinoidella boneti, C. sp. cf. C. pinarensis (Furrazola-Bermúdez and Kreisel), and Chitinoidella spp. These came from a level with ammonites indicating the lower boundary of the Windhausencieras internispinus Zone. In his remarks on the Tithonian and Berriasian ammonite biostratigraphy of west-central Argentina, Riccardi (2015, p. 35) affirmed that the presence at Chacay Melehue of Massutiniana hinders the value of this biozonation. Thus, these data shed new light into the discussion and offer a preliminary view of the vertical distribution of this fossil group in the Neuquén Basin and the prospect of using them in the definition of the Jurassic/Cretaceous boundary in the Andean region.

Our recorded assemblage of Crassicollaria colomi, Cr. parvula, Cr. massutiniana, Cr. brevis and Tintinnopsella remanei in the upper part of the Crassicollaria Zone, Colomi Subzone, is very similar to that reported by López-Martínez et al. (2013b) in Cuba and López-Martínez et al. (2013a, 2015) in Mexico. The presence of Tintinnopsella remanei and Crassicollaria brevis in the upper part of the Crassicollaria Zone was first assumed to be the result of reworking (López-Martínez et al., 2013a) but its persistent appearance in Mexican sections and now in the Neuquén Basin suggests a similar distribution pattern in westernmost Tethys (Mexico and Cuba) and the Andes.

In the Las Loicas section, there are seven calcareous nannofossil bioevents previously identified in the Tethys (Bralower et al., 1989; Casellato, 2010) (Fig. 3). The Tethyan NJK zone can be recognized here and its NJK–A, NJK–B, NJK–C and NJK–D subzones are confined to the studied interval, suggesting a late Tithonian to early Berriasian age (Fig. 4). The FAD of Umbria granulosa is considered the base of subzone NJK–B and is correlated with the uppermost Tithonian. The appearance of Rhagodiscus asper (Stradner) Reinhardt is a secondary bioevent (Casellato, 2010) and correlates with the subzone NJK–B (Bralower et al., 1989). The FAD of Nannoconus winteni is considered a late Tithonian marker, and a bioeoot of subzone NJK–C (Bralower et al., 1989), which defines the base of subzone NJT 17 b (Casellato, 2010). The FAD of Nannoconus kamptneri minor defines the base of subzones NJK–D (Bralower et al., 1989) and NKT (Casellato, 2010), assigned to the Berriasian. Other bioevents identified are the FAD of Nannoconus steinmanni minor and the LOs of Nannoconus winteni and Polycostella senaria.

The vertical distribution of the studied calpionellids compared with previous records of nannofossils (Figs. 1 and 4) shows a coincidence between the FAD of Nannoconus winteri and the uppermost calpionellid Crassicollaria Zone, Colomi Subzone and the FAD of Nannoconus kamptneri minor with the acme of Calpionella alpina (small and globular form). These bioevents clearly indicate the Jurassic/Cretaceous boundary even though the calpionellid resolution on its own is not enough to establish a complete biozonation. This correlation between calpionellids and nannofossils has also been reported by several authors elsewhere (Ondrejíčková et al., 1993; Michalík et al., 2009; Reháková et al., 2009; Lukeneder et al., 2010; Hoedemaeker et al., 2016).

Kietzmann (2017) reported chitinoidellids distributed from the lower Tithonian up to the lower Berriasian. In the present work we do not have any range with microgranular calcite walls and we only record hyaline calpionellids in the upper Tithonian and lower Berriasian.

More detailed work is necessary to clarify the vertical distribution of calpionellids in the Andean region and its correlation with ammonite zones, but at least the main calpionellid bioevents for the Crassicollaria and Calpionella zones are very similar when compared with those of the westernmost Tethys (Mexico and Cuba) and can also be correlated in a lesser extent with those typical of the Mediterranean Tethys.

7. Possible dispersal pathways of calpionellids from Tethys to the Neuquén Basin

Calpionellids represent one of the most important constituents of tropical calcareous microplankton in Upper Jurassic - Lower Cretaceous pelagic carbonates (Reháková and Michalík, 1997) and have been recorded in numerous surface sections in the Tethys, from Iran and Kurdistan in the east to Mexico in the west (Remane, 1968, 1985; Adatte et al., 1993, 1994, 1996; Reháková and Michalík,
Other reports came from North Atlantic (offshore) (Remane, 1985; Azéma and Jaffrezo, 1984), Eastern Canada (offshore) (Jansa et al., 1980), Venezuela (Bermúdez and Rodríguez, 1962) and New Guinea (Rickwood, 1955; Ali et al., 2001). All these records demonstrate the wide distribution of this
group not only restricted to the Tethyan domain, even if the Australian record of *Calpionella* (Brunnschweiler, 1960) has been dismissed by Remane (1971). Some records still remain dubious as those reported by Heim and Gansser (1939) from the Himalayas and Salazar Soto (2012) from Chile.

The distribution of calpionellids during Tithonian and Berriasian times provides data suggesting three possible pathways for their dispersal from Tethys to the Neuquén Basin. The first one can be postulated along the Tethys across the Paleo-Pacific (Fig. 5, arrow 1). This option is possible, but difficult, due to the long distance...
between both regions but the record of calpionellids in New Guinea and perhaps in Australia may support a possible connection by this route.

A potential second route (Fig. 5, arrow 2), is along the eastern African margin of Gondwana down the Mozambique Corridor and crossing towards the Paleo-Pacific near the Antarctic Peninsula. The most important factor not in favor of this route is the absence, up to now, of calpionellid records between north-eastern Africa and the Nequén Basin. Another factor in opposition to this hypothesis is that calpionellids should have to migrate across high Austral latitudes. However, it is known that calpionellids have been reported in the North Hemisphere as high as 45° North Latitude in clear mix with typical Boreal fauna (Jansa et al., 1980). Then, it may be possible that calpionellids migrated at least to similar latitudes in the southern Hemisphere, as seen for example by the bivalves *Anapaea* Eichwald and *Arctotis* Bodylevsky, taxa known from rocks in Mexico (Zell et al., 2015a, b). According to Ballent and Whatley (2009) during latest Jurassic and Berriasian times the opening of a shallow intermittent epicontinental seaway between southern South Africa and southern Patagonia favored faunal interchange of ostracods. This proposal is in accordance with Riccardi (1991) who stated that in the Late Jurassic the break-up of Gondwana was initiated and a seaway began to open between South America, Africa and Antarctica, though the connection of the Eastern Pacific with Tethyan waters through southern Africa was sporadic.

Nonetheless, the clearest route and the one proposed herein, is across the Hispanic Corridor (Fig. 5, arrow 3). This continuous seaway through Central America, at least since the Early Jurassic (Arias, 2008) allowed free migration and dispersal of Tethyan bionts to the Pacific along the western margin of Gondwana (Damborenea et al., 2013; Zell et al., 2013, 2015a, b; Bardet et al., 2014; among many others).

During Kimmeridgian and Tithonian times a second order sea level transgression is reported in the Gulf of Mexico and the Proto-Caribbean (Goldhammer and Johnson, 2001). This sea level rise affected the shallow water platform in Cuba (San Vicente Member of Guasasa Formation) which was totally drowned during the Chitinoidea Zone (late Tithonian) (López-Martínez et al., 2013b). The same sea level event is reported by Reháková (2000) in the Carpathian area and can be correlated with the appearance of saccoecomasies facies in Mexico (Aguilera-Franco and Franco Navarrete, 1995), Cuba (López-Martínez et al., 2013b) and Argentina (Kietzmann and Palma, 2009). With this sea level rise, planktonic organisms from the Gulf of Mexico and the Proto-Caribbean (westernmost Tethys) could have spread to the Pacific Realm and to the Nequén Basin.

Additional studies are necessary for a better understanding of the migration pathways of calpionellids to the Nequén Basin, but strong evidence point to a clear connection between the Tethys and the Nequén Basin at least during Tithonian and Berriasian times.

8. Concluding remarks

The record of calpionellids in the Las Loicas section of the Vaca Muerta Formation in the Nequén Basin, Argentine Andes, allows recognizing the Crassicollaria Zone, Colomi Subzone (late Tithonian) and the Calpionella Zone, Alpina Subzone (early Berriasian). In this work there are reported for the first time the following species: *Crassicollaria colomi*, *Cr. parvula*, *Cr. brevis*, and *Tintinnopsis remanei*.

The identification of calpionellids encompassing the Tithonian-Berriasian boundary in south-western Gondwana is an important step forwards the correlation with the Tethyan Realm based on the presence of the same fossil markers. Up to now, the correlations between these two far reaching areas: Andes and Tethys were only based on ammonites and nannofossils which are presently accepted as secondary markers for the base of the Berriasian (Wimbledon et al., 2011).

This finding of hyaline calpionellids opens not only a new window in the determination of the Jurassic/Cretaceous boundary in the Andes but also for studies of the calpionellid dispersal pathway from the Tethys to the Paleo-Pacific throughout the Hispanic Corridor.

Research projects in progress in the Neuquén Basin on biostratigraphy, magnetostratigraphy and high precision radio-isotopic dating will certainly improve our knowledge of the Jurassic/Cretaceous transition in the Andes and the correlation with the classic Tethyan region, helping to solve decades of debate over the J/K boundary.

Acknowledgements

We want to specially thank Drs. Mabrouk Boughdiri, Peter Rawson, Daniela Reháková and Patrick Zell for the revision of the manuscript and their suggestions that enhanced the quality of the present paper. We also thank Dr. Francisco Vega Vera for his editorial work. This research was funded by projects PAPIIT IA102616 to RLM; ANPCYT 1413/13 to BAU and PIP-CONICET (0542) to VR. This is a contribution to the Berriasian Working Group of the ICS and R-220 of the Instituto de Estudios Andinos “Don Pablo Groeben”.

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