THE JURASSIC-CRETACEOUS BOUNDARY CONTROVERSY: ITS DETERMINATION IN THE NEUQUEN BASIN, ARGENTINA USING MAGNETOSTRATIGRAPHY AND CYCLOSTRATIGRAPHY

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ABSTRACT

The J-K boundary is controversial at a global scale. Recently, it has been proposed that the J-K could be defined through microfossils (i.e. calpionellids) and/or magnetostratigraphy. The J-K boundary is comprised within the Vaca Muerta Formation that crops out in the Neuquén basin, Argentina, and represents one of the most important unconventional hydrocarbon reservoirs in the world. The Vaca Muerta Formation bears ammonites and calpionellids among the most important fossils for dating purposes; therefore the importance of obtaining a robust magnetostratigraphy in this unit. In the Arroyo Loncoche section, the Vaca Muerta Formation is up to *c.*280 m-thick bearing ammonites from the Andean Region. 450 specimens were collected from 55 paleomagnetic sites were analysed, and the primary origin of the isolated magnetization proved through several field tests. Polarities were dated with ammonites and thus, a magnetostratigraphic scale was constructed and correlated with the International Geomagnetic Polarity Time Scale. Two independent chronostratigraphic tools such as cyclostratigraphy and magnetostratigraphy, were therefore used to successfully define the position of the J-K. This position is consistent with the magnetostratigraphic scales obtained in other sections of the Neuquén basin.

Keywords: Jurassic-Cretaceous, magnetostratigraphy, Neuquén Basin

RESUMEN

La posición del límite J-K es objeto de importante controversia a nivel mundial. Recientemente, se ha establecido que las únicas herramientas que podrían ayudar a la determinación del mismo son microfósiles (i.e. calpionélidos) y/o magnetoestratigrafía. El límite J-K está comprendido dentro de la Formación Vaca Muerta que aflora en la Cuenca Neuquina, Argentina, y representa uno de los reservorios de hidrocarburos no convencionales más importantes del mundo. La Formación Vaca Muerta contiene amonites y calpionélidos entre los fósiles más importantes para su datación; de allí la relevancia de obtener una magnetoestratigrafía confiable en esta unidad geológica. En la localidad Arroyo Loncoche, la Formación Vaca Muerta alcanza los 280 m de espesor y porta amonites de la Región Andina. Un total de 450 especímenes fueron recolectados de 55 sitios paleomagnéticos, y se probó el origen primario de la magnetización aislada a través de varias pruebas de campo. Las polaridades fueron datadas con amonites y de este modo se construyó una escala magnetoestratigráfica que fue correlacionada con la Escala Internacional de Polaridades Geomagnéticas. Así, se utilizaron dos herramientas cronoestratigráficas independientes como la cicloestratigrafía y la magnetoestratigrafía para definir la posición del límite J-K. Esta posición del límite es consistente con los estudios magnetoestratigráficos obtenidos en otras secciones de Cuenca Neuquina.

Palabras clave: Jurásico-Cretácico, magnetoestratigrafía, Cuenca Neuquina

The most relevant feature of the Jurassic-Cretaceous boundary is the lack of a faunal turnover and the remarkable increase of faunal provinciality, especially in ammonites (*e.g.* Remane 1991, Wimbledon *et al.*, 2011, 2013, Ogg and Hinnov, 2012). This makes the determination of the J-K boundary very controversial.

There are at least three definitions to be considered (*e.g.* Grabowski 2011, Gradstein *et al*. 2012): 1) the base of the Grandis ammonite Subzone that corresponds to the lower part of the Calpionella Zone and almost coinciding with the base of polarity subzone M18r; 2) the base of the *Jacobi* ammonite Zone equivalent to the base of the Calpionella Zone in the upper part of polarity subzone M19n2n, and 3) the base of the Occitanica ammonite Zone, correlated with the middle part of the Calpionella Zone in the lower part of magnetozone M17r (Hoedemaeker 1990). Recently, the Berriasian Working Group has defined the Jurassic-Cretaceous boundary at the base of the Calpionella Zone in the middle part of magnetosubzone M19n2n (in Ogg *et al.,* 2016). This prompted the J-K boundary defined by magnetostratigraphy to shift from the M18r to the M19n2n polarity subzone.

Jurassic–Cretaceous Andean biostratigraphy in the Neuquén basin (Vaca Muerta Formation) is well defined by ammonites (*e.g.* Riccardi 2008, 2015), and to a lesser extent, by microfossils such as calcareous nannofossils (*e.g.* Bown and Concheyro 2004) and calpionellids (Fernández Carmona and Riccardi, 1999, Kietzmann 2017), as well as dinoflagellate cysts (Ivanova and Kietzmann, 2017). On the other hand, Kietzmann *et al*. (2015) presented a regional floating orbital scale of the Vaca Muerta Formation, using high and low frequency eccentricity cycles, and tied to the international time scale using ammonites.

This contribution is thus focused to help calibrating biostratigraphic correlations through magnetostratigraphy and cyclostratigraphic data.

The study section crops out along the Loncoche creek (Arroyo Loncoche) located in southern Mendoza province, where the Vaca Muerta Formation reaches up *c*. 280 m-thick of rhythmic alternations of marlstones, shales and limestones intruded in the lower part by a *c*. 20 - thick andesitic sill. A detailed facies analysis of the Vaca Muerta Formation in the studied section was published by Kietzmann *et al*. (2011, 2014), and interpreted as basinal to middle carbonate ramp deposits. Ammonite data from the studied section restrains the deposition of the Vaca Muerta Formation to the early Tithonian (*Virgatosphinctes mendozanus* Zone) – late Berriasian (*Spiticeras damesi* Zone) (Leanza *et al*. 1977, Kietzmann *et al*. 2011, 2014).

Two magnetic components were recognized in most of the section. The soft component yields northern declinations with negative inclinations, and is removed at < 300°C or 15 mT, and is interpreted as a remagnetization. The second component shows NE (SW) declinations with negative (positive) inclinations when tectonic corrected and was generally removed between 450 and 500°C, or 40 and 60 mT, and is interpreted as the characteristic (ChRM). The ChRM was calculated using principal component analysis (Kirschvink 1980) or remagnetization circles (Halls, 1976; McFadden and McElhinny 1988). It passes a reversal and a contact test, and therefore it is interpreted to represent the primary magnetization. A third component was found in the lower part of the studied section associated to the sill carried most likely by pyrrhotite, corresponding to the time of the sill's intrusion.

AMS fabrics vary from dominantly normal (minimum K_3 axes perpendicular to bedding plane) in the lower part of the section, followed by inverse (maximum K_1 axes perpendicular to bedding plane), intermediate (intermediate K_2 axes perpendicular to bedding plane), and in the upper part of the section, normal.

Rock magnetic studies performed in several sections of the Vaca Muerta Formation prove that the primary remanence is carried by titanomagnetite whereas in the sill the carrier is pyrrhotite (Kohan Martínez *et al.*, this Congress)

The employment of cyclostratigraphy together with magnetostratigraphy tied to the biostratigraphic correlation locate the J-K boundary precisely in the lower part of the *S. koeneni* Zone, either at the M19n.1-M18r boundary (c. 190 m from the base) or in the middle of magnetozones M19n.2. Both alternatives, shown in Ogg *et al*. (2016), are concordant with the biostratigraphic criteria from Riccardi (2015). The combination

of biostratigraphy, magnetostratigraphy and cyclostratigraphy allowed to identify the J-K boundary with a higher accuracy, which is relevant not only at a regional but also a global scale.

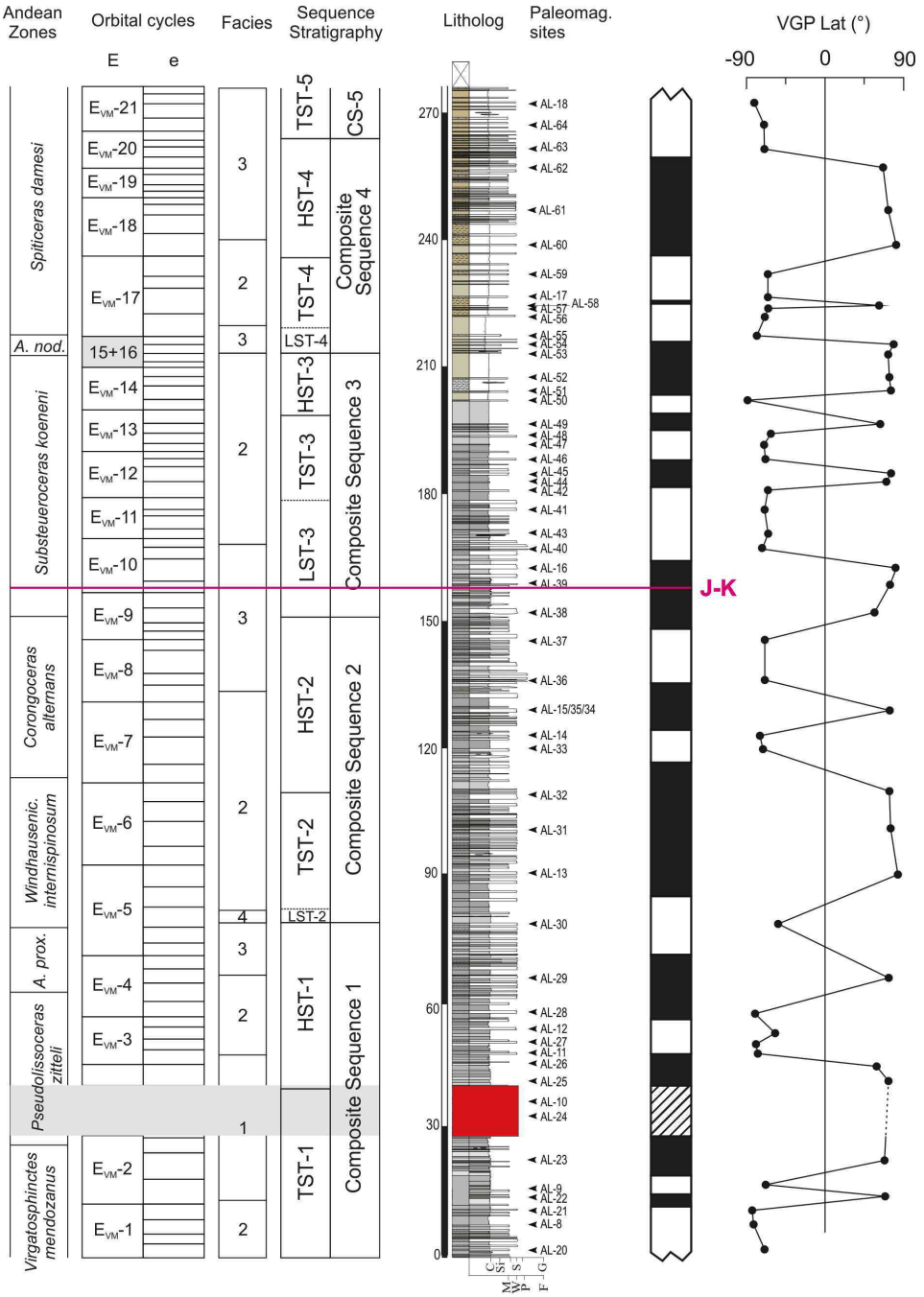

Figure 1. Stratigraphic column of the Vaca Muerta Formation at the Arroyo Loncoche section. Data show (left to right): Andean ammonite zones, low (E) and high (e) frequency eccentricity cycles (Kietzmann *et al.* 2015), sequence stratigraphy (Kietzmann *et al.* 2014), paleomagnetic sites, polarities sequence and VGP latitudes. J-K: Jurassic-Cretaceous boundary determined by magnetostratigraphy and cyclostratigraphy.

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