Cyclostratigraphy of a Tithonian–Valanginian Carbonate Ramp Succession, Southern Mendoza, Argentina: Implications for the Jurassic–Cretaceous Boundary in the Neuquén Basin

Diego A. Kietzmann and Ricardo M. Palma

Abstract We conducted detailed sedimentological, sequence-stratigraphic, and cyclostratigraphic analyses on four sections of the Vaca Muerta Formation. This unit is characterized by a decimetre-scale rhythmic alternation of marls and limestones. It consists of five facies associations, which represent basin to middle carbonate ramp deposits. The rhythmic vertical organization shows a well-ordered hierarchy of cycles, where elementary cycles, bundles of cycles, and superbundles within the Milankovitch frequency band are recognized. Cyclostratigraphic data allowed us to build a floating orbital scale for the lower Tithonian–lower Valanginian interval in the Neuquén Basin. Orbital calibration of these sections is consistent with Riccardi's biostratigraphic scheme, which places the Jurassic–Cretaceous boundary within the *Substeueroceras koeneni* ammonite Zone (equivalent to *Durangites* spp., *Jacobi/Grandis,* and initial *Occitanica* standard zones).

Keywords Orbital cycles · Milankovitch · Biostratigraphy · Jurassic–Cretaceous boundary

Introduction

Cyclostratigraphic studies have frequently been conducted in the Northern Hemisphere, but rarely applied to the geological record of the Southern Hemisphere. Previous studies in the Neuquén Basin include those of Sagasti (2000) on the Agrio Formation, and some preliminary investigations on the middle Tithonian of the

D. A. Kietzmann (✉) · R. M. Palma
IDEAN-CONICET, Departamento de Ciencias Geológicas, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Intendente Güiraldes 2160, CABA 1428EHA Buenos Aires, Argentina
e-mail: diegokietzmann@gl.fcen.uba.ar

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Vaca Muerta Formation (Scasso et al. 2002). The cyclicity of the Vaca Muerta Formation has been studied by Kietzmann et al. (2011). The aim of this contribution is to build a floating orbital scale for the lower Tithonian–lower Valanginian of the Vaca Muerta Formation, to provide new data on the existing dispute about the position of the Jurassic–Cretaceous boundary in the Neuquén Basin.

Methodology

Detailed sedimentological sections were measured bed-by-bed in four localities of the southern Mendoza sector of the Neuquén Basin (Fig. 1a). Relative ages are based on the Andean ammonite biostratigraphic scheme of Riccardi (2008). Cyclostratigraphic analysis is based on the differentiation of dm-scale couplets of limestone–marl lithofacies (elementary cycles). Spectral analyses (using the Blackman–Tukey method) are based on the following premises/points: (1) The section consists of a succession of elementary cycles showing similar thicknesses, which are considered similar in average duration. (2) The number of cycles is large enough to obtain statistically significant results. (3) Data sets were corrected prior to spectral analysis, by subtracting the mean value and trends generated by changes in sea level. (4) Poorly cyclic intervals were not incorporated into the spectral analysis. However, these noncyclic intervals were considered for estimations of the total number of cycles in stratigraphic sections.

Facies Analysis

The Vaca Muerta Formation consists of five facies associations. Facies association 1 consists of black shales, deposited under anoxic conditions below the storm-wave base. Facies association 2 consists of alternating marls and lime mudstones–wackestones, deposited in a dysaerobic to aerobic, low-energy outer ramp environment. Facies association 3 is dominated by marls and bioclastic wackestones. It was deposited in an aerobic to dysaerobic outer to middle ramp environment. Facies association 4 is dominated by HCS peloidal grainstones and marls, which were deposited in a well-oxygenated middle ramp setting. Facies association 5 consists of peloidal wackestones–packstones, oyster biostromes, and marls, deposited in a well-oxygenated muddy bottom located within the storm wave base.

Cyclostratigraphy

The vertical organization within the Vaca Muerta Formation shows a well-ordered hierarchy of cycles, where elementary cycles, bundles of cycles, and superbundles are recognized. Elementary cycles show a relatively regular thickness in the order

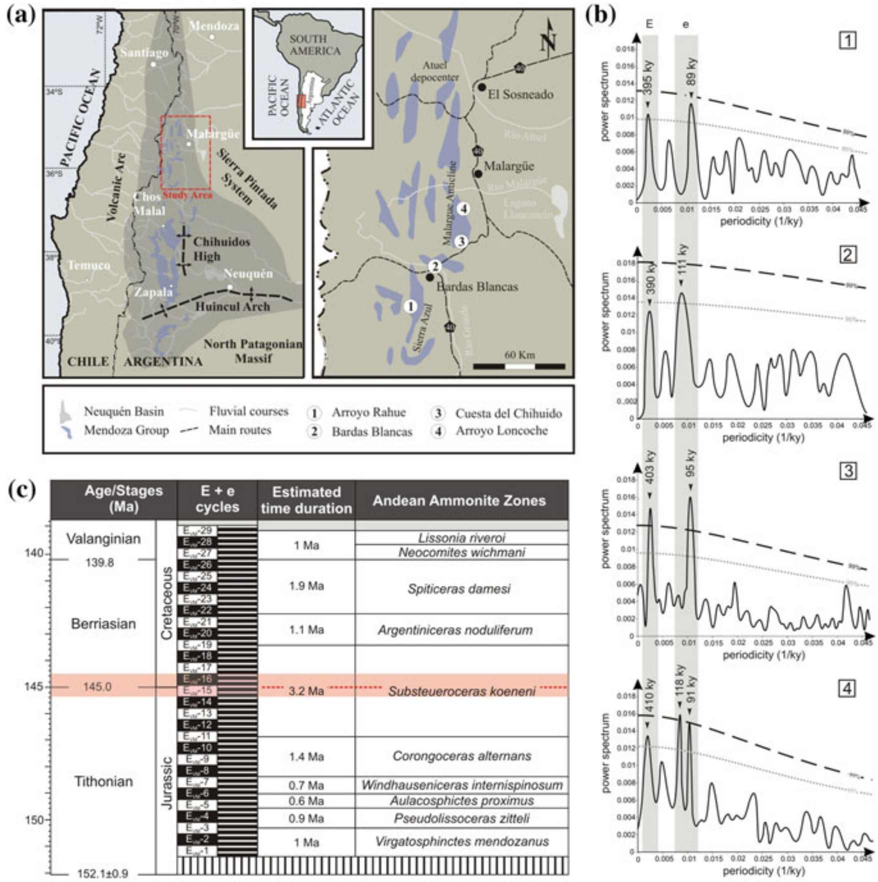

Fig. 1 **a** Location map of the Neuquén Basin showing the main geological features and studied localities; **b** Fourier frequency spectra (Blackman–Tukey method) for the studied localities (refer to **a** for locations 1–4); **c** Orbital calibration of Andean ammonite zones. The boundary between *Neocomites wichmanni* and *Spiticeras damesi* zones is chosen as the datum level to fit the orbital floating scale, because there is consensus in its temporal position

of 20–40 cm, so that they can be regarded as temporally equivalent units controlled by a regular climatic cycle. Elementary cycles are grouped into sets of 4–5 cycles or bundles of cycles, and these are grouped into sets of 4–5 bundles of cycles or superbundles.

According to our biostratigraphic data, the Vaca Muerta Formation covers the early Tithonian to early Valanginian. Adopting the timescale proposed by Gradstein et al. (2012), the Vaca Muerta Formation interval would be about 11 Myr in duration. Integrating the information from the four analysed sections, the Vaca Muerta Formation contains 521 elementary cycles, 102 bundles, and 28 superbundles. Dividing the lengths of these sections by the number of cycles, elementary cycles in this area are calculated to have durations of about 21 kyr, which can be attributed to Earth's precessional cycle. Spectral analyses show two or three main peaks above the confidence levels, which correspond to periodicities of 390–410 and 89–118 kyr (Fig. 1a). These periodicities can be attributed to the low- and high-frequency eccentricity cycles, respectively.

As the eccentricity cycle can be considered more or less constant over the last 500 Myr, it has been used to build astronomical time scales (e.g., Hinnov and Ogg 2007). Using high- and low-frequency eccentricity cycle identified in the four studied stratigraphic sections, we built a floating astronomical scale for the lower Tithonian–lower Valanginian of the Neuquén Basin, which allowed us to calibrate ammonite zones (Fig. 1c). This biozone distribution is consistent with: (1) the absence of the lowermost lower Tithonian; (2) the middle Tithonian position of the *Pseudolissoceras zitteli* and *Aulacosphinctes proximus* zones; (3) the presence of *Saccocoma* acme (middle Tithonian) in the *Pseudolissoceras zittelli* and *Aulacosphinctes proximus* zones, and its last appearance within the *Corongoceras alternans* Zone; and (4) the presence of *Chitinoidella* in the *Windhauseniceras internispinosum* Zone, as well as the presence of large forms of *Calpionela alpina* Lorenz, *Crassicollaria* sp., and *Tintinnopsella* sp. within the *Corongoceras alternans* Zone and lowermost part of the *Substeueroceras koeneni* Zone.

The calibrated biozone distribution is consistent with the biostratigraphic scheme proposed by Riccardi (2008), which places the Jurassic–Cretaceous boundary within the lower part of the *Substeueroceras koeneni* Zone, rather than in the base of the *Argentiniceras noduliferum* Zone.

References

Gradstein, F. M., Ogg, J. G., Schmitz, M., & Ogg, G. (2012). *The geologic time scale 2012* (p. 1176). Amsterdam: Elsevier.

Hinnov, L. A., & Ogg, J. G. (2007). Cyclostratigraphy and the astronomical time scale. *Stratigraphy, 4*(2/3), 239–251.

Kietzmann, D. A., Martín-Chivelet, J., Palma, R. M., López-Gómez, J., Lescano, M., & Concheyro, A. (2011). Evidence of precessional and eccentricity orbital cycles in a tithonian source rock: The mid-outer carbonate ramp of the vaca muerta formation, northern neuquén basin, Argentina. *AAPG Bulletin, 95*(9), 1459–1474.

Riccardi, A. C. (2008). El Jurásico de la Argentina y sus amonites. *Revista de la Asociación Geológica Argentina, 63*(4), 625–643.

Sagasti, G. (2000). La sucesión rítmica de la Formación Agrio (Cretácico Inferior) en el sur de la provincia de Mendoza, y su posible vinculación con Ciclos de Milankovitch. *Research Academy of Social Sciences, 7*(1–2), 1–22.

Scasso, R. A., Alonso, S. M., Lanés, S., Villar, H. J., & Lippai, H. (2002). Petrología y geoquímica de una ritmita marga-caliza del Hemisferio Austral: El Miembro Los Catutos (Formación Vaca Muerta), Tithoniano medio de la Cuenca Neuquina. *RAGA, 57*(2), 143–159.