PRELIMINARY MAGNETOSTRATIGRAPHY AND ROCK MAGNETIC ANALYSIS OF THE VACA MUERTA FORMATION (UPPER JURASSIC-LOWER CRETACEOUS) IN THE PUERTA CURACO SECTION, ARGENTINA

M. Kohan Martínez[1,2]*, M. P. Iglesia Llanos[1,2], D. A. Kietzmann[1,2], T. Luppo [1,2]

[1] Consejo Nacional de Investigaciones Científicas y Técnicas
[2] IGEBA, Depto. de Cs. Geológicas, Fac. de Cs. Exactas y Naturales, Universidad de Buenos Aires, Pab. 2 Ciudad Universitaria, C1428EHA Buenos Aires, Argentina
*e-mail: melisa.kohan@gmail.com

ABSTRACT

A systematic paleomagnetic study was carried out in the Vaca Muerta Formation, a carbonate- ramp system cropping out in the Neuquén basin, west-central Argentina. The Vaca Muerta Formation is one of the most important unconventional hydrocarbon reservoirs in the world and its exhaustive study has become a relevant target in Argentina. In the Puerta Curaco section, this unit is *c.* 360 m – thick bearing ammonites that indicate Upper Jurassic – Lower Cretaceous ages. Here, paleomagnetic sites were sampled from which nearly 500 specimens were collected and processed. The primary origin of the magnetization was proved through paleomagnetic field tests. As a result, a preliminary magnetostratigraphic scale was constructed dated with ammonites of the Andean Realm, and then correlated to the most recent International Geomagnetic Polarity Time Scale. The resultant magnetostratigraphic scale proved to be consistent with other studies, and allowed the refinement of the temporal framework of the lower part of the Vaca Muerta Formation. Simultaneously, in order to determine the main magnetic carriers of the magnetic remanence several rock magnetism studies were carried out such as isothermal remanent magnetization (IRM) acquisition curves, thermomagnetic curves and *K* vs. field curves that were complemented with observations of magnetic minerals under reflected light and scanning electron microscopy.

Keywords: Vaca Muerta Formation, magnetostratigraphy, magnetic mineralogy, Neuquén basin

The Vaca Muerta Formation is a thick rhythmic alternation of dark bituminous shales, marlstones and limestones deposited as result of a rapid and widespread Paleo-pacific early Tithonian to early Valanginian marine transgression in the Neuquén Basin, west-central Argentina (Legarreta & Uliana 1991). Its importance is that, on the one hand, it is a valuable oil and gas resource. On the other hand, its abundant fossil content and its temporal continuity along several hundreds meters of thickness, make this unit ideal for paleomagnetic and magnetostratigraphic studies.

The primary goal of this study has been to construct a magnetostratigraphic scale in order to refine the age of the Vaca Muerta Formation, which has been interpreted to span the early Tithonian (*Virgatosphinctes mendozanus* Zone) - early Valanginian (*Olcostephanus atherstoni* Zone), based on the its biostratigraphy (*e.g.* Leanza *et al.* 1977, Leanza 1980, Riccardi *et al.* 2011, Kietzmann *et al.* 2014a). In addition, several rock magnetic studies such as acquisition curves and thermomagnetic curves were carried out, in combination with thin sections and SEM analysis, in order to determine the nature of main carriers of the remanence.

The formation was logged for a detailed paleomagnetic study and a thorough sedimentologic analysis in the Puerta Curaco section, located in the northern part of the Neuquén Province. A total of 69 paleomagnetic sites were sampled and four to five cores were drilled and oriented in each site using a portable driller. In the laboratory, cores were cut in at least two standard specimens, and thus, 8 standard specimens were obtained on average for each site obtaining a total 550 specimens in Puerta Curaco section.

At Puerta Curaco, on average, half of 10 specimens per sampled horizon were processed, for the paleomagnetic analysis (hence the term preliminary). Demagnetization was performed using high temperatures (TH) and alternating fields (AF). Residual magnetizations were measured in a 2G cryogenic magnetometer. Demagnetization procedures involved approximately 19 steps, usually up to 70, occasionally 100 mT in case of AF, and up to 550º-640º C for TH, which proved to be most efficient to isolate the primary magnetic component. Two different paleomagnetic behaviors were recognized. One behavior exhibits straight paths to the origin (Zijderveld 1967). The other behavior shows curves trajectories up to the origin indicating superposition of coercivity spectrums. Specimens that showed straight paths were analyzed by principal component analysis (PCA) (Kirschvink 1980), and specimens with the second behavior, were analyzed by remagnetization circles. The characteristic component passes a reversal test, and is interpreted as primary, as acquired during deposition of the Vaca Muerta sediments.

Rock magnetic studies were conducted over samples of representative lithologies. These include isothermal remanent magnetization (IRM) acquisition curves, thermomagnetic curves, *k v.s.* field curves and hysteresis loops. Observations of magnetic minerals under reflected light and scanning electron microscopy were performed so as to complement these rock magnetic studies.

So far, virtual geomagnetic poles (VGP) were calculated from site mean directions, yielding 10 reverse and 11 normal polarity intervals (Fig.1). Having dated these polarity intervals with the Andean ammonite zones, a consistent correlation was made between the local magnetostratigraphic scale and the Geomagnetic Polarity Time Scale (GPTS) compiled by Ogg & Hinnov (2012). So far, results allowed to position the J-K boundary precisely in the lower part of *S. koeneni.* Accordingly, the age of the sampled section in Puerta Curaco would be restrained to the Lower Tithonian - Lower Valanginian (*Virgatosphinctes mendozanus - Neocomites wichmanni).* As a first insight into a detailed determination of the main magnetic carriers in the Puerta Curaco section of the Vaca Muerta Formation, most of the samples show a typical behavior of titanomagnetite. Also, a minority of the processed samples shows behaviors that could point out the presence of pyrrhotite (Lowrie 1990).

The resultant magnetostratigraphic scale comprises 10 reverses and 11 normal polarity intervals, spanning the Andean *Virgatosphinctes mendozanus* (lower Tithonian) to *Neocomites wichmanni* Zones (Valanginian). These polarities were correlated with those of the International Geomagnetic Polarity Time Scale using the correlation between Andean and Tethyan ammonite zones, and they are consistent with the results obtained in previous studies in Southern Mendoza (Kietzmann *et al.* 2015; Iglesia Llanos *et al.* 2017, Kohan Martínez, 2017). This correlation allowed to restrain the unit between M22 and M12 Chrones (upper part of *Hybonoticeras hybonotum* to *Tirnovella pertransiens* zones, respectively).

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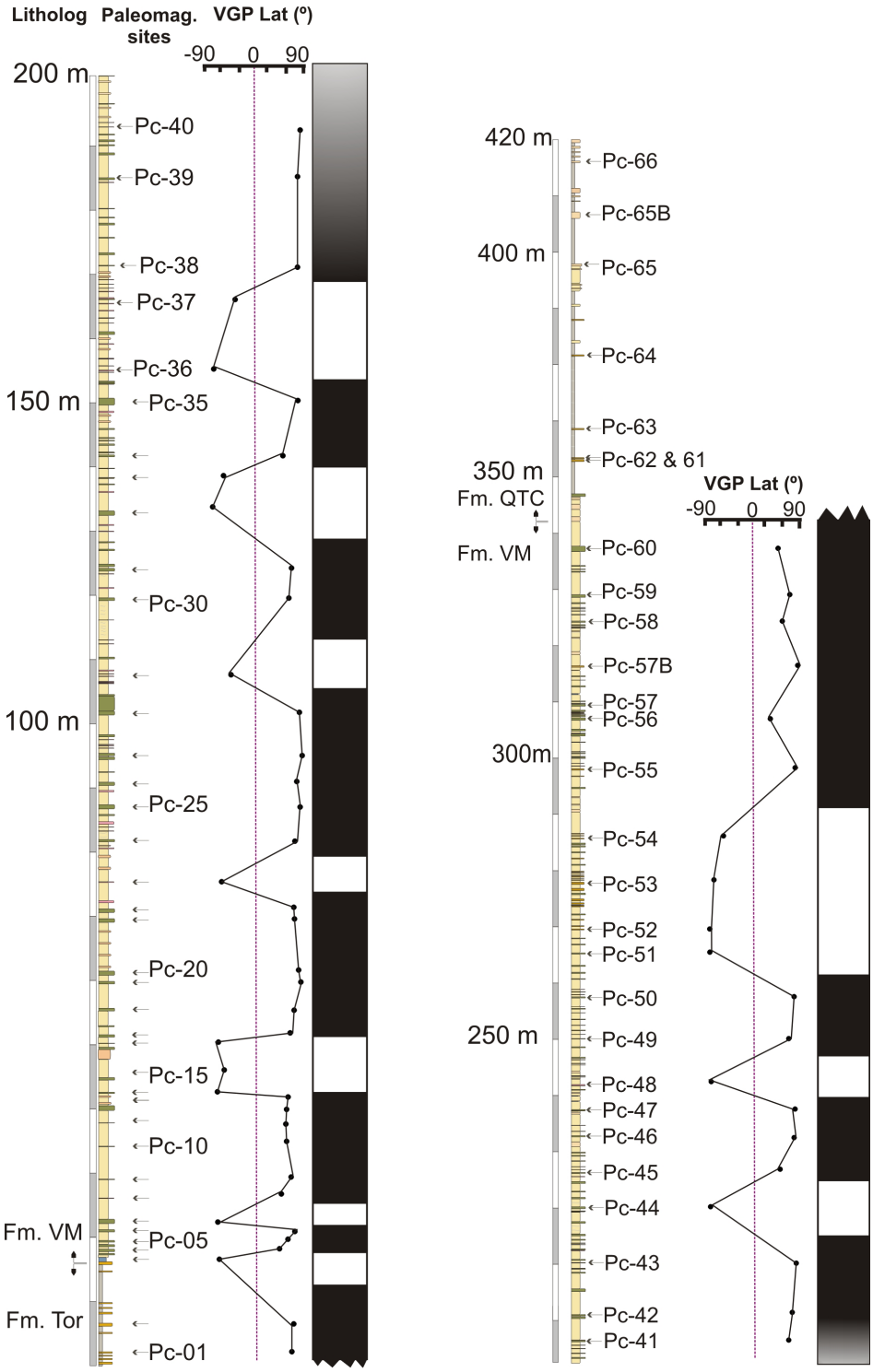

Figure 1. Stratigraphic column with sampled sites. Magnetostratigraphic scale obtained; white color for reverse polarity and black for normal polarity.

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