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MAGNETOSTRATIGRAPHY OF AN UPPER CRETACEOUS SUCCESSION OF JAMES ROSS BASIN, ANTARCTICA

Florencia N. Milanese[1*], Joseph L. Kirschvink[2], Eduardo B. Olivero[3], Augusto E. Rapalini[1]

[1] Laboratorio de Paleomagnetismo Daniel A. Valencio, Instituto de Geociencias Básicas, Aplicadas y Ambientales (IGEBA), Depto. de Cs. Geológicas, FCEN-UBA.

[2] Division of Geological & Planetary Sciences, California Institute of Technology, Pasadena CA, 91125, USA

[3] Laboratorio de Geología Andina, CADIC – CONICET. B Houssay 200, 9410 Ushuaia, Tierra del Fuego, Argentina

ABSTRACT

A magnetostratigraphic study was carried out in three Upper Cretaceous sections exposed in the SE area of James Ross Basin, Antarctic Peninsula. We present preliminary results of paleomagnetism, rock magnetism and magnetofabric. Anisotropy of magnetic susceptibility studies were carried out in all collected samples and indicate a likely depositional origin (characterized by low anisotropy degrees, oblate ellipsoids and vertical K3 axes) in the two first sections, and a particular grouping of K1 axes along vertical direction (inverse magnetofabric?) in the upper section. From hysteresis loops and Lowrie-Fuller tests, Ti-poor PSD magnetite is interpreted as the characteristic remanence carrier.

After combined AF+thermal demagnetization a characteristic remanence was isolated in most samples which allowed us to build preliminary local magnetostratigraphic columns. Comparison with the GPTS suggests that chrons C33R, C33N, C32R? and C32N are represented in the studied sections. Polarity change between chrones C33R and C33N, dated in 79.543 Ma, occurs in member II of the Rabot Formation (at a stratigraphic level of 120 m in the first section and 100 m in the second one), indicating that the whole formation would have deposited in middle Campanian.

Key words: Magnetostratigraphy, Antarctica, Cretaceous.

RESUMEN

Fue llevado a cabo un estudio paleomagnético en tres secciones del Cretácico Superior expuestas en el SE de la cuenca James Ross, Península Antártica. Se presentan resultados preliminares de un estudio paleomagnético, de magnetismo de rocas y magnetofábrica. Estudios de anisotropía de susceptibilidad magnética fueron llevados a cabo en todas las muestras e indican un probable origen depositacional (caracterizada por un bajo grado de anisotropía, elipsoides oblados y un agrupamiento vertical de los ejes K3) en las dos primeras secciones y un particular agrupamiento de los ejes K1 en la dirección vertical en la sección superior (probable magnetofábrica inversa). A partir de ciclos de histéresis y tests de Lowrie-Fuller, se propone magnetita PSD pobre en Ti como mineral portador de la remanencia característica.

Luego de una desmagnetización combinada mediante AF y altas temperaturas fue aislada en la mayoría de las muestras la magnetización remanente característica y se construyeron columnas magnetoestratigráficas locales preliminares. La comparación con la GPTS sugiere que los crones C33R, C33N, C32R? y C32N son representados en las secciones estudiadas. El cambio de polaridad entre los crones C33R y C33N, datado en 79.543 Ma, se encuentra en el miembro II de la Formación Rabot (a los 120 m en la primera sección y a los 100 m en la segunda), indicando que dicha formación se habría depositado en el Campaniano medio. Las direcciones medias paleomagnéticas obtenidas de estas unidades cretácicas de la cuenca James Ross sugieren la ausencia de rotaciones tectónicas significativas en el área desde hace 80 Ma.

Palabras clave: Magnetostratigrafía, Antarctica, Cretácico.

Introduction

James Ross Basin is located in the north eastern sector of the Antarctic Peninsula and includes, among others, the James Ross, Snow Hill and Seymour islands (fig. 1). It is a back-arc basin developed to the east of a magmatic arc located along Antarctic Peninsula. Cretaceous units include the Gustav Group (Barremian – Coniacian), that is made up of deep marine deposits (Ineson, 1989) and the Marambio Group (Santonian – Danian) composed of deltaic and platform deposits (Macellari, 1988; Olivero y Medina, 2000; Crame *et al*., 2004; Olivero, 2008). This contribution is restricted to the Marambio Group successions exposed in the southeastern sector of the James Ross Basin. In this area, the Marambio Group is composed by the Rabot, Snow Hill Island, Haslum Crag and López de Bertodano formations. Oriented samples for paleomagnetic studies were collected from three sections:

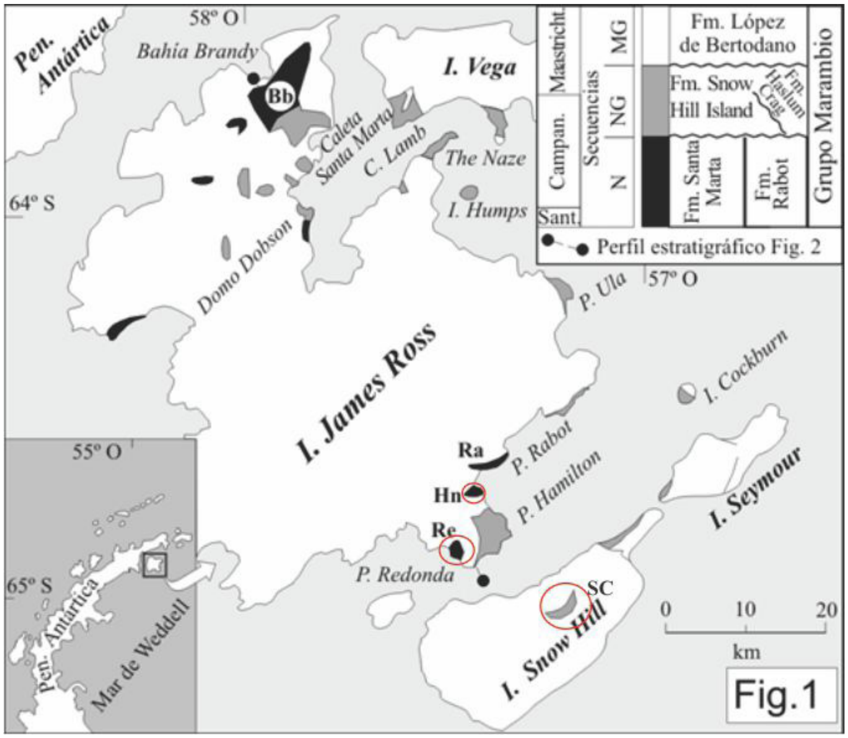

Figure 1. Location and stratigraphy of the studied zone (modified from Olivero *et. al*, 2008). Sections studied are circled in red.

a) *Hn* (lower Campanian), includes 200 m thick of mudstones (unconsolidated) with alternating fine sandstones. It is exposed to the North of Hamilton point (64º19’2” S; 57º23’12” W). It includes members II and III of the Rabot Formation (the lowest, member I, is not exposed in this area). Their age is early Campanian (Lirio *et al*., 1989; Marenssi *et al*., 1992; Pirrie *et al*., 1997, Olivero y Medina, 2000; Olivero *et al*., 2011).

b) *Re* is located in Redonda point (64º 22’ 13” S; 57º 26’ 45” W), where only members II and III of the Rabot Formation are exposed, being therefore correlative to *Hn* However, in this locality the succession is significantly thicker (324 m). Litology is similar to *Hn*.

c) *SC* (250m, late Campanian) is exposed in a nunatak in Snow Hill Island (64º 26’ 29.6” S, 57º 12’ 9.6” W) and corresponds to Sanctuary Cliffs Member of Snow Hill Island Formation and it is stratigraphically above the other two sections (Pirrie *et al*., 1996; Olivero y Medina, 2000; Olivero *et al*., 2008) and it consists in mudstones (unconsolidated) with a few alternating sandstones beds.

The main objective of this study is the construction of a local magnetostratigraphic column from these sections in order to better constrain the age along the whole sequence.

Methodology

Paleomagnetic sampling was carried out with a Pomeroy™ (ASC) portable drill, with which cores of 2.54 cm in diameter were extracted from the outcrops using water. In SC section the sampling was made collecting blocks and drilling them in the laboratory. About 170 specimens were analized in two campaigns during February–March of 2010 and February-March of 2012.

An MFK1-A susceptometer was used to measure the bulk susceptibility and the anisotropy of magnetic susceptibility (AMS). Its components CSL and CS-2 were used to measure total susceptibility versus temperature between -200°C and 700°C. The equipment is located at the Laboratorio de Paleomagnetismo Daniel A. Valencio of the Instituto de Geociencias Básicas, Aplicadas y Ambientales de Buenos Aires (IGEBA), in the Facultad de Ciencias Exactas y Naturales from the Universidad de Buenos Aires.

Hysteresis loops were recorded with a VSM vibrating magnetometer “Molspin”.

Paleomagnetic studies were made in the Laboratory of Paleomagnetism of the California Institute of Technology, Division of Geological and Planetary Sciences. Intensity and direction of remanence were measured with an automatic 2G magnetometer described by Kirschvink *et al*., (2008). After initial measurements of the NRM, a series of low alternating field demagnetization steps were made (reaching low field values, about 7 mT) followed by progressive temperatures thermal demagnetization in an N_2-controlled atmosphere, reaching up to 555°C in steps of 10° to 25˚ C steps.

Analysis and results

Anisotropy of magnetic susceptibility (AMS)

AMS studies consist in measuring the bulk magnetic susceptibility of every specimen of the collection in many different directions, to be able to determine the distribution of susceptibility values in the three dimensions. This should allow us to determine preferential orientations (petrofabric) of constituent minerals, and determine if they record depositional or strain fingerprints. From Figure 2 we can see:

a) Samples from *Hn* possess low susceptibilities (8×10^{-5} SI < k < 2×10^{-4} SI), which indicates a control of paramagnetic minerals in the susceptibility of the rocks (Hrouda and Kahan, 1991; Tarling & Houda, 1993). Cores were taken from sandstones beds and concretions. All of these yield a low degree of anisotropy, oblate anisotropy ellipsoids, and have the K3 perpendicular to the bedding plane. K1 and K2 are poorly defined but tend to fall in the bedding plane. These results suggest a depositional or compactational fabric. K1 axes present a rough grouping in NW-SE direction.

b) Samples from the *Re* section generally have depositional fabrics and oblate AMS ellipsoids. Compared to the *Hn* section they present a better grouping of K3, and a rough K1 grouping in the SSW direction. Magnetic susceptibility corresponds to the paramagnetic field (8×10^{-5} SI< k < 1.4-4 x 10^{-5} SI). In this section paramagnetics minerals also are the carriers of the bulk susceptibility. Anisotropy degree is in most cases lower than 1.03.

c) Data from the *SC* samples also show a low degree of anisotropy, but an incipient inverse fabric seems to be present, with a rough grouping of K1 axes in the vertical direction. Susceptibilities are beetwen 1×10^{-4} SI and 2×10^{-3} SI, which indicates that susceptibility and anisotropy of the rocks are controlled by both paramagnetic and ferrimagnetic minerals.

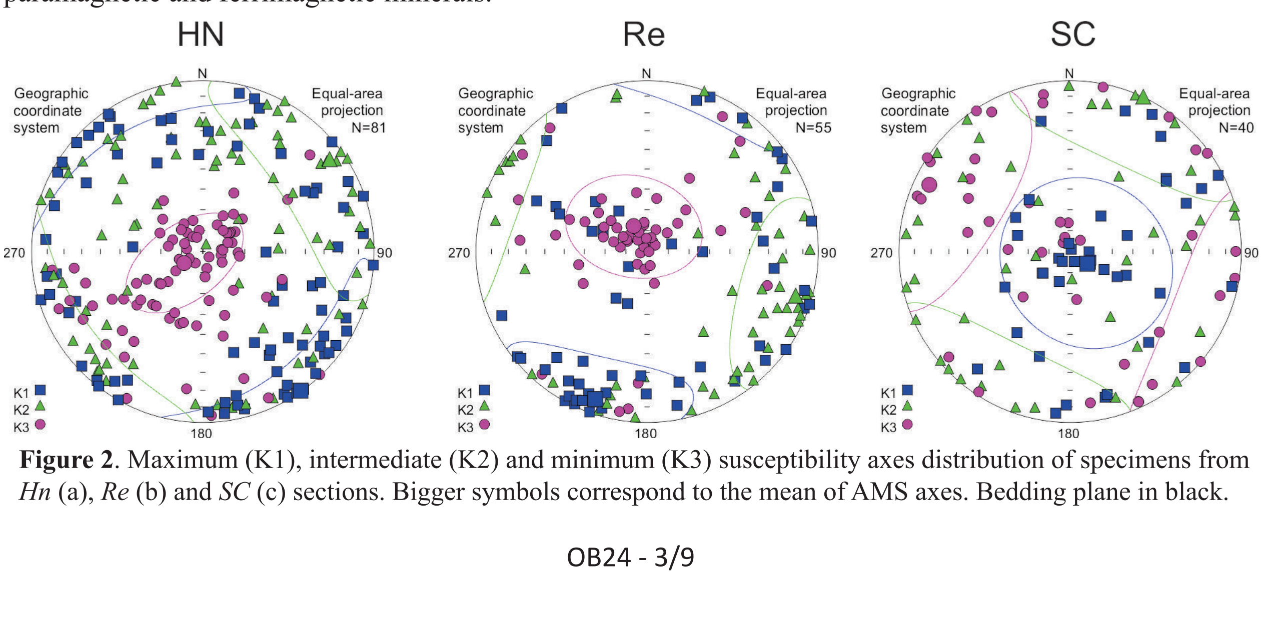

Figure 2. Maximum (K1), intermediate (K2) and minimum (K3) susceptibility axes distribution of specimens from *Hn* (a), *Re* (b) and *SC* (c) sections. Bigger symbols correspond to the mean of AMS axes. Bedding plane in black.

Thermomagnetic curves

Curves of magnetic susceptibility versus temperature are useful tools to characterize the dominant mineralogy and domain states carrier of magnetization. Low and high temperature thermomagnetic curves were obtained with this objective. Figure 3 presents data from one such sample. The pattern observed is characteristic of paramagnetic minerals. Although magnetic fabric and susceptibility seem to be controlled by these type of minerals, we can observe in Figure 3b a Hopkinson effect and abrupt decay of k (Curie point) at about 570º C, that suggest the presence of SD, Ti-poor titano-magnetite that alters at temperatures above 450˚C.

Hysteresis loops

Magnetization response of a sample to a variable external magnetic field is diagnostic of its diamagnetic, paramagnetic or ferromagnetic nature. With a "Molspin" vibrating magnetometer, we recorded hysteresis cycles (fig. 4) for a selected set of samples. Magnetization dependence on the field was mostly linear and with positive slopes, confirming the dominance of paramagnetic minerals. By removing the paramagnetic contribution, hysteresis loops that show a ferrimagnetic contribution could be isolated. Parameters Jsat, Jr, and Hc were computed from these cycles.

Samples analyzed showed coercive forces (Hc) between 7.5 and 16.3 mT, which are lower than those expected for SD titanomagnetites (40-190 mT, Day *et al*., 1971) but higher than those expected for MD titanomagnetites (3 mT, Day *et al*., 1976). Jr/Jsat relations for these samples are between 0.08 and 0.15. They are closer to MD titanomagnetites values (0.018 - 0.052, Day *et al*., 1976) than to SD values (0.38 to 0.59, Day et. al., 1976).

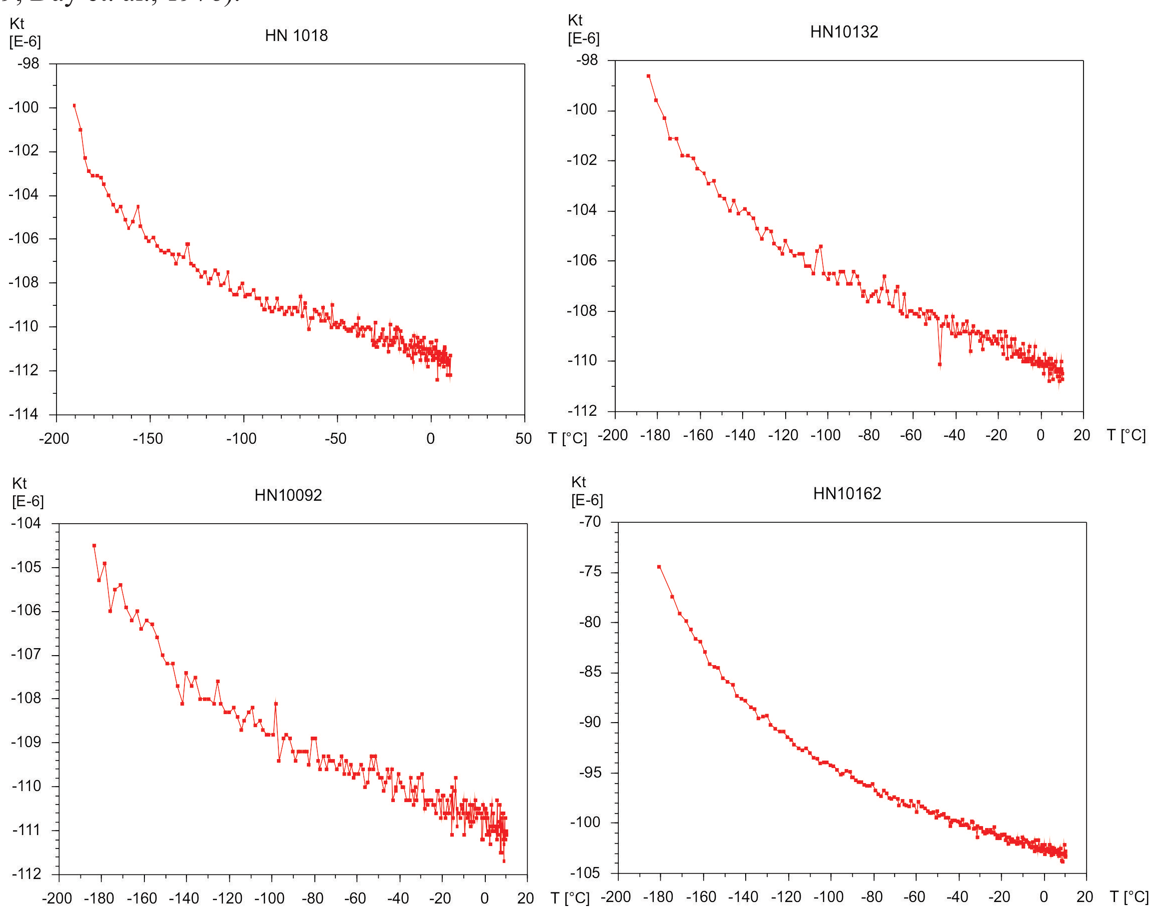

Figure 3. Termomagnetic curves (low temperature) for samples of *HN* section.

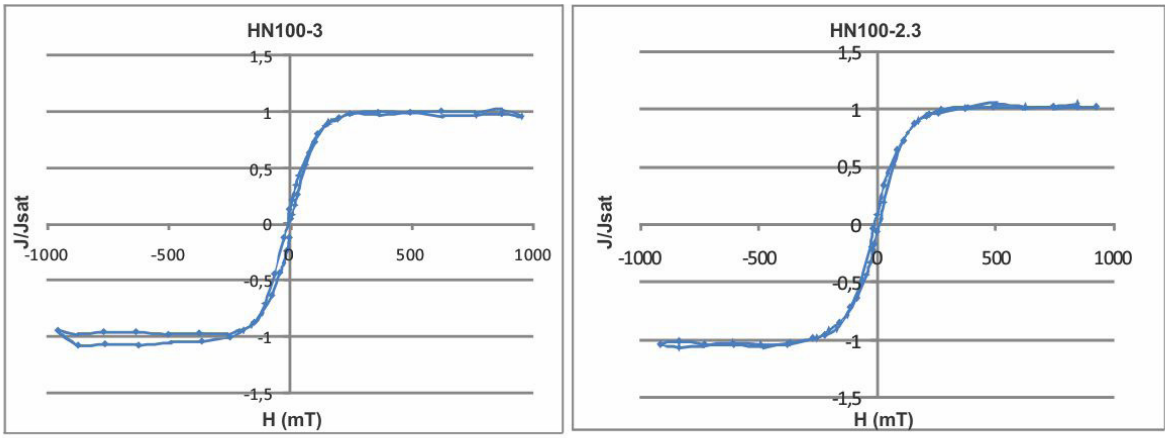

Figure 4. Hysteresis loops, after correction for paramagnetic contribution, for two *Hn* samples

Lowrie-Fuller test

In a set of SD grains, anhisteretic remanence (ARM) is more resistant to AF demagnetization than isotermal remanence (IRM, Lowrie and Fuller, 1971). The opposite occurs with MD grains. A few representative samples of our collection were submitted to ARM and IRM and subsequently demagnetized with alternating fields after each artificial magnetization. In all cases ARM appeared harder to be erased by AF demagnetization, which would indicate presence of SD titanomagnetites (fig. 5).

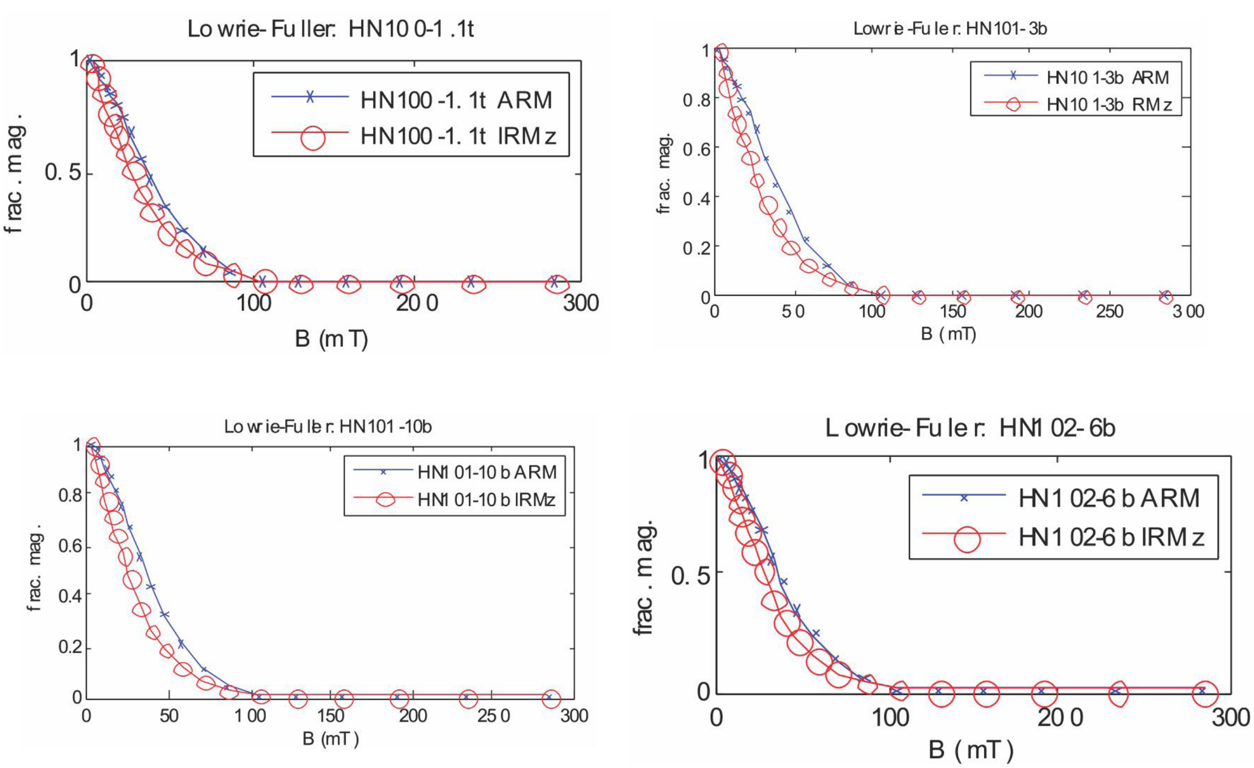

Figure 5. Lowrie-Fuller tests of samples from *Hn* section. All of them show more resistance to AF demagnetization of anhysteretic magnetization than isothermal remanence

Paleomagnetism-Magnetostratigraphy

All samples were submitted to stepwise demagnetization. Only a few provided reliable determination of remanence components. Figures 6, 7 and 8 show a simplified sedimentological log of the sections with

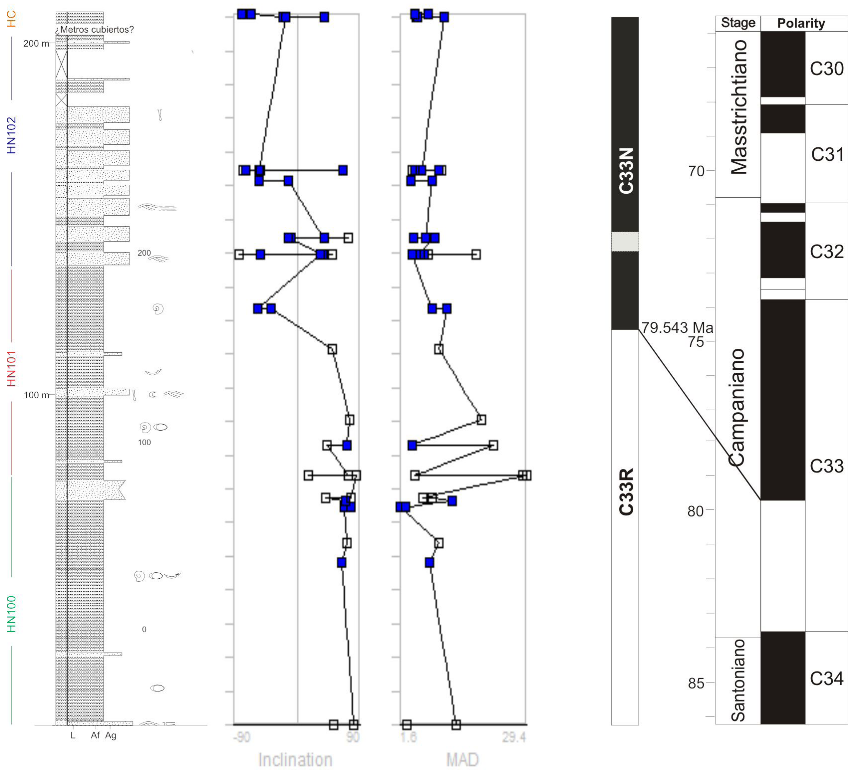

Figure 6. Sedimentary log, polarity of remanence and magnetostratigraphic column for *Hn* section. Local column is correlated to global polarity time scale from Gradstein *et al*. (2004).

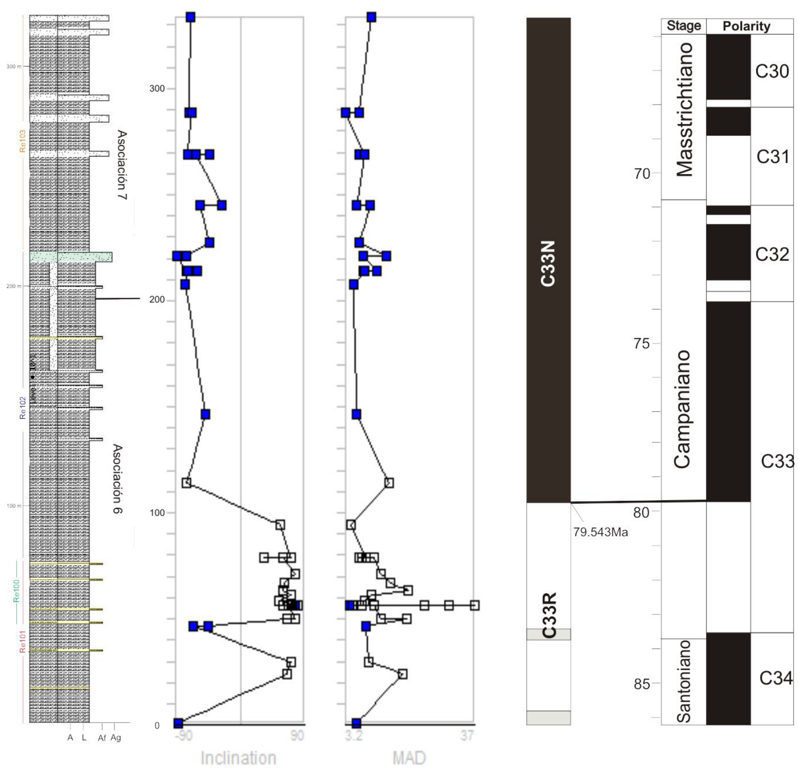

Figure 7. Sedimentary log, polarity of remanence and magnetostratigraphic column for *Re* section. Local column is correlated to global polarity time scale from Gradstein *et al*. (2004).

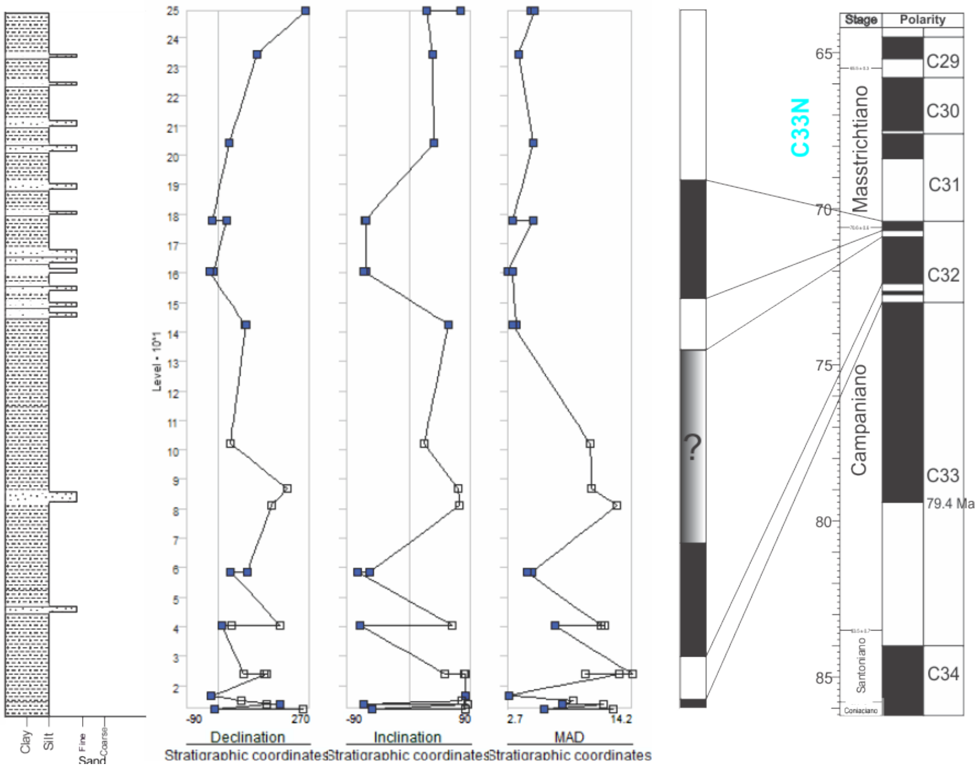

Figure 8. Sedimentary log, polarity of remanence and magnetoestratigraphy column for *Re* section. Local column is correlated to global polarity time scale from Gradstein *et al*. (2004).

samples magnetic polarity. From these data preliminary local magnetostratigraphic columns were built. Four chrons are apparently recorded in the study sequences. Based upon fossil assemblages of Olivero and Medina (2000) they are provisionally attributed to C33R, C33N, C32R and C31N (fig. 9). Polarity change between chrones C33R and C33N, dated in 79.543 Ma, occurs in member II of the Rabot Formation (at a stratigraphic level of 120 m in the first section and 100 m in the second one), indicating that the whole formation would have deposited in middle Campanian.

Preliminar sedimentation rates were calculated and they are between 0.016 and 0.013 mm/y (fig. 9).

Conclusions

From magnetic fabric studies, a low anisotropy degree and depositional fabric with oblate ellipsoids are established for samples from *Hn* and *Re* sections. *SC* shows also a low anisotropy degree but ellipsoids are mostly prolate and magnetic fabric is inverse.

Thermomagnetic curves and hysteresis loops show that magnetic susceptibility is dominated by paramagnetic minerals (rock-forming minerals). These plus the Lowrie-Fuller test results suggest PSD Ti-poor titanomagnetite as the most likely carrier of the remanence.

Local magnetostratigraphic columns were built for the sections. Four polarity intervals that could correspond to C33R, C33N, C32R and C32N were interpreted, based on fossil assemblages from Olivero and Medina (2000).

Polarity change between chrones C33R and C33N, dated in 79.543 Ma, occurs in member II of the Rabot Formation (at a stratigraphic level of 120 m in the first section and 100 m in the second one), indicating that the whole formation would have deposited in middle Campanian.

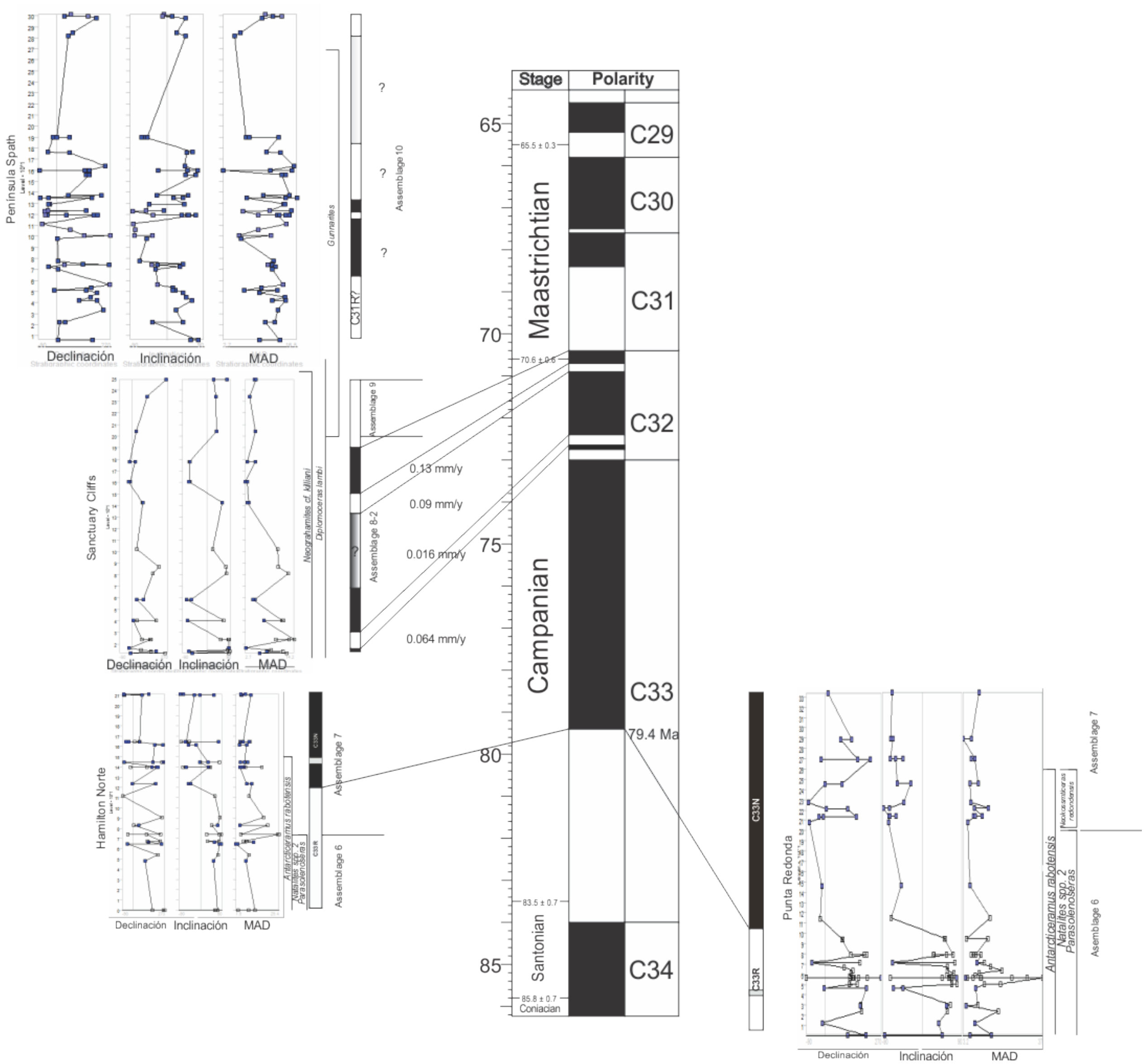

Figure 9. Correlation of local magnetostratigraphic columns with the geomagnetic polarity time scale from Gradstein *et al*. (2004).

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