MAGNETIC FABRICS, ROCK MAGNETISM AND PRELIMINARY MAGNETOESTRATIGRAPHY OF A LATE CRETACEOUS SUCCESSION OF JAMES ROSS AND SNOW HILL ISLANDS, ANTARCTICA

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Abstract

Preliminary results of a paleomagnetic, rock magnetic and magnetofabric study on samples from three sections of Late Cretaceous age exposed in the James Ross and Snow Hill islands (Antarctica) are presented. These sections are: a) *Hn* (Campanian), located in Hamilton point (S 64º19’2’’; W 57º23’12’’) which comprises 200 m of the upper part of the Rabot Formation (members II y III) and the lower section of the Snow Hill Island Formation; b) *Re*, located at Redonda point (S 64º 22' 13"; W 57º 26' 45") only comprising members II and III of the Rabot Formation, with a thickness of 324 m; and c) *Sh* (Mastrichtian), located stratigraphically on top of the previous sections in Snow Hill Island (S 64°21’46’’; W 56°59’15’’) and including the Karlsen Cliffs Member of Snow Hill Island Formation and Haslum Crag and López de Bertodano formations. Anisotropy of magnetic susceptibility studies were carried out in all collected samples. The magnetic fabric parameters obtained from these rocks indicate a likely depositional origin (characterized by low anisotropy degrees, oblate ellipsoids and vertical K3 axes). Thermomagnetic curves (k vs T) indicate that magnetic susceptibility is mainly controlled by paramagnetic minerals. From information obtained from hysteresis loops and Lowrie-Fuller tests it is proposed that PSD (Ti poor?) titano-magnetite is the most common remanence carrier. Only a few samples presented stable behaviour during thermal demagnetization. However they allow us to infer a preliminary local magnetostratigraphic column. Polarity intervals likely corresponding to chrons C33N, C32R?, C32N? and C32R? or C31R? have been identified suggesting deposition late Campanian-early Maastrichtian.

Resumen

Se presentan resultados preliminares de un estudio paleomagnético, de magnetismo de rocas y magnetofábrica realizado en tres secciones del Cretácico Superior de las islas James Ross y Cerro Nevado (Snow Hill), Antártida. Dichas secciones son: a) *Hn* (Campaniano), ubicada en punta Hamilton (S 64º19’2’’; W 57º23’12’’), que comprende 200 m de espesor de la parte superior de la Formación Rabot (miembros II y III) y la parte inferior de la Formación Snow Hill Island; b) *Re* (Campaniano), que está ubicada en la localidad de Punta Redonda (S 64º 22' 13"; W 57º 26' 45") y comprende solamente a los miembros II y III de la Formación Rabot, con un espesor de 324 m; y c) *Sh* (Maastrichtiano), que se encuentra estratigráficamente por encima de las secciones anteriores en la isla Cerro Nevado (S 64°21’46’’; W 56°59’15’’) y comprende al Miembro Karlsen Cliffs de la Formación Snow Hill Island y a las formaciones Haslum Crag y López de Bertodano. Se realizaron estudios de anisotropía de susceptibilidad magnética y las fábricas obtenidas son mayoritariamente depositacionales, (presentando

grados de anisotropía bajos, elipsoides de forma oblada y ejes K3 subverticales). Curvas termomagnéticas (k vs T) indican que la fábrica magnética es mayormente controlada por minerales paramagnéticos. A partir de la información obtenida de ciclos de histéresis y del test de Lowrie-Fuller, se propone que el mineral portador más frecuente de la remanencia es probablemente titano-magnetita pobre en titanio PSD. Solo unas pocas muestras presentaron comportamiento estable durante la desmagnetización. A pesar de ello se pudo inferir una columna magnetoestratigráfica local. Se identificaron tentativamente los intervalos de polaridad correspondientes a los crones C33N, C32R?, C32N? y C32R? o C31R?, sugiriendo que estas unidades se depositaron en un intervalo aproximado entre los 79 y 71 Ma.

Introduction

James Ross Basin is located in the northeastern 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, particularly in Hamilton and Redonda points (Fig. 1). 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:

a) *Hn* (Campanian), includes 200 m thick of mudstones (unconsolidated) with alternating fine sandstones. It is exposed in Hamilton point (S 64º19’2’’; W 57º23’12’’). It includes members II and III of the Rabot Formation (the lowest, member I, is not exposed in this area) and the lower part of the Hamilton Point Member of the Snow Hill Island Formation. Their ages are early Campanian and late Campanian, respectively (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 (S 64º 22' 13"; W 57º 26' 45"), where only members II and III of the Rabot Formation are exposed, being therefore correlative to the lower levels of *Hn*. However, in this locality the succession is significantly thicker (324 m). Lithology is similar to *Hn*. c) *Sh* is exposed in Snow Hill Island (S 64°21’46’’; W 56°59’15’’), being stratigraphically on top of the previous sections. It includes the Karlsen Cliff Member of the Snow Hill Island Formation and the Haslum Crag and López de Bertodano Formations. The age of the whole succession is early Maastrichtian (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.

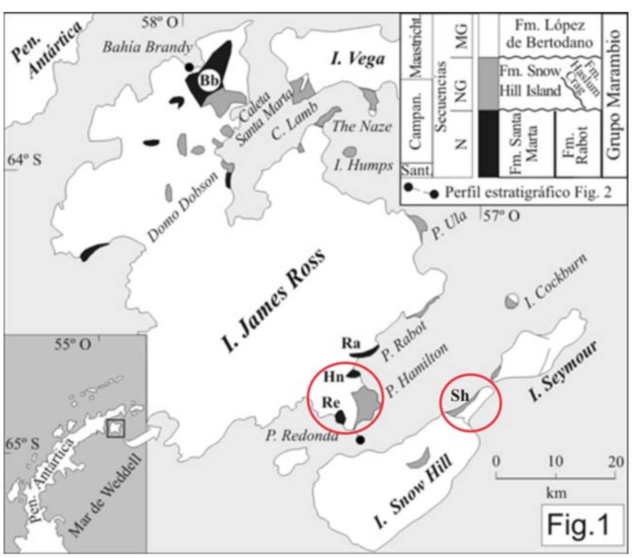

Figure 1: Location and stratigraphy of the studied zone (Olivero et. al, 2011). The locations of the sections studied are circled in red.

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. About 240 cores were collected in two campaigns during February–March of 2010 and February-March of 2011.

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)

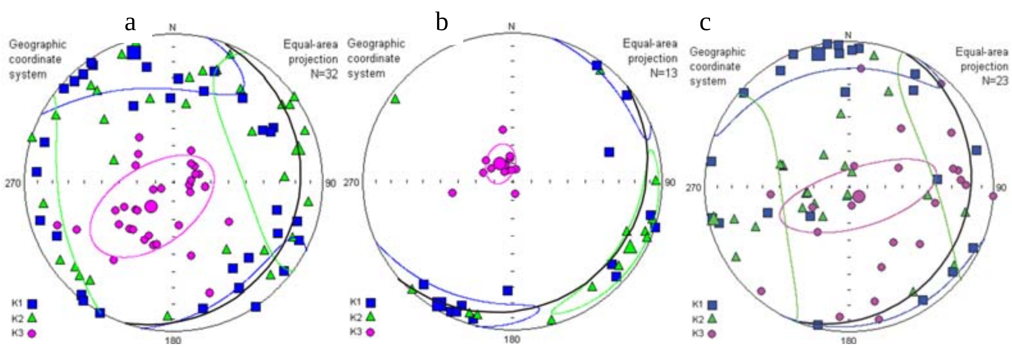

Figure 2: Maximum (K1), intermediate (K2) and minimum (K3) susceptibility axes distribution of specimens from *Hn* (a), *Re* (b) and *Sh* (c). Bigger symbols correspond to the mean of AMS axes. In black bedding plane.

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.

Samples from the *Hn* posses low susceptibilities (8×10^{-5} SI < k < 5×10^{-4} SI). 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 planes. K1 and K2 are poorly defined but tend to fall in the bedding plane. These results suggest a depositional or compactional fabric. K1 axes present a rough grouping in NW-SE direction. Bedding attitude is 20º/10º.

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 x 10^{-5} SI< k < 1.4-4 x 10^{-5} SI). Anisotropy degree is in most cases lower than 1.03. Bedding attitude is 21º/18º.

Data from the *Sh* samples also show a low degree of anisotropy, but no fabric is identified. There is a rough grouping of K1 axes in the NNW direction. There are two populations, one with higher susceptibility (1 x 10^{-5} SI < k < 2 x 10^{-3} SI) than the other (9.4 x 10^{-5} SI). The last one includes samples of the upper part of the section, from level 130 m up. A limit between the Haslum Crag and the López de Bertodano formations can probably be placed at this boundary. All samples of *Sh* were taken from concretions, which may explain the absence of a significant magnetic fabric. Bedding attitude is 20º/10º.

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 570ºC, that suggest the presence of SD, Ti-poor titano-magnetite that alters at temperatures above 450˚C.

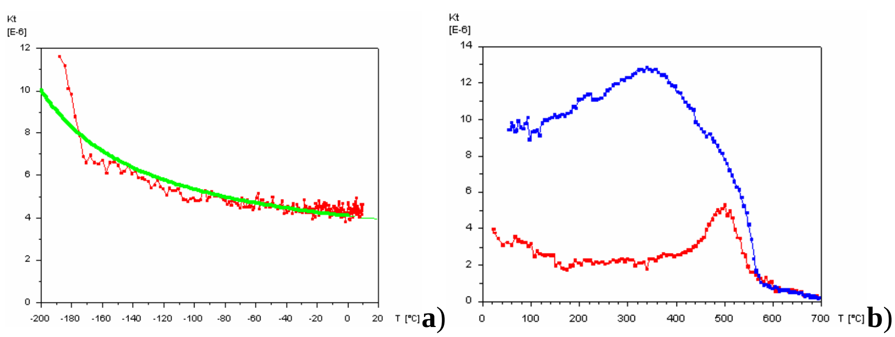

Figure 3: Magnetic susceptibility Vs. Temperature for low (left, fit line in green) and high temperatures (right) for the sample Hn100-10. In fig. 3b, the red curve shows the warming, blue the cooling.

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 hystersis cycles 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.

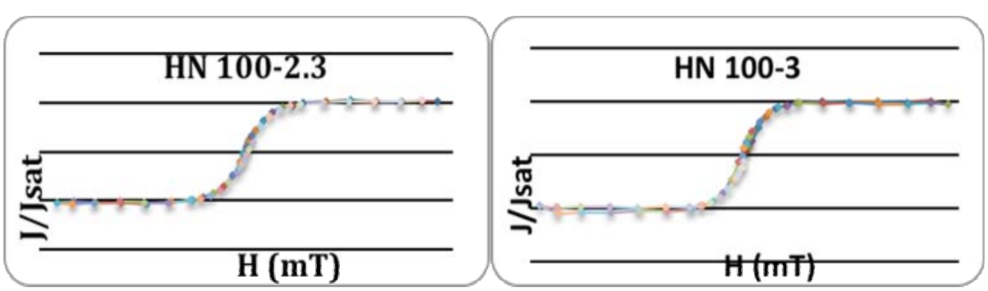

Figure 4: Hysteresis loops, after correction for paramagnetic contribution, for two *Hn* samples.

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).

Lowrie-Fuller test

In a set of SD grains, anhisteretic remanence (ARM) is more resistant to AF demagnetization than isothermal 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.

Magnetostratigraphy

All samples from *Hn* were submitted to stepwise demagnetization. Only a few provided reliable determination of remanence components. Figure 6 shows a simplified sedimentological log of the section *Hn* together with the stratigraphic position of collected samples (red dots) and those that provided reliable (black dots) and doubtful (grey dots) information about the magnetic polarity. From these data a preliminary local magnetostratigraphic column was built. At least four chrons are apparently recorded in the study sequence. Based upon fossil assemblages they are provisionally attributed to C33N, C32R, C32N and C31R, although alternative interpretations are possible. Confirmation or modification of this preliminary interpretation waits for the processing of the succession exposed at Redonda Point. The first interpretation suggests deposition of the studied succession between around 79 and 71 Ma.

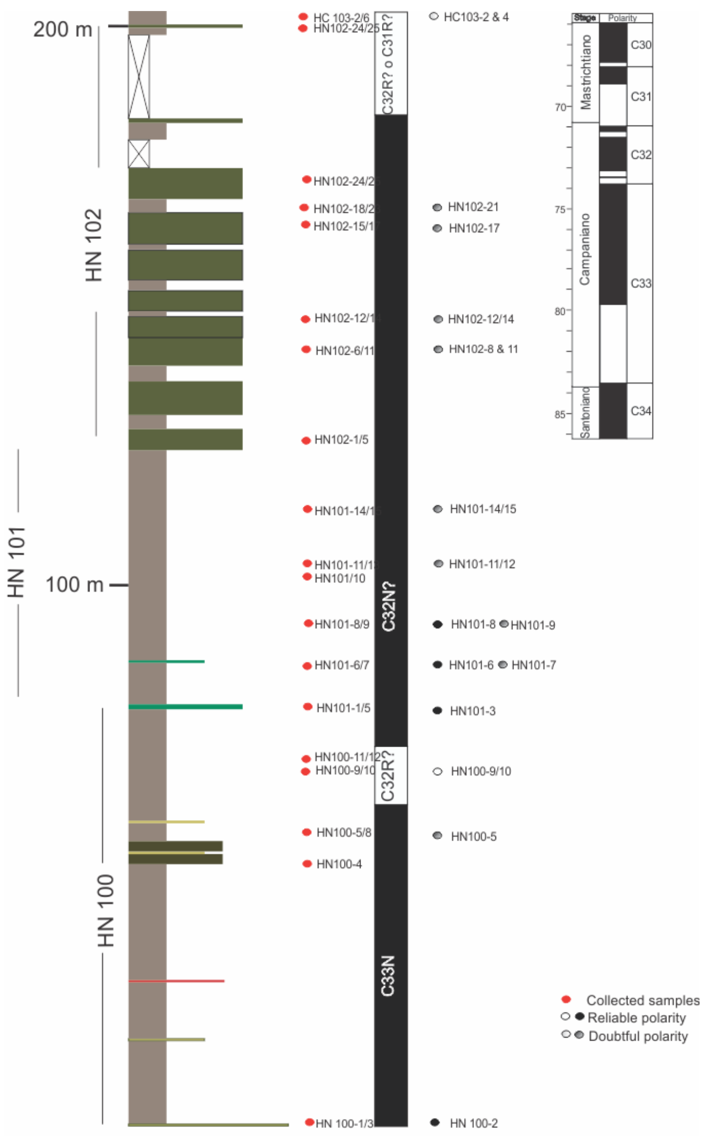

Figure 5: Local sedimentary and magnetostratigraphic columns for the *Hn* section. Top right, global polarity time scale for the Late Cretaceous (Ogg, 1997).

Conclusions

From magnetic fabric studies, a depositional fabric is established for samples from *Hn* and *Re* sections.

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.

A preliminary local magnetostratigraphyc column was built for the *Hn* section, from a reduced number of samples, since most of them showed unstable behaviour during demagnetization. Four polarity intervals that could correspond to C33N, C32R?, C32N? and C31R? were interpreted

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