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PRELIMINARY PALEOMAGNETIC RESULTS FROM LAGUNA MELINCUÉ (LA PAMPA, ARGENTINA)

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ABSTRACT

We present preliminary results of rock magnetic and paleomagnetic studies on a short sediment core (LMe, 74 cm) collected from Laguna Melincué (33° 41' 27.8''S, 61° 31' 36.5''W). The core was manually collected from the shore of the Laguna Melincué using a plastic tube during October of 2014. It shows centimeter-scale lamination and frequent textural variations. Measurements of intensity and directions of natural remanent magnetization (NRM), volumetric magnetic susceptibility (k), isothermal remanent magnetization (IRM), saturation isothermal remanent magnetization (SIRM), back field experiments and anhysteric remanent magnetization at 100 mT (ARM) were performed. As a first estimate of magnetic grain-size variations, the ratios ARM/SIRM and ARM/k were calculated. The stability of the NRM was analyzed by alternating field demagnetization. Rock magnetic analysis (S_{ratio} and B_{cr}), hysteresis curves and the temperature-dependence of magnetic susceptibility (k_T) suggest that the magnetic mineralogical content is dominated by pseudo single-domain (titano) magnetite and/or maghemite.

Keywords: Laguna Melincué, Rock magnetism, Magnetic grain-size, stability on NRM, magnetic mineralogy.

RESUMEN

Se presentan los resultados preliminares de los estudios magnéticos y paleomagnéticos de un testigo de sedimento corto (LMe, 74 cm) recogido en la Laguna Melincué (33° 41' 27.8''S, 61° 31' 36.5''W). El testigo se colectó en forma manual en la orilla de la laguna con un tubo de plástico en noviembre de 2014. Muestra laminación a escala centimétrica y variaciones texturales frecuentes. Se realizaron mediciones de la intensidad y las direcciones de magnetización remanente natural (MRN), susceptibilidad magnética volumétrica (k), magnetización remanente isotérmica (MRI), saturación de magnetización remanente isotérmica (MRIS), experimentos vuelta campo reverso y magnetización remanente anhistérica con un campo máximo de 100 mT (MRA). Como una primera estimación de las variaciones de tamaño de grano magnético, se analizaron las variaciones de ARM/SIRM y ARM/k. La estabilidad de la NRM se analizó mediante la desmagnetización por campos alternos. El análisis de magnetismo de roca (S_{ratio} y B_{cr}), curvas histéresis y los estudios de la dependencia de la susceptibilidad con la temperatura (k_T) sugiere que el contenido de minerales magnéticos está dominado por (titano) magnetita y/o maghemita.

Palabras Clave: Laguna Melincué, Magnetismo de rocas, Tamaño de grano magnético, Estabilidad NRM, Mineralogía magnética.

Introduction

Water bodies and their sediments are containers of diverse information. In particular, shallow lakes or lagunas are widely used for palaeoclimatic and palaeomagnetic studies around the world. Hydrological and paleoclimatic studies were performed in laguna Melincué by Pasotti *et al.* (1984) and Guerra *et al.* (2015). In this research, we present the first rock magnetic and paleomagnetic studies in order to contribute to the previous studies of the Laguna Melincué.

Magnetic parameters

Methodology

The LMe core was sub-sampled continuously with cubic plastic boxes (20 mm × 20 mm × 20 mm) that were pressed into the surface of the open core face. A total of 32 samples were obtained. A set of laboratory experiments were carried out on every sample of LMe to procure a magnetic characterization of the sediments.

Magnetic susceptibility (k) was measured at low and high frequency using a Bartington MS2 magnetic susceptibilimeter at 0.47 kHz (k_{low}) and 4.7 kHz (k_{high}), respectively. The difference between both measurements was used to calculate the frequency dependent susceptibility (F = klow − khigh / klow).

The intensity of NRM and directions (declination D and inclination I) were measured using a JR6A Dual Spinner Magnetometer. The stability of the magnetization and the directions were analyzed by alternating-field (AF) demagnetization. In the cases that were possible, the samples were demagnetized successively at peak fields of 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70 and 100 mT.

The ARM was acquired in a peak alternating field (AF) of 100 mT and a direct current (DC) biasing field of 0.05 mT using an alternating field demagnetizer (Molspin Ltd.) with an ARM device. IRM was acquired at room temperature in increasing steps until 2T, reaching saturation (SIRM) and in increasing steps back until cancelling the magnetic remanence was achieved using a IM-10-30 Pulse Magnetizer (ASC Scientific). Subsequently, AF demagnetization of the ARM and SIRM, respectively, were measured using the same steps as for the NRM demagnetization.

The associated parameters S_{ratio} (IRM_{-300mT}/SIRM), remanent coercive field (BCR), SIRM/k, ARM/k and ARM/SIRM (Kirschvink, 1980) were calculated. The median destructive field of the NRM, ARM and SIRM (MDFNRM, $MDF_{ARM\ and}$ MDF_{SIRM} respectively) were calculated in order to determine the required applied field to remove 50% of the initial remanence. This is a measure of the coercivity of the remanence carriers and hence depends on the magnetic mineralogy and magnetic grain size. When the magnetic mineralogy is uniform, the MDFNRM gives us information about the magnetic grain size of the magnetic recording assemblage.

All sediment samples were measured using a Variable Field Translation Balance (Model MMVFTB) in order to obtain the hysteresis curves and derived properties, including the bulk coercive force (Hc), the remanent coercive force (Hcr), the saturation magnetisation (Ms) and the saturation remanence (Mr). The coercivity (Hcr/Hc) and the remanence (Mr/Ms) ratios are commonly used as magnetic grain size indicators (Day et al., 1977; Dunlop, 2002) and the hysteresis properties, together with the IRM acquisition curve, inform on the coercivity of the remanence carriers (Dunlop and Özdemir, 1997, 2007). In order to further investigate the magnetic mineralogy, the temperature-dependence of magnetic susceptibility (k_T) was measured for all core samples using the same equipment.

Results and discussion

The logs of k, NRM, ARM and SIRM show similar characteristics (Fig. 1a), with correspondence in peaks and troughs. Magnetic susceptibility oscillates between 113×10^{-5} and 393×10^{-5} SI, values corresponding to ferromagnetic materials. The mean value of k is 186×10^{-5} SI, except for the first 16 cm where the values are greater. F values are mostly below 4%, which implies that super-paramagnetic grains are not important in the assemblages of magnetic grains (Bartington Instruments Ltd., 1994). The mean values of NRM, ARM and SIRM are 36.7 mA/m, 639 mA/m, and 32958 mA/m, respectively. The remanence values follow the same behaviour as k, suggesting that they are mostly influenced by changes in concentration of magnetic minerals.

The AF demagnetization results of a representative sample are illustrated in Figures 1b and 1c. Most of the samples show no systematic change in the direction of their remanent magnetization during AF demagnetization but they show a small viscous magnetization, which could be easily removed by AF demagnetization at 5 mT (Fig. 1c). In samples 20 to 24 it was not possible to perform the demagnetization. This might indicates that the Laguna Malincué water level was low during this period and the sediment could have been moved in a more energetic environment.

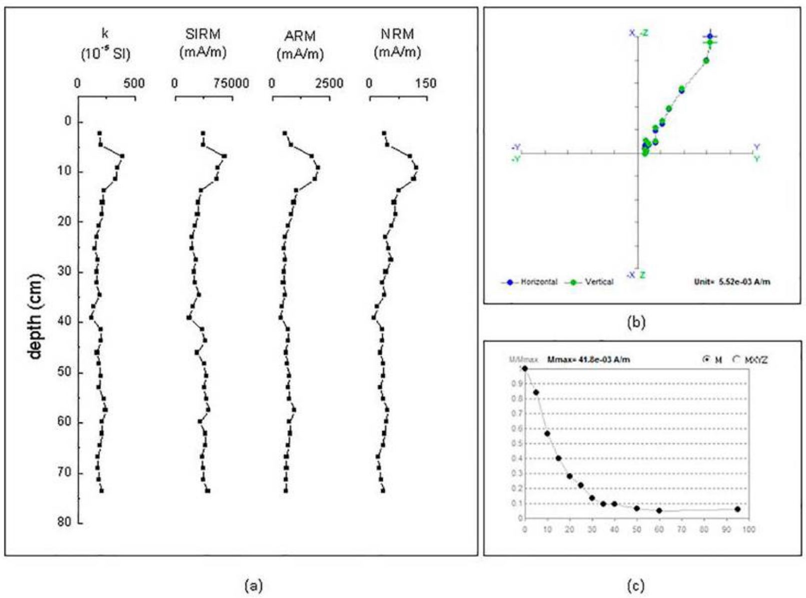

Figure 1. (**a**) Logs of concentration parameters *vs.* depth. (**b**) Zijderveld plot for representative sample. (**c**) Desmagnetization of NRM for the same sample (MDFNRM = 11.8 mT).

NRM intensities were almost completely demagnetized in fields of 60 mT (Fig. 1c). MDF_{NRM} ranges from 9.6 to 15.1 mA/m, in Figure 1c it can be observed that the MDF_{NRM} of the representative sample is approximately 12 mA/m. The MDF_{ARM} ranges from 16.5 to 18.6 mA/m. These results indicate that the magnetic signal is carried by soft magnetic minerals like (titano) magnetite. Since the core was not oriented, the declination values for each core are centered about average declination, and then this value was subtracted to the entire record. According to measurements, the inclination is centred at 52° ±°5 latitude (I = arctg (2 tg (latitude) = -53°)).

Variations in the magnetic grain size can be typically monitored by analyzing ARM/SIRM and ARM/k records (Fig. 2 a). Both ratios suggest that the magnetic grain size has small variations from bottom to approximately 30 cm depth, after this point, it has an important decrease (ARM/SIRM and ARM/k increase) until 9.2 cm and from there to the top it becomes thicker. These results suggest that the behavior of these parameters is determined mainly by the concentration of ferromagnetic minerals.

Stepwise acquisition of IRM documents that 90% of SIRM were acquired in fields of 200 mT for most samples, also indicating the presence of soft-minerals like magnetite in the sediment. Progressive removal of SIRM indicates that B_{CR} varies approximately between 26 and 43 mT (decreasing from bottom to top)

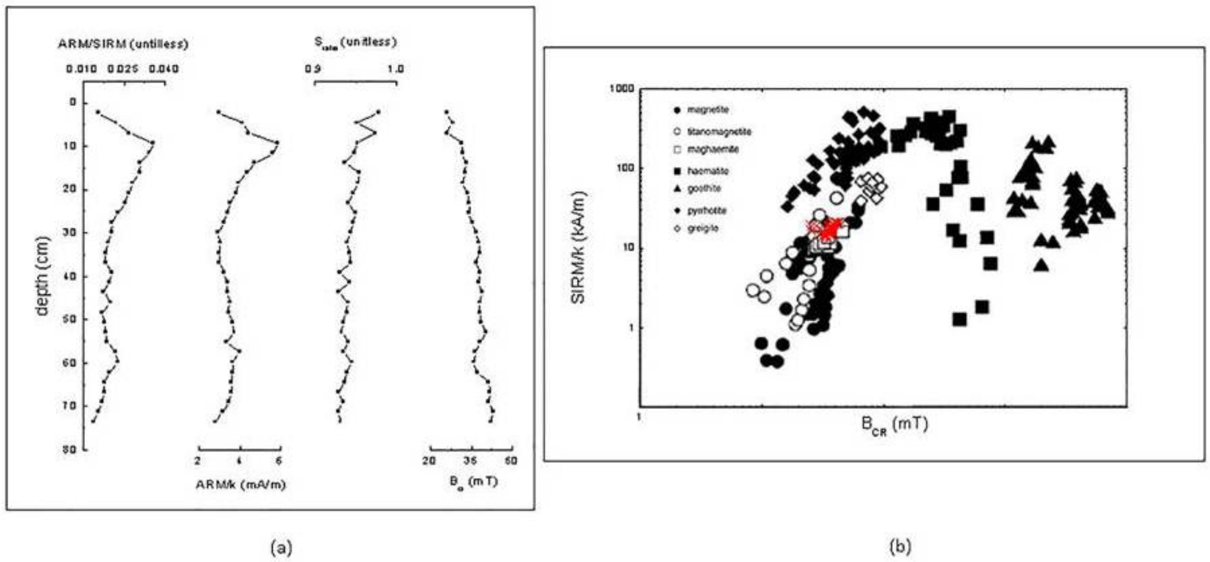

Figure 2. (**a**) Logs of magnetic grain size and magnetic mineralogy parameters *vs*. depth. (**b**) SIRM/k *vs*. Bcr. The mineralogy is suggested by Peters and Dekkers (2003).

and the S_{ratio} varies between 0.93 and 0.95 (increasing from bottom to top) as it can be seen in Figure 2a, suggesting that low coercivity magnetic minerals might be predominant within the sediments. This is in accordance with the graph of SIRM/k *vs*. B_{cr} (Fig. 2b) and the typical shape of the hysteresis loop (Fig. 3b) (Tauxe *et al.*, 1996) that shows clearly that the mineral that predominates in the samples is (titano) magnetite (Peters and Dekkers, 2003). Furthermore, zero magnetic susceptibility is reached during heating at or near the Curie temperature of magnetite (580° C; Dunlop and Özdemir, 1997, 2007) (Fig. 3a). A very low proportion of antiferromagnetic minerals cannot be excluded.

Correlating k measurements by Guerra *et al*. (2015) with k measurements carried out in our investigation can be done matching peaks and troughs. This makes possible to estimate the age of the core, which is approximately 85 years.

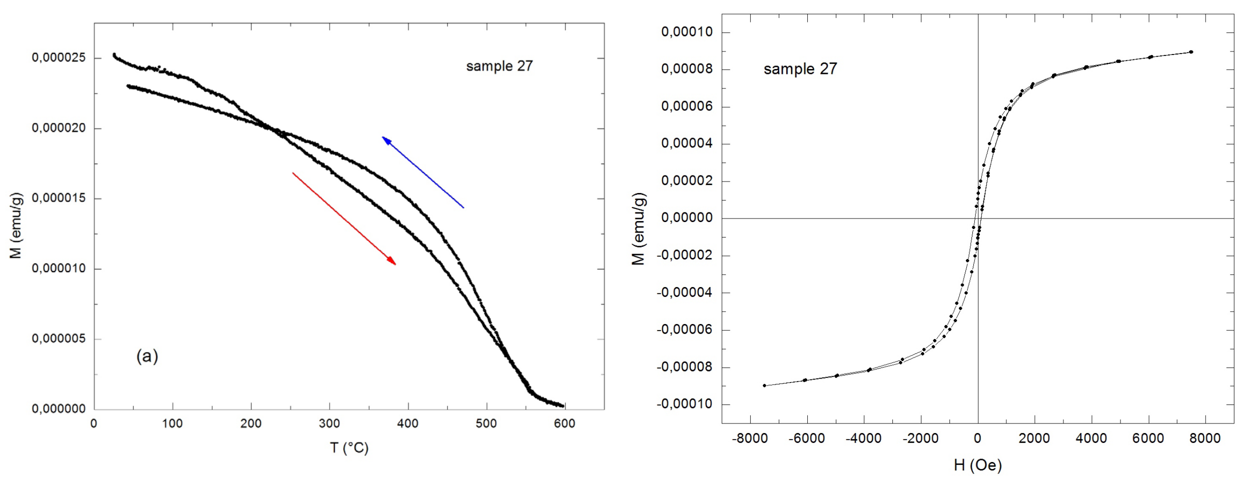

Figure 3. (**a**) Heating (red) and cooling (blue) curves of the magnetic susceptibility and (**b**) Hysteresis curve for a typical sample.

Conclusion

Rock magnetic studies suggest the presence of ferrimagnetic minerals with PSD (titano) magnetite as main magnetic carrier of the remanent magnetization. The magnetic grain size has changes indicating different climatic environments. The concentration of magnetic minerals also changes suggesting periods of high and low lake level.

It was able to isolate a stable remanent magnetization in most of the samples. According to the correlation with the susceptibility *vs*. age curves of Guerra *et al.* (2015), our record spans the last 85 years.

The changes in magnetic parameters (directional and non-directional data) show the potential of this lake for paleoenvironmental and paleomagnetic studies.

Acknowledgement

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