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VARIATION OF MAGNETIC PROPERTIES IN SEDIMENTS FROM LAKE TONCEK (PATAGONIA, ARGENTINA)

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ABSTRACT

We investigated the mineral-magnetic behavior of sediments from Laguna Toncek located in the Nahuel Huapi National Park, Northern Patagonia, Argentina. Rock magnetic analysis complemented by X-ray diffraction and scanning electron microscopy analysis were carried out on sediment core TON1 to provide insights on the environmental and sedimentary processes controlling the magnetic properties of the sediment and its paleoclimatic implications. The studies suggest the presence of titano-magnetite with a grain size of ~1–2 µm and a concentration that varies between 0.03 and 0.15%.

Keywords: rock magnetism, lake sediments, Patagonia

RESUMEN

En este trabajo ha sido investigado el comportamiento magnético de los sedimentos de la Laguna Toncek localizado en el Parque Nacional Nahuel Huapi, Patagonia Norte, Argentina. Los sedimentos del testigo TON1 fueron analizados mediante estudios de magnetismo de rocas complementados con difracción por rayos X y microscopía electrónica de barrido con la finalidad de obtener información acerca de los procesos ambientales y sedimentarios que controlan las propiedades magnéticas de los sedimentos e implicaciones paleoclimáticas. Los estudios realizados sugerirían la presencia de titano-magnetita, con un tamaño de grano de ~1–2 µm, con una concentración que varía entre 0.03 y 0.15%.

Palabras Clave: magnetismo de rocas, sedimentos lacustres, Patagonia

1. Study Site

Lake Toncek (41°11’52’’ S, 71°29’17’’ W, 1747 m a.s.l.) is a small, shallow (max. depth 12 m), open lake with a surface area of ~3 ha located in the Nahuel Huapi National Park (NHNP), Patagonia, Argentina. It is one of the largest national parks in southern South America (Massaferro *et al*., 2017) (Fig. 1). The climate of the area is temperate with a strong W-E precipitation gradient that defines the vegetation pattern, the Sub Antarctic forest transitions to the semi-arid steppe in barely 200 km (Massaferro *et al*., 2017). Lake Toncek is an ultraoligotrophic, dimictic system, with direct stratification in summer and 6 to 8 months of ice cover reaching a thickness of up to 2 m (Ribeiro Guevara *et al*., 2010).

2. Methods

A short sediment core with a length of approximately 103.5 cm was extracted with a gravity corer from the deepest part of the lake (Fig. 1) during a field campaign in 2014. The core was transported to the CENAC/

Figure 1. Study area, modified from Ribeiro Guevara *et al*. (2010).

APN - *Programa de estudios aplicados a la conservación de la biodiversidad del Parque Nacional Nahuel Huapi* (Bariloche, Argentina), where it was split lengthwise and photographed. Magnetic measurements on core TON1 were carried out in three stages. First of all, the core sections were split lengthwise and the magnetic susceptibility of the complete sediment profile was continuously measured with a Bartington MS2E spot reading sensor in steps of 5 mm on the split halve of the core to obtain continuous and high-resolution profile (κ) (not shown). Second, cubic plastic boxes (8 cm^3) were pushed into the split core face, and the samples (n = 41) were removed with a plastic spatula. We performed detailed magnetic measurements at the Paleomagnetism and Environmental Magnetism Laboratory (CIFICEN-UNCPBA).

The measurements include magnetic susceptibility at low (κ_{lf}) and high (κ_{hf}) frequencies (470 Hz and 4700 Hz). These two parameters give rise to a frequency dependent susceptibility (κ_{FD}) that provides a measure of the relative contribution of superparamagnetic (SP) grains in samples ($\kappa_{FD} = (\kappa_{lf} - \kappa_{hf}) / \kappa_{lf}$). Anhysteretic Remanent Magnetization (ARM) was produced along the positive z-axis of the samples by applying a decaying alternating field (peak field of 100 mT) with the superimposed steady magnetic field of 0.09 mT. Isothermal Remanent Magnetization (IRM) was imparted by exposing the sample at increasing steps of up to 1.2 T reaching saturation (SIRM), and in increasing steps back until the magnetic remanence was cancelled using a IM-10-30 Pulse Magnetizer (ASC Scientific). Both ARM and IRM were measured using a JR6A Dual Speed Spinner Magnetometer. S-ratio was calculated as IRM_{-300mT} / SIRM following Thompson (1986). Inter-parametric ratios ARM/SIRM was calculated to discriminate different magnetic grain sizes in bulk samples (King and Channell, 1991). Magnetic hysteresis curve and temperature-dependent measurements of magnetic susceptibility (κ-T) were performed at the Laboratory of Paleomagnetism of Burgos University (Spain) using a Variable Field Translation Balance (MM_MFTV). The morphology of the extracted magnetic particles was observed using a scanning electron microscope (SEM). The extracted magnetic particles were prepared with a thin coating of Au/Pd by a metallizer EMITECH module SC7720 Sputter Coater, and then analyzed with a Philips SEM 505. The elemental composition of magnetic minerals was measured using energy dispersive spectroscopy (EDS) using an EDAX DX PRIME 10 at CINDECA (Centro de Investigación y Desarrollo en Ciencias Aplicadas "Dr. Jorge Ronco", La Plata, Argentina) and at the Laboratory of Universidad de Vigo, Spain.

3. Results

Different magnetic properties and inter-parametric ratios were used to determine down-core variations in the type, concentration, and grain size of magnetic minerals. Magnetic susceptibility was used as a first order indicator of the concentration of magnetic (*sensu lato*) minerals. From bottom up to 12 cm, κ fluctuates around a mean value of 270 × 10^{-5} in TON1 (with a full range of variability from ca. 173 ×10^{-5} to 371 ×10^{-5}), with few sharp peaks, which are linked to tephra layers. From about 12 cm to top of core, k displays a significant decrease. κ_{FD} displays values lower than 0.04 (Fig. 2), indicating that SP grains do not control the assemblages of magnetic grains (Bartington Instruments Ltd., 1994). The inter-parametric ratio ARM/SIRM is considered potential magneto-granulometric indicators, with higher values for finer grained (SD) ferrimagnetic particles and lower values for larger (MD) grains. ARM/SIRM shows small variations, except in the last 12 cm, where the magnetic grain size underwent an abrupt decrease. Progressive removal of SIRM by back-field demagnetization indicates that BCR varies between 65 and 77 mT (Fig. 2), except for sample 7 (15 cm) for which the value of BCR is 56 mT. According to Peters and Dekkers (2003), these results, a little higher than the characteristic value of pure magnetite, could be explained by the presence of oxidized titano-magnetite, greigite (Roberts and Turner, 1993; Reynolds *et al*., 1994) and/or antiferromagnetic minerals in low concentrations, or by the relative decrease in the grain size. Parameter S_{ratio} is interpreted to reflect the dominant magnetic minerals and, in particular, to differentiate between soft magnetite and hard hematite minerals (Anderson and Rippey, 1988). It varies between 0.89 to 0.92, which suggest the predominance of low-coercivity minerals like titano-magnetite and a lower contribution of antiferromagnetic minerals (hematite-type) (Oldfield, 1991). This parameter can also be influenced by grain size variations; lower values are related to finer grained ferrimagnetic particles (Stockhausen and Zolitschka, 1999).

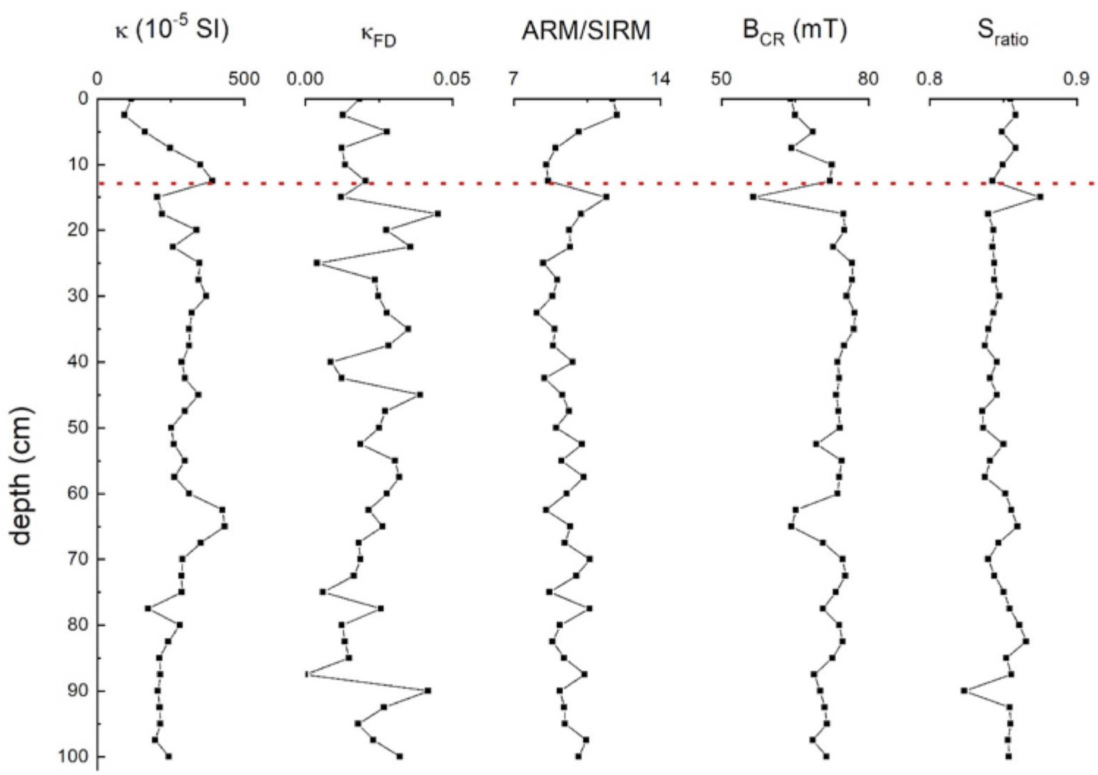

Figure 2. Down-core variations in rock magnetic parameters: magnetic susceptibility (κ), κ_{FD}, ARM/SIRM, B_{CR} and S_{ratio} of core TON1.

Combining magnetic parameters graphically is very useful for assessing magnetic mineralogy (e.g. Peters and Thompson, 1998). Fig. 3.a, SIRM/κ vs. Bcr, indicates the presence of magnetite in the sediments of Laguna Toncek. In this case, in which the magnetic mineralogy is dominated by magnetite, the best way to assess variations in concentration is by means of the bilogarithmic plot of κ vs. SIRM (Fig. 3.b), which was calibrated according to Thompson and Oldfield (1986). From this relationship, we estimated that the concentration and the magnetic grain size of ferrimagnetic minerals vary approximately between 0.03% and 0.15% and, 1 and 2 μm, respectively.

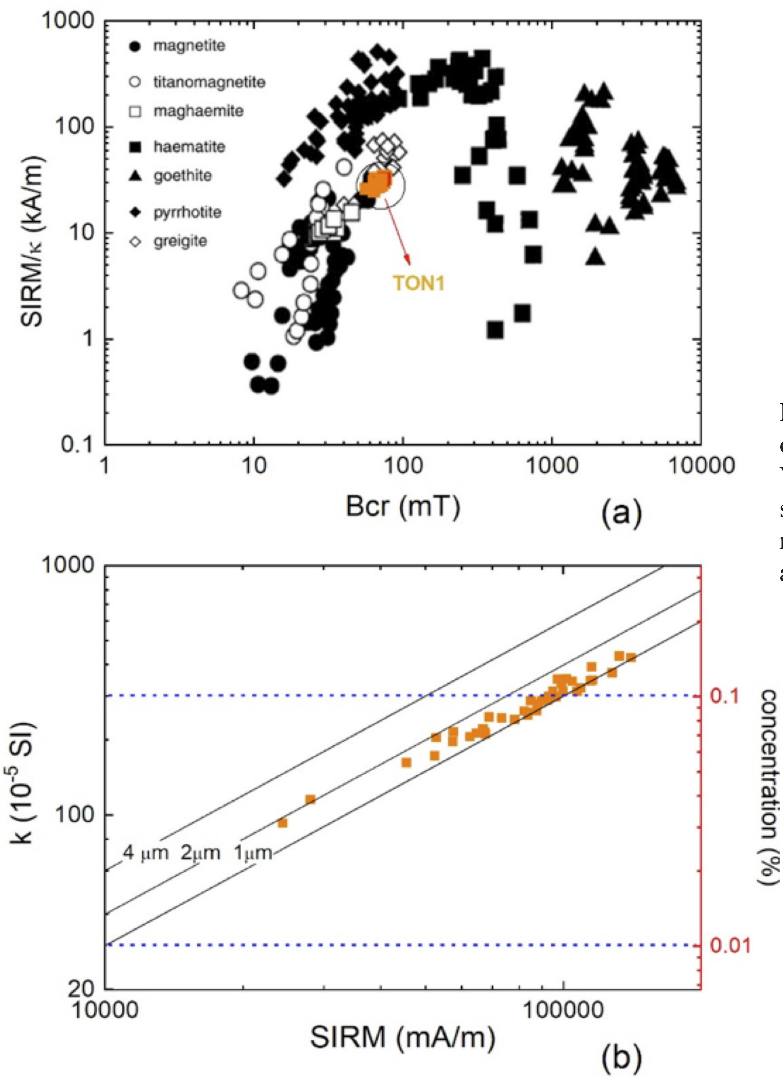

Figure 3. Rock magnetic properties of the Lake Toncek sediments. (**a**) Variation of the ratio of SIRM to susceptibility, SIRM/κ, versus the remanent acquisition coercivity, Bcr and (**b**) SIRM/κ vs. B_{CR}.

Fragmented magnetic grains often found in SEM analyses (Fig. 4) clearly indicate the presence of magnetic minerals that are detrital in origin. The XRD analyses confirm the presence of titano-magnetite in all analyzed samples (Fig. 4). Thermomagnetic curves are typical for low-Ti content magnetite with almost constant values of the magnetization up to ~350 ºC followed by a rapid decrease until complete removal of the magnetization between 550 ºC and 580 ºC. Moreover, secondary magnetite is also created as revealed by the increase in magnetization in most cooling curves (Fig. 4). The shape of hysteresis loops (Fig. 4) also provide strong evidence of a dominant low-coercivity ferrimagnetic components.

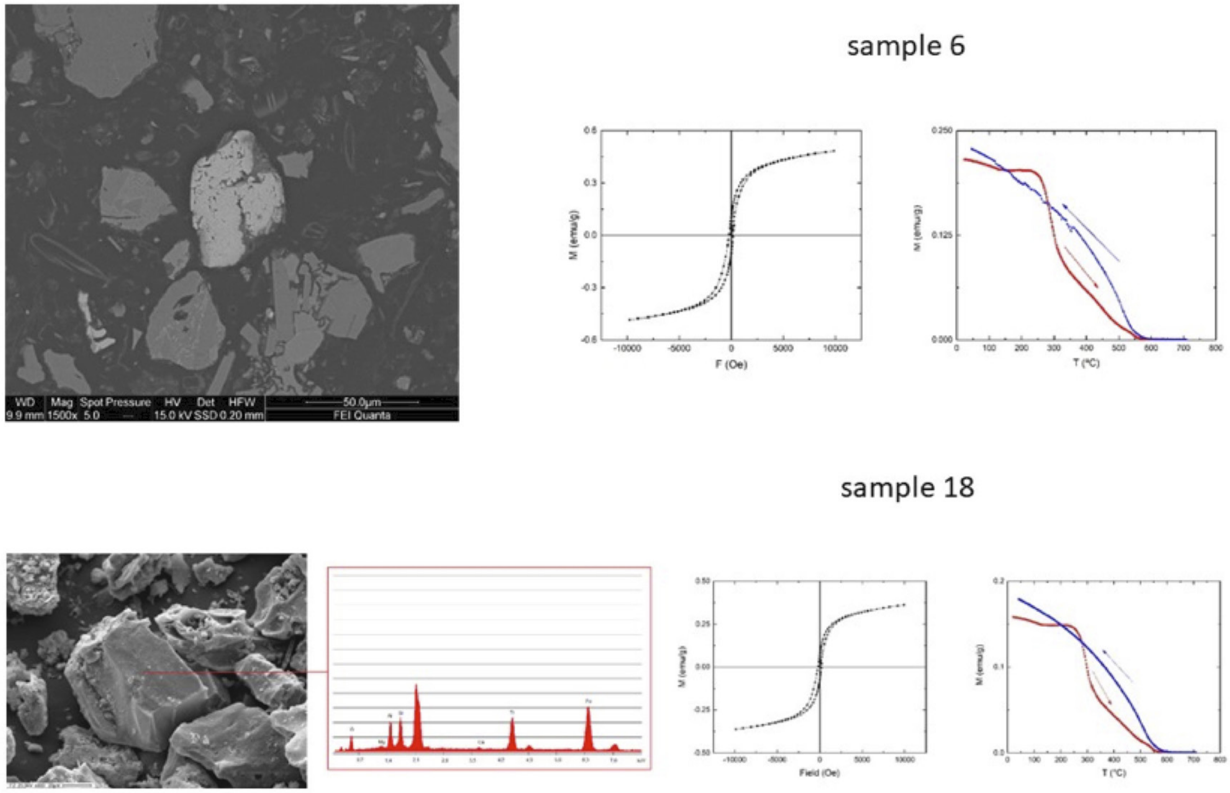

Figure 4. SEM observations and X-ray diffractogram of magnetically extracted grains from sediment samples, hysteresis cycle and thermal demagnetization results.

4. Conclusions

We present rock magnetic results obtained from sediment samples from Lake Toncek. The magnetic properties of all samples are dominated by titano-magnetite with a grain size of ~1–2 µm while the mineral concentration varies between 0.03 and 0.15%. Sediments from Lake Toncek are characterized by higher k and S_{ratio} values, suggesting higher concentrations of ferrimagnetic minerals and increased proportions of ferrimagnetic minerals to anti-ferromagnetic minerals.

Acknowledgments

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