PRELIMINARY PALAEOMAGNETIC AND ROCK-MAGNETIC STUDIES ON SEDIMENTS FROM LAKE ESMERALDA (VEGA ISLAND), ANTARCTICA

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Abstract

In this work, three up to 2.5 m long sediment cores from Lake Esmeralda (Antarctica) were investigated for rock-magnetism and palaeomagnetic studies. It is a glacial lake and the clastic sediment input is mostly carried by meltwater during summer. Such lake sediments can be useful palaeoclimatic and palaeomagnetic data of the Holocene record from Antarctica. The record may span 9000 years BP according to the last glacial ice retreat in the Antarctic continent.
The rock-magnetic measurements –magnetic susceptibility, hysteresis cycles, anhysteretic and isothermal remanent magnetisation, and thermal demagnetisation– suggest the presence of paramagnetic and ferrimagnetic minerals. These ferrimagnetic, and in lower proportion antiferromagnetic, minerals control the remanent magnetisation. On the other hand, sedimentological analysis evidence sediment changes that may be related to climatic changes in Antarctic Peninsula. Such changes are observed from magnetic parameters as well; hence they could be used as proxies for this lake. A preliminary directional (inclination) SV curve for 3 cores was obtained from studies of palaeomagnetism. It may be possible to fit the curve to well dated master curves from Argentina, hence contributing to establish a chronology for such sediments and others in the area.

Resumen

Se presentan estudios de magnetismo de rocas y paleomagnetismo de tres testigos de sedimentos lacustres del Lago Esmeralda (Antártida), con longitud máxima de 2.5 m. Este lago, de origen glaciario, posee un importante aporte de sedimentos clásticos transportado por hielo de fusión durante el verano. Estos sedimentos podrían brindar una valiosa información paleoclimática y paleomagnética Holocena, ya que representarían un registro de los últimos 9000 años posteriores al retroceso del frente de hielos en Antártida.
Las mediciones de magnetismo de rocas –susceptibilidad magnética, ciclos de histéresis, magnetización remanente anhistérica e isotérmica, desmagnetización térmica– revelan la presencia de minerales paramagnéticos y ferrimagnéticos; estos últimos y, en menor proporción, los antiferromagnéticos, controlan la magnetización remanente. El análisis sedimentológico muestra cambios en el tipo de sedimentación que pueden atribuirse a variaciones climáticas. Dichos cambios también se reflejan en los parámetros magnéticos, que pueden considerarse potenciales proxies para este lago. Los estudios preliminares de paleomagnetismo permitieron obtener la curva de inclinación para tres testigos. Es posible ajustar la curva obtenida con curvas patrones bien datadas de Argentina, contribuyendo establecer la cronología de estos y otros sedimentos de lagos de la región.

Introduction

Palaeomagnetic studies of Late Quaternary sedimentary sequences have shown that high-resolution palaeomagnetic secular variation (PSV) records can be recovered from lacustrine and marine sediments (e.g. Barton and McElhinny, 1983; Lund and Baneerje, 1985; Saarinen, 1999; Richter et al., 2006). Studies on Late Pleistocene–Holocene lake sediments carried out in Europe, North America, and Australia have revealed the existence of PSVs of the ancient geomagnetic field of the order of a few thousands of years. These records show that PSVs can be correlated between sediment sequences on a regional basis, and can help to constrain models of core dynamic processes. Moreover, logs of the intensity of natural remanent magnetization (NRM) and magnetic susceptibility can be used for lithostratigraphic correlation of sediments within a particular depositional basin.
Most of the PSV results were obtained from records on sediments from the Northern Hemisphere. Experimental results from South America are scarce. Palaeomagnetic and sedimentological studies on sediments from cores obtained from lakes in south-western Argentina have been presented by Creer et al. (1983), Gogorza et al. (1997, 1999, 2000, 2002), Irurzun et al. (2006). Here, we describe new palaeomagnetic results from cores collected in Lake Esmeralda (Vega Island, Antarctica).
Lake Esmeralda would become a palaeoclimatic record of great worth for the last 9000 years subsequent to the retreat of the ice front in the Antarctica. The detailed study of the cores can supply palaeoenvironmental and palaeoclimatic information for the northern area of the Antarctic Peninsula. With this aim, sedimentological, palaeomagnetic and rock-magnetic studies will be carried out.

Sampling and Methodology

During January-February 2007, a field work was carried out in order to study Cenozoic sediments from Cape Lamb, Vega Island, Antarctica (Fig. 1). After a bathymetric study of Lake Esmeralda, various sediment cores (about 2.5 m long) were collected. It is worth mentioning that it is uncommon the collection of lacustrine cores longer than 1 m in Antarctic lakes from James Ross basin. In this case, the core extraction was favoured by the mild weather conditions of the summer 2007 and the water depth (up to 6 m) of Lake Esmeralda. The drillings were carried out by using a manual drill from a pneumatic boat; semi-cylindrical cores of 7 cm diameter and sections of 1 m long were obtained.

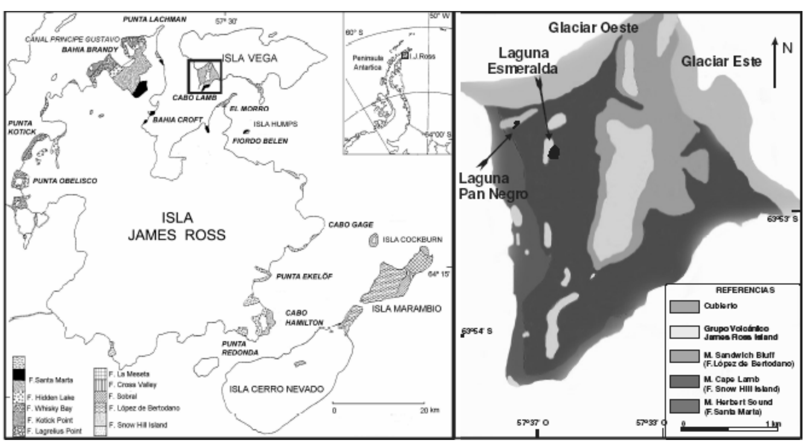

Figure 1. Study area

The cores were transported and studied in palaeomagnetic laboratories from the Centro de Geociencias (CGeo, Mexico), the GeoForschungsZentrum (GFZ, Germany) and the Instituto de Fisica Arroyo Seco (IFAS, Argentina). The sediments were stored at 4°C and the freshly exposed surface of the half core was then photographed and described stratigraphically. These sediments were subsampled using (8 cm^3)

palaeomagnetic plastic cubes. Most of the measurements were done in the GFZ Potsdam. Low-field magnetic susceptibility (κ) was measured with a KLY-3 instrument from AGICO and a Bartington MS2 instrument. For remanence measurements, a 2G-Enterprises long-core rock-magnetometer with attached alternating field (AF) demagnetizer was used (max. field 150 mT). IRM acquisition was done with a ASC Scientific model IM-10-30 pulse magnetizer, and the IRM produced measured in a Molspin magnetometer. ARM acquisition was done with a 2G-Enterprises single-axis AF demagnetizer. The NRM was measured and stepwise AF demagnetized with the 2G system. Then an ARM was produced in the samples and demagnetized in several steps. Next, IRM acquisition was carried out to obtain the saturation (SIRM), followed by backfield magnetization for calculating the Hcr and S-ratio. For the core ESM-7, a detailed sampling at 4 mm was also done, selecting a small amount of material (<50 mg) that was used to measure magnetic hysteresis loops in fields between –1 and 1 T at room temperature using a Princeton Measurement Corporation Micromag 2900 AGM system equipped with a 2.2 T magnet. Before the experiments, the material was dried and weighed to allow for calculation of mass-corrected hysteresis parameters.

Core Description

The cores show predominance of clay, rythmites of variable thickness (1- 5mm), anoxic zones and abundant organic matter. The sediments of Lake Esmeralda show at the base a dark deposit consistent of coarse gravel with basaltic sharp clusters. The sequence has horizontal thin lamination at the lower and middle zone, which becomes inclined towards the top. The rythmites are composed by clay and fine sand; some cores show deformation and folding of rhytmites. There are dark layers, several centimetres thick, with microscopic algae. The cores show lateral changes, possibly due to the influence of the river that flows into the lake. The inclined layers on the top suggest deltaic-lacustrine environment.

Results and discussion

The base layer could represent a till deposit and the dark colour would be related to anoxic conditions. The cause of these processes could be the periodic freezing of the lake, which prevents the wind circulation and the water mixing; so the anoxic levels could be proxies of cold climate. On the other hand, the abundance of algae in anoxic events suggests high oxygen consumption due to decomposition of organic matter.

Magnetic mineralogy was studied by rock-magnetic parameters. The IRM curves and S-ratio (Fig. 2a) showed the dominance of ferrimagnetic minerals. A low proportion of antiferromagnetic minerals (e.g. hematite) was also found from IRM curves. In addition, the Hcr values (50-65 mT, Fig. 2a) showed that (titano) magnetite is the main magnetic carrier of the remanent magnetisation. The hysteresis parameters (Day's Plot, Fig. 2b) revealed the presence of PSD grains. On the other hand, the King's Plot showed magnetic grain sizes between 1 and 5 μm (Fig. 2c).

Fig. 3 shows the Zijderveld diagrams for two samples from different cores and depths. In most of the cases, a viscous remanent magnetization (VRM) is present. This VRM is removed between 5 and 10 mT. The remaining data show a stable behaviour and a characteristic remanent magnetization can be calculated with principal component analysis (Kirschvink, 1980). All the samples have maximum angular deviations (MAD) < 10º.

The palaeomagnetic studies allow obtaining the declination (D) and inclination (I) profiles for three cores (ESM-4, ESM-6 y ESM-7a and b). In order to build a secular variation curve, the depth scales of all cores were transformed to the equivalent depth of the master core (ESM-6, Fig. 4) using lithology and κ for correlation. Because of the high density of the tie lines, the depth scale was adjusted using linear spacing between every two of them (Irurzun et al., 2006).

To obtain a composite record for Lake Esmeralda, the directional data (e.g. Inclination data are shown in Fig. 4) from all cores were combined. An interpolation every 2 cm was made in order to have equivalent values of depth in all cores. Then, the arithmetical mean was calculated. Fig. 5 shows the inclination results from the stacking process. The stacked curves show features similar to the individual curves, but smoother as a consequence of the averaging process.
According with the geological survey, the lake was formed after the last glaciations (around 9000 cal. BP).

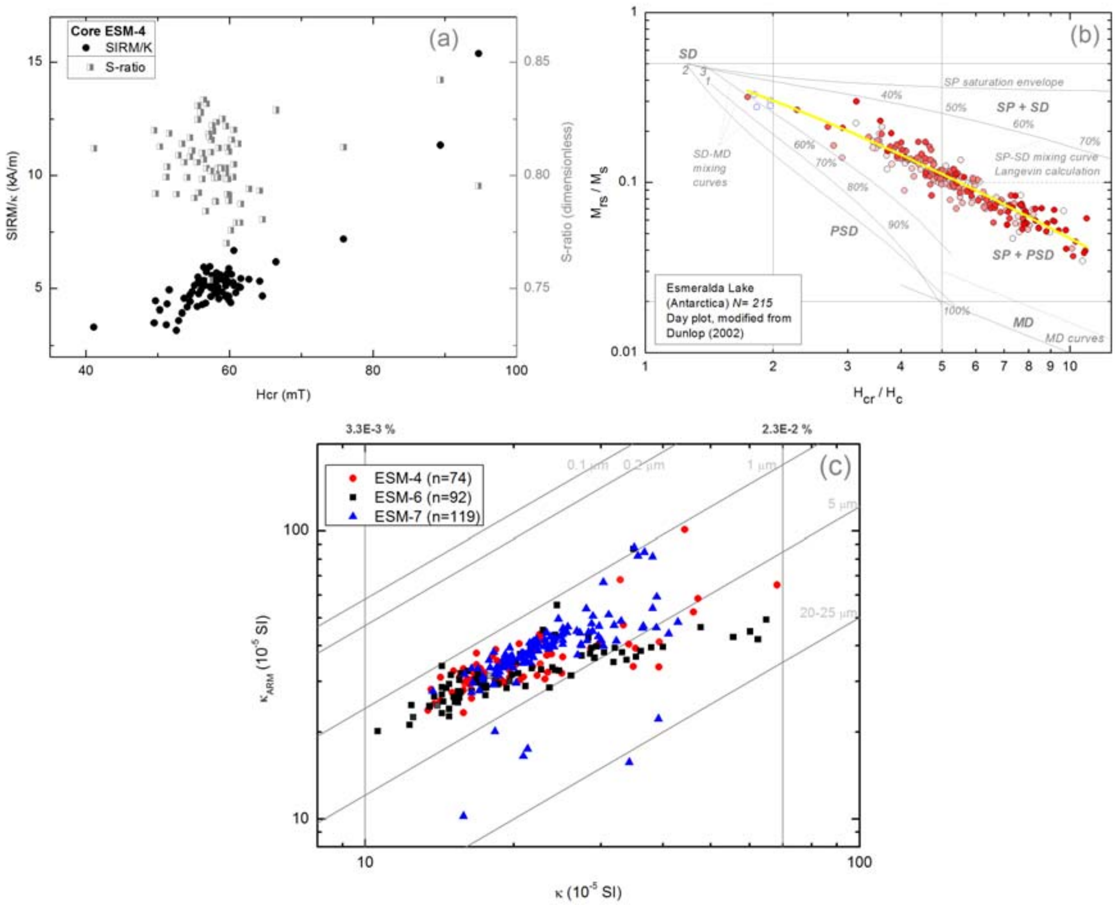

Figure 2. (a) Magnetic mineralogy: Biplots SIRM/κ versus Hcr, S-ratio versus Hcr for samples of core ESM-4.Magnetic grain sizes: (b) Day's Plot for core ESM-7 and (c) King's Plot for all cores.

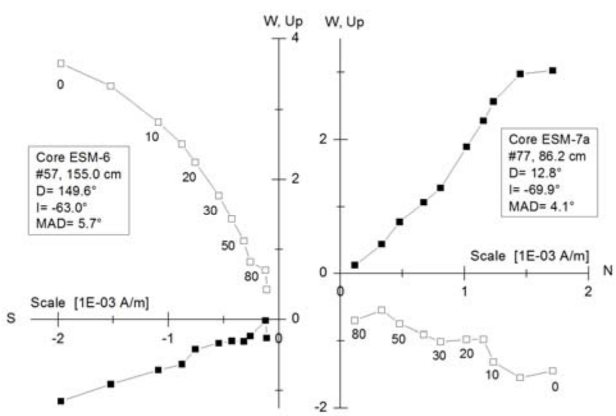

Figure 3. Examples of AF demagnetization data. Zijderveld diagrams, solid (open) symbols are projections onto the horizontal (vertical) plane.

To transform the palaeomagnetic records into time series, magnetic features of the stacked values of I and D were correlated with similar features of the PSV obtained for Lake El Trébol (Irurzun et al., 2006) and Lake Escondido (Gogorza et al., 2002) and Lake Moreno (Gogorza et al., 2000). The main features found between the lakes are shown in Fig. 5. Such comparison is possible because of the PSV curves have similarities in sub-continental regions and are reproducible in regional scale (Butler, 1992; Merril et al., 1998).

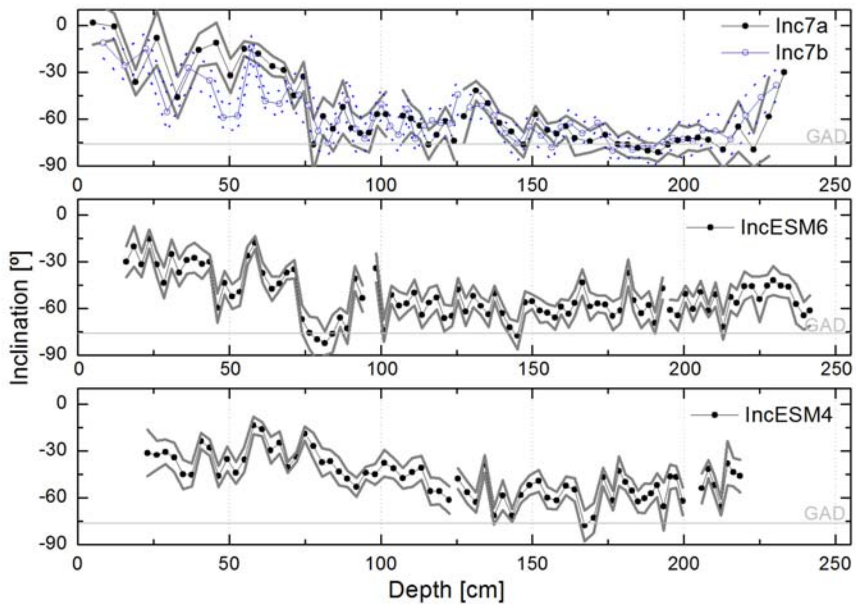

Figure 4. Palaeomagnetic results (Inclination) versus stretched depth of all cores.

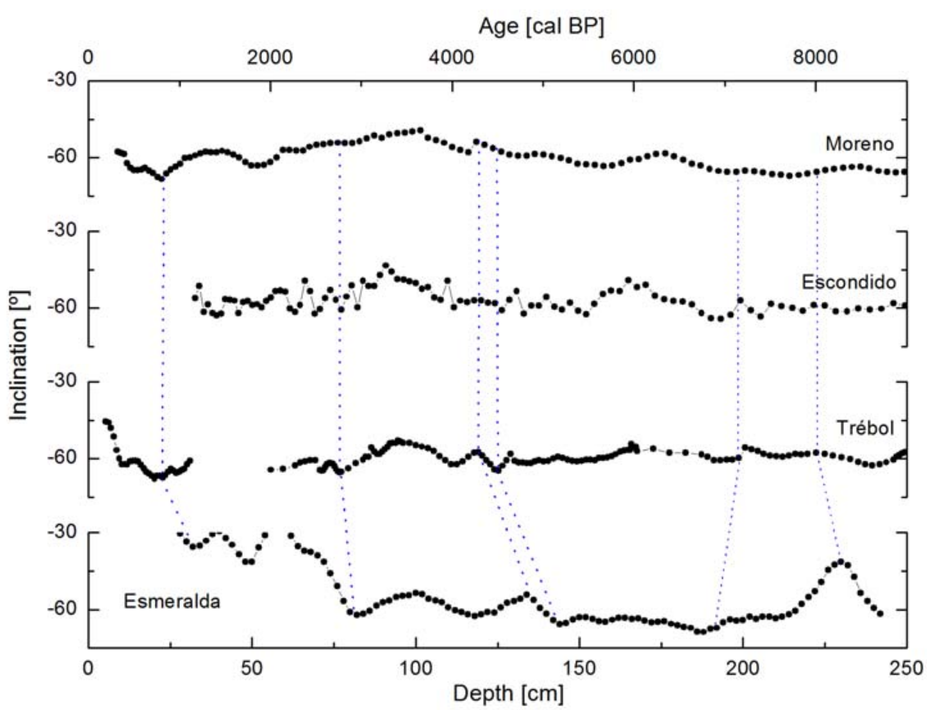

Figure 5. Composite records of data from cores ESM. Stacked inclination versus the adjusted depth. Results of inclination curves for lakes El Trébol, Escondido and Moreno vs age.

Conclusions

The absence of dropstones suggests that the lake was not in contact with the glacial front. The dark zones suggest anoxia. The anoxia in the bottom sediments may be caused by a low supply or a high consumption of oxygen.

Rock magnetic studies suggest the presence of ferrimagnetic minerals with PSD (titano)magnetite as main magnetic carrier of the remanent magnetisation. A low proportion of paramagnetic and antiferromagnetic minerals was also found. The magnetic grain size is around 1-5 μm.

A good correlation based on rock magnetic measurements was performed. It was able to isolate a stable remanent magnetisation in all samples. The individual PSV curves showed a good agreement between them, allowing the comparison with dated records from Patagonia, Argentina. According to this correlation and the geological survey, the record spans the last 9000 cal BP.

The changes in types of sedimentation could be related to climatic variations in the Antarctic Peninsula and reflected in the magnetic parameters. Therefore, they can be considered potential proxies for this lake.

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