Environmental magnetic records of mid-late Pleistocene drift sedimentary sequences from the Antarctic Peninsula, Pacific margin

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Summary The Pacific Continental Margin of the Antarctic Peninsula was the area of interest of the Sediment Drift of The Antarctic Offshore Project (SEDANO Project). A paleomagnetic and environmental study was carried out on four Pleistocene sequences from Drift 7. High resolution measurements were performed on u-channels and about forty-three discrete samples. This work focus on the definition of the mineralogy of the main magnetic carriers which is still matter of debate and on the study of the short time variability of magnetite grain-size which results particularly evident during the last glaciation. ARM/κ magnetic parameter resulted to be a good record of such variability and reflects changes in the sedimentation on the rise when the ice sheet was probably closer to the continental shelf edge. An integrated age model has been provided for cores SED-12 and -13, which have the higher sedimentation rates.

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Introduction

Sediment drifts off the Pacific margin of the Antarctic Peninsula were investigated in 1995-1999 during two SEDANO (*Sediment Drift of the Antarctic Offshore*) cruises of R/V *OGS-Explora* (Fig. 1). Multichannel seismic, gravity coring, deployment of moorings with current meter, and sediment traps at the bottom were used (Camerlenghi et al., 1997; Pudsey and Camerlenghi, 1998). The distal depositional system consisted in twelve sedimentary mounds ranging between sediment drift (i.e., drift 7) and channel levee (i.e., mound 5A) (Rebesco et al., 2002).

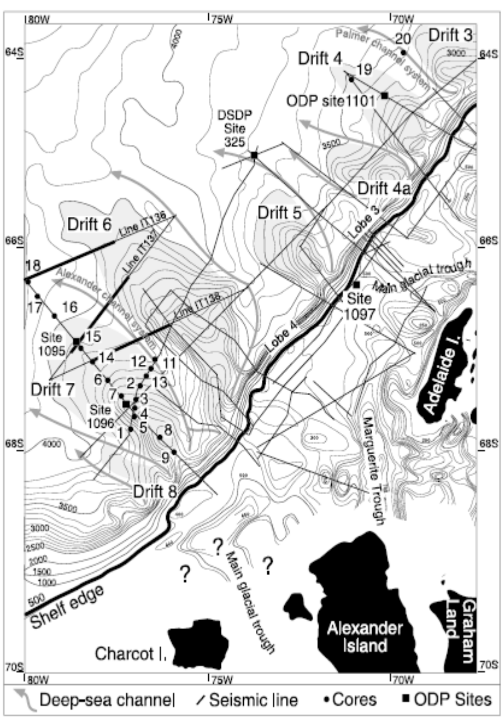

Figure 1. Location map of the SEDANO and ODP drilled sites on sediment drifts off the Antarctic Peninsula Pacific margin (after Lucchi et al., 2002).

The coring was yielded mainly on the gentle side of the drift 7 at c. 3500 m water depth, within the upper seismic unit, the Drift Maintenance Stage, that represents the Pleistocene time (Rebesco et al., 1996, 1997). The sequences show alternations of grey laminated terrigenous and brown hemipelagic intervals, which reflect glacial-interglacial cycles according to the model of drifts deposition (Rebesco et al., 1996). The interaction of along-slope bottom water flow with down-slope turbidity currents controls the formation and the shape of the drifts on the rise (Rebesco et al., 1997, 2002). The grey units have a low barium (Ba) (a paleoproductivity proxy in the Southern Ocean; Villa et al., 2003 and reference therein) and represent glacial stages 2, 4 and 6. During interglacial stages, terrigenous supply is low and bioturbation homogenizes the sediments. The brown units have an high biogenic Ba content and indicate the marine isotope stages 1 and 5. Sediment transport processes during interglacial and glacial for the Drift 7 have been summarized by Pudsey and Camerlenghi (1998), which used the low field magnetic susceptibility for cores correlation.

Sedimentological and compositional investigations on the sequences from Drifts 7 and 4 allowed the identification of a succession of four climatic stages: glaciation, glacial, deglaciation and interglacial (Lucchi et al., 2002).

In the lithostratigraphic Unit C, Quaternary calcareous nannofossils along with planktic foraminifera were found in sites south of 65°S. This Unit is correlated to the Marine Oxygen Isotope Stage 5 and documents Sea Surface Temperature (SST) higher than today and more variable respect to the East Antarctica (Villa et al., 2003, 2005).

A previous paleomagnetic study on cores SED-2 and -4 tells about a possible link between the occurrence of magnetic coercivity minima intervals and periods of sea-ice extent (Sagnotti et al., 2001). In this study, it has been analyzed the magnetic properties of gravity cores SED-7 (67°29.30'S; 77°21.05'W) and -14 (67°06.82'S; 78°10.48'W) from the top of the Drift 7 and of cores SED-12 (67°12.48'S; 76°29.45'W) and -13 (67°17.16'S; 76°38.80'W) in proximity of Alexander channel. The main purposes were to (1) shade light on the definition of the main magnetic carriers and to (2) investigate the climate variability of the Antarctic Peninsula at millennial scale using the expanded sequence SED-12.

Methods

The half cores were sampled pushing plastic u-channels in the sediment. The samples were collected mainly from the archive halves, with the exception of SED-12 core and section 14-3 which are from the working halves. Paleomagnetic measurements were performed at 1-cm space resolution at the Istituto Nazionale di Geofisica e Vulcanologia (INGV) in Rome using a 2-G cryogenic magnetometer (model 755R). The natural remanent magnetization (NRM) was stepwise demagnetized using peak alternating field (AF) of 10, 20, 30, 40, 50, 60, 80, and 100 mT. The estimate of the characteristic remanent magnetization (ChRM) directions and maximum angular deviation (MAD) of the principal component analyses (PCA) fit (Kirschvink, 1980), were computed using a new software by Mazaud (2005).

A laboratory induced anhysteretic remanent magnetization (ARM) was imparted using a direct current (DC) bias field of 0.1 mT and 100 mT AF peak. Subsequently, it was stepwise AF demagnetized up to 100 mT peak field. Forty-three discrete samples were chosen in selected interval distributed throughout the cores and subjected to thermomagnetic and hysteresis analyses using a KLY-3 (AGICO) Kappabridge and Micromag Model 2900 AGM (Alternating Gradient Magnetometer) system, respectively. The chronostratigraphies of the cores are referred to the summary of the stratigraphic units of Lucchi et al. (2002).

Results

Paleomagnetism

The NRM has high intensity of about 0.1-0.2 A/m and a good demagnetization behaviour with MAD angle mostly < 5° and never > 10° (Fig. 2). A secondary component of magnetization was easily removed at 10-20 mT demagnetization steps, thus for the PCA were considered the peak fields of 20-80 mT.

For some intervals the samples are not completely demagnetized at AF peak of 100 mT implying the contribution of a higher coercivity mineral. NRM inclination records normal polarity (C1n, Brunhes Chron) but it is quite noisy with shallow peaks up to -30° for all the sites, except for the distal site SED-14 which inclination is noisy only in the interval between ca. 3 and 4 mbsf similarly to the other sites.

Rock magnetic results and discussion

Low-coercivity (MDF=30-60 mT) intervals characterize the interglacials and some thin intervals within the stratigraphic unit B (Fig. 2). Higher coercivities (MDF=75-90 mT) characterize the glacial intervals similar to what was found in cores SED-02 and -04. Sagnotti et al. (2001) interpreted these variations as due to the presence of two main magnetic carriers, indicating that magnetite and pyrrhotite are the most probable.

The temperature dependence of the low-field magnetic susceptibility is similar for all the analysed discrete samples. The κ lightly decreases at 280-300° C, suggesting the presence of iron sulfides, and then decreases up to about the Curie temperature of magnetite (580°C). The heating curves up to 350° show the occurrence of irreversible mineralogical changes during heating which may be not consistent with the presence of pyrrhotite (Dekkers, 1989; Horng and Roberts, 2006). Conversely, the iron sulphide greigite (Fe_3S_4) could represent a possible carrier along with magnetite, but additional temperature dependence of magnetic susceptibility analyses in argon and other mineralogical analyses are necessary to confirm it.

ARM intensity seems not to be affected by the higher coercive fraction (Sagnotti et al., 2001) and the ARM/κ ratio can be used as indicator of magnetite grain-size. ARM/κ shows an inverse correlation to NRM intensity, κ and MDF (Fig. 2). Because the NRM intensity and κ are mainly concentration dependent parameters, the correspondence with coercive force dependent parameter points out a link between concentration and mineralogy in these cores. During glacials times the supply of terrigenous material was higher and the concentration of relatively hard minerals may have been increasing as a consequence of changes in sedimentary processes. It seems that turbiditic currents and turbid plumes affected the sedimentation on the rise during periods in which the ice sheet was close enough to the continental shelf edge (Lucchi et al., 2002; Giorgetti et al., 2003). The ARM shows a slight decreasing trend up-core and could reflect a continuous extent of the ice shelf.

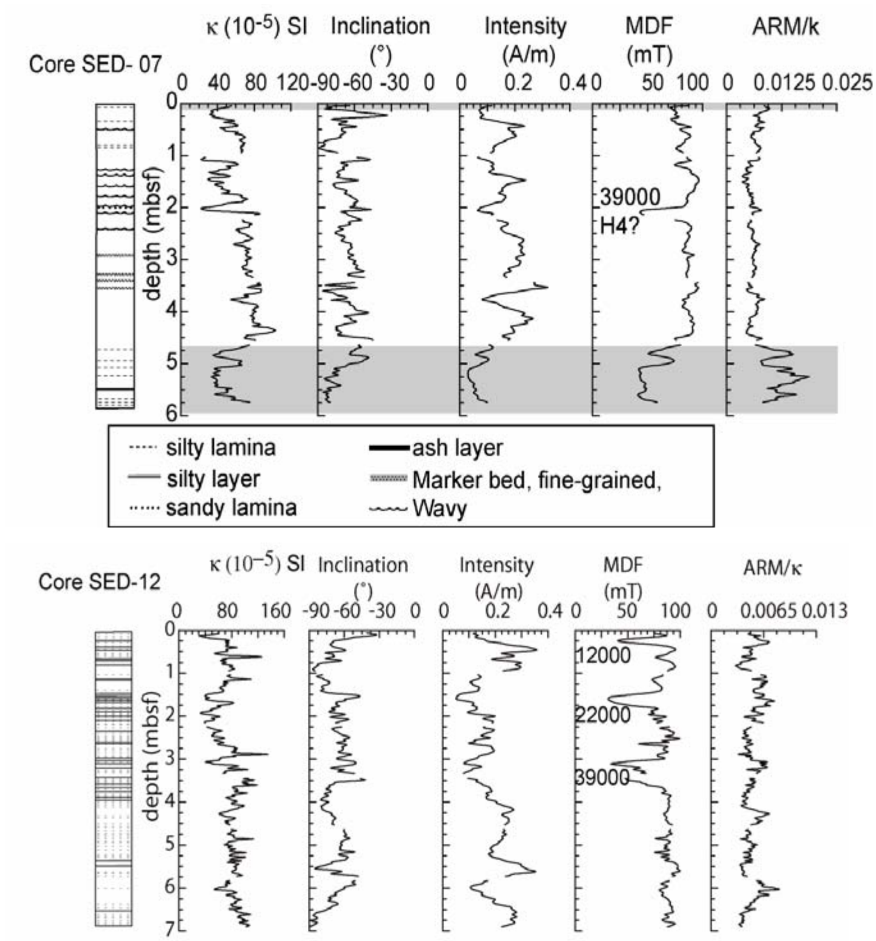

Figure 2. Lithology and downcore variations of magnetic parameters for core SED-07 and SED-12. Magnetic susceptibility (κ), magnetic inclination, NRM_{20} intensity, MDF, ARM/κ are shown. The grey area corresponds to interglacial. Possible Heinrich events are also indicated (Stoner et al., 1998; Chapman et al., 2000; Sagnotti et al., 2001).

The SED-12, and -13 cores are located in proximity of Alexander channel where the sedimentation rates are higher (> than 11.5 cm/kyr; Lucchi et al., 2002). They span the last glacial (stratigraphic unit B) and can be easily correlated by the use of different parameters (κ, NRM intensity, inclination, MDF, and ARM/κ). Thus, these cores represent an opportunity to study short time climatic variations through the analysis of magnetic grain-size given the succession within glacial facies of terrigenous mud and silty layers evident also from X-ray images (Lucchi et al., 2002).

Work in progress

It has been developed an integrated age model for core SED-12 and 13. More specifically, by mean of κ these two cores have been correlated to SED–02 record, which age model is based on paleointensity study (Sagnotti et al., 2001). In order to distinguish the nature of the higher coercivity fraction (iron sulfides?), additional mineralogical investigations are needed. It would be interesting to integrate magnetic measurements to X-ray diffraction (XRD) analysis and scanning electron microscope (SEM) observations (e.g., Horng and Roberts, 2006). This would give information also about the authigenic or detrital origin of the minerals and about the source areas improving or updating the initial hypotheses made on the basis of limited evidences.

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