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Environmental Magnetic Record of the Eocene-Oligocene Transition in CRP-3 Drillcore, Victoria Land Basin, Antarctica

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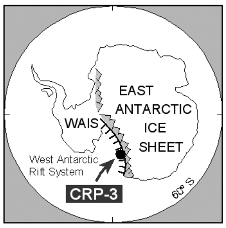

Abstract - A 1500-m-thick Cenozoic sequence was recovered in a series of 3 drill holes from the Victoria Land Basin, Antarctica, in association with the Cape Roberts Project. The CRP-3 drill hole penetrated the oldest Palaeogene strata in the Granite Harbour region and terminated in strata from the Devonian Beacon Supergroup. The upper 823-m of the CRP-3 drill-core is an expanded sequence that may span the Eocene-Oligocene boundary. Lithostratigraphic analysis indicates a transition from rapidly deposited deltaic strata below 480 metres below sea floor (mbsf) to distinctly glaciomarine strata above 307 mbsf. A variety of rock magnetic parameters indicate that magnetite is the main magnetic mineral in the CRP-3 Eocene-Oligocene sequence. Magnetite concentration varies in a distinct pattern, which allows subdivision of the CRP-3 sequence into four main rock magnetic intervals that do not correspond to the lithostratigraphic units or to the sequence stratigraphic subdivisions identified in the core. Intervals I (0-243 mbsf) and IV (627-790 mbsf) have high concentrations of magnetite, with moderate variations. Intervals II (243-440 mbsf) and III (440-627 mbsf) have low background magnetite concentrations, but contain thin zones with higher magnetite concentrations. Rock magnetic interval III coincides with the part of the core that is dominated by clean sands. The transition upward from high to low magnetite concentration at 627 mbsf coincides with the chron C13r-C13n transition and is correlated with a major oxygen isotope shift in deep-sea records (Oi-1) across the Eocene-Oligocene boundary. Comparison with other Eocene and Oligocene environmental magnetic records from the southern Victoria Land Basin indicates that transition observed in the environmental magnetic record of the CRP-3 core may mark the most prominent cooling event in Antarctica during a stepwise deterioration of climate that extended across the (~5 m.y.) Eocene-Oligocene transition.

INTRODUCTION

The drilling efforts of the Cape Roberts Project (CRP) were completed with recovery of the CRP-3 drill hole in the Victoria Land Basin (VLB) of the Ross Sea, Antarctica. The CRP-3 site was selected to partly overlap and extend downward the Cenozoic sequence previously recovered in the CRP-1 and CRP-2/2A drill holes, which were located about 2 km and 3 km to the east of CRP-3, respectively (Cape Roberts Science Team, 1998; 1999). The CRP-3 hole was drilled in the austral spring of 1999 to a depth of 939.42 mbsf (metres below sea floor) and a poorly dated thick sequence of possible Late Eocene - Early Oligocene age was recovered in the upper 823 mbsf (Cape Roberts Science Team, 2000; Florindo et al., this volume). Below this depth, sandstones of the Devonian Beacon Supergroup were encountered (Cape Roberts Science Team, 2000).

The main aims of the Cape Roberts Project were: (1) to investigate the Cenozoic climatic history of the Antarctic continent and the early phases of development of the East Antarctic Ice Sheet, and (2) to characterize the tectonic history of the Cenozoic Antarctic rift system by providing age estimates for the uplift of the Transantarctic Mountains (TAM) and the formation of the VLB. These objectives were pursued by a multidisciplinary scientific team from 6 countries (Cape Roberts Science Team, 1998; 1999; 2000). Initial characterization of the CRP cores was carried out in Antarctica during each drilling season; later analyses were made at the home laboratories of the respective scientists.

The oldest Cenozoic sediment in the Granite Harbour region of the Victoria Land Basin was recovered in the CRP-3 drill-hole. Coarse siliciclastic sediments, which accumulated rapidly in a shallow coastal setting (Cape Roberts Science Team, 2000), were recovered below 480 mbsf. A glacial influence is increasingly apparent in strata between 480 and 307 mbsf, with glaciomarine strata, which accumulated in distinctive unconformity-bounded

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**Corresponding author* (sagnotti@ingv.it) sequences, dominant above 307 mbsf (Cape Roberts Science Team, 2000).

In this paper, we present environmental magnetic results from the CRP-3 core which have important implications for interpretation of Eocene-Oligocene climatic deterioration in the Antarctic. Environmental magnetism involves the analysis of variations in composition, concentration and grain-size of magnetic particles in a sedimentary sequence in terms of local environmental change and/or larger-scale climate dynamics (Thompson & Oldfield, 1986; Reynolds & King, 1995; Verosub & Roberts, 1995; Maher et al., 1999). Environmental magnetic measurements have the advantage of being non-destructive, rapid, inexpensive, and highly sensitive to environmental factors that control the type and distribution of iron-bearing minerals. We have already carried out environmental magnetic studies of the CRP-1 (Sagnotti et al., 1998a), CRP-2/2A (Verosub et al., 2000) and CIROS-1 (Sagnotti et al., 1998b) cores from the VLB, and have detected pronounced variations in rock magnetic properties throughout the VLB Cenozoic sequence, which we have related to palaeoenvironmental processes.

METHODS AND MEASUREMENTS

Rock magnetic measurements were carried out on standard palaeomagnetic samples collected for a magnetostratigraphic study of the CRP-3 core (Florindo et al., this volume) and on rock chips collected from the same stratigraphic horizons. For the present study we used only the sub-set of palaeomagnetic samples that had been subjected to alternating field (AF) demagnetization.

Eleven hundred and seventeen palaeomagnetic samples were collected from the CRP-3 core, of which 105 were from the Beacon Supergroup strata in the lower part of the core and were not part of this study. Most of the CRP-3 Cenozoic sequence (*c.* 80%) consists of sandstones, with the remainder divided about equally between diamictites and conglomerates (Cape Roberts Science Team, 2000). Our original sampling strategy was to collect samples at 0.5-m intervals, preferably from fine-grained horizons. However, due to the scarcity of silt and clay lithologies (which are found only in the upper 410 m of the core), most samples were taken from sandstone-dominated lithofacies. Well-sorted, clean sandstones predominate between *c.* 380 and 580 mbsf; these sandstones have little or no fine-grained matrix. Coarse sand grains, granules and pebbles are also dispersed throughout the CRP-3 sequence. For the present study, we only used samples that were representative of the rock matrix. We excluded those samples that had been eliminated from our magnetostratigraphic study (Florindo et al., this volume) on the basis of palaeomagnetic behaviour that suggested the presence of extra-formational pebbles (which are usually evident from complex multiple-component magnetizations).

During the drilling season, the low-field magnetic susceptibility (κ) of all samples was routinely measured at the Crary Science and Engineering Center, McMurdo Station, Antarctica, using a Bartington Instruments magnetic susceptibility meter with an MS-2B probe. Susceptibility was measured at low-frequency (κ_{lf}, at 0.465 kHz) and high-frequency (κ_{lf}, at 4.65 kHz) and the percentage frequency-dependence of the magnetic susceptibility (κ_{fd}) was computed as $\kappa_{fd} = (\kappa_{lf} - \kappa_{hf})/\kappa_{lf} \times 100\%$ (*e.g.* Bloemendal et al., 1985). Anhysteretic remanent magnetization (ARM) was measured for 805 samples at the *Istituto Nazionale di Geofisica e Vulcanologia* (Italy). The ARM was imparted along a single axis of the samples (z-axis) with a DC bias field of 100 μT and a peak AF of 100 mT. The ARM was then subjected to AF demagnetization, using an automated pass-through 2G Enterprises cryogenic magnetometer with an in-line, three-axis AF demagnetizer. These measurements were used to determine the median destructive field (MDF_{ARM}), which is the value of the peak AF necessary to reduce the ARM intensity to half of its initial value.

Hysteresis parameters (up to peak fields of 1 T) were measured at the University of California, Davis (USA), on rock chips from the same stratigraphic levels as the discrete samples, using a Princeton Measurements Corporation alternating gradient magnetometer (Micromag). The measured hysteresis parameters include the saturation magnetization (M_s), saturation remanent magnetization (M_r), coercive force (B_c) and coercivity of remanence (B_{cr}).

Thermomagnetic curves were measured during heating-cooling cycles from room temperature to 700°C on 41 selected powders at roughly 20-m stratigraphic intervals. These measurements were made in air with a Variable Field Translation Balance at the Southampton Oceanography Centre (UK) with an applied field of 76 mT and heating at 10°C/minute.

Rock magnetic parameters reflect the contribution of all magnetic minerals in a sample. The magnetic mineralogy of a sample can be determined by combining data from thermomagnetic curves (such as Curie points and/or thermal decomposition temperatures) with information from coercivity parameters (such as B_c, B_{cr}, and MDF_{ARM}). When a sedimentary sequence contains a single magnetic mineral, it is possible to interpret the stratigraphic variations of the magnetic properties in terms of parameters that reflect the concentration of the magnetic mineral (such as κ, ARM intensity, M_s, and M_r) and parameters that reflect the magnetic grain size (such as frequency-dependent magnetic susceptibility and ARM/κ, B_{cr}/B_c, and M_r/M_s). Interpretation of these parameters is more difficult when a sequence contains mixtures of magnetic minerals, and inferences concerning concentration and grain size of the magnetic particles should be made with caution in such situations. However, when dealing with mixtures of a low coercivity ferrimagnetic mineral (*e.g.* magnetite) and a high coercivity canted antiferromagnetic mineral (*e.g.* hematite), the joint analysis of concentration-dependent and mineralogy-dependent parameters can be extremely useful in deciphering the various contributions of each component to the environmental magnetic record.

RESULTS

The data available at the end of the drilling season suggested a subdivision of the CRP-3 Cenozoic sequence into four rock magnetic intervals, based on stratigraphic variations of κ and changes in κ observed during thermal demagnetization of pilot samples for the magnetostratigraphic study (Cape Roberts Science Team, 2000). The measurements carried out after the drilling season, which are reported here, confirm the rock magnetic zonation proposed earlier.

Stratigraphic variations of the ARM intensity closely match the pattern reported for κ (Fig. 1). This correspondence enables identification of two intervals of high magnetic intensity (rock magnetic interval I: 0-243 mbsf and rock magnetic interval IV: 627-790 mbsf), where concentration-dependent rock magnetic parameters are consistently high with moderate variations. There are two intervals of relatively low magnetic intensity (rock magnetic interval II: 243-440 mbsf and rock magnetic interval III: 440-627 mbsf) where the concentration-dependent rock magnetic parameters generally have low base level values (κ = 5-20 x 10^{-5} SI and ARM = 1-2 x 10^{-2} A/m), although there are sharp transitions to thin zones with relatively high values. Thin high magnetic intensity zones are frequent in interval II but occur only at *c.* 550 mbsf in interval III (Fig. 1).

All of the thermomagnetic curves have a single distinct Curie point at *c.* 580ºC which indicates that magnetite is the dominant magnetic mineral in each of the four rock magnetic intervals (Fig. 2). There is no evidence for significant amounts of relatively high coercivity minerals (such as hematite) in the CRP-3 core, in contrast to our findings in the CRP-1 and CRP-2/2A cores (Sagnotti et al., 1998a; Verosub et al., 2000). For the majority of samples, the thermomagnetic curves are not reversible; during cooling the magnetizations are lower, possibly as a result of partial oxidation of magnetite to maghemite and/or hematite. Samples from low magnetic intensity intervals (*e.g.* 493.40 mbsf; rock magnetic interval III) are extremely weakly magnetized and it is difficult to obtain high quality data for such samples (Fig. 2). Regardless, when the data are interpretable, they are consistent with the dominance of magnetite. However, the thermal alteration products are often distinctly different for these samples, as indicated in the cooling curves. The precise cause of these differences is unknown, but it might relate to the matrix mineralogy.

κ_{fd} could not be properly determined for low susceptibilities (*i.e.* κ < 10 x 10^{-5} SI), however, measurements that were reliable indicate that κ_{fd} is generally below 3-4% and < 1% for about 60% of the CRP-3 samples, suggesting that the content of superparamagnetic (SP) magnetite grains in the size range of 0.015 – 0.03 µm is negligible. A more comprehensive characterization of superparamagnetic contents would require additional investigation.

Hysteresis parameters (M_r, M_s, B_c, B_{cr}, M_r/M_s and B_{cr}/B_c) for the CRP-3 core are shown in figure 3. Hysteresis data are presently available at 0.5-1 m intervals for most of the CRP-3 sequence, with larger spacings between 415 and 507 mbsf. Magnetite is the dominant magnetic mineral in the CRP-3 Cenozoic sequence (Fig. 2), therefore it is useful to plot the hysteresis data using the method of Day et al. (1977). The data are consistent with the presence of magnetic particles in the pseudo-single domain size range, with significant fluctuations in concentration. Coercivity parameters are relatively uniform throughout the core, although there is a tendency to slightly higher coercivities in interval I (Tab. 1).

For samples with magnetite as the dominant magnetic mineral, the ARM/κ value can be used as an indicator of magnetic grain size (King et al., 1983) because ARM acquisition is more effective in finer ferrimagnetic grains, whereas magnetic susceptibility is relatively insensitive to magnetite grain size (Heider et al., 1996). Grain-size and coercivity-dependent parameters indicate a general down-core coarsening trend of magnetite particles: both the ARM/κ ratio and MDF_{ARM} values are variable, but generally decrease with depth (Fig. 4). Rock magnetic interval IV is characterized by remarkably uniform ARM/κ and MDF_{ARM} values, which indicate uniform magnetite grain-sizes. Relative magnetic grain size can also be determined from the slope of the best-fitting line on a plot of ARM versus κ (Fig. 5). On such plots, the distance of a data point along a line of constant slope is indicative of the concentration of ferrimagnetic (magnetite) particles (King et al., 1983). For CRP-3, the progressive reduction in slope of the best-fit lines with depth on plots of ARM/κ confirms the general down-core increase in magnetic grain size (Fig. 5). Comparison of these plots with analogous plots for the CRP-1 and CRP-2/2A cores (see Fig. 6 in Verosub et al., 2000) demonstrates a progressive decrease in magnetite grain size with decreasing age in the composite CRP sequence.

The combined use of concentration-dependent and coercivity-dependent parameters also leads to a clear differentiation of the identified rock magnetic intervals. In a plot of MDF_{ARM} versus ARM (Fig. 6), the data from rock magnetic intervals I, III and IV fall into three distinct clusters, with little or no overlap among them. Data from interval II are more scattered and partly overlap with each of the three clusters, suggesting that interval II comprises a mixture of magnetic particles. Interval IV has distinctively lower coercivities than intervals I and III, which is consistent with the presence of coarser-grained magnetite. Even though intervals I and III have similar values of coercivity-dependent parameters, they can be differentiated on the basis of

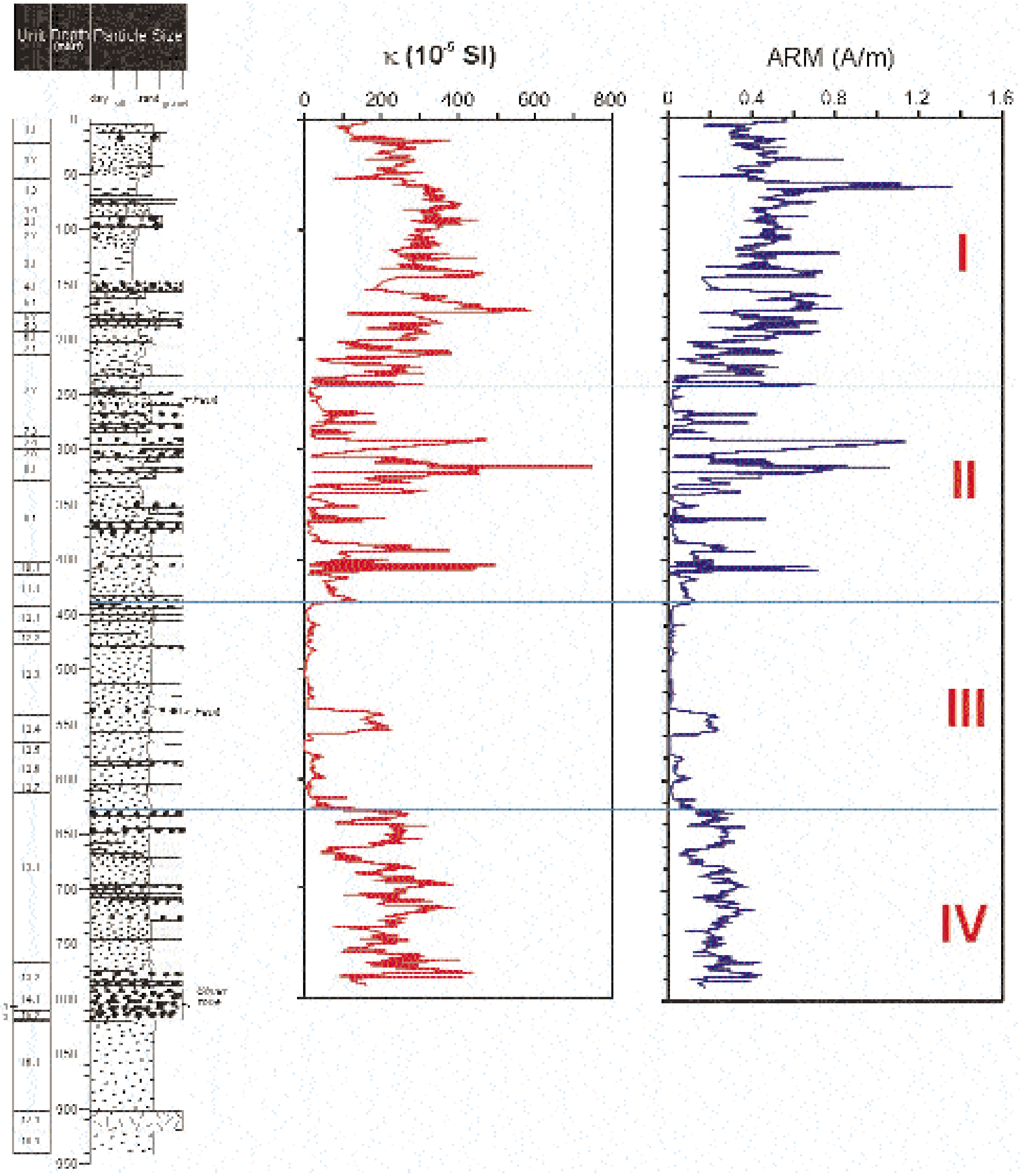

Fig. 1 - Stratigraphic variation of concentration-dependent rock magnetic parameters in the CRP-3 Cenozoic sequence (κ = magnetic susceptibility, ARM = anhysteretic remanent magnetization). Alternation of intervals of high and low magnetic intensity suggest a subdivision of the core into four main rock magnetic intervals (I-IV). Magnetic intensities are high in intervals I and IV with moderate variations. A background base level of low magnetic intensity is found in intervals II and III, with generally sharp transitions to alternating intervals of higher magnetic intensity. Such high magnetic intensity horizons are common in interval II and rare in interval III.

magnetite concentration because the ARM intensities are about one order of magnitude higher in interval I than in interval III.

DISCUSSION AND CONCLUSIONS

The CRP-3 environmental magnetic record consists of alternating intervals with high and low concentration of magnetite particles, respectively, and a generally progressive increase in magnetite grain size with depth. The environmental and climatic factors that resulted in this zonation can be understood by comparing the results with other data from the CRP-3 core. In particular, intervals of high magnetite concentration correspond to intervals with markedly higher abundances of clasts and grains

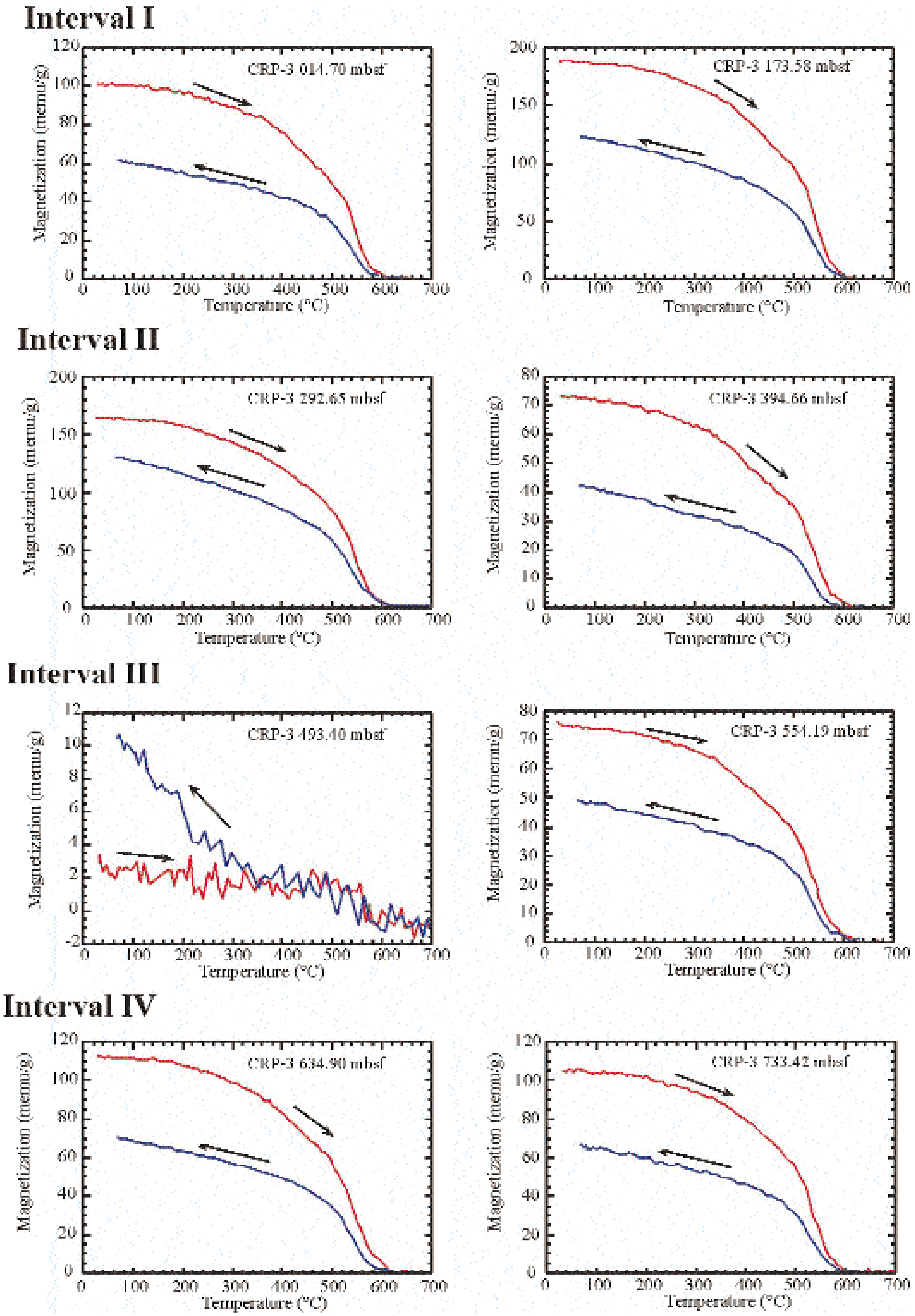

Fig. 2 - Thermomagnetic curves of magnetization changes during heating-cooling cycles from room temperature to 700ºC for eight selected samples. The heating curves distinctly show the Curie temperature for magnetite at *c.* 580ºC and indicate that magnetite is the dominant magnetic mineral in the CRP-3 Cenozoic sequence. The Curie point of magnetite is identifiable also in samples with extremely low magnetic intensity (*i.e.* 493.40 mbsf in rock magnetic interval III). The trend of the cooling curves below the heating curves indicate oxidation of original magnetite during the thermal cycles.

Tab. 1 - Hysteresis properties of the CRP-3 core.

Interval	B_{cr} (mT)	B_c (mT)	M_r/M_s	B_{cr}/B_c
I (0-243 mbsf)				
Mean	33.3	14.5	0.17	2.31
St dev.	3.3	2.0	0.03	0.17
II (243-440 mbsf)				
Mean	29.8	12.8	0.16	2.36
St dev.	4.2	2.5	0.05	0.37
III (440-627 mbsf)				
Mean	29.9	13.9	0.18	2.20
St dev.	4.1	3.3	0.04	0.28
IV (627-790 mbsf)				
Mean	27.8	12.2	0.15	2.29
St dev.	3.3	1.7	0.03	0.25

derived from the Ferrar Dolerite (Cape Roberts Science Team, 2000; Smellie, this volume). Sandroni & Talarico (this volume) reported a high content of dolerite clasts above *c*. 250 mbsf (average of 66%), with a progressive decrease down-core (average of 29% between 440 and 627 mbsf) followed by an increase between 627 and 800 mbsf (average of 44%). These results imply that high magnetic intensities in intervals I and IV result from increased erosion of the Ferrar Group rocks in the adjacent Transantarctic Mountains, which produced a greater input of magnetite particles.

Reductive diagenesis may also affect the concentration of magnetite in sediments. In reducing environments, magnetite dissolution is common (*e.g.* Canfield & Berner, 1987; Karlin & Levi, 1983; Karlin, 1990a, b). It has also been suggested that ultra-fine-grained ferrimagnetic particles might be diagenetically produced in reducing sediments and that stratigraphic variations in concentration of these particles might be related to variations in organic carbon input induced by major climatic changes (Tarduno, 1994; 1995). These possibilities are considered unlikely as primary determinants of the magnetic properties of the CRP-3 sequence for two reasons. First, there is a close correspondence between rock magnetic variations and fluctuations in detrital grains from the Ferrar dolerites, which suggests that the rock magnetic signal is primarily controlled by detrital fluxes rather than by diagenetic processes. Second, as discussed above, the concentration of SP particles appears to be negligible, which suggests that diagenetic production of fine-grained particles has not been significant.

Sagnotti et al. (1998b) observed intervals of increased magnetite and smectite concentration in late Eocene rocks (chrons C15n-C16n) in the lower half of the CIROS-1 core from Ferrar Fjord. They argued that such intervals resulted from increased chemical weathering of Ferrar Group rocks in the

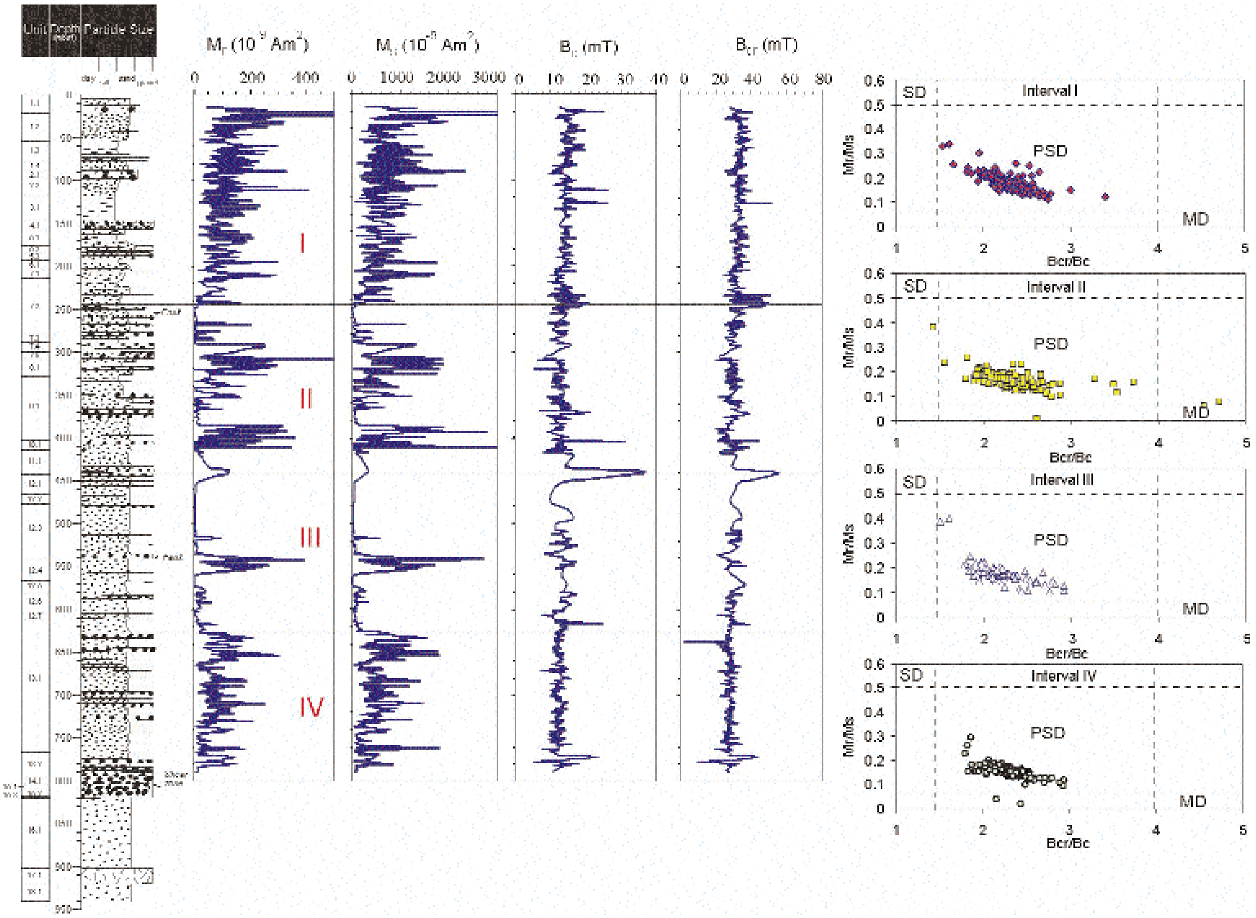

Fig. 3 – Down-core variation of hysteresis parameters (M_r, M_s, B_c, Bc_r) and plot of M_r/M_s versus B_{cr}/B_c ("Day plot"; Day et al., 1977) for the CRP-3 core. In the "Day plot" the fields marked for SD = single-domain, PSD = pseudo-single-domain, and MD = multi-domain particles, respectively, correspond to the ranges of values expected for crushed (titano)magnetite grains.

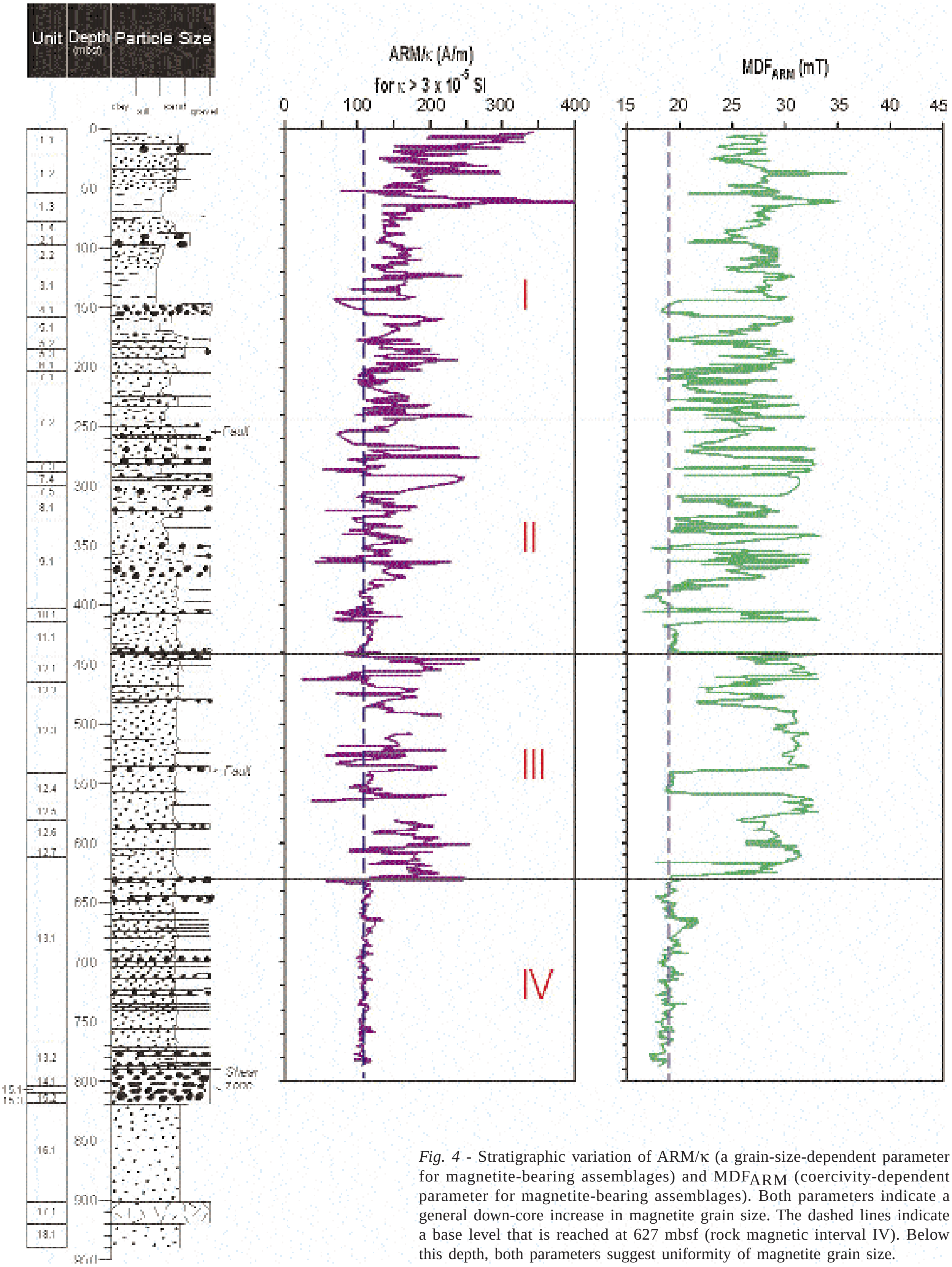

Fig. 4 - Stratigraphic variation of ARM/κ (a grain-size-dependent parameter for magnetite-bearing assemblages) and MDF$_{ARM}$ (coercivity-dependent parameter for magnetite-bearing assemblages). Both parameters indicate a general down-core increase in magnetite grain size. The dashed lines indicate a base level that is reached at 627 mbsf (rock magnetic interval IV). Below this depth, both parameters suggest uniformity of magnetite grain size.

Transantarctic Mountains in warmer climates, and, conversely, that the intervening intervals of decreased ferrimagnetic mineral and smectite concentrations indicated periods of physical weathering during relatively cold periods. Ehrmann (this volume) and Setti et al. (this volume) reported high concentrations of Mg-rich smectites (of the intermediate beidellite-saponite group) with high values of the crystallinity index in the clay fraction below 602 mbsf. This interval also corresponds to an increased content of

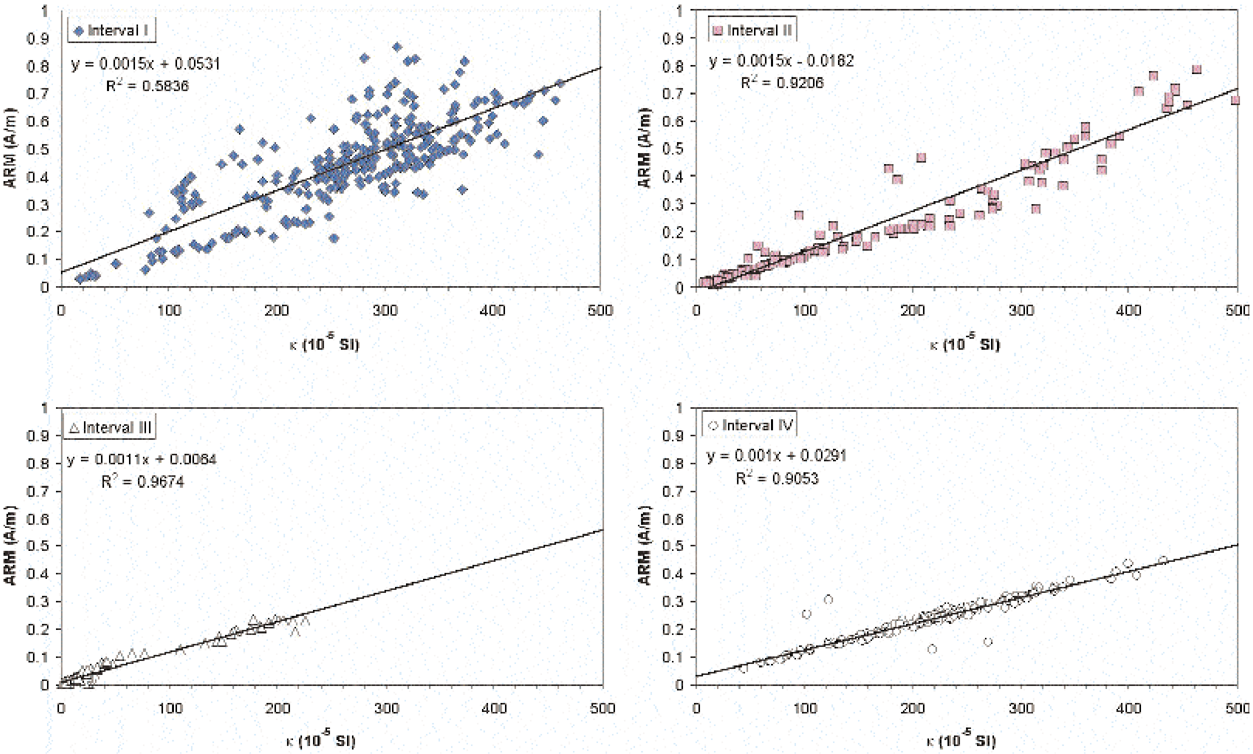

Fig. 5 - Plots of ARM versus κ for the CRP-3 Cenozoic sequence. The concentration of magnetite particles is expressed by the distance from the origin and the grain-size is expressed by the slope of the best-fit line. The relevant linear regression equations and correlation coefficients (R^2) are shown in each plot.

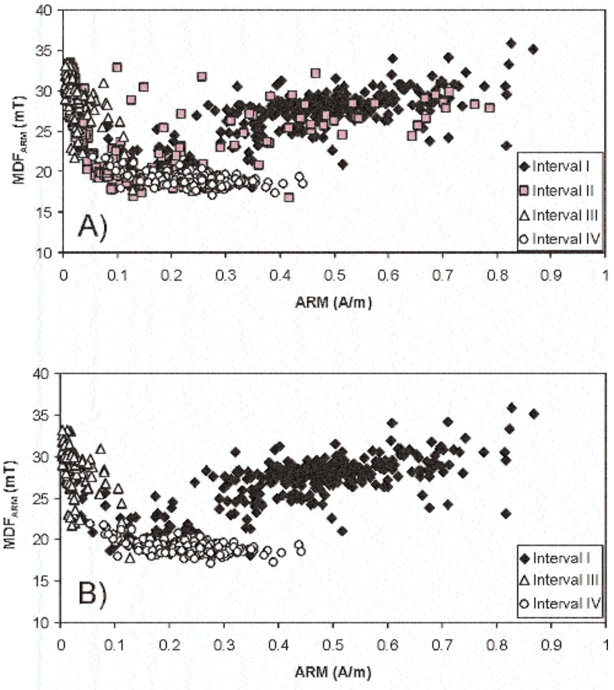

Fig. 6 - Plot of MDF_{ARM} (coercivity-dependent parameter) versus ARM intensity (concentration-dependent parameter) for the CRP-3 Cenozoic sequence. Data from rock magnetic intervals I, III and IV fall within three distinct clusters (B) and indicate a different origin or transport mechanism of magnetite particles for the three intervals. Data from rock magnetic interval II fall between the different clusters (A) and suggest a mixture of particles for this interval.

magnetite and Ferrar Dolerite clasts, that, analogously to the CIROS-1 core, may suggest a relatively warm period of increased chemical weathering on land. However, Setti et al. (this volume) suggest an authigenic origin for the smectites below 602 mbsf and state that interpretation of smectite concentrations in terms of palaeoclimatic reconstructions should be approached with care. In contrast, smectites in the upper part of the CRP-3 core are Fe-Al beidellites and are similar to those found in the CRP-1 and CRP-2/2A cores (Setti et al., this volume). Sagnotti et al. (1998a) and Verosub et al. (2000) also observed alternations of magnetite concentrations in the CRP-1 and CRP-2/2A cores, respectively, that did not correspond to clay mineralogical indicators of climatic variation. We assume, as suggested by Sagnotti et al. (1998a), that the higher magnetite concentration in rock magnetic interval I of CRP-3 resulted from a climatically induced increase in erosion of the Ferrar Group that occurred below the threshold required to alter the style of clay mineral formation on the Antarctic continent. In support of this interpretation, morphometric analysis of selected benthic foraminifera suggests that the upper 200 m of the CRP-3 core represent a warm period (Galeotti & Coccioni, this volume).

The link between the high magnetite concentration in rock magnetic interval IV of the CRP-3 core and relatively warm climate is supported by correlation with high-resolution deep-sea foraminiferal oxygen

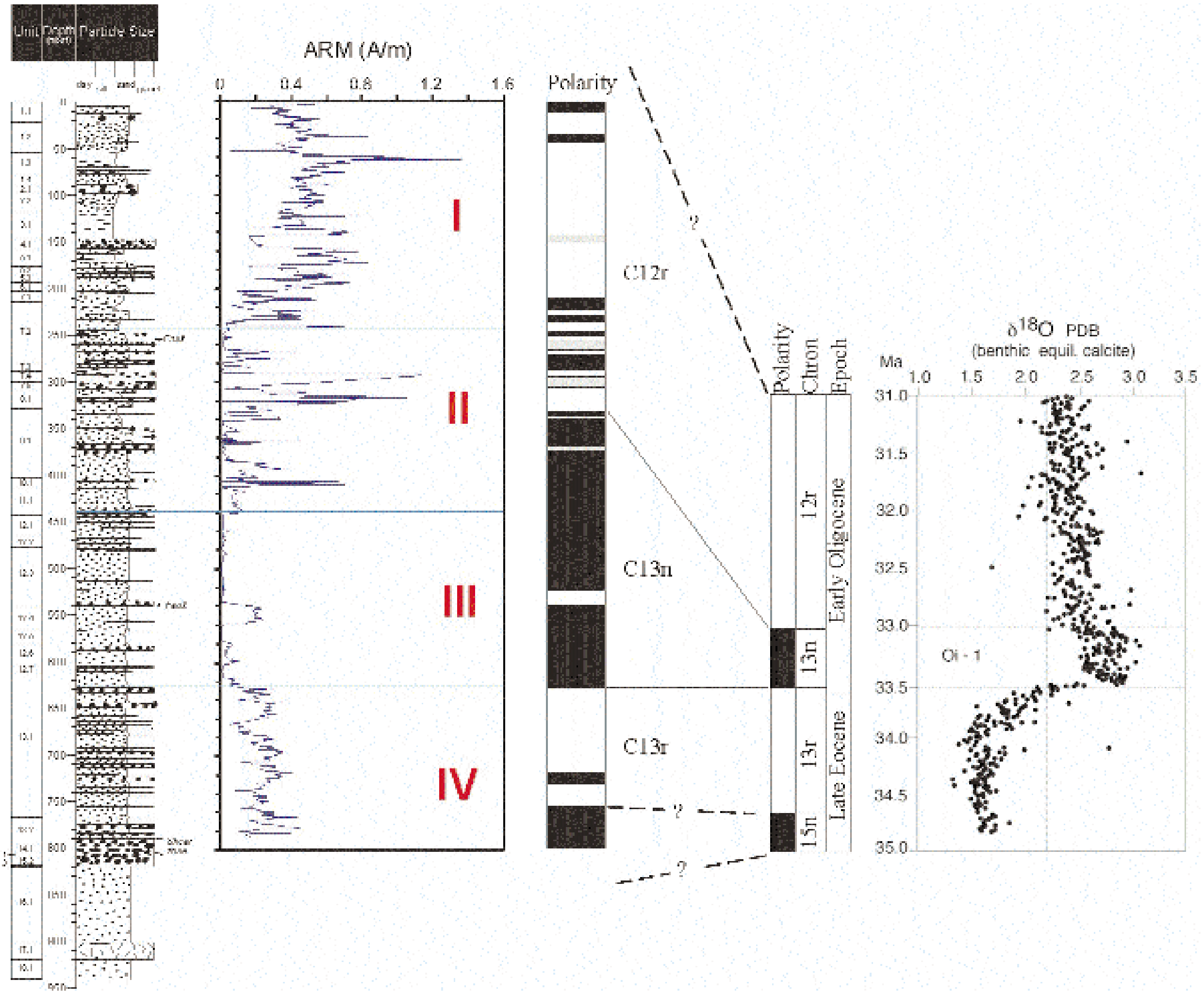

Fig. 7 - Stratigraphic variation of ARM and magnetostratigraphic zonation (from Florindo et al., this volume) for the CRP-3 core and correlation with a deep-sea $\delta^{18}O$ record from benthic foraminifera (Zachos et al., 1996), where the $\delta^{18}O$ values are reported in the delta (per mil) notation relative to the Pee Dee belemnite (PDB) standard. The oxygen isotope shift Oi-1 at the base of chron C13n, which is identified as a proxy for a major global cooling event, correlates to the boundary between rock magnetic intervals III and IV in core CRP-3. See text for discussion.

isotope records (Zachos et al., 1996; Fig. 7). Zachos et al. (1996) recognized a major $\delta^{18}O$ shift (Oi-1) that spans the chron C13r/C13n polarity transition. The C13r/C13n transition occurs just above the Eocene-Oligocene boundary and is dated at 33.55 Ma (Cande & Kent, 1995; Berggren et al., 1995). The Oi-1 event had a duration of <350 kyr, which spans the Eocene-Oligocene boundary, and marks one of the most significant global climatic deteriorations in the Cenozoic (Berggren & Prothero, 1992). In the magnetic polarity zonation of the CRP-3 core (Florindo et al., this volume), the boundary between rock magnetic intervals IV (high magnetite concentration) and III (low magnetite concentration) correlates with the interpreted position of the C13r/C13n polarity transition, which indicates that the warm-to-cold transition that we infer from CRP-3 strata corresponds to the Oi-1 isotopic event.

Zachos et al. (1996) suggested that the Oi-1 event might be linked to the rapid expansion of continental ice sheets in Antarctica. However, Wilson et al. (1998) and Sagnotti et al. (1998b) concluded, from lithological, magnetostratigraphic and environmental magnetic studies of the CIROS-1 core, that while cooling and climatic deterioration had begun in Antarctica earlier than the Oi-1 event, with alternating warm and cold climates in late Eocene times, there was no indication of major ice sheet growth prior to the early/late Oligocene boundary. We suggest the coincidence of decreasing magnetite concentration in the CRP-3 core and the major global $\delta^{18}O$ shift (Oi-1) at the base of chron C13n represents the most prominent step in the Eocene-Oligocene transition and a major cooling of Antarctic climate.

We also recognize higher frequency oscillations in rock magnetic parameters for the CRP-3 core. These fluctuations may have a climatic origin, but they may also be due to non-climatic local effects. In particular, the interval around 550 mbsf, which constitutes the single high magnetic intensity peak in rock magnetic interval III, is close to a fault (Wilson & Paulsen, this volume). Diagenetic siderite has formed in this zone

(Aghib F.S, pers. comm.) and there is a pronounced anomaly in the downhole temperature trend (Bücker et al., this volume) which indicates active fluid migration. The possibility of diagenetic modification of the environmental magnetic signal should be considered in this interval. In addition, repeated oscillations in magnetite concentration in rock magnetic interval II often correspond to distinct lithological changes (such as the positive peaks in fine-grained horizons at 240-243 mbsf; 264.3-270.5 mbsf; 275.5-277.5 mbsf; 312.3-324.9 mbsf; 363-364 mbsf; 408.5-412 mbsf). This implies a local lithological control on the environmental magnetic signal in these parts of the core.

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