Terra Antartica
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6 - Palaeomagnetism

INTRODUCTION

The goal of the palaeomagnetic investigations was to develop a magnetic polarity zonation for CRP-2/2A. The magnetostratigraphy for the Pliocene-Quaternary interval is described above (see Introduction chapter). The present discussion is restricted to the pre-Pliocene sequence below 26.79 mbsf.

Coarse-grained lithologies, such as diamicts, sands and sandy diamicts are common in CRP-2/2A (see Lithostratigraphy and Sedimentology chapter). Such lithologies are usually not suitable for palaeomagnetic analysis. However, in previous palaeomagnetic studies of sedimentary units from the Victoria Land Basin, strong and stable magnetizations have been recorded and even coarse-grained units have proved suitable for palaeomagnetic analysis (Wilson et al., 1998; Roberts et al., 1998). We attribute the stability of the magnetizations to the presence of fine magnetite particles within the fine-grained sediment matrix in these otherwise coarse-grained units (*cf.* Sagnotti et al., 1998a, 1998b; Wilson et al., 1998; Roberts et al., 1998). The success of previous palaeomagnetic work in the Victoria Land Basin suggests that further studies will provide valuable information for dating and correlating cores from the Cape Roberts Project.

METHODS

The majority of the sediments in CRP-2/2A are sufficiently consolidated to allow drilling of conventional cylindrical palaeomagnetic samples with a modified drill press. These samples were analysed in the palaeomagnetic laboratory at the Crary Science and Engineering Center, McMurdo Station, Antarctica. The sampling techniques, laboratory facilities and equipment used in this study are the same as those described by the Cape Roberts Science Team (1998a). Unconsolidated sediments were sampled with plastic cubes (6.25 cm^3) and were analysed in the palaeomagnetic laboratory at the University of California, Davis. The unconsolidated samples were measured on an automated, pass-through cryogenic magnetometer and were subjected to in-line stepwise alternating field (AF) demagnetization up to peak fields of 60 mT.

Information was collected at the drill site to enable azimuthal orientation of the core. However, these constraints were not available at the time of data analysis and no effort has been made to re-orient the core. Lack of azimuthal orientation does not pose a problem for magnetostratigraphical studies because the geomagnetic field has a steep inclination at the high latitude of the CRP-2 site (77°S). As a consequence, the palaeomagnetic inclination, which is determined from linear fits to characteristic remanence components on vector demagnetization plots, is sufficient to determine polarity uniquely (*i.e.* negative (upward) magnetizations correspond to normal polarity; positive (downward) magnetizations correspond to reversed polarity).

Where possible, the CRP-2/2A core was sampled at 0.5 m intervals. This strategy was adopted to avoid missing any short polarity intervals due to inadequate sampling. Lower sampling resolution was achieved in intervals where the lithology was unsuitable. However, sediment accumulation rates appear to have been sufficiently high (*c.* 10 m/My), for much of the core, that it is unlikely that short polarity intervals were missed due to inadequate sampling resolution. It is more likely that significant time is missing in the numerous disconformities in the core.

Diamictites and other coarse-grained sediments are common in CRP-2/2A. Whenever possible, samples were selected from fine-grained horizons. However, there was often no alternative but to sample diamictites or sandstone-dominated lithofacies. The diamictite matrix is often silt-sized and is, therefore, potentially useful for palaeomagnetic study. However, very coarse sand grains, granules and pebbles within samples from diamictites pose a problem because the deposition of such large particles would be controlled by gravitational rather than magnetic forces. Thus, their orientation could not be expected to represent the geomagnetic field at or near the time of deposition. This problem would be most severe for strongly magnetic basic igneous material, which is a common clast constituent in CRP-2/2A (see Petrology chapter). The presence of such grains means that care should be taken in interpreting palaeomagnetic data from coarse-grained intervals. The possible presence of clasts was taken into account by adopting a conservative interpretive approach within coarse-grained lithologies. After magnetic measurements were completed, such samples were examined to determine the presence of clasts. Results from such samples are considered reliable only if no clasts were visible, if the palaeomagnetic inclinations are consistently steep throughout coarse-grained intervals, and if the results from these intervals are consistent with results from surrounding finer-grained intervals.

One thousand and eleven samples were collected from CRP-2/2A (including the 25 samples from the Pliocene-Quaternary interval). Forty-four pairs of samples, each separated stratigraphically by a few cm, were collected at 5-10 m intervals from varying lithofacies throughout the core. These samples were used for a pilot study, which was aimed at determining the most suitable demagnetization technique for routine treatment of the samples. The pilot study was conducted by subjecting one sample from each pair to stepwise AF demagnetization, while the corresponding sample was subjected to thermal demagnetization. After measurement of the natural remanent magnetization (NRM), AF demagnetization was conducted at successive peak fields of 5, 10, 15, 20, 25, 30, 40, 50 and 60 mT and thermal demagnetization was conducted at temperatures of 120, 180, 240, 300, 350, 400, 450, 500, 550, and 600°C. Magnetic susceptibility was measured after each thermal demagnetization step to monitor for thermal alteration. Seven hundred and twenty five samples (including the Pliocene - Quaternary ones) were subjected to detailed stepwise demagnetization. Time constraints limited the number of samples that could be measured. Almost all samples from between 7 and 350 mbsf were measured; the spacing between measured samples was increased below 350 mbsf to enable preliminary assessment of the magnetic polarity stratigraphy to the bottom of CRP-2/2A.

Mineral magnetic studies were conducted on 18 samples after they had been subjected to stepwise AF demagnetization. These samples were given an isothermal remanent magnetization (IRM) with inducing fields of 0.05, 0.15, 0.2, 0.3, 0.4, 0.5, 0.75 and 1 T. The IRM (at 1 T) was then demagnetized by inverting the sample and applying fields of 10, 20, 30, 40, 50, 60, 80, 100, and 300 mT. IRM acquisition and back-field demagnetization studies were performed to determine the coercivity of remanence (B_{cr}) and a parameter known as the S-ratio ($-IRM_{-0.3T}/IRM_{1T}$). These parameters provide information about the bulk coercivity of the magnetic assemblage and are therefore useful in understanding the magnetic mineralogy (*e.g.* King & Channell, 1991; Verosub & Roberts, 1995). The IRM at 1 T (IRM_{1T}) and the low-field magnetic susceptibility are useful indicators of magnetic mineral concentration. Magnetic susceptibility was measured for 973 samples and the data were compared with the whole-core susceptibility log that was obtained at the Cape Roberts drill site.

RESULTS

PILOT STUDY

Results of the pilot study indicate that thermal and AF demagnetization are equally efficient in removing secondary remanence components and in isolating characteristic remanence components for both normal and reversed polarity samples (Fig. 6.1). The efficiency of the two techniques did not vary among intervals of relatively high and low coercivity. AF demagnetization was adopted for routine treatment of samples for the entire core because

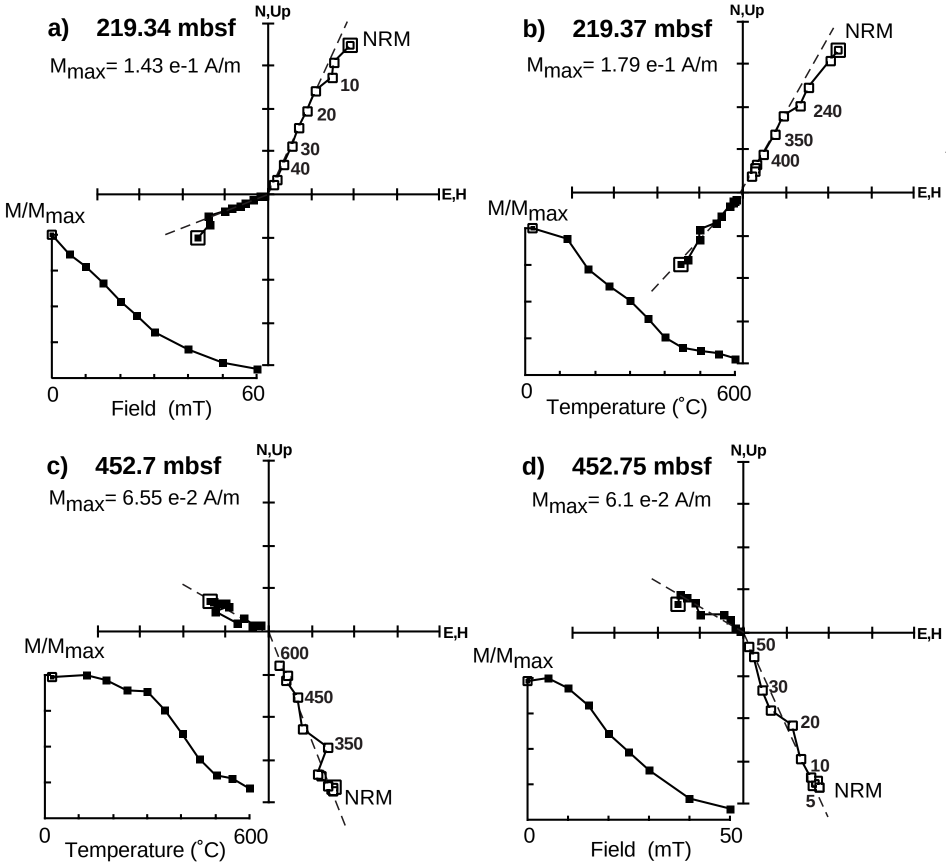

Fig. 6.1 - Vector component diagrams (with normalized intensity decay plots) of demagnetization behaviour of representative samples from the pilot study of CRP-2/2A: *(a)* and *(b)* comparison of AF and thermal demagnetization of normal polarity samples from 219.34 and 219.37 mbsf, respectively; *(c)* and *(d)* comparison of thermal and AF demagnetization of reversed polarity samples from 452.7 and 452.75 mbsf, respectively. Open (closed) symbols represent projections onto the vertical (horizontal) plane. The dashed lines represent linear regression fits which indicate the characteristic remanence component for each sample. The core is not azimuthally oriented, therefore declination values are not meaningful. The results indicate that thermal and AF demagnetization are equally efficient at removing secondary overprints and isolating characteristic remanence components for both normal and reversed polarity samples.

it is less time-consuming than thermal demagnetization and it also avoids thermal alteration.

PALAEOMAGNETIC BEHAVIOUR

Many of the analysed samples display a low coercivity, near-vertical, normal polarity component that is interpreted as representing a drilling-induced overprint. In most cases, this component was removed with peak AFs of less than 20 mT. In some cases, the drilling-induced overprint and the original remanence had completely overlapping coercivity spectra. In these situations, it was not possible to isolate the two components (*e.g.* Fig. 6.2a). Such samples were excluded from subsequent magnetostratigraphic interpretations. In some cases, particularly in dominantly sandy lithologies between 199.64 and 212.10 mbsf, another overprint is present. This overprint has a nearly horizontal inclination and a southward-directed declination (*e.g.* Fig. 6.2b). We attribute this overprint to contamination introduced by cutting the samples (after drilling) because the overprint is always perpendicular to the cut face of the sample (*i.e.* in sample coordinates, the overprint is entirely in the x-z plane, with y = 0). Rotation of the saw blade produces a measurable magnetic induction perpendicular to the blade. In most cases, the overprint produced by this field was easily removed by application of peak AFs of 10 mT. Where present, this overprint is usually stronger than the drilling-induced overprint. The saw-overprint is only sporadically present below 212.10 mbsf (mainly in sandy lithologies).

Many of the samples are from intervals where clasts may dominate the magnetic properties of the sample and

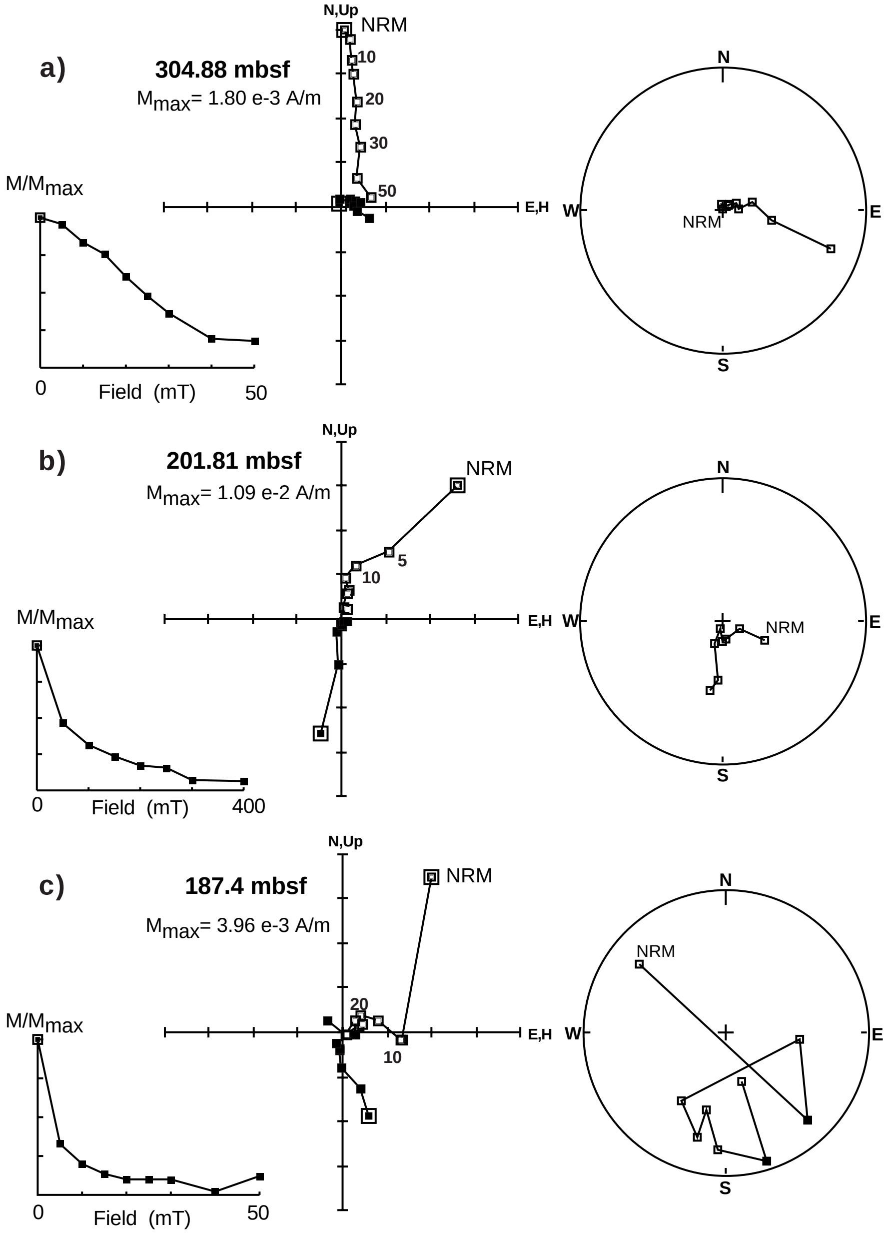

Fig. 6.2 - Vector component diagrams (with normalized intensity decay plots) for CRP-2/2A samples that illustrate: *(a)* a dominant drilling-induced overprint (304.88 mbsf), *(b)* a low coercivity saw overprint (201.81 mbsf), and *(c)* low coercivity and random behaviour in a sample that contains pebbles (187.4 mbsf). The conventions are the same as in figure 6.1. The stereoplots are equal area projections, with open (closed) symbols indicating upper (lower) hemisphere projections.

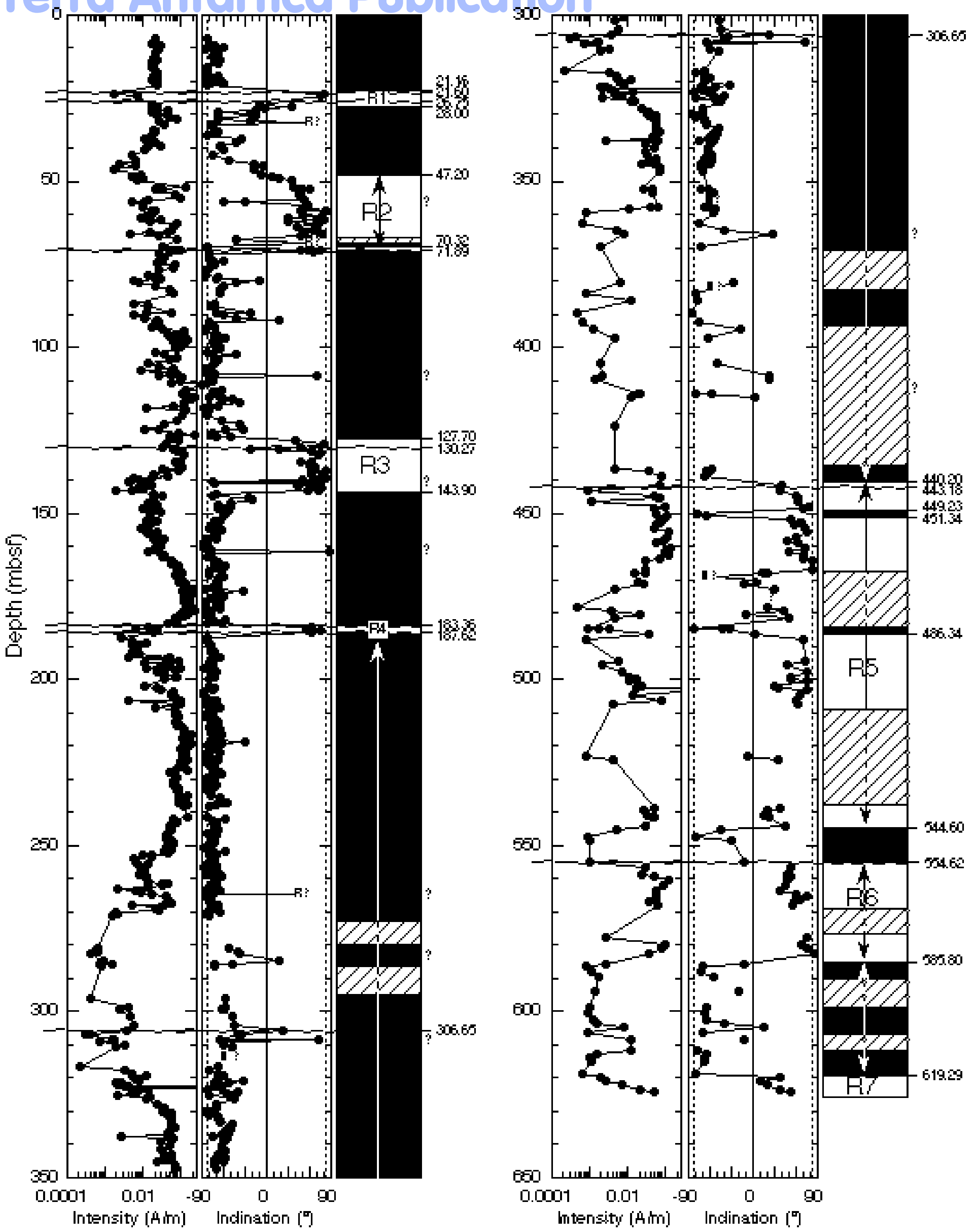

Fig. 6.3 - Plot of NRM intensity and inclination of the characteristic remanence component (identified from best-fit lines through data from multiple demagnetization steps, as shown in Fig. 6.1) with respect to depth for CRP-2/2A. Polarity is shown on the log to the right (black (white) = normal (reversed) polarity; cross-hatching indicates uncertain polarity), with magnetozones labelled from top to bottom (N1 to R7). The depths of polarity boundaries and major disconformities are also indicated. Dashed lines on the inclination plot indicate the expected inclination (± 83.4°) at the site latitude (77°S).

produce a magnetization that does not represent the geomagnetic field orientation at or near the time of deposition. Samples that contain such clasts usually display abnormal palaeomagnetic behaviour and are readily detected (*e.g.* Fig. 6.2c). Such samples were excluded from subsequent magnetostratigraphical interpretations.

Stable palaeomagnetic behaviour was evident from the vector component plots of 612 of the 700 demagnetized samples (87%). In most cases, the characteristic remanence direction was determined using a best-fit line that was constrained through the origin of the vector component diagram (*e.g.* Fig. 6.1). In some cases, the best-fit lines

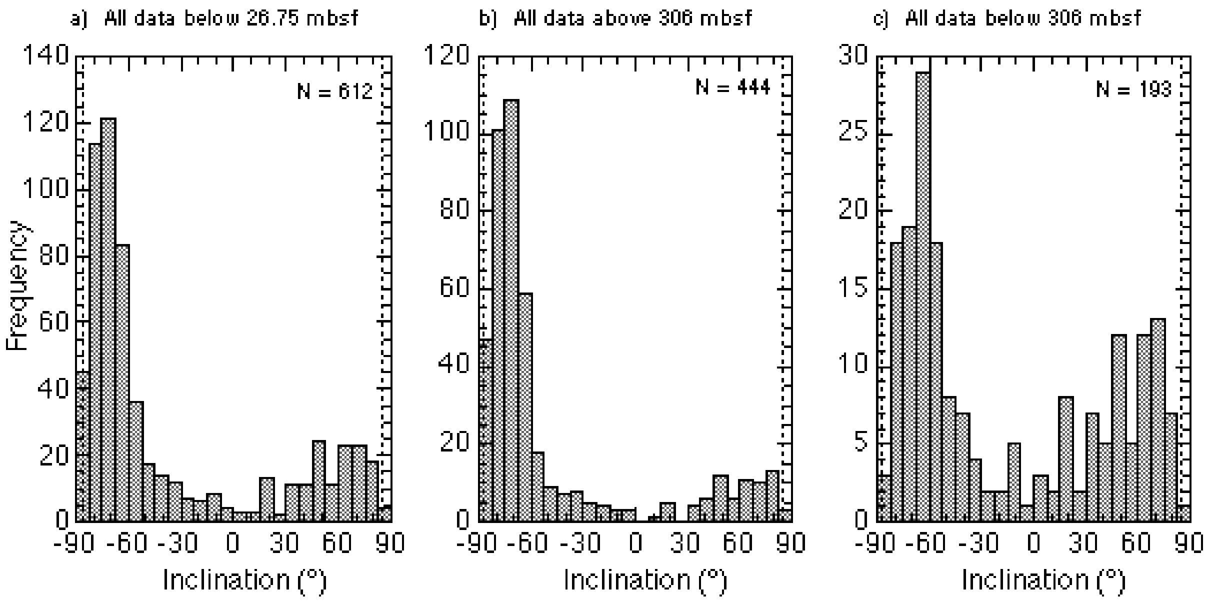

Fig. 6.4 - Histograms of palaeomagnetic inclinations for CRP-2/2A (from Fig. 6.3). *(a)* All data below 26.75 mbsf, *(b)* all data above 306 mbsf (including the Pliocene - Quaternary), *(c)* all data below 306 mbsf. In all cases, the inclinations are shallower than expected (± 83.4°; shown by dashed lines) for the site latitude. The inclinations appear to be shallower for the interval below 306 mbsf, which indicates that the disconformity at *c*. 306 mbsf probably represents an angular unconformity.

were not constrained through the origin of the plots. In other cases, the polarity of the characteristic remanence component was clear, but because of a low signal/noise ratio or incomplete removal of secondary components, the final direction of magnetization could not be precisely determined. In these cases, the sample is represented on figure 6.3 by either an N? or an R?

The inclinations of the characteristic remanence directions have a clear bimodal distribution that demonstrates the dominance of the two stable polarity states (Fig. 6.4a). Steep normal and reversed polarity directions, as would be expected at high latitudes, are clearly dominant. In conjunction with evidence from vector component diagrams (*e.g*. Fig. 6.1), this indicates that secondary remanence components have been successfully removed. The distribution of inclinations is strongly biased toward normal polarity. This is because of a combination of relatively high sedimentation rates (see discussion below), possible stratigraphical breaks that juxtapose more than one normal polarity zone, and a high measurement density. Furthermore, intervals in the lower part of the core, in which reversed polarity was dominant, were not analysed in such detail because of time constraints. It should therefore not be assumed that this polarity bias is cause for concern about the reliability of the palaeomagnetic signal from CRP-2/2A.

In addition, it appears that the palaeomagnetic inclinations below the disconformity at 306.65 mbsf are shallower than those above the disconformity (Fig. 6.4b, c). While more data (particularly reversed polarity data) are needed to demonstrate this possibility rigorously, the palaeomagnetic data may indicate that the disconformity at 306.65 mbsf represents an angular unconformity. This hypothesis needs to be tested with structural analyses of the core. This observation will also be more easy to quantify when a more complete palaeomagnetic data set is obtained after the drilling season.

Overall, both normal and reversed polarity directions are up to 15° shallower than expected (± 83.4°) for the site latitude (77°S; Fig. 6.4). There are two plausible explanations for this observation. First, tectonic tilting will cause rotation of the magnetic vector with the rock unit and, if the tilting was in an appropriate direction, it would cause shallowing of the palaeomagnetic vector for both normal and reversed polarity samples. Second, inclination error is commonly observed in sedimentary environments where bioturbation is not widespread, such as seems to be the case for some lithostratigraphical units in CRP-2/2A. In environments where bioturbation is widespread, magnetic particles have freedom to rotate and to follow the geomagnetic field in water-saturated shallow sediments. Thus, when the remanence is locked in, the magnetization of bioturbated sediments can provide an accurate record of the geomagnetic field. On the other hand, in sediments where bioturbation is absent, magnetic grains can roll as they settle onto the substrate and the resultant inclination can be retained in the absence of bioturbation (Verosub, 1977). In addition, sediment compaction has been interpreted as being responsible for inclination errors (*e.g*. Anson & Kodama, 1987; Arason & Levi, 1990). At present, we cannot distinguish between these possibilities. From core observations and seismic reflection studies, it seems likely that the sequence is tilted, but it is unlikely to be tilted by as much as 15° (Henrys et al., 1994; Core Properties and Down-Hole Geophysics chapter). It is therefore likely that the shallow palaeomagnetic inclinations result from a combination of these effects.

In addition to the dominantly steep normal and reversed polarity directions, a significant number of samples display behaviour that is transitional between normal and reversed polarity (*e.g*. Figs. 6.3 & 6.4). Most of these samples display stable palaeomagnetic behaviour and are not obviously affected by the presence of clasts. It is not

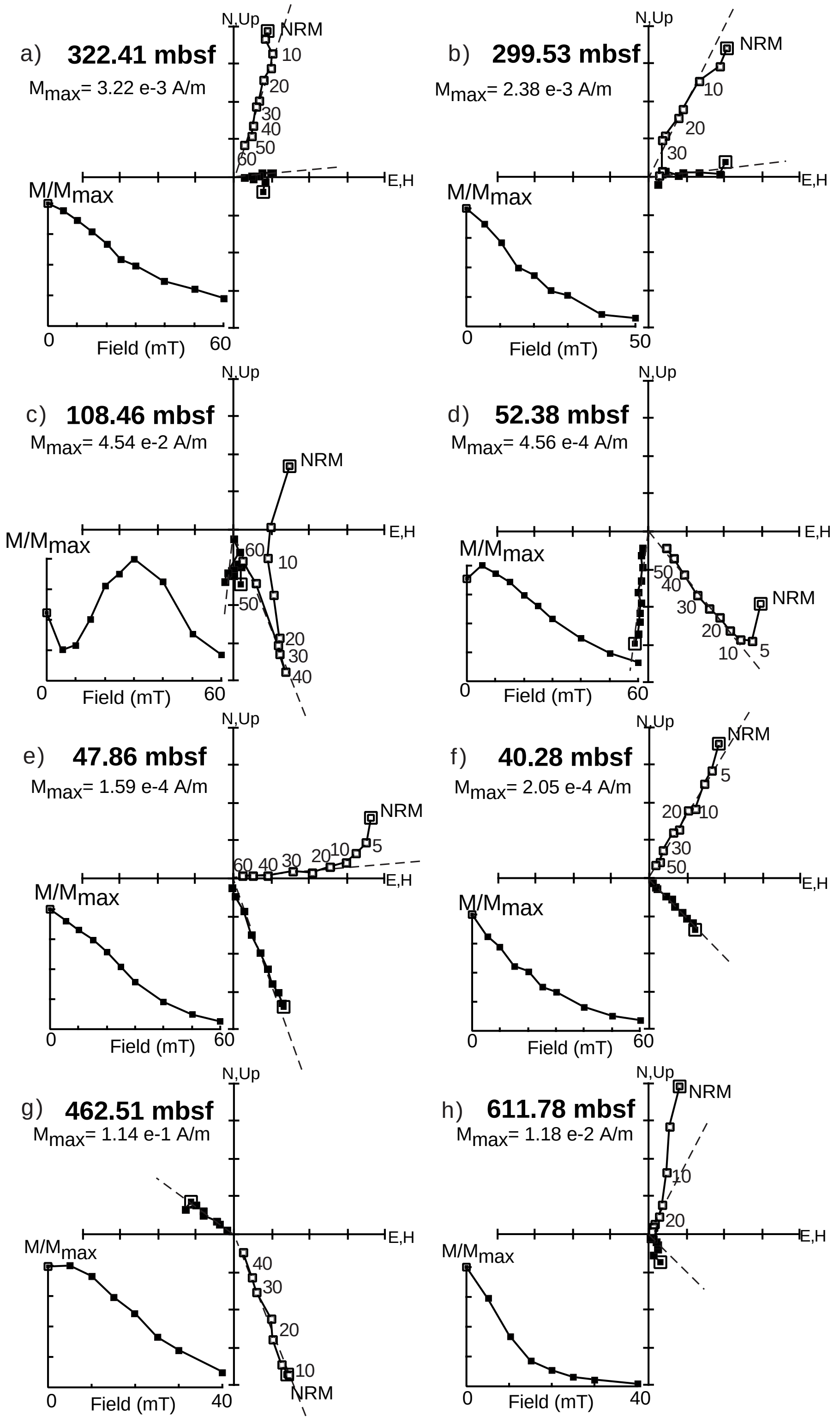

Fig. 6.5 - Vector component diagrams (with normalized intensity decay plots) for selected samples from CRP-2/2A: *(a)* a relatively high coercivity sample (322.41 mbsf), *(b)* a relatively low coercivity sample (299.53 mbsf), *(c)* a stable, but anomalous, reversed polarity sample from magnetozone N3 (108.46 mbsf), *(d)* a reversed polarity sample from magnetozone R2, below the detailed polarity transition (52.38 mbsf), *(e)* a sample from the polarity transition between magnetozones R2 and N2 (47.86 mbsf), *(f)* a normal polarity sample from magnetozone N2, above the detailed polarity transition (40.28 mbsf), *(g)* a stable reversed polarity sample from the lower part of the core (462.51 mbsf), *(h)* a normal polarity sample, from the lower part of the core, with behaviour that is difficult to interpret (611.78 mbsf). The conventions are the same as in figure 6.1. See text for discussion.

surprising that transitional directions are recorded in parts of the record that were rapidly deposited: there is a higher probability of recording deposition during geomagnetic polarity transitions in such intervals (see below).

Data from 88 demagnetized samples were not included in the magnetostratigraphic interpretation (Fig. 6.3). In total, 9% of the samples were unstably magnetized (*i.e.* the demagnetization behaviour was either incoherent or the samples had low coercivity), 2% of the samples had coercivity spectra that did not permit discrimination between a drill-string overprint and a stable characteristic remanence direction (*e.g.* Fig. 6.2a), and 2% of the samples were dominated by the effects of pebbles (*e.g.* Fig. 6.2c).

The quality of palaeomagnetic data does not seem to depend on whether the samples have high or low coercivity (unless the median destructive field is less than about 15 mT and the samples are clearly dominated by magnetically unstable multi-domain grains). Relatively high coercivities are observed in samples from 306.5 to 328 mbsf (about 25% of the NRM intensity remains after AF demagnetization to 60 mT; Fig. 6.5a). High coercivity is also observed in some samples between 297 and 306.5 mbsf, but here they alternate with low coercivity samples (fully demagnetized after AF treatment at 40-50 mT; Fig. 6.5b). Preliminary rock magnetic measurements indicate that there are significant concentrations of high coercivity minerals in samples from much of the core. Plots of IRM acquisition have steep slopes at low magnetic inductions. However, saturation is not usually achieved until above 300 mT (Fig. 6.6). This indicates that a fraction of high coercivity particles is present. S-ratios vary between 0.89 and 0.99 (Fig. 6.7). S-ratios of 0.98-1.00 indicate a dominance of low coercivity minerals. The S-ratio is highly non-linear and ratios of 0.95 can indicate the presence of substantial quantities of high coercivity minerals (*e.g.* Bloemendal et al., 1992). The observed range of S-ratios therefore indicates the presence of significant concentrations of high coercivity phases. The lack of significant differences in the relative efficiency of AF and thermal demagnetization in isolating characteristic remanence components indicates that, despite the presence of high coercivity particles, AF demagnetization is suitable for routine sample treatment.

Palaeomagnetic stability appears to be stratigraphically controlled, with data from zones of high remanence intensity being of better quality than those from zones of low intensity. In the upper *c.* 270 m of CRP-2/2A, the palaeomagnetic behaviour is of consistently high quality (Fig. 6.3). Below *c.* 270 mbsf, the palaeomagnetic behaviour is more variable because zones of low remanence intensity are more common. The lower quality of palaeomagnetic data in the lower part of CRP-2/2A, coupled with the lower measurement density, makes it difficult to interpret the magnetic polarity stratigraphy (see discussion below).

MAGNETIC SUSCEPTIBILITY

Previous studies of the CIROS-1 and CRP-1 cores demonstrated that the magnetic susceptibility (κ) signal is representative of changes in the concentration of pseudo-single domain magnetite and that these changes are environmentally (probably palaeoclimatically) controlled (Sagnotti et al., 1998a, 1998b). While it is impossible to interpret the κ signal from CRP-2/2A directly in terms of environment until more detailed rock magnetic investigations are carried out, some preliminary observations are relevant to the present discussion of the magnetostratigraphy.

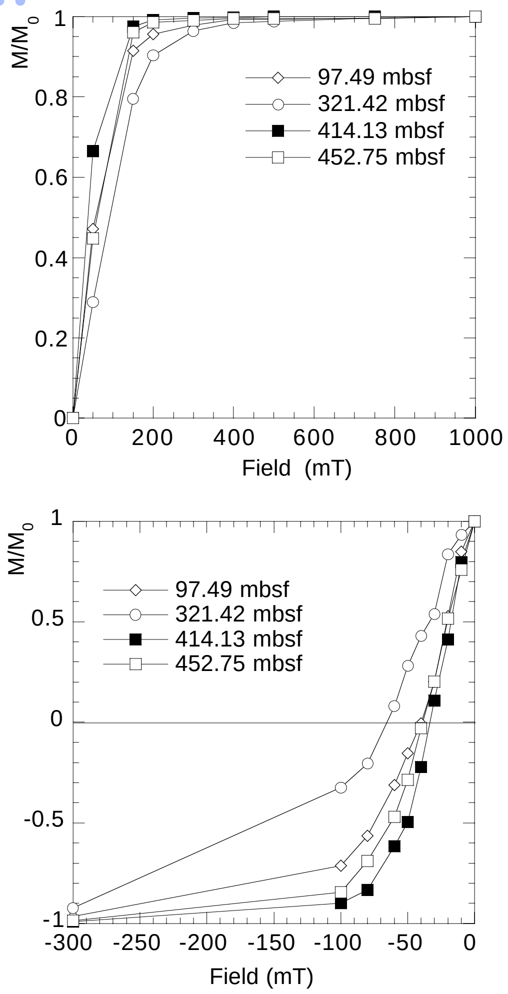

Fig. 6.6 - Plot of IRM acquisition and DC demagnetization of four representative samples from CRP-2/2A. Some samples have low coercivity (B_{cr} of about 40 mT) and saturate rapidly (below 300 mT), while other samples have high coercivity (B_{cr} of about 60 mT) and saturate above 300 mT, which indicates the presence of significant amounts of high coercivity phases.

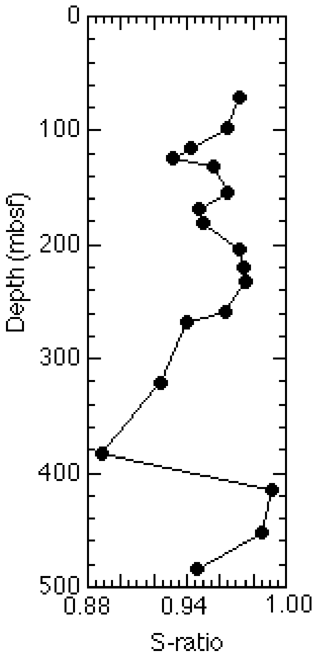

Fig. 6.7 - Plot of S-ratio (see text for definition) for 18 pilot samples with respect to depth for CRP-2/2A. S-ratios below about 0.97 indicate a significant high coercivity content.

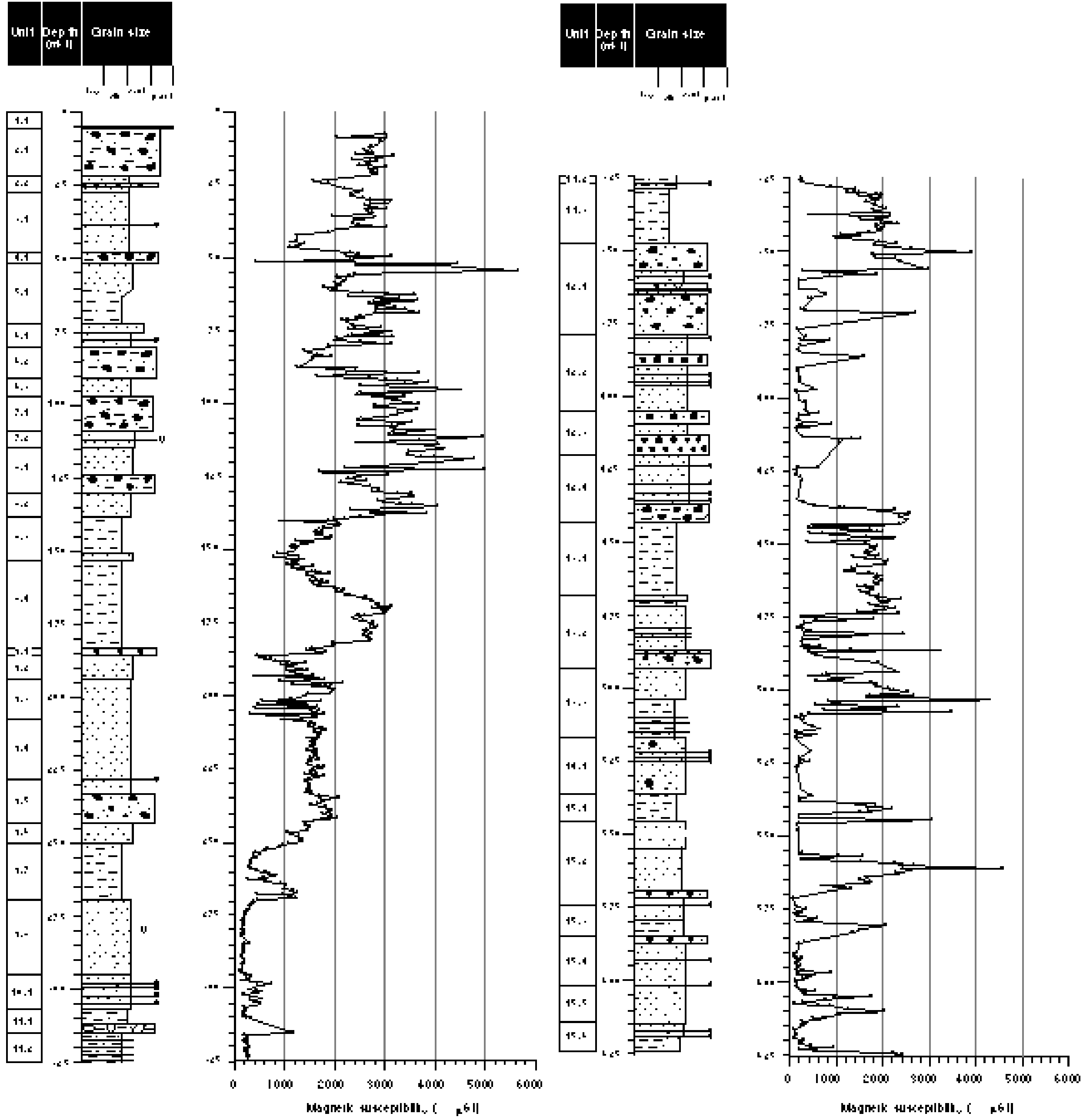

Fig. 6.8 - Magnetic susceptibility (in µSI) and lithostratigraphical variations for CRP-2/2A from discrete samples. The susceptibility record from discrete samples is similar to the whole-core record obtained at the drill site, except in conglomerate and diamictite units. In these lithologies, the whole-core record is affected by the presence of large clasts. The discrete sample record represents a better estimate of the magnetic susceptibility of the fine sediment matrix, although samples from some intervals contain pebbles and have more erratic susceptibility variations.

Volume susceptibility values include the contribution of all the minerals present in the sediment, in proportion to their intrinsic susceptibility and abundance. For susceptibilities larger than 300 µSI, it is generally assumed that the ferrimagnetic component dominates the para-magnetic and diamagnetic components (*cf.* Tarling & Hrouda, 1993). A paramagnetic "base level" susceptibility of *c.* 235 µSI was estimated for the CRP-1 core (Sagnotti et al., 1998b). The similar range of κ values in the many low κ zones (*c.* 150-250 µSI) below *c.* 270 mbsf (Fig. 6.8) suggests that the magnetic susceptibility in these zones is dominated by paramagnetic phases. It therefore seems likely that in the stably magnetized high-susceptibility zones (which dominate the upper part of CRP-2/2A), the contribution from ferrimagnetic grains overwhelms that of the paramagnetic matrix. In the weakly magnetized low-susceptibility zones (which are more common in the lower part of CRP-2/2A), the contribution of the para-magnetic grains may be comparable or even larger than that of the ferrimagnetic grains. The low values of remanence intensity in the low-susceptibility zones (Figs. 6.3 & 6.8) probably indicate that ferrimagnetic grains occur in low abundances in the low κ zones. These observations may account for the comparatively poor quality of palaeomagnetic behaviour in the lower part of CRP-2/2A.

It is evident, with respect to the sequence stratigraphical interpretation (see Sequence Stratigraphical Interpretation section), that some of the sequence boundaries correspond to sharp susceptibility changes. The relevant boundaries are at 21.6 mbsf (sequences 1-2), 51.94 mbsf (sequences 4-5), 185.94 mbsf (sequences 9-10), 356.83 mbsf (sequences 13-14), 420.53 mbsf (sequences 17-18), 443.18 mbsf (sequences 18-19) and 494.08 mbsf (sequences 19-20). Two sharp increases in κ are evident at *c.* 183.5 and 186 mbsf (Fig. 6.8). These sharp increases in κ correspond to the upper and lower boundaries of a magnetic polarity zone (Fig. 6.3) and coincide with the position of disconformities at 183.36 and 185.94 mbsf, respectively.

The discrete sample κ record agrees well with the whole-core κ record for most of CRP-2/2A. Careful selection of samples that represent only the matrix in diamictite units allows recovery of a susceptibility signal that is free from the influence of extraformational pebbles. As a consequence, the susceptibility record from discrete samples is more representative of the sediment matrix than the whole-core susceptibility log (see Physical Properties from On-Site Core Measurement section) for the intervals that are dominated by diamictites and/or dropstones. The discrete sample κ record from CRP-2/2A is still partially affected by the presence of extraformational pebbles, but such samples can be removed. This procedure produced a remarkable improvement of the susceptibility log in CRP-1 (compare Cape Roberts Science Team (1998c) with Sagnotti et al. (1998b)) and will be repeated for the CRP-2/2A core after the drilling season.

MAGNETIC POLARITY STRATIGRAPHY

The magnetic polarity stratigraphy shown in figure 6.3 is tentatively divided into 14 magnetozones: 7 of dominantly normal polarity and 7 of dominantly reversed polarity. The uppermost two magnetozones (N1 and R1) are of Quaternary and Pliocene age, respectively, and are discussed in the Pliocene-Quaternary Strata section. Here, we will only discuss the polarity zonation from N2 to R7, with implicit reference to figure 6.3. Also, any references to sequence stratigraphical interpretations refer to the Sequence Stratigraphical Interpretation section. It should be noted that the magnetic polarity zonation described below is preliminary and awaits refinement after measurement of further samples from the lower part of the record. It is unlikely, however, that further measurements will result in refinement of the zonation for the upper 350 m of CRP-2/2A (except, perhaps, for the sandy intervals from 273.5 to 281 mbsf and from 286.7 to 291.5 mbsf).

In many of the polarity zones, there are sporadic samples that display opposite polarities to those of the surrounding rocks (*e.g.* Fig. 6.5c). In each case, the palaeomagnetic behaviour is stable and the presence of a steep normal polarity drill-string overprint suggests that the samples have not been inadvertently inverted. In the following discussion, no interpretations are based on results from single samples because such samples could be anomalous.

Normal polarity dominates the interval from *c.* 28 to 47.20 mbsf. The transition from R2 to N2 is gradual and occurs across a lithostratigraphical boundary between LSU 4.1 (diamicton) and 3.1 (sands). Facies analysis indicates that the sands were rapidly deposited in a shoreface or deeper environment after glacial retreat (see Facies Analysis section). It is expected that time would be missing between the diamicton and the sands because the contact is sharp and not gradational. Stable palaeomagnetic directions are observed within both of the lithostratigraphical units below, within, and above the polarity transition (Fig. 6.5d-f). The diamicton and the sands have a significant mud content, which we presume is responsible for the strong and stable magnetizations. Transitional directions are recorded over a stratigraphical interval of about 6 m (Fig. 6.9). The upper part of the diamicton could have been disturbed by ice movement, which could have produced anomalous palaeomagnetic directions. However, all of the observed lithostratigraphical units are marine and it is possible that the entire sequence was water-lain (see Facies Analysis section). It is well-known that the process of polarity reversal occurs over periods of about 5-10 ky (Jacobs, 1994). If it is assumed that this interval represents a high-resolution polarity transition record, it is possible to directly estimate a sedimentation rate for the interval (*c.* 0.5-1 m/ky). This is a minimum estimate because the amount of missing time at the contact between LSU 4.1 and 3.1 is unknown. Given the thickness of the polarity transition, and the apparently continuously varying palaeomagnetic directions, it is likely that the sand, and possibly the underlying diamicton, were deposited relatively continuously rather than as discrete events (because the geomagnetic field usually varies slowly). Furthermore, this record suggests that little time is missing in the disconformity between LSU 4.1 and 3.1 (probably less than 1 ky). Our preliminary interpretation is that the boundary between magnetozones R2 and N2 is represented by a high-resolution polarity transition in rapidly deposited sediments. If this suggestion is verified by further work, it could provide valuable insights into rates of glacial processes. Such rapid deposition is likely to have occurred only over restricted time intervals because estimates of longer-term sediment accumulation rates for CRP-2/2A are much lower (*c.* 10 cm/ky; see below).

The boundary between magnetozones N3 and R2 occurs at a stratigraphical contact (71.89 mbsf) that is not interpreted as representing a sequence stratigraphical boundary. The boundaries between magnetozones N4 and R3 and between R3 and N3 do not appear to occur at disconformities, although several disconformities and sequence stratigraphical boundaries occur within these magnetozones. Magnetozone R4 is about 4.3 m thick and is restricted to the diamictite that comprises LSU 9.1. R4 is truncated by disconformities at the lower and upper surfaces of the diamictite. The lower disconformity is interpreted as a sequence stratigraphical boundary, but the upper disconformity is not.

N5 is a thick zone of normal polarity with several zones in which the polarity is uncertain. The intervals from *c.* 273.5 to 281 mbsf and from *c.* 286.7 to 291.5 mbsf are dominated by poorly consolidated sands. These intervals were sampled, but, because of the friable nature of the samples, it was not possible to analyse them on the high-

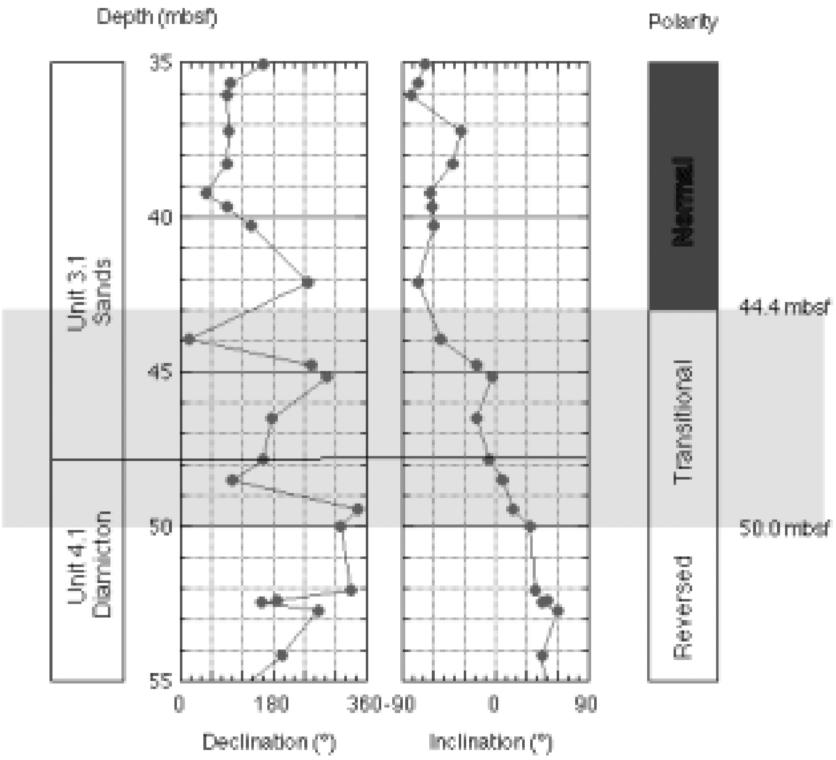

Fig. 6.9 - Variations in palaeomagnetic declination and inclination (identified from best-fit lines through data from multiple demagnetization steps) through the inferred geomagnetic polarity transition (shaded) between magnetozones R2 and N2. The core is not azimuthally oriented, therefore declination values are not meaningful. The transition crosses the contact between LSU 4.1 and 3.1. A minimum sedimentation rate can be estimated for the interval. This can help to quantify rates of glacial processes.

speed (89.2 revolutions per second) spinner magnetometer used at McMurdo Station. These samples will be analysed after the drilling season. It was not possible to collect samples from the following intervals because either the lithology was unsuitable or because the sediment was too deformed: *c.* 371-379, 401.5-404.5, 415.4-423.8 and 429.2-433.6 mbsf. In addition, significant parts of the two cross-hatched intervals in the lower part of N5 (Fig. 6.3) are unstably magnetized and, at present, reliable interpretations cannot be made for these intervals. Analysis of the remaining samples from these intervals may resolve the uncertainty.

Significant intervals of the lower part of CRP-2/2A are dominated by reversed polarity. A major disconformity occurs in the upper part of R5 at 443.18 mbsf. This disconformity is interpreted as a sequence stratigraphical boundary (between LSU 13.1 and 12.4); significant breaks have also been noted in sediment provenance and palaeontology at this level (see Petrology and Palaeontology chapters). One reversed polarity sample is recorded above this disconformity. It is therefore possible that R5, like other magnetozones that contain significant stratigraphical breaks, represents a composite magnetozone of more than one period of reversed polarity. Many of the reversed polarity zones in the lower part of CRP-2/2A have strong remanence intensities, whereas several zones of unstable magnetic behaviour, including some normal polarity zones, occur in intervals of weak remanence intensity. The reversed polarity samples are clearly interpretable (Fig. 6.5g), whereas the normal polarity samples can be difficult to interpret (Fig. 6.5h). There are two zones of normal polarity within R5. The upper zone (449.23 to 451.34 mbsf) is thin, but has strong and stable magnetizations, whereas the lower normal polarity zone has weaker magnetizations with erratic palaeomagnetic directions that are difficult to interpret. In addition, there are two zones in R5 from which samples were not collected due to a lack of suitable material for sampling: 516.3-520.7 and 548.5-554.7 mbsf.

Samples from magnetozone N6 are weakly magnetized and have scattered characteristic remanence component directions. The lower boundary of N6 occurs at a disconformity at 554.62 mbsf which represents a sequence stratigraphical boundary within LSU 15.2. R6 is a zone of stable reversed polarity which includes an interval with weak and unstable magnetizations that cannot be interpreted. Magnetozones N7 and R7 are relatively poorly defined: N7 contains numerous scattered normal polarity directions and R7 is defined by only a few reversed polarity samples at the base of CRP-2/2A.

The common occurrence of magnetozone boundaries at disconformities that do not coincide with interpreted sequence stratigraphical boundaries, as well as at sequence stratigraphical boundaries, suggests that there is a significant amount of time missing and that this missing time could be distributed throughout the record. It is clear that such a record requires independent constraints before a useful chronostratigraphical scheme can be developed.

Furthermore, because of the relatively poorly constrained magnetic polarity zonation for the lower part of CRP-2/2A, it is only possible, at this stage, to propose tentative correlations to the magnetic polarity timescale (MPTS) for this part of the core.

DISCUSSION

A preliminary correlation of the polarity of CRP-2/2A to the MPTS is plotted against lithology in figure 7.1, and includes constraints from available biostratigraphical data. The resulting age model and its construction are discussed in the Chronology section. Using the age model, it is possible to reach some preliminary conclusions about the CRP-2/2A record. Most of the record (*c*. 500 m) is Oligocene in age, with sedimentation rates of *c*. 100 m/My. This sedimentation rate suggests that only *c*. 5 My of the Oligocene has been recorded in CRP-2/2A, whereas the chronological constraints indicate that the record covers a span of about 14-16 My.

ADDITIONAL WORK

The above-reported initial characterization studies have served to identify several areas that warrant additional work. The magnetostratigraphy of CRP-2/2A clearly needs to be refined, particularly in the lower part of the record. This could have significant implications for the chronostratigraphical interpretation. The present interpretation is preliminary and should be used with caution. Although high quality palaeomagnetic results have been obtained from many of the CRP-2/2A samples, it is still important to characterize the mineral magnetic properties of different parts of the core. The mineral magnetic measurements will provide the basis for studies of the environmental magnetic record of CRP-2/2A.