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11. CORING-INDUCED MAGNETIC FABRIC IN PISTON CORES FROM THE WESTERN MEDITERRANEAN[1]

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ABSTRACT

We measured the magnetic fabric of 386 samples from Ocean Drilling Program from Hole 974B (Tyrrhenian Sea) and Holes 976B, 977A, and 979A (Alboran Sea). Samples are taken from the center of the working core section. The paramagnetic phyllosilicates dominate the magnetic susceptibility so that magnetic fabric mirrors essentially the clay fabric. In general, the magnetic fabric is typical of sedimentary fabric: (1) the shape of the magnetic fabric ellipsoid is oblate, (2) the magnetic foliation is horizontal and parallel to the bedding, (3) the degree of anisotropy is <1.04. When considering the magnetic fabric more closely, however, we observed deviation of the magnetic lineation parallel to the intersection of the split surface and the horizontal, as well as a small tilting of the magnetic foliation. These deviations, although better expressed in soft sediments, remain visible in lithified sediments where biscuiting is present. To explain the anomalous magnetic fabric, we propose drilling disturbance as the most probable cause. Piston coring causes a weak alignment of minerals in a conical fabric with an apex parallel to the vertical. The pervasive nature of the conical fabric and its occurrence from the edge to the center of the core suggests a relationship with the pervasive radial remagnetization observed in piston core sediments from Sites 974, 976, and 977.

INTRODUCTION

Our initial objective for this study was to document the possible imprint of recent deformation by studying the magnetic fabric of weakly deformed sediments. As we observed systematic anomalous magnetic fabric, we consequently focused our interest on the origin of the bias.

The determination of the magnetic fabric (i.e., the texture of magnetic grains) is a fast, volumetric, and nondestructive method (for comprehensive reviews, see Hrouda, 1982; Rochette et al., 1992). The magnetic fabric study of deep-sea sediments has proven to be a powerful technique to determine the grain texture of sedimentary (Rees and Frederick, 1974; Ellwood, 1980) or tectonic origin (Hounslow, 1990; Owens, 1993; Housen et al., 1996). The reliability of magnetic fabric determination was questioned by several authors. Kent and Lowrie (1975) observed anomalous magnetic fabric on the top and bottom of piston cores and proposed that it results from flow-in disturbance. Flow-in disturbance is generally visible when the sediment is not too homogeneous. Inverse magnetic fabric (i.e., with the minimum susceptibility axis parallel to the bedding plane) has been reported in the uppermost deep-sea sediments (Rees and Frederick, 1974; Kent and Lowrie, 1975; Hounslow, 1990). Explanations involved sample shape anisotropy (Kent and Lowrie, 1975; Ellwood, 1979), flow-in piston-core perturbation (Kent and Lowrie, 1975), change of magnetic mineralogy (Harrison and Peterson, 1965), or tectonic deformation (Hounslow, 1990). Sampling may also cause a significant bias of the magnetic fabric. Gravenor et al. (1984) observed deviation of the susceptibility axes up to 37° toward the push direction when sampling was performed parallel to the bedding. Copons et al. (1996) observed in piston core sediments deviation of the maximum susceptibility axis parallel to the intersection of the split surface and the horizontal plane of the core (Y-axis). They attributed this anomalous fabric either to the sampling effect or to the separation of halves after splitting the core (J. Parés, pers. comm., 1996). Recently, Herr et al. (1998) documented a sorting effect of the magnetic fabric from the right and left sides of the working half of the core. The maximum susceptibility axis is tilted from the bedding plane downwards. They proposed that bending and smear effects resulting from the coring technique are presumably responsible for the anomalous fabric.

Magnetic overprints also need some consideration, although their relationship with the magnetic fabric has not yet been proved. The magnetic overprints can completely obscure the natural remnant magnetization (NRM) of piston core sediments. During Leg 161, two kinds of magnetic overprints were reported (Shipboard Scientific Party, 1996a):

1. A steep downward overprint with a positive inclination of ~80°. This overprint is soft and is generally removed by the application of alternating field (AF) demagnetization at 5–10 mT.
2. A clustered declination at ~N0° for the archive half and N180° for the working half, parallel to the X-axis of the core coordinates. In short, bulk magnetization of the archive and working halves are both perpendicular to the split core surface.

Leg 154 paleomagnetists first documented the second type of overprint and found that it is a radially concentrated horizontal magnetization, namely "pervasive radial remagnetization" (PRR). Contrary to the steep downward overprint, the PRR is hard and resists demagnetization to 60 mT as well as at temperatures of 120°C (Shipboard Scientific Party, 1996b). Fuller et al. (1998) investigated the possible sources of PRR with tests on wash cores. They proposed that mechanical disturbance, in combination with magnetization of the advanced piston coring system (APC) barrel, is the most probable cause. PRR was found at all sites of Leg 161 mostly in APC cores. Note that below 120 meters below seafloor (mbsf), a deviated PRR is reported from the archive halves of the more lithified, extended coring system (XCB) sediments with a declination of 20° (Shipboard Scientific Party, 1996a). Coring deformation was proposed as a possible mechanism to explain PRR (Shipboard Scientific Party, 1996a). A similar conclusion was obtained by Herr et al. (1998). The outer parts of the core that are dragged down by the friction of the core liner

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are effectively strongly remagnetized, as shown by Leg 134 paleomagnetists (Shipboard Scientific Party, 1992). Whether the center of the core is affected by coring deformation remains unknown, but PRRs are also observed in U-channel samples (Herr et al., 1998). In addition, Herr et al. (1998) documented an anomalous magnetic fabric from samples taken from the edge of the core. They proposed a possible relationship between magnetic overprints and anomalous magnetic fabric. Our study completes the work of Herr et al. (1998) because we investigated the magnetic fabric from samples taken from the center of the core.

THE MAGNETIC FABRIC METHOD

Susceptibility axes ($K_1 > K_2 > K_3$) are the eigenvalues of a second-order tensor determined from low-field magnetic susceptibility measurements. The anisotropy of magnetic susceptibility (AMS) measures the ferromagnetic, paramagnetic, and diamagnetic grains. Magnetic susceptibility is dimensionless and is expressed in SI volume units. Basic elements of magnetic fabric are the magnetic foliation ($K_1 - K_2$ plane) and the magnetic lineation (grouping of K_1), when they exist. The shape of the tensor can be defined using lineation ($L = K_1/K_3$) and foliation ($F = K_2/K_3$) parameters. The tensor is oblate (prolate) when $L < F$ ($L > F$). Parameter F is sensitive to compaction, whereas L indicates the stretching of the magnetic ellipsoid. We measured the magnetic fabric using an impedance bridge Kly-2 (Geofyzika Brno) that works in a low magnetic field (40 µT) at a frequency of 1 Khz. The sensitivity is 5×10^{-8} SI, with an accuracy of 0.1% in stable conditions. The second-order symmetric tensor is resolved by measuring 15 positions, according to the Jelinek (1977) procedure. K_1 and K_3 susceptibility axes are plotted on a lower hemisphere equal area stereogram.

SAMPLING

Site 974 is located in the central Tyrrhenian Sea. We analyzed 187 samples of Pliocene–Pleistocene sediments from 1.85 to 201.66 mbsf. Sites 976, 977, and 979 are located in the Alboran Basin. From Hole 976B, we analyzed 57 samples from 1 to 571 mbsf. From Hole 977A, we analyzed 63 samples from 16 to 155 mbsf. From Hole 979A, we analyzed 79 samples from 4 to 569 mbsf.

During Leg 161, we sampled standard cubes (19×25 mm, 6 cm^3) from the working halves of the cores. Coordinates systems of the cubes and cores are shown in Figure 1. The Z-axis is parallel to the drilling direction, and the X-axis is perpendicular to the split surface of the core. Note that the sample coordinates are comparable for all samples from the same core (assuming no significant twist during core penetration). In soft-sediment sections, samples were collected by pushing the cubes into the half core until the cube was completely filled. In more lithified material (typically at ~40 mbsf), before sampling, we cut a cubic shape into the core using a knife. The second method was used whenever possible because it avoided rotation of K_1 parallel to the pushing direction (X-axis) (Gravenor et al., 1984).

MAGNETIC FABRIC RESULTS

Magnetic Mineralogy

Sources of magnetic susceptibility and the origin of magnetic susceptibility are discussed by Aubourg et al. (Chap. 9, this volume). Paramagnetic susceptibility is dominant when magnetic susceptibility is <300 µSI (10^{-6} SI units by volume). This is true for most of the samples from Holes 976B, 977A, and 979A (Fig. 2). Only a few samples from Hole 974B have ferromagnetic susceptibility larger than the paramagnetic susceptibility (Aubourg et al., Chap. 9, this volume). The large dominance of paramagnetic susceptibility means that magnetic fabric basically mirrors the texture of paramagnetic clays (Table 1, on CD-ROM, this volume).

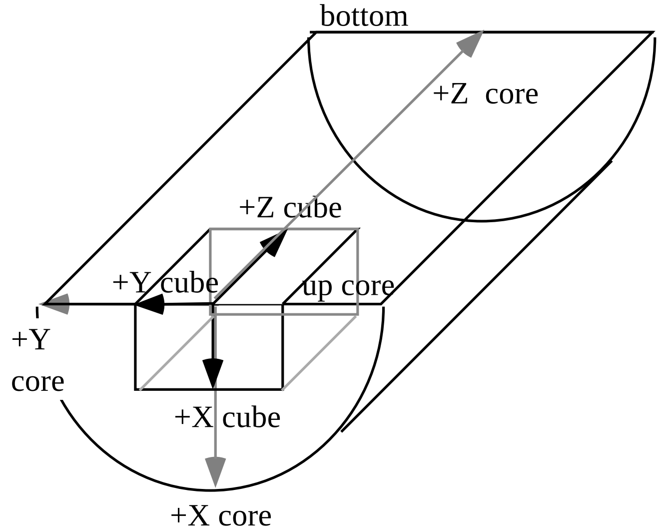

Figure 1. Samples and working half coordinate systems. X, Y, and Z in both systems are coaxial.

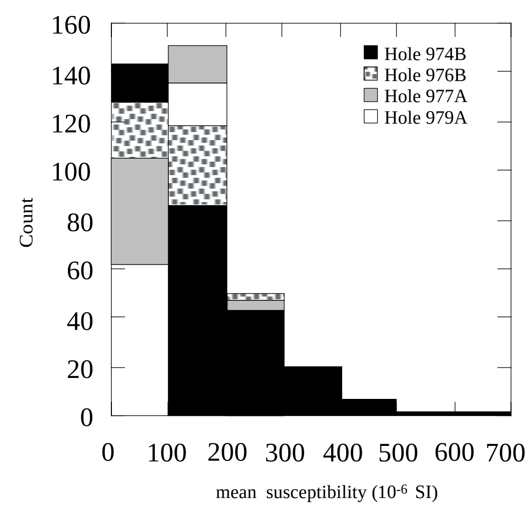

Figure 2. Histogram of mean magnetic susceptibility K_m (µSI) of samples from Holes 974B, 976B, 977A, and 979A.

Scalar Values

Magnetic fabric is characterized by an oblate shape for almost all samples (Fig. 3). In Hole 974B, F ranges from 1 to 1.072 and L from 1 to 1.025. The mean values of F are 1.020, 1.020, 1.014, and 1.035 for Holes 974B, 976B, 977A, and 979A, respectively. The mean value of L is ~1.005 for all sites. These values indicate a very low degree of deformation, which essentially results from compaction. In Hole 976B, F values are particularly low and are close to L values below 500 mbsf (Fig. 3). F increases roughly with depth in Hole 976B. Conversely, F decreases with depth in Hole 974B. In Holes 977A and 979A, F shows no systematic change.

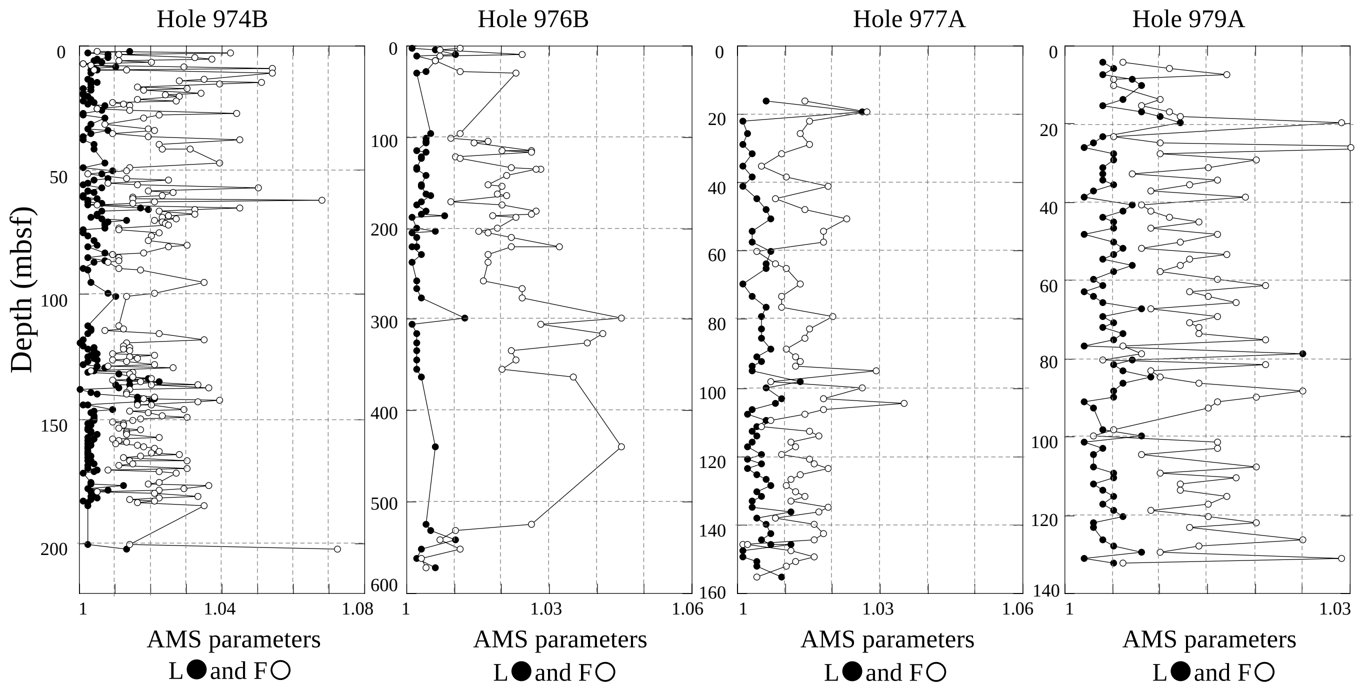

Figure 3. Anisotropy of magnetic susceptibility (AMS) parameter profiles. $L = K_1/K_2$ (solid circles) and $F = K_2/K_3$ (open circles) are plotted vs. depth (mbsf). Note that horizontal and vertical scales are different for each hole.

Directional Elements

The magnetic foliation in all holes is generally subhorizontal and parallel to the bedding. Histograms of the declination of K_1 and K_3 in core coordinates (Fig. 4) show a systematic bias of the magnetic fabric. K_1 is closely parallel to the Y-axis (N90° and N270°), whereas K_3 declination seems deviated toward the –X-axis (N180°). The magnetic lineation parallels the split surface of the core within the horizontal plane (Y-axis of the cube), whereas the magnetic foliation dips slightly parallel to the X-axis of cube. The clustering of AMS directions vs. depth (Fig. 5) shows the following:

1. A clustering of K_1 parallel to N90° and N270° between 0 and 200 mbsf. Below 200 mbsf, data from Hole 976B are too scarce to reveal any deviation; and
2. A close grouping of K_3 near N180° between 0 and ~60–100 mbsf (Holes 974A, 977A) and a greater scale of K_3 declination below 100 mbsf.

Sediments from the uppermost 8 mbsf (Fig. 6A) have a vertical magnetic foliation (plane K_1/K_2), in contrast with the subhorizontal bedding plane. K_1 is either vertical (Z-axis) or horizontal (Y-axis). Samples from Cores 161-974B-1H (Fig. 6B) and 19X (Fig. 6C) are good examples of the deviation of K_1 and K_3 toward the Y-axis and the X-Z plane, respectively. It is remarkable that this deviation is also observed in sections where biscuiting affects the core (Core 161-974B-19X). Samples from Core 161-974B-15H (Fig. 6D) show two distinct magnetic lineations: the weakest ($L = 1.002$) is parallel to the Y-axis, and the most anisotropic ($L = 1.012$) is oriented N60°. Samples from Cores 161-974B-20X (Fig. 6E) and 18H (Fig. 6F) show similar features. The histogram (Fig. 4A) shows that the K_1 declination deviates from the Y-axis by 10°–20° in a significant number of samples. There is a fair grouping of K_1 parallel to N80 and N260 in samples from Hole 974B, whereas it is N100°–N110° in samples from Hole 979A. Samples from Core 161-977A-15H (Fig. 6H) show a typical sedimentary magnetic fabric in which no bias is apparent. The stack of samples from 15 different cores from Hole 974B below 275 mbsf (Fig. 6I) shows horizontal magnetic foliation and no clear deviation of K_1 parallel to the Y-axis.

DISCUSSION

The Origin of Magnetic Fabric Bias

Several explanations can account for the relationship between the core coordinates and the magnetic fabric axes. We will examine shape anisotropy of the cube, sampling procedure, piston core deformation, core splitting, and shape anisotropy.

Several studies have documented a shape-sensitive anisotropy in cylindrical samples measured using a spinner magnetometer (Kent and Lowrie, 1975; Veitch et al., 1983) or torque magnetometer (Ellwood, 1979). These authors noticed a significant deviation of K_1 along the length axis of core specimens. Kent and Lowrie (1975) found that deviations occurred only when using a spinner magnetometer and disappeared when using a torque magnetometer. They rejected grain interaction as a possible source because of the very weak susceptibility (10^{-5}–10^{-3} SI). Instead, they proposed that the anomalous fabric results from the measurement procedure and the position of the cylindrical sample relative to the detector. In contrast, Ellwood (1979) found that a sample shape effect also exists when using a torque magnetometer and is more important if magnetite grain diameter is <10 mm. To date, no shape anisotropy problem has been recorded when measuring cores or cubes using an impedance bridge, such as the Kly-2 (F. Hrouda, pers. comm., 1997).

We investigated two possible causes of shape anisotropy that result in parallelism of K_1 and K_2 to, respectively, the X- and Y-axes of the cube: (1) the interaction of ferromagnetic grains distributed uniformly within the matrix; (2) a nonhomogeneous magnetic field during measurement.

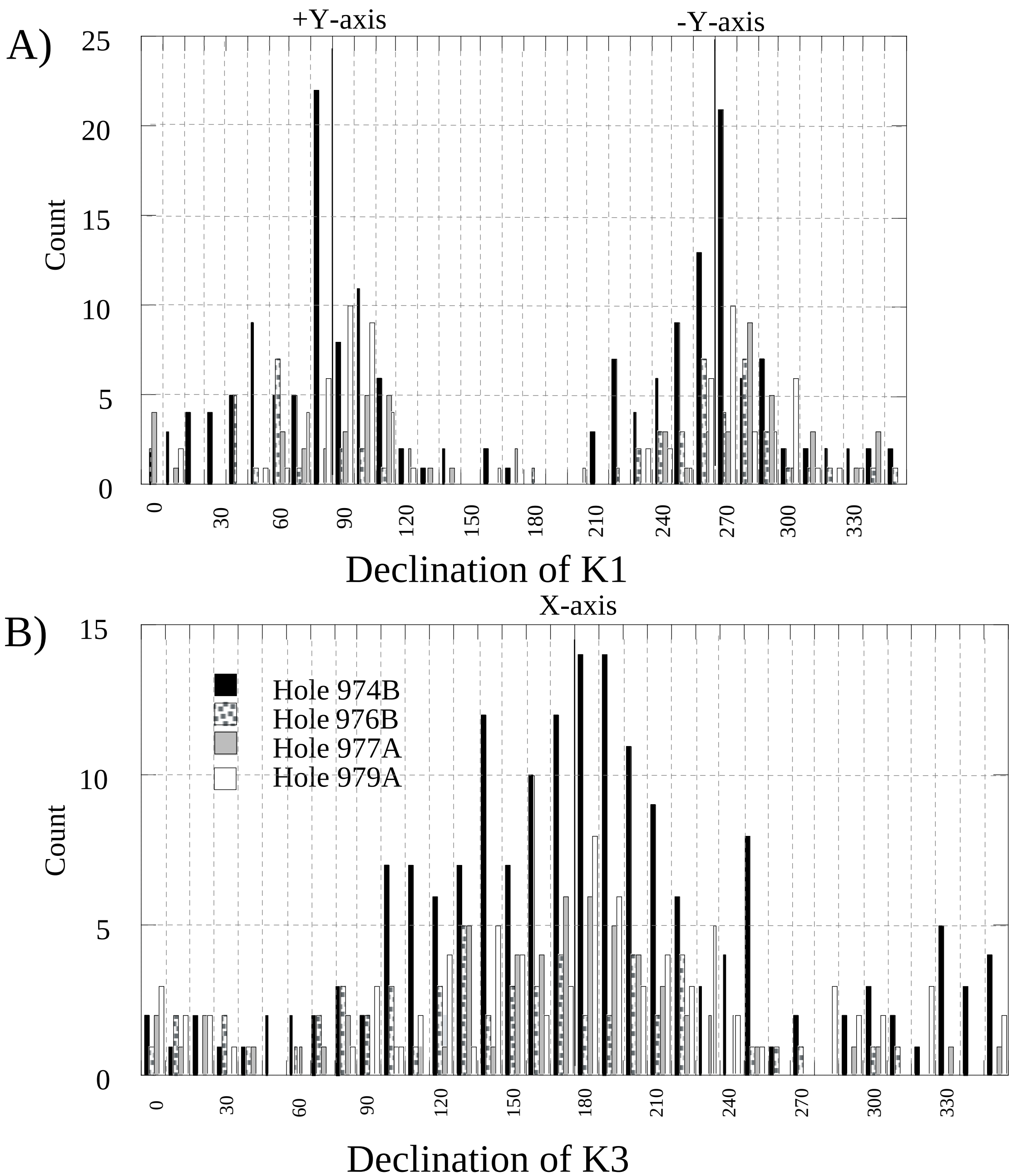

Figure 4. **A.** Histogram of declination of maximum AMS axes (K_1). **B.** Histogram of declination of minimum AMS axes (K_3). Both declinations are in sample and core coordinate systems.

1. A non-uniform distribution of equant magnetites may result in a significant anisotropy (Canon-Tapia, 1996). According to Stephenson (1994), “distribution” anisotropy is likely when ferromagnetic grains exceed 0.1% by volume. In the studied samples, a large part of the susceptibility is controlled by paramagnetic grains and magnetite content is generally <0.01% and very rarely a maximum of 0.1% (given a ferromagnetic susceptibility of 10^{-4} and 10^{-3} SI, respectively). We conclude that the interaction of ferromagnetic grains is not responsible for the anomalous magnetic fabric.
2. It is possible to obtain a sorting effect of AMS of isotropic material if a parallelepipedic holder is in a nonhomogeneous AF magnetic field. The magnetic susceptibility may not have the same magnitude from the center to the edge of the holder because of the decreasing value of the alternating field. The coil of the Kly-2 has a uniform field at 0.2° within a cylinder of 43–41 mm (diameter and length). Because the 19- × 25-mm cube nearly fills this area of uniform field, we assume no sorting effect resulting from the holder position.

To test the shape anisotropy, we performed two experiments. First, we reshaped eight samples that show deviation of K_1 parallel to the Y-axis. Magnetic lineation did not change orientation after cutting the samples, and the K_y/K_x ratio increased only slightly (Fig. 7A). Second, we measured sediment powder from Holes 974B in the 19- × 25-mm cubes. Note that there was a small compaction when the cube was closed if the cube was completely filled. This compaction may have minimized the susceptibility parallel to the X-axis and con-

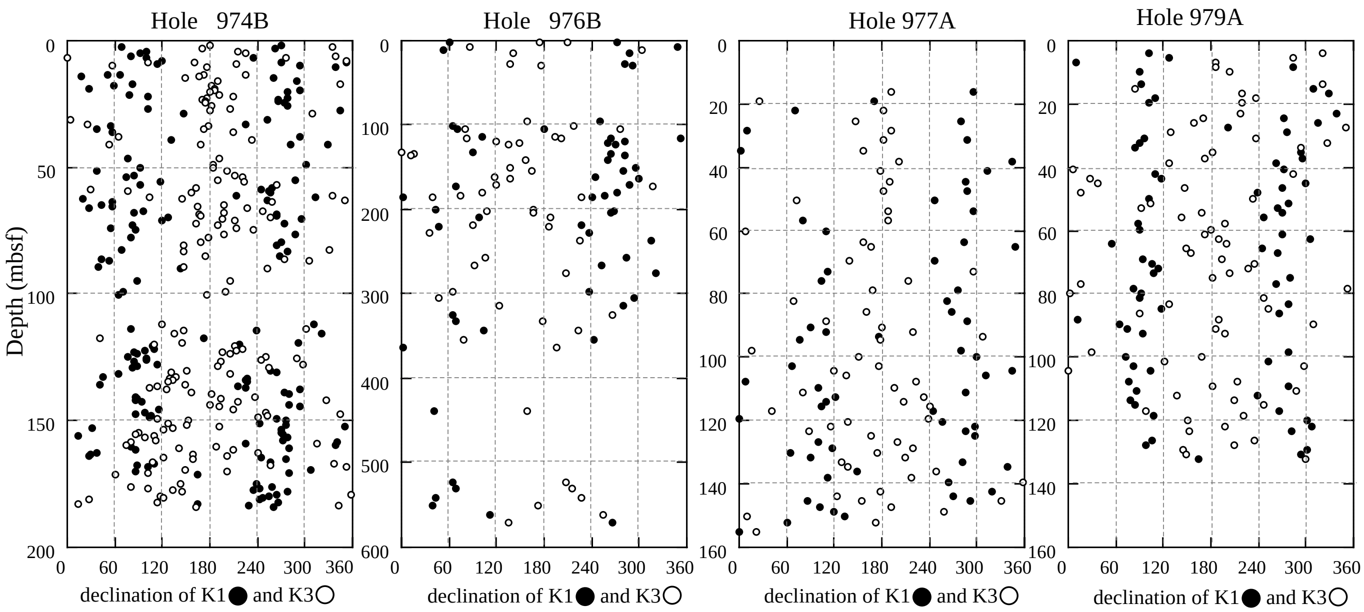

Figure 5. Declinations of K_1 (solid circles) and K_3 (open circles). Declinations are plotted in sample coordinates vs. depth (mbsf).

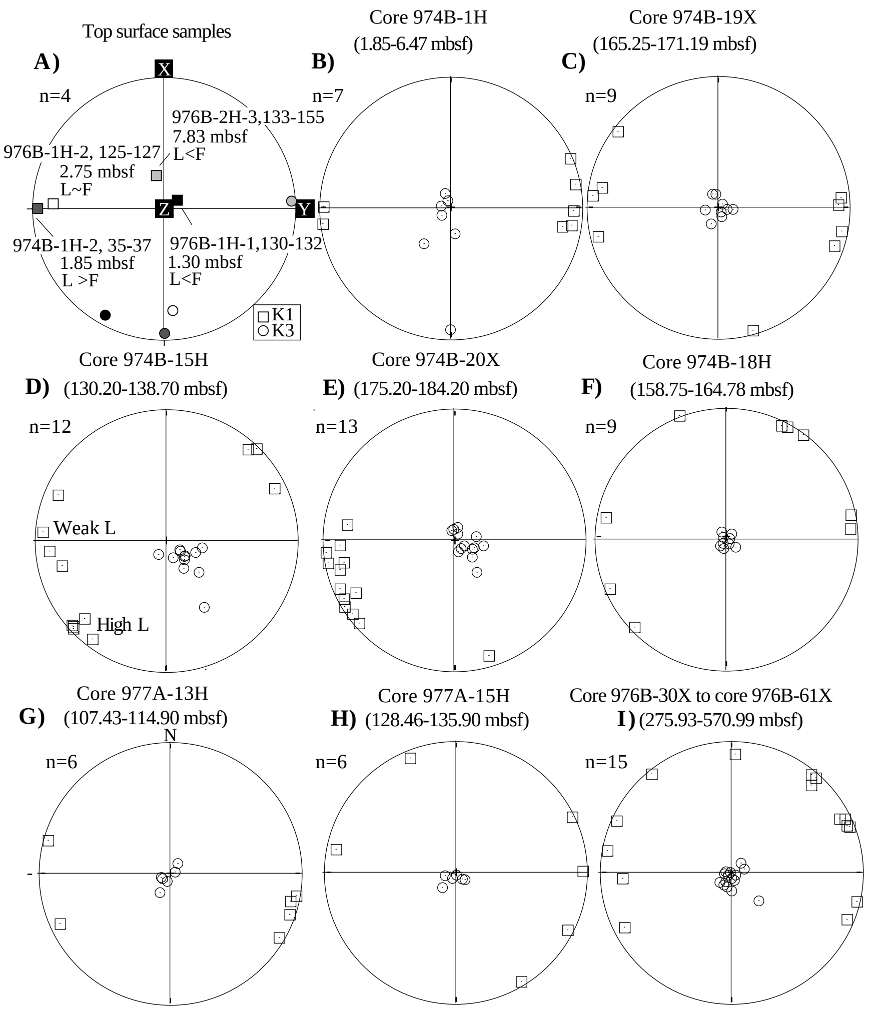

Figure 6. Examples of magnetic fabric in sample coordinates. K_1 (squares) and K_3 (circles) are plotted in equal area projection on the lower hemisphere. **A.** Inverse magnetic fabric from top surface samples. **B–I.** Examples of normal magnetic fabric. See text for further explanations.

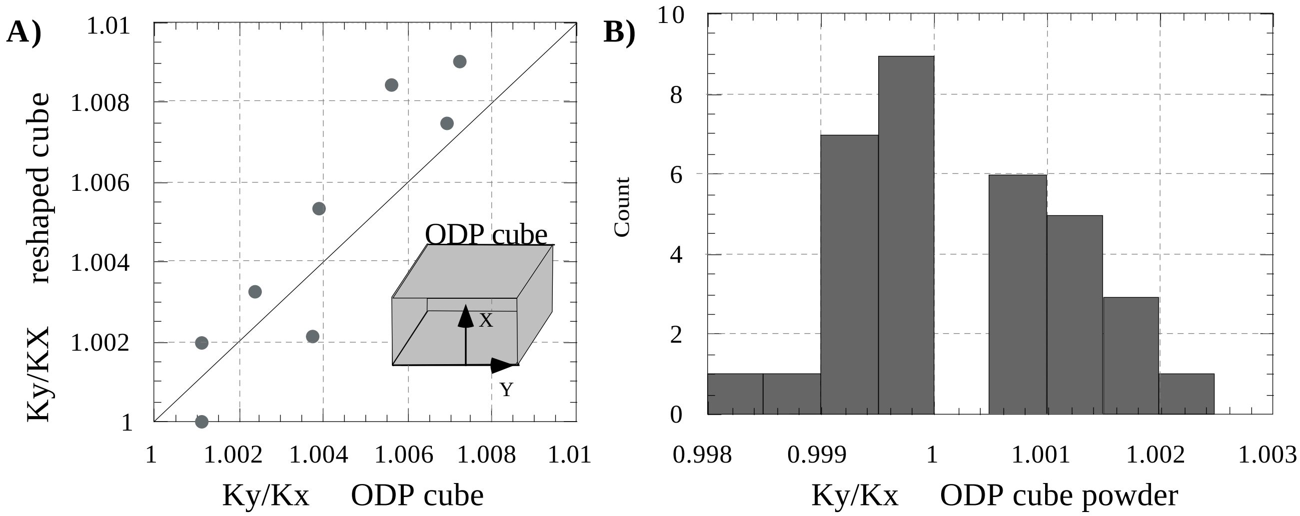

Figure 7. Results of two experiments to test whether shape anisotropy is a possible source of the anomalous magnetic fabric. **A.** First, we measured magnetic susceptibilities along X and Y axes of samples that exhibited a maximum susceptibility parallel to the Y-axis. Second, we cut samples into 19-mm cubes and measured susceptibility along the two axes. No relevant sorting effect was observed, and K_y remained the maximum susceptibility. **B.** We measured the magnetic susceptibility along the X and Y axes of cubes filled with powder obtained from Hole 974B sediments. The ratio K_y/K_x is low and no axis was favored during this experiment.

sequently enhanced the susceptibility along the Y-axis. To avoid this compaction, we did not completely fill the cube with powder. The ratio of susceptibility along the two axes of the cube (K_y/K_x) ranged from 0.998 to 1.002, and no apparent deviation of maximum susceptibility parallel to Y-axis was observed (Fig. 7B). From these two experiments and theoretical considerations, we conclude that there is no obvious shape anisotropy. Moreover, shape anisotropy cannot explain the deviation of K_3.

Sampling

When the sampling box is pushed down parallel to the X-axis of the core, one can expect flow-in parallel to the bedding, as well as edge deformation parallel to the X-Y and X-Z planes. Gravenor et al. (1984) documented significant deviation up to 37° of the maximum susceptibility toward the push direction when sampling was performed parallel to the foliation. Thus, according to their results, one can expect a deviation parallel to the X-axis of the cube, which clearly contradicts the Y-axis deviation that we observed.

Drilling Deformation

The penetration of the piston typically causes an edge deformation in soft sediments (Fig. 8A). Herr et al. (1998) found anomalous magnetic fabric directly related to the edge smearing. Coring deformation has a circular symmetry and results in a conical fabric with an apex parallel to the Z-axis of the core. Conical fabric essentially concerns the edge of the core, and its extension to the center of core is not clear. If conical fabric extends through the center of the core, samples must record a weak asymmetry of the conical fabric within the plane X-Z (Fig. 8B). Conical fabric at the scale of the sample may thus result in a small tilting of the bedding toward X-axis in the X-Z plane and a weak arcuate shape of the bedding in the Y-Z plane. The small tilting of the bedding toward the X-axis can be compared to the deviation of the magnetic foliation observed in this study (Fig. 8C). The origin of magnetic lineation parallel to the Y-axis remains unclear (Fig. 8C). We consider two different mechanisms: (1) the existence of composite magnetic fabric between the bedding (presumably

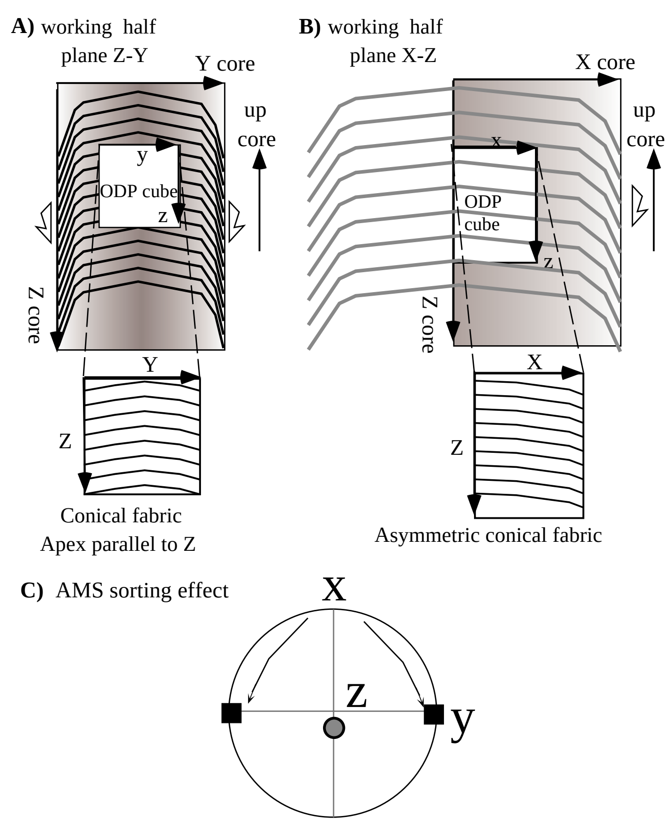

Figure 8. **A.** Sketch showing the geometry of conical fabric caused by coring deformation in the vertical plane Y-Z of the working half. Location of sampling is shown. A small bend is expected to form within the Y-Z plane because of the conical fabric. **B.** The X-Z section of archive half shows the asymmetrical bending of the conical fabric. We proposed that the sample was also affected by a small asymmetrical bending within the X-Z plane. **C.** The sorting effect of magnetic fabric observed in this study.

horizontal) and a secondary fabric resulting from coring deformation that may produce an intersection lineation parallel to Y-axis (Housen et al., 1993); (2) an alignment of ferromagnetic grains resulting from the smearing effect of coring deformation. Because there is no evidence of secondary magnetic fabric, we prefer the second hypothesis.

Other types of drilling perturbation are flow-in disturbance and biscuiting. Note that these disturbances are generally visible. Our study was not affected by the flow-in effect because we always sampled 50 cm away from both the top and bottom of the core (Kent and Lowrie, 1975). Biscuiting is observed in lithified sediments. No particular asymmetry related to the X-Y plane of the core can be expected, and biscuiting cannot be the cause of the observed bias.

Core Splitting

When splitting the section into halves, two possible sources of perturbation must be considered:

1. A surface alteration of the Z-Y plane caused by wire cutting (Fig. 9A). Soft sediments are likely to record such disturbance, where a small deviation of the bedding foliation can be expected, always in the Z-Y plane for a given half. The deviation of the magnetic foliation should be accompanied by a crenulation parallel to the Y-axis of the core. A subtle crenulation leads to significant magnetic lineation (Housen et al., 1993). However, the sedimentary structures are generally well preserved despite scraping (Shipboard Scientific Party, 1996b), and it is unlikely that surface alteration is pronounced enough to disturb magnetic fabric. Moreover, scraping does not explain the magnetic lineation below 100 mbsf where, apparently, the magnetic foliation is no longer deviated.
2. A small expansion of the section parallel to the Y-axis (Fig. 9B). This expansion, if it exists, is probably more pronounced in soft sediments. The weak ductile stretching parallel to theY-axis that may accompany this release is capable of imprinting the magnetic fabric and generating a magnetic lineation parallel to Y-axis. However, it does not account for the deviation of the magnetic foliation.

To summarize, sample shape anisotropy, sampling procedure, and biscuiting are not good explanations of the origin of the anomalous magnetic fabric. Scraping disturbances, as well as expansion of sections when splitting the cores, are possible causes, but hardly explain the deviation of the magnetic foliation and why bias is also observed in lithified sediments. Finally, we conclude that the conical fabric induced by piston core deformation is the best mechanism to account both for the deviation of magnetic lineation and the magnetic foliation. Note that Copons et al. (1996) documented a very similar disturbance characterized by a deviation parallel to the Y-axis of the core in Holocene glacio-lacustrine ritmites**.** They considered sampling-induced artifact to explain their results, but also favored core splitting as the main mechanism (J. Parés, pers. comm., 1996).

Two problems remain unsolved: the inverse magnetic fabric observed in the uppermost sediments, and the magnetic lineation close to, but statistically different from, the Y-axis.

Inverse magnetic fabrics have been observed several times in deep-sea sediments (Rees and Frederick, 1974; Kent and Lowrie, 1975; Hounslow, 1990). Explanations involved instrumental effect (Kent and Lowrie, 1975; Hounslow, 1978), flow-in piston core perturbation (Kent and Lowrie, 1975), change of magnetic mineralogy (Harrison and Peterson, 1965), and tectonic deformation (Hounslow, 1990). Flow-in perturbation is possible in soft sediments and is generally visible, but it cannot explain the parallelism with the core axes alone. Moreover, two magnetic lineations (Fig. 6E) remain horizontal, which contradicts flow-in perturbation (vertical magnetic lineation). Alternatively, we propose that these inverse magnetic fabrics originated as a combination of coring deformation and inverse properties of magnetic grains. Coring deformation tends to align the long axis or zonal axis of magnetic grains parallel to Y-axis, whereas inverse properties of magnetic grains interchange AMS axes, as well as AMS parameters (Rochette, 1988). Single-domain magnetite (Potter and Stephenson, 1988) or siderite (Ellwood et al., 1986) are good candidates to explain such behavior, but more studies are necessary to further constrain this hypothesis.

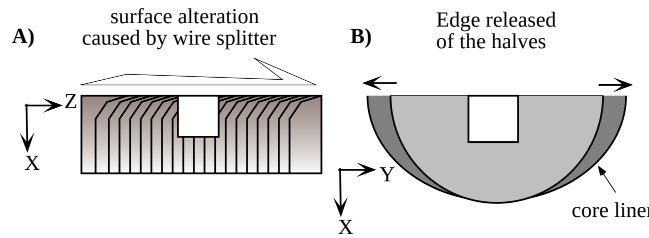

Figure 9. Sketches showing the effect of the splitting operation. **A.** A thin surface alteration caused by the wire splitter. This must be a limited effect (few mm) because the sedimentary structures are well preserved. **B.** Expansion of the half parallel to the Y-axis of the core. The stretching induced by this expansion may account for a magnetic lineation parallel to Y-axis, but not for a deviation of the magnetic foliation.

The declinations of the magnetic lineation close to, but significantly different from, the Y-axis are particularly visible in Holes 974B and 979A (Fig. 4A). A shape sample anisotropy with a magnetic lineation parallel to the diagonal is unlikely. First, we expect to observe the two diagonals, which is not the case in Hole 974B (Fig. 4A). Second, the deviation of K_1 is N80° in Hole 974B and N280° in Hole 979A (Fig. 4A). It differs statistically from the diagonals of the sample (N45° or N315°). Third, shape anisotropy is unlikely when measuring paramagnetic material using an impedance bridge as discussed above. We cannot yet explain the magnetic lineations oblique to the Y-axis of the cube.

Anomalous Magnetic Fabric and PRR

During Leg 161, anomalous magnetic fabric and hard PRR were observed in samples from Holes 974B, 976B, 977A, and 979A. Measurements of the NRM from half core, U-channel (Herr et al., 1998), and discrete samples (Shipboard Scientific Party, 1996a) confirmed the existence of the PRR from the edge to the center of the core. Similarly, anomalous magnetic fabrics occur from the edge of the core (Herr et al., 1998) to the center (this study). We conclude that pervasive anomalous magnetic fabrics define the conical fabric induced by coring deformation. Further, we propose (Fig. 10) a relationship between magnetic fabric and conical fabric based on both Herr et al. (1998) and our results. In this interpretation, we assume that magnetic lineation mirrors an alignment of ferromagnetic grains parallel to the split surface from the edge to the center. It is possible to have a radially inward alignment of ferromagnetic grains extended to the whole core, although this must be demonstrated. The degree of alignment of ferromagnetic grains cannot be evaluated because the magnetic fabric in this study essentially mirrors the clay texture. In the study of Herr et al. (1998), the paramagnetic and ferromagnetic contributions are not elucidated. The association of the PRR and the anomalous magnetic fabric led us to conclude that both originate from a conical fabric. Whether this alignment of ferromagnetic grains is responsible for the PRR remains questionable because the mechanisms of remagnetization are so numerous.

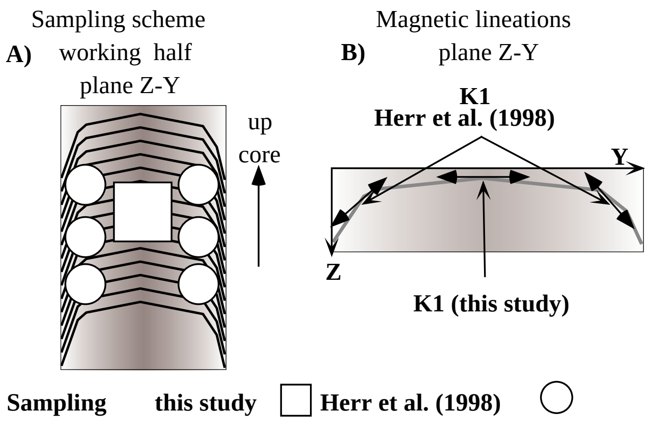

Figure 10. **A.** Sampling scheme of Herr et al. (1998) and this study. **B.** Magnetic lineations of this study and Herr et al. (1998). The magnetic lineations within the Y-Z section of the conical fabric suggest a possible weak alignment of ferromagnetic grains.

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