3. MAGNETIC-FIELD MEASUREMENTS ABOARD THE *JOIDES RESOLUTION* AND IMPLICATIONS FOR SHIPBOARD PALEOMAGNETIC STUDIES[1]

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INTRODUCTION

Paleomagnetism has played an increasingly prominent role among scientific investigations allied with ocean drilling. Typical paleomagnetic studies include magnetostratigraphy, analysis of rock magnetic properties, and the determination of paleolatitudes to constrain models of plate motion. The importance of such investigations has made it desirable to have a state-of-the-art paleomagnetic laboratory aboard ship.

A ship is not a magnetically "clean" environment. Ferrous metals and electrical equipment give rise to large and variable magnetic fields. Researchers working on samples from the Deep Sea Drilling Project (DSDP) often noted anomalous secondary magnetizations, which were occasionally attributed to the exposure of the samples to large magnetic fields while aboard the drilling ship. Consequently, knowledge of the magnetic environment aboard the *JOIDES Resolution* is of interest because it will enable investigators to take steps to protect their samples against magnetic contamination.

During DSDP Leg 75, magnetic-field measurements were made on the drilling-rig floor and in the vicinity of the core-cutting rack and drill-pipe racks aboard the *Glomar Challenger* (Keating, 1984). Fields greater than 2000 milliGauss (1 mG = 100 nanoTeslas) were noted near steel drilling pipes and the steel holders used to support the core as it was cut into sections. As a result, the steel core supports were replaced by ones made of aluminum. Furthermore, the magnetic field on the drilling-rig floor, in the vicinity of the top of the drill string, was found to range from 200 to 1700 mG (2×10^4 to 1.7×10^5 nT). However, the same survey also revealed that the magnetic field 20 cm inside the top of the drill string was only 30 mG (3×10^3 nT), about 1/10 of the strength of the ambient geomagnetic field. Evidently, the steel drill pipe, an excellent electrical conductor, acts as a magnetic shield, reducing the strength of the geomagnetic field within the pipe. Thus, cores are probably not exposed to large magnetic fields except at the ends of the drill string.

Aboard the *JOIDES Resolution*, paleomagnetic samples typically spend the most time either in the paleomagnetic lab (as discrete samples taken from the working half of the core) or in one of the refrigerated storage compartments located on the 'tween and lower 'tween decks. The trip from rig floor to storage usually takes only a few hours. During this trip, the cores are exposed to magnetic fields for periods of 30 minutes to an hour on the catwalk cutting rack, on the storage rack inside the door to the bridge deck lab, in the port corridor of the bridge deck lab (physical-properties section), in the paleomagnetic lab, and on the sampling and core-description tables. The cores are exposed to magnetic fields elsewhere in the lab only briefly.

In order to characterize the significant magnetic fields to which cores and samples are exposed aboard the *JOIDES Resolution*, several magnetic surveys were undertaken. Magnetic contour maps of the ambient geomagnetic field have been prepared for the paleomagnetic laboratory, the port corridor of the laboratory and catwalk on the bridge deck, and the refrigerated storage compartment on the lower 'tween deck. Although the measured magnetic field will change with the latitude, longitude, and orientation of the vessel, it was felt that these maps would provide some useful insights into the protection of paleomagnetic samples from spurious magnetic fields.

MAGNETOMETER SURVEY

The shipboard Schonstedt digital fluxgate magnetometer (model DM-2220) was used for this study. This device can measure fields up to 2000 mG (2×10^5 nT) in strength. Magnetic readings were recorded to the nearest milliGauss in three orthogonal directions: forward, port, and down. During the surveys the sea was calm, and the roll and pitch of the ship, which was on station and dynamically positioned, were barely discernible. In order to quantify the error resulting from hand-holding the magnetic sensor, repeated measurements were made of each magnetic-field component at two points, one in an area of low magnetic gradient and the other in an area of moderate to high gradient. The former should give a lower bound for the effects of positioning error, whereas the latter should give an upper bound. Twenty measurements were made of each component and averaged. In the area of low magnetic gradient, the standard deviation of the measurements ranged from 2 to 3 mG (200 to 300 nT). A larger range of standard deviations was found in the higher gradient region, 6–13 mG (600–1300 nT).

The survey on the bridge deck was conducted while the ship was on station at Site 634. During the survey, the vessel maintained a constant heading of 055°. The survey in the refrigerated compartment was done while on station at Site 636. The ship's heading during these measurements was also constant, but at 095°. The strength and direction of the geomagnetic field external to the ship were calculated from the 1980 International Geomagnetic Reference Field (IGRF) (Peddie, 1982) for each of these sites. These parameters are listed in Table 1.

All measurements were made at a level 1 m above the deck. This was done by tying a string 1 m in length to the magnetometer sensor. The string was attached to a flat piece of wood with a screw eye. One of us would stand on the piece of wood and stretch the string tight, being careful to hold the sensor steady. The other recorded the readings shown on the face of the magnetometer electronic package.

Each survey was done on a grid laid out in string on the deck using meter sticks. Measurements were made at intersections on the grid. In the paleomagnetic laboratory, the grid spacing was

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Table 1. External magnetic-field parameters for Sites 634 and 636 calculated from IGRF 1980.

	Site 634	Site 636
Latitude:	25.38°N	25.42°N
Longitude:	77.31°W	77.31°W
Inclination:	56.8°	56.9°
Declination:	−4.9°	−4.9°
Intensity:	47024 nT	47050 nT
Ship's heading:	55°	95°

0.5 m, but measurements elsewhere were made at a grid spacing of 1.0 m.

OBSERVATIONS

For ease of interpretation, the three magnetic-field components recorded at each measurement point were converted to a single value of total-magnetic-field strength using the Pythagorean theorem. An anomaly field was created by calculating the average magnetic field in each survey area and subtracting this datum from the observed values. This had the effect of dividing the measurements into roughly equal amounts of positive and negative values, which aids in highlighting the field variations. Contour maps of the total-field anomalies were made for the catwalk, port corridor, and paleomagnetic laboratory on the bridge deck as well as the refrigerated compartment on the lower 'tween deck. The maps were contoured at intervals of 100 and 50 mG (1×10^4 and 5×10^3 nT). As these contour intervals are well in excess of the errors found in the measurement consistency tests, the contours should be an accurate indication of the variation of the ambient shipboard magnetic field.

Bridge Deck Survey

Figure 1 shows the total-field magnetic anomalies for the bridge deck catwalk, the port laboratory corridor, and the paleomagnetic laboratory. The most surprising aspect of this survey is that the ambient magnetic-field strength is on average significantly lower than that of the external magnetic field. The average field strength in the survey was 330 mG (3.3×10^4 nT), about 30% less than the 470 mG (4.7×10^4 nT) calculated from the 1980 IGRF. Apparently, the metal of the ship slightly shields its interior from the external geomagnetic field. However, this map amply demonstrates that the magnetic field within the ship is also highly variable. The highest measurement recorded was 1326 mG (1.326×10^5 nT), which corresponds to the 996-mG (9.96×10^4 nT) positive anomaly in the aft part of the lab corridor. This value is roughly 2.8 times the external field strength.

In general, the strongest magnetic fields were recorded above the equipment benches near the exterior bulkheads (Figs. 1 and 2). The 1-m survey level placed the sensor approximately 10–15 cm above the tops of these benches. Although the bench tops are made of wood, each has metal supports and cabinets beneath, and most have metal equipment resting upon them. The high fields at these locations are probably related mostly to the metal benches and the equipment on them rather than the bulkheads themselves, as the aft bulkhead in the paleomagnetic laboratory has no large anomaly. The cryogenic magnetometer, currently located next to this bulkhead, was not installed until a later leg.

Within the paleomagnetic laboratory, a positive magnetic anomaly is elongated on a port–starboard axis through the middle of the room (Fig. 2). Its cause is not clear. Although it may be related to the shape of the lab, this anomaly might also be related to the placement of the furniture within. The strongest magnetic-field values were recorded above the equipment benches on the port and starboard sides of the lab. The two relative maxima in the middle of the lab are located just aft of the computer table and the demagnetizing equipment bench, and thus may be related to these pieces of furniture.

A relative minimum is located near the metal storage cabinet in the port-forward corner of the laboratory. It may be related to the metal cabinet or the metal bench adjacent to the cabinet. Interestingly, both the aft external bulkhead and the forward internal bulkhead seem to have a negligible effect on the magnetic field. A relative magnetic anomaly low is located in the vicinity of each bulkhead.

Lower 'Tween Deck Refrigerated Compartment

The results of the lower 'tween-deck survey are shown in Figure 3. Like the bridge-deck survey, the refrigerated-compartment survey revealed that the ambient magnetic field is significantly lower than the calculated external-field strength. The average magnetic-field reading in the compartment was 200 mG (2×10^4 nT), only 43% of the external field. The highest recorded value within the compartment was 380 mG (3.8×10^4 nT). In this compartment, the main feature of the magnetic survey is a positive anomaly running along the fore–aft axis of the room. This orientation suggests a relation to the shape of the compartment.

An analysis of the directions of the magnetic vectors in the compartment displayed an interesting correlation. Unlike the field vectors in the bridge-deck survey, which appeared uncorrelated at points separated by more than about 2 m, the vectors in the refrigerated compartment point predominantly in the same direction. At every point except one within the compartment, the magnetic field points to port (the direction of magnetic north), but with inclinations much closer to horizontal than the external field. The average declination was 10.1°, reasonably close to the calculated value of −4.9° for the external field. On the other hand, the average inclination, 17.0°, is significantly shallower than the external-field inclination of 56.9°. Evidently, the ship exerts a strong but coherent influence on the direction of the magnetic field in this region of its interior.

DISCUSSION

The magnetic surveys reported here have given a few interesting insights into the magnetic environment for paleomagnetic samples aboard the *JOIDES Resolution*. Except for locally strong fields, the overall magnetic field within the laboratory space and refrigerated storage compartment is lower than the external-field strength. This probably represents a slight shielding effect from the surrounding metal of the ship. Although it is difficult to pinpoint the sources of the strong fields in such a metal-rich environment, it appears that they correlate well with the metal equipment and metal-framed equipment benches. It is clearly impractical to eliminate these sources from all parts of the ship, but with the awareness that these high magnetic fields exist, the exposure of cores to such fields can be minimized. Moreover, though it may be prohibitively expensive to shield the entire paleomagnetic laboratory, the results of this study suggest two ways in which the contamination of sensitive paleomagnetic samples can be reduced. First, scientists and technicians must be aware of the placement of ferrous-metal objects within the paleomagnetic laboratory. The replacement of metal-frame furniture with wood furniture could significantly reduce the ambient field within the lab. Second, several cabinets or boxes made of mu-metal are desirable, as they would provide the scientist with a shielded environment in which to store paleomagnetic samples while on board ship.

It is likely that little can be done to protect the stored cores from exposure to magnetic fields while they are on the ship.

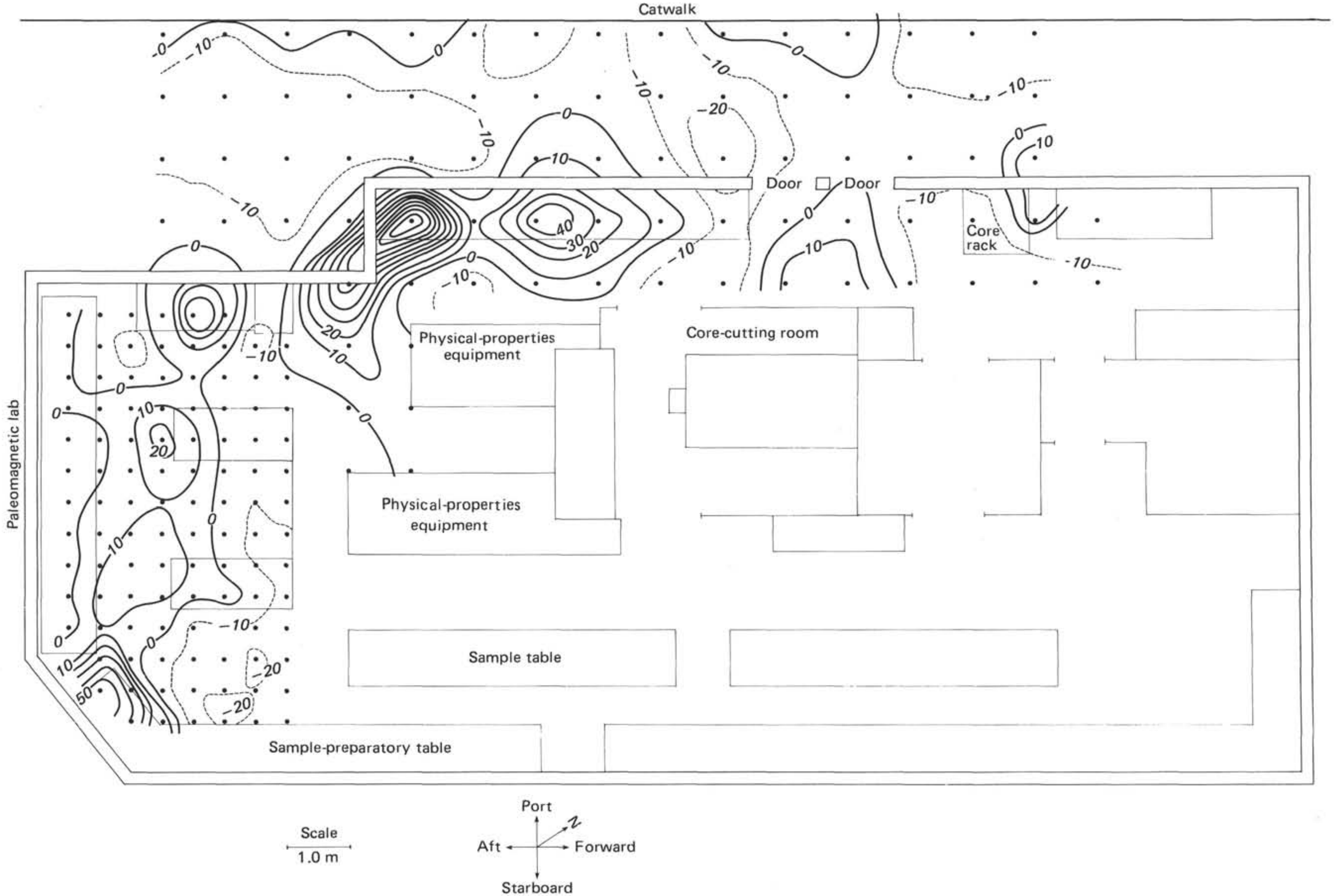

Figure 1. Magnetic anomalies on the bridge deck. Contours are labeled in tens of milliGauss (thousands of nanoTeslas). Dots correspond to measurement grid points. The grid spacing was 0.5 m in the paleomagnetic laboratory and 1.0 m elsewhere. A datum of 330 mG (3.3×10^4 nT) was subtracted from the observed values to obtain the plotted anomalies. This survey was done while the ship was on station at Site 634 with a constant heading of 55°.

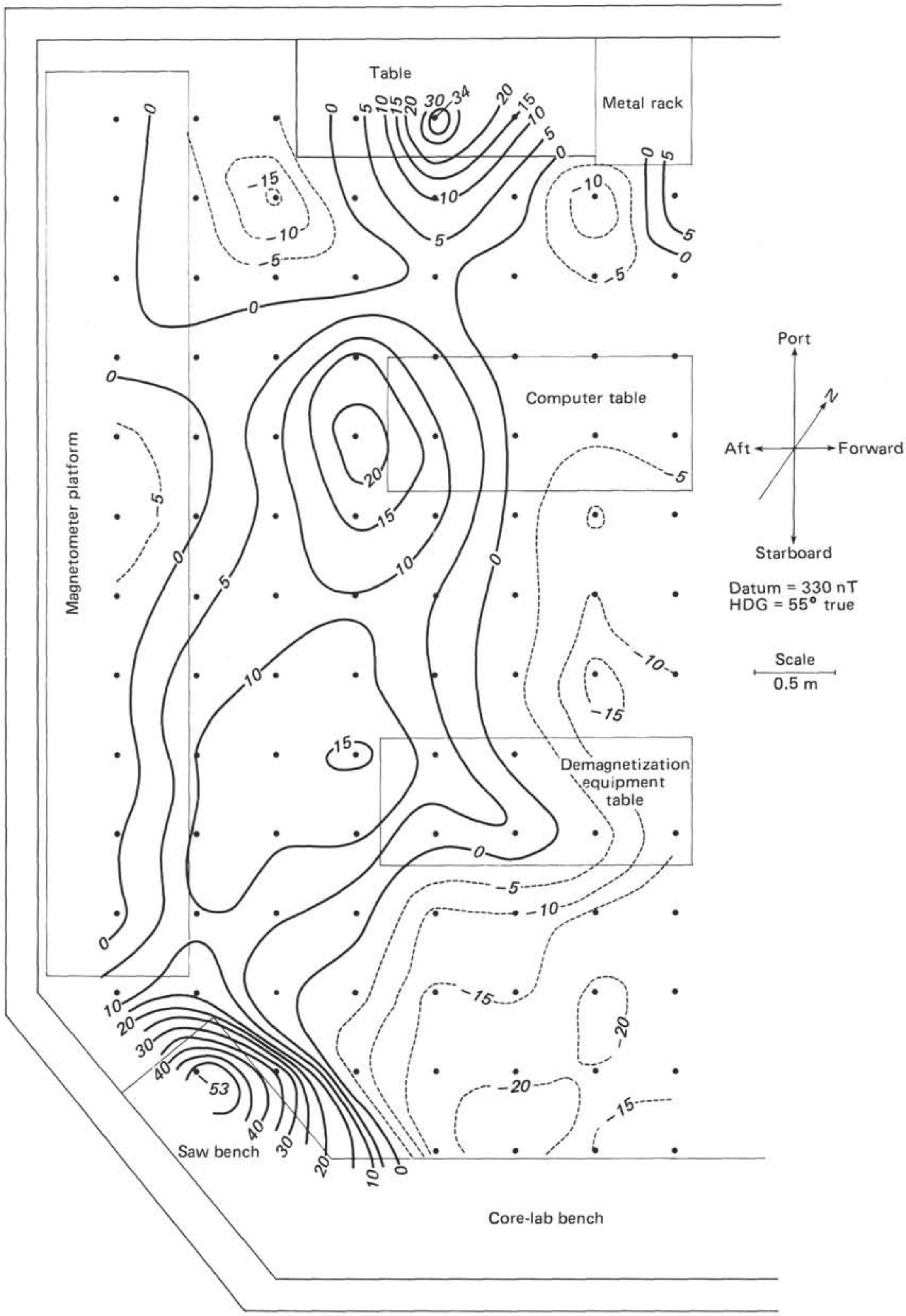

Figure 2. Detail of magnetic anomaly map of the paleomagnetic laboratory. Dots represent measurement grid points. Contours are labeled in tens of milliGauss (thousands of nanoTeslas).

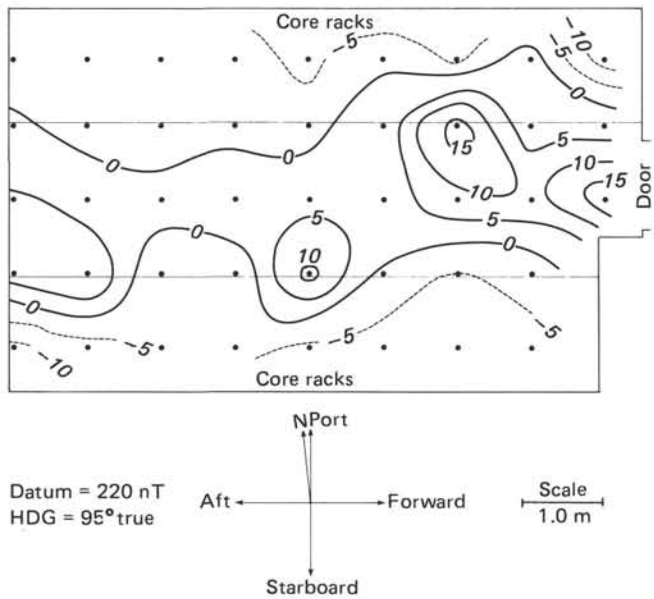

Figure 3. Magnetic anomalies in the refrigerated core-storage compartment on the lower 'tween deck. Dots represent measurement grid points. Contours are labeled in tens of milliGauss (thousands of nanoTeslas). A datum of 200 mG (2×10^4 nT) was subtracted from the observed magnetic field to obtain anomaly values. The grid spacing is 1.0 m. This survey was done while the ship was on station at Site 636 with a constant heading of 95°.

Fortunately, the ambient magnetic field in the refrigerated storage compartments appears to be only about half of the external-field strength. Unfortunately, that field is rather coherent, with a direction close to horizontal. Because the cores are stored horizontally, this means that the magnetic vector will be close to a plane that is parallel to the split face of the core (i.e., a vertical plane in the core reference frame). Although the azimuthal direction of the magnetic field will apparently depend on the heading of the ship, its consistent inclination near horizontal may be one of the factors contributing to the anomalously steep inclinations measured from some DSDP and ODP cores.

SUMMARY

Magnetic surveys of the catwalk, the port lab corridor, and the paleomagnetic lab on the bridge deck as well as the lower 'tween deck refrigerated core-storage compartment were undertaken on Leg 101 to examine the magnetic environment that paleomagnetic samples will encounter during handling aboard the *JOIDES Resolution*. In general, the ambient magnetic field inside the ship was found to be significantly lower (30%–50% lower on average) than the external geomagnetic field, probably as a result of a partial shielding effect by the ship's metal structure. However, locally strong magnetic fields, up to 2.8 times the external-field strength, were associated with metal equipment and metal-frame cabinets and benches in the laboratories. Because of this observation, we recommend that the exposure of cores to these objects be minimized and that wood furniture replace the metal fixtures within the paleomagnetic lab.

An interesting observation was made concerning the direction of the ambient magnetic field in the refrigerated storage compartment. Unlike the laboratory space, in which the observed magnetic vectors seemed to be randomly perturbed from the geomagnetic-field direction, the direction of the magnetic field in the refrigerator was primarily directed north, close to the external-field declination, but with an inclination that was nearly horizontal. This consistently horizontal field may bias the stored core material toward steeper inclinations if it remains in the refrigerator for an extended period of time.

ACKNOWLEDGMENT

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