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Appendix: Observations on the Effect of a Nonmagnetic Core Barrel on Shipboard Paleomagnetic Data: Results from ODP Leg 202[1]

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ABSTRACT

During Leg 202, we observed and tested the effects of drilling on the magnetic remanence of sediments in a variety of lithologies. We found substantial magnetic overprints superimposed on the sediment natural remanent magnetization because of the use of steel core barrels and the time the sediment spends within them. The use of the advanced piston corer temperature (APCT) tool, which extends the duration of the coring process by 15 min for each core, induced a substantially larger overprint as compared to cores not using this tool. Laboratory experiments indicated that this large overprint is not APCT tool specific, but rather due to the extra time the sediment rests in the core barrel. Alternating use of a nonmagnetic core barrel on even-numbered cores (e.g., on Cores 2H, 4H, 6H, etc.) with a normal magnetized (steel) core barrel on odd-numbered cores (e.g., on Cores 1H, 3H, 5H, 7H, etc.) within a hole, at three sites, demonstrated a reduced overprint with the nonmagnetic core barrel. The improvement of the magnetic record due to the use of the nonmagnetic core barrel was most dramatic in relatively coarse siliciclastic sediments from the continental margin of Chile. The effect, though less dramatic, was still noticeable in fine-grained, open-ocean pelagic carbonate sediments. Based on these experiments and observations, we recommend that nonmagnetic core barrels, cutting shoes, and associated coring equipment that is in close contact with the sediment

[1]Examples of how to reference the whole or part of this volume.
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be made available for full-time use in coring with the advanced piston corer where a paleomagnetic record is of interest.

BACKGROUND

Drilling-induced magnetic overprints are ubiquitous in Ocean Drilling Program (ODP) paleomagnetism and have been known to exist since the program began. In some cases, these are easily dealt with. In other cases, magnetic overprints may completely compromise the paleomagnetic objectives of a leg (e.g., see Leg 154; Curry, Shackleton, Richter, et al., 1995). How to deal with this problem has been a matter of discussion within the JOIDES advisory structure for a decade or more, and at various times recommendations have been made to explore the use of nonmagnetic drilling tools. Preliminary tests of the benefits of using such expensive tools have been, until now, inconclusive, and as a result the use of nonmagnetic core barrels is still not a standard feature aboard the *JOIDES Resolution*. Here we discuss observations and experiments made during Leg 202 that shed new light on the use of a nonmagnetic core barrel and other equipment (i.e., the advance piston corer temperature [APCT] tool) to reduce the effects of drilling-induced magnetic overprints on paleomagnetic objectives.

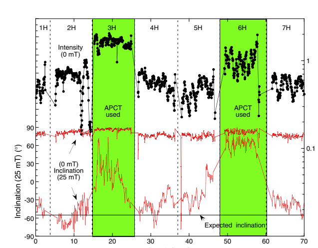
OBSERVATIONS FROM THE CHILE BASIN AND MARGIN SITES

Cores from Leg 202 sites off Chile (1232–1235) contain a drilling-induced magnetic overprint on the sediment natural remanent magnetization (NRM) prior to demagnetization. This overprint is easily quantified at all these sites because only sediments of Brunhes Chron age (0–0.78 Ma) were recovered, and therefore, the majority of the NRM should be restricted to normal polarity directions with negative inclination values near –55°. The overprint is generally along the positive z-axis, therefore inducing a steep positive inclination in the NRM.

A primary concern is that overprints may be either incompletely removed or, in some cases, not removed at all during routine shipboard demagnetization. This is critical, as the higher the field required to remove the overprint, the substantially greater the chance that the original NRM (the paleomagnetic component that we study) will be lost during the process.

Site 1235 was the shallowest site drilled on the Chile margin and contained the highest silt content. It was at this site that we discovered exceptionally strong overprints in cores taken when the APCT tool was deployed (Fig. **F1**). The APCT tool is an electronic device encased in the steel cutting shoe to measure in situ sediment temperatures. When a core barrel is shot into the sediment to cut a core, an instantaneous heat pulse is created that immediately starts to decay toward equilibrium with the surrounding sediments. The core barrel is left in place while the APCT tool records the time-temperature series of this decay for ~10 min. After the core is pulled from the bottom of the hole and raised to the seafloor, the ascent is interrupted for another ~5 min during which ocean-bottom temperature is measured. This procedure adds ~15 min to the time a core rests in the steel (magnetic) core barrel acquiring a magnetic overprint. The magnetic effect of the APCT tool is best illustrated in Hole 1235A by the presence of exceptionally high

F1. Effect of APCT tool usage on sediment NRM, p. 7.



NRM (0 mT) intensities and positive inclinations even after 25-mT alternating-field (AF) demagnetization (Fig. F1). The observation that the inclinations are still positive after 25-mT AF demagnetization suggests that this overprint may have permanently compromised the NRM of these sediments.

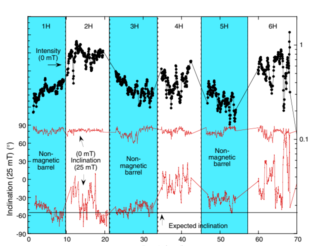
Laboratory experiments were conducted on the APCT tool and its cutting shoe housing by placing a demagnetized sediment core inside the housing (with the electronics of the APCT tool active) and letting it sit for 30 min. The sediment core NRM measured after this experiment approached the intensities measured on regular cores (~0.5 A/m; Fig. F1). A second experiment was made using a normal cutting shoe without the APCT tool, and the same result was observed. For both cutting shoe experiments, we also measured the magnetic field inside the steel housing and found it to be 10–20 Gauss (1–2 mT) in both cases. This is a magnetic field more than 10 times the general strength of the Earth's magnetic field. We interpret the NRM, which was acquired inside the cutting shoe, to be a viscous remanent magnetization (VRM) related not to the APCT tool itself but rather to the time (~30 min) that the magnetic core barrel was in contact with the sediment.

It is well known that magnetic moments within any ferromagnetic material will align with an ambient magnetic field at a rate linearly proportional to log (time) (e.g., Collinson, 1983). This magnetization is termed a VRM. The rate at which a VRM is acquired depends on material properties, especially grain size. Coarse-grained titanomagnetites, which are common in marine sediments, acquire VRM relatively quickly, whereas fine-grained titanomagnetites may acquire VRM slowly or not at all. Thus, we might expect significant changes in the VRM acquired by relatively coarse grained sediments from the continental margin, even with relatively short changes in the time sediment spends in contact any applied magnetic field such as with a magnetic core barrel. This effect should be less pronounced in fine-grained pelagic sediment far from the continental margin.

EXPERIMENTAL USE OF A NONMAGNETIC CORE BARREL

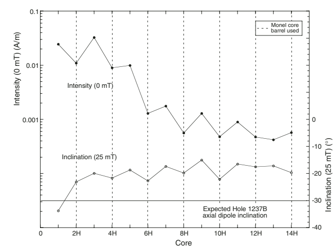
In an experiment in Hole 1235C, we deployed a nonmagnetic core barrel in place of one of the two standard steel core barrels. The nonmagnetic barrel was used every other core. The pattern of NRM (0 mT) and inclination (25 mT) for the first six cores of Hole 1235C are shown in Figure F2. Higher NRM (0 mT) intensities and more positive inclination (25 mT) values were obtained from the steel barrels in Cores 202-1235C-2H, 4H, and 6H. The steel core barrel results are consistent with results using steel core barrels without APCT tool deployment in Hole 1235A (Fig. F1). Significantly lower NRM (0 mT) intensities and more negative inclination (25 mT) values were obtained when using the nonmagnetic core barrel in Cores 202-1235C-1H, 3H, and 5H. The inclinations obtained with the nonmagnetic core barrel are much closer to the expected Site 1235 average (axial dipole) inclination of –55.6°. The reduction in overprint associated with the nonmagnetic barrel is significant in that it may mean the difference between a usable vs. an unusable paleomagnetic record. The nonmagnetic core barrel was alternated with a steel (magnetic) core barrel at all remaining sites during Leg 202 to further assess its effect on a variety of sediment types.

F2. Effect of a nonmagnetic core barrel on sediment NRM, p. 8.



At Site 1237 on Nazca Ridge we cored open-ocean pelagic ooze. This site is located significantly closer to the equator (expected inclinations of about –30° during normal polarity). The sediments consist of a fine-grained nannofossil ooze with significantly lower concentrations of finer-grained siliciclastic components than the sediments on the Chile margin. The effects of the nonmagnetic core barrel on the upper 14 cores from Hole 1237B are shown in Figure F3. Because this interval represents approximately the last 6.5 m.y. of geomagnetic field behavior with both normal and reversed polarities, we show the mean values of only the negative inclination (normal polarity) intervals so that the contrast between the drill string overprint and the NRM becomes apparent. Even though the sediments at Site 1237 are significantly finer grained than those from the Chile margin and less susceptible to VRM, the reduced overprints associated with the nonmagnetic core barrel are easily observed. The sediments cored with the nonmagnetic core barrel have lower NRM (0 mT) intensities and more negative inclinations (after demagnetization at 25 mT) than those cored with the steel barrel. Additionally, the APCT tool was used in conjunction with the nonmagnetic core barrel on even-numbered Cores 202-1237B-4H through 14H (Fig. F3). Therefore, any VRM effect caused by the extra time that the core barrel sat on the ocean bottom (e.g., Fig. F1) was mitigated by the nonmagnetic core barrel's use.

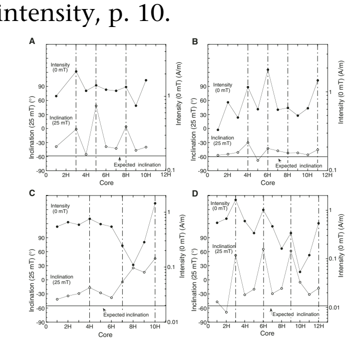
F3. Effect of a nonmagnetic core barrel on NRM and AF demagnetized negative inclinations, Hole 1237B, p. 9.



EVIDENCE FROM OTHER SITES

After further evaluation, it was observed that all four Chile margin sites contained a higher degree of overprinting with the use of the APCT tool even after demagnetization at 25 mT (our self-imposed shipboard demagnetization limit). This effect is noticeable in Figure F4, in which the average initial NRM intensity (0 mT) and AF demagnetized inclination (25 mT) per core from one hole at Sites 1232–1235 is plotted. Initial inclinations at all four sites were near +80°, completely masking the original NRM. For Sites 1232, 1234, and 1235, the demagnetized inclinations (25 mT) still had values that were far from the expected direction of about –55°. For Site 1233, only a few cores were significantly overprinted after demagnetization at 25 mT and, for these, the overprint, though incompletely removed, appears to be minor and should be able to be removed during shore-based research.

F4. Variations in mean paleomagnetic inclination and initial NRM intensity, p. 10.



SUMMARY AND RECOMMENDATIONS

During Leg 202, we found that one significant source of magnetic overprints in ODP cores involves the time a core spends in contact (through the liner) with the steel (magnetic) core barrel. This is not the only source of overprints, but it is one that can be mitigated. In a series of experiments we have found that the use of a nonmagnetic core barrel, cutting shoe, and flapper valve is helpful in reducing magnetic overprints in marine sediments, especially in continental margin lithologies with a substantial silty siliciclastic component. Most importantly, we found that VRM acquired from a steel core barrel may be difficult or impossible to remove with stepwise AF demagnetization, whereas the weaker VRM acquired when the nonmagnetic core barrel was used was more easily removed at sea. Given the success of the experiments during Leg 202, we recommend the use of nonmagnetic core barrels for all future ODP legs that include paleomagnetic objectives. The nonmagnetic core barrel may reduce the magnetic overprints even at sites containing pelagic carbonate-rich sediment and will enhance the prospects of paleomagnetic success in many sediment types.

Although more expensive than steel core barrels, the use of nonmagnetic core barrels will overall prove its worth in terms of better sampled and better understood records of magnetic field variability. Considering the cost of labor that over the years has gone into the often futile efforts to remove magnetic overprints from ODP cores, and the even larger cost of lost scientific opportunities caused by magnetic overprints, the incremental cost of purchasing and maintaining nonmagnetic drilling tools seems to us like money well spent.

REFERENCES

Collinson, D.W., 1983. *Methods in Rock Magnetism and Paleomagnetism:* New York (Chapman and Hall).

Curry, W.B., Shackleton, N.J., Richter, C., et al., 1995. *Proc. ODP, Init. Repts.,* 154, College Station, TX (Ocean Drilling Program).

Figure F1. The effect of advanced piston corer temperature (APCT) tool usage on the sediment NRM of Hole 1235A. Unusually large magnetic overprints, observed in Cores 202-1235A-3H and 6H when the APCT tool was used (shaded interval), are indicated by higher than normal initial NRM intensities and AF demagnetized inclinations (25 mT) that deviate significantly from the expected values at this site (–55°). Note the steep positive inclination (0 mT) prior to demagnetization. The residual positive inclination (25 mT) documents that the overprint could not be effectively removed through limited AF demagnetization.

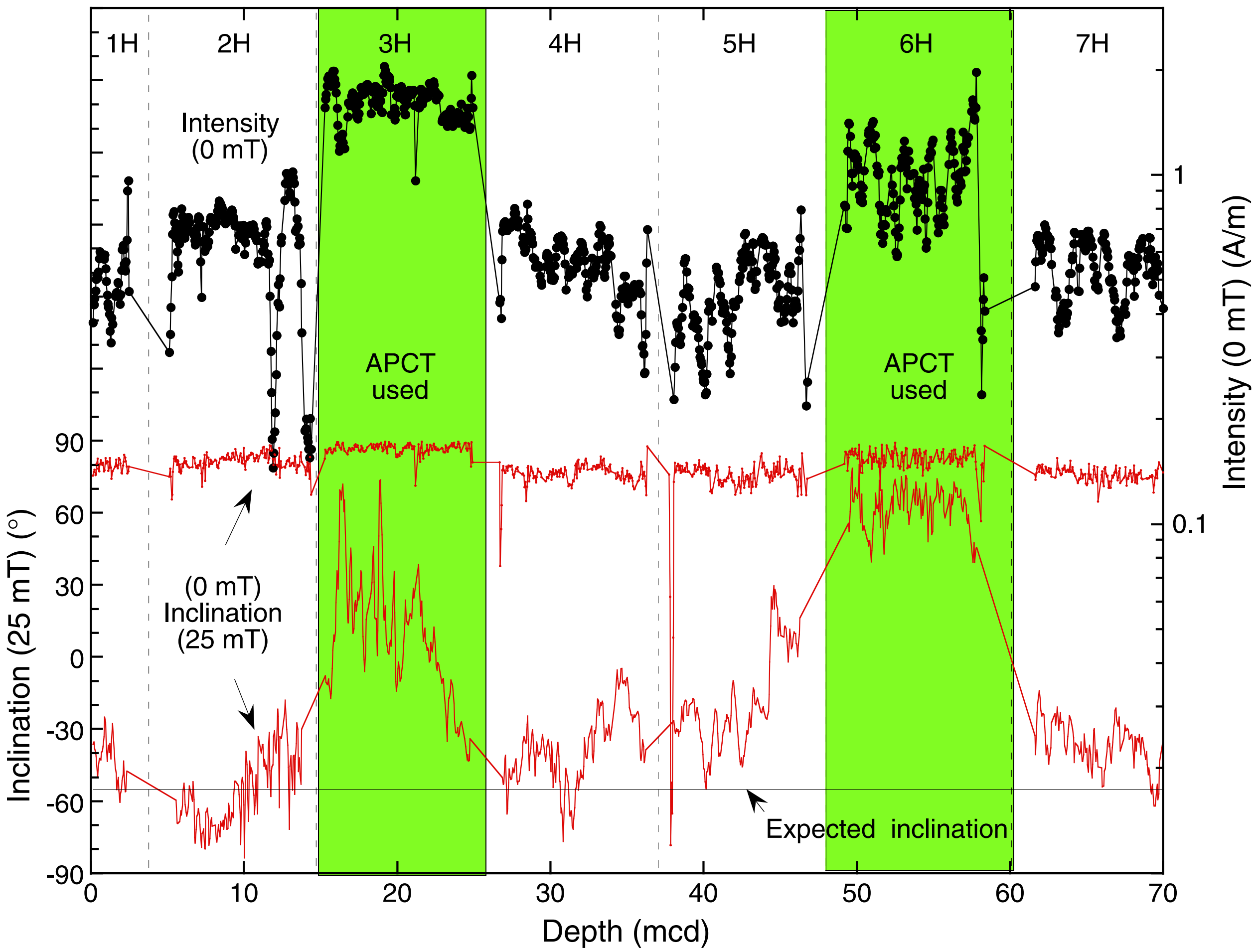


Figure F2. The effect of a nonmagnetic core barrel on the sediment NRM of Hole 1235C. Sediments recovered with a nonmagnetic core barrel (odd-numbered cores; shaded) had initial NRM intensities significantly lower than sediments recovered with a normal steel (magnetic) core barrel (even-numbered cores). Both the nonmagnetic and steel core barrels had steep positive inclinations prior to demagnetization. After AF demagnetization, the inclinations of the nonmagnetic core barrels are close to the expected inclinations due to the Earth's magnetic field at this site. Even after AF demagnetization, the inclinations of the steel core barrels deviate from the expected values.

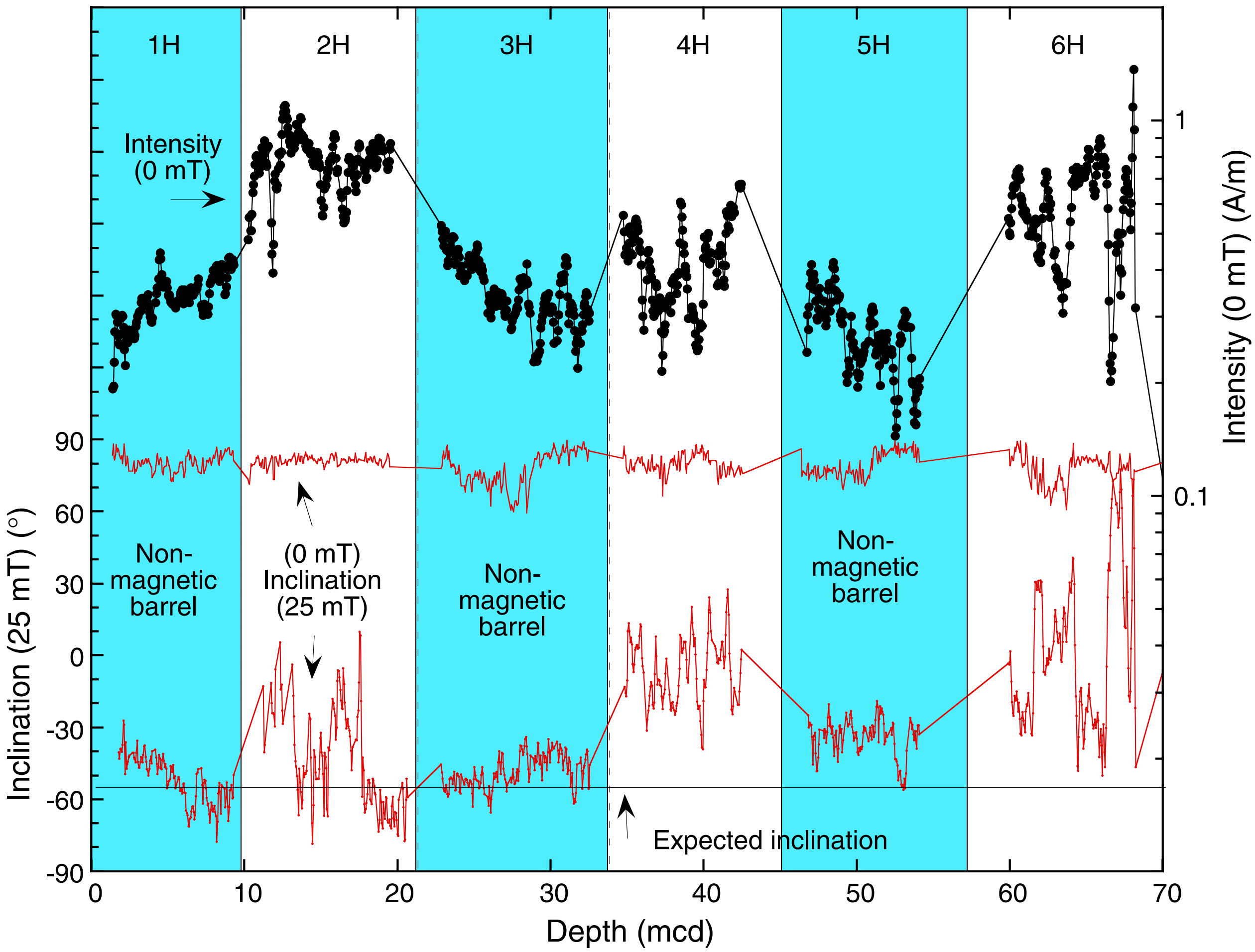


Figure F3. The effect of a nonmagnetic core barrel, indicated by dashed lines, on the mean initial NRM intensities and mean AF demagnetized negative inclinations (25 mT) at Hole 1237B. Inclination means are taken only from the negative inclination values (normal polarity) of the upper 14 cores representing ~6.5 m.y. of geomagnetic behavior. The mean inclination prior to demagnetization is ~70° due to a significant drilling overprint. The expected geomagnetic inclination for normal polarity at this site latitude is –30° as indicated by the solid line. Shallower (less negative) inclinations during times of normal polarity indicate a bias caused by the drilling overprint. Sediment at Site 1237 is a pelagic nannofossil ooze and therefore represents a very different lithology than at the sites previously discussed. The weaker overprint observed in the nonmagnetic barrel cored sediments at Site 1237, though small, indicates that the use of a nonmagnetic core barrel will improve the probability of paleomagnetic success in a range of sediment types and intensity ranges.

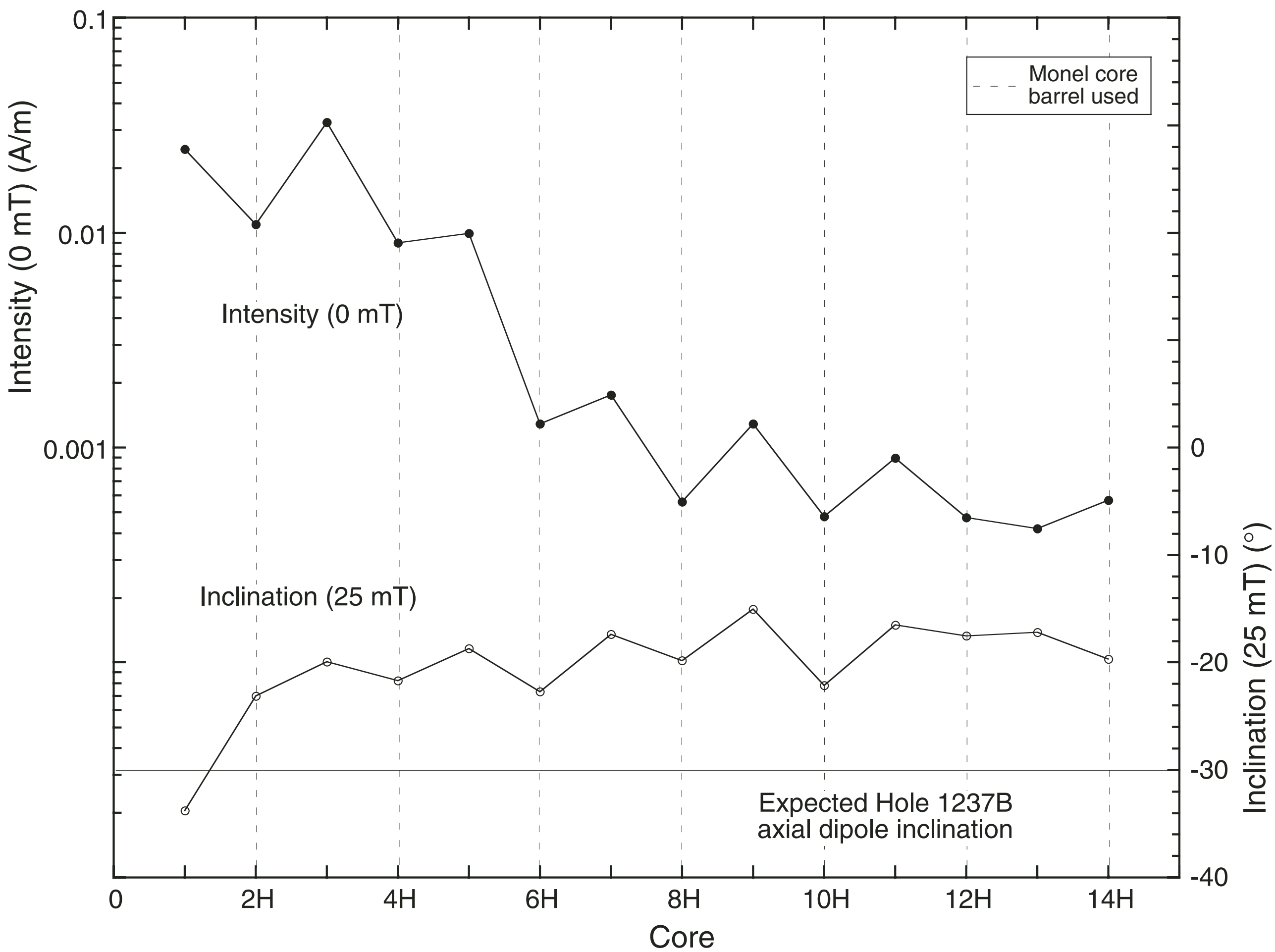


Figure F4. Variations in mean paleomagnetic inclination (25 mT) and initial NRM intensity (0 mT) for Section 2 of all cores from the uppermost 100 mcd at (**A**) Hole 1232A, (**B**) Hole 1233B, (**C**) Hole 1234A, and (**D**) Hole 1235B. Vertical dashed lines indicate cores in which advanced piston corer temperature (APCT) tool measurements were taken. In these experiments, the sediment sits below or at the seafloor in the steel (magnetic) core barrel for an extra ~10 min prior to recovery. In almost all cases, the cores that were obtained when the APCT tool was in use had a larger magnetic overprint, indicated by higher NRM intensities and inclinations that are farther from expected values (horizontal lines) even after demagnetization.