Report of the Paleomagnetism WG for the iSciMP meeting of July 14-16, 2003
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(revised)

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Drilling

Drilling-induced magnetic overprint has been frequently observed in Ocean Drilling Program (ODP) paleomagnetism. To solve this problem, it has been recommended to asses effect the use of non-magnetic drilling tools. During ODP Leg 202, a non-magnetic core barrel was tested to use alternately with a regular magnetic core barrel for APC coring, and the result exhibited that such overprints were dramatically reduced when the non-magnetic core barrel was (Lund et al., 2003). Therefore, it is strongly recommended that the non-magnetic core barrel be used for IODP APC coring to prevent drilling induced magnetic overprint on sediments.

Samples

It is recommended that u-channels will constitute the standard paleomagnetic sample in all cases when it will be feasible to perform u-channel sampling of the cores (i.e in favourable lithologies, like unconsolidated fine-grained sediments), and they should be routinely collected both on the riser and non-riser vessels to be employed in IODP. U-channels have become increasingly popular since the advent of narrow-access long-core superconducting rock magnetometers, in 1991, because of the large amount of detailed data that can be obtained in a minimum amount of time at highest resolution. In the framework of ODP, u-channels were first used during Leg 138 and more than 4800 u-channel samples have been collected since. U-channels are sampled by pushing rigid Ushaped plastic liners (2 x 2 cm cross section, up to 1.5 m in length) into the split core sections. The high resolution data essential for several paleomagnetic study require that u-channel will be collected as a continuous strip from the centre of the cores, since this will ensure the minimum physical disturbance and will minimize the effect of drilling-induced remagnetization (see the recent specific publication by Acton et al., JGR, 107, 10.1029/2001JB000518, 2002). Since (paleo)magnetic measurements are typically not-destructive (apart from paleomagnetic properties themselves), after the paleomagnetic study the u-channels can be either stored as undisturbed permanent archives of the cores or made available for further scientific sampling. In all cases where u-channel sampling will not be feasible (i.e. hard rock cores), continuous paleomagnetic measurements should be carried out on split cores (archive halves of cores). For both soft sediment and hard rock cores it is also recommended to perform additional paleomagnetic measurements on discrete samples (i.e. standard paleomagnetic plastic boxes in the case of soft sediments or drilled cylinders in the case of lithified rocks), that will ensure independent checks for short-lived paleomagnetic features

and will greatly help in the evaluation of deconvolution techniques applied to data from continuous measurements of u-channels or split cores. Drilling facilities (drill press, drill bits, rock saws) should be provided in all IODP expeditions.

Measurements and instrumentation

All paleomagnetic and rock magnetic measurements should be carried out in dedicated, specific, paleomagnetic laboratories, with an appropriate number of scientists and supporting technicians. Measurements and analysis should be carried out as soon as possible during the expedition. For MSP, in which paleomagnetic properties are very important, a "basic" dedicated paleomagnetic van/lab may be considered for measurement and analyses directly "at sea" (i.e. on the model adopted for the Cape Roberts Project in Antarctica, where a temporary paleomagnetic lab was installed during all the three drilling seasons). The software running the instruments should be continuously updated, possibly taking into account comments and suggestions by IODP users. A sort of active interaction between users and the oftware designers by instrument companies is highly advisable.

Basic magnetic properties (required)

1- Magnetic susceptibility

Magnetic susceptibility of all paleomagnetic samples should be routinely measured soon after collection of the samples and, during progressive thermal demagnetization of discrete paleomagnetic samples (see below), as an indicator of thermal alteration. Instruments recommended are the Kappabridges manufactured by AGICO (KLY-3 or KLY-4) for discrete samples and the magnetic susceptibility system MS2 manufactured by Bartington with the loop (MS2 C) of point (MS2 F) sensors for continuous measurements on u-channels or half cores.

2- Natural remanent magnetization

The natural remanent magnetization (NRM) of all paleomagnetic samples should be routinely measured soon after collection of the samples. Instruments recommended are the 2G Enterprises pass-through rock magnetometer with DC SQUID sensors and in-line alternating field (AF) coils with anhysteretic remanent magnetization capability and pulse magnetizer. The diameter of the instrument is critical, but sample-dependent. The small diameter will ensure the high-resolution required for u-channel measurements, but half-cores will not fit in it. On the other hand, the large diameter will allow the passage of half-cores through the magnetometer but will significantly decrease the resolution (i.e. it will be poorly suited for u-channels and discrete samples). The 2G Enterprises pass-through superconducting rock magnetometer installed on the Joides Resolution is a large diameter instrument (standard access diameter of 7.6 cm), whose SQUID's response functions, with half-peak widths of ca. 8 cm, span nearly 20 cm. Each measurement averages the signal of a region of 100-150 cm^3. Conversely, the small diameter (standard access diameter of 4.2

cm) version of the same instrument, designed for u-channels and discrete samples, has half-peak widths of the pick up coils response functions comprised between 4 and 6 cm (referred to the two transverse and the axial coils, respectively). Each measurement averages the signal of a region of 15-25 cm^3. Ideal configuration for IODP paleomagnetic labs will be to have two pass-through rock magnetometer systems, one with small access – high resolution, the other with large access – low resolution. Practical consideration concerning space limitations on board of IODP vessels may prevent the installation of two pass-through rock magnetometer systems, moreover time constraints will also prevent the routine detailed measurement and stepwise demagnetisation of u-channels on board. Such limitations will not apply to shore-based paleomagnetic laboratories (i.e. like those that could operate for MSPs). A practical solution could be to measure split cores onboard, and to measure u-channels in shore-based laboratories. Under such setting, a safe transportation system to shore-based laboratories should be established to prevent magnetic alteration of paleomagnetic samples. An additional spinner magnetometer for discrete samples (i.e the DSPIN spinner magnetometer manufactured by Natsuhara-Giken Inc., or the JR6 spinner magnetometer manufactured by AGICO) may be useful in several cases (i.e. in all cases when the magnetization of samples is too high for the dynamics of the SQUID sensors).

Magnetic cleaning and Paleomagnetism (required)

A paleomagnetic study relies on the stepwise demagnetization of the NRM for all samples, to be carried out soon after the collection of the samples. Stepwise demagnetization is needed to identify the NRM components, to define their stability and orientation and to isolate a characteristic remanent magnetization (ChRM). Demagnetization treatment can only be by AF for continuous samples (u-channel or half cores), while it could either AF or thermal for discrete samples. It is recommended to carry out a complete stepwise demagnetization for u-channels and discrete samples, whereas the stepwise demagnetization treatment should be limited to low AF (i.e. AF peak values up to 20 mT) for half cores. Instruments required are an AF demagnetizer for continuous samples, installed in-line with the pass-through rock magnetometer, and a paleomagnetic oven (i.e. like the ASC Scientific TD48 thermal demagnetizer). It is recommended to have an additional AF demagnetizer for discrete samples, with ARM capabilities, like the D-2000 DTech Inc. or the AGICO LDA-3A AF demagnetizer and AMU-1A anhysteretic magnetizer. It is advisable to have in each IODP paleomagnetic lab a Three-Axis Fluxgate Magnetometer for the measurement of small ambient magnetic fields (of the order of a few nT) in the sensing/demagnetizing regions of each instrument.

Rock Magnetic Measurements (highly recommended)

The characterization of the magnetic particles in paleomagnetic samples is necessary for a proper interpretation of the paleomagnetic signal and is the main target for studies on environmental magnetism. For such studies it is essential to measure the stepwise

acquisition and demagnetization of artificial remanence (ARM and IRM), the hysteresis properties and the thermomagnetic behaviour of selected samples and powders. Such measurements are time consuming and practical considerations imply that during the expeditions such measurements should be limited to selected representative samples only. It is recommended that such measurements will be extended to larger sample collections in the post-cruise measurements, whenever they could be important for the scientific objectives of the Expedition. In some cases it could be also important to study the magnetic anisotropy (either of the magnetic susceptibility or of the remanence) of the paleomagnetic samples. Instruments required are, partly, those used for the paleomagnetic study (i.e AF demagnetizer with ARM capabilities and pulse magnetizers, kappabridges), with the addition of a vibrating sample magnetometer for hysteresis measurements (i.e. the VSM manufactured by the Princeton Measurement Corporation), and some additional devices for the AGICO kappabridge (i.e. the CS-3 for the KLY-3 or KLY-4).

Sequence for the measurements

The order of measurements on discrete samples and/or u-channels is as follows:
1) Magnetic susceptibility
2) Natural Remanent Magnetization (NRM)
3) Stepwise demagnetization of the NRM
4) (Stepwise) Acquisition and demagnetization of an ARM
5) (Stepwise) Acquisition and demagnetization of an IRM
Hysteresis loops and thermomagnetic curves should be measured on powders or chips, independently from the cycle of measurements listed above. Magnetic anisotropy can also be studied on selected discrete standard paleomagnetic specimens.

Calibration and Units

It is necessary to indicate:
- Description of the instruments (system specifications, i.e. in terms of response functions, resolution, range, accuracy….) and calibration standards/procedures. Paramagnetic Rare Earth oxides (i.e. Gd_2O_3), are recommended for calibration of susceptibility meters, permanent magnets for calibration of magnetometers. Calibration standards should be measured before the routine work to produce reliable data. The results of standard measurement should be saved into shipboard databases.
- SI units for each parameter. Paleomagnetic data need to be expressed by declination, inclination and intensity at each demagnetization step. It is also recommended to produce a web based equipment history sheet for all the equipment in each P-Mag lab. The idea being that anyone having problems with a particular piece of equipment could look in the history of that tool to see if it has happened before and how to fix it. It should be a sort of dynamic online manual that would be continuously updated.

Summary Table

Data	Riser	Non-riser	MSPs	Notes
Magnetic susceptibility	b, d	b, d	b, d	
Natural Remanent Magnetization (NRM)	b	b	b	Practical considerations imply NRM to be measured as soon as possible in shore-based laboratories for MSPs
Stepwise demagnetization of the NRM	b, c, d	b, c, d	b, c, d	Practical considerations imply NRM to be measured as soon as possible in shore-based laboratories for MSPs
Stepwise acquisition and demagnetization of artificial remanences (ARM, IRM)	d	d	d	Practical considerations imply rock magnetic properties to be analyzed on representative selected samples only during the Leg
Hysteresis properties	d	d	d	Practical considerations imply rock magnetic properties to be analyzed on representative selected samples only during the Leg
Thermomagnetic runs	d	d	d	Practical considerations imply rock magnetic properties to be analyzed on representative selected samples only during the Leg
Magnetic anisotropy	d	d	d	Practical considerations imply rock magnetic properties to be analyzed on representative selected samples only during the Leg
Magnetic ambient field				Necessary to monitor small ambient magnetic fields in each paleomag lab

Codes:
a. needed for safety,
b. needed to be made on the ship because it is an ephemeral property,
c. needed because it can affect drilling decisions on the cruise or expedition,
d. needed because making the measurements on the ship results in the best science overall (for example, if not made on the ship, it is unlikely that the measurements will ever get made at all, or, having the capabiliity on the ships will deliver better science more rapidly).