MSP-Tool: a software tool for the analysis of multispecimen palaeointensity data in Microsoft Excel

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1. Introduction

To better understand the Earth's magnetic field, we need more information on how it behaved in the past. This information is recorded by e.g. archaeological artefacts, lavas and sediments. However, while palaeomagnetic directions are relatively straightforward to obtain, it is notoriously difficult to obtain reliable absolute palaeointensity data. As these methods generally involve multiple heating steps, chemical alteration is common. Furthermore, multidomain effects may influence the result.

The fairly recent multispecimen protocol (MSP, Dekkers and Böhnel, 2006; Fabian and Leonhardt, 2010) largely circumvents these issues by using a single low temperature and aligning the samples' NRM parallel to the field in the oven. **MSP-Tool** is a VBA-based software tool for Microsoft Excel that can be used to analyse data acquired using this protocol. Apart from calculating the three commonly used ratios, it also provides important reliability checks and can detect and largely correct alignment issues.

2. An optimised MSP workflow

A complete multispecimen experiment was carried out on lavas from Mt Etna that were given a full TRM. Half of the specimens were deliberately misaligned by 15, 30 or 90° to showcase MSP-Tool's alignment error detection and correction.

2.1 Selecting the right temperature
The temperature selected for the multispecimen experiment should be below the specimen's alteration temperature, but high enough to unblock a significant (preferably at least 20%) fraction of its NRM. The ARM test (de Groot et al., 2012) provides an additional way to test for subtle alteration at the chosen temperature. If the amount of ARM gained by a heated sample is equal to the amount gained by a pristine sample, the MSP protocol should produce the correct palaeointensity (PI).
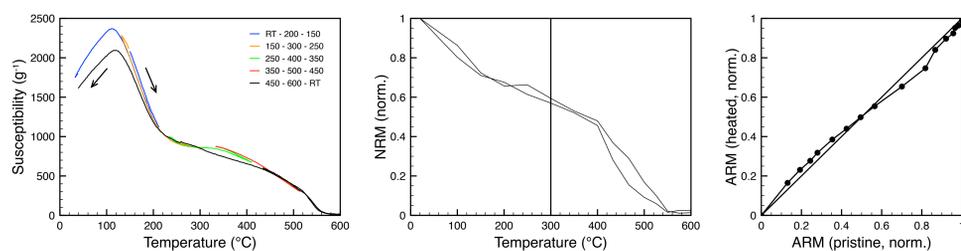

Fig. 1. Left: No visible alteration occurs until after 600 °C. **Middle:** At the selected MSP temperature of 300°C, this site has lost c. 40% of its NRM. **Right:** The ARM test is on the ideal line, so no alteration at the MSP temperature is expected.

2.2 Specimen alignment
To minimise the effects of pTRM tails, the specimens are aligned parallel to the field in the oven. We used a custom-made sample holder similar to the one used by Böhnel et al. (2009).
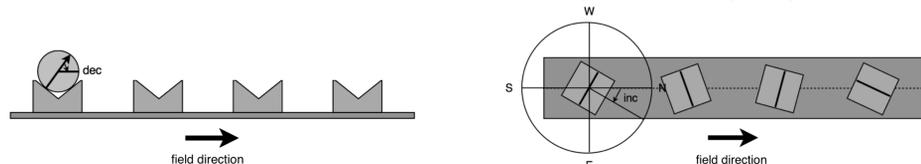

Fig. 2. Left: First, the plane of the declination and inclination is put parallel to the field in the oven. **Right:** Second, the sample holders is rotated by the inclination to align the specimen's NRM parallel to the furnace field.

2.3 The MSP experiment
In the original multispecimen protocol (MSP-DB; Dekkers and Böhnel, 2006) every sample is heated only once. In the extended DSC (domain-state-corrected) protocol (Fabian and Leonhardt, 2010) several steps are added to estimate (and partially correct for) the amount of NRM remaining, the domain state and the amount of alteration. The five measurements are then:

1. m_0: the NRM
2. m_1: remanence after heating and cooling in a parallel field
3. m_2: remanence after heating and cooling in an anti-parallel field
4. m_3: remanence after heating in zero field and cooling in a parallel field
5. m_4: same as m_1 to check for alteration

When the laboratory field H_{lab} is equal to the palaeofield, m_1 should be equal to the NRM (and when H_{lab} is larger or smaller, m_1 should be larger or smaller, respectively). This is expressed in the MSP ratios, where Q_{DSC} is normalised to the NRM lost rather than the entire NRM and corrects for the domain state.

$$Q_{DB} = \frac{m_1 - m_0}{m_0}$$

$$Q_{DSC} = 2 \cdot \frac{(1+\alpha)m_1 - m_0 - \alpha m_3}{2m_0 - m_1 - m_2}$$

α is generally set to 0.5, as recommended by Fabian and Leonhardt (2010).

2.4 Data analysis using MSP-Tool
Data can be imported into MSP-Tool using either the three cartesian components of the remanence or the intensity, declination and inclination of the remanence. Circular standard deviation and exponent (e.g. JR6 spinner magnetometer) are optional. MSP-Tool's input sheet calculates m_0 to m_4, isolates the NRM remaining and pTRM gained and calculates the angle between them (Δdec and Δinc). Furthermore, it estimates the fraction NRM lost and checks for overprints. The plot sheets provide additional reliability criteria, such as the progressive alteration and the intersection with the y axis. Data are analysed using bootstrap statistics.

Fig. 3. MSP-Tool input sheet showing the input (columns A-F), the isolated pTRM components (G-I), the standard and alignment-corrected m_0 to m_4 (J, K), the declination and inclination of the remanence (L, M), the angular difference between the NRM remaining and the pTRMs (N, O), the fraction NRM lost (Q) and an overprint warning (R). The 'm2 factor' in column P is equal to +1 when m_2 is parallel to m_0 and equal to -1 when they are antiparallel.
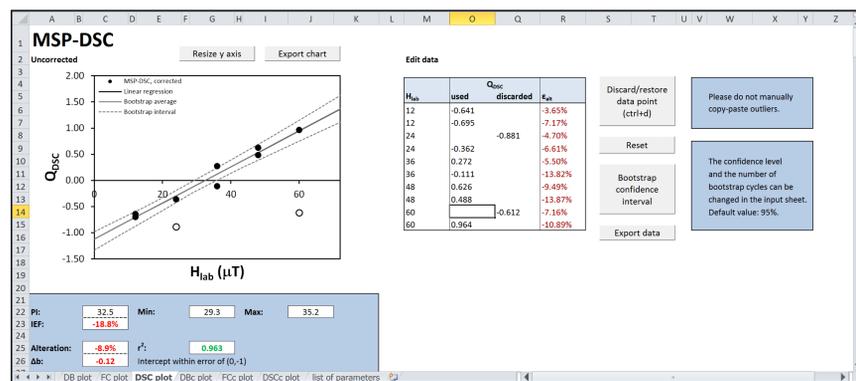

Fig. 4. MSP-Tool plot sheet using the DSC protocol. The two outliers were misaligned at angles of 90°. This site shows a large progressive alteration of nearly 9% and underestimates the 'palaeofield' of 40 μT by nearly 19%. (The intensity error fraction, Biggin et al. (2007).)
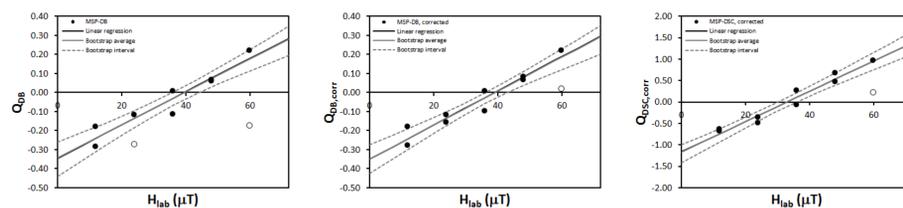

Fig. 5. Left: The DB protocol, which only uses one heating step, does reproduce the palaeofield. **Middle and right:** The alignment-corrected plots for MSP-DB and MSP-DSC show significantly less scatter than the uncorrected plots (Fig. 5, left and Fig. 4, respectively).

3. Summary and recommendations

MSP-Tool is an easy-to-use VBA-based tool for Microsoft Excel that can be used to analyse multispecimen experiments. Apart from calculating all ratios and parameters from Dekkers and Böhnel (2006) and Fabian and Leonhardt (2010), it also detects and partially corrects misalignment and provides important reliability criteria. For an optimal experiment, the following aspects should be taken into account:

- A preliminary ARM test (de Groot et al., 2012) is recommended to check for subtle alteration at the MSP temperature.

- A large (> 3%) progressive alteration often leads to significant scatter and/or underestimates in the DSC protocol. In these cases the MSP-DB plot may be preferred, as a positive ARM test implies that a single heating step did not cause appreciable alteration.

- MSP-DB plots may substantially improve when samples are selected based on similar fractions NRM lost, as these plots are normalised to the entire NRM rather than the amount of NRM lost as in the MSP-FC and MSP-DSC plots.

References

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