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Comparison between the domain-state-corrected multispecimen and microwave methods using historical lavas from La Palma, Spain

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Reliable palaeointensities (PIs) are necessary to determine the full vector variation of Earth's magnetic field as a function of geological time, and hence to provide constraints for geodynamo models. Knowledge of PIs also has implications for cosmic abundance ratios, as the strength of Earth's magnetic field influences the amount of radiation entering the atmosphere. Most current palaeointensity determination methods are based on the classic Thellier-Thellier protocol. These protocols are usually fairly laborious and are characterised by rather low success rates.

A new method of determining palaeointensities was proposed by Dekkers and Böhnel in 2006. In this 'multi-specimen parallel differential pTRM method' (MSP-DB) an ancient TRM is overprinted by an laboratory pTRM pointing at the same direction, at a single low measurement temperature. The method is based on the linearity of pTRM with inducing field, a property that is independent of domain state. It uses multiple specimens to ensure that all specimens experienced the same magnetic history. However, especially for intermediate grain sizes the MSP-DB protocol seems to overestimate palaeointensities. To solve this problem, Fabian and Leonhardt (2010) proposed a new, domain-state-corrected protocol (MSP-DSC) based on a statistical theory of weak-field thermoremanence and a phenomenological thermoremanence model that quantifies the domain-state-induced overestimate. The DSC protocol uses three additional steps in comparison to the original DB protocol, which isolate the overprinted pTRM, make an estimate of the domain state and detect alteration.

Both the MSP-DB and the DSC protocols have been tested on historical lavas from La Palma and compared to microwave results obtained using the Aitken protocol and pTRM checks. Nine flows were sampled, including the 1949 and 1971 flows, which were sampled at 5 and 3 sites respectively. These twentieth-century flows are particularly important, as their PI results can be compared to IGRF values. All samples were within the pseudo-single-domain range, but their hysteresis ratios varied widely, from close to the single-domain range to very near the multi-domain range. Curie temperatures varied from 80 to 540 °C and differed between sites within one flow. Palaeomagnetic directions determined using thermal and alternating-field demagnetisation were within error of the IGRF values. When applying the MSP-DB protocol, the three sites with high Curie temperatures (540 °C) all yielded PI underestimates within 10% of the IGRF value, whereas the sites with low (135 °C) to very low (80 °C) Curie temperatures yielded large under- or overestimates (30 to 50%), perhaps fortuitously. The overestimates were reduced considerably by the MSP-DSC protocol, but were still quite high. Sparse data, in conjunction with results from Mount Etna by De Groot (2009) indicate that underestimates occur as well, but this aspect remains enigmatic.

The microwave method was successful for six out of eight sites and generally yielded the best results, within 4 to 11% of the IGRF values. Differences between the results from multispecimen and microwave measurements were in some cases as large as 40%. This is interesting, because in an earlier study by Böhnel et al. (2009), microwave and multispecimen results were found to be very similar; the multispecimen results generally being slightly higher than those obtained using the microwave.

References

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