Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 423 (C-112), 2018, pp. 9-10
DOI: 10.25171/InstGeoph_PAS_Publs-2018-006
16th Castle Meeting New Trends on Paleo, Rock and Environmental Magnetism, Chęciny, Poland, 2018

Thermal Fluctuations in FORC Diagrams: the Missing Link Between FORC Diagrams and Natural Remanence Acquisition

Thomas A. BERNDT[1,✉], Liao CHANG[1], and Shishun WANG[1]

[1]Laboratory of Orogenic Belts and Crustal Evolution, School of Earth and Space Sciences, Peking University, Beijing, P. R. China

✉ tberndt@pku.edu.cn

Abstract

First-order reversal curves (FORC) have become an extremely successful method to assess domain states such as single-domain (SD), pseudo-single-domain (PSD), and multi-domain (MD) grains as well as magnetostatic interactions and are therefore an invaluable tool for basic sample characterization. There use to predict remanence acquisition behaviour, however, has traditionally been limited and mostly qualitative. Traditionally, FORC diagrams are interpreted in terms of Preisach theory that breaks the magnetic behaviour of the different domain states down into individual elementary hysteresis loops (hysterons). These effectively depend on a grain's coercivity and an interaction field, but do not contain any information about a grain's thermal or viscous (thermoviscous) behaviour. In the case of igneous rocks, natural remanence (NRM) acquisition is, however, (chemical alterations apart) almost always thermoviscous in nature. Hence, in order to use FORC diagrams for NRM analysis, the inclusion of thermal fluctuations in the model is essential.

Recently, Muxworthy and Heslop (2011), measured and interpreted FORC to simulate and predict thermoremanence (TRM) acquisition of the given sample in order to obtain paleointensity estimates from alternating field (AF) demagnetization data. This work, the first attempt at predicting remanence behaviour from FORC diagrams, yielded some encouraging results, although their interpretation of FORC diagrams completely neglects thermal fluctuations and obtains TRM behaviour purely from model assumptions.

This work extends the hysteron-model by a thermal fluctuation field that allows to account for and interpret thermoviscous effects in FORC diagrams in order to obtain better NRM predictions from FORC diagrams. It is shown that thermal fluctuations have a visible effect in FORC diagrams that is similar to a magnetostatic interaction field in appearance and can hence easily be misinterpreted. It is shown how thermal fluctuations manifest in the diagrams for single-domain (SD) and multi-domain (MD) grains and that accounting for them is essential to predict NRM acquisition such a s paleointensities.

Secondly, a new type of FORC measurements, termed time-asymmetric FORC (TAFORC) diagrams is proposed which allows to quantify thermal fluctuations and to distinguish them from interactions. It makes use of two different (asymmetric) timescales for the reversal field H_a and the FORC measurement field F_b: the reversal field H_a is applied for an extended period of time (e.g., 100 s) to allow grains to thermoviscously relax, but the measurement field H_b of the FORC is kept for the commonly used short interval (e.g., 150 ms), inhibiting thermoviscous relaxation. This results in a measurable shift along the H_u (vertical) axis of the FORC diagram that is dependent the on mineralogy, grain shape, microcoercivity, etc. – quantities contribute to the TRM acquisition behaviour. Hence, while traditional FORC diagrams only provide information on the domain states and coercivities of a sample, TAFORCs may provide much more information, and in particular those quantities that determine TRM acquisition.

Keywords: FORC diagrams, thermal fluctuations, viscous remanent magnetization.

References

Muxworthy, A.R., and D. Heslop (2011), A Preisach method for estimating absolute paleofield intensity under the constraint of using only isothermal measurements: 1. Theoretical framework, *J. Geophys. Res.* **116**, B4, B04102, DOI: 10.1029/2010JB007843.