微小磁性体の非線形緩和過程と新しい温度・時間関係

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Non-linear viscous relaxation and a new time-temperature relation in magnetite nanoparticles

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Neel's thermal activation theory of magnetic relaxation is a fundamental basis of rock and paleomagnetism. Following Pullaiah et al. (1975), we can derive a time-temperature nomogram for single domain nanoparticle ensembles describing that a remanence acquired during a time at a temperature can unblock during shorter heating step at higher temperature. This nomogram does not fit natural rock examples, which show anomalously higher unblocking temperatures than predicted by Pullaiah's nomogram. Although this departure from Neel theory is often attributed to multidomain particles, it is also well known that there are counter-examples indicating higher unblocking temperatures in Kent (1985)'s Appalachian carbonates and Jackson and Worm (2001)'s Trenton limestone even with stable single domain particles. Better agreement has been found for the nomogram based on Walton (1980)'s calculation invoking viscous relaxation. However, Walton's formula fails to deduce a previous Dunlop's experimental viscous relaxation data (Dunlop 1983). The Dunlop's data showed a concave down slope of logarithmic viscous relaxations with increasing ambient temperature. To fit this data, I extend the Neel's exponential relaxation model (dJ/dt = - (1/W)J, W: relaxation constant) to a new time-dependent William-Watts relaxation one (W=$W(t)$=A$*t^D$: 0˜D˜1). This extension generates a stretched exponential viscous relaxation and agrees well with the Dunlop's data with D of 0.7. Using this stretched exponential viscous relaxation, I derived a non-linear time-temperature relation of magnetite nanoparticles, involving the Neel's exponential model with D=0 and the natural data with D=0.5 (Walton 1980, Kent 1985) and D=0.7 (Jackson and Worm 2001). The non-linear time-temperature relation shows that this model continuously deduced previous theories and also predicts the much higher anomalous unblocking temperatures results of Kent (1985) and Jackson and Worm (2001) with D=0.5 and 0.7 for single-domain magnetite ensembles.