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A new theory for acquisition of thermoremanent magnetization: temperature and interaction-field blocking model

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Although Neel's theory (1949) satisfactorily explains the magnetic properties of an isolated single-domain (SD) grain, which is an ideal recorder of both direction and intensity of the past geomagnetic field, numerous subsequent paleomagnetic researches showed that only rarely the magnetic carriers in rocks are pure non-interacting SD grains. In most cases, samples contain mixture of pseudo-single domain (PSD), multidomain (MD), and/or SD particles with strong magnetic grain (or domain) interactions. Our recent investigations indicate that magnetostatic interactions between magnetic assemblages can seriously affect the properties of TRM and generate non-ideal behavior for the Thellier-Coe paleointensity experiment. Here we extend the Neel's SD theory to the case where magnetostatic interactions between particles are generally present. Based on our new theory, we also present a new method for absolute paleointensity determination. We demonstrate that, with the presence of magnetostatic interactions, not only grain's unblocking temperature (T_{ub}) will not equal to the blocking temperature (T_b), but also additional TRM due to grain's interacting field will be created and blocked in the sample. The additional TRM blocked by the interacting field is caused by the existing average remanent magnetization of clustered particles. In addition, a small but significant difference in the direction of partial TRM and the applied external field can often be observed. By using an uniaxial single-domain particles model, we show that for the case where particles are well-isolated there is an ideal relationship $T_{ub} = T_b = vJs(T_b)\, hc(T_b)/(50\,k)$; and for the case where magnetostatic interacting field (h_{int}) is present, $T_{ub}' = vJs(T_{ub}')\,\{ hc(T_{ub}') + 2h_{int}(T_{ub}') \}/(50\,k)$; $T_b' = vJs(T_b')\,\{ hc(T_b') - 2h_{int}(T_b') \}/(50\,k)$. Thus, the unblocking temperature of grains with interacting field would shift to a higher temperature value compared to that of well-isolated grains, whereas the blocking temperature tends to shift towards a lower value. At the temperature that is higher than the ideal maximum T_{ub} of an assemblage of clustered SD particles, the interacting field will disappear statistically, and the particles will acquire a completely magnetized TRM (CM_TRM) during successively cooling, which is identical to the total TRM (cooled from Curie temperature to room temperature). This is the crucial point of our new experimental method for paleointensity determination: we compare the unblocking temperature spectra of the CM_TRM part of an artificial TRM with that of natural remanent magnetization (NRM) to estimate paleointensity, rather than comparing the unblocking spectra of NRM with blocking spectra of progressive artificial TRM, which is used in the traditional Thellier-Coe method. The premise of our new method is that, if the unblocking spectra of CM_TRM of an artificial TRM can be obtained before significant laboratory physicochemical alteration occurs, a reliable paleointensity can be extracted from samples, even for those samples that contain PSD and MD grains. To illustrate these characteristics and validate our method, we have conducted detailed experiments were on several representative suites of historical lava flows from Hawaii and Izu-Oshima, and baked hearths from archaeological sites and successfully extracted reliable paleointensity that is highly in agreement with the known results.