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Basic properties of transition remanent magnetizations due to the Verwey transition of magnetite

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Nagata et al. (1963) found that synthetic stoichiometric magnetite (Fe3O4) acquired a fairly intense and stable remanent magnetization by warming in a magnetic field from -150 C to room temperature, called transition remanent magnetization. It is worth noting that while ordinary thermoremanent magnetization (TRM) is demagnetized by heating treatment, the magnetite acquired remanence during heating from low-temperature to room temperature. Ozima et al. (1963), Ozima and Ozima (1965), and Creer and Like (1967) further investigated the transition remanence.

Dunlop (2006, 2007) studied a suite of experiments using crushed magnetite sample with various grain sizes and reported interesting features as follows: (1) A remanence was acquired not only during warming from 77 to 300 K (transition warming remanent magnetization, TrWRM) but also during cooling from 300 to 77 K in a magnetic field (transition cooling remanent magnetization, TrCRM). (2) Various sizes of magnetite ranging from 0.6 to 135 um (PSD-MD) acquired the remanences. (3) TrWRM has similar thermal demagnetization curve with 400C -T0 and 500C -T0 partial TRMs.

The acquisition processes of transition remanences are non-destructive and easily treat as bulk sample (e.g., one-inch core). Moreover, the remanences have the potential to reflect the information concerning low-temperature properties of magnetite. Therefore, we conducted systematic experiment using natural rock samples containing nearly stoichiometric magnetite, to understand the basic properties of the transition remanent magnetization. Depending on a magnetic field condition during cooling and warming cycle, we defined three transition remanences: (1) TrWRM, acquired during zero-field cooling (ZFC) and field warming (FW), (2) TrCRM, field cooling (FC) and zero-field warming (ZFW), and (3) transition cycle remanent magnetization (TrRM), FC and FW.

We prepared natural granite samples containing nearly stoichiometric magnetite. The samples were collected at five sites (SH03, SH09, SH29, SH49, and SH59) of the Scared Heart granite in Minnesota River Valley (Minnesota, USA). Two cylindrical core-samples of one-inch diameter (SH03-A and SH03-B) and small chip-sample of mineral assemblage were cut from the SH03 block, while fourteen core-samples were cut from SH09, SH29, SH49, and SH59 blocks.

The transition remanences were imparted to the SH03 core-samples by cooling to liquid N2 temperature (77 K) and warming back to room temperature in a DC (or zero-) field. We conducted stepwise alternating field (AF) demagnetization of the transition remanences, anhysteretic remanent magnetization (ARM), and low-temperature demagnetization (LTD) component of ARM. Magnetizations of SH03 chip-sample were continuously measured at 10-300 K with an MPMS. The TrWRM, TrCRM, and TrRM acquisition cycles were measured in the same procedures as those of the core-sample experiments.

TRMs were imparted for the fourteen core-samples of SH09, SH29, SH49, and SH59 by heating from room temperature to 610 C and cooling back to room temperature in a 50 uT field. After LTD treatment, TrRMs were given for each sample by cooling and warming in a 100 uT field. Then the ratio of LTD component of TRM and TrRM were estimated.

Based on the core-sample experiment, basic properties of the transition remanent magnetizations due to the Verwey transition are revealed as follows: (1) Directions of the remanences are parallel to directions of the ambient field (parallelism). (2) Intensities of the remanences are proportional to the weak magnetic field (proportion rule). (3) Median destruct fields (MDFs) are in the order corresponding to TrRM, TrWRM, and TrCRM. (4) Calculated values of TrWRM + TrCRM are well agree with TrRM in intensities and AF decay curves. Together with the results of chip-sample and TRM/TrRM acquisition experiments, we will discuss the detailed properties of the transition remanent magnetizations.

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