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Delineating Individual Ferromagnetic Minerals in Synthetic Mixtures of Magnetite and Hematite

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Abstract

Magnetite and hematite are the most common ferromagnetic minerals in rocks and sediments. Many methods have been developed to identify their occurrence in geological material. Because the saturation magnetization of magnetite is much stronger than hematite, it may not be easy to identify both minerals when using induced magnetic methods, e.g., hysteresis loops or thermomagnetic curves. Frank and Nowaczyk (2008) demonstrated that the hematite concentration must be at least 95 wt% of the mixture before a change in coercivity can be detected, and 99.5 wt% before B_{cr}/B_c is affected. Parameters involving remanent magnetization rather than induced magnetisation, e.g., SIRM or HIRM, noted hematite at concentrations of 90 wt% or higher. In this study, we reexamine mixtures of magnetite and hematite to evaluate the ability of FORC analysis to distinguish mixtures. The end members for the mixtures were magnetosomes of biogenic magnetite (LMU-30) that were provided by the group of Prof. Dirk Schüler from the Department of Microbiology at the University of Bayreuth, Germany. The hematite sample (Hem21) was obtained from Merck. The magnetic properties were defined for these end member samples. Hysteresis loops are closed by 100 mT for mixtures up to 85 wt % hematite; at higher concentration the loop remains open to maximum field. The coercivity, $B_{c,}$ remains relatively stable with a decrease until above 80 wt % hematite. B_{cr} shows a gradual decrease up to 80 wt % hematite. M_s shows a linear cdecrease with increasing hematite concentration. Acquisition IRM curves are saturated by approximately 60 mT for the mixtures of magnetite and hematite up to 61 wt %. By 70 wt % hematite, it is clear that the IRM is not saturated, and the non-saturated contribution increases with increasing hematite content. S-ratio, however, remains above 0.95 for all mixtures until 95 wt% hematite, similar to what was found by Frank and Nowaczyk (2008).

FORC analysis shows that a concentration of hematite (around 90 wt %) visibly influences the FORC distribution. The FORC distribution is confined along $B_u = 0$, but with different spread along B_c. Although the FORC distribution shows different characteristics depending on the hematite concentration, it is still difficult to depict a general change. For a more detailed study of the mixtures, we analyse the FORC data using principal component

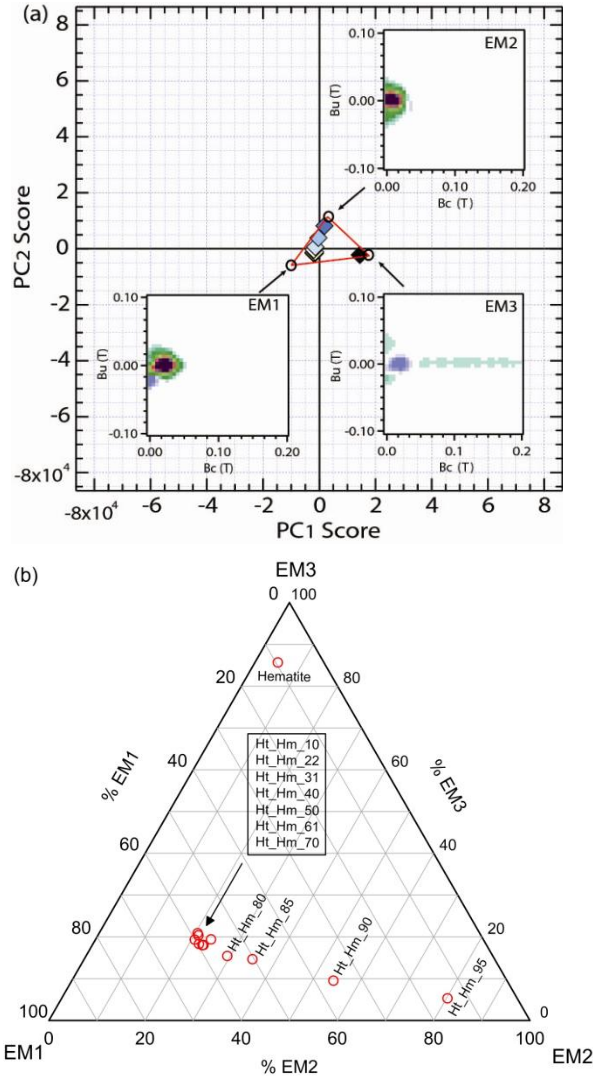

Fig. 1: (a) PCA score plot of the magnetite and hematite mixtures. The resolution for PCA grid on 5 mT; (b) Ternary diagram. Showing relative abundances of the three EMs in each sample.

analysis (PCA) with FORCem (Lascu et al., 2015). The data resolution for the PCA grid is 5 mT. The variability in the mixtures is mainly accounted for by PC1 (Fig. 1), i.e., magnetite, which explains 69% of the data variability. PC2, i.e., the low coercivity hematite component, explains 29% of the variability, and PC3, the higher coercivity hematite component, explains 2% of the variability. Thus, the series can be described as a ternary mixture. This result indicates that hematite influences significantly the magnetic properties at a relative low concentration. Therefore PCA of FORC data can be a powerful technique to detect hematite in mixtures with magnetite.

Keywords: magnetite and hematite, FORC, PCA.

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