THERMAL DEMAGNETISATION OF PSEUDO-SINGLE-DOMAIN MAGNETITE GRAINS EXAMINED BY *IN SITU* TEM AND OFF-AXIS ELECTRON HOLOGRAPHY

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Abstract

Magnetite (Fe_3O_4) is arguably the most important naturally occurring magnetic mineral on Earth due to its high abundance and strong, dominating magnetisation. Understanding its thermal behaviour and recording fidelity is therefore crucial to the field of palaeomagnetism. Of the constituent magnetic minerals found in rocks, particles in the single domain (SD) grain size range (< 100 nm) are regarded as ideal palaeomagnetic recorders because of their strong remanence and high magnetic stability, with potential relaxation times greater than that of the age of the Universe. However, magnetic signals from rocks are often dominated by small multi-domain grains that exhibit magnetic recording fidelities similar to those of SD grains (termed pseudo-SD (PSD)).

In this context, the thermomagnetic behaviour of remanence-induced Fe_3O_4 particles in the PSD size range (~ 0.1–10 μm) was investigated through combining *in situ* heating within the transmission electron microscope and off-axis electron holography. Construction of magnetic induction maps allowed for the visualization of the vortex domain states within individual Fe_3O_4 grains, both in powder form and confined within a silicate matrix, as a function of temperature. In one instance, acquisition of a series of electron holograms at 100 °C intervals during *in situ* heating up to 600 °C demonstrates that the vortex state of a Fe_3O_4 grain remains thermally stable close to its unblocking temperature and exhibits a similar in-plane remanent state upon cooling; i.e., the particle is effectively behaving like a uniaxial SD particle up to temperatures near its Curie temperature. Examination of another Fe_3O_4 grain with a vortex structure flowing in a clockwise direction reveals narrowing of magnetic contours with increasing temperature and transformation to a single domain state at 500 °C, before becoming fully demagnetised at 600 °C. The vortex structure is then recovered upon cooling but with the magnetic contours flowing in an anti-clockwise direction. These results suggest both rotation of the magnetic vortex with increasing temperature and possible collapse into a SD state prior to reaching its blocking temperature. Relaxation into a vortex state flowing in the opposite direction upon cooling further confirms that the Fe_3O_4 grain recovers its remanence like a uniaxial SD particle.