QUANTIFYING THE ROLE OF LOW PRESSURES (< 1 GPa) ON THE FIDELITY OF MAGNETIC RECORDING IN ROCKS AND METEORITES.

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Palaeomagnetic recordings by rocks are routinely used to solve problems in the Earth and Planetary Sciences. Many of these rocks and meteorites will have experienced significant pressures due to a wide range of processes, from tectonics through to earthquakes through to impacts. The theory for the effect of stress on palaeomagnetic signals has for much of the last 70 years been based on theories for uniform magnetic (single-domain, Fig. 1a) particles (< 100 nm for magnetite). These theories predict that stress only becomes important for very high pressures, i.e., > 10-100 GPa. Consequently, the effect of stress on palaeomagnetic recording fidelity has largely been ignored – until now. This assumption that stress does not affect palaeomagnetic signals does not, however, agree with experimental evidence (e.g., Nagata, 1971). Nagata (1971) showed that magnetic recordings in rocks can be altered by pressures < 100 MPa in synthetic samples. There have not been many follow up studies to those of Nagata (1971), as subsequent pressure experiments have focussed on high-energy impact events, where although high pressures are generated, impact-induced heating dominate the magnetic response. Why were the data of Nagata (1971) ignored? The argument has been that the stress-magnetism relationships reported by Nagata (1971) were due to larger grains that display non-uniform magnetisations. Such larger grains were thought until recently not to carry meaningful geological signals. We now know this not to be true.

Recent developments in numerical micromagnetic models (Nagy et al., 2019) and nanometric magnetic imaging (Almeida et al 2016) have shown that stable magnetic remanences in most rocks are recorded by grains > 100 nm that contain non-uniform magnetic structures (vortex structures, Fig. 1b), not uniform magnetic structures as previously thought. There is now an urgent need to study the effect of stress on non-uniform magnetizations. We have recently conducted the first numerical micromagnetic model for the effect of stress on palaeomagnetic recorders (North et al., 2023), and have shown that vortex structures can be remagnetized by compressional pressures as low at ~10 MPa. Such pressures are very common in nature, and rocks often experience such pressures during mountain building and/or burial. Although a ground-breaking study, this paper of North et al. (2023) has only scratched the surface on the effect of stress on non-uniform structures. We are yet to numerically quantify a whole range of physical effects, which will alter the stress-magnetism relationships, e.g., tensile stresses, strain-rate, temperature (depth), grain geometry, distributions of grain sizes, inter-grain magnetic interactions *etc*.

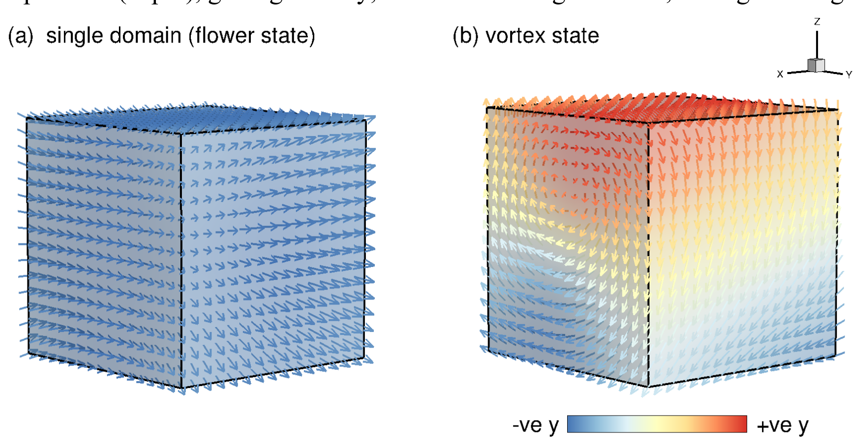

Figure 1. *Micromagnetic solutions for metallic iron particles: a) a small grain with a uniform (single domain or 'flower state') magnetisation, and b) a slightly larger particle showing a non-uniform vortex structure. From Muxworthy and Williams (2015).*

It is proposed that the student will investigate the effect of stress using a state-of-the-art existing finite-element (FEM) numerical micromagnetic model (Nagy et al, 2019, North et al., 2023). The aim is to fully understand the effect of stress on natural magnetic systems. Knowledge of a computer programming language is essential.

References

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