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Constrained Magnetic Vector Inversion of Scanning Magnetic Microscopy Data for Modelling Magnetization of Multidomain Mineral Grains

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We are using 3D magnetic vector inversion (MVI) of scanning magnetic microscopy (SMM) data to investigate the fine‐scale magnetization of rock samples, and particularly of their remanence carriers, which can record geologically meaningful information. Previous investigations of magnetite grains suggest variable remanence intensities and directions coherent with multidomain behaviour. This research seeks to improve our understanding of the contribution of different microstructures on remanence acquisition.

SMM offers a spatial resolution down to tens of micrometers, allowing detailed investigation of discrete magnetic mineral grains, or magnetic textures and structures. However, all magnetic measurements are, at some scale, bulk measurements. Further analysis of the data is required to extract information about the magnetization within the samples: for this, we employ state-of-the-art MVI methods. The MVI problem suffers from a high degree of nonuniqueness. Additional constraints are required to obtain accurate, reliable and interpretable results. Such constraints are readily available for this application.

SMM instruments use magnetic shields or Helmholtz coils to allow collection of data in controlled magnetic fields, enabling the removal of induced magnetization effects. Measurements can be taken both above and below the sample. Individual magnetized mineral grains are easily outlined through optical and electron microscopy. The internal geometry of the oxide mineral phases and compositions can also be constrained. Physical property information constrains the range of magnetization intensity. As such, there is a tremendous amount of constraining information invaluable for reducing the nonuniqueness of the inverse problem. We use a highly flexible and functional inversion software package, MAGNUM, developed jointly at Mount Allison University and Memorial University of Newfoundland, that allows incorporation of all available constraints.

We take a multitiered approach for investigating specific magnetized grains. First, coarse regional inversions are performed to assess and remove any effects of other magnetized grains in the vicinity. The entire grain is then modelled with a homogeneous magnetization to obtain an approximate but representative bulk magnetization. The grain is then modelled as a collection of independent subdomains, each with a different homogeneous magnetization direction. Subsequently, more heterogeneous scenarios are considered by relaxing inversion constraints until the data can be fit to the desired degree.

Obtaining reliable information about the magnetic mineralogy of rock samples is vital for an understanding of the origin of rock bulk behaviour in both the laboratory and larger scale magnetic surveys. This work is among the first to simultaneously invert SMM data collected above and below a thin sample, which is critical for improving depth resolution on thicker samples. It is also the first time we have been able to incorporate all available constraints into inverse modelling to improve results.