Determining ancient field intensities from chemical remanent magnetisations in rocks and meteorites

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Background

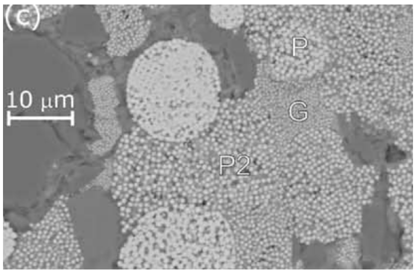

Figure 1. Diagenetic greigite and pyrite framboids. From Rowan and Roberts [2006].

To understand how the geomagnetic field has changed in the past, we look at the magnetic remanence recorded by rocks and meteorites. Determining the ancient geomagnetic field direction is relatively straightforward, however, estimating the ancient geomagnetic field intensity (palaeointensity) is more difficult. Currently al palaeointensity determinations are obtained from minerals whose natural remanent magnetisation (NRM) is thought to be a thermoremanent magnetisation (TRM) in origin. A TRM is the remanent magnetisation acquired by magnetic minerals as they cool from above their ferromagnetic ordering temperature (the Curie temperature) to ambient temperature in the presence of a field, e.g., lavas normally carry TRMs. Such magnetisations can be stable for billions of years, however, there are many cases in nature where the magnetic minerals are formed below the Curie temperature, i.e., the NRM is not a TRM but a grain-grown CRM (chemical or crystallization remanent magnetisation)? A grain-growth CRM is acquired as magnetic crystal grows in size: when a crystal is small, thermal fluctuations randomise the orientation of its magnetic moment, however, as the volume increases the relative importance of the thermal fluctuations decreases and the magnetisation becomes frozen. Such CRMs are recorded in diagenetic greigite (an iron sulphide) (Figure 1) and in hydrothermal alteration in meteorites. Similarly change of iron oxide phase, e.g., magnetite to maghemite, can lead to a change in the magnetic remanence state (Figure 2.)

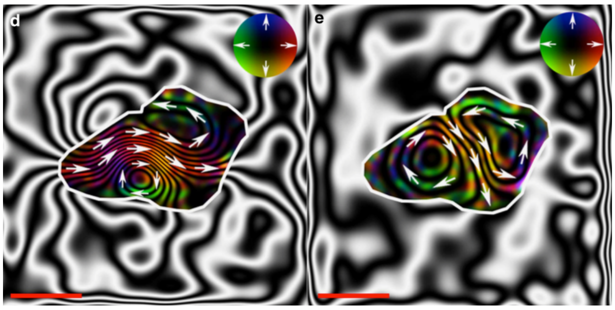

Figure 2. Magnetic structures in a grain of magnetite (d), before oxidation to maghemite (e). Scale bar is 100 nm. From Almeida [2014].

Project

The aim of the PhD project is to empirically test a Preisach-based protocol that uses only room-temperature measurements to determine the palaeointensity recorded by a grain-growth CRM. Prof. Adrian Muxworthy has already developed a Preisach-based protocol for determining palaeointensities from rocks carrying TRMs (Muxworthy & Heslop, 2011; Muxworthy et al., 2011), and have recently developed similar model for Preisach CRM (Baker and Muxworthy, 2023). However, the model has yet to be empirically tested.

To do this, the PhD student will synthesise minerals in the laboratory under controlled magnetic field conditions, i.e., where we know the answer, and to study historical samples from Hawaii, previously identified as carrying a grain-growth CRM where the geomagnetic inducing field is known.

Student Profile

This project is primarily lab-based in nature and would suit a candidate with an interest in sample-synthesis and cutting-edge rock magnetism as well as possessing excellent organizational and time management skills. Candidates should have a degree in Earth Science, Material Science or Physics and a good background in laboratory-skills.

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Baker, E.B. & Muxworthy, A.R., 2023. Using Preisach Theory to Evaluate Chemical Remanent Magnetization and Its Behavior During Thellier-Thellier-Coe Paleointensity Experiments, J. Geophys. Res., 128, e2022JB025858, doi:10.1029/2022JB025858.

Muxworthy, A. R., Heslop, D, (2011). A Preisach method to estimate absolute paleofield intensity under the constraint of using only isothermal measurements: 1. Theoretical framework, J. Geophys. Res., Vol:116 (doi)

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Rowan, C. J., and A. P. Roberts (2006), Magnetite dissolution, diachronous greigite formation, and secondary magnetizations from pyrite oxidation: Unravelling complex magnetizations in Neogene marine sediments from New Zealand, Earth Planet. Sci. Lett., 241, 119-137.

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