

PhD Project Description

Project Title

Testing the Geocentric Axial Dipole hypothesis at low latitude: full-vector records from Kenya and the Marquesas Islands

Supervisors

Lead Supervisor: Prof. Adrian Muxworthy, Department of Earth Science and Engineering, Imperial College London

Co-supervisor(s): Prof. Conall Mac Niocaill, Department of Earth Sciences, University of Oxford

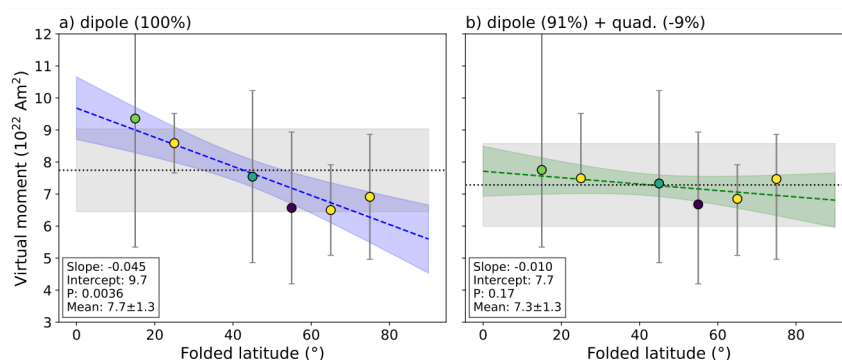
Research Group

Natural Magnetism Group, Department of Earth Science and Engineering, Imperial College London.

Project Summary

Palaeomagnetism rests on a simplifying assumption: that although the geomagnetic field varies continuously, its long-term average behaves as a geocentric axial dipole (GAD), aligned with the rotation axis. Almost all plate reconstructions and palaeogeographic estimates depend on it. Whether, and over what timescale, that assumption actually holds has been debated for decades, and recent evidence suggests it may not hold as well as generally assumed.

We have now shown as much at high latitude. A new set of 43 ancient geomagnetic field intensity (palaeointensity) estimates from Icelandic lava flows spanning 2 to 8 million years, combined with the global database through a Bayesian latitude-dependent analysis, indicates that the time-averaged field is only around 91% dipole, with a persistent quadrupole contribution of about 9% (Muxworthy et al., 2026). A pure GAD field cannot account for the observed latitudinal pattern in palaeointensity. Intriguingly, closer inspection suggests that the deviation from GAD may actually be largest at low latitude rather than high latitude, but the existing global compilation is too sparse and heterogeneous there to test this properly (Fig 1.)



*Figure 1. Tests for the GAD hypothesis. Virtual moment (palaeointensity) vs latitudinally binned data. A) Dipole fit, and b) dipole and quadrupole fit – **a perfect fit would be horizontal with no latitudinal variation**. The data at low-latitudes is of poor quality. The 0-10° does not have enough high-quality points to form a bin, and the 10-20° bin has a large error. From Muxworthy et al. (2026).*

This project takes the test to where the data are weakest. It will build two new, independent, full-vector time-averaged-field datasets from young low-latitude volcanic provinces that have never been used for palaeointensity work: the Chyulu Hills of southeastern Kenya and the

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Marquesas Islands of French Polynesia. Using the same rigorous Thellier-Thellier-Coe methodology as the Icelandic study, the student will determine whether the apparent low-latitude deviation from GAD is real, and whether it is consistent between two geographically independent sites.

Research Context and Objectives

The geocentric axial dipole hypothesis underpins the use of palaeomagnetic data to reconstruct plate motions and palaeogeography, yet direct field observations of the last four centuries are strongly non-GAD, and it is unclear over what timescale the field actually averages to a dipole. Global compilations of time-averaged field (TAF) directional data suggest a persistent non-dipole contribution of up to about 5% (e.g. de Oliveira et al., 2021), thought to be largest at high latitude. Palaeointensity-based TAF studies, which are far less numerous, have suggested even larger deviations, but almost entirely from high-latitude datasets (Muxworthy, 2017).

Our group has now tested this directly at high latitude. New palaeointensity data from Iceland, combined with the global Borok-Munich database through Bayesian inference, show the time-averaged field over the last 8 Myr comprises around 91% dipole and 9% quadrupole, with the deviation from GAD not clearly concentrated at high latitude as expected: **the low-latitude bins, though currently poorly resolved, appear to deviate at least as much** (Muxworthy et al., 2026).

This project will resolve that ambiguity by building dense, well-dated, full-vector palaeomagnetic records from two low-latitude volcanic provinces chosen specifically because they have not previously been used for absolute palaeointensity work: the young basaltic Chyulu Hills field in Kenya, and the older Marquesas shield volcanoes in French Polynesia. Sampling two independent low-latitude sites, in different oceans and tectonic settings, will also test whether any deviation from GAD is a genuine low-latitude signature of the core field or a local artefact of regional field structure. The student will address four objectives:

1. Carry out fieldwork in the Chyulu Hills, Kenya, and the Marquesas Islands, French Polynesia, to characterise lava-flow stratigraphy, age range and preservation state, and to select sampling localities.
2. Undertake systematic field sampling and rock-magnetic characterisation of both sequences plus existing samples, including assessment of the effects of tropical weathering and alteration on the magnetic mineralogy.
3. Determine site-level palaeodirections and palaeointensities using the IZZI Thellier-Coe method with the TTB selection criteria, following the protocol of Muxworthy et al. (2026), supported by new $40\text{Ar}/39\text{Ar}$ age control.
4. Combine the new Kenyan and Marquesan datasets with the global palaeointensity database to test the latitude dependence of the time-averaged field, assess the agreement between the two independent low-latitude records, and refine the virtual-moment correction for non-dipole contributions.

Collaborators and partners on the project:

A joint project with Prof. Conall Mac Niocaill at the University of Oxford, building on the collaboration behind Muxworthy et al. (2026). The student will be based in the palaeomagnetic laboratories at Imperial and Oxford, with fieldwork in southeastern Kenya and the Marquesas Islands, French Polynesia.

Further reading:

Muxworthy, A.R., Døssing, A., Mac Niocaill, C., Riishuus, M.S., Supakulopas, R., Barfod, D.N., Turner, K., 2026. High-latitude palaeointensity data do not support the geocentric axial dipole hypothesis, *Geophys. Res. Lett.* (submitted).

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Johnson, C.L. & Constable, C.G., 1995. The time-averaged geomagnetic field recorded by lava flows over the past 5 million years, Geophys. J. Int., 122, 489-519.

de Oliveira, W.P., Hartmann, G.A., Terra-Nova, F., Brandt, D., Biggin, A.J., Engbers, Y.A., Moncinhatto, T.R., 2021. Palaeosecular variation and the time-averaged geomagnetic field since 10 Ma, Geochem. Geophys. Geosyst., 22, e2021GC010063.

Who are we looking for?

We are looking for a motivated student with a degree in Earth Science, Geophysics or Physics and a good background in laboratory and field skills. This is a strongly field- and laboratory-based project combining remote fieldwork in East Africa and the Pacific with rock-magnetic and palaeointensity measurement, so resilience, adaptability and a genuine enthusiasm for fieldwork in remote settings are essential.

The student will develop expertise in palaeomagnetic measurement, rock magnetism and Bayesian time-averaged-field analysis, working across two leading UK palaeomagnetic laboratories. There will be opportunities to present at international conferences and publish in high-impact journals, and the project involves close interaction with research groups at Imperial and Oxford.

Informal enquiries are welcome: adrian.muxworthy@imperial.ac.uk