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What was the strength of the Precambrian magnetic field?

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Key words:	Early Earth, Magnetism, Geodynamo
Research theme(s):	• Geophysics and Geodynamics • Planetary Evolution and Materials
Eligible courses for this project:	• MSc by Research in Earth Sciences (2-3 years) • DPhil in Earth Sciences (3-4 years) • Interdisciplinary Life and Environmental Science Landscape Award (ILESLA)

Overview

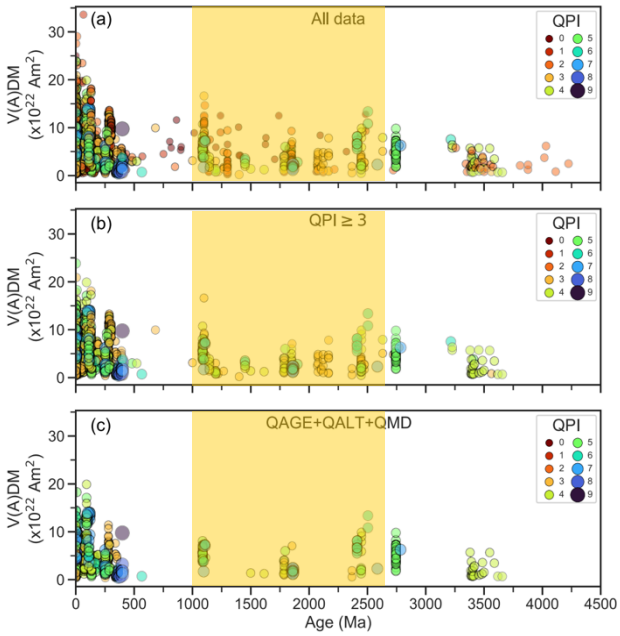


Figure from Bono et al.,(2022) showing all existing paleointensity studies, where the strength of the magnetic field is given as a virtual axial dipole moment (VADM), i.e., the strength of a dipolar magnetic field. The size and colour of each data point depends on the QPI score, which reflects the 'quality' of paleointensity data. Panel a shows all data, and panel b and c show increasingly strict filtering of high quality data. This highlights very large gaps in our understanding of the Precambrian magnetic field, and the aim of this project will be to assess some of these gaps (yellow region).

The Precambrian makes up the vast majority of Earth's history, spanning from 541 Ma ago to the beginning of geological time. Many major events affected our planet during this time, from the origins of life to the first multicellular life forms, the onset of modern-day plate tectonics and the rise of atmospheric oxygen—to name just a few. It is often argued that a magnetic field is necessary for planetary habitability to shield the surface from harmful radiation and to protect our atmosphere. However, the strength of the Earth's magnetic field during this time is poorly known (see Figure), leaving open several fundamental questions:

- Is Earth's magnetic field important for the origins of life or the long-term habitability of our planet?
- Does the magnetic field play a role in the evolution of our atmosphere?
- How was the geodynamo driven before the solidification of the inner core, when the mantle was hotter and plate tectonics likely operated under a different regime?

We will address these questions by measuring paleointensities in rocks that formed before and after the great oxygenation event (GOE) at 2.5 Ga ago. Samples have already been collected from 2.7 Ga old rocks in Canada to explore the strength of the magnetic field immediately prior to the GOE. Existing samples of mafic dykes from Greenland with promising paleomagnetic properties that span 2.2 - 1 Ga ago will be used to explore the strength of the Earth's magnetic field immediately after the GOE. This time period may also span the onset of modern day plate tectonics and nucleation of the inner core and we will look for trends that may be related to these events. New paleointensities will be combined with modelling to explore how the dynamo may have operated during the Precambrian. These results will be used to target new field sites and determine paleointensities at time periods which are predicted to be the most informative for uncovering the behaviour of the Precambrian magnetic field.

Methodology

Rock and paleomagnetism:

- IZZI-Thellier experiments (Yu & Tauxe, 2005)
- Paleomagnetic field tests (Nichols et al., 2024)
- Fidelity tests (Tikoo et al., 2012)
- Rock magnetic characterization (hysteresis loops, FORC diagrams, temperature-susceptibility curves, quantum diamond microscopy) (Tauxe, 2010)

Field geology and petrology:

- Sample collection using a paleomagnetic drill
- Geological mapping
- Thin section analysis using a transmitted light microscope/SEM

Fluid dynamics:

- Modelling of various dynamo generation scenarios

Timeline

Year 1: Training in using equipment in Oxford Magnetism Group laboratory and interpretation of paleomagnetic data on existing samples. Fieldwork to collect new samples (tbc). First paleointensity experiments. Write a literature review highlighting gaps/challenges in the field.

Years 2 and 3: Rock magnetic and petrological characterization of samples. Finish paleointensity experiments. Additional fieldwork (tbc). Integrate results into dynamo models. Submit first paper on paleointensity experiments and prepare draft of a second paper on modelling study.

Year 4: Combine experimental and modelling results to consider implications for the Precambrian and the role of the geodynamo. Present key results at an international conference (EGU or AGU). Write up and submit thesis.

Training & Skills

Any specific training the student would undertake as part of the project and other training and skills that will be taught / developed over the period of the project.

- Making and presenting a scientific talk/poster
- Writing a scientific paper
- Good practices in data management
- Computational skills (e.g., Python, GitHub)
- Field skills: geological mapping, rock identification, good sampling practices, field safety, avoiding parachute science
- Lab skills: paleomagnetic analysis, rock magnetic analysis, basic microscopy
- Teaching/mentoring undergraduates and Masters students

References & Further Reading

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Further Information

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