The University of Oxford Department of Earth Sciences

EARTHSCIENCES

UNIVERSITY OF OXFORD

Using paleomagnetism and plate tectonics to understand core crystallization and early geodynamics

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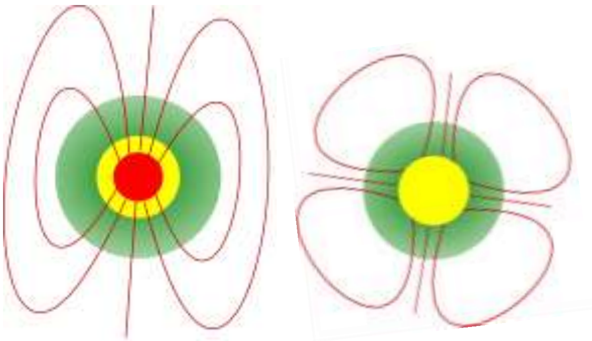
Overview

The motion of tectonic plates over the Earth's surface is typically constrained using paleomagnetism. The recovered magnetic field direction can be used to locate the paleolatitude of the continents. However, these tectonic reconstructions fundamentally rely on the assumption that the magnetic field was dipolar and aligned along Earth's spin axis (Evans et al., 2021).



Since inner core nucleation, the dynamo has generated a dipolar magnetic field aligned along the spin axis as shown by the figure on the left. However, prior to inner core nucleation, the magnetic field may have had a more multipolar field morphology, as illustrated in the figure on the right.

Core dynamo models, which describe the strength and geometry of the geomagnetic field when the core began to solidify, suggest that it may have had stronger multipolar terms prior to inner core nucleation (Landeau et al., 2017). Detecting such changes in magnetic field morphology is highly challenging, since paleomagnetic studies only recover the strength of the field and a point measurement for the direction of the magnetic field at a single location. Therefore, plate tectonic reconstructions offer a novel approach to tackling this question. If the magnetic field has had episodes of multipolar behaviour, the assumption of a dipolar magnetic field must fail, and these failures may be related to unrealistic tectonic reconstructions, allowing variations in the geomagnetic field geometry to be identified.

The age of crystallization of the inner core itself is still poorly constrained, with different experimental approaches, including high-pressure/high-temperature experiments and magnetic field paleointensity studies, suggesting ages that span from the Hadean (>4 Ga) to the Phanerozoic (c. 0.5 Ga). Determining the age of the inner core is also critical for understanding the material properties of the deep Earth, including the core thermal and electrical conductivities (Duarte et al., 2021). Plate tectonic reconstructions will therefore be interrogated throughout the Precambrian to look for signatures that may related to inner core nucleation.

Alongside using plate tectonic reconstructions to identify geometric variations in Earth's magnetic field, paleomagnetism can be used to improve our understanding of geodynamics, for example by determining the rate of tectonic plate motion at various points in geological time (Brenner et al., 2020). Given continued debate concerning the timing of onset of global plate tectonics, paleomagnetic studies focused on measuring Precambrian plate motion may shed important light on the age of transition from a stagnant lid regime to a mobile lid regime (Palin and Santosh, 2021). These data may be interrogated alongside independent lines of evidence, such as petrological, geochemical, and isotopic data sources.

This project will review existing paleomagnetic poles as well as creating new paleomagnetic data for Precambrian targets of interest in order to address two fundamental questions: first, when did the inner core begin to solidify, and second, when did modern-style plate tectonics first initiate on Earth. The results have far-reaching implications for the material properties of Earth's deep interior and long-term geodynamic regimes.

Methodology

The project will combine a literature review of plate tectonic reconstructions using paleomagnetic poles with GPlates models. In addition, there will be an opportunity to conduct fieldwork and paleomagnetic analyses using a range of experimental techniques including the superconducting rock magnetometer and quantum diamond microscope.

Timeline

Year 1: Doctoral training courses, literature review of plate tectonic reconstructions, fieldwork planning, and familiarisation with GPlates.

Years 2 and 3: Fieldwork to Canada, South Africa and/or Australia to collect samples for paleomagnetic experiments. Publish results of literature review.

Year 4: Interpreting results in the context of inner core nucleation and the onset of tectonics. Thesis writing. Attend AGU Fall meeting. Publish results of experimental work.

Training & Skills

The successful student will join the Oxford Magnetism Group at the University of Oxford, UK, which has a history of research excellence in rock magnetism, early Earth and planetary magnetism and tectonic reconstructions. They will also have the opportunity to integrate with faculty at external institutions and industry partners at annual career fairs.

The student will be trained how to plan and conduct a field campaign, and to prepare and analyze samples returned to the laboratory for study using a range of novel paleomagnetic techniques. They will also learn how to use the plate motion modelling software GPlates (Müller et al., 2018).

The student will also be mentored on how to prepare scientific results for presentation at international conferences to an expert and/or general audience, and how to write papers for publication in high-profile, international journals

References & Further Reading

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Further Information

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