High Latitude Variations of the Earth's Magnetic Field: the Holocene Icelandic Lava Record

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Introduction:

The Earth's magnetic field is generated in the molten core of the planet but extends far out to space and acts as a shield against the potentially harmful effects of the 'solar wind.' The nature of the process generating the Earth's magnetic field means that it undergoes *secular variation* on timescales of decades to tens of thousands of years. It is important that we study these variations so that we can understand their cause and also to potentially determine what is likely to happen in the future.

Many natural materials contain ferromagnetic grains. When these grains cool down from high temperatures (600-700°C) (such as when a lava flow cools or archaeological material is fired) they lock in properties of the Earth's magnetic field at the time and place of the last cooling. This spot reading of the field provides not only the ancient field direction but also the absolute field strength or palaeointensity. In combination with age estimates this palaeomagnetic data provides records of Earth's magnetic field evolution. Palaeomagnetic data can also be obtained from sedimentary sequences acquiring remanence from detrital and or chemical processes but rather than spot readings they give a smoothed record. Sedimentary sequences can only provide relative palaeointensity records; however, some form of calibration is required for them to be really useful. There are currently far more directional than palaeointensity (absolute and relative) data due to the more complex experimental procedures needed and difficulties in finding suitable material to study.

Whilst the magnetic field we measure at the Earth's surface can be approximated to that of a bar magnet at the centre of the Earth (roughly aligned with the geographic North and South Pole) it is in fact much more complicated than this. In field maps at the core-mantle boundary, four high latitude, high intensity, flux lobes are prominent. They are approximately symmetric about the equator: two under Arctic Canada and Siberia and two under the eastern and western edges of Antarctica. These flux lobes have been identified as the signature of two columnar convection rolls in the core which are important in geomagnetic field generation. For the last 400 years the flux lobes have remained approximately stationary probably due to mantle influence. Over longer timescales the persistence and dynamics of the flux lobes is not clear but Korte & Holme (2010) suggest that the N Hemisphere lobes for the last 7000 years have exhibited other periods of stability over 400 years but with sharp changes in between.

Project Summary:

Whilst there is a substantial database of palaeomagnetic data for the Holocene period (last 10,000 years) (Brown et al 2015a; b) with Western Europe in particular having good data coverage, the majority of data from high latitudes comes from sedimentary records. In order to better constrain field evolution at high latitudes and thus determine the persistence and dynamics of the N Hemisphere flux lobes more data is needed from volcanic and fired archaeological material. The Holocene lava flows of Iceland are an ideal target and obtaining palaeomagnetic data (with a particular emphasis on determining the field strength) is the primary aim of this studentship. Additionally, we have access to well dated archaeological ceramics from Scandinavia which are another excellent source material for palaeointensity data.

The student will carry out targeted field sampling in Iceland as well as make use of existing sample collections. Experimental work will predominantly be carried out in the Liverpool however it is expected that the student will also carry out some work in the palaeomagnetic laboratory at the University of Iceland.

In addition to producing new data the student also has the opportunity to carry out geomagnetic field modelling in order to elucidate what is happening at the core mantle boundary. The new data can be added to existing global field models such as the pfm9k.1 model of Nilsson et al (2014) and the hypothesis that the flux lobes exhibit quasi-stationary structure separated by rapid change will be explored and investigated.

Full training in traditional and state of the art palaeomagnetic techniques will be given including microwave instrumentation for palaeointensity analysis (as well as traditional thermal techniques) and MPMS/VFTB/Kappabridge instrumentation for analysis of magnetic mineralogy. This is a combination of advanced instrumentation only to be found in Liverpool, which also offers a high degree of post-doctoral and technical support. In addition there will be the opportunity for the student to carry out companion experiments at the palaeomagnetic laboratory at the University of Iceland. Training and tools will also be provided to conduct field modelling to test the implications of their data on core-field structure.

During the studentship, research skills will be developed, and there will be the opportunity to strengthen the student's background in appropriate areas of geophysics. This will be supplemented by the standard department and university training schemes, which are already in-place for all graduate students in the department.

This PhD project is suitable for candidates with an undergraduate background in (geo)physical or geological sciences.

Image 1– Dr Maxwell Brown Palaeomagnetic Field sampling in Northern Iceland

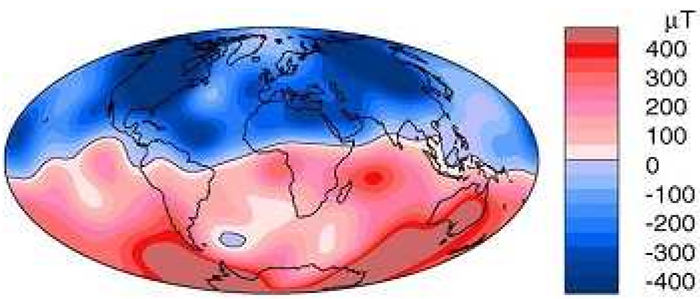

Image 2 - Time averaged radial field at the CMB (1590-1990) showing four high latitude flux lobes.

References

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