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Mapping the Phase Space of Fe-Ni alloys in Meteorites: revealing the chemical and crystallographic complexity of REE-free magnet analogues

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Rare-earth permanent magnets play a critical role in green technologies such as wind turbines and electric vehicles. These elements are mainly sourced from a limited number of countries, many of which suffer from complex political situations. A desire for secure and ethical materials drives a strong global interest in developing low-cost alternatives for permanent magnetic materials.

For over 20 years the meteoritic mineral tetratenite has promised one such solution due to excellent magnetic properties arising from its crystallographic and chemical structure. Recent advances in synthesis have finally started to produce large volumes of this mineral synthetically. However, this has brought to focus new questions about the role of minor and trace elements as well as cooling rate in the formation of this extraterrestrial alloy.

Particular focus for this project will be on the formation of the nanoscale intergrowth called the cloudy zone. It possesses a high magnetic coercively due to the combination of small tetrataenite particles (<100 nm) being embedded in a different Fe-Ni alloy matrix. These properties provide a natural analogue to rare-earth permanent magnet materials.

The project plans to re-map the Fe-Ni phase space represented in the wide range of cooling rates and compositions contained in meteorite samples available. The chemical and crystallographic information will be combined with magnetic characterisation to develop structure-function relationships. The student will employ a range of machine learning tools to design sampling strategies as well as leverage out 'hidden' details in the often large and complex microanalysis data collected.

Sample analysis will work across length scales to understand how the cloudy zone forms and to understand the role of trace and minor element diffusion in controlling its formation. This will include scanning and transmission electron microscopy, energy dispersive spectroscopy, electron back scatter diffraction, as well as atom probe tomography. These multi-scale datasets will be combined to form digital twins of the samples which offer quantitative insight into the formation of the cloudy zone.

The results from this project will be communicated to the wider scientific community via student attendance at both national and international conferences, as well as scientific publications.

Application details: The project is suitable for a graduate with a 2:1 honours degree or above in Geology or Earth Science, Chemistry, Physics or a related subject. The application deadline is Wednesday 31 January 2024. Interviews will be held in mid-late February 2023, and the studentship will start in October 2024.

Information on how to apply is **here**: