Project Title

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Project Highlights:

- Explore how magmatic unconformities and associated PGE deposits develop in large layered igneous intrusions;
- Build predictive tools to improve PGE deposit exploration in layered intrusions;
- Lead your own project development and receive training in geological and technical skills and knowledge sought after by industry.

Overview:

Platinum Group Elements, or PGE (Platinum, Palladium, Iridium, Rhodium, Ruthenium, Osmium), are critical metals with substantial present and future applications; they are used extensively in electronics, medical implants, and cancer treatments. With the growing reliance on technological solutions to the energy transition, we need to ensure our supply of PGE resources is growing, secure, and sustainable. Improving the efficiency of exploration and extraction of PGE mineral deposits is thus key, at length-scales spanning deposit discovery and quantification, to sub-micron level recovery and beneficiation.

Most economic PGE deposits are found within large, ancient, layered mafic and ultramafic igneous intrusions. During the cooling and crystallisation of these intrusions, dynamic processes lead to the segregation of different mineral assemblages into layers, some of which host concentrations of minerals containing PGE. Although many studies have examined the chemical and petrological evolution of such layers, the structural setting of these deposits is often neglected. For example, many PGE deposits are associated with magmatic unconformities, so-called because they represent boundaries where igneous layering appears discordant. Yet we know little about how these unconformities or their PGE deposits mechanically develop. Were these unconformities created by dynamic 'erosive' processes analogous to sedimentary systems, or relatively by late-stage metasomatic dissolution-reprecipitation reactions in the solidifying crystal mush? Such uncertainty means PGE ore distribution is notoriously difficult to predict, which limits the targeted exploration of PGE deposits, the securing of sustainable supply chains, and the minimising of the environmental impact of mining.

In this project, you will conduct fieldwork to study key parts of the Rum (Scotland) and Stillwater (USA) layered intrusion using digital mapping techniques, and sample outcrops and drill core for rock magnetic and Electron-Backscatter Diffraction (EBSD) analyses. These analytical methods will allow you to quantify mineral alignments and crystallisation dynamics in the rocks, shedding new light on the processes by which magmatic unconformities and their associated PGE deposits form. From this information on processes driving unconformity and PGE deposit formation, you will create numerical models that simulate PGE these environments to develop a predictive tool for future exploration.

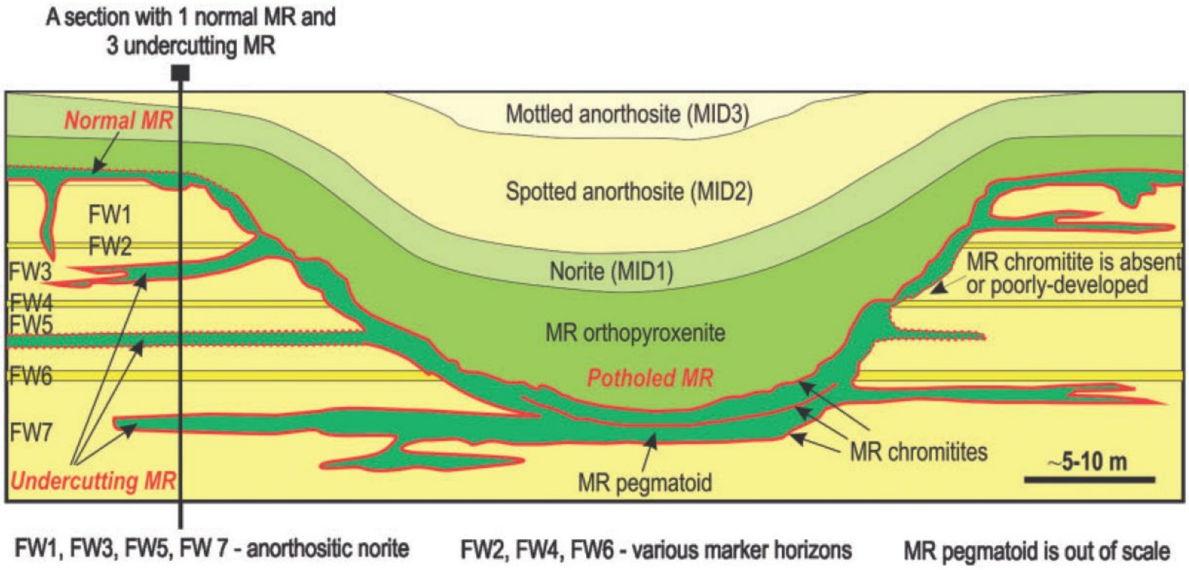

Figure 1: A magmatic unconformity and associated chromitite-hosted PGE deposit in the Merensky Reef (MR), within the Bushveld Complex (South Africa) layered igneous intrusion (Latypov et al. 2017).

This project aims to answer the following key research questions:

1) How do magmatic unconformities mechanically develop within layered mafic and ultramafic intrusions?
2) How is the formation of PGE deposits related to magmatic unconformity development?
3) Can we model the mechanical development of magmatic unconformities and PGE deposits to provide a predictive tool for exploration targeting?

Methodology:

1) Fieldwork – you will use digital mapping (e.g. FieldMOVE) and drone photogrammetry to examine field relations of magmatic unconformities and PGE deposits. You will be trained in logging and sampling core and assay data (e.g. geochemical, conductivity).
2) Rock magnetics – you will use Anisotropy of Magnetic Susceptibility and Anisotropy of Magnetic Remanence to measure the shape and orientation of mineral fabrics in collected samples. Using magnetic remanence experiments, you will characterise the oxide and sulphide mineralogy of ore deposits.
3) Electron-Backscatter Diffraction (EBSD) & Electron Probe Micro-Analyzer (EPMA) – you will collect Crystal Preferred Orientation data using EBSD to validate rock magnetic data. EPMA will be used to collect in situ grain scale geochemical data to identify magma reservoir chemical flux during unconformity development.
4) Numerical modelling – you will build 3D structural models using industry-standard software (e.g. Leapfrog) and conduct flow modelling using COMSOL Multiphysics.

Possible Timeline

Year 1: Months 0-6 – Literature review and rock magnetic training using previously collected samples from Rum. Attendance at a national conference. Months 6-12 – Fieldwork to Rum and Stillwater.

Year 2: Months 12-18 – Sample preparation, rock magnetic and EBSD analyses (and training). Compilation of field data and photogrammetry into 3D structural model. Presentation at a national conference. Months 18-24 – Continued rock magnetic and EBSD analyses, as well as EPMA analysis. Population of 3D structural model with rock magnetic and EBSD data.

Year 3: Months 24-30 – Continued rock magnetic and EBSD analyses, as well as EPMA analysis. Population of 3D structural model with rock magnetic, EBSD, and EPMA data. Training in numerical modelling and building of initial models.

Months 30-36 – Numerical modelling and PhD write-up. Presentation of work at an international conference.

Year 4: Months 36-42 – PhD write-up

Training and skills:

TARGET researchers will participate in a minimum of 40 days training over the 3.5 years of study composed of:

- an annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;
- a number of one-day workshops;
- additional online events and in-person workshops attached to relevant conferences.

Specific to this project, you will receive training in:

- the field analysis of layered intrusions [all supervisors];
- sample preparation and conducting or rock magnetic experiments, including anisotropy of magnetic susceptibility (AMS), at the M3Ore lab in the University of St Andrews [McCarthy];
- EBSD analysis at the Electron Microscope Facility at the University of Leeds [run by in-house team];
- EPMA analysis at the University of Ottawa [O'Driscoll];
- structural modelling using Leapfrog [McCarthy];
- numerical modelling using COMSOL [Magee].

Partners and collaboration (including CASE):

You will spend 3-weeks at both the University of Leeds and University of Ottawa to conduct laboratory training and work for the EBSD and EPMA analyses. Quarterly online meetings between all partners will be held to discuss plans and progress. You will collaborate with the U.S. Geological Survey, learn data management procedures and gain access to workplace mentorship.

Further reading:

Boudreau, A.E., Butak, K.C., Geraghty, E.P., Holick, P.A. and Koski, M.S., 2019. Mineral deposits of the Stillwater Complex. *Montana Bureau of Mines and Geology Special Publication*, *122*(2), pp.1-33.

Latypov, R., Chistyakova, S., Barnes, S.J. and Hunt, E.J., 2017. Origin of platinum deposits in layered intrusions by in situ crystallization: evidence from undercutting Merensky Reef of the Bushveld Complex. *Journal of Petrology*, 58(4), pp.715-761.

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply. *Please contact Dr William McCarthy, University St Andrews for further information on this project (wm37@st-andrews.ac.uk).*