Petrogenesis of V-Ti rich magnetite layers in the Upper Zone of the Bushveld Complex, South Africa

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Project Highlights:

- First comprehensive LIBS and microXRF study of Bushveld magnetite layers
- Opportunity to study the largest layered intrusion and ore deposit on Earth

Overview:

The Bushveld Complex of South Africa is the most mineralised layered intrusion on the planet. It hosts the Merensky, UG2 and Platreef which are located in the intrusion's Critical Zone and have been the object of numerous detailed studies. The current project focusses on the origin of the magnetite layers in the intrusion's Upper Zone (UZ), hosting the world's largest vanadium resource as well as significant titanium and phosphorous. The seams have been examined in several past studies using mostly conventional whole rock and mineral chemistry. In the present project, you will apply, for the first time, LIBS and microXRF to examine all 18 magnetite seams of the UZ. The project is in cooperation with Ivanhoe Mines who are engaged in exploring the northern lobe of the Bushveld Complex. The company will make available for study more than 2km of diamond drill core and associated assay data. They will facilitate a minimum of 2 months of field work and sampling in the intrusion during which they will host the student. The project will provide opportunities to improve our understanding of the stratigraphy and ore formation of the complex, thereby contributing to making exploration and mining of critical minerals (i.e. those that are essential to facilitate the green energy transition) more efficient.

Figure 1: (left) Main magnetite layer in drill core to be studied, (right) MicroXRF image of magnetite layer (Nikonow et al. 2026).

Methodology

The project goals will be achieved by logging and sampling drill core, and by analysing the composition of the rocks and their main constituent minerals. The student will use the state-of-the-art laboratories at Cardiff (CELTIC laboratory), Exeter University and the Bundesanstalt fuer Geowissenschaften und Rohstoffe (BGR) in Hannover, Germany. Key techniques include petrography using transmitted and reflected microscopy, mineral compositional analysis using EPMA, generation of chemical maps using FESEM, microXRF and LIBS (laser-induced breakdown spectroscopy), and whole rock major and trace element analysis using ICP-MS. The objective is to constrain the petrogenesis of the magnetite seams and the lithological and chemical stratigraphy of the intersected sequence. We aim to involve the student in the design of the project, including bringing in his/her own ideas on the research direction.

Possible Timeline

Year 1: Literature review, logging and sampling of drill core, microscopic study of samples, 1 month of fieldwork in South Africa, preparation of samples for chemical analysis and beginning of geochemical analytical program at BGR in Hannover/Germany (summer 2027). Reporting of initial results at MDSG in Belfast (Jan 2027).

Year 2: Interpretation of analytical results, 1 month additional field work in South Africa to collect fill-in samples (February 2028), preparation of 2nd batch of samples for analysis, second analytical visit to BGR in Hannover, reporting of results at an international magmatic ore deposit conference (mid 2028) and MDSG (Jan 2028).

Year 3: Interpretation of data, writing-up of thesis, writing of manuscripts for publication, presentation of project results at an international conference (mid 2029).

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.

Through interaction with the partner company and the supervisors, the PhD student will be trained in research methodology, mineral exploration techniques, and a variety of petrological, analytical and modelling techniques (petrographic microscope, ICP-MS, FESEM, Laser ICP-MS, microXRF, LIBS, EPMA, thermodynamic modelling software such as MELTS). He/she will spend 5% of his/her time demonstrating in the School of Earth and Environmental Sciences and thereby gain teaching experience, which is essential when planning an academic career. Further training will be provided through attendance of national and international conferences.

Partners and collaboration (including CASE):

The student will interact with Ivanhoe staff during field work in South Africa. Ivanhoe will provide access to their field areas and >2000m of drill core and matching analytical data and train the student in drill core logging, sampling, and field mapping. The company will also contribute 1000£ pa to analytical support. The student will interact closely with co-supervisor Dr. Hannah Hughes at Exeter who will provide training in electron microprobe analysis and contribute to supervision in the form of regular in-person and virtual meetings.

Further reading:

Kinnaird, J. A. and McDonald, I., 2018. The northern limb of the Bushveld Complex: a new economic frontier. Society of Economic Geologists Special Publication, 21, 157-176.

Maier, W.D., Barnes, S.J. and Groves, D.I., 2013. The Bushveld Complex, South Africa: formation of platinum–palladium, chrome-and vanadium-rich layers via hydrodynamic sorting of a mobilized cumulate slurry in a large, relatively slowly cooling, subsiding magma chamber. Mineralium Deposita, 48(1), pp.1-56.

Nikonow, W., Junge, M., Rammlmair, D., Meima, J., Goldmann, S., Roelofse, F. and Holtz, F., 2025. Magnetitites in the Upper Zone of the Bushveld Complex–continuous LIBS and µXRF data of magnetitite layer 17 with a focus on cryptic variation of mineral chemistry. Ore Geology Reviews, p.107072.

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply.

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