The Duluth Complex: Helium exploration in a world-class Ni-Cu-PGE magmatic sulphide system

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Project Highlights:

- Helium exploration and reservoir characterisation.
- Ultramafic-mafic Ni-Cu-PGE magmatic sulphide system.
- International fieldwork and magmatic core logging.

Overview:

The Duluth Complex (1.1 Ga) in Minnesota (USA) is a world-class layered mafic, Ni-Cu-PGE magmatic sulphide system, hosted within carbonaceous Palaeproterozoic (2.6 Ga) basement, the assimilation of which is commonly associated with Ni-Cu mineralisation (Miller & Ripley, 1996). During mineral exploration for Ni-Cu-PGE sulphide deposits in the Bald Eagle Intrusion (part of the Duluth Complex), significant quantities (up to 7%) of helium (He) gas accumulations were discovered in 2011. Pulsar Helium are currently conducting an extensive coring campaign into this He discovery to define its overall resource size. This core, as well as petrophysical and seismic acquisition, provides a valuable dataset for investigating the magmatic, and subsequent fluid-dynamic evolution of the Ni-Cu-PGE+He-bearing Bald Eagle Intrusion, as well providing the opportunity for detailed He reservoir characterisation (Fig. 1).

The occurrence of both Ni-Cu-PGE sulphide mineralisation and significant He accumulations greatly increases the prospectivity of the Duluth Complex. This project provides the opportunity to study a unique system, characterising the geological processes that led to the formation/accumulation of valuable resources.

During this project, the student will aim to:

1. Conduct detailed logging, petrographic, and geochemical analyses of the Bald Eagle Intrusion, utilising the newly acquired core and petrophysical data from the Topaz Project. This will allow the production of a detailed magmatic stratigraphy and evolution for the Bald Eagle Intrusion and identification of Ni-Cu-PGE bearing horizons.
2. Perform comprehensive core and downhole fracture analyses for the Topaz Project, quantifying the helium reservoir potential to produce a He reservoir model.
3. Investigate whether there is a link between zones of mineralisation and helium accumulation in the Duluth Complex and assess their association with carbonaceous crustal contamination. This could lead to new pathways for He and/or Ni-Cu-PGE sulphide exploration globally.

The vast and disparate dataset available in the Bald Eagle Intrusion allows the student to build a detailed understanding of the magmatic stratigraphy, mineralisation, and geological controls on helium prospectivity of the Duluth Complex. This study will provide better understanding of layered ultramafic intrusion systems and controls on resource.

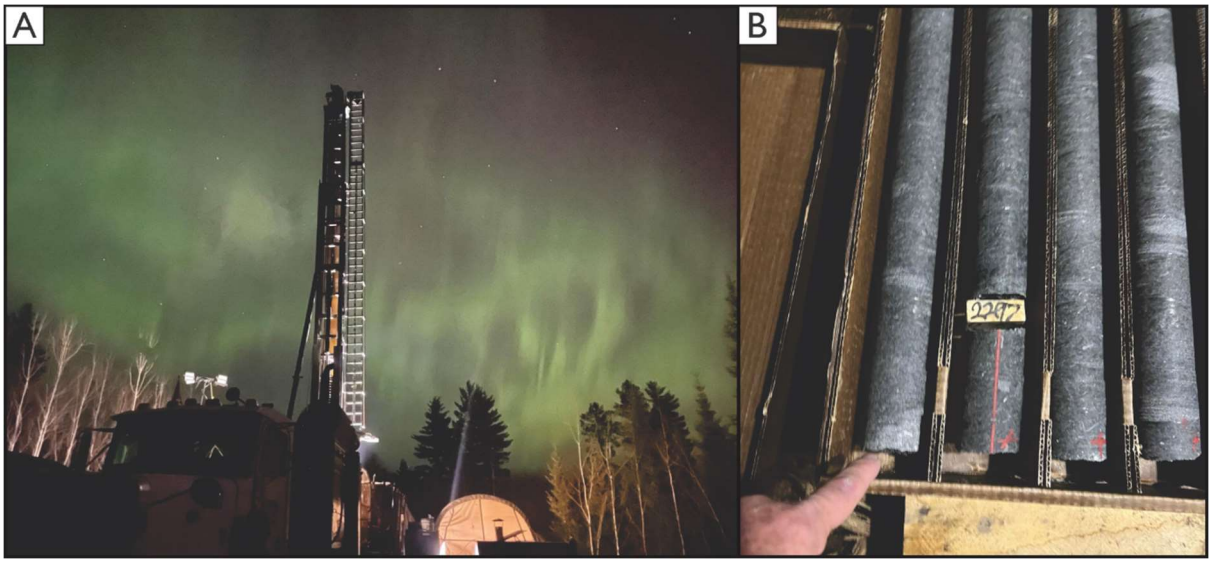

Figure 1: Field photos from Pulsar Helium; (A) Drill rig on site at Topaz Project, Minnesota; (B) New drill core from the Topaz project.

Methodology:

Site visits and extensive fieldwork to Topaz Project, Minnesota and global analogues to the Duluth Complex layered basic intrusions. Fieldwork will include core logging, core analyses, sampling and field mapping. Lab techniques to be utilised at Aberdeen: Petrography (optical, SEM, XRD, pXRF), fluid inclusions. Lab techniques to be used externally; stable isotope analysis (He, S, C, O). Office-based techniques: petrophysical log analysis, 2D seismic interpretation, reservoir modelling.

Possible Timeline

Year 1:

- Initial literature review into the Duluth mafic-ultramafic magmatic sulphide system/deposits and other comparable systems globally.
- Investigate the occurrence of subsurface helium resources globally (including the newly discovered Pulsar Helium Topaz project), their origins and the conditions required for helium generation, accumulation, and discovery.
- Initial fieldwork to the Pulsar Helium Topaz Project and conduct detailed core logging to determine the magmatic stratigraphy and the relationship between helium accumulations and Ni-Cu-PGE magmatic sulphide mineralisation.
- Interpretation of image logs and downhole petrophysics for the boreholes drilled by Pulsar.
- Draft first publication based on findings from core logging at the end of this year.
- Provide regular feedback to the CASE partner (Pulsar) through meetings and annual report.

Year 2:

- Conduct geochemical analyses of samples collected from previous field season.
- Interpret 2D seismic data from the Topaz Project.

- Conduct further visits to the Pulsar Helium prospect and perform targeted core logging based on previous log interpretations, including fracture analyses.
- Compare their findings to analogous layered mafic intrusions globally and undertake fieldwork in these locations, aiming to produce a global crustal model for co-location of helium and magmatic sulphide accumulations.
- Provide regular feedback to the CASE partner (Pulsar) through meetings and annual report.

Year 3:

- Produce a reservoir model of the Topaz Project, utilising the logged magmatic stratigraphy, fracture analyses and seismic interpretation.
- Critically assess the association between crustal contamination, Ni-Cu-PGE mineralisation and He accumulations in the Duluth Complex and other comparable systems globally.
- Draft third publication and write thesis.

Training and skills:

The student will receive training in field skills, core logging and analysis, petrography, petrophysical log analysis, seismic interpretation and reservoir modelling at the University of Aberdeen. Where appropriate, the student will receive training in stable isotope analyses and interpretation. The student will also be able to attend relevant taught MSc classes / courses in the School of Geoscience at the University of Aberdeen, based on need and availability. The student will have access to the resources and research-skills training of the PGR College.

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.

Partners and collaboration (including CASE):

This project will be support by industry CASE partner Pulsar Helium, who are currently conducting exploration for the recent Topaz Project Helium discovery, Minnesota. Pulsar Helium will provide financial and in-kind support to the student and supervisor(s) for fieldwork, training, core logging and sample analyses. Pulsar Helium will also offer an internship to the student to gain hands-on experience in resource exploration.

Further reading:

Miller & Ripley, 1996: https://doi.org/10.1016/S0167-2894(96)80010-8

Further details:

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

Please contact Dr Joe Armstrong (joe.armstrong@abdn.ac.uk) to discuss the project further.