Developing a mineral systems framework for North East Scotland using new geological and geophysical data

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Project Highlights:

- Develop a new model of the lithosphere for North East Scotland integrating geophysical and geological data to deepen understanding of mineral systems in the region and globally, and guide future exploration.
- Fieldwork in Scotland, deploying a new seismometer network and undertaking near-surface geophysical surveys at a current mineral exploration site, and processing, analysing and interpreting these data in the context of mineral systems.
- A collaborative project including CASE support from, and a 3 month placement with, Aberdeen Minerals, and opportunities to work with partners from the BGS and Canada.

Overview:

Critical minerals are a fundamental component of the energy transition, underpinning the technologies necessary to tackle climate change (BEIS, 2022; IEA, 2021). We need to better understand how economic levels of mineral enrichment occur and how the geological settings that have the potential for critical mineral resources can be located. North East Scotland has been identified as a region of the UK that is particularly worthy of further investigation (Deady et al., 2023) due to the presence of multiple critical raw materials, including lithium and nickel. Despite this significant potential, we do not yet have good models for the deeper geology and lithospheric scale structures necessary to understand the regional mineral system. Basic controls on mineral endowment such as crustal thickness (e.g. Chen et al., 2020) remain unknown, and crustal scale structural pathways are not well defined. Developing a geodynamic framework is key to understanding controls on mineral distribution in NE Scotland, which in turn furthers global understanding of mineral systems.

To develop these models, high-resolution geophysical data is essential (Deady et al., 2023). Existing geophysical data across NE Scotland is typically either on UK-wide or local prospect mapping scale. In this project you will collate, (re)process and (re)interpret these data to develop a single regionally-focussed model. However, these data are insufficient to answer key questions relating to mineral systems in NE Scotland: we also need to gather new data. Therefore you will deploy a new network of seismometers in Aberdeenshire and Moray to make a crust and upper mantle model of the region for the first time. Using passive seismic data, you will map crustal thickness and lithospheric structure, which you will then integrate with existing geophysical data across the region. Through

joint analysis and interpretation of multiple geophysical datasets with existing geological information you will develop the first regional mineralisation models for NE Scotland.

Local-scale near-surface geophysical and borehole geological data focussed at the Aberdeen Minerals' Arthrath nickel-copper-cobalt project site (Figure 1) will provide an opportunity for a ground-truthing test for the regional mineral system model.

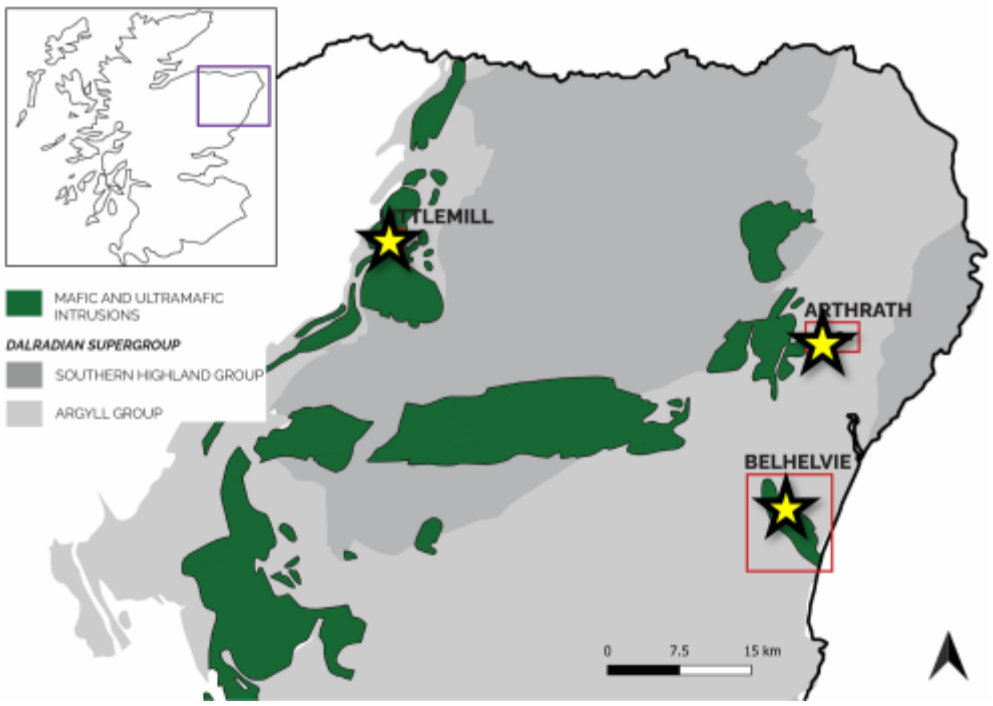

Figure 1: Simplified geology of NE Scotland showing the locations of magmatic sulphide deposits (Yellow stars) (courtesy Aberdeen Minerals).

Methodology:

In this project you will conduct both geophysical fieldwork in NE Scotland and computer-based analyses of new and legacy geophysical data.

Fieldwork will involve:

1. Scouting, deployment, servicing, and recovery of broadband seismometers at sites across NE Scotland.
2. Near-surface geophysical surveys focused on the nickel-copper magmatic sulphide deposit at Arthrath (including magnetics, gravity, resistivity, induced polarisation, and self-potential)

You will combine existing geophysical data with geological and borehole data to develop a new regional mineral systems model using GIS and Seequent Leapfrog software. Crustal thickness and lithospheric structure will be constrained using seismological methods including receiver functions, and ambient noise and local source tomography.

You will integrate multiple data sets to develop a model of the whole lithosphere in the region using software such as LitMod (Kumar et al., 2020), which uses petrological, geochemical, thermal, and geophysical data to constrain the subsurface conditions and geological setting.

Possible Timeline:

Year 1: Deployment of seismometers and 1-2 service runs to collect data, passive seismic data archiving. Literature review of geology and tectonics of NE Scotland, and mineral systems (Scotland and globally). Skills building in coding and geophysical data processing and interpretation. Begin compilation and integration of existing geophysical data in the region. Attend a UK based conference (e.g. BGA PGRIP and/or MDSG).

Year 2: Interpret existing geophysical data from the region in the context of mineral systems, forming the basis of your first paper. Final data collection and archiving from seismometers. Apply seismological methods to constrain crustal thickness and lithospheric structure. This will form the basis for your second paper. Attend a UK-based mineral focussed conference (e.g MSDG), and an international conference.

Year 3: Continue analysis and interpretation of passive seismic data in a mineral systems context. Integrate new passive seismic data with existing geophysical data, and develop an integrated model for the lithosphere, forming the basis for your next paper. Near surface geophysical fieldwork at the Arthrath site. Data analysis and interpretation of this new data set, in the context of your previous research work.

Training and skills:

You will receive relevant training in coding, use of specialist software, deployment of seismometers, and passive seismology and near-surface geophysical field methods. You will develop skills in managing geophysical field campaigns, working with, and managing, large data sets, and translating geophysical results into outputs useful for the minerals industry, UK and globally.

PhD students at the University of Aberdeen undertake training in “Research Integrity”, “Research Ethics and Governance”, “Equality, Diversity and Inclusion” and “Health, Safety and Wellbeing” and have access to optional transferable skills courses and the University of Aberdeen’s Centre for Energy Transition training courses and events.

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):

You will be supervised by an interdisciplinary team spanning geophysics and minerals geology. Initially you will meet weekly with the primary supervisory team and the whole supervisory team every 2-3 months. There may be the opportunity for an extended visit to visit Fiona Darbyshire, and participation in mineral systems-related in Canada.

CASE partner Aberdeen Minerals will provide geophysical datasets, drill core materials for geological study and petrophysical analysis, field support for seismometer deployment and a 3-month placement in year 1. Fraser Gardiner (CEO Aberdeen Minerals) is a co-supervisor and will direct the link between PhD research and industry application.

Further reading:

Barnes, S.J., et al., The mineral system approach applied to magmatic Ni‐Cu‐PGE sulphide deposits, Ore Geol. Rev. (2015), http://dx.doi.org/10.1016/j.oregeorev.2015.06.012

Chen, C., Lee, C. T. A., Tang, M., Biddle, K., & Sun, W. (2020). Lithium systematics in global arc magmas and the importance of crustal thickening for lithium enrichment. Nature Communications, 11(1), 5313.

Deady et al, 2023. Potential for Critical Raw Material Prospectivity in the UK. BGS Decarbonisation and Resources Management Programme Commissioned Report CR/23/024

Hayward, N. (2024). Improving Multiscale Structural Targeting Precision for Large Ni-Cu (±PGE, Co) Sulfide Discoveries from Global Case Studies. Econ Geol, v.119, no. 8, pp. 1745-1767

McCuaig, T. C., Beresford, S., & Hronsky, J. (2010). Translating the mineral systems approach into an effective exploration targeting system. Ore Geology Reviews, 38(3), 128-138.

Further details:

Please contact the lead supervisor Amy Gilligan (amy.gilligan@abdn.ac.uk) for more

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