

The importance of faults, fractures and fluid flow for mineralisation

Lead supervisor: Prof. Clare Bond, University of Aberdeen

Co-supervisors: Dr Alex Braisier, University of Aberdeen; Dr **Matthieu Clog**, SUERC and University of Glasgow; Dr **Laura Hepburn**, SUERC and University of Glasgow.

Project Highlights:

- Mapping of natural faults and fracture systems in intrusive igneous rocks to create predictive models of fractures networks at a range of scales.
- Understand the potential for heat extraction from Grampian granites using Spectral Gamma Ray and borehole data.
- Assess the importance of natural fracture systems to extract heat and mineralise CO₂ and define controlling factors on reaction rates.

Overview:

Faults and fractures in crystalline rocks determine fluid pathways and hence fluid-rock interaction. They are therefore a critical control on mineral deposition and the exchange of reactants and heat between rock and fluids. Fault and fracture networks contribute to the economics of hot-geothermal systems, mineral resources and the efficacy of CO₂ storage through mineralisation. This project considers how faults and fractures in intrusive igneous rocks control the potential for heat extraction and mineralisation of CO₂ from fluids to contribute to net zero targets through understanding natural systems.

The Grampian granites and associated ultramafic intrusions provide Scotland with potential resources for geothermal heat, critical minerals and the potential to contribute to climate change mitigation through CO₂ mineralisation. These resources are being explored but are yet untapped at scale, due to a lack of data and high capital costs in the development of pilot investigations. This project will contribute to the data available on fracture and faults systems in these intrusive igneous rocks through fracture mapping to create a series of maps and predictive fracture models. These maps will be integrated with spectral gamma ray data, collected in the field, that will be used to predict heat at depth and model the heat extraction potential for the granites. Core and field samples will be used to investigate mineralisation of CO₂ through fluid rock interaction with ultramafic rocks; analyses of natural vein and mineral samples will be compared with laboratory derived mineralisation in experiments to test predicted key control factors e.g. pH, temperature, fluid and rock composition. The aim is to gain insight on mineralisation rates in different environments.

The student will gain a range of skills from field mapping, GIS data integration. Spectral Gamma Ray analysis and predictive modelling, through to interpretation of stable isotope geochemical data.

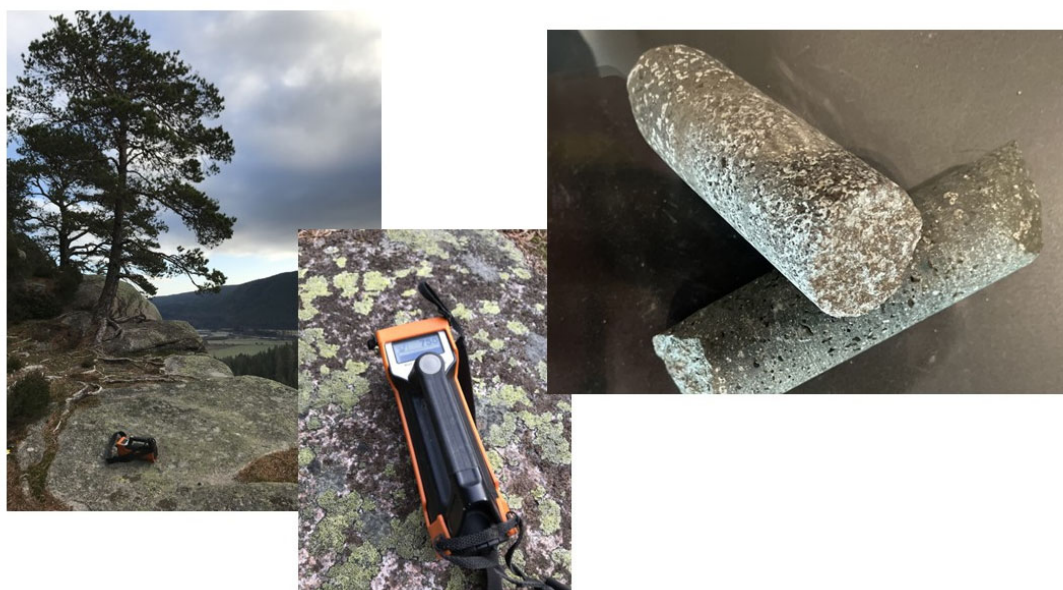


Figure 1: Collecting Spectral Gamma Ray data on Grampian granites in Aberdeenshire; the Spectral Gamma Ray; cores from the CarbFix project Iceland, showing carbonate and pyrite mineralisation in pore space from reaction with CO₂ and hydrogen sulphide (Photos: Clare Bond).

Methodology:

The project will focus on the Grampian intrusive rocks of Scotland, with fieldwork potential on the doorstep of Aberdeen and across Scotland. Comparison with field sites elsewhere is also possible e.g. Cornwall. Fracture mapping will be undertaken at a range of scales: satellite, aerial photography and on the ground mapping will be integrated in a GIS with spectral gamma ray data collected in the field. Predictive tools will be used to model potential heat at depth. Samples of mineralised veins will be collected for fluid inclusion, CL and SEM work; further geochemical analysis could include clumped and stable isotopes to determine fluid temperatures and compositions to inform fluid rock interaction. U/Pb will be used to constrain timing of mineral deposition. In the laboratory in Aberdeen the student will investigate controls on mineralisation rates: including surface volume (fracture intensity), pH and temperature.

Possible Timeline

Year 1: Fracture Mapping, and creation of GIS dataset, including spectral gamma ray data. Site visits and mapping of ultra mafic bodies, sample collection and identification of relevant core material. Output - map/GIS of intrusive igneous bodies, fracture systems and Grampian granite heat potential, uncertainties and controls.

Year 2: Core analysis from appropriate igneous bodies e.g. Huntly and Bathgate; including SEM, fluid inclusion and isotope work on mineralisation. Preparation of ideas for experimental test and initial laboratory experimental work. Output – geochemical dataset on carbon mineralisation.

Year 3: Experimental work in the laboratory to test factors defined by literature and in the studied natural systems. Geochemical comparison with natural systems and with work on other areas/rock types. Output - Integration of data and information into GIS, to create predictive tool on heat extraction and fluid reaction potential in different intrusive igneous bodies.

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.

The PhD will provide training in: GIS systems, spectral gamma ray data acquisition and associated thermal modelling, SEM, CL and fluid inclusion work; as well as isotope analyses and experimental work. In completing the PhD, the student will be well trained across a breadth of geoscience and in the integration of data.

Partners and collaboration (including CASE):

The student will undertake work in the laboratories at SUERC and be trained in isotope geochemistry. Interpretation of the geochemical data and integration of the experimental work with the geochemical analysis will involve input from all supervisors and all supervisors will contribute to the design of the experimental tests.

The University of Aberdeen has strong links with local firm and TARGET partner Aberdeen Minerals, with opportunities available students as internships getting hands-on experience in the sector. We would look to develop other opportunities e.g. with Tektonik on the structural side, and other partners who cover a breadth of mining related expertise.

Further reading:

[Busby, J., Gillespie, M. and Kender, S., 2015. How hot are the Cairngorms?. *Scottish Journal of Geology*, 51\(2\), pp.105-115.](#)

[McCay, A.T. and Younger, P.L., 2017. Ranking the geothermal potential of radiothermal granites in Scotland: are any others as hot as the Cairngorms?. *Scottish Journal of Geology*, 53\(1\), pp.1-11.](#)

[Nisbet, H., Buscarnera, G., Carey, J.W., Chen, M.A., Detournay, E., Huang, H., Hyman, J.D., Kang, P.K., Kang, Q., Labuz, J.F. and Li, W., 2024. Carbon mineralization in fractured mafic and ultramafic rocks: A review. *Reviews of Geophysics*, 62\(4\), p.e2023R](#)

Further details:

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

Please feel free to contact Clare Bond clare.bond@abdn.ac.uk for further project information.

Information on the School of Geosciences at the University of Aberdeen and supervisors can be found from the links below:

<https://www.abdn.ac.uk/geosciences/>

<https://www.abdn.ac.uk/people/clare.bond>

<https://www.abdn.ac.uk/people/a.brasier#publications>

<https://www.gla.ac.uk/research/az/suerc/staff/clogmatthieu/>

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