Blowing The Top: Mineralisation in Magmatic Roof Zones (Motzfeldt, S Greenland)

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Co-supervisors: Dr Sam Broom-Fendley, University of Exeter; Dr Will Hutchison, University of St Andrews.

Project Highlights:

- Understanding how critical metal mineralisation takes place in a magmatic roof zone is a key unanswered question in economic geology.
- Greenland fieldwork in the Motzfeldt region, South Greenland, one of the world's great natural laboratories for studying magmatic processes.
- Detail geochemical and petrology to reconstruct the chemical interactions that give rise to mineralisation and the clues that such mineralisation occurs at depth.

Overview:

A fundamental question, implicated in both economic and igneous geology, is precisely how magma interacts with country rocks in a magmatic roof zone. We know there is a mixture of stoping, assimilation and melting, creating thermal and chemical gradients which precipitate commercially important metals from enriched alkaline magmas (e.g. Finch et al. 2019). However, as well as precipitation within the top of the magma chamber, mineralisation continues up into the roof itself, thanks to planar magma sheeting and magmatic chimneys, which are form locally mineralised structures (Rooks et al., in review). These are important for two reasons – the first is for the minerals they contain, but the second (and arguably more important) is the way that they indicate roof-zone mineralisation at depth.

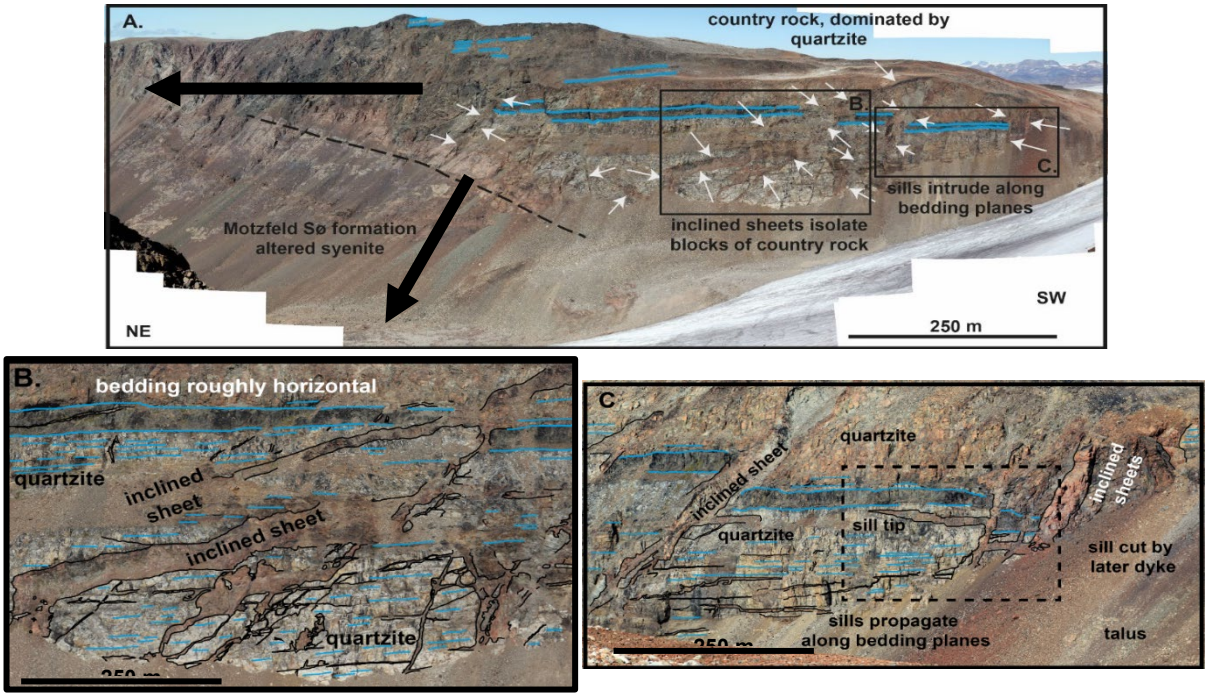

Figure 1: Motzfeldt contains glaciated slices through the roof of a magma chamber, allowing us to reconstruct processes in this part of the magmatic system. We will explore this area, predicting the nature of rocks formed beneath. In doing so, we provide insights into mineralised rocks here and elsewhere in the world.

This project explores the mineralisation in the Motzfeldt magmatic centre in South Greenland, one of the world's largest Ta and Nb deposits. Glaciation has dissected the complex, providing km-scale vertical sections through a magmatic roof zone, making it one of the world's great natural laboratories in which to understand magmatic processes. This project will test the hypothesis that different parts of the licence area constitute different horizontal slices through a single magma chamber and that, by putting all the regions together into a single genetic model, we acquire a complete 3D understanding of the geology. We will therefore be able to predict what is at depth.

Methodology:

The candidate will explore the mineralisation in the field, examining the surface expression of chimney and inclined sheets. Samples will be returned for optical and luminescence (CL) petrography, Electron Probe Micro Analysis (EPMA), isotopic studies (notably sulfur, carbon, oxygen). We have used sulfur isotope fractionation and REE phosphate partitioning as geothermometers, and these tools constrain the temperature of mineralisation. A key target is to generate textural and microchemical evidence for reactions in the roof-zone and act as vectors for mineralisation at depth. The project will have at least one field season (possibly two) with the CASE partners in Greenland.

Earth & Environmental Sciences, University of St Andrews (https://www.st-andrews.ac.uk/earth-sciences/) is one of the best equipped geochemical laboratories globally, with stable isotopic systems in house, as well as trace element (ICPMS), a world-leading electron microscopy suite (including EPMA) with micro-raman, UV-Vis and luminescence spectroscopy and imaging facilities. Via Exeter, we access microXRF and microFTIR.

Possible Timeline

Year 1: Analysis of material in St Andrews in existing collections, followed by a summer field season on Motzfeldt with the CASE partner. Preliminary isotope and petrographic analysis to create hypotheses to be tested by field sampling. Conference attendance.

Year 2: Collation of drone and other field data from the summer, plus sectioning and preliminary analysis of samples collected. Geothermometry from rare earth phosphate pairs. Development of roof-zone geochemical pathways. Creation of geochemical hypotheses. Preparation of first manuscript. Possibly a second field season in Greenland. One conference presentation.

Year 3: Logistics and field data collation from Greenland, analysis of final samples. Major conference presentation. Distillation of key points for publication. Testing of final hypotheses.

Year 4: Final write up of data for publication and submission of thesis for the award of a PhD.

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.

Partners and collaboration (including CASE):

This is a CASE partnership with Elemental Rare Metals Ltd, a UK-based exploration company holding the licence to Motzfeldt. The candidate will join Elemental for field seasons in Greenland for one (maybe two) summers, being part of an exploration team developing the region. We will meet the clients in their London offices, or a mutually convenient conference. In addition, the project will access the expertise and facilities of Dr Sam Broom-Fendley at the Camborne School of Mines. Broom-Fendley is an expert on magmatic carbonate-rich systems with experience across Africa. Finch, Hutchison and Broom-Fendley have collaborated on several global projects on critical metal mineralisation.

Further reading:

Rooks CJW, Finch AA, Hutchison W, Herd DA, Frangeskides G (in review) Rare Earth and Niobium Mobility at the Magmatic-Hydrothermal Transition: Motzfeldt Sø Centre, Greenland. *Mineralium Deposita*, under review.

Finch AA, McCreath JA, Reekie CDJ, Hutchison W, Ismaila A, Armour-Brown A, Andersen T, Simonsen SL (2019) From Mantle to Motzfeldt: A Genetic Model for Syenite-hosted Ta,Nb-mineralisation. *Ore Geology Reviews*, **107**, 402-416.

Beard CD, Finch AA, Borst AM, Goodenough KM, Hutchison W, Millar IL, Andersen T, Williams HM, Weller OM (2024) A phlogopite-bearing lithospheric mantle source for Europe's largest REE-HFSE belt: Gardar Rift, SW Greenland. *Earth and Planetary Science Letters*, **640**, 118780.

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