Testing the Convection Hypothesis; Assessing the Structural Controls on Mineralisation in the Younger Giant Dykes, Southeast Greenland

Lead supervisor: Dr. William McCarthy, University of St Andrews

Co-supervisors: Prof. Sandra Piazolo, University of Leeds; Dr. Zoja Vukmanovic, University of East Anglia, Dr Craig Magee, University of Leeds, Prof. Richard Bates, Dr. Damon Stanwell-Smith

Project Highlights:

- Expedition to Greenland supported by Viking Cruises
- Become an expert in the structural geology & petrology of layered igneous deposits
- Build your network and prospects by working with professionals across several sectors

Overview:

Many of the world's largest critical metal deposits occur in mineral layers within igneous intrusions, yet the processes controlling layer formation and metal enrichment remain poorly understood. While early-stage magmatic mechanisms, such as gravitational settling and in situ crystal growth at the mush–melt interface, are relatively well studied, the role of late- to post-cumulus processes in remobilising and concentrating metals is less clear (Jones et al. 2025a). Physical controls such as melt remobilisation, mush permeability, convection, and fluid-capping structures are increasingly recognised as key influences on residual melt and fluid migration, highlighting the importance of structural pathways in ore genesis (Jones et al. 2025b).

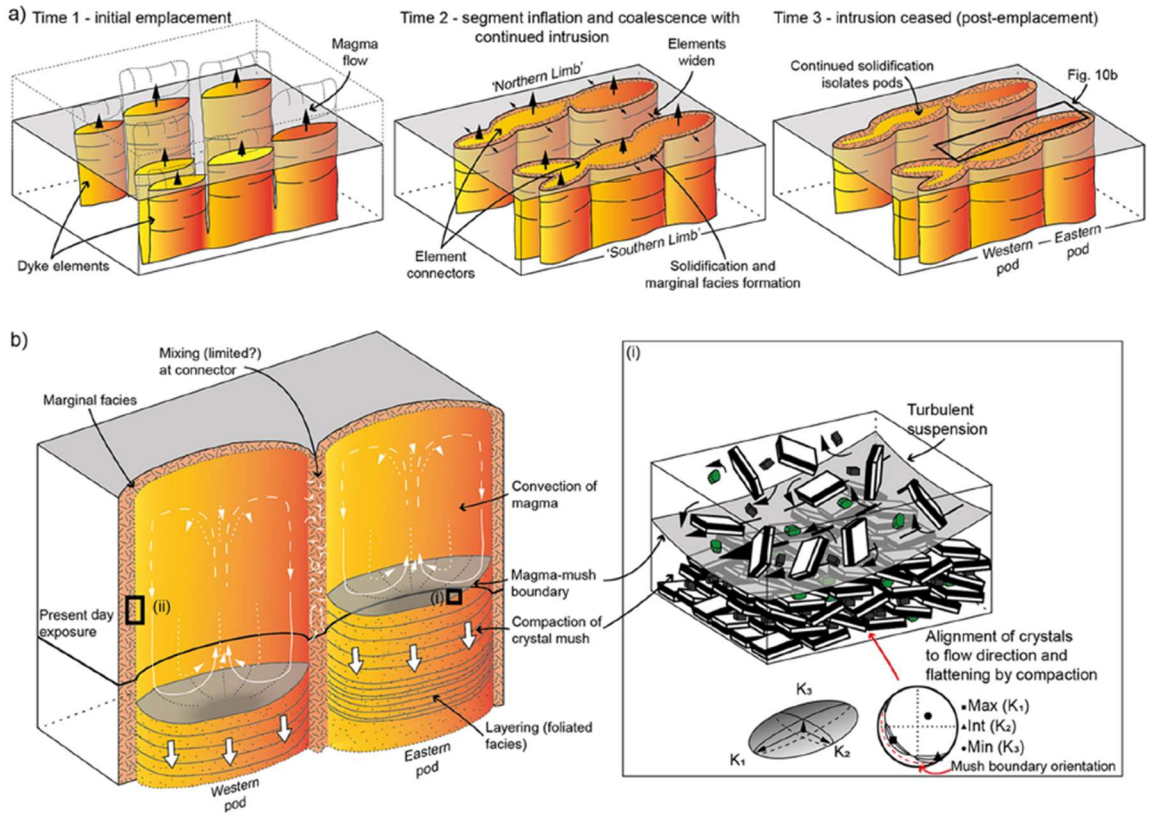

Figure 1: After Koopmans et al. (2022), a model for crystal accumulation and compaction below convecting magma cells within East Greenland's Giant Dykes.

Recent advances in microstructural and petrofabric analysis offer powerful tools for decoding the complex, overprinted histories of melt migration and mush dynamics. Rock magnetic techniques such as anisotropy of anhysteretic remanent magnetization (AARM) and anisotropy of magnetic susceptibility (AMS) are particularly sensitive to overlapping crystal fabrics, providing direct evidence of late-stage melt flow within crystal mushes (Latimer et al. 2024; Jones et al. 2025). These methods preserve subtle records of melt transport and offer fresh insight into how critical metals become concentrated during the evolution of layered intrusions.

Giant dykes host some of the world's largest metal deposits (Markwitz et al. 2010; Steenfelt et al. 2016). These Proterozoic intrusions, typically 0.5–10 km wide and extending tens to hundreds of kilometres, are among Earth's most enigmatic tectonic features. This project focuses on the Younger Giant Dykes of the Gardar Province, SE Greenland, where layered, foliated interiors are hypothesised to form via accumulation and compaction of crystals at the base of large convection cells (Koopmans et al. 2022). At the kilometre scale, we assess how dyke segments compartmentalise convection and control ore distribution; at meso- to micro-scale, we apply fabric and microstructural techniques to trace post-cumulus fluid pathways.

A unique CASE partnership with Viking Cruises provides access and critical support to remote, geologically significant sites, alongside funding for high-impact field research. This partnership also offers an exceptional career development opportunity through integrated residential scientist internships.

Methodology:

This project is underpinned by geological fieldwork supported by CASE partners Viking Cruises. Viking provides logistical and financial support and integrates the candidate into an onboard research team, offering exposure to diverse science projects and mentorship via the Global Partnership Program (see below). We view the Viking Science Research and Outreach Program as a key element of the project's methodological training and the candidate's professional development.

Fieldwork will involve drone- and tablet-based mapping, with boat access to remote sites, to investigate macro-scale structural controls on dyke emplacement and mineral layering. Laboratory analysis will include rock magnetic techniques (AMS and ARM) and Electron Backscatter Diffraction (EBSD) to study microstructures related to magma flow, convection, and crystal settling. In the final year, COMSOL Multiphysics will be used to construct a 3D convection cell model, integrating field and lab data to test and refine proposed mechanisms of dyke evolution and metal concentration.

Possible Timeline

Year 1: Literature review, pre-expedition field training, followed by expedition with Viking Expedition, culminating in mapping and sampling in SE Greenland.

Year 2: Rock fabric analysis (AMS, ARM), followed by EBSD analyses. Evaluate field, magnetic, and EBSD data to revise the physical model of layer formation. Presentation at a national conference.

Year 3: COMSOL numerical modelling to test the feasibility of the model developed from field data. PhD write-up. Presentation of work at an international conference

Training and skills:

The candidate will be supported by an advisory team of UK based researchers with experience in working in the Arctic region, including the proposed field area Greenland. Specific to this project, you will receive training in:

- Onboard training for small boat operations, scientific ship-based sampling program, outreach workshops for guest engagement
- Drone survey and digital mapping training (McCarthy & Bates);
- Magnetic analysis facilitated at the M^3Ore Lab, University of St Andrews (McCarthy);
- EBSD +/- EPMA analysis facilitated at the University of Leeds (Piazolo & Vukmanovic);
- Numerical modelling using COMSOL facilitated at the University of Leeds (Magee).

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):

The Viking Science Fellowship Program offers a unique, paid opportunity to work as a field scientist and outreach educator aboard a Viking Expedition vessel, alongside the Global Partnership Program (Scripps, Cornell, Cambridge, NOAA, UWA, Norwegian Institute of Water). Gain hands-on experience in field operations, data management, and mentorship in a dynamic maritime setting. STCW training (1 week, Year 1) prepares you to join as crew. Complete 2 weeks of EBSD analysis (Year 2) and 2 weeks of numerical modelling (Year 3) at the University of Leeds. Collaborate through online meetings and build a global network across research, academia, and industry.

Further reading:

Jones, E., McCarthy, W., Magee, C., Mattsson, T., Humphreys, M. and Piazolo, S. 2025a. Igneous layering and magma dynamics in alkaline intrusions: textural evidence for gravitational settling and compaction within cumulates. Journal of the Geological Society.

Jones, E., McCarthy, W., Piazolo, S., Magee, C., Humphreys, M.C.S. and Hutchison, W. 2025b. Microstructures Reveal Mechanical Compaction and Volatile-Rich Liquid Migration in the Layered Alkaline Ilímaussaq Complex, South Greenland. Journal of Petrology 66(8), p. egaf067. Available at: https://doi.org/10.1093/petrology/egaf067.

Koopmans, L., McCarthy, W. and Magee, C. 2022. Dyke Architecture, Mineral Layering, and Magmatic Convection; New Perspectives From the Younger Giant Dyke Complex, S Greenland. Geochemistry, Geophysics, Geosystems 23(3). doi: 10.1029/2021GC010260.

Latimer, B., McCarthy, W., Mattsson, T. and Reavy, J. 2024. Enclaves as mushy magma strain archives: New perspectives on composite magmatic fabrics in plutons. Geosphere 20(5), pp. 1390–1410. Available at: https://doi.org/10.1130/GES02786.1.

Markwitz, V., Maier, W.D., González-Álvarez, I., McCuaig, T.C. and Porwal, A. 2010. Magmatic nickel sulfide mineralization in Zimbabwe: Review of deposits and development of exploration criteria for prospectivity analysis. Ore Geology Reviews 38(3). doi: 10.1016/j.oregeorev.2010.07.004.

Steenfelt, A., Kolb, J. and Thrane, K. 2016. Metallogeny of South Greenland: A review of geological evolution, mineral occurrences and geochemical exploration data. Ore Geology Reviews 77. doi: 10.1016/j.oregeorev.2016.02.005.

Further details:

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

Please contact Dr William McCarthy, University of St Andrews for further information on this project (wm37@st-andrews.ac.uk).