Project Title | Enrichment of critical elements in granites: melting process or protolith?
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Host University | The Open University
Theme | Dynamic Earth
Key words | granite, geochemistry, critical elements, mineral deposits
Supervisory team | PI: Tom Argles (OU; tom.argles@open.ac.uk)
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Is the PhD suitable for part time study? | Yes

### Project Highlights:

- Resolve the provenance of critical elements such as lithium in mineralised granites and pegmatites
- Field sampling of European or African granites, pegmatites and source rocks
- Training in sophisticated geochemical analysis

### Overview:

The rise of electric vehicles is driving demand for critical elements (http://tinyurl.com/z77y4v7) such as Li, Nb, Ta, and Be. These elements are currently produced in relatively few countries, raising the spectre of disruption to their supply. They are commonly hosted in Sn-W bearing granites and pegmatites, but little is known about which minerals carry and concentrate these elements from the crustal protolith, via metamorphism and partial melting (anatexis), to the granitic magma. This project will track these trace elements from their original source to the host granite.

A recent study\(^1\) proposes a critical role for both the composition of the starting materials and the melting conditions in determining whether granites are enriched in critical elements or not. Unmineralised Himalayan leucogranites represent a rare example of granites formed from a known, accessible single source: pelitic metasediments\(^2\). This situation offers an opportunity to investigate the partitioning of critical elements by key mineral phases (e.g. feldspar, micas, tourmaline, titanite, magnetite, rutile) through metamorphism and low temperature (<750°C) anatexis by muscovite breakdown. By contrast, studies of mineralised granites suggest that critical elements may only be released into the melt as their host minerals break down at the higher temperatures of biotite dehydration melting (>750°C)\(^1,3\).
This project will exploit advances in laser ablation in situ analysis\textsuperscript{4} to determine element concentrations in minerals from mineralised and unmineralised granites and their corresponding source rocks. Existing samples will be supplemented by field sampling in Europe or Africa. The elemental data will constrain the budgets of critical elements at the mineral species level and investigate potential enrichment processes from protolith to melt formation. The results will test a recent model\textsuperscript{1} that links Sn-W granite mineralisation to high-temperature anatexis of an intensely weathered protolith.

We can test the hypothesis by 1) modeling element concentrations in high-T (>750°C) melts that would theoretically be formed by biotite breakdown in Himalayan samples; 2) comparing these model results with other metalliferous high-T melts to assess the role of temperature in causing mineralisation of economic proportions during granite formation.

**Methodology:**

The Open University holds samples of Himalayan crustal melts (granites), sub-solidus protoliths (mica schists) and in situ anatectic migmatites that are ideal for this study. Initial analysis of these curated samples will focus field sampling of contrasting, high-temperature granites and their source rocks (e.g. from NW Iberia or various African localities) for comparison studies. Recently-developed laser ablation (LA) ICP-MS protocols will be employed for in situ analysis of critical element concentrations in key minerals, alongside bulk rock analysis by solution ICP-MS. These results will evaluate element partitioning at different peak metamorphic temperatures and during incongruent melting by muscovite breakdown\textsuperscript{2}. Modelling elemental concentrations in these samples during biotite breakdown (>750°C) will test the hypothesis that higher melt reaction temperatures are essential for Sn and W (and potentially other critical element) mineralisation in granitic crustal melts.

**Training and skills:**

The successful student will be trained in fieldwork techniques as well as petrological and geochemical analysis of igneous and metamorphic samples. In situ LA-ICP-MS analysis is central to the project. Training in modelling behaviour of trace elements during melting and metamorphic phase relationships will also be provided.

The School of Environment, Earth and Ecosystem Sciences has a thriving postgraduate community. Online teaching opportunities via the Open University Virtual Learning Environment are available, including on Massive Open Online Courses (MOOCs). Our current graduate students are very active in science outreach at local schools as well as on digital platforms (e.g. http://www.fieldworkdiaries.com/).
Students will be awarded CENTA2 Training Credits (CTCs) for participation in CENTA2-provided and ‘free choice’ external training. One CTC equates to 1/2 day session and students must accrue 100 CTCs across the three years of their PhD.

**Partners and collaboration (including CASE):**

Kathryn Goodenough of BGS will act as an external supervisor on this project. The project will also benefit from collaboration with Gabriel Gutierrez Alonso, Salamanca University.

**Possible timeline:**

**Year 1:** Induction and literature review;
Petrographic and electron microprobe (EMP) analysis of existing samples at OU;
Detailed LA-ICP-MS analysis of first sample batch; Evaluation of suitable sites for fieldwork;
**Field season** (potential sites include NW Iberia, Cornwall, Saxony, Namibia, South Africa): Characterising mineralisation field relations; sampling granites and protoliths for geochemical analysis.

**Year 2:** Complete analysis of first sample batch;
Trace element modelling on initial results;
Petrographic, EMP analysis of samples from field;
Preparation and LA-ICP-MS analysis of field samples;
Further trace element and pseudosection modelling; Scope potential publication topic(s) and refocus analytical programme as necessary.

**Year 3:** Complete remaining geochemical analyses;
Finish data collation and interpretation;
Refine trace element modelling;
Integrate results with published data to test the factors influencing mineralisation;
Develop manuscripts of papers for publication; Prepare and deliver conference presentation(s);
Draft and revise thesis chapters, complete thesis.

**Further reading:**


Further details:

You should have a strong background in, and enthusiasm for, at least two of the fields of magmatic systems, geochemistry, and metamorphic petrology. Fieldwork experience is desirable. You will join a well-established team of Earth scientists studying all aspects of geochemistry, magmatism and orogeny at the Open University (http://www.open.ac.uk/science/environment-earth-ecosystems/research/dynamic_earth/geochemistry; www.open.ac.uk/research-groups/himalaya-tibet/).

Please contact Tom Argles (tom.argles@open.ac.uk) for further information.

Applications must include:

- a cover letter outlining why the project is of interest and how your skills are well suited to the project
- an academic CV containing contact details of three academic references
- a CENTA application form, downloadable from: http://www.centa.org.uk/media/1202/centa-studentship-application-form.docx
- an Open University application form, downloadable from: https://tinyurl.com/y73hrfou

Applications should be sent to STEM-EEES-PhD-Student-Recruitment@open.ac.uk by 12pm (noon) on 21st January 2019