Project title: What controls the redistribution of critical elements during high-grade metamorphism and partial melting?

Project code: OU25

Host institution: The Open University

Theme: Dynamic Earth

Key words: geochemistry, critical elements, granite, mineral deposits

Supervisory team: Tom Argles (OU; tom.argles@open.ac.uk), Frances Jenner (OU; frances.jenner@open.ac.uk), Sam Hammond (OU; sam.hammond@open.ac.uk), Nigel Harris (OU; n.b.w.harris@open.ac.uk)

Project Highlights:
• Training in sophisticated geochemical analysis
• Investigate the key factors controlling granite-related mineralisation
• Resolve how critical elements become concentrated into economic deposits

Overview:
Several elements essential to our technological society have been identified as ‘critical elements’ by both the UK (http://tinyurl.com/z77y4v7) and the EU (http://tinyurl.com/zsux5qx). Not only do these elements underpin the future of green technologies, but the bulk of their production is based in very few countries, so the risk of supply disruption is high. Granite-related mineral deposits are a major global resource for many of the critical elements, such as the Rare Earth Elements (REE), In, W, Nb, Ta, Sb, Ga and Be. However, little is known about how these elements behave during partial melting (anatexis) of crustal rocks to form granitic magmas. Is it the composition of the starting materials, the melting conditions, or segregation processes that dictate the redistribution of these elements as melts form?

Himalayan anatexis provides a rare example of granites formed from a known, accessible single source: pelitic metasediments (e.g. 1,2). This situation offers an opportunity to investigate the partitioning of critical elements by key mineral phases (e.g. feldspar, micas, tourmaline, zircon, monazite) through metamorphism and low temperature (<750°C) anatexis by muscovite breakdown. Moreover, studies of highly mineralised granites suggest that crustal melting associated with breakdown of biotite, at higher temperatures, is an essential condition for promoting Sn-W mineralisation in anatexitic granites3.

We can test this 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 Hercynian metalliferous high-T melts to assess the role of temperature in causing mineralisation of economic proportions during granite formation.

This project will exploit recent advances in laser ablation in situ analytical methods4 to determine element concentrations in minerals from Himalayan granites and their source rocks. These data will constrain the budgets of critical elements and investigate potential enrichment processes during metamorphism, metasomatism and anatexis. The results will establish whether the composition of starting materials, or the conditions of melt formation, are critical in the formation of mineralised granites derived from melting of the Earth’s crust.

Methodology:
A comprehensive collection representing Himalayan melts (granites), sub-solidus protoliths (mica schists) and in situ anatexis (migmatites) exists at the Open...
University. These samples are ideal for this study, with many of them having an established metamorphic or magmatic context. Results from the initial study of these curated samples will enable us to target contrasting, high-temperature granites (e.g. from Cornwall and northern Iberia) for further sampling to pursue project objectives. Recently-developed laser ablation (LA) ICP-MS protocols will be employed for in situ analysis of critical element concentrations in key minerals and whole rock pressed powder pellets. These results will evaluate element partitioning at different peak metamorphic temperatures and during incongruent melting by muscovite breakdown. 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 in Spain, as well as advanced petrological and geochemical analysis of igneous and metamorphic samples. In situ LA-ICP-MS analysis will be central to the project. Training in modelling techniques, including the behaviour of trace elements during melting and metamorphic phase relationships, will also be provided where appropriate.

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 the new Massive Open Online Courses (MOOCs).

CENTA students are required to complete 45 days training throughout their PhD including a 10 day placement. In the first year, students will be trained as a single cohort on environmental science, research methods and core skills. Throughout the PhD, training will progress from core skills sets to master classes specific to CENTA research themes.

Partners and collaboration:

We are collaborating with Beth Simons (Camborne), who is currently engaged in research into the Cornish granites that is complementary to this project.

Possible timeline:

Year 1:

Literature review, petrographic and electron microprobe (EMP) analysis of existing samples at Open University. Thin section preparation of selected samples for detailed elemental analysis; LA-ICP-MS analysis of critical elements in first sample batch. Evaluation of suitable sites for fieldwork; literature review of potential field areas.

Field season (NW Iberia): Determination of small-scale field relations, characterising form of mineralisation; sample collection for geochemical analysis.

Year 2:

Complete elemental analysis of first sample batch. Trace element modelling on results from first batch. Petrographic and EMP analysis of samples from field season. Thin section preparation of selected samples for detailed elemental analysis; LA-ICP-MS analysis of critical elements in field season samples. Further trace element and pseudosection modelling as appropriate. Scope potential publication topic(s) and refocus analytical programme as necessary.

Year 3:

Complete remaining geochemical analyses. Finish data collation and interpretation, and refine trace element and pseudosection modelling approach. Integrate results with published data to test the factors influencing mineralisation during crustal melting. Identify and develop manuscripts of papers for publication. Prepare and deliver conference presentation(s); draft and revise thesis chapters. Revise paper manuscripts and 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 mountain building processes at the Open University (www.open.ac.uk/research-groups/himalaya-tibet/).

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

Applications should include:

- a cover letter outlining why the project is of interest and how their skills match those required,
- an academic CV containing contact details of three academic references
- a CENTA application form, downloadable from www.centa.org.uk/media/1202/centa-studentship-application-form.docx
- and an Open University application form, downloadable from:
  - http://www.open.ac.uk/students/research/sites/www.open.ac.uk.students.research/files/documents/Application%20form.docx

Apologies that some bits of information are requested multiple times on different forms. Please fill in everything requested.

Applications should be sent to STEM-EEES-PhD-Student-Recruitment@open.ac.uk by 5 pm on 25th January 2017.