Building a holistic model for rare metal pegmatite formation

Overview

Lithium-bearing pegmatites are an important subset of granitic rocks that account for over half of global Li production, and almost all of the world’s Cs and Ta (Bradley et al., 2017). Most such pegmatites are hosted in metamorphosed supracrustal rocks that reached upper greenschist to lower amphibolite facies pressure–temperature (P–T) conditions, representative of the middle continental crust. These bodies may form either via extreme fractionation of a cooling parental granite (Bradley and McCauley, 2013; Liu et al., 2022), indicating they have a magmatic origin, or as products of partial melting of nearby metasediments (Müller et al., 2017; Koopmans et al., 2023) during orogenic deformation (Fig. 1). However, despite detailed study, there remain many unanswered questions concerning fluid–melt–rock reactions in Li-bearing systems; specifically, regarding the importance of solute-rich magmatic volatile phases that occur in crystal-rich (mushy) magma reservoirs.

This research project will compare the efficacy of competing models for lithium pegmatite formation, focusing on the validity of (1) metamorphically driven partial melting processes and the mobilization of Li in small-volume silicate melts ascending through the continental crust, (2) extreme fractional crystallization as a mechanism to statically enrich incompatible elements during a single episode of magmatic cooling at a fixed crustal depth, and (3) episodic compaction-driven recharge of Li-bearing fluids and cycles of in situ crystallization within a cooling and crystallizing magmatic mush. This work aims to develop a holistic geochemical model that can advance our understanding of the evolution of lithophile magma reservoirs and the formation of economically important Li-bearing ore deposits in different geological environments.

Methodology

Fieldwork will involve geological mapping and collection of a variety of metamorphic and magmatic rocks from case study regions, potentially in Africa. Subsequent laboratory work will involve bulk-rock and mineral chemical analysis, with these data used to perform petrological modelling of trace element behaviour. Isotope geochronology will constrain the absolute ages of metamorphism in the host rocks, and the nature of source and evolution of the studied pegmatite system via in-situ U–Pb, Hf isotope and trace element analyses of zircon.

A student working on this project will gain experience using the following tools and techniques:

• Optical microscopy
• X-ray fluorescence (XRF) analysis
• Scanning-electron microscopy (SEM)
• Electron probe micro-analysis (EPMA)
- Laser-ablation multi-collector inductively coupled mass spectrometry (LA-MC-ICP-MS)
- Reactive transport petrological modelling using the Theriak-Domino software package

**Timeline**

**Year 1**: Literature review, fieldwork planning, fieldwork and sample collection, sample characterisation, and laboratory training.

**Years 2 and 3**: Microanalytical work (XRF, SEM, EPMA), isotope geochronology (LA-MC-ICP-MS), and petrological modelling. Data compilation and interpretation. Presentation of results at domestic and international conferences.

**Year 4**: Data integration, thesis completion, write papers for submission and publication in scientific journals.

**Training & Skills**

The successful student will join the Hard Rock Group at the University of Oxford, UK, which has a long-standing history of research excellence in metamorphism, tectonics, and economic geology. They will also have the opportunity to interact with faculty at external institutions and industry partners at annual career fairs.

The student will be trained how to plan and conduct a field campaign, how to prepare and characterise geological thin sections, and perform petrological and geochemical analyses of igneous and metamorphic rocks. This will include hands-on work with SEM, EPMA, and LA-MC-ICP-MS equipment in leading laboratories across the UK. Training will also be provided on how to conduct geochemical and petrological modelling, for use in performing thermobarometry and interpreting the mineralogical evolution of crystallizing magmas.

The student will also be mentored on how to prepare scientific results for presentation at international conferences and how to write papers for publication in high-profile, international journals.

**References & Further Reading**


**Further Information**

Applicants are encouraged to contact the project lead (Richard Palin) for further information:

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