

Tracing the genesis of rare metal (Li-Ta-Sn) Archean pegmatites

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Collaborators: Prof. Tony Kemp, University of Western Australia; Prof. Hugh Smithies, Geological Survey of Western Australia.

Project Highlights:

- Archean pegmatites are the main source of battery grade lithium
- Magmatic sources to these deposits are poorly constrained
- Aim to apply geochemical and isotopic techniques to build petrogenetic models

Overview:

Archean-aged pegmatites are now the main source of battery-grade lithium. Lithium-bearing pegmatites, small granitic intrusions which also carry other rare metals such as tantalum and tin, are part of the so-called “LCT” family. The canonical view is that akin to S-type granites, LCT pegmatites are formed via the partial melting of a metasedimentary protolith, which may be enriched in the economic metals of interest. However, this model as applied to Archean-aged examples is undermined by the fact that in many major Archean terranes hosting abundant mineralised pegmatites – e.g. the Pilbara and Yilgarn cratons in Western Australia, and the Zimbabwe Craton – there are no obvious examples of S-type granites, nor suitable metasedimentary protoliths observed in any of the greenstone belts (e.g. Jelsma et al. 2021; Smithies et al. 2025).

Pegmatite melts form via the partial melting of existing continental crust. This PhD will use isotopic and geochemical tools to tackle the issue of the crustal source(s) to mineralised Archean pegmatites. Possible models include incorporation of Li-enriched sedimentary material; multi-cycle crustal recycling of juvenile continental crust (TTG) or granites; or even a deeper mantle origin (e.g. Koopmans et al. 2024, Gardiner et al. 2024).

The candidate will develop and deploy non-traditional mineral-based isotopic tools such as Sr isotopes in apatite or Pb-Si isotopes in feldspar coupled with geochronometers e.g. U-Pb in apatite and cassiterite. They will compare both selected mineralised and barren examples to surrounding continental crust including greenstone belt units.

The project builds on recent work by the supervisory team and the establishment of new analytical techniques at the University of St Andrews. The project is in partnership with the Geological Survey of Western Australia, who will provide assistance for fieldwork and samples, and the University of Western Australia and associated ARC Centre for Critical Resources, both with whom the successful candidate will work.



Figure 1: The Archean mineralised Li pegmatites in Zimbabwe. left: pegmatitic melt hosted by Paleoarchean TTG granitoids; right, petalite crystals in an economic pegmatite from the Harere greenstone belt.

Alt text: Lithium pegmatites in the field. Left: Paleoarchean TTG crust hosting a pegmatite vein, the thickness of a geological hammer; right: detail of a pegmatite with a 10cm long petalite crystal.

Key research questions:

This project aims to answer the following key research questions:

- 1) What are the most reliable petrogenetic tracers for pegmatites?
- 2) What is the genetic relationship of mineralised pegmatites to the surrounding host rocks – both greenstone belts and continental crust?
- 4) How do mineralised and unmineralized pegmatites differ, and does this hint at a distinct origin?
- 5) Can we develop enhanced rare metal pegmatite formation models, and how might this inform mineralisation?

Methodology:

The student will:

- (i) Sample appropriate mineralised and unmineralized pegmatite, and country rocks in Western Australia, and augment these with archived samples from Australia and Zimbabwe;
- (ii) Develop and deploy mineral-based chronometers via LA-ICPMS to further develop a chronological framework within the context of regional magmatism;
- (iii) Apply mineral-based isotopic tracers of source such as Sr in apatite to both mineralised and barren examples to probe their genetic origins.

Possible Timeline

Year 1: Fieldwork, initial sample collection and training

Year 2: Geochronology and isotope analysis; possible 2nd field season

Year 3: Data interpretation, presentation at conferences and paper writing.

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.

The student will train in isotope geochemistry and geochronology analysis via LA-ICPMS, data reduction and interpretation at the St Andrews Geochronology Laboratory (StAGE) and at the Isotope and Tracing Facility, British Geological Survey. They will become part of a vibrant research culture in the School of Earth and Environmental Sciences, with MSc, PhD and postdocs working on a range of research projects in the PALS (Pegmatites and Laser) and PaStA (Petrology at St Andrews) research groups. It is anticipated a number of publications will arise from this study, and training in scientific manuscript preparation and presentation will be given.

Partners and collaboration (including CASE):

This project is in partnership with the British Geological Survey, the Geological Survey of Western Australia, and the University of Western Australia. At least one visit to the BGS in Keyworth is expected, where the student will perform some of the analytical work. Additionally, at least one trip to Western Australia is expected for fieldwork and sample collection, and for collaboration with both the GWSA and UWA.

Further reading:

Gardiner, N.J. et al. 2024b. On tin and lithium granite systems: A crustal evolution perspective. *Earth-Science Reviews* 258, 104947. <https://doi.org/10.1016/j.earscirev.2024.104947>

Jelsma, H.A., Nesbitt, R.W., Fanning, C.M., 2021. Exploring our current understanding of the geological evolution and mineral endowment of the Zimbabwe craton. *South African Journal of Geology* 124, 279–310.

Koopmans L, Martins T, Linnen R, Gardiner NJ, Breasley C, Palin R, Groat L, Silva D, Robb L. 2024. The formation of lithium-rich pegmatites through multi-stage melting. *Geology* 52(1) 7-11

Smithies, R.H. et al., 2025. Giant lithium-rich pegmatites in Archean cratons form by remelting refertilised roots of greenstone belts. *Communications Earth & Environment* 6, 630. <https://doi.org/10.1038/s43247-025-02622-5>

Further details:

Please visit <https://target.le.ac.uk/> for additional details on how to apply. Informal enquiries regarding this project may be addressed to Nick Gardiner (nick.gardiner@st-andrews.ac.uk).

<https://www.st-andrews.ac.uk/earth-sciences/people/njg7>