Revealing the 'hidden' source of lithium brines in the Northern Pennines

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Project Highlights:

- The 'hidden' evidence for the source of lithium in the Pennines is revealed by studies of cores from the buried Weardale Granite.
- A mineral-microstructural pathway-fluid methodological approach is supported by analytical techniques that can 'see' lightweight lithium.
- The project contributes to an emerging body of research about lithium brines as an alternative to pegmatites and evaporate deposits, with lower environmental impacts.

Overview:

Lithium is a critical mineral of the energy transition, due to escalating demand for Li-batteries. Global production is dominated by pegmatite-hosted ore deposits and evaporite (salar) deposits. Lithium brines are alternative sources that create smaller negative impacts. This project seeks to find and interpret evidence that demonstrates how lithium became sufficiently enriched in groundwaters of the North Pennines to become prospective as a resource.

The groundwater brines in the North Pennines host lithium in concentrations that rival and sometimes significantly exceed global occurrences (Robinson et al 2025). However, the source mineral of lithium and process by which it was transferred to the brine are unknown. The suspected source of the lithium is the Weardale Granite, an Early Devonian pluton on the North Pennine batholith. The Weardale granite is buried, with its presence confirmed by the drilling of the Rookhope and Eastgate Boreholes (Kimbell et al, 2010; Manning et al, 2007). Fluid convection, related to magmas that contrast with those from other ore fields of the UK, has been associated with vein deposits in the North Pennine Orefield (Kimbell et al, 2010; Bott and Smith, 2018). The student will specifically examine how fluid migration harnessed lithium from source rocks, with implications for its subsequent enrichment and geographic distribution.

The student will consider how structural and microstructural pathways facilitated interaction between granites and fluids. The samples will be taken from cores of the buried granite and investigated using techniques at the Critical Minerals Equipment Hub (UoE) that can analyse directly for lithium-bearing minerals, which is challenging by conventional techniques due to the low atomic weight of lithium. This will enable proxies to be established to trace the lithium minerals through conventional techniques, in support of quantitative analysis of core structures and microstructures (UoL) that could have acted as fluid pathways. Fluid inclusion studies (BGS) will be used to establish the nature of early and late-stage fluids that would have the ability to mobilise the lithium. Using these three investigations, a geomodel for the origin of the lithium enrichment will be created, and used to further the emerging concept of lithium brine formation by dissolution of granitic minerals.

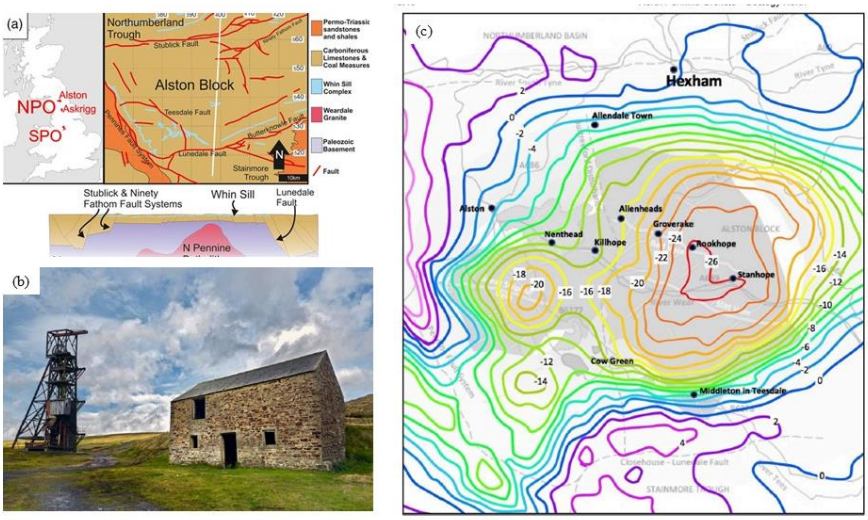

Figure 1: (a) Simplified geological map and schematic north–south cross-section of the Alston Block based on the line of section (white). Source of image a - https://www.lyellcollection.org/doi/full/10.1144/jgs2020-226; (b) Groverake Mine is near Rookhope in Weardale in the North Pennine Orefield and (c) a Bouguer Gravity Anomaly map reveals the contours of granite mass below the North Pennine Orefield in close relationship to the fluorite zone and major ore seams. Source of images b and c - https://www.geologynorth.uk/north-pennine-orefield/

Methodology:

The successful candidate will begin by familiarisation with North Pennine geology and inspecting cores to develop a sampling program. They will be aided in this by Arup Limited and the Camborne School of Mines, with chemical characterisation by portable XRF analysis and scanning by micro-XRF to produce element/mineral maps. Prepared samples will be used for detailed mineral analysis by e-beam techniques and laser ablation techniques in the Minerals Analysis Laboratories for context, and lithium-capable techniques in the new Critical Minerals Equipment Hub, dominantly advanced Raman techniques and XRD methods. Structural analyses are key for fluid pathways, particularly in a rock as impermeable as granite, where fractures and faults are fluid drivers. Integrated with the mineral characterisation, microstructural characterisation will be supported by UoL state-of-the-art microscopy facilities (EBSD, EDS, TEM) and LA-ICPMS techniques. Supported by the knowledge of the microstructural pathways along which fluids can move, and how they chemically affect minerals, the student will investigate the nature of fluids using petrographic characterisation of inclusions and heating-freezing experiments at BGS.

Possible Timeline

Year 1: Field visits for familiarisation with North Pennine Geology; placement with Arup International to understand lithium brine extraction; core logging and scanning for selection/preparation of samples; petrographic characterisation and minerals analysis; mineral paragenesis (ordering of events). Manuscript drafting: characteristics of a lithium source rock.

Year 2: Outstanding mineral analyses; placement with Arup International to place source rock in regional exploration context; microstructural investigations; fluid inclusion petrography and experiments. Manuscript and thesis drafting: mobilisation of lithium from granite - understanding fluid pathways and rock interactions.

Year 3: Outstanding analyses and experiments; placement with Arup International to understand the use of geomodels in exploration; creation of a North Pennine Lithium geomodel; comparison with models of lithium brine formation globally. Manuscript submission(s) and thesis preparation.

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.

Training in the industrial application of research will be provided by the CASE partner, Arup International, by annual placements. PhD students at the Camborne School of Mines can access MSc modules on mineral deposits, exploration geology and minerals processing for further training.

Technical training in advanced analytical techniques will be delivered at the Universities of Exeter and Liverpool, and by the British Geological Survey in Year 1 and 2. It will include advanced electron microscopy, geochemistry and fluid inclusion experimentation, geochemical data interpretation, and temperature and salinity reconstruction.

Partners and collaboration (including CASE):

Arup international are the CASE partner in the project and will actively participate in and provide direction to the project. The successful candidate will be embedded with Arup by regular meetings and (at least) annual placements (as per the timeline). Arup will facilitate access to cores and data under NDA.

Further reading:

Bott MHP, Smith FW (2018) The role of the Devonian Weardale Granite in the emplacement of the North Pennine mineralization. Proceedings of the Yorkshire Geological Society 62, 1-15 https://doi.org/10.1144/pygs2017-391

Kimbell GS, Young B, Millward D, Crowley QC (2010) The North Pennine batholith (Weardale Granite) of northern England: new data on its age and form. Proceedings of the Yorkshire Geological Society 58, 107-128 https://doi.org/10.1144/pygs.58.1.273

Manning DAC, Younger PL, Smith FW, Jones JM, Dufton DJ, Diskin S (2007) A deep geothermal exploration well at Eastgate, Weardale, UK: a novel exploration concept for low-enthalpy resources. Journal of the Geological Society 164, 371-382 https://doi.org/10.1144/0016-76492006-015

Robinson AD, Acikalin S, Stewart G, Bishop BA, Robbins LJ, Flynn SL (2025) Use of near-surface waters in identifying elemental associations with geothermal-sourced Li. Applied geochemistry 188, 106428. https://doi.org/10.1016/j.apgeochem.2025.106428

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply. Correspondence about the project can be directed to Kate Moore: k.moore@exeter.ac.uk; https://experts.exeter.ac.uk/21180-kathryn-moore