Optimising lithium-bearing reactive fluid flow in rough fractures using geomechanical measurements and flow modelling

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- Opportunity to help the development of low-environmental impact resources of critical minerals to energy transition and net zero in the UK
- Gain an extensive, highly industry-relevant skillset, including petrophysical and geomechanical laboratory measurements and analysis, field work, fluid flow and fractal fracture modelling, and industry placement with Cornish Lithium
- Publish papers or develop an industry-focused CV according to your career trajectory

Overview:

Lithium is a critical metal for the energy transition because it is needed to make batteries for energy storage. Currently, 91.5% of global lithium comes from Australia, Chile, and China using mining and salar exploitation which are environmentally destructive. It is essential to find less destructive resources, and ensure security of supply.

Cornish Lithium is developing granites in Cornwall, which have potentially economic lithium concentrations (zinnwaldite and lepidolite). The region has permeable fault zones hosting lithium-rich geothermal waters, which have been accessed via boreholes drilled from the surface. The lithium is then extracted using environmentally responsible Direct Lithium Extraction (DLE) technologies. Use of local geothermal energy provides an opportunity to produce zero-carbon lithium.

Production depends on interactions between fracture water and lithium mineralisation, and on the efficacy of flow of the resulting lithium-bearing fluids. Fluid-rock interaction and fluid transport depend on individual fracture roughness and how networks of fractures interlink. Flow in any given fracture also depends on the effective stress, which controls the flow aperture. Consequently, there is a complex interdependence between fracture roughness, mineralisation, fracture networks, the geochemistry of lithium dissolution and the stress regime, which is not presently understood, and represents a significant risk to the development of the resource.

This PhD will develop an understanding of the main interdependencies controlling the generation of lithium-rich fluids and their flow through rough fracture networks. A dual experimental and modelling approach will be used. Experimental work will start with petrophysical measurements, including μCT imaging. Samples will be subject to triaxial testing in order to ascertain the geomechanical characteristics of the material and the fractal properties of the resulting fractures. Electrical conductivity and fluid flow measurements will then be made on fractured samples for a

range of stress conditions relevant to the location. The experimental results will be compared to modelling of single rough fractures and fracture networks. Since the University of Leeds already has access to all experimental apparatus and modelling software, the candidate will have the opportunity to mould the project in their own direction, with the best mix of experiment and modelling.

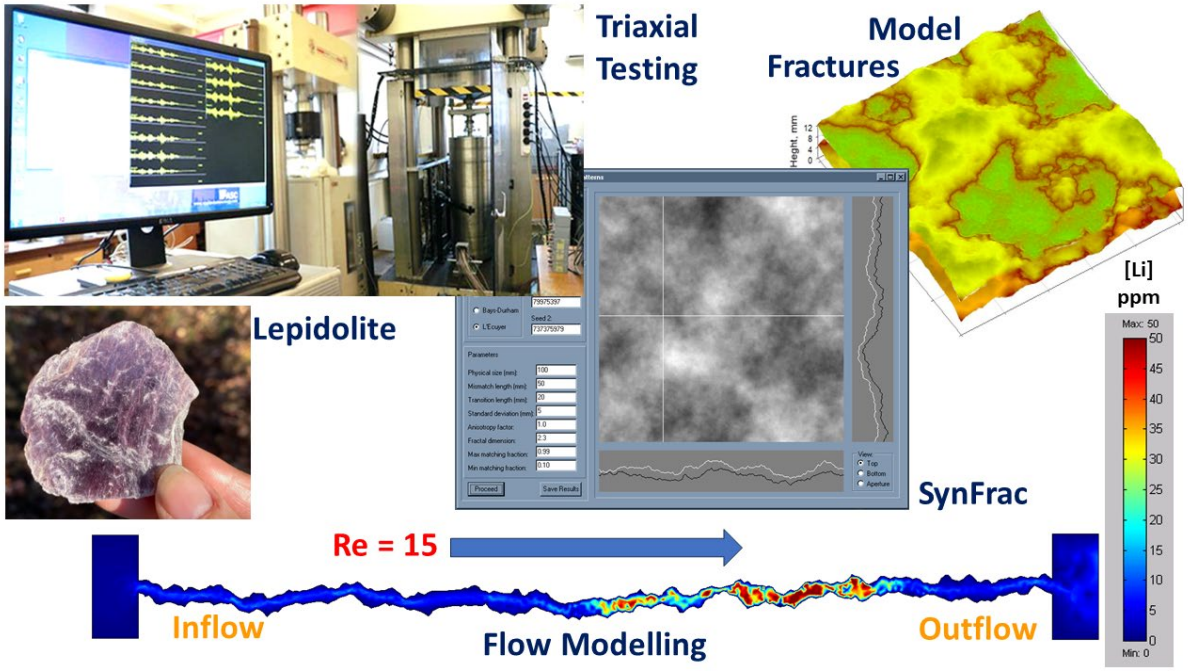

Figure 1: *A range of resources to be used in the research at the University of Leeds.*

Methodology:

Samples obtained from Cornish Lithium will be tested for their basic microstructural, petrophysical and compositional properties in the University of Leeds Petrophysics Laboratory, including 3D μCT imaging and image analysis. Unfractured samples will undergo triaxial testing to ascertain their geomechanical properties and the resulting fractures will be analysed for their fractal roughness properties. Fractured samples will be tested for fluid flow and electrical conductivity during controlled triaxial deformation to ascertain their hydraulic conductivity as a function of the effective stress field. Individual model fractures will be created to mimic the properties of the measured fractures using in-house fracture modelling codes SynFrac and ParaFrac. These models will be flow simulated to find the hydraulic conductivity, and to compare it with the measured value as a function of the stress field. All facilities and software are available at Leeds.

Possible Timeline

Year 1: Familiarisation, sample collection, fundamental microstructural, petrophysical and compositional properties, start unfractured mechanical properties measurements.

Year 2: Finish unfractured sample geomechanical properties. Calculation and analysis of hydraulic conductivity as a function of stress. Analyse the resulting samples for fractal properties of the rough fractures. Start the creation of model rough fractures using SynFrac/ParaFrac.

Year 3: Finish the creation of model rough fractures using SynFrac/ParaFrac. Flow modelling for hydraulic conductivity as a function of stress. Comparison with experimental values. Examination of

the range of effective stress likely to be encountered in production considering the power of topside equipment.

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.

In addition, the project provides specialist training in microanalytical and petrophysical techniques as well as geomechanical methods, fractal analysis, fracture modelling and flow simulation. The PhD is equally suited to career pathways in academia or industry. The application of both experimental and modelling approaches to characterising flow of fluids in rough fractures in ores is novel. All aspects of the research will be publishable in high quality peer-reviewed academic and professional journals, whilst exposure to industry-relevant skills and data and internship at the CASE partner provide non-academic vocational experience. We anticipate that you will be able to attend and present your work in both national conferences (e.g., MDSG) and international academic or industry facing conferences (e.g., SGA, EGU, GSA, SEG) according to your career trajectory.

Partners and collaboration (including CASE):

Prof Tom Mitchell specialises in earthquake geology and rock physics at UCL. His interests combine experimental deformation of rocks under simulated geological conditions with detailed field studies on fault zones over a range of scales. He is ideally placed to advise on rock deformation experiments in the context of the fractured ores.

Cornish Lithium (CL) will provide rock samples as well as background information and support. They will also provide critical feedback on research focus in order to ensure that the research has impact on the development of geothermal lithium extraction in the UK.

Further reading:

For further reading on Direct Lithium Extraction (DLE) at Cornish Lithium:
https://cornishlithium.com/projects/lithium-in-geothermal-waters/united-downs/

For further reading of geomechanical testing:
https://www.sciencedirect.com/science/article/pii/S2352380824000431?via%3Dihub

For further reading on rough fracture flow modelling:
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/97JB02836 and
https://www.nature.com/articles/s41598-024-73011-9

Further details:

Please visit https://target.le.ac.uk/ for additional details on how to apply. Application is made to the University of Leicester even though the work will be carried out at the University of Leeds.

For further details on the research, please contact either:

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More information on the research environment at the University of Leeds and Cornish Lithium can be found at:

School of Earth and Environment, Leeds University: https://environment.leeds.ac.uk/see
Institute of Applied Geoscience: https://environment.leeds.ac.uk/institute-applied-geoscience
Geosolutions Leeds: https://geosolutions.leeds.ac.uk/
Cornish Lithium: https://cornishlithium.com/