Creative Destruction: sub-critical stress corrosion cracking and the formation of critical mineral deposits

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Project Highlights:

- An exciting opportunity to combine fundamental studies in rock deformation with critical minerals and their host rocks;
- Gain an advanced technical skillset including field work, standard and advanced microanalytical and experimental approaches as well as working with multifaceted datasets;
- Gain in-depth knowledge of ore-forming processes including crystallization, deformation and reactions.

Overview:

Many major deposits of critical minerals occur in fractures. Examples include copper and cobalt (Cu, Co) and lead-zinc (Pb, Zn). Some of this mineralisation can be related to 'fast' seismogenic faulting, with mineral-rich brines infiltrating newly created pore space in damage zones and trapping against tectonically-induced permeability barriers (Rowe & Burley, 1997). But some deposits may have a closer genetic link with slower – i.e., sub-critical – fractures that form due to a reactive fluid enabling crack propagation at lower loads (Atkinson & Meredith, 1983; Barnett & Kerrich, 1980). Mineral-rich fluids percolating through porous rocks can contribute to the generation of sub-critical tensile fractures at stresses well below yield, and this means predictive fracture-based models may need revision. The concept of structural diagenesis (Laubach et al., 2010) could be extended to link the diagenetic evolution of sedimentary rocks, fracture propagation and mineral deposit formation. This project addresses a fundamental scientific question with a direct application to critical minerals for the energy transition: What role does sub-critical cracking play in the accumulation of critical mineral ore deposits?

Methodology:

The key research questions to be addressed by this project are:

- How do pore fluids evolve during the diagenesis, compaction and fracturing of mineralised host rocks?
- How does these changes in chemistry affect crack propagation and vein formation?

And therefore, the relevant methods to be deployed include:

- Detailed multiscale mapping and sampling of mineralised fracture systems in selected mineral deposits in mudstone, sandstone and limestone;
- Microstructural and microchemical analysis of fracture-filling mineralisation in natural samples and laboratory;
- Laboratory double torsion experiments designed to explore the interaction of sub-critical crack propagation with pore fluid chemistry and mineral precipitation;
- Numerical modelling of the relationship between sub-critical fracturing and the deposition of critical minerals.

Possible Timeline

Year 1: Detailed multiscale maps and sample suites of mineralised fracture systems in selected mineral deposits in mudstone, sandstone and limestone; Microstructural and microchemical analysis of fracture-filling mineralisation in natural samples

Year 2: Laboratory experiments designed to explore the interaction of sub-critical crack propagation with pore fluid chemistry and mineral precipitation; Microstructural and microchemical analysis of fracture-filling mineralisation in laboratory samples; Write Paper #1

Year 3: Analysis and integration of laboratory results; Numerical modelling of the relationship between sub-critical fracturing and the occurrence of critical minerals; Write Papers #2 & #3.

Training and skills:

Training will be given in field-based structural geology, experimental rock mechanics, microstructural and microchemical analysis and numerical modelling. Field training will include detailed structural mapping, including the use of digital photogrammetry, scanline surveys and oriented sample collection (with permissions). Experiments will use a new state-of-the-art double torsion deformation apparatus. The student will be trained in all aspects of laboratory sample preparation, machine calibration, rock property testing and experimental data analysis. Microstructural analyses will be conducted on selected pre- and post-test samples at the Bragg Centre for Materials Research. Cathodoluminescence, Secondary, Backscatter Electron and X-CT imaging along with chemical and crystallographic data using EBSD and EDS will be used to map changes in porosity, microcracking mineralization and plastic deformation.

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.

Partners and collaboration (including CASE):

The project team comprises researchers from the universities of Leeds and Cardiff with extensive and overlapping track records across the skills needed in this project. The supervisory team at Leeds covers field-based structural geology, microstructural and microchemical analyses, laboratory rock deformation and numerical modelling. The co-supervisor at Cardiff covers field-based structural geology, especially around major ore deposits, and a sustained track record in microstructural analysis. We will have whole group meetings online every 3 months and look to exploit conference attendance wherever possible to minimise unnecessary travel (and carbon emissions).

Further reading:

Laubach, S.E., Eichhubl, P., Hilgers, C. and Lander, R.H., 2010. Structural diagenesis. Journal of Structural Geology, 32(12), pp.1866-1872.

Meredith, P.G. and Atkinson, B.K., 1983. Stress corrosion and acoustic emission during tensile crack propagation in Whin Sill dolerite and other basic rocks. Geophysical Journal International, 75(1), pp.1-21.

Barnett, R.L. & Kerrich, R., 1980. Stress corrosion cracking of biotite and feldspar. Nature, 283(5743).

Rowe, J. & Burley, S.D., 1997. Faulting and porosity modification in the Sherwood Sandstone at Alderley Edge, northeastern Cheshire: an exhumed example of fault-related diagenesis. Geological Society, London, Special Publications, 124.

Further details:

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Please visit https://target.le.ac.uk/ for additional details on how to apply.