Making the most of galena: the effect of deformation on trace element distribution in galena

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Project Highlights:

- A unique opportunity to investigate the deformation- and reaction induced (re)distribution of energy transition metals and elements associated with galena; to do this you will work on world class deposits including the Ag-Pb-Zn Broken Hill and Cannington deposits, Australia
- 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:

Galena is not only the most important ore mineral for lead, but it typically includes significant amounts of silver, zinc, antimony and bismuth which are elements of critical importance to energy transition technologies. To gain the most of mining galena ensuring energy efficiency and sustainability, knowledge of the distribution and elemental behaviour of these galena "by-products" is crucial. This exciting project explores the underlying physical and chemical processes that lie at the core of the distribution of critical elements associated with galena and its deformation and fluid-rock interaction history. In this novel project, you will integrate knowledge obtained from targeted field studies and sampling, unique quantitative microstructural and -chemical analyses, and real rock deformation-reaction experiments to gain an in-depth understanding of the processes associated with trace element clustering and phase separation in and around galena. Insights gained will be far reaching in the fundamental science of trace element mobility in ores and, importantly, provide the knowledge-base to utilize galena to the fullest for the energy transition.

Even though galena hosts significant amounts of silver, zinc, antimony and bismuth, the physio-chemical processes responsible for their concentration into galena remain incompletely understood. It is well recognised that trace elements are incorporated into sulphides either as inclusions, or via a substitution process into the crystal lattice during crystallisation. Recent research highlights the importance of post-crystallisation deformation processes with and without fluid presence in remobilising and concentrating trace elements along deformation bands and/or during recrystallization [1-3]. Furthermore, reactions with percolating hot fluids may change ore mineral compositions significantly [4].

At present, there are no studies on trace element redistributions associated with galena even though it deforms easily [5]. This project will address with knowledge gap, establishing the link between deformation and elemental redistribution in galena. Such a link can only be drawn by in-depth analysis of natural and experimental samples for which conditions of deformation-fluid-reaction are well known. This novel project will make use of the unique combination of analytical tools and experimental facilities available at Leeds and Liverpool. The multi-disciplinary supervisory team and techniques available are ideally suited to ensure project success especially as the student will have access not only to UK field sites and samples but also to two of the larges Pb-Zn-Ag deposits know on Earth (Broken Hill & Cannington, Australia).

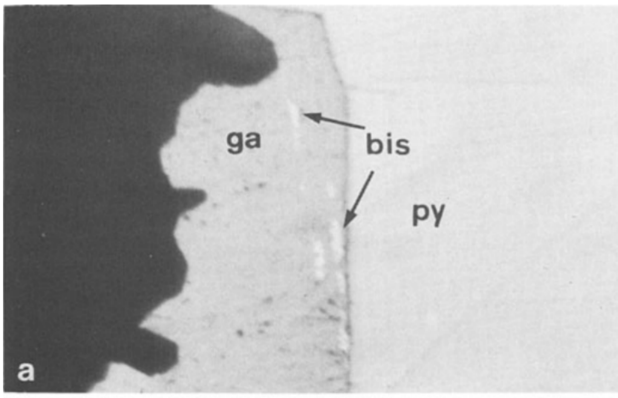

Figure 1: Inclusion of bismuthinite (Bis) in Galena (Ga), width_of_view 40 micron [6]

Methodology:

The projects' key research questions are:

1) Does post-crystallization deformation and/or reaction of galena remobilise and concentrate trace elements in and around galena?

2) What processes concentrate trace elements and how can they be recognized?

Field work: 1-3 week field campaigns in 2 mineralised localities across England and Scotland

Sample Selection: From UK field sites, and well documented Broken Hill and Cannington deposits, Australia

Sample Analysis: Optical/BSE/CL imaging, and elemental and phase mapping. Electron Backscatter Diffraction analysis (EBSD) to characterize deformation structures (e.g. [1, 7]); EBSD is entirely novel for galena (enabled by specialist polisher (UoLeeds)). Trace element analysis with EMPA/La-ICPMS, and unique Time of Flight mass-spectrometer mounted on Scanning Electron Microscope (UoL).

Experiments at elevated PT: Static fluid rock interaction, triaxial and direct shear deformation experiments in fluids presence/absence of under confining pressure and elevated temperature and controlled pore fluid pressure.

Timeline

Year 1: Literature review, field work with sampling, start of sample analysis

Year 2: Visit Geological Survey of Queensland / UoNE, sample selection, experimental work, analytical phase, publication#1

Year 3: Finish analyses and experimental work; publication#2&3; write-up

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 project provides specialist training in: (i) focussed, ore mineralization related field work, (ii) state-of-the-art microanalytical techniques and experimental approaches, (iv) working with multiscale and -subject datasets typically provided by geological surveys/industry, (v) conduction of a multi-disciplinary research project. The PhD provides exposure to industry-relevant understanding of ore geology and deposit-forming processes, non-academic vocational experience and a route towards an academic career with an excellent potential for high-impact publications. You will be able present at national and international, academic or industry facing conferences. You will be part of a large PhD cohort and research community at the UoL.

Partners and collaboration (Case support):

Supervisory team at the UoLeeds covers field work, microanalytical and experimental techniques, and in ore deposits research. The co-supervisor at the UoLiverpool, Prof. Faulkner, provides guidance in direct shear tests on galena samples using their unique apparatus [9]. Several reciprocal day and 4* 1 week visits to UoLiverpool will ensure experimental success and integration. Visit Geological Survey of Queensland (Partner EB) and University of New England (UoNE; Partner Chapman) for 2-4 weeks each for sample selection, added analysis on all samples (phase mapping, La-ICPMS analysis), geological background of Australian deposits and in-depth discussions. Whole group meetings over Zoom/TEAMS every 3 months.

Further reading:

[1] Piazolo, S., La Fontaine, A., Trimby, P., Harley, S., Yang, L., Armstrong, R. and Cairney, J.M., 2016. Deformation-induced trace element redistribution in zircon revealed using atom probe tomography. *Nature communications*, *7*(1), p.10490.

[2] Börner, F., Keith M., Fougerouse, D., Macauley C, P, Yokosawa T, Apeleo Zubiri B, Spiecker E, 2023. Between defects and inclusions: The fate of tellurium in pyrite. Chemical Geology 635, 121633.

[3] Fougerouse D, Reddy SM, Kirkland CL, Saxey DW, Rickard WD, Hough RM, 2019. Time-resolved, defect-hosted, trace element mobility in deformed Witwatersrand pyrite. Geoscience Frontiers 10, 55-63.

[4] Putnis, A., 2009. Mineral replacement reactions. *Reviews in mineralogy and geochemistry*, *70*(1), pp.87-124.

[5] McClay, K.R., 1980. Sheared galena; textures and microstructures. *Journal of Structural Geology*, *2*(1-2), pp.227-234.

[6] Cook, N. J., Klemd, R., & Okrusch, M. (1994). Sulphide mineralogy, metamorphism and deformation in the Matchless massive sulphide deposit, Namibia. *Mineralium Deposita*, *29*, 1-15.

[7] Piazolo, S., Kaminsky, F.V., Trimby, P., Evans, L. and Luzin, V., 2016. Carbonado revisited: Insights from neutron diffraction, high resolution orientation mapping and numerical simulations. *Lithos*, *265*, pp.244-256.

[8] Bedford, J.D. and Faulkner, D.R., 2021. The role of grain size and effective normal stress on localization and the frictional stability of simulated quartz gouge. Geophysical Research Letters, 48(7), p.e2020GL092023.

Further details:

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

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