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
- 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, 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, 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 has, however, highlighted the importance of post-crystallisation deformation processes with and without fluid presence in remobilising and concentrating trace elements along deformation (dislocation) 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.

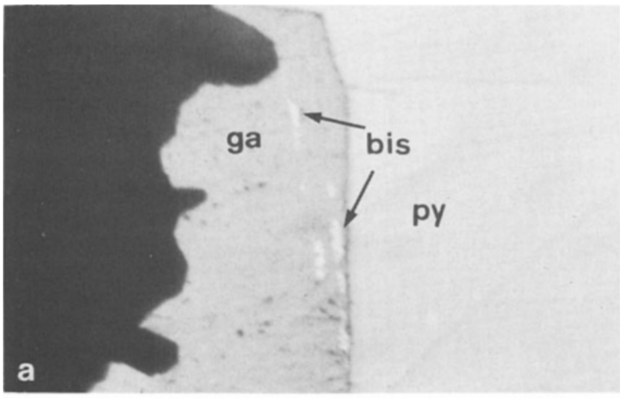

Figure 1: Inclusion of bismuthinite (Bis) in Galena (Ga), width_of_view 40 micron [6]

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 3 mineralised localities across England and Scotland guided by already existing sample sets.

Analytical methods: BSE imaging and elemental mapping. Quantitative crystallographic orientation analyses using Electron Backscatter Diffraction (EBSD) to characterize deformation structures (e.g. [1, 7]); EBSD will be entirely novel for galena (enabled by broad ion beam polisher). Trace element distribution analysis with electron microprobe analyser (EMPA) and a world-wide unique Time of Flight mass-spectrometer mounted in a dual beam Scanning Electron Microscope.

Experiments: Fluid rock interaction experiments at elevated temperatures and pressures. Triaxial deformation experiments in fluids presence/absence of under confining pressure and elevated temperature and controlled pore fluid pressure, including direct shear tests.

Possible Timeline

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

Year 2: Main analytical phase, experimental work, publication#1

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

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: (i) focussed, ore mineralization related field work, (ii) state-of-the-art microanalytical techniques as outlined above, (iii) several experimental approaches, (iv) conduction of a multi-disciplinary research project. The PhD provides both exposure to industry-relevant understanding of ore geology and deposit-forming processes and 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 School of Earth and Environment.

Partners and collaboration (including CASE):

The expertise of the supervisory team at the University of Leeds covers field work, microanalytical and experimental techniques, and in ore deposits research. The co-supervisor and project partner at the University of Liverpool, Prof. Faulkner, complements the team as an internationally acknowledged expert in rock deformation experiments and their interpretation. In particular, the student will perform direct shear tests on galena samples in Liverpool, using their unique apparatus [9]. Several reciprocal day and 4* 1 week visits of the student to Liverpool are planned to ensure integration.

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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