

Reading the textures of zircon crystals from porphyry copper deposits using machine learning

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Project Highlights:

- Build a catalogue of zircon cathodoluminescence textures from a range of porphyry Cu deposits and unmineralised rocks
- Develop machine learning models to extract quantitative textural information from zircon textures and make predictions of provenance and porphyry fertility
- Test machine learning models in active exploration sites using detrital zircons from known mineralised sites integrated with trace element data

Overview:

Porphyry copper deposits are the main source of society's copper and account for large amounts of molybdenum, gold and other metals. Zircon compositions have been widely used in mineral exploration since they are resistant to alteration and indicate conditions favourable to porphyry Cu mineralisation such as high-water contents. It has also been shown that the textures of zircon crystals from porphyry copper deposits can form distinct textures relative to unmineralized plutons. These textures record the long-lived compositional and physical evolution of magmas during their cooling and fluid exsolution.

Machine learning presents a novel method to rapidly extract information from crystal textures. This project aims to use machine learning and computer vision to make predictions of provenance, porphyry Cu prospectivity and magmatic conditions using zircon textures. It also aims to better understand textures of zircon growth in porphyry environments using high resolution mapping and microanalytical geochemistry. The results will provide a new tool for deployment in mineral exploration in collaboration with industry partners. The methods will also be strongly applicable to understanding provenance in sedimentology and tectonic studies.

This project provides a unique opportunity to work with internationally recognised researchers in economic geology, petrology, geochemistry and machine learning/AI. Collaboration with industry partners will provide unique insights into methods at the forefront of mineral exploration, placing the candidate in a strong position for a future career in academia and/or industry.

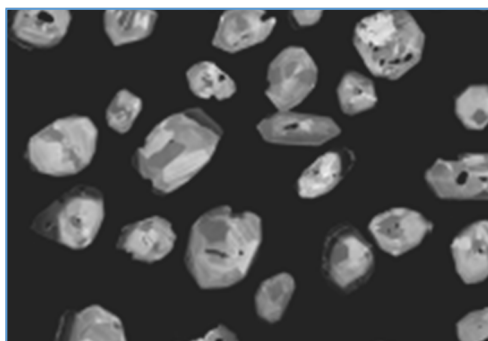


Figure 1: Zircon crystal from a porphyry copper deposit imaged under cathodoluminescence using a scanning electron microscope

Methodology:

Sampling of zircon crystals from a range of mineralised and unmineralised rock types will be undertaken which will include fieldwork and using existing sample collections. Zircon will be imaged using scanning electron microscopy and cathodoluminescence techniques at the Natural History Museum. High resolution chemical mapping (laser ablation and/or electron microprobe) will be performed to better understand controls on zoning textures in zircon. Quantitative analysis may also be performed using laser ablation at the Natural History Museum.

Deep learning (convolutional neural networks) based models will be used to make predictions of provenance (mineralised vs unmineralized) from zircon textures. Unsupervised techniques will also be used to cluster together zircon textural populations without the requirement of a label, for application to detrital samples. Work with industry partners and the Natural History Museum will develop workflows for the use of zircon textures in provenance and exploration work.

Possible Timeline

Year 1: Literature review, training courses in machine learning and computer vision, sampling work, initial characterisation of zircon textures

Year 2: Labwork and data acquisition (largely using SEM and some LA-ICP-MS), method development for machine learning techniques, beginning to write first paper, international conference attendance

Year 3: Tool development, case study applied to detrital samples, paper writing, international conference attendance

Training and skills:

Full training will be provided in machine learning and computer vision methods through training courses and in house expertise. The student would be able to engage with a wide range of training courses in data science and machine learning at Imperial College London. Training and supervision in laboratory techniques will be provided by the Natural History Museum, London.

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 successful candidate will be primarily based at Imperial College London, with close collaborations with the Natural History Museum. The student will benefit from training and collaboration with laboratory staff at the Natural History Museum, London. The candidate will also be part of the Data Learning research group in the Earth Science and Engineering department at Imperial College London, and be encouraged to engage with Imperial's Data Science Institute. The candidate will work closely with mineral exploration companies for access to study sites. This will include reporting of results and discussions with industry partners.

Further reading:

Carrasco-Godoy, C., Campbell, I.H. and Cajal, Y. (2024) 'Quantifying the Criteria Used to Identify Zircons from Ore-Bearing and Barren Systems in Porphyry Copper Exploration', *Economic Geology*, 119(5), pp. 1035–1058. <https://doi.org/10.5382/econgeo.5086>.

Gillespie, J. *et al.* (2024) 'A dendritic growth mechanism for producing oscillatory zoning in igneous zircon', *Geology*, 53(2), pp. 171–175. <https://doi.org/10.1130/G52641.1>.

Lu, Y.-J. *et al.* (2016) 'Zircon Compositions as a Pathfinder for Porphyry Cu $\pm$ Mo $\pm$ Au Deposits'. Special Publications of the Society of Economic Geologists. <https://doi.org/10.5382/SP.19.13>.

Nathwani, C.L. *et al.* (2023) 'Mineral Texture Classification Using Deep Convolutional Neural Networks: An Application to Zircons From Porphyry Copper Deposits', *Journal of Geophysical Research: Solid Earth*, 128(2). <https://doi.org/10.1029/2022JB025933>.

Scharf, T. *et al.* (2024) 'Predicting source rock silica from igneous zircon characteristics', *Earth and Planetary Science Letters*, 638, p. 118745. <https://doi.org/10.1016/j.epsl.2024.118745>.

Further details:

Please visit <https://target.le.ac.uk/> for additional details on how to apply. Please contact lead supervisor Chetan Nathwani for further questions: chetan.nathwani@imperial.ac.uk