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PhD Project Description

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

Supervisors

Lead Supervisor: Dr. Chetan Nathwani

Co-supervisor(s): Dr. Rossella Arcucci and Dr. Ethan Tonks (Natural History Museum)

Research Group

The student will be based in the London Centre for Ore Deposits and Exploration (LODE) group at Imperial and allied with the DataLearning group in the department.

Project Summary

Zircon trace element compositions are widely used to predict the ore-forming potential of granitoids sampled during exploration, and to indicate the high-water contents and oxygen fugacity of ore-forming magmas. It has previously been suggested that zircon textures may also provide useful insights.

This project aims to use develop machine learning models to extract quantitative textural information from zircon textures from porphyry copper deposits and other igneous rocks. It will determine the textural characteristics of zircon crystals from porphyry copper deposits and interpret the magmatic processes that generate these textures. The approach will be applied to active exploration sites using detrital zircons to test whether it can discriminate porphyry zircons from background zircons using textural information. The project will provide a new methodology for mineral exploration, and for application in provenance studies. It will also contribute to new advances in the novel field of applying machine learning to extract information from the textures of rocks and minerals in geoscience.

Research Context and Objectives

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 a 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.

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.

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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.

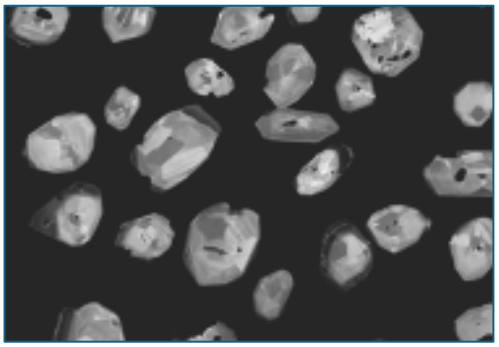

Figure 1: Zircon crystal from a porphyry copper deposit imaged under cathodoluminescence using a scanning electron microscope

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.

Collaborators and partners on the project:

This project will involve collaboration with our neighbours at the Natural History Museum, through training and use of world-class analytical facilities at the Imaging and Analysis Centre. Collaboration with mineral exploration companies is also expected, providing access to case studies sites and for valuable exchanges of ideas.

Further reading:

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.

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.

Who are we looking for?

We are looking for motivated hard-working students with a background in geoscience and some experience with computational methods, with the willingness to learn machine learning techniques and laboratory methods. Skills developed will include programming, machine learning, computer vision and electron microscopy with extensive training provided.

Successful applicants have a proven aptitude for practical, experimental and /or analytical work and a genuine curiosity for scientific research.

The candidate will have the opportunity to develop their career and profile by presenting at international conferences and publishing in internationally recognised journals. The projects involve interaction with other research groups within and beyond ESE.