PhD Project Description

Developing machine learning models for using crystal textures to investigate magmatic evolution leading to explosive volcanic eruptions

Supervisors

Lead Supervisor: Dr. Chetan Nathwani

Co-supervisor(s): Dr. Chiara Petrone (NHM), Dr. Martin Mangler (Southampton), Dr. Rossella Arcucci

Research Group

The student will be based between the London Centre for Ore Deposits and Exploration (LODE) group and the DataLearning group in the department at Imperial, with integration within the Volcano Petrology group at the Natural History Museum.

Project Summary

Crystals brought to the surface during volcanic eruptions provide important windows into the dynamics of magma reservoirs. This project aims to use deep learning and computer vision to develop automated methods for extracting information from crystal textures. The developed models will be applied to sequences of eruptive units from Santorini caldera (Greece), to track changes in the makeup and textures of crystal cargos over the history of the volcano. This will test whether crystals erupted by explosive eruptions (compared to effusive eruptions) have specific textures that may be diagnostic of perturbations triggering explosive volcanism.

Research Context and Objectives

Crystals in volcanic rocks (e.g., plagioclase and pyroxene), typically have complex textures reflecting perturbations in the magmatic environment in which they grew. Some textures, such as sieve textures and reverse zoning, can reflect magma recharge, decompression and fluid exsolution, which can trigger explosive volcanic eruptions. Often there are multiple crystal populations present in a single volcanic rock, each originally grown in a different magmatic environment before being juxtaposed at some point before the eruption.

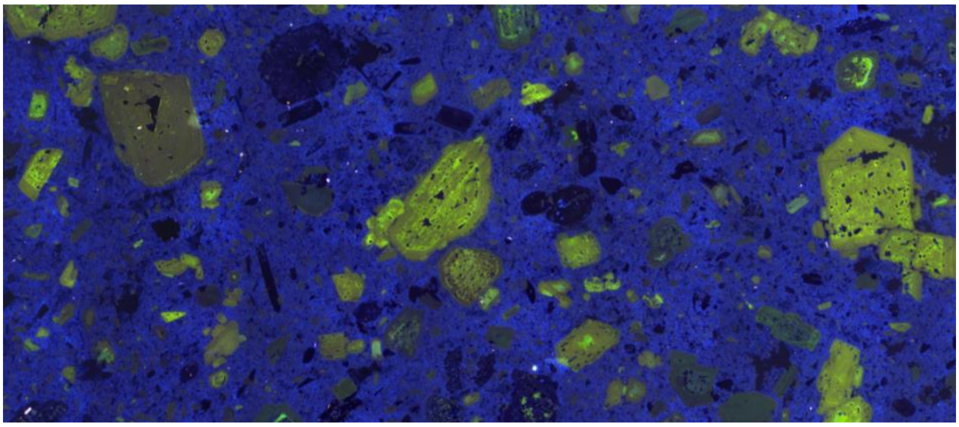

Figure 1: Cold-cathodoluminescence image of a volcanic rock from Methana, Greece showing variety of plagioclase textures (green tabular phases)

The textures of crystals in volcanic rocks may vary between those erupted by hazardous explosive eruptions versus non-hazardous effusive eruptions (Fabbro et al. 2017, Mangler et al. 2022). Quantifying variations in the nature and abundance of crystal textures may therefore provide critical information for volcano monitoring to indicate changes in magma dynamics and anticipate shifts towards hazardous eruption styles. However, until now, most studies of crystal textures in volcanic rocks depend on manual data acquisition and are thus time-consuming and subject to sampling bias.

This study aims to develop methods using machine learning and computer vision to produce automated and scalable models to extract information from crystal textures in volcanic rocks. The project will focus on Santorini volcano (Greece), one of the largest active volcanic systems in Europe with a rich history of explosive and effusive eruptions as recent as 1950 (Fabbro et al. 2017). Field sampling will be done to complement existing sample sets. Thin sections of volcanic rocks will be imaged at high resolution using cold-cathodoluminescence and/or scanning electron microscopy. The study will then implement, train and test machine learning models to segment crystals from thin sections and cluster different populations and extract quantitative information (e.g., crystal size distributions). The trained models will be applied to fresh volcanic ejecta, and work alongside volcano observatories may be undertaken to test the applicability of the developed methods.

Collaborators and partners on the project:

Collaboration with the Natural History Museum will provide expertise in volcanology, world-class analytical facilities and access to historic collections from volcanic eruptions. Co-supervision with the University of Southampton will provide expertise in interpreting volcanic textures in the context of experimental studies and physical modelling. Potential for collaboration with volcano observatories (e.g., Montserrat Volcano Observatory; INGV Catania) will provide a unique site access and the opportunity to disseminate research outputs for application in hazard management.

Further reading:

Fabbro, G. N., Druitt, T. H., & Costa, F. (2017). Storage and eruption of silicic magma across the transition from dominantly effusive to caldera-forming states at an arc volcano (Santorini, Greece). *Journal of Petrology*, *58*(12), 2429-2464. https://doi.org/10.1093/petrology/egy013

Mangler, M.F., Petrone, C.M. and Prytulak, J. (2022) ‘Magma recharge patterns control eruption styles and magnitudes at Popocatépetl volcano (Mexico)’, *Geology*, 50(3), pp. 366–370. Available at: https://doi.org/10.1130/G49365.1.

Toth, N. and Maclennan, J. (2024) ‘MinDet1: A deep learning-enabled approach for plagioclase textural studies’, *Volcanica*, 7(1), pp. 135–151. Available at: https://doi.org/10.30909/vol.07.01.135151.

Who are we looking for?

We are looking for motivated hard-working students with an interest in developing computational methods for application in volcanology and petrology. A background in geoscience would be advantageous, and some experience with programming is necessary. Skills developed will include programming, machine learning, computer vision and microscopy with extensive training provided. The candidate will have the opportunity to develop their career and profile by presenting at international conferences and publishing in internationally recognised journals. The project will involve interaction with other research groups within and beyond ESE, and with collaborators at volcano observatories.