The University of Oxford Department of Earth Sciences

EARTHSCIENCES

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The influence of oxygen fugacity on peralkaline eruption dynamics

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Overview

Continental rift volcanism represents ca. 10% of terrestrial volcanism on Earth. Most of this rift volcanism on Earth is associated with the East African Rift, comprising >100 active volcanoes that represent potential hazards but also vast resources of geothermal energy. Overall low eruptive frequency rates (e.g. Fontijn et al. 2018) and limited historical observations of eruptions at rift volcanoes however mean that rift volcanism is generally less well understood compared to arc volcanism. This project will aim to better understand the eruption characteristics that are unique to rift volcanism and therefore contribute to improved hazard assessment.

Many rift volcanoes are characterised by silicic magmas of peralkaline trachytic or rhyolitic compositions that can either erupt effusively, in the form of obsidian lava flows, or explosively. Geological observations suggest that explosive eruptions of peralkaline magmas can happen as sustained Plinian-style eruptions, generating widespread pumice and ash fall deposits and/or welded ignimbrites, or as Strombolian-like eruptions building pumice cones (e.g. Fontijn et al. 2018). These latter eruptions are particularly enigmatic and pose important questions on the volatile degassing and fragmentation mechanisms in peralkaline melts and how they may lead to highly explosive eruptions (e.g. Hughes et al. 2017).

The high alkali contents of peralkaline magmas greatly influence their rheological properties, leading to a generally low viscosity for a given temperature, volatile and SiO_2 content relative to that of calc-alkaline (arc) magmas (e.g. Di Genova et al. 2013; Romano et al. 2004). In addition to the high alkali contents, the oxygen fugacity (hence iron oxidation state) is also thought to influence the magma rheology and thus eruptive style (Di Genova et al. 2017). The pre-eruptive thermodynamic properties including oxygen fugacity and also volatile budgets of peralkaline melts however remain poorly documented (e.g. Gleeson et al. 2017).

Methodology

This project will make use of an existing sample collection of peralkaline rhyolites erupted in a range of styles (pumice and obsidian) from several volcanoes in the Main Ethiopian Rift. In addition a field trip is planned to collect obsidian lava flow samples at Tullu Moye volcano. A systematic characterisation of the chemical properties of the glassy rocks and their minerals will help better constrain the (variation in) pre-eruptive thermodynamic properties of the magmas. Textural observations will further help model the degassing dynamics and relate them to eruptive style.

Analytical methods to be used:

- Whole-rock major and trace element chemistry (ICP-OES/XRF, ICP-MS)
- Scanning Electron Microscopy (SEM)
- Electron Microprobe Analysis (EPMA)
- X-ray Absorption Near Edge Structure Spectroscopy (XANES)
- X-ray microtomography

Timeline

Year 1: Training courses (DTP Environmental Research), literature review, sample selection, laboratory training in whole-rock geochemistry, sample analysis

Years 2 and 3: Training courses (participation in field excursions), training in microanalytical techniques (SEM, EPMA), submission of proposals for XANES and XMT at Diamond Light Source, data acquisition, conference presentation

Year 4: Data integration, thesis completion, papers for international journals/conference presentation.

Training & Skills

Limited new fieldwork and sample collection are required for this project but the student will be exposed to volcanic deposits in the field through participation in various field trips.

Specialised training foreseen:

- Personalised training in whole-rock and microanalytical geochemistry (ICP-OES/XRF, ICP-MS, SEM, EPMA, SIMS, XANES)
- Melts, Glasses and Magmas summer course in Munich, Germany
- Volcanology summer school to familiarise with volcanic deposits in the field, and/or conference field trip (e.g. IAVCEI 2021 – Rotorua)
- Participation in 10-day field excursion to Italian volcanoes (ULB Master course)

References & Further Reading

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Further Information

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