The behaviour of Nitrogen in igneous systems and the how this contributes to the evolution of Earth's atmosphere

Curious12

Geodynamics-Geochemistry-Resources

IAP2-20-112

Overview

The nitrogen cycle is intimately link with plate tectonics and this has contributed to Earth's atmospheric distinction on a planetary scale (Mikhail and Sverjensky, 2014). The ratio between the subduction-driven deep Earth inputs and outputs is known as the surface-mantle flux. For nitrogen, this flux is poorly constrained (see Zerkle and Mikhail, 2017). Some key unknowns are the behaviour of nitrogen in igneous systems and the relative sizes of Earth's reservoirs (i.e. continental crust, oceanic crust, mantle, and core). In short, there are many unknowns to be explored in this field. Therefore, the characterisation of reservoir geochemistry and the determination for the equilibrium behaviour of nitrogen in high-temperature systems are both urgently required to move the field forward. This project will use natural samples to examine mineral-melt and mineral-mineral elemental partitioning of nitrogen alongside any associated stable isotope fractionation factors during igneous processes (melting, differentiation, degassing).
The samples cover both alkali (carbonatites + alkali intrusions) and silicic (basalt to rhyolite + gabbro to granite) extrusive and plutonic systems. The diversity of samples in this study enable the work to speak towards characterising a broad range of nitrogen reservoirs, from mantle sources (gabbro, carbonatite) to the continental crust (granite). In addition, this project will speak towards a number of processes including stable isotope fractionation (all samples), mineral-mineral partitioning (plutons), and the effects of volcanic degassing during volcanism and igneous differentiation (lavas). These data are required to [a] constrain the amount of nitrogen stored in Earth's continental crust, and [b] the behaviour of nitrogen during subduction-related magmatism.
This project is ready to go. We have all of the samples and all of the analytical kit required at the two institutions (St Andrews and Durham). There are no travel requirements, which reduces risk in these difficult and uncertain times. However, the supervisory team will support the student in seeking external funding to undertake fieldwork for the purpose of acquiring new samples.

Methodology

The samples will be filtered to ensure we only examine the freshest material. Hand specimen and thin section analysis will be followed by high spatial resolution mineral-specific analysis using a brand-new JEOL electron probe microanalyzer and a JEOL field-emission scanning electron microscope. Both are specially designed for light element analysis (i.e. with Light Element Crystals and a Soft X-Ray Emission Spectrometer). In addition, the project will utilize laser-ablation ICP-MS for trace element mapping (Univ. St Andrews and Durham,

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Key Words

- Volcanism

respectively). For nitrogen isotope determinations, we will use the recently established nitrogen analysis laboratory at St Andrews. This involves a bespoke gas-line attached to a MAT253 (ThermoFischer) isotope ratio mass spectrometer (see Boocock et al., 2020). Training will be provided throughout the PhD.

- Igneous Petrology
- Geochemistry
- Stable Isotopes

Project Timeline

Year 1

Year 1: This project is discovery driven, so there will need to a degree of flexibility. However, the project is not without direction, or a plan. In the first year the objects are to get settled into the research group of the primary supervisor (3 PhDs + 1 PDRA), the broader Planetary Geodynamics Research Group at St Andrews (https://www.st-andrews.ac.uk/earth-sciences/research/centres/planetary-geodynamics-/), and the Durham team led by Dr Prytulak. The first year will work to constrain the petrography, petrology, and geochemistry of the sample suite alongside building on method development for the sealed-tube combustion and micro-beam techniques applicable to the samples in this project.

Year 2

Year 2: Constrain the nitrogen geochemistry of the selected samples. Attend and present results at national conferences (i.e. the annual meetings of the Geochemistry Group, and the Volcanic and Magmatic Studies Group).

Year 3

Year 3: Finalise the 3 studies for PhD thesis chapters (and publications). Presently, these are envisaged to focus on [1] nitrogen geochemistry of the mantle using Namibian carbonates and Greenlandic alkali intrusions (building on C-O isotope work from a 2020 MSc thesis at St Andrews), [2] the behaviour of nitrogen during igneous differentiation using gabbroic to granitic samples from zoned plutons, and [3] the effects of degassing using extrusive volcanic samples from East Africa (Hutchison et al., 2018) and Iceland (Savage et al., 2011). Present results at international meeting (Goldschmidt).

Year 3.5

Year 3.5: Complete analyses and write thesis.

Training & Skills

This IAPETUS DTP project will provide training in petrology and stable isotope geochemistry, and the data generated will be focused on explaining the EarthÃ¢â‚¬â„¢s total volatile fluxes (biased towards nitrogen). The student will also attend training workshops on micro-analysis (at Bristol University, UK) and isotope geochemistry (with supervisory team). The focus on petrological characterisation of rock and minerals, advanced isotope geochemistry, and geochemical modelling will provide the student a skill-set to competitively acquire postdoctoral research positions, or to transition from an academic to industrial career in mineral resources, analytical chemistry, or data-driven (non-scientific) professional sectors.

References & further reading

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Further Information

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