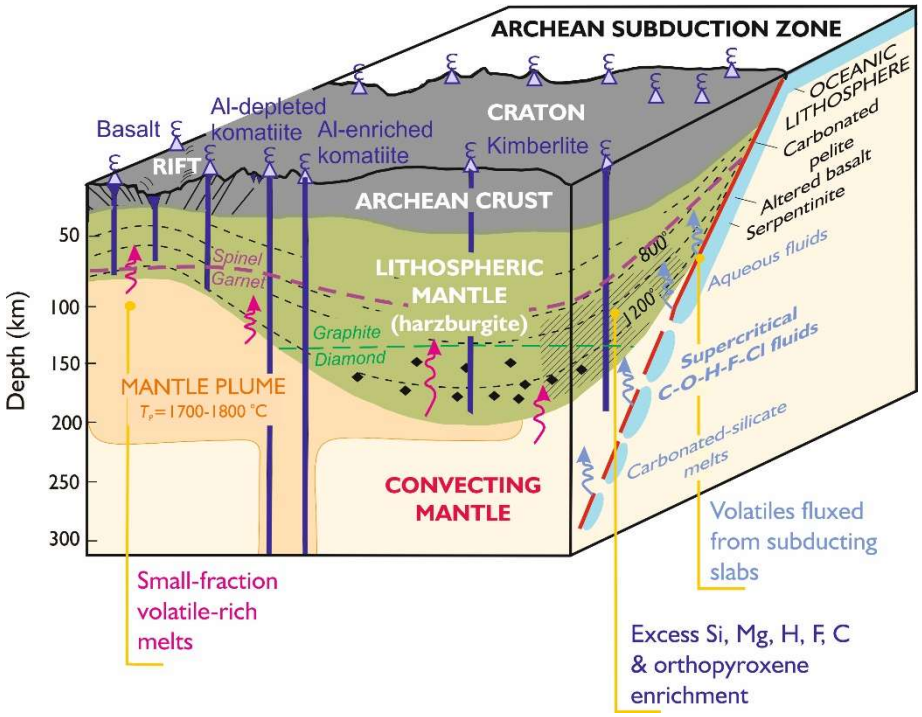
Project Title: Magmatic and volcanic cycling of volatiles and critical metals

Brief description: This proposed PhD research explores fundamental aspects as to how volatiles, including those essential for life (such as water and carbon dioxide), are cycled through the solid Earth in deep time and their link with critical metals.

Importance of the area of research concerned



The deep cycling of volatiles—such as CO_2, H_2O, F, Cl and S—is fundamental to Earth's long-term climate stability, surface habitability, and the formation of critical metal deposits essential to the global energy transition. Volcanic outgassing of these volatiles has also played a central role in shaping Earth's surface environment through geological time. One of the least understood yet potentially significant reservoirs controlling volatile fluxes is the lithospheric mantle. This ancient layer has the capacity to both sequester and release deep-sourced volatiles during episodes of magmatism (Gibson *et al.*, 2020, 2025; Gibson and McKenzie, 2023) and they may also influence it's long term stability (Jackson and Gibson, 2023). However, the origin and oxidation state of volatiles stored in this reservoir remain contentious. Key questions include: (i) are these volatiles introduced by oxidised carbonatitic melts/fluids from subducted slabs, or by less oxidised silicate melts from the deep mantle? (ii) how does the interplay of multiple volatiles influence mantle redox conditions and the genesis and preservation of diamonds? and (iii) what role do volatiles play in concentrating critical metals during volcanism (Gibson *et al.*, 2024)?

Project summary

The transport of volatiles between the solid-Earth, oceans and atmosphere remains poorly constrained. This is especially true for the continents. This research project aims to improve our understanding of volatile behaviour in the continental lithospheric mantle and associated surface volcanism. By integrating petrological, geochemical, and modelling approaches, the project seeks to resolve fundamental uncertainties about deep volatile cycling and its link to surface processes and mineral systems.

What the student will actually do?

A critical aspect of the project is to address the cause of the wide scatter in oxygen fugacity determined for mantle peridotites entrained from similar depths, and establish if this permits the extrapolation of redox conditions into the underlying convecting mantle. The project will focus on

the petrology (textures and mineralogy), together with the geochemistry of peridotite xenoliths entrained from the ancient lithospheric mantle 'roots' of continents by kimberlites of varying ages. An extensive set of peridotite xenoliths will be made available from the supervisors' collections. Mantle phases in these xenoliths will be analysed for major, trace elements and volatile contents (C, H etc) together with Fe^{2+}/Fe^{3+} ratios. Key volatile and non-volatile trace element ratios will act as proxies for the compositions of infiltrating melts and fluids. Pressure and temperature estimates derived from mineral chemistry will enable construction of stratigraphic profiles and geothermal gradients through the continental mantle and allow quantification of how the influx and distribution of volatiles and corresponding oxidation state has changed over billions of years.

Training to be provided: The student will be trained in the optical characterisation of igneous rocks, together with a variety of *in-situ* micro-analytical techniques, including electron microprobe, 193 nm laser-ablation ICP-MS, ion-probe and Mossbauer spectroscopy. The student will be encouraged to participate in national and international conferences (VMSG, Goldschmidt, AGU, EGU etc). Additional training in data analysis (python), writing and presentation skills will be provided via the Cambridge DTP.

If there are requirements as to the educational background of candidates that would be suitable for the project, please specify below:

A strong background in petrology and a basic understanding of the solid Earth is required for this project. A more detailed knowledge of mantle geochemistry, geophysical structure of the lithosphere and modelling of volatile cycles will be gained during the PhD research.

References:

Gibson, S. A., Jackson, C. J., Crosby, J. C. & Day, J. A. F. (2025). The role of C-O-H-F-Cl fluids in the making of Earth's continental roots. *Nature Communications (in press)*.

Gibson, S. A. & McKenzie, D. (2023). On the role of the lithospheric mantle in global volatile cycles. *Earth and Planetary Science Letters* **602**, 117946.

Gibson, S. A., Rooks, E., Day, J. A., Petrone, C. M. & Leat, P. T. (2020). The role of sub-continental mantle as both "sink" and "source" in deep Earth volatile cycles. *Geochimica et Cosmochimica Acta* **275**, 140–162.

Gibson, S., McKenzie, D. & Lebedev, S. (2024). The distribution and generation of carbonatites. *Geology* **52**, 667–671.

Jackson, C. J. & Gibson, S. A. (2023). Build-up of multiple volatiles in Earth's continental keels: Implications for craton stability. *Earth and Planetary Science Letters* **611**, 118134.