Draw down of volcanic CO_2 as a mechanism of climate recovery following periods of enhanced volcanism in Earth's geological past

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Research theme(s):	• Geodesy, Tectonics, Volcanology and related hazards • Oceanography, Climate and Palaeoenvironment
Eligible courses for this project:	• DPhil in Earth Sciences • Environmental Research (NERC DTP)

Overview

Large igneous provinces (LIPs) have been linked with major disruptions of Earth's climate system. These include four of the five major mass extinctions of the Phanerozoic and widespread episodes of environmental change during Ocean Anoxic Events (OAE). LIP volcanism and metamorphic degassing driven by shallow intrusions are often considered as a driver of transient spikes in atmospheric CO_2 such as the Palaeocene–Eocene Thermal Maximum (PETM) and the Jurassic Toarcian OAE (T-OAE) (Fendley et al., 2024). However, the manner in which the climate system has recovered from such catastrophic disruptions has received less attention (Black et al., 2024).

A prevailing paradigm is that chemical weathering is a major mechanism which acts to drawdown CO_2, as silicate minerals (e.g. in fresh basalt lavas) weather faster during the warmer climate perturbation. This provides a stabilising feedback in the Earth System, and acts to cool the climate again over geological timescales.

However, chemical weathering can also act as a CO_2 source. Most of the modern-day continental area is covered by sedimentary rocks, and the oxidative weathering of rock organic matter and sulfide minerals can release CO_2 in globally significant volumes (Zondervan et al., 2023). Indeed, these oxidative weathering reactions may increase with a more vigorous hydrological cycle and warmer temperatures (Soulet et al., 2021), meaning that weathering could extend warming events rather than countering them.

This project will assess the response of Earths' weathering engine to LIP induced warming. Periods of the geological record will be used where clear associations between LIP activity and climate change have been established, combining high-resolution volcanic, carbon cycle and weathering proxies to understand the recovery and feedbacks in more detail.

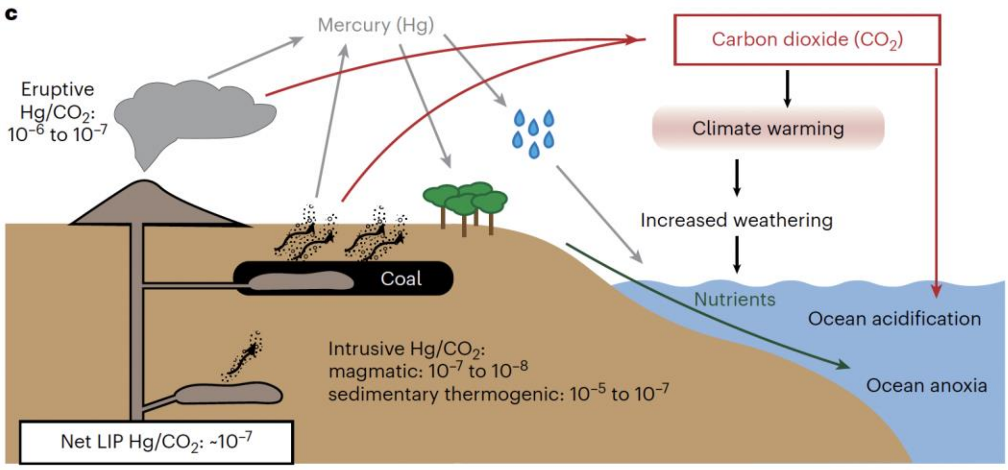

Figure illustrating the direct and indirect feedback effects of LIP-associated CO_2 emissions and simplified LIP Hg emissions pathways (Fendley et al., 2024).

Methodology

This project will combine a set of geochemical proxies to reconstruct the carbon cycle (C isotopes); volcanic CO_2 inputs (normalised Hg concentrations); oxidative weathering (trace element proxies e.g., Re/OC and Re isotopes) and silicate weathering (detrital Li isotopes) on high resolution records of periods covering enhanced volcanism and its recovery.

Timeline

Year 1: The first stages of the project will focus on a well-studied core such as the Mochras core covering the T-OAE and will extend past work to complete a high-resolution record of the Re weathering proxy and detrital Li.

Years 2 and 3: The student will receive further training on other proxies such as Hg and will extend their studies to cover other events at high-resolution.

Year 4: Data integration and the presentation of papers for international journals/conferences will be an integral part of the project throughout. In this final year these efforts will be corralled into a complete thesis format.

Training & Skills

The student will receive full training in the Oxford and RHUL geochemistry labs. Transferable skills such as technical writing, presentation skills and data processing will also be taught during the project.

References & Further Reading

B.A. Black, L. Karlstrom, B.J.W. Mills, T.A. Mather, M.L. Rudolph, J. Longman and A. Merdith, Cryptic degassing and protracted greenhouse climates after flood basalt events. Nature Geoscience (2024). https://doi.org/10.1038/s41561-024-01574-3.

I.M. Fendley, J. Frieling, T.A. Mather, M. Ruhl, S.P. Hesselbo and H.C. Jenkyns, Early Jurassic large igneous province carbon emissions constrained by sedimentary mercury, Nature Geoscience, 17 (2024) 241-248. (https://doi.org/10.1038/s41561-024-01378-5)

J. R. Zondervan, R. G. Hilton, M. Dellinger, M. et al. Rock organic carbon oxidation CO_2 release offsets silicate weathering sink. Nature 623 (2023), 329–333. https://doi.org/10.1038/s41586-023-06581-9

G. Soulet, R. G. Hilton, M. H. Garnett, et al. Temperature control on CO_2 emissions from the weathering of sedimentary rocks. Nature Geoscience 14 (2021), 665–671. https://doi.org/10.1038/s41561-021-00805-1

Further Information

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