Fate of past submarine volcanic input to the ocean

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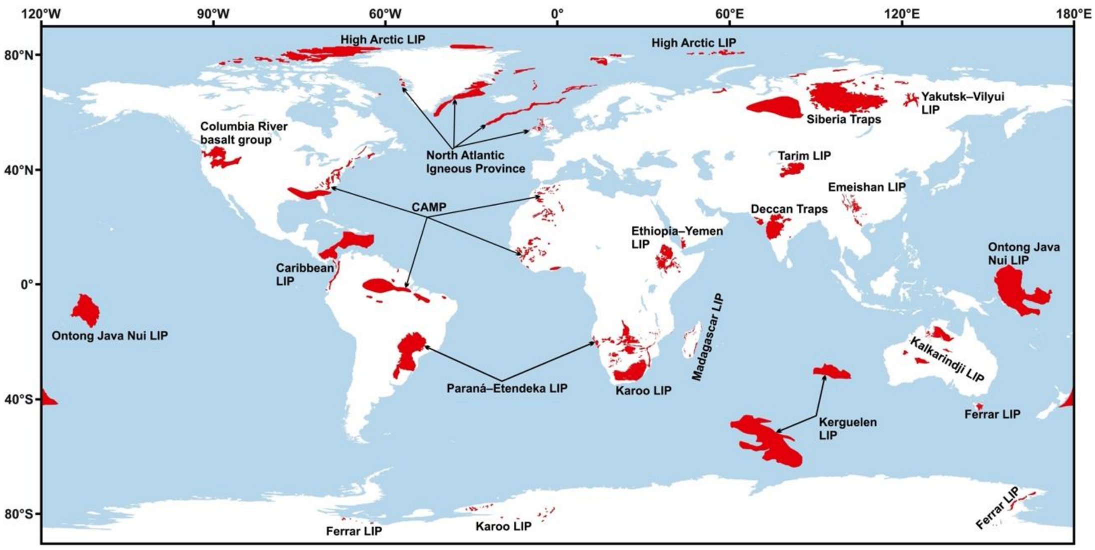
Key words:	Ocean circulation, submarine volcanism, mineral distribution, palaeoclimate
Research theme(s):	• Geodesy, Tectonics, Volcanology and related hazards • Earth Resources • Oceanography, Climate and Palaeoenvironment
Eligible courses for this project:	• DPhil in Earth Sciences • Environmental Research (NERC DTP) • Intelligent Earth (UKRI CDT)

This project would best suit a student with a background in Physics, Maths, Earth Science or Computer Science who is interested in ocean circulation, numerical modelling and interdisciplinary aspects of the changing Earth system.

Overview

Large Igneous Provinces (LIPs) are extremely large volumes of extrusive igneous rock, created during relatively short-lived volcanic events during the Phanerozoic, often coinciding with major environmental (e.g., Cenozoic hyperthermals and Mesozoic oceanic anoxic events or OAEs) and biotic change (e.g., mass extinctions). Consequently, LIP emplacement and weathering is thought to have been a key mechanism in driving these 'hyperthermal events' and the subsequent Earth system response and feedbacks (e.g., Foster et al., 2018).



Global distribution of Phanerozoic large igneous provinces (Jiang et al. 2023)

LIPs are also associated with high emission rates of iron, copper, and nickel as well as being involved in the origins of many major mineral provinces. The largest Phanerozoic LIPs occur in the ocean basins (e.g., the Ontong Java Plateau in the western Pacific and the Kerguelen Plateau in the Indian Ocean) and it has been suggested that their submarine emplacement, as well as the subsequent recycling of water through hydrothermal vents, resulted in the release of large quantities of (potentially) biolimiting nutrients (i.e., Fe, Cu, Ni and others) into the water column (e.g., Larson and Erba, 1999; Erba et al., 2015). The subsequent redistribution of these important and otherwise trace elements in seawater will have been influenced by regional ocean currents and their changes over geological time. Although there is some geological evidence to suggest spatial variation in the influence of volcanically-derived materials (e.g., Bottini et al., 2012; du Vivier et al., 2014), the spatial distribution and timescales of metal supply to seawater associated with LIP emplacements is largely unknown and may differ between events. Whether LIP-sourced metals were mixed globally in the upper ocean during periods of major environmental change is key to determining whether or not they were the driver of enhanced primary production that is often invoked as a negative Earth system feedback during hyperthermals such as OAEs.

This project will use Lagrangian tracking of virtual water parcels in palaeoclimate model simulations of ocean circulation to elucidate and understand the oceanic and seafloor distribution of elements and particles derived from submarine LIPs, for various Late Mesozoic and Cenozoic events. We will focus on these events as the paleogeography and palaeobathymetry of older time periods (e.g., the Palaeozoic) are more poorly constrained. The project has implications for our interpretation of seafloor sediment records through time, the connections between solid Earth processes and surficial environments, and for the distribution of Earth resources.

Methodology

Simulations of ocean circulation are available throughout the Late Mesozoic and Cenozoic (https://climatearchive.org/) We will use a Lagrangian particle tracking tool such as TracMass (https://www.tracmass.org/) to determine the trajectories of water originating from the major oceanic LIPs, and build in information about settling time (for particles) and reaction times (for elements) to determine the likely fate of mantle and hydrothermally derived inputs. We will also compile observational records to help constrain and validate our simulations.

Timeline

Year 1: core training programme in research skills, quantitative methods and ocean modelling techniques; literature review; initial Lagrangian experiments.

Years 2 and 3: trajectory analysis for a range of different LIPs/time periods/elements, and comparison with available data.

Year 4: further analysis, thesis completion, write papers for international journals, presentation of research at an international conference.

Training & Skills

You will learn how to work with ocean and climate model output, as well as with Lagrangian trajectory modelling tools, and will acquire a solid grounding in ocean dynamics and an understanding of a range of geochemical tracers. You will receive training and guidance on how to interpret and synthesize model and observational data, how to present scientific results and how to write scientific papers for publication. There may be opportunities to expand your skill set further by participating in an ocean research cruise if you desire, and to ground truth palaeo observations through consideration of modern systems.

References & Further Reading

Bottini et al., 2012, Osmium-isotope evidence for volcanism, weathering, and ocean mixing during the early Aptian OAE 1a. *Geology*, 40, 583–586. doi: https://doi.org/10.1130/G33140.1

du Vivier et al., 2014 Marine 187Os/188Os isotope stratigraphy reveals the interaction of volcanism and ocean circulation during Oceanic Anoxic Event 2. *Earth and Planetary Science Letters*, 389, 23-33. https://doi.org/10.1016/j.epsl.2013.12.024

Erba et al., 2015, Environmental consequences of Ontong Java Plateau and Kerguelen Plateau volcanism, *in* Neal, C.R., Sager, W.W, Sano, T., and Erba, E., eds., The Origin, Evolution, and Environmental Impact of Oceanic Large Igneous Provinces: *Geological Society of America Special Paper* 511, p. 271–303, https://doi.org/10.1130/2015.2511(15)

Foster et al., 2018, lacing our current 'hyperthermal' in the context of rapid climate change in our geological past. *Phil. Trans. R. Soc. A* **376**: 20170086. http://dx.doi.org/10.1098/rsta.2017.0086

Larson and Erba, 1999, Onset of the mid-Cretaceous greenhouse in the Barremian–Aptian: Igneous events and the biological, sedimentary and geochemical responses: *Paleoceanography*, v. 14, p. 663–678, https://doi.org/10.1029/1999PA900040

Further Information

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