Linking Phanerozoic carbon cycle perturbations, mass extinctions and large igneous provinces using novel geochemical proxies

Global Environmental Change
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Overview

The Phanerozoic Eon (past ~541 Million years) was marked by a number of fundamental events such as mass extinctions or ocean anoxic events that have shaped the course of the evolution of life and climate on Earth. Large igneous provinces (LIPs), known for their rapid production of voluminous magma and carbon release, have been synchronous with several of these events, however, the link between them still remains poorly understood. Illuminating the underlying link is critical for untangling the driving mechanism of extinctions, and their feedbacks and consequences, as well as for improving our overall understanding of climatic and ecological sensitivities.

This project will provide new constraints on pH and CO2 during key Phanerozoic periods (such as e.g. the Permian-Triassic boundary), alongside further changes in seawater chemistry – via weathering and volcanism – associated with carbon cycle variations.

To do this we will measure novel isotope and trace element ratios in selected fossil brachiopods and other carbonate archives from specific time intervals. Boron isotopes ($^{11}B$) will be used to reconstruct seawater pH (Jurikova et al., 2019; Foster & Rae 2016). This method has been successfully applied to constrain changes in CO2 over the Cenozoic, but deep-time reconstructions remain limited due to the lack of suitable, well-preserved archives (Fig. 1). Recent developments on the use and calibration of brachiopods as geochemical archives open the possibility for extending CO2 into earlier periods.

In this project, we will take the advantage of these archives together with a suite of novel geochemical proxies associated with a new ERC project, to provide constraints on carbon cycle and climate feedbacks during key periods of Earth’s evolutionary history.

Boron isotope data will be integrated with complementary proxies and traces of...
seawater chemistry, such as e.g. lithium, magnesium, calcium, strontium, and isotopes, made on the same unique archives. Measurements will take advantage of a bespoke new laser ablation system and new collision-cell ICPMS instrumentation. These will allow us to constrain secondary controls on the carbonate system, as well as evaluate the preservation of the fossils and constrain potential intra-shell heterogeneities (Fig. 2).

![Image Caption](image)

**Image Captions**

**Methodology**

This project will involve the application of boron isotopes as well as the development of new complementary methods for trace element and isotope analysis using novel collision-cell ICPMS instrumentation. This opens new possibilities for analyses not previously possible by argon-plasma instruments, and may make previously challenging measurements more straightforward (e.g. Ca or Sr isotopes).

Analyses will be made on carbonate fossils, chiefly brachiopods, but additional archives such as bivalves or echinoderms may also be explored. Samples will be available from existing collections, and fieldwork may also be undertaken to bolster these samples sets.

As well as solution-based analyses, we will use a laser ablation system to make in-situ analyses and evaluate microstructural variability and degree of preservation within the fossils.

The project is designed to be flexible, with the opportunity to focus on approaches, time intervals, and techniques of particular interest to the student.

**Project Timeline**

**Year 1**

Year 1: Training in clean laboratory methods and mass spectrometry, method development, experimental set-up, sample selection and inspection, initial measurements, literature review, possible fieldtrip.

**Year 2**
Year 2: Complete experiments, generate boron, carbon and oxygen isotope records from fossil carbonate archives, complemented with novel isotope and trace element systems.

Year 3
Years 3 and 3.5: Finalize data sets, apply numerical techniques, prepare written manuscripts and write thesis.

Year 3.5
Year 3.5: Finalize data sets, manuscripts and thesis.

Training & Skills

The student will gain specific training in mass spectrometry, clean lab chemistry, and experimental geochemistry, as well as broader education in geochemistry, geology, palaeontology, oceanography, and climate science. Over the course of the PhD the student will gain transferable skills such as scientific writing, statistics and data analysis, and problem-solving, as well as time management and working towards a long-term goal.

References & further reading
Jurikova et al. (2019), GCA 248, 370-386.
Royer et al. (2004), GSA Today 14, 4-10.

Further Information
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