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doctoral training partnership

NERC SCIENCE OF THE ENVIRONMENT

Ocean acidification and mass extinction

University of St Andrews, School of Earth and Environmental Sciences

In partnership with University of Glasgow

Supervisory Team

- **[Dr James Rae](), University of St Andrews**
- **Dr Eva Stüeken, University of St Andrews**
- **Dr Catherine Rose, University of St Andrews**
- **Dr Tim Raub, University of St Andrews**
- **Prof Darren Mark, University of Glasgow**
- **Dr Sarah Greene, University of Birmingham**

Key Words

1. **Carbon Cycle, Isotope Geochemistry, Ocean Acidification, Mass Extinction**

Overview

Ocean acidification is implicated in many of the most profound mass extinction events in the geological record (Hönisch et al. 2012). However until recently it has not been possible to reconstruct past pH change, so the role of acidification in mass extinction remains largely untested (Clarkson et al. 2015).

This project aims to transform our understanding of pH change through geological time by application of the boron isotope pH proxy in the rock record. The use of the boron isotope proxy has grown rapidly in recent years due to new MC-ICPMS methods and improved understanding of the proxy's systematics (e.g. Rae et al. 2011; Foster & Rae 2016). However to date the application of boron isotopes beyond the reach of deep sea sediment cores has been limited.

The initial phase of this project will develop new methods of extracting primary carbonate signatures from geological samples. By pairing a variety of elemental and isotopic measurements (including strontium and sulphur isotopes), we will screen for diagenetic influences and obtain complementary geochemical reconstructions. Preliminary data have yielded coherent signals from biogenic carbonates taken from ~200 Myr micrite, illustrating the vast potential of this technique.

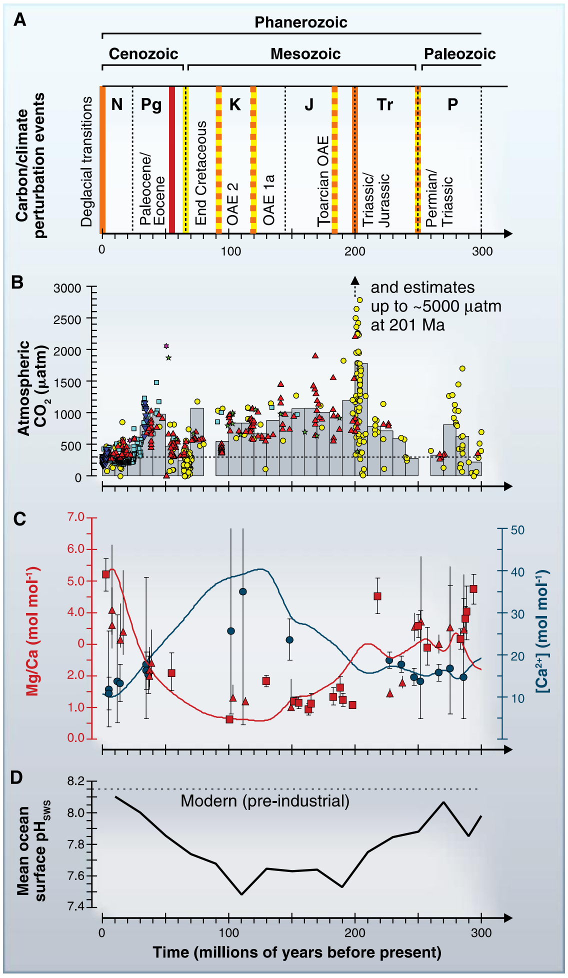

Fig 1: Major perturbations to the carbon cycle over the last 300 Myr (A) and their relationship to long-term changes in CO_2 (B), ocean chemistry (C), and pH (D). Taken from Hönisch et al. 2012.

We will then generate boron isotope records over major carbon cycle perturbations in the geological record. A particular focus will be times of massive volcanic eruptions from large igneous provinces (LIPs). LIPS are commonly associated with mass extinction, but some events leave the biosphere relatively unscathed. Our data will allow us to constrain the relative importance of buffering in the ocean-atmosphere carbonate system versus resilience in marine communities.

To explore these data in a quantitative framework we will perform a series of experiments with the GENIE Earth System model. We will test the influence of different eruption rates (constrained with the latest geochronology data) on the carbon cycle over a range of boundary conditions. For instance did the evolution of a buffering blanket of seafloor carbonate during the Mid-Mesozoic dampen the ability of LIPS to drive extensive acidification? Or is the major ion chemistry of the ocean a more crucial control?

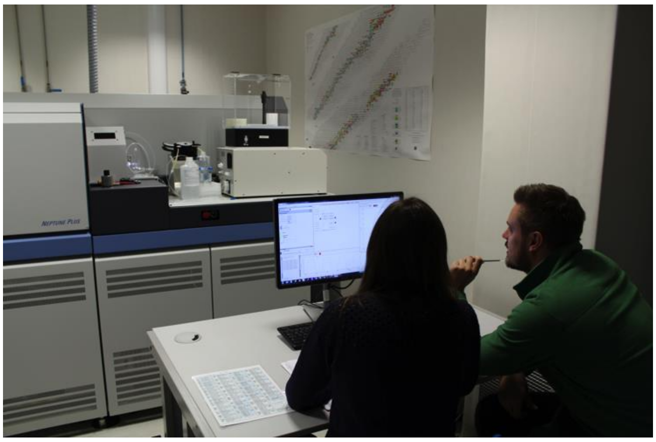

Fig 2: The Neptune MC-ICPMS at the St Andrews Isotope Geochemistry (STAiG) labs.

Methodology

Geochemical method development will take place in the state of the art St Andrews Isotope Geochemistry labs (STAiG) with Rae and Stüeken. Boron isotope analysis will build from techniques established by Foster (2008) and Rae et al. (2011), with further development to constrain secondary influences and allow paired sulphur and strontium isotope analyses on the same samples.

Initial samples from key sections are in-hand from Rose and Raub. Further field work will be undertaken to build these collections, with geochronology developed in collaboration with Mark.

Modelling will be carried out in collaboration with Greene and through on-going collaboration with Prof Andy Ridgwell.

Timeline

Year 1: Literature review, training in clean laboratory methods and mass spectrometry, geochemical method development. Initial field campaign.

Year 2: Generation of boron isotope records. Earth System modelling. Second field campaign.

Years 3 and 4: Finalize data sets, apply numerical techniques, assess model output, prepare manuscripts and write thesis.

Training & Skills

The student will gain specific training in geochemical analyses, field geology, and Earth system modelling. The balance of these skills can be tailored to the student's particular strengths and interests. Over the course of the PhD the student will also gain transferable skills such as scientific writing, statistics, and problem-solving, as well as time management and working towards a long-term goal.

References & Further Reading

Clarkson et al. (2015), *Science*, *348,* 229-232
Foster (2008), *EPSL*, *271*, 254-266.
Hönisch et al. (2012), *Science, 335,* 1058-1063.
Rae et al. (2011), *EPSL*, *302*, 403-413.
Ridgwell (2005), *Marine Geology, 217,* 339-357.

Further Information

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