Novel reconstructions of seawater chemistry and CO2 over the last 100 Myr

Curious12

Biogeochemical Cycles

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Overview

During the last 100 Million years, Earth witnessed a number of fundamental changes in climate (Zachos 2001). CO_2 is implicated in many of the long term trends, Milankovitch rhythms, and abrupt events that characterise long-term climate change, but despite recent progress, absolute CO_2 levels remain poorly constrained (Figure 1). This in turn limits our understanding of processes ranging from the sensitivity of major ice sheets to CO_2 forcing, to the range of ocean acidities that marine life can tolerate.

This project will provide new constraints on pH and CO_2 during key intervals of the last 100 Million years, alongside the changes in seawater chemistry – via weathering and volcanism – that caused CO_2 to change.

To do this we measure novel isotope and trace element ratios in carbonate and salt samples spanning the last 100 Myr. Boron isotopes (d11B) will be used to reconstruct seawater pH (Foster & Rae 2016; Rae 2018). This method has been successfully applied to constrain changes in CO_2 on these timescales, but estimates of absolute CO_2 levels remain limited by a lack of constraints on the boron isotope composition of seawater, around which the d11B-pH proxy hinges. Here, we will take advantage of novel archives of seawater chemistry, associated with a new ERC project, including evaporite minerals and carbonates from unique ecological niches.

Boron isotope data will be complemented by complementary tracers of secular changes in seawater chemistry, such as lithium, magnesium, calcium, and potassium isotopes, made on the same unique archives. Measurements will take advantage of a bespoke new cryostage laser ablation system and new collision-cell ICPMS instrumentation. These will allow us to constrain secondary controls on the carbonate system, including seawater calcium, magnesium and alkalinity, and their governing controls.

Supervisory Team

Dr James Rae
University of St Andrews

Prof Erin McClymont
Durham University

Dr Hana Jurikova
University of St Andrews

Dr Robert Steele
University of St Andrews

Dr Andrea Burke
University of St Andrews

Further Information

for informal enquiries, contact:

Dr James Rae

jwbr@st-andrews.ac.uk

University of St Andrews

Key Words

- Ocean Chemistry
- Geochemistry
- Climate
- Carbon Cycle
- Isotopes

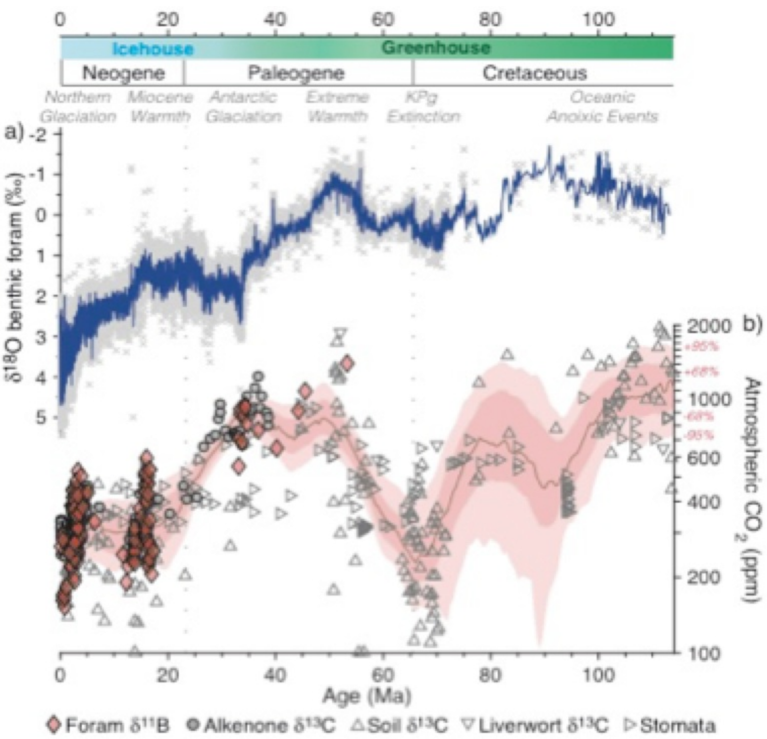

Figure 1: 100 Myr of climate and CO_2 change, as reflected in $\delta^{18}O$ data from benthic foraminifera (a) and various CO_2 proxies (b). While progress has been made in CO_2 reconstruction, there are still major uncertainties in this record, including the absolute values and phasing of change compared to climate.

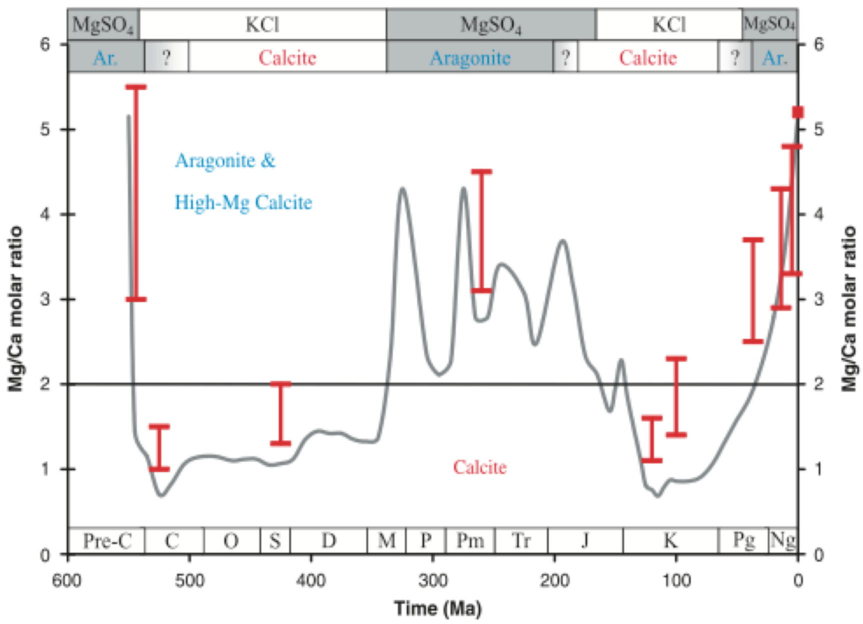

Fig 2: Reconstructing seawater chemistry from evaporite minerals has the intuitive appeal of a bulk composition more similar to seawater than are carbonate archives, and has been used to constrain past changes in seawater Mg/Ca (Lowenstein et al., 2001). Here we will extend this approach to isotope compositions and minor elements.

Methodology

This project will involve development of new 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, may make previously challenging measurements more straight-forward (e.g. Ca and K isotopes).

Analyses will be made on evaporites and carbonate fossils, including corals and foraminifera. Evaporites are made available by collaborator Tim Lowenstein and carbonates use existing sample collections and IODP samples. Fieldwork may be undertaken to bolster these sample sets.

As well as solution analyses, we will use a bespoke new cryo-stage laser ablation system to make in-situ analyses of brine inclusions, and microstructural variability within fossils. Targeting specific phases has the potential to improve constraints on starting seawater composition.

Analyses of evaporite samples from the field may be complemented by laboratory precipitation experiments.

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

Training in clean laboratory methods and mass spectrometry, method development, experimental set-up, initial measurements, literature review, possible fieldtrip.

Year 2

Generate boron isotope records from carbonate and evaporite archives, complement with novel isotope and trace element systems.

Year 3

Finalize data sets, apply numerical techniques.

Year 3.5

Prepare written manuscripts and write 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, 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

Foster & Rae (2016), AnnRev, 44, (207-237)
Lowenstein (2001), Science, 294, (1086)
Rae et al. (2011), EPSL, 302, 403-413.
Zachos et al. (2001), Science, 292, 686-693.

Further Information

Dr James Rae
Department of Earth and Environmental Sciences
University of St Andrews
St Andrews
KY16 9AL
+44 (0)1334 463901
jwbr@st-andrews.ac.uk