

Michael Henehan, Ph.D.

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Education

PhD, Geochemistry and Palaeoclimate, University of Southampton 2009 - 2013

Title: "Ground-truthing the boron-based proxies". *Project Supervisors:* Prof. Gavin L. Foster, Prof. Paul A. Wilson, Prof. Jonathan Erez. *Examiners:* Prof. James C. Zachos and Prof. Martin R. Palmer.

M/Sci, Palaeontology and Evolution, University of Bristol 2005-2009

First Class Honours. *Tutor:* Prof. Michael J. Benton.

Research Interests

- The development and application of palaeoclimate proxies (geochemical and micropalaeontological), with a view to better understanding past climate and carbon-cycle perturbations.
- Biogeochemical and geochemical cycles and feedbacks on climate.
- The biology, physiology and evolution of foraminifera and other marine calcifiers.

Grants and Awards

NASA C5. Exobiology Grant

submitted and pending, 2015

Project title: "*Quantifying Carbon-Cycle Influence on Macro-evolutionary Turnover at the Cretaceous-Paleogene Boundary using Boron Isotopes.*"

Proposal submitted to investigate the interplay between perturbations in the carbon cycle and macroevolutionary processes (extinction and biotic recovery) around the K-Pg boundary. Grant amount: **\$220,788**

[*Project Leader and Author: Michael Henehan, PI: Noah J. Planavsky, Co-I: Pincelli M. Hull*]

EU FP7 Assemble Marine Science Grant

2013

Project title: "*Investigating controls on boron incorporation and boron isotope fractionation in planktic foraminifera, and the origin of vital effects*"

Awarded funding to take 4 University of Southampton researchers to the Interuniversity Institute of Eilat, Israel, for 3 weeks. Led culturing of planktic foraminifera to test the environmental controls on $\delta^{11}\text{B}$ and B/Ca ratios in foraminiferal shells.

[*Project Leader and Author: Michael Henehan, PI: Gavin Foster*]

2011: Awarded **UK-IODP Student Bursary (€1,000)** to attend the ECORD Urbino Summer School in Palaeoclimatology.

2008: Awarded a **Nuffield Foundation Student Research Bursary (£1,400)** bursary for a summer research project in palaeoceanography at the University of Bristol using IODP sediment core material.

2007: Awarded a **BMSS-funded studentship** to undertake carbon and oxygen isotope analysis of soil and biological samples via GC-IRMS at IGER (now [North Wyke Research](#)).

Research Publications

Martínez-Botí, Miguel. -A., Marino, Gianluca, Foster, Gavin L., Ziveri, Patrizia, **Henehan, Michael J.**, Mortyn, P. Graham, and Vance, Derek, **2015.** *The role of the ocean in deglacial atmospheric CO₂ rise.* Nature, 518 (7538) 219-222. [Journal Impact factor: 36.280, 14 citations to date]

Henehan, Michael J., Foster, Gavin L., Rae, James W.B., Bostock, Helen C., Marshall, Brittney J., Erez, Jonathan, Kucera, Michal, and Wilson, Paul A., **2015** *Evaluating the utility of B/Ca ratios in planktic foraminifera as a proxy for the carbonate system: A case study of Globigerinoides ruber.* Geochemistry, Geophysics, Geosystems 16 (4), 1052-1069. [Journal Impact factor: 3.054, 2 citations to date]

Marshall, Brittney J., Thunell, Robert C., Spero, Howard J. **Henehan, Michael J.** and Astor, Yrene. **2015.** *Morphometric and stable isotopic differentiation in Orbulina universa morphotypes from the Cariaco Basin, Venezuela.* Marine Micropalaeontology 120, 46-64. [Journal Impact factor: 2.582]

Henehan, Michael J., Rae, James W.B., Foster, Gavin L., Erez, Jonathan, Prentice, Katherine C., Kucera, Michal, Bostock, Helen C., Martínez-Botí, Miguel A., Milton, J. Andy, Wilson, Paul A., Marshall, Brittney J. and Elliott, Tim. **2013.** *Calibration of the boron*

isotope proxy in the planktonic foraminifera *Globigerinoides ruber* for use in palaeo-CO₂ reconstruction. Earth and Planetary Science Letters, 364, 111-122. [Journal Impact factor: 4.636, 38 citations to date]

Marshall, Brittney J., Thunell, Robert C., **Henehan, Michael J.**, Astor, Yrene and Wejnert, Katherine E. **2013**. *Planktonic foraminiferal area density as a proxy for carbonate ion concentration: A calibration study using the Cariaco Basin Ocean Time Series*. Paleooceanography, 28 (2), 363-376. [Journal Impact factor: 3.296, 6 citations to date]

Selected Publications in Review/Preparation

Evans, David, Wade, Bridget S., **Henehan, Michael J.**, Erez, Jonathan and Müller, Wolfgang. **2015**. *Revisiting carbonate chemistry controls on planktic foraminifera Mg/Ca: Implications for sea surface temperature and hydrology shifts over the Paleocene-Eocene Thermal Maximum and Eocene-Oligocene Transition*. Climates of the Past Discussions, 11, 1- 43. [Journal Impact factor: 3.482]

Henehan, Michael J., Hull, Pincelli M., Penman, Donald E., Rae, James W. B and Schmidt, Daniela N. (in review, Philosophical Transactions of the Royal Society B) *Biogeochemical Significance of Pelagic Ecosystem Function: An end-Cretaceous Case Study*. [Journal Impact factor: 11.668]

Wang, Xiangli, Planavsky, Noah J., Hull, Pincelli M., Tripathi, Aradhna, Zou, Huijuan, Elder, Leanne and **Henehan, Michael J.** (in review, Geobiology) *Assessing the utility of foraminifera as an archive of seawater $\delta^{33}\text{Cr}$* . [Journal Impact factor: 4.111]

Henehan, Michael J., Foster, Gavin L., Bostock, Helen C., Greenop, Rosanna, Marshall, Brittney J., and Wilson, Paul A., (in prep.) *A new boron isotope-pH calibration for *Orbulina universa*, with implications for understanding and accounting for 'vital effects'*. (intended submission EPSL, within two weeks) [Journal Impact factor: 4.636]

Henehan, Michael J., Klein-Gebbinck, Christa, Foster, Gavin L., Clymans, Jill, and Kim, Sang-Tae (in prep.) *A demonstration of the pH-dependence of boron isotope composition in inorganically precipitated aragonite*. (intended submission to Geochimica et Cosmochimica Acta, Spring 2016) [Journal Impact factor: 4.414]

Hull, Pincelli M., Bornemann, André, Norris, Richard D., Wilson, Paul A., Blum, Peter, with **Henehan, Michael J.** and 15 others. (in prep.) *Disentangling Impact and Volcanism in Marine Extinctions across the Cretaceous-Paleogene Boundary*. (intended submission to Science, Winter/Spring 2016) [Journal Impact factor: 31.48]

Henehan, Michael J., Edgar, Kirsty M., Foster, Gavin L., Bohaty, Steve M., and Pearson, Paul N. (in prep.) *Solving the Middle Eocene Carbon Cycle Conundrum*. (intended submission to Nature Geoscience, Spring 2016) [Journal Impact factor: 11.668]

Recent Conference Abstracts

Henehan, M. J., Hull, P. M., Planavsky, N. J., Thomas, E., and Özen, V. **2015**. *Between a Rock and a Hard Place: The History of Palaeocene Ocean pH*. Goldschmidt, Prague (talk).

Henehan, M. J., Klein-Gebbinck, C., Foster, G. L., Clymans, J., and Kim, S.-T. **2015**. *Spreading the good news: corroborating the inorganic basis of the boron isotope-pH proxy*. Boron Geochemistry Meeting, Goldschmidt, Prague (talk).

Pearce, C., Foster, G. L., Sexton, P., **Henehan, M. J.**, Edgar, K. M. and Parkinson, I. **2015**. *Searching for Silicate Weathering Feedback in the Geological Record*. Goldschmidt, Prague (talk).

Henehan, M. J., Hull, P. M., Planavsky, N. J., Huber, B. and Thomas, E. **2014**. *Investigating Carbonate System Perturbations across the Cretaceous-Palaeogene Transition using Boron Isotopes in Planktonic Foraminifera*. AGU Fall Meeting, San Francisco, Abstract PP51B-1122 (poster, session convenor).

Mikenas, M., Hull, P. M., and **Henehan, M. J.** **2014**. *Morphological Analysis of Cretaceous-Paleogene Boundary Foraminiferal Taxa*. AGU Fall Meeting, San Francisco, Abstract PP51B-1131 (poster).

Henehan, M. J., Edgar, K. M., Foster, G. L., and Hull, P. M. **2014**. *Using boron isotopes to characterise past carbon cycle perturbations: the case of the MECO*. Climatic and Biotic Events of the Palaeogene, Pesarra (talk).

Klein-Gebbinck, C., Kim, S.-T. **Henehan, M. J.**, and Foster, G. L. **2013**. *Investigation of boron, carbon and oxygen stable isotope systematics in the aragonite-CO₂-H₂O system*. Goldschmidt Conference in Geochemistry, Florence (talk).

Martínez-Botí, M. A., Marino, G., Foster, G. L., Ziveri, P., **Henehan, M. J.**, Mortyn, P. G., Vance, D. **2013**. *Surface ocean $\delta^{11}\text{B}$ -pH*

reconstructions and insights into the ocean-atmosphere carbon exchange during the last deglaciation. Goldschmidt Conference in Geochemistry, Florence (talk).

Henehan, M. J., Foster, G. L., Erez, J., Bostock, H. C., Rae, J. W., Kucera, M., Martínez-Botí, M. A., Prentice, K. C., Marshall, B. J., Wilson, P. A., Elliott, T. R. **2012**. *Symbiont-host relationships in foraminifera and their importance for palaeo-CO₂ reconstruction: Insights from boron isotopes*. AGU Fall Meeting, San Francisco, Abstract B14B-05 (talk).

Marshall, B. J., Thunell, R., **Henehan, M. J.**, McConnell, M. C., Astor, Y. **2012**. *Planktonic foraminiferal shell weight and boron isotopic composition as proxies for carbonate system parameters: Insight from sediment trap studies in the Cariaco Basin, Venezuela*. AGU Fall Meeting, San Francisco, Abstract OS53C-1983 (poster).

Henehan, M. J., Foster, G. L., Rae, J. W. B., Ries, J., Erez, J., Bostock, H. C., Kucera, M., Castillo, K. D., Martínez-Botí, M. A. **2012**. *Insights on biomineralisation and the nature of 'vital effects' using Boron isotopes*. Goldschmidt Conference in Geochemistry, Montreal (talk).

Henehan, M. J., Foster, G. L., Rae, J. W. B., Erez, J., Wilson, P. A. and Kucera, M. **2011**. *Calibrating the Boron Isotope pH-Proxy in *Globigerinoides ruber* by MC-ICPMS*. Goldschmidt Conference in Geochemistry, Prague (talk).

Guest Speaker: Lamont-Doherty Earth Observatory, Yale University, University of Tübingen, NIWA, Cardiff University, University of Oviedo, and the Interuniversity Institute of Eilat.

Research Experience

Post-Doctoral Research Associate, Yale University

April 2014-Present (PI: Dr. Pincelli Hull)

Currently nearing the end of a 2-year post-doc at Yale, investigating carbon cycle perturbations around the Cretaceous-Palaeogene boundary. I have successfully set up the infrastructure, procedures and protocols required to generate boron isotope data via MC-ICPMS at Yale, and started producing records of $\delta^{11}\text{B}$ in fossil planktic foraminifera. A low-resolution Palaeocene pCO₂ record is almost complete, and was the subject of one of my two presentations at last year's Goldschmidt Conference in Prague (the other on validating the inorganic basis of the boron isotope proxy). Prior to this project's conclusion, we will extend our initial analyses in the latest Maastrichtian. These investigations extend our record of atmospheric CO₂ levels (as derived from boron isotopes) into the Mesozoic, and will be a crucial resource in understanding late Cretaceous climate, recovery from the Chicxulub impact, and the drivers of long-term warming in the Palaeocene. Data from this project are yielding new insights into 'vital effects' in extinct foraminiferal species, and their importance in interpreting records of $\delta^{11}\text{B}$.

Post-Doctoral Research Associate, University of Southampton

August 2013 - February 2014 (PI: Dr. Gavin Foster)

Undertook a 6-month post-doc as part of the 'Abrupt Ocean Acidification Events' project (under the NERC/DECC/DEFRA Ocean Acidification programme), working with Prof. Gavin Foster (University of Southampton, CO-I), Dr. Kirsty Edgar (Cardiff University, PDRA), and Professor Paul Pearson (Cardiff University, PI). During this time, I led a foraminiferal culturing expedition to Eilat, Israel under the EU FP7 ASSEMBLE program, and generated boron isotope and trace elements proxy records (generated via MC-ICPMS and ICPMS) over the enigmatic MECO (Middle-Eocene Climatic Optimum) event, to elucidate the role of atmospheric pCO₂ in driving this event and the strength of earth system feedbacks in prompting recovery. This work will provide a new record of atmospheric CO₂ levels and ocean temperature during the MECO, incorporating robust quantification of uncertainty.

Community Contributions

- Reviewer for *Science*, *Geology*, *Nature Scientific Reports*, *Chemical Geology*, *Geophysical Research Letters*, *Marine Micropalaeontology*, *Earth and Planetary Science Letters*, *Mass Spectrometry Reviews*, *Palaeo*.
- Co-convened a session at AGU in 2014 titled *Global Climate Events and Ocean Chemistry of the Palaeogene and K-Pg Transition*.

Professional/Academic Development

Courses attended:

- 2013 *Storytelling in Science* (University of Southampton).
- 2012 *Communicating Climate Change* (Union of Concerned Scientists, San Francisco).
- 2012 *NERC Life and the Planet Spring School* (NERC, Southampton).
- 2012 *Nuts and Bolts of Mass Spectrometry Short Course* (EAG, Bristol University).

- 2011 *ECORD Urbino Summer School in Palaeoclimatology* (ECORD/NSF, University of Urbino).
 2011 *Media Handling Skills* (University of Southampton).
 2010 *Postgraduate Introduction to Learning and Teaching* (University of Southampton).
 2010 *Skills for Postgraduate Researchers* (University of Southampton).

Professional Affiliations:

The Micropalaeontological Society, The Cushman Foundation, American Geophysical Union,
 European Association of Geochemists.

Teaching and Outreach

Yale University

2014- present

Lectured on Greenhouse and Icehouse Climates, and their relevance to macroevolutionary history, as part of the undergraduate 'History of Life' course. Also lectured on the boron isotope proxy as part of the graduate level 'Paleoenvironments' course. Co-teaching in graduate level course *Advanced Critiques of Paleooceanographic Methodologies*, Autumn 2015.

Bestival Science Tent and Bestiversity

2011-2013

At *Bestival* Music Festival (Isle of Wight, UK) I lectured to festival-goers on the science behind climate change, co-ordinated and staffed the National Oceanography Centre's interactive exhibits in the Science tent. The science tent also exhibits at other festivals in the UK, including Glastonbury Music Festival (attendance 180,000).

Teaching Assistant, University of Southampton

2010-2012

Geochemistry (Level 2), Maths (Level 1), Palaeobiology, including 2 field trips (Level 2).

IUI Eilat

2010

Taught Planktic Foraminifera as a guest lecturer, as part of the *Plankton Ecology* course.

Outreach: Delivered many talks to diverse public audiences on climate science, including:

The Science Café (Southampton, UK), the *Marine Life* public lecture series (Southampton, UK), *Headford Environment Group* (Galway, Ireland), the *Eco-Schools Initiative* (Southampton, UK), a *Curriculum-building workshop for Teachers* (Yale, USA) and the *Countryside Education Trust* (Beaulieu, UK). I am also a registered participant in the Climate Voices initiative (climatevoices.org).

Student Mentoring

At the University of Southampton, I supervised a Masters student (*Joe Durrant*) on a project investigating the drivers of foraminiferal shell weight. Here at Yale, I am co-supervising four independent research projects involving undergraduates and graduate students: investigating foraminiferal shell weight (*Madison Shankle*, culminating in a manuscript in prep.), foraminiferal diversity and disparity in the run up to the Cretaceous-Palaeogene Boundary (*Megan Mikenas*, culminating in a poster at last year's AGU), and applying paired Li and B isotope measurements (*Rain Tsong*, to feed into his undergraduate dissertation). Supervising graduate student Shuang Zhang in applying boron isotopes to natural precipitates of inorganic CaCO₃ and to foraminifera over the MECO.

Other Research Skills

- Skilled in culturing marine organisms (foraminifera) under controlled laboratory conditions.
- Experienced operator of ICPMS machines, including quadropole, sector field and multicollector ICPMS.
- Skilled geochemical clean lab operator and co-ordinator, incl. trace element cleaning and ion exchange column chemistry.
- Expertise in statistical methods, including uncertainty propagation and multivariate analysis (using R and Matlab).
- Experienced user of scanning electron and light microscopes and image analysis software.
- Taxonomic expertise in identification of a range of planktic and benthic foraminifera from the Cretaceous to the present.
- Experience in undertaking shipboard research, using MOCNESS plankton sampling nets and piston coring apparatus.
- Expertise in aqueous carbonate chemistry and the use of MyAMI, PHREEQC, CO2sys, CO2calc, and Seacarb.

References available on request