Application for the Steve Farrell Memorial Fund

The impact of the Palaeocene-Eocene Thermal Maximum (PETM) in the deep seas: An integrated ichnological, stratigraphical and geochemical approach

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Introduction

The early Palaeogene climate was punctuated by a number of hyperthermal events, the most prominent being the Palaeocene-Eocene Thermal Maximum (PETM). This rapid episode of global warming lasted at least 100 kyr (Zachos et al. 2005), and saw sea surface temperatures increase by up to 5°C at low latitudes and by as much as 9°C at high latitudes (Kennett & Stott 1991; Zachos *et al.* 2005). The event had major effects on oceanic circulation patterns (Tripati & Elderfeld 2005), terrigenous sediment supply to the oceans (Barlower *et al.* 1997) and led to rapid shoaling of the calcite compensation depth by more than 2km (Zachos *et al.* 2005). Biotic effects of the PETM include the largest extinction of benthic foraminifera in the entire Cenozoic with as many as 50% of all taxa becoming extinct (Alegret *et al.* 2009), latitudinal migration of plants (Wing *et al.* 2003) and dispersal and diversification of land mammals (Clyde & Gingerich 1998). The dominant hypothesis regarding elevated temperatures during the PETM, and the associated elevated SSTs and benthic ocean temperatures is a catastrophic release of 1400 – 2800gt of methane stored in ocean clathrates into the atmosphere (Dickens *et al.* 1997). The PETM was therefore an episode of global warming that resulted from rapid input of a greenhouse gas (GHG) into the atmosphere and as such provides a valuable analogue in predicting future anthropogenic global warming consequences.

Key research questions:

The PETM is an intensively researched topic in terms of climatic and oceanographic change, but little effort has been made to assess the response of Earth surface processes and marine benthic macrofauna to this episode of global warming. My PhD research utilises a multidisciplinary approach (ichnology, stratigraphy and geochemistry) to investigate how Earth surface processes are linked to the deep marine realm during times of climatic extremes. There are a number of reasons why this is important:

1.) Contrary to the benthic extinction event experienced by microfauna, benthic macrofauna communities represented by trace fossil assemblages actually experience the highest diversity throughout the whole of the Phanerozoic during the earliest Eocene (Uchman 2004). *Is this due to increased terriginous nutrient/food supply?*

2.) Little attempt has been made to discriminate between tectonic and climatic drivers of sediment supply to the oceans during the PETM. *Can increased runoff/erosion be detected in clay mineralogical changes?*

3.) An abrupt increase in kaolinite in the clay fraction of PETM deposits has been reported from almost all studied global sites and is considered to be a diagnostic geochemical feature of the PETM. Kaolinite generally forms in warm, humid environments. Terrestrial deposits located near to the main study area of this project (Basque country, northern Spain) display caliche soils (indicative of semi-arid conditions) and palynological evidence suggests the collapse of perennial vegetation cover (Schmitz *et al.* 2001). Again, this is not consistent with a warm, humid climate. *Is the reported increase in kaolinite the result of erosion of older kaolinite rich successions?*

Progress to date: Field work

Two field seasons have been completed in the Basque country, northern Spain, spanning 10 different localities providing a basin scale analysis. The localities studied provide a variety of siliciclastic and mixed siliciclastic-carbonate deep marine environments and are mid Palaeocene- early Eocene in age. These deposits contain some of the richest, and best preserved trace fossil assemblages in the world and as such, the area provides an ideal natural laboratory for a detailed ichnological analysis. The Zumaia, Ermua and Trabakua Pass sections have all been previously investigated and the PETM interval is well constrained and easily identifiable. These localities provided excellent opportunities for clay mineralogy sampling. The following datasets have been generated from the two field seasons:

- Detailed sedimentary logs from over 800m of stratigraphy have been constructed.
- c.1000 bedding planes have detailed ichnological data (taxa level identification, abundance and diversity).
- >200 physical samples have been taken for clay mineralogical analysis using X-Ray Diffraction (XRD) and Fourier Transform Infra-Red spectroscopy FT-IR.
- More than 500 Spectral Gamma Ray (SGR) readings have been recorded at outcrop. This is to supplement palaeoclimate data inferred from clay mineralogical analysis.

Core investigation (ODP Leg174ax):

Cores obtained from Bass River, Ancora, Sea Girt and Millville (ODP leg174ax – onshore New Jersey) all include the Palaeocene-Eocene boundary and the PETM interval.
Bioturbation has been reported in these cores (Miller *et al.* 1999) but no attempt has been made to quantify either the type or intensity and diversity of the bioturbation. Cores have been re-investigated (01/2010) to assess the following:

- To discriminate between climatic and tectonic controls on changes to rates of sediment supply during periods of global warming and high sea-level during the earliest Eocene through the analysis of clay mineralogy changes on both sides of the Atlantic.
- To examine the response of benthic macrofauna to increases in ocean bottom temperature, nutrient availability and oxygenation through quantitative analysis of ichnotaxa diversification and dispersal, and bioturbation intensity during the earliest Eocene. The New Jersey core dataset provides controls across the Atlantic Ocean.
- To test published models of ichnofacies (trace fossil assemblages defined by bathymetry and depositional environment) during periods of climatic extremes when the depth and range of benthic macrofauna habitats changed.
- To critically evaluate ichnological analysis at outcrop versus core.

Justification for Farrell Fund request:

The upcoming EGU conference in Vienna is hosting a session entitled **'Cenozoic and Mesozoic climate: forcing factors and feedbacks between biosphere and geosphere'**. I feel that my research can provide a fresh, original perspective on this topic. I am particularly excited at presenting data recently obtained from ODP leg 174ax cores as nobody has yet investigated these cores from an ichnological perspective. The opportunity to present my research to my peers (including many prominent scientists in this subject area) would not only greatly enhance my own personal development but will hopefully provide me with some valuable feedback that may generate some fresh ideas as I approach the concluding stages of my research. I will present these data and revised findings after talking to the leading researchers in the field, at BSRG 2010, which will be my third BSRG presentation.

Budget

Flights: Manchester – Vienna (return) with Lufthansa	£160
4 nights accommodation in budget hotel	£160
Subsistence for 5 days	£100
Total:	**£420**
Amount requested from Steve Farrell Memorial Fund:	**£300**

Remainder: Balance of this amount will be paid via my NERC conference allowance. This allowance is budgeted to allow me to partake in at least one international conference. However, I feel that I need to attend an international conference directly linked to ichnology for my own personal development and for networking purposes. Therefore, the EGU meeting is beyond the scope of my original NERC budget but I feel the opportunity to present in such a relevant session is too good an opportunity to miss. Therefore, I respectfully request assistance from the Steve Farrell Memorial Fund.

References

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Education

PhD University of Liverpool (NERC funded) Commenced 10/2007 (year 3)
The impact of the Palaeocene-Eocene Thermal Maximum (PETM) in the deep seas: An integrated ichnological, geochemical and stratigraphical approach.
Supervisors: D.M. Hodgson, C.H. Jeffery-Abt, R.H. Worden.
This project investigates the impact that the PETM hyperthermal event had on deep sea benthic communities by analysing ichnological (trace fossil) changes in diversity and abundance across the Palaeocene-Eocene boundary on a basin scale, in the Basque Country, Northern Spain. Ichnological data is correlated with palaeoclimatic information obtained from geochemical analysis including clay mineralogy (using XRD and FT-IR) and ^{13}C and ^{18}O isotopes (using MS). The project will also utilise a core data set that has been made available from onshore New Jersey. This will provide palaeoclimate and ichnological data from the West Atlantic margin during the PETM.
Additional training: Applied Ichnology short course (Run by S. George Pemberton, BGS Core Store, Edinburgh 10/2009). Applications of Ichnology to Hydrocarbon industry student course (run by S. George Pemberton, Royal School of Mines, Imperial College, London 04/2008).
Awards: IAS PGS scheme award (€1000)
BSc Geography. School of Geography, University of Leeds, LS2 9JT
09/2003 – 06/2006 (2:1)
This degree course equipped me with a solid grounding in Quaternary Palaeoecology and Palaeoclimatology as well as providing an introduction to a variety of laboratory techniques later utilised in a professional and educational capacity.
Dissertation: *Evaluating the climatic impact of the UK Government's proposed 500% increase in Aviation by 2030.*
Other independent research: *The Eocene-Oligocene greenhouse-icehouse transition.*

Employment

RSK Group (Envirolab). Sandpitts Business Park, Mottram Road, Hyde (06/2006- 10/2007)
Analytical Chemist-Shift Supervisor (06/2007-10/2007)
This role required the supervision of between 3-8 analytical chemists carrying out duties as described below. The role placed more of an emphasis on providing client reports and ensuring client schedules were met whilst monitoring staff performance/productivity. The role also enabled greater participation in new method development.
Analytical Chemist (06/2006-05/2007)
Analysing soil and water samples sourced from contaminated (remediation) sites. Main analysis suites were targeting petroleum hydrocarbons using GC FID and GC MSD technology. Data analysis formed a key part of the role along with the production of client reports. The role required prioritisation of workloads to ensure instrument optimisation. Basic instrument maintenance/calibration was also an important part of the role. UKAS, MCERTS and ISO9001 accredited.