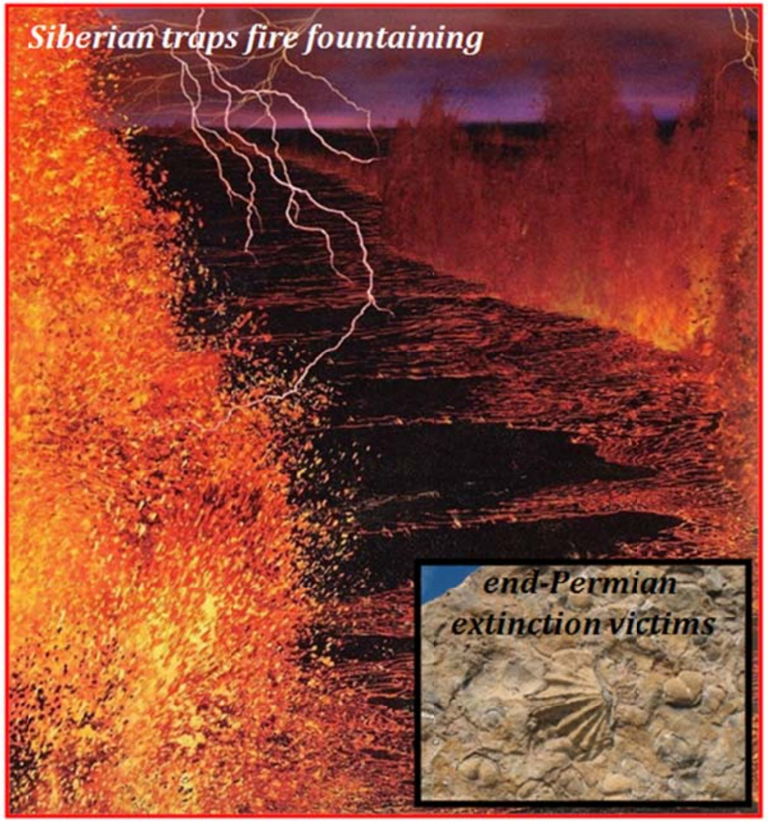
UNIVERSITY OF LIVERPOOL

Earth Sciences

HERDMAN SYMPOSIUM

Saturday 16th February 2013

GEOSCIENCE FRONTIERS 4



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GEOSCIENCE FRONTIERS 4
HERDMAN SYMPOSIUM PROGRAMME
Saturday February 16th 2013

9.30 Arrival at Sherrington Lecture Theatre complex, University of Liverpool

10.00 **Welcome**: Richard Evans (Herdman Society President), Emma Mailey (Herdman Symposium Secretary) and Pete Kokelaar (George Herdman Professor of Geology)

10.05 **Impact: Earth! The hazard and mitigation of asteroid impacts**
Dr Gareth Collins, Department of Earth Science and Engineering, Imperial College, London

11.00 *Coffee Break*

11.10 **Dinosaur evolution and Mesozoic faunas as a guide to biodiversity**
Dr Roger Benson, Department of Earth Sciences, University of Oxford

12.05 **The end-Permian mass extinction and its aftermath: out of the frying pan and into the fire**
Professor Paul Wignall, School of Earth and Environment, University of Leeds

1.00 *Buffet Lunch*

1.45 **Nuclear waste: Geology has a better answer**
Professor Fergus Gibb, Department of Materials Science and Engineering, University of Sheffield

2.40 **The Mediterranean: *Mare Nostrum* of Earth Sciences**
Professor Cor Langereis, Paleomagnetic Laboratory Fort Hoofddijk, Department of Earth Sciences, Utrecht University, The Netherlands

3.35 *Short Break*

3.45 **Bubble, bang, burp! Big experiments in volcano physics**
Dr Ed Llewellin, Department of Earth Sciences, University of Durham

4.40 **Closing remarks** Professor Pete Kokelaar

5.00 Wine Reception

Venue: Sherrington Lecture Theatre, Number 311 on campus map, see:
http://www.liv.ac.uk/files/docs/maps/liverpool-university-campus-map.pdf

Impact: Earth! The hazard and mitigation of asteroid impacts

Dr Gareth Collins, Department of Earth Science and Engineering, Imperial College, London

The impact of an asteroid or comet with Earth is the ultimate low-probability, high-consequence natural hazard. As well as forming a large crater, the violent collision of a km-scale asteroid or comet with Earth causes the global dispersal and re-entry of debris, thermal radiation from the impact vapour plume and re-entering debris, an atmospheric blast wave, earthquakes and, in the case of oceanic impact, tsunamis. In particular, the global distribution of dust, vapour and impact-generated aerosols can inhibit photosynthesis and cause major perturbations in the climate.

Considering these catastrophic consequences, it is fortunate that large impacts are rare compared to volcanic eruptions, floods, earthquakes and other more conventional hazards. Only 2-3 impacts capable of causing global environmental effects strike Earth every million years, and only one impact, Chicxulub, has so far been conclusively linked to a major mass extinction event - the K/Pg or Cretaceous/Paleogene event.

How humanity should respond to the impact hazard is a difficult question, as we must balance an extreme threat against a very small risk. In addition, a unique feature of the impact hazard is that a major event can potentially be predicted in advance (by tracking Earth-crossing asteroids) and mitigated, using a variety of asteroid deflection techniques.

In my talk, I will review what we know about the hazard of asteroid impacts on Earth and discuss the efficacy of methods for deflecting hazardous Earth-bound asteroids or comets.

Short biography: *Gareth Collins is a Senior Lecturer in the Department of Earth Science and Engineering at Imperial College London. He graduated from the University of Liverpool in 1998 with a BSc in Geophysics and has a PhD from Imperial College London. His research interests cover all aspects of impact cratering and other violent geological processes such as large rock avalanches and tsunamis. To study these processes and their effects on the Earth and solar system, he develops numerical models. A particular focus has been simulating the Chicxulub impact, to understand the formation of the crater and the ensuing catastrophic environmental effects. He has been instrumental in developing the 'Impact Earth!' website, which estimates the environmental consequences of meteorite impacts for user-input parameters.*

Dinosaur evolution and Mesozoic faunas as a guide to biodiversity

Dr Roger Benson, Department of Earth Sciences,
University of Oxford

Mesozoic faunas saw the origination of many modern tetrapod groups, including turtles, snakes, birds and crown-group (‘living today’) mammals. However, those faunas were dominated by groups that are not familiar to us today, such as dinosaurs and pterosaurs (flying reptiles) on land and marine reptiles in the oceans.

Palaeontologists are developing an understanding of the biology of these organisms, revealing fundamental biological differences between these groups and the modern fauna. Given these distinctions, it is natural to ask whether fundamental macroecological principles governing the distribution of organisms in today's planetary ecosystem can be extrapolated back in deep time.

Understanding the accumulation of biodiversity through extended time intervals is a fundamental goal of palaeontology. However, our ability to address macroevolutionary questions like these is impeded by highly uneven fossil record sampling, both in space and in time. Vertebrate fossil discoveries proceed at an unprecedented rate and sample sizes are beginning to exceed those required for a rational assessment of sampling bias and its impact on our understanding of Mesozoic diversity. Results suggest that dinosaur diversity was highest at temperate latitudes (not in the tropics, as it is for present-day animals), biodiversity of many clades was fairly constant through the course of the Mesozoic, and the evolution of body plans adapted for open ocean life allowed marine reptiles to 'escape' from periodic extinctions afflicting the shallow marine biota driven by regression events.

Short biography: *Roger Benson is a vertebrate palaeontologist interested in tetrapod phylogeny, the properties of morphological evolution, and interactions between ancient biodiversity, rock deposition, and Earth's physical history. He is a lecturer in Earth Sciences at the University of Oxford since October 2012, having studied as a postgraduate and research fellow at Cambridge University and Imperial College.*

The end-Permian mass extinction and its aftermath: out of the frying pan and into the fire

Professor Paul Wignall, School of Earth and Environment,
University of Leeds

The end-Permian mass extinction was the greatest crisis in the history of life and it was followed by a 5 million year interval of exceptionally low global diversity. Both the cause of the extinction and the prolonged failure of recovery are the topics of intense current debate. Over 20 years ago it was realised that the extinction coincided with the eruption of the vast lava province known as the Siberian Traps. Relating these eruptions to extinction is not straight forward, but likely involved the harmful effects of voluminous gas emissions, notably carbon dioxide, sulphur dioxide and halogens. The prolonged aftermath of the extinction has recently been shown to coincide with a phase of intense global warming that reached a point where equatorial seawater temperatures were becoming lethally hot for many animals. Only the higher polar latitudes provided a respite from these unparalleled conditions.

Short biography: *Paul Wignall has been investigating mass extinctions for 25 years and has travelled the world to see many of the most important Permian/Triassic boundary locations. He is especially interested in the frequent link between volcanism and extinctions and how these links are manifest in the sedimentary record. He has published over 150 papers and two books, mostly on extinctions although he also maintains an interest in the origin of petroleum source rocks.*

Nuclear waste: Geology has a better answer

Professor Fergus Gibb, Department of Materials Science and Engineering, University of Sheffield

The future of nuclear power, with all its implications, depends on finding a solution to the waste problem. At the same time, many industrialised nations have a legacy of nuclear wastes for which a ‘final solution’ is becoming increasingly urgent. After a brief introduction to radioactive wastes and their sources, this talk will focus on the most problematic materials, such as high-level wastes from spent fuel reprocessing and spent fuels themselves. Most countries, including the UK, are looking to geological disposal in a mined and engineered repository at geologically shallow depths as the answer and some of these proposals will be reviewed briefly. However, the fact remains that, over 70 years after such wastes were first created, there is no repository for HLW or spent fuel operating anywhere in the world. Clearly, mined repositories have their technical (as well as political) problems and a better option that relies more on the geology and places less emphasis on engineered barriers is proposed – deep borehole disposal (DBD) at depths of several kilometres in the continental crust.

Following an outline of the principles of DBD, its advantages and disadvantages will be discussed and the former shown to far outweigh the latter in terms of safety, security, cost effectiveness, environmental impact, etc. Different variants of DBD developed for different types of high-level radioactive wastes and nuclear materials will be described and their workings illustrated and explained. Which variant would be employed depends not only on the type of material to be disposed of but also on its heat generating capacity. This necessitates sophisticated and accurate prediction of the evolution of temperatures in and around the waste packages in the borehole through numerical modelling of heat flow. This modelling will be explained and the results of its applications to the DBD of spent fuels, both UO_2 and mixed oxide (MOX), described and discussed. It will be shown that the outcomes of the thermal modelling demonstrate not only that the different variants of DBD are scientifically and technically viable, but that they can be used to manage and control the disposal strategy for a wide range of heat-generating radioactive wastes.

The talk will conclude by considering the question: “If DBD is so much better than other forms of geological disposal, why are countries with high-level wastes not planning to implement it?” Setting aside the relative newness of the technology, this will be addressed by discussing the history and current position of DBD in the UK and other countries.

Short biography: *Fergus Gibb is Emeritus Professor of Petrology and Geochemistry in the Department of Materials Science and Engineering at the University of Sheffield. A geology graduate from the University of St Andrews, he held staff positions at the Universities of Toronto and Manchester before moving to Sheffield. An authority on igneous intrusions, notably basic sills, he is a former vice-president of The Mineralogical Society of Great Britain and Ireland and an elected fellow of the Mineralogical Society of America. His research into geological disposal of nuclear wastes, especially the use of deep boreholes, has been funded by BNFL, the NDA and the EPSRC. In 2007 he was appointed to the Government´s advisory Committee on Radioactive Waste Management (CoRWM).*

The Mediterranean: *Mare Nostrum* of Earth Sciences

Professor Cor Langereis, Paleomagnetic Laboratory Fort Hoofddijk, Department of Earth Sciences, Utrecht University, The Netherlands

The Romans considered the Mediterranean Sea as *Mare Nostrum*, 'our sea'. Little did they know that 'their' sea is one of the most appealing natural laboratories in the world to study all kinds of geodynamic processes. It is one of the most tectonically active regions in the world, wedged in the collision zone between Africa and Europe. In addition, because of its semi-enclosed, land-locked position it is very sensitive to climatic and environmental changes, which are recorded in the geological archive with unprecedented detail. These climatic archives have formed the basis of constructing accurate astrochronological time scales that now form the standard in geological time for the past 23 Myr.

Consequently, the Mediterranean Sea can be considered as the *Mare Nostrum* of Earth sciences, and there still remain many intriguing research questions. For example, what were the connections of the Mediterranean with the *Paratethys Sea* to the east, an ancient sea of which now remains only the Black Sea, Caspian Sea and Aral Lake, but which once extended to China. And what happened to the Mediterranean when it was completely cut off from the Atlantic, some 6 million years ago, causing kilometres of salt and gypsum to be deposited on the sea floor?

For many years to come, the Mediterranean will remain a fascinating area, since there are certainly still many enigmas in its history waiting to be solved.

Short biography: *Cor Langereis is the Head of the Paleomagnetic Laboratory Fort Hoofddijk of the Department of Sciences, Utrecht University (The Netherlands). His research interests cover nearly all fields of paleomagnetism, but in particular the acquisition of reliable and detailed records of the geomagnetic field at all time scales, which serves to understand the past magnetic field of our planet Earth. This work includes secular variation studies – from recent periods (archaeomagnetism), during periods when the field did not reverse (superchrons), and also properties of the earliest field billions of years.*

An important expertise of the research group is building high resolution and accurate time scales, using magnetostratigraphy and astrochronology (cyclostratigraphy), based on correlation to astronomical solutions of past changes in the Earth’s orbit and rotation. Another key interest concerns geodynamic/tectonic studies, at different spatial and temporal scales and on several continents, but with an emphasis on the Alpine-Himalayan mountain belt. This includes the Mediterranean area as one of the most active tectonic regions in the world.

Bubble, bang, burp! Big experiments in volcano physics

Dr Ed Llewellin, Department of Earth Sciences,
University of Durham

Volcanic eruptions are spectacular, fascinating and diverse. Some produce explosions that blast many cubic kilometres of rock into the stratosphere and cause regional devastation. Others produce fountains and rivers of lava that create a dramatic natural tourist attraction. Many do no more than quietly release gas into the atmosphere. Despite this diversity of eruptive style, all volcanic eruptions are driven by the same fundamental mechanism - the formation and growth of bubbles of magmatic gas. So why do some volcanoes explode violently, whilst others bubble quietly?

Answering this question is one of the key goals of physical volcanology. In this talk I will present results from the world's largest volcano experiment, and show how laboratory experiments at a range of scales combine with fieldwork and numerical modelling to help us to understand the fascinating physics of volcanic eruptions.

WARNING: talk will include live volcanic eruption.

Short biography: *Ed Llewellin gained his PhD from the University of Bristol in 2002, on "The rheology of bubble-bearing magma". He continued research with NERC Fellowships at Bristol 2002-2005 and at Cambridge 2005-2007. Since 2007 he has been Lecturer and then Senior Lecturer in Volcanology at Durham. His main research contributions concern hot, sticky and frothy stuff – politely, the rheology of multiphase magma – and linking macro-scale volcanic eruptive behaviour to the physical processes that occur at the micro-scale in the magma. He has also been seen on TV fiddling with an extremely large cylinder and looking anxious…*