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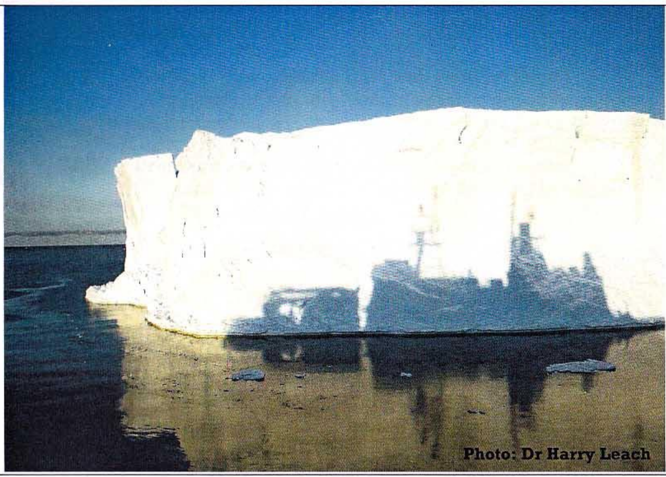
UNIVERSITY OF LIVERPOOL

**Earth and Ocean Sciences Department**

# HERDMAN SYMPOSIUM

## 20th February 2010

# GEOSCIENCE FRONTIERS




**PROGRAMME**

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| **9.30** | Arrival |
| **10.00** | **Welcome**: Ashley Clarke (Herdman Society President) and Rebecca Southworth (Symposium Secretary) |
| **10.05** | **Professor Nick Kusznir, University of Liverpool**<br>'Exploring Arctic Ocean basins and micro-continents'. |
| 11.00 | *Coffee Break* |
| **11.10** | **Professor Jane Francis, University of Leeds**<br>'Fossil forests of Antarctica – Life at the South Pole in a warmer world'. |
| **12.05** | **Professor Tim Druitt, University of Clermont Ferrand**<br>'The Late Bronze Age eruption of Santorini and the demise of the Minoan Civilization'. |
| 1.00 | *Buffet Lunch* |
| **1.45** | **Professor Steve Sparks FRS, University of Bristol**<br>'Assessment of volcanic hazards, risks, vulnerability and uncertainty'. |
| **2.40** | **Professor Ian Stanistreet, University of Liverpool**<br>'Pliocene life and times, environments exploited by earliest man, Olduvai Gorge, Tanzania'. |
| 3.35 | *Short Break* |
| **3.45** | **Professor Trond Torsvik, University of Trondheim**<br>'Mantle dynamics: Linking surface and deep processes'. |
| **4.40** | **Professor Peter Kokelaar, University of Liverpool**<br>Closing remarks. |
| 5.00 | Wine Reception |

## Professor Nick Kusznir (University of Liverpool)

### Exploring Arctic Ocean basins and micro-continents

The ocean basins of the Arctic formed during the Late Jurassic, Cretaceous and Tertiary as a series of small, distinct ocean basins leading to a complex distribution of oceanic crust, thinned continental crust and rifted continental margins. Their exploration is the focus of much current attention motivated by territorial claims, hydrocarbon exploration and climate change. The spatial evolution of Arctic Ocean basin geometry and bathymetry is critical for understanding its palaeo-oceanography and ocean gateway connectivity to the global ocean and hence its influence on global climate. Unfortunately the plate tectonic history of the Arctic, and the Amerasia Basin and Arctic-Pacific gateway in particular, is poorly understood hindering our understanding of Arctic palaeo-oceanography.

Using a new gravity anomaly inversion method that incorporates a lithosphere thermal gravity anomaly correction, we* have produced the first comprehensive maps of crustal thickness and oceanic lithosphere distribution for the Arctic region. We use crustal thickness and continental lithosphere thinning factor maps, determined by gravity inversion to predict the distribution of oceanic lithosphere and ocean-continent transition (OCT) location for the Amerasia and Eurasia Basins. Predicted crustal thickness, OCT location and oceanic lithosphere distribution can be used to test plate tectonic reconstructions of the Amerasia Basin, which may be used to predict palaeo-oceanographic templates, palaeo-bathymetries and Arctic Ocean gateway history.

Our gravity inversion predicts thin crust and high continental lithosphere thinning factors in the Makarov, Podvodnikov, Nautilus and Canada Basins, consistent with these basins being oceanic or highly thinned continental crust. Larger crustal thicknesses, in the range 20 – 30 km, are predicted for the Lomonosov, Alpha and



Mendeleev Ridges. Moho depths predicted by gravity inversion compare well with estimates from the TransArctica-Arctica seismic profiles.

*Co-workers: A. Alvey, N. Lebedeva-Ivanova, C. Gaina & T.H. Torsvik

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Professor of Geophysics, Department of Earth & Ocean Sciences, University of Liverpool (1986 - ). BSc Physics (1972, Durham); PhD Geophysics (1976, Durham). Leader Geodynamics Research Group, University of Liverpool. Bigsby Medallist of the Geological Society of London, 1988; Bullerwell Lecturer of the Royal Astronomical Society Geological Society of London, 1987.

His research aims to develop a quantitative understanding of the geophysical and surface response of the Earth's lithosphere to applied forces, and the resulting deformation. His key scientific contributions include: (i) the prediction of upward stress transfer and amplification within continental and oceanic lithosphere; (ii) the development of the flexural cantilever model of intra-continental rift-basin formation; (iii) the observation of lithosphere depth-dependent stretching at rifted continental margins; (iv) the development and successful testing of new models of continental lithosphere thinning leading to continental break-up and sea-floor spreading initiation; (v) the development of new geophysical techniques for mapping crustal thickness and ocean-continent transition location using satellite gravity inversion, and the production of the first comprehensive crustal thickness maps for the Arctic and Indian Oceans. Achievements (iii) and (iv) featured in the 2006 NERC (UKRC) report to the UK Government.

He has trained and supervised over 50 PhD students to date. He led the Liverpool-Cambridge NERC Ocean Margins iSIMM project (2002-2006) and currently leads the follow-on MM2 consortium project (2006-2010).



## Professor Jane Francis, University of Leeds.

### Fossil forests of Antarctica – Life at the South Pole in a warmer world.

On a continent on which over 99% of the land is now covered with ice sheets, paradoxically some of the most common fossils are those of plants. They indicate that for most of its history Antarctica was a green forested land, even though the continent was situated over the South Pole. The fossils contain a rich store of climate information that provides a window into past greenhouse worlds with ice-free poles.

The evolution of the Antarctic climate from a Cretaceous greenhouse into the Neogene icehouse is captured within a rich record of fossil leaves, wood, pollen and flowers from the Antarctic Peninsula and the Transantarctic Mountains. About 85 million years ago, during the Late Cretaceous, flowering plants thrived in sub-tropical climates in Antarctica. Analysis of their leaves and flowers, many of which were ancestors of plants that live in the tropics today, indicates that summer temperatures averaged 20°C during this global thermal maximum. During the onset of cooler climates in the Palaeocene (~60Ma) warmth-loving plants gradually lost their place in the vegetation and were replaced by floras dominated by araucarian conifers (monkey puzzles) and the southern beech Nothofagus, which tolerated freezing winters. Plants hung on tenaciously in high latitudes, even after ice sheets covered the land, and during periods of interglacial warmth in the Neogene small dwarf plants survived in tundra-like conditions only 500 km from the South Pole.

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Jane Francis is Professor of Palaeoclimatology in the School of Earth and Environment at the University of Leeds. A geologist by training from the University of Southampton (BSc, PhD), she was a NERC



Postdoctoral Research Fellow, University of London and then palaeobotanist at the British Antarctic Survey. She was an Australian Research Fellow at the University of Adelaide in Australia for five years, before taking up a lectureship at the University of Leeds. She became Professor of Palaeoclimatology in 2004, head of the School of Earth and Environment in 2006 and Dean of the Faculty of Environment in 2008.

Her research interests include ancient climates, particularly of the polar regions, the regions on Earth most sensitive to climate change, both now and in the past. She studies fossil plants from the Arctic and Antarctica to decipher greenhouse climates of the past, when forests, not glaciers, covered the high latitudes. The fossils provide a window into a world that may come again if climate warming continues at its present pace.

Jane has undertaken many scientific expeditions to the Arctic and Antarctica in search of fossil forests and ancient climates, in collaboration with research teams from the UK, Europe, New Zealand, USA, Australia and Canada. In addition, she has worked in the hot red deserts of central Australia as part of Australian funded research and in southern Patagonia in collaboration with colleagues from Argentina. She was awarded the Polar Medal in 2002 in recognition of her contribution to British polar research.

## Professor Tim Druitt (Blaise Pascal University, France)

**The Late Bronze Age eruption of Santorini and the demise of the Minoan civilization.**

The explosive eruption of Santorini Volcano, Greece, in the Late Bronze Age (LBA) discharged 40 to 60 cubic km of rhyodacitic magma as pyroclastic flows and associated ash and pumice fallout and caused caldera collapse. It has been speculated that this eruption might have had widespread impacts on LBA societies of the Aegean region, and particularly on the Minoan civilization on Crete, 120 km south of Santorini, which disappeared shortly afterwards. Possible effects of the eruption included ash fallout, tsunamis and transient climate change due to input of large volumes of aerosols into the upper atmosphere. This talk will review what is known about the LBA eruption and its possible effects on the Minoan world, emphasising some recent findings.

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After gaining his PhD at Cambridge in 1984, Tim held postdoctoral positions at the USGS and at Liverpool University, and a lectureship at Cardiff University. Since 1993 he has been Professor at Blaise Pascal University in France, where he heads an active and rapidly growing research group in physical volcanology. He has been executive editor of Bulletin of Volcanology and editor in chief of Journal of Volcanology and Geothermal Research. His research investigates the dynamics of explosive volcanism and associated phenomena such as pyroclastic flow emplacement and caldera collapse, through a combination of field, laboratory and modelling approaches. Principal field areas have included Santorini in Greece, Crater Lake in Oregon, Mount St Helens in Washington, and Soufrière Hills Volcano on Montserrat in the Caribbean.



## Professor Stephen Sparks, FRS (University of Bristol)

**Assessment of volcanic hazards, risks, vulnerability and uncertainty.**

Volcanic eruptions in arcs are complex natural phenomena, involving the movement of magma to the Earth's surface and interactions with the surrounding crust during ascent and with the surface environment during eruption, resulting in secondary hazards. Magma changes its properties profoundly during ascent and eruption and many of the underlying processes of heat and mass transfer and physical property changes that govern volcanic flows and magmatic interactions with the environment are highly non-linear. Major direct hazards include tephra fall, pyroclastic flows from explosions and dome collapse, volcanic blasts, lahars, debris avalanches and tsunamis. There are also health hazards related to emissions of gases and very fine volcanic ash. These hazards and progress in their assessment are illustrated mainly from the ongoing eruption of the Soufriere Hills volcano, Montserrat. There are both epistemic and aleatory uncertainties in the assessment of volcanic hazards, which can be large, making precise prediction a formidable objective. Indeed in certain respects volcanic systems and hazardous phenomena may be intrinsically unpredictable. As with other natural phenomena, predictions and hazards inevitably have to be expressed in probabilistic terms that take account of these uncertainties. Despite these limitations significant progress is being made in the ability to anticipate volcanic activity in volcanic arcs and, in favourable circumstances, make robust hazards assessments and predictions. Improvements in monitoring ground deformation, gas emissions and seismicity are being combined with more advanced models of volcanic flows and their interactions with the environment. In addition, more structured and systematic methods for assessing hazards and risk are emerging that allow impartial advice to be given to authorities during volcanic crises. There remain significant issues of how



scientific advice and associated uncertainties are communicated to provide effective mitigation during volcanic crises.

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Steve Sparks FRS is leader of the Volcanology and Geological Fluid Dynamics Research Group in the Department of Earth Sciences at University of Bristol, United Kingdom. He is also the Director of the newly established Bristol Environmental Risk Research Centre (BRISK), which seeks to nurture interdisciplinary research in risk and uncertainty science across the University. His research interests include how magma chambers form, how volcanoes erupt, kimberlite geology, the movement of sediment gravity flows, assessment of volcanic hazards, the development of new methods to quantify risk and uncertainty in the assessment of natural hazards, and risk perception in relation to natural hazards and disasters. He is recipient of a European Research Council Advanced Grant of 2.5 million Euros from January 2009 for 5 years. This project seeks to understand how magma chambers form. His field research includes studies on the andesite and dacite volcanoes, including the Soufrière Hills Volcano (Montserrat), Lascar Volcano (Chile), Uturuncu (Bolivia), and research on the geology and petrology of kimberlites. He leads the international project VOGRIPA, which is developing a global database of volcanic hazards and risk. Sparks is currently a member of the Board of the British Geological Survey, the Science Board of the Earth Observatory of Singapore, the Science Advisory Panel of the Istituto Nationale Geofisica e Volcanologia (Italy), the science R & D advisory panel for the Nuclear Decommissioning Agency (UK), and on an international science group advising the Japanese Nuclear waste Management Organisation (NUMO) on natural hazards assessment for rad waste repositories. Sparks was Chair of the Panel for Earth Systems and Environmental Science that assessed research in UK Universities in 2008.



## Professor Ian Stanistreet, University of Liverpool

**Pliocene life and times, environments exploited by earliest man, Olduvai Gorge, Tanzania.**

Olduvai Gorge was a site developed by Louis and Mary Leakey because of its sequence context for Pliocene-Pleistocene mammals. From the type specimen hominin skeletal material and associated tool kits they collected, they documented most stages of hominin evolution. Their discovery of contemporaneous *Homo habilis* (our earliest ancestor) and *Australopithecus boisei* caused much excitement in the palaeoanthropological discipline. From bone and tool assemblages dating at about 1.84 Ma, they developed ideas of early hominins as hunter-gatherers setting up "home bases", at which hominin groups were resident for a period of time, nurturing their young.

The present Geoscience Frontier involves multiple testing of that "home base" hypothesis and an alternative model, which sees *Homo habilis* working in groups as opportunistic scavengers of lion and leopard kills, competing with others, such as hyenas. Only short periods could have been maintained for butchery at kill sites for fear of predation.

The objective of the Olduvai Landscape and Palaeoanthropological Project (O.L.A.P.P.) is to undertake testing of such models by developing an accurate reconstruction of the palaeoenvironmental and palaeoecological contexts: the landscapes in which the hominin sites occur. Average 15Ka intervals between successive volcanic ash layers are not precise enough to develop a contemporaneous palaeolandscape, but we apply sequence stratigraphic techniques and this brings time slices down to the order of a few thousand years, which is adequate for reconstruction.

Such new techniques have been applied by O.L.A.P.P. to the palaeolandscapes around the sites at which *Australopithecus boisei* and *Homo habilis* surfaces were originally found by the Leakeys. The hominin activity is concentrated at the facet (ecological) boundary between freshwater wetland and an island or peninsula that itself sat between a river channel and the wetland. Trees colonized the peninsula and *Typha* (cattail or bulrush) covered the wetland floor. Tree roosting birds inhabited the peninsula, and owls dropped rodent pellets onto its surface, while waders dominated in the wetland facies. Eruption of the Mount Olmoti volcano covered the surface with surge and airfall tuff layers (Tuff IC), "freezing" the details of the landscape. The hominin type and other specimens show predation or scavenging marks of terrestrial carnivores, but also intriguingly toothmarks of crocodiles. The hominins were exploiting the peninsula/wetland interface at which both mammals and crocodiles made their kills, with the advantage that escape trees were available on the peninsula to lessen risk. But the setting still offered considerable perils, as shown by the evidence of predated hominin skeletal material, obviating the concept of "home base" development.

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Ian gained his degree and then Ph.D. at the University of Liverpool, studying the Late Ordovician glacial regressive sequence of the Oslo area. Academic positions at the University of the Witwatersrand led to an Associate Professorship, and started a life-time love affair with African Geology. Studies of the sedimentology of Precambrian basins such as the Late Archaean Witwatersrand Basin of South Africa and Neoproterozoic Damara Sequence of Namibia, and of the Palaeozoic to Mesozoic Karoo Sequence of Namibia were followed by the modern sedimentology of the Okavango Fan system of northwest Botswana. It was this latter experience and those publications that led to an invitation to join the Olduvai Landscape and Palaeoanthropological Project about which his talk deals today. He is presently studying the Pliocene-Pleistocene of the Skeleton



Coast of Namibia as well as that of the Olduvai Basin in northern Tanzania. Ian was awarded the University Council Overseas Fellowship and then Vice-Chancellor's Research Awards at the University of the Witwatersrand. He held the positions of Guest Professor and then Alexander von Humboldt stipendiate at the University of Würzburg, Germany, before taking up honorary positions as Senior Research Fellow and then Professor at the University of Liverpool. He has over 90 peer-reviewed articles derived from his various research interests.



## Trond Helge Torsvik (University of Oslo)

### Mantle dynamics: Linking surface and deep processes

Plate tectonics, as fundamentally unifying to the Earth Sciences as Darwin's Evolution Theory is to Life Sciences, characterises the complex and dynamic evolution of the outer shell of the Earth in terms of rigid plates. These plates overlie and interact with the slowly convecting Earth's mantle. Even though our understanding of links between mantle convection and plate tectonics is improving, notably through subsurface tomographic images, advances in mineral physics and improved absolute plate motion reference frames, there is still no generally accepted mechanism that consistently explains plate tectonics in the framework of mantle convection. It is now a prime challenge to integrate Plate Tectonics into Mantle Dynamics in order to allow a full dynamic treatment of Earth motion and deformation on all scales.

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After doctoral graduation at the University of Bergen (1985) and post-doctoral periods at Oxford University, Trond Torsvik joined the Geological Survey of Norway (NGU) in 1991. Since 1997 he has held Professorships in Geodynamics at the University of Bergen, the Norwegian University of Science and Technology, the Academy of Sciences, and the University of Oslo since 2008. Trond is a leading expert in palaeomagnetism, plate kinematics and geodynamics; he has published 170 papers in international refereed journals and written more than 50 technical reports for the petroleum industry. Honours include Fellow of the American Geophysical Union, the Norwegian Academy of Sciences, the Royal Danish Academy of Sciences, the Royal Society of Norway, the Academia Europea, and honorary Professor from the Witwatersrand University (South Africa).