#QRAPG16

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21st Annual QRA Postgraduate Symposium

14th – 16th September 2016

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Quaternary Research Association

POSTGRADUATE SYMPOSIUM 2016

Hello from your conference team!

Welcome to the 21st Annual Postgraduate Symposium of the Quaternary Research Association at the University of Nottingham.

The QRA Postgraduate Symposium provides postgraduate students a forum to present their research in a relaxed and supportive environment and the opportunity to meet other researchers interested in the field of Quaternary Science.

We hope you have a great time in Nottingham, are able to meet new people and share ideas – if there is anything we can do to help, or if you have any questions at all, please do not hesitate to ask.

We wish you the best of luck with your presentations, and on behalf of all of us here at Nottingham… thank you for attending the symposium.

QRAPG16 Organising Committee

Jack Lacey

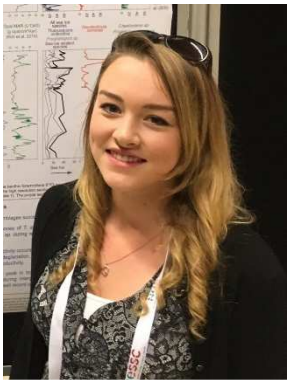
@JackHLacey

Rowan Dejardin

@rowandejardin

Nick Primmer

@NickPrimmer



Savannah Worne

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QRAPG16 Sponsorship

We are grateful for support from the following sponsors:

Quaternary Research Association

The QRA is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. The QRA was founded in 1964. Today the QRA has an international membership of over 1000, with a large and thriving postgraduate student membership. The Association operates a number of grant schemes to support research activities by members, especially new researchers and postgraduate students.

Centre for Environmental Geochemistry

The Centre for Environmental Geochemistry combines the British Geological Survey's and the University of Nottingham's strengths, focusing on the use of geochemistry in research, training and teaching around reconstructing past environmental and climate change, biogeochemical cycling including pollution typing/provenance and the use of geochemical tools for research into the subsurface. Inorganic Geochemistry, Organic Geochemistry and the Stable Isotope Facility all form an integral part of the Centre for Environmental Geochemistry.

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The School of Geography Geosciences community is leading research in earth and environmental systems over a range of spatial and temporal scales. The group investigate patterns and processes within the biosphere, atmosphere, hydrosphere and lithosphere to make inferences about past, present and future change. Staff and students pioneer cutting-edge technologies for geoscience data collection, analysis and knowledge transfer. Supported by state-of-the-art laboratories and information systems, they engage in fundamental and applied research with a strong focus on resource and environmental management, biodiversity, risk mitigation and ecosystem

The Micropalaeontological Society

The Micropalaeontological Society (TMS) exists “to advance the education of the public in the study of Micropalaeontology” and is operated “exclusively for scientific and educational purposes and not for profit”. The Society publishes The Journal of Micropalaeontology and a series of Special Publications. The Society comprises five specialist groups which study Foraminifera, Nannofossils, Ostracods, Palynology and Silicofossils. The groups hold separate meetings, including field trips, throughout the year; these are becoming progressively more international in their scope. The Society holds its AGM in London during November each year to which guest speakers are invited.

University of Nottingham School of Geography

The School of Geography is a leading international centre for geographical scholarship.The field of geography is very broad and the school teaches right across this spectrum, offering undergraduate, postgraduate taught, and postgraduate research courses, with subjects ranging from flooding to financial crises and areas of study from Italy to India. Members of academic staff are leading international researchers in their specialist fields and this research activity underpins teaching, ensuring that the latest developments are incorporated into teaching programmes.

Contents

QRA Postgraduate Representatives

As Postgrad Reps, we attend QRA Executive Committee meetings several times a year and speak on behalf of the QRA postgraduate community. We provide feedback to the committee on the annual symposium, are involved in decisions about the running of the organisation, and maintain the QRA's social media accounts. This is an important role within the QRA as postgraduates form a significant part of the membership, regularly attend QRA-led and -sponsored field meetings and conferences, and have targeted funding opportunities.

A new Junior Postgraduate Representative to the QRA Executive Committee will be elected at this year's Postgraduate AGM.

If you are interested in becoming more involved with the QRA and nominating yourself for the postgrad rep position (2-year term), or want to find out more about the role, just speak to one of us at the meeting! We would also value any feedback you have on the symposium or the QRA as an organisation.

Hope you have a great meeting!

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Programme

Wednesday 14th September

12:00-12:30	Arrival at Nottingham Train Station
12:30	Coach departs for British Geological Survey
12:45	Coach arrives at BGS, Registration, Introduction to QRAPG16 in De la Beche Conference Suite
13:15	Keynote presentation by Dr Colin Waters (British Geological Survey), followed by refreshments
14:30	Tour
16:00	Coach departs to University of Nottingham campus for accommodation check-in
18:00-19:30	Ice breaker in the University of Nottingham Museum of Archaeology
20:00	Social at the Malt Cross pub, Nottingham City Centre

Thursday 15th September

8:30-9:00	Registration @ Engineering and Science Learning Centre
9:00-9:30	Welcome, Introduction, Safety announcements
9:30-10:30	ECR Training Course I
10:30-11:00	Break
11:00-12:00	ECR Training Course II
12:00-13:00	Lunch
13:00-14:00	Keynote presentation by Professor Melanie Leng (University of Nottingham/British Geological Survey)
14:00-14:30	Break

Session 1 - Marine Palaeorecords & Glacial Systems

14:30-14:45	Rowan Dejardin	A multiproxy palaeoceanographic record of the deglacial and Holocene from the Subantarctic island of South Georgia
14:45-15:00	Martha Coleman	Reconstruction of the British-Irish Ice Sheet over North Mayo
15:00-15:15	Katrina Kerr	Investigating the Indian Monsoon's Variability During the Penultimate Deglaciation and the Last Interglacial Period
15:15-15:30	Stuart Umbo	Reconstructing Quaternary North Atlantic temperatures using clumped isotopes
15:30-15:45	Denise McCullagh	The evolution of Galway Bay, Western Ireland since the last glacial maximum
15:45-17:00	Poster session & refreshments in the ESLC Atrium	
18:30-21:30	Conference Dinner at 4550 Miles from Delhi, Nottingham City Centre	

Friday 16th September

09:00-09:30	Coffee	

Session 2 - Palaeoecology, Landscape Evolution & Management

09:30-09:45	Robert Collier	Peatland carbon accumulation: can palaeoenvironmental investigations contribute to policy formulation?
09:45-10:00	Laura Crossley	Assessing the safe operating space for nutrient loads to river estuaries: a palaeoenvironmental approach to estuary management
10:00-10:15	Havananda Ombashi	NPP identification as part of a study on relative importance of different land use types during the Bronze- and Iron Age at Great Buscombe, Exmoor
10:15-10:30	Christine Hamilton	A coast under attack: lessons from the past
10:30-11:00	Break	

Session 3 - Palaeoclimate from the Terrestrial Realm

11:00-11:15	Alexander Bolland	The chironomid palaeoecological archive of Oukaïmeden: a novel contribution to the palaeoclimate of the High Atlas Mountains, Morocco
11:15-11:30	Elizabeth Peneycad	Stable oxygen isotope analyses of modern and fossil rodent teeth from Britain: implications for palaeoclimate reconstructions
11:30-11:45	Nick Primmer	Mid to Low latitude Holocene climate change using varve analysis
11:45-12:00	Ashley Abrook	Does vegetation respond to centennial-scale climatic oscillations? Evidence from Tirinie, a last glacial-interglacial transition site in the Scottish Highlands
12:00-12:30	QRA Postgraduate Symposium AGM, Elections, Awards	
12:30-13:00	Lunch	
13:00	Delegates depart	

Professor Colin Waters

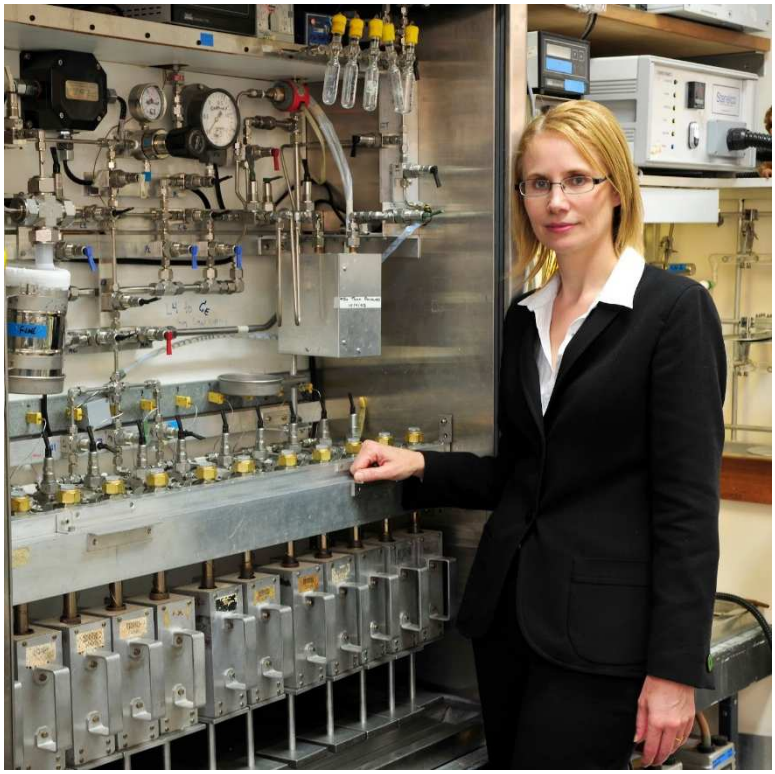
British Geological Survey

Are we living in a new epoch: the Anthropocene?

Human activity is leaving a pervasive and persistent signature on Earth and vigorous debate continues about whether this warrants recognition as a new geologic time unit known as the Anthropocene. This presentation briefly describes the history of research into the Anthropocene, reviews diverse anthropogenic markers of functional changes in the Earth system through the geological record based upon Waters et al. (2016), summarises the results of recent decisions made by the Anthropocene Working Group and introduces possible examples of environments in which a potential Global Boundary Stratotype Section and Point (GSSP) could be placed. The appearance of manufactured materials in sediments – including aluminium, plastics and concrete – coincides with global spikes in fallout radionuclides and particulates from fossil-fuel combustion, suggesting that the most dramatic changes occur during the mid-20th century. Carbon, nitrogen, and phosphorus cycles have been substantially modified over the last century. Biotic changes including species invasions, adaptations to anthropogenically forced environmental factors and worldwide and accelerating rates of extinction. These combined signals render the Anthropocene stratigraphically distinct from the Holocene and earlier epochs.

Reference:

Waters, C.N., Zalasiewicz, J., Summerhayes, C., Barnosky, A.D., Poirier, C., Gałuszka, A., Cearreta, A., Edgeworth, M., Ellis, E.C., Ellis, M., Jeandel, C., Leinfelder, R., McNeill, J.R., Richter, D. deB., Steffen, W., Syvitski, J., Vidas, D., Wagreich, M., Williams, M., An Zhisheng, Grinevald, J., Odada, E., Oreskes, N. and Wolfe, A.P. (2016). The Anthropocene is functionally and stratigraphically distinct from the Holocene. Science Vol. 351 issue 6269, 137.



Professor Melanie Leng

British Geological Survey
University of Nottingham

@MelJLeng

Isotopes in palaeoclimate research – an introduction

This lecture will introduce the science of isotope geochemistry in relation to palaeoclimate research. There will be a brief introduction on isotope geochemistry, a description of isotopes in the hydrological cycle (the precursor to all palaeoclimate studies), finally there will be examples of how isotopes are used in lakes, oceans and speleothem deposits.

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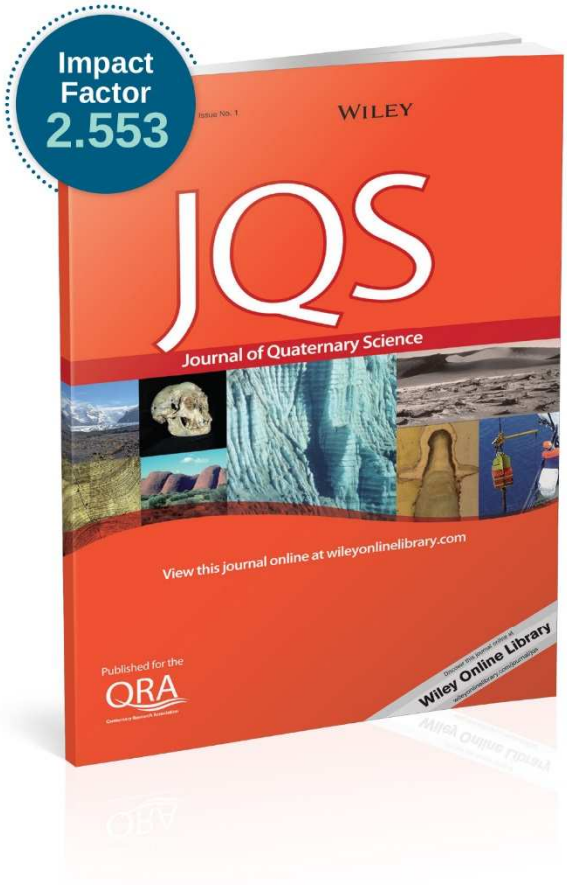

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Session 1: Marine Palaeorecords & Glacial Systems

Chair: Nick Primmer

A multiproxy palaeoceanographic record of the deglacial and Holocene from the Subantarctic island of South Georgia

Rowan L.S. Dejardin[1,2*], Claire S. Allen[3], Sev Kender[1,2], Melanie J. Leng[1,4], Victoria L. Peck[3], George E.A. Swann[1]

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** Rowan Dejardin, rowan.dejardin@nottingham.ac.uk*

In order to assess the Southern Ocean's sensitivity to climate change and place recent environmental changes within a historical context, it is important to develop our understanding of how water mass properties and circulation patterns have varied through the Holocene, particularly in the Subantarctic Zone. Understanding oceanographic variation in this region is important because the Southern Ocean has been proposed as an important carbon sink and source during transitions between glacial and interglacial periods. South Georgia is of particular interest because it sits in the path of the Antarctic Circumpolar Current, and the interaction of the current with the island supports intense phytoplankton blooms. These blooms form one of the largest seasonal sinks of atmospheric CO2 south of the Antarctic Polar Front, in addition to supporting one of the most diverse ecosystems in the Southern Ocean.

Here we present micropalaeontological and geochemical data from a sediment core on the continental shelf east of South Georgia, spanning the last 15 kyrs. Benthic foraminiferal assemblages and organic carbon accumulation indicate a highly productive late deglacial and early Holocene, with phytodetritivore *Fursenkoina fusiformis* dominating benthic foraminiferal assemblages. Subsequent environmental changes, possibly affecting carbonate preservation potential, during the mid and late Holocene lead to assemblages dominated by *Miliammina arenacea*. We consider that the changing oceanographic conditions on the South Georgia shelf, revealed by a suite of palaeoceanographic proxies, may inform us about sub-Antarctic ocean-climate evolution since the last deglacial.

Reconstruction of the British-Irish Ice Sheet over North Mayo

Martha Coleman

Irish Sediment Core Research Facility (ISCORF), Department of Geography, Maynooth University, Maynooth, Co Kildare, Ireland
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New AMS ^{14}C dates widen and strengthen the British-Irish Ice Sheet reconstruction along Ireland's North Mayo coast between ~19573 – 20691 cal BP. Dates concur with previous literature and brings evidence of late Quaternary glacial activity 1km further west along the coast. The AMS ^{14}C dating of macrofauna, *Macoma calcarea,* provides substantial evidence for *in situ* depositional conditions along with the presence of dated articulated bivalves and pristine foraminifera assemblages, non recrystallisation of mollusc samples dated and bedrock exposure indicating no break in sequence help identify the importance of North Mayo as an area of glacial research. Dating and palaeoenvironmental evidence points to a deglacial sequence correlating with the end of the Last Glacial Maximum. However, foraminifera shelf taxa are common indicating a possible deeper sea environment than previously hypothesised. Current research includes the development of new palaeo ice flow models using detailed field observation, palaeoenvironmental reconstruction and remote sensing analysis. Particle Size Analysis on freshly exposed laminated muds from Belderg Harbour also forms part of the present research. The ongoing aim of the research is to build a robust and comprehensive model of glacial activity in North Mayo while also demonstrating the importance of the area's glacial history.

References:

McCabe, A.M. Haynes, J.R. MacMillan, N.F. (1986). Late-Pleistocene tidewater glaciers and glaciomarine sequences from north Mayo, Republic of Ireland. *Journal of Quaternary Science* 1(1):73-84.

Investigating the Indian Monsoon's Variability during the Penultimate Deglaciation and the Last Interglacial Period

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The Indian Monsoon is a significant component of the global climate system that affects some of Earth's most densely populated areas. The ability to accurately constrain and model future monsoon behaviour relies on having a robust record of past variability and an understanding of the influence of internal and external forcing parameters. The penultimate deglaciation (TII, ~138-130 ka) and the Last Interglacial Period (LIG, ~130-118 ka) present a suitable case study for investigating the sensitivity of the monsoon to climatic forcing operating during a period of abrupt climate change.

Samples will be utilized from IODP Exp. 353 (sites U1446 and U1448) recovered from the core region of the monsoon, within the Bay of Bengal, an area formerly understudied and thus this project has the potential to provide an improved constraint of the temporal-spatial extent of monsoon variability. A detailed reconstruction of terrigenous sediment flux and palaeosalinity changes will be produced through the bulk sediment geochemistry (including stable isotopes) in foraminifera from 150-70 ka. These climate proxies exploit the Bay of Bengal's unique characteristic of changing salinity patterns associated with Indian Summer Monsoon rainfall and riverine runoff. Preliminary Ti/Ca ratios from bulk sediment using portable X-ray fluorescence indicates the occurrence of a reduction in summer monsoon induced run-off into the Bay of Bengal during TII, subsequent strengthening coinciding with the onset of the LIG and interruption of optimum climatic conditions with an intra-interglacial arid period. This record provides an initial first working model to investigate internal teleconnections operating between the monsoon system and high latitude climate during different climatic states. These preliminary low resolution results will be complemented by a record of *G. ruber* $\delta^{18}O_{sw}$ in order to assess palaeosalinity changes associated with variation in the intensity of the Indian Summer Monsoon.

Reconstructing Quaternary North Atlantic temperatures using clumped isotopes

S. Umbo[1], M. Chapman[1], P. Dennis[1], A.Marca[1]

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Clumped isotope analysis of carbonate proxies offers an exciting new means of quantifying palaeotemperatures. Unlike conventional stable isotopes, no knowledge of the isotopic composition of precipitation waters is required – something which has long hindered the establishment of reliable palaeothermometers. Instead temperatures are deduced by measuring the degree to which heavy isotopes 'clump' together in the calcite lattice – an experimentally determinable function of temperature[1].

This project aims to quantify North Atlantic temperatures during key glacial cycles and selected millennial scale climatic fluctuations of the Quaternary using clumped isotope analysis of foraminifera. North Atlantic circulation is thought to have undergone significant realignment during these periods[2] with dramatic impacts on global climate. Quantifying palaeotemperatures during these times can help establish drivers of such change, improve understanding of the global climate system and better constrain future models of anthropogenic warming.

The University of East Anglia is uniquely placed to conduct clumped isotope analysis with its Multiple-Isotopologue-Ratio-Analyser (MIRA) instrument, the only mass spectrometer in the world specifically designed for clumped isotope analysis[3]. Since the use of clumped isotope analysis on foraminifera remains largely unexplored, it has been necessary to first establish robust experimental procedure, some of which will be explored throughout this talk.

References:

[1]Eiler, J (2007) 'Clumped-isotope' geochemistry – The study of naturally-occurring, multiply substituted isotopologues , *Earth and Planetary Science Letters* 262: 309 – 327

[2]Lynch-stieglitz et al., (2007). Atlantic Meridional Overturning During the Last Glacial Maximum, *Science 316*, 66–69.

[3]Dennis, P. F., Vinen, S., Marca-bell, A., & Rowe, P. J. (2013). MIRA: a new isotope ratio mass spectrometer for clumped isotope studies of CO2, 1–25 (Download https://pfigshare-u-files.s3-eu-west-1.amazonaws.com/1345823/MIRAPLOS2013v2.pdf)

The evolution of Galway Bay, Western Ireland since the last glacial maximum

Denise McCullagh[1], Sara Benetti[1], Ruth Plets[1] and Robin Edwards[2].

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During the late Quaternary significant environmental and relative sea-level variations have contributed to shaping present day coastlines. This is particularly evident along formerly glaciated continental margins. Strong evidence of these changes are recorded in Galway Bay, Western Ireland. This research uses a multidisciplinary approach. Seismic and multibeam data, sedimentological, micropaleontological, geochemical analysis and 15 radiocarbon dates of sediment cores from the bay provide post last glacial maximum (LGM) sea level and environmental reconstructions for the region.

The acoustic stratigraphy of the bay includes 3 seismic units: the deepest unit represents the acoustic basement, composed of limestone and granite bedrock; the middle unit is composed of the oldest preserved sediments, deposited during and after the LGM, and interpreted to be glacial till. The uppermost unit represents deposition and reworking after glacial retreat. The erosive action of the ice sheet that extended off the Irish coast is thought to be responsible for the removal and reworking of all sediments older that the LGM. In the sediment cores, three main lithofacies were identified: 1) a sandy silt and clay facies, 2) a distinct shell hash interlayer and, 3) a fine silty sand facies. These 3 facies are found within the uppermost seismic unit, and initial radiocarbon dating of shells in 4 cores, constrain these sediments and the uppermost seismic unit to the Holocene. A further four samples taken from a prominent *Turritella* layer visible in several cores, are currently in the process of being submitted for radiocarbon dating. Preliminary qualitative analysis on foraminifera from several cores shows a general trend of progression from estuarine to open marine conditions, inferred from indicator species. This trend is supported by X-ray fluorescence (XRF) analysis which shows increased ratios of Cl/Fe in younger deposits. Constraining dates on sea level variations in the region will be added to the sea level database for Ireland and possibly used to adjust the existing relative sea level models. These are important for understating past sea level variations and modelling future trends.

Session 2: Palaeoecology, Landscape Evolution & Management

Chair: Rowan Dejardin

Peatland carbon accumulation: can palaeoenvironmental investigations contribute to policy formulation?

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The Climate Change Act commits the UK Government to an 80% reduction in greenhouse gas emissions by 2050 relative to 1990 levels. Quantifying how contemporary land use activities affect the carbon cycle is imperative if this target is to be achieved. Blanket peatlands are the most efficient terrestrial carbon store of the British Isles. As a carbon sink they are 'labile', in that auto- and allogenic forcings can both release previously sequestered carbon and inhibit future accumulation. A history of human land use (e.g. burning, drainage, grazing) has exploited UK blanket peatlands to the extent the International Union for the Conservation of Nature declared <20% remain in a 'natural' or 'near-natural' condition. Considering such a stark outlook regarding their integrity on a national scale, a paucity of data on the impact of land management practices on peatland carbon dynamics is surprising. Such uncertainty hampers efforts to promote the 'carbon conscious' management of blanket peatlands to both conserve existing deposits and maintain or enhance future sequestration.

Presented here is an assessment from four blanket peatlands through North and mid-Wales. Attempts are made to establish whether differing management regimes produce 'characteristic' carbon accumulation rates, alongside investigating how land use practices affect other aspects of the peatland biophysical environment (e.g. vegetation community composition). Quantification of carbon accumulation rates under differing management practices is required if blanket peatland land use is to be recognised by 'Payment for Ecosystem Services' schemes. These schemes seek to commoditise the supply of traditionally non-marketable services (e.g. carbon accumulation) and may promote 'carbon conscious' management through addressing the failure of markets to appropriately recognise the value of these services. This study adds to the growing body of evidence demonstrating the application and relevance of palaeoenvironmental analyses to landscape management; approaching the issue of quantifying ecosystem variability over a temporal range greatly exceeding understanding yielded from 'traditional' ecological approaches.

Assessing the safe operating space for nutrient loads to river estuaries: a palaeoenvironmental approach to estuary management

Laura Crossley[1]*, Prof. Peter Langdon[1], Prof. David Sear[1] & Prof. John Dearing[1]

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Poole Harbour estuary, southern England, is an area of ecological importance with a history of long term eutrophication and subject to extensive variability in nutrient fluxes. Along with minor rivers and streams, Poole Harbour is mainly fed by the Rivers Frome and Piddle. These two major rivers are the likely main nutrient sources along with sewage treatment effluent which enters to the north within Holes Bay. Human activities and land use change over the past ~50 years have led to an increase in nutrient loading into the rivers which provide a transport route for the nutrients to coastal zones via the estuary. Estuarine processes can alter these fluxes and therefore the riverine nutrients do not necessarily pass through to coastal waters but can stay within the estuarine boundary. It is therefore important to improve the understanding of anthropogenic influences with regards to estuarine nutrient fluxes over a multi-centennial scale and their corresponding influence on ecological activity.

This research aims to use palaeoecological techniques to reconstruct Poole Harbour's nutrient and ecological history over the last ~250 years. Focus will be on where the main sources of nutrients enter the estuary to identify the nutrient and ecosystem baseline. It can then be determined how the nutrients drive parts of this complex system and whether it responds in a linear manor or through abrupt changes. Greater understanding of the system component responses can therefore lead to develop a safe operating space from which future management decisions can be made.

NPP identification as part of a study on relative importance of different land use types during the Bronze- and Iron Age at Great Buscombe, Exmoor.

Havananda Ombashi [1*]

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NPP identifications from peat samples from a site on Exmoor have been carried out in order to gain new insights in how different types of land management influenced the moorland vegetation in the past. Several dung fungi that have been identified throughout the peat sequence are often regarded as grazing indicators and can suggest the presence of grazing as a form of land use at certain points in the past. The newly retrieved NPP data has been carried out in order to consider the relative importance of grazing, burning and small-scale arable activity on the moorland vegetation of Great Buscombe. The time period covered by the research ranges from 3800 to 2200 years ago, based on radiocarbon dates. This time period is known for significant changes in the landscape, but the relative roles of different factors that can shape the landscape are yet to be better understood.

The research builds on previously carried out pollen research done by Fyfe and Head (2015), which includes a high-resolution pollen sequence and charcoal counts. The three main periods of intense land use previously identified from the pollen sequence are used as a reference to compare with the recently produced NPP data. The site lies within a region rich in prehistoric field archaeology, which can potentially be integrated with the new knowledge of land use patterns identified from the data.
Identifications have been done with the use of the still unpublished fungal spore guide of Blackford et al. Sediment depths range from 150cm to 215cm and cover every other half a cm.

The presentation will focus on how the changes in fungal spore species throughout the sequence correlate with the already identified pollen zones and charcoal data and how this can be interpreted as the relative importance of grazing, burning and small scale arable activity in Great Buscombe during the prehistory.

References:

Blackford, J., Innes, J.B., Long, D., Ryan, P.A., Van Geel, B., Watling, R. and Wiltshire, P.E.J. *Unpublished - Fungal spore identification guide*.

Fyfe, R. and Head, K. (2015). *The context of prehistoric landscapes: preliminary analysis of sites on Exmoor. Palaeoenvironmental investigation at Great Buscombe. Stages 2 report.* School of Geography, Earth and Environmental Science, Plymouth University. Prepared for Exmoor National Park Authority 1-19.

A coast under attack: lessons from the past

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Future vulnerability and resilience of coastal landscapes, and their associated communities, infrastructure and nature conservation interests, is of increasing concern due to the combined effects of climate change and sea-level rise. The Suffolk coast, characterised by gravel barrier beaches extending southwards to Orford Ness and a spit feature of international geomorphological interest, has changed dramatically. Long-term subsidence and the combined effects of sea-level rise and lack of sediment supply significantly compromise stability. The coastline experiences high rates of erosion and is particularly vulnerable to storms. Dunwich, the most iconic example of this, is 90 % submerged beneath the sea. The sediment supply to the gravel beaches is no longer sufficient to retain system resilience to storms, and there is a need for adaptive and sustainable strategies to manage the coast effectively. The region is home to significant infrastructure (Sizewell B nuclear power station), in addition to high conservation and heritage value (Special Area for Conservation protected under the EU Habitats Directive and an AONB).

This research aims to reconstruct Holocene changes in the coastlines behaviour utilising sediment records contained within Suffolk's enclosed wetlands. Producing robust baseline data on coastal evolution, relating to relative sea level, sediment supply and storm incidence, will enhance understanding of the long-term controls on coastal system behaviour in addition to informing future management strategies for significantly unstable coastal areas.

A stratigraphic framework will be established for the regions coastal deposits and cores collected for detailed analysis. Micropalaeontological (e.g. diatoms, foraminifera, pollen), sedimentological (e.g. particle size) and geochemical methods, supported by a programme of radiocarbon dating, will be undertaken to determine how the Holocene coastal system developed. Stratigraphy revealed that sections of the coast have been subject to periodic opening and closing. Preliminary diatom analysis supports this and preservation has been shown to be good.

Session 3: Palaeoclimate from the Terrestrial Realm

Chair: Jack Lacey

The chironomid palaeoecological archive of Oukaïmeden: a novel contribution to the palaeoclimate of the High Atlas Mountains, Morocco

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Chironomids are a widely used biological proxy for palaeoenvironmental change with a worldwide distribution (Walker, 1995). Despite this they have not previously been used to assess palaeoclimatic change in Morocco, North Africa. This project set out to utilise chironomids in the development of a novel temperature inference dataset within the Oukaimedan Valley, Morocco, situated in the High Atlas Mountain range. Additional analysis used to accompany the novel chironomid dataset included particle size analysis, LOI, magnetic susceptibility and X-ray fluorescence.

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Stable oxygen isotope analyses of modern and fossil rodent teeth from Britain: implications for palaeoclimate reconstructions

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The stable oxygen isotope compositions ($\delta^{18}O$) of fossil rodent teeth can potentially provide valuable, quantitative palaeoenvironmental information. However, despite the abundance of rodent teeth in Quaternary terrestrial records, few isotope studies have utilized these teeth for palaeoclimate reconstructions, and this is in part due to a lack of understanding on what the isotope compositions of rodent teeth record (Royer et al., 2013). Accurate interpretations of oxygen isotope data from fossil teeth are dependent upon an understanding of: 1) the factors that contribute to inter-tooth isotopic differences, and 2) the relationship between tooth $\delta^{18}O$ compositions and the mean $\delta^{18}O$ of local meteoric water (a proxy for air temperature). Modern analogue studies are essential to this understanding, though at present, isotope data from modern rodents are limited.

Here, we present the results of 2 studies aimed at testing whether oxygen isotopes in rodent teeth are a reliable climate proxy. The first study investigates the $\delta^{18}O$ compositions of modern vole teeth from multiple sites across Britain. Preliminary results of this study demonstrate that average tooth $\delta^{18}O$ values closely parallel the mean $\delta^{18}O$ of local meteoric water. These findings are supported by the second study, which uses the $\delta^{18}O$ compositions of fossil vole teeth to reconstruct the mean $\delta^{18}O$ of meteoric water and the mean summer air temperature for the Middle Pleistocene site of West Runton, Norfolk. The resulting meteoric water and temperature values indicate that climatic conditions at West Runton were similar to the present day, in agreement with other palaeoenvironmental evidence from this site. The $\delta^{18}O$ compositions of fossil vole teeth can therefore provide accurate and relatively precise records of past environmental conditions.

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Mid-low latitude Holocene climate change using varve analysis

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Sub-annually laminated, lacustrine sediments (or "varves") can produce an exceptionally high resolution record of environmental change with a robust, absolute chronology. Each varve contains a specific set of laminations which reflect the annual succession of limnic deposition. By comprehensively understanding the annual processes which effect sediment deposition, palaeoseasonality can be reconstructed through the analysis of varve microfacies and their geochemical composition - this is achieved using thin sections microscopy and micro X-ray fluorescence (µXRF) respectively.

Analysing varved sediment cores from closed lakes Nar Gölü, Turkey and Yaal Chac, Mexico, annual climate is reconstructed over the last ~4,000 years. Both of these sites display highly seasonal climatic regimes which are driven, in part, by the annual migration of the sub-tropical high pressure belt. Comparing incremental records of seasonality from sites either side of this belt can provide insight into the dynamics of sub-tropical high pressure, and the sub-decadal periodicities that influence regional climate.

The sub-annual nature of varves also represents an appropriate resolution for understanding climate change at a societal scale - both study regions have complex cultural and climatic histories throughout the Holocene. The impact of climate on societies in these regions is often a topic of contention; much of the debate centres on the extent societal change is causally related to climate (e.g. Aimers and Hodell, 2011; Haldon *et al.* 2014). A detailed understanding of climatic history can aid analysis of the relative impact climate had on cultural development as well as contextualise both present day climate patterns and future predictions.

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Does vegetation respond to centennial-scale climatic oscillations? Evidence from Tirinie, a last glacial-interglacial transition site in the Scottish highlands

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The Last Glacial-Interglacial Transition (LGIT) (16-8 ka BP) in northern Europe is a well-characterised period of abrupt climatic change where millennial-scale oscillations in climate led to large-scale reorganisation of ecosystems. Imprinted upon these longer term episodes are a number of centennial-scale climatic oscillations which are far less well understood. These short-lived events appear to be spatially and temporally complex across northern Europe and frequently have either not been identified or are shown to have limited impact. However, many records have not been studied for proxies which provide evidence of both drivers and response, or they are not resolved in sufficient detail. Consequently, landscape responses to these events are largely unknown. In order to address this issue, we use high-resolution proxies of past vegetation, temperature and hydrology to understand how climatic regimes drive landscape changes.

Here we present a pollen, stable isotope and charcoal record from Tirinie, a palaeo-lake basin in the Grampian Highlands. The data suggests that the vegetation record is responding to both millennial-scale and centennial-scale climatic oscillations as seen in the isotope record. Abrupt changes in vegetation occur where 'revertence' events depict replacement of taxa with ecologies of landscape stability with those indicating landscape disturbance. Revertences in the pollen record are matched by concomitant changes in the lithostratigraphy and lag oxygen isotopic depletion events in the isotopic profile. Furthermore, wildfires appear to be locally important drivers of vegetation change but their occurrence is governed by the development of sufficient biomass within the landscape. One important distinction between revertences within the LGIT is that climatic events with similar magnitudes have far larger vegetational responses during the Interstade than the Holocene, the reasons for this are currently unclear.

Poster Abstracts

Assessing the extent of semi-arid environments in Late Quaternary Eurasia using mammalian evidence: implications for understanding ecological and human responses to abrupt climate change

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The Late Pleistocene is a period characterised by abrupt shifts in climate in Europe, driven by a range of forcing factors (Rasmussen et al., 2014). There is evidence of semi-arid environments spreading through the Late Pleistocene, highlighted by the westward migrations of arid-adapted mammals (Currant, 1987). However, relating these faunal migrations to the wider unstable climatic regime is hampered by a current lack of quantitative precipitation estimates at a representative spatial scale and within a robust dating framework.

Recent work on both modern herbivores and Neogene fossils has revealed the utility of large herbivore hypsodonty (tooth crown height) as a method of quantifying past and present precipitation (Eronen et al., 2010a,b; Liu et al., 2012). Fortunately, the abundance of Late Pleistocene mammal assemblages provides excellent spatial coverage and have often had robust dating methods applied.

Preliminary analysis of the existing hypsodonty-precipitation models and datasets indicates generalisation of the relationship between hypsodonty and precipitation across large spatial areas as well as suppression of natural variations in hypsodonty. Here, we attempt to improve existing models by creating a large modern training set using well-provenanced museum specimens, before using it to quantify precipitation at Late Pleistocene sites. This will provide the first quantitative reconstructions of past precipitation. Existing radiocarbon based chronologies will be used to deliver a robust chronology of past precipitation values at a high temporal resolution. This will permit us to assess the control of abrupt climate changes on aridity and the effects of this upon faunal migration and hominins.

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Reconstructing the connectivity history of the Black Sea and Caspian Sea during the last 2 Ma using strontium isotopes.

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Over the last two million years, the Black Sea and the Caspian Sea (collectively known as the Pontocaspian Basin) have experienced multiple periods of connectivity and progressive isolation events. These oscillating connectivity events are driven by changes in fresh water hydrologic budgets caused by regional and global climate change and active tectonics. These events promote changes in basinal environment and facilitate faunal exchange between the two basins thus, giving rise to a unique biodiversity across this region. However, the Pontocaspian region has been facing a biodiversity crisis for the last century.

Pontocaspian biodiversity Rise and Demise (PRIDE) is an integrated cross-disciplinary research project that combines geology, biology and climate science to investigate drivers of the past and current biodiversity crises in the region. As part of the PRIDE, connectivity history of the Pontocaspian region is studied using strontium isotope. Strontium isotopic ratio (87Sr/86Sr) is measured in fossil ostracods, micro-crustaceans with calcitic exoskeleton, collected from cross the region. In addition, 87Sr/86Sr is also measured in present day Pontocaspian rivers to constrain its hydrological budget. These datasets will be combined to reconstruct the hydrologic evolution of the Pontocaspian basin and to understand the role of abiotic processes that controls the evolution of the Pontocaspian biota.

Using annually-resolved records to assess how the Baltic Ice Lake influences the climatic regimes across the North Atlantic region during the Last Glacial-Interglacial Transition

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During the last deglaciation, ocean circulation in the North Atlantic was highly variable in strength and direction, with abrupt climate changes driven by salinity variations and fluctuations in the strength of the Atlantic Meridional Overturning Circulation (AMOC). It is widely accepted that injections of freshwater to the North Atlantic from the collapsing Laurentide ice sheet led to temporary shutdown of the AMOC, initiating widespread reorganisation of the ocean-atmosphere systems (Clark et al., 2001). However, recent transient climate model simulations demonstrate that gradual freshwater input from the drainage of the Baltic Ice Lake, rather than freshwater outbursts from the Laurentide Ice Sheet, may have been sufficient to trigger cold stadials during the last glacial cycle (Muschitiello et al., 2015). To date, several conflicting ages for the timing of Baltic Ice Lake drainage have been proposed, ranging from the Late Allerød (c. 13,100 yrs BP; Björck, 2008) to the Younger Dryas/early Holocene boundary (c. 11, 700 yrs BP; Swärd et al., 2015), and many have contested whether drainage was catastrophic or occurred over several hundred years (Andrén et al., 2002). The distinct lack of robust, independent age estimates for the timing of Baltic Ice Lake drainage prohibit confident assertions regarding the potential impacts on regional climatic change. This research seeks to resolve outstanding chronological uncertainties through a combination of tephrochronology and microfacies analysis of annually laminated glaciolacustrine sediments deposited in the Baltic Ice Lake in the Östergötland region of Sweden. Identification of isochronous tephra layers offers the rare opportunity to refine the Swedish varve chronology, and provide absolute age estimates for Baltic Ice Lake drainage. This will enable reconstruction of the synchronicity of ice and ocean responses to abrupt climatic shifts, and assessment of the potential impact of Baltic Ice Lake drainage on the North Atlantic ocean-atmosphere systems.

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Surface pollen spectra from Shennongjia Mountains, central China: An interpretation aid to Quaternary pollen deposits

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As an initial step to aid Quaternary pollen interpretation, we investigated modern pollen deposits from both moss polsters within the forests and surface sediments from an open swamp (Dajiuhu swamp) in the Shennongjia Mountains, central China. Pollen spectra from the moss polsters show similar patterns to local vegetation zones following an elevation gradient. Such pollen spectra reflect more local vegetation landscape than regional one. However, the pollen spectra from the Dajiuhu swamp (especially in the center area) reflect regional vegetation with more deciduous than evergreen broadleaf trees. The pollen ratio of D/E (deciduous/evergreen tree pollen) is developed and its variations in different forest zones show a rising trend with increasing elevation, which gives an alternative to interpret palaeoelevation and/or temperature changes based on Quaternary pollen in monsoon climate controlled areas. The quantitative distribution of key pollen taxa and their source areas are also discussed in this paper. Our study contributes robust bases for interpretation in reconstructing past vegetation and climate changes using Quaternary pollen data in Shennongjia Mountains, central China.

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Cold and humid Atlantic Forest in the Late Glacial, Northern Espirito Santo State, Southeastern Brazil

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From Northern Espirito Santo to Southern Bahia states, the composition of native Atlantic forests can be related structurally and taxonomically to the Amazon Rainforest (Prance, 1982). The area was considered as an stable forest during the Pleistocene glacial times, referred as Bahia forest refuge by Prance (1982) or as the most "historically stable regions of Atlantic forest" by Carnaval & Moritz (2008). This study aims to reconstitute the vegetation dynamic since ~33,000 yr cal BP, using an interdisciplinary approach as Palynology, Radiocarbon Dating and Carbon and Nitrogen elemental and isotope of organic matter, to infer climatic changes since the Late Glacial at the Atlantic Rainforest. Vegetation changes were verified at “Brejo do Louro's” bog located at Vale Nature Reserve at Espirito Santo State, Southeastern Brazil. From ~33,460 to ~13,740 cal yr BP the arboreal/shrub vegetation was dominated by C3 plants (δ13C ~-28‰), mainly constituted by Tapirira, Ilex, Symplocos and other species in low percentage as Podocarpus and the rare Amazon genera Glycidendron, suggesting the dominance of cold and humid forest. From ~13,740 to ~9500 cal yr BP the pollen pattern starts to change with the increase of grasses and decrease of arboreal types. Between ~9500 and ~7300 cal yr BP was observed the dominance of herbaceous C3 plants with probable presence of C4 plants (δ13C ~-24‰), suggesting a less humid period than the previous one. From ~7300 cal yr BP until present, Typha becomes dominant followed by Melastomataceae, Alchornea and Moraceae/Urticaceae and the peat layer initiates its development, possibly due to the sea level rising (transgressive) phase recorded in the region (Buso-Junior, 20013; Lorente, 2014), which could influence the dynamic of the water table under the bog and the humidity of the site, highly significant for the peat deposition.

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Reconstructing Carbon Accumulation at Pyllau Cochion Bog, SW Wales: Assessing the Human and Climatic Impact

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The world's peatlands hold ~30% of terrestrial carbon, representing an important component in the global carbon cycle. However, predicted atmospheric warming and shifts in hydrological regimes, coupled with persistent human interference, threatens to destabilise peatland carbon stocks, potentially creating a self-sustaining feedback loop that could trigger unprecedented runaway CO2 emissions. Pyllau Cochion peat bog in Carmarthenshire, SW Wales, represents one of the most southerly, and in a warming climate, a threatened peatland in the UK. However, to date, no research has been conducted at this 'at risk' site. By using an innovative multi-proxy approach, this study explores how carbon accumulation has responded previously to human and climatic impacts, so that appropriate management strategies can be implemented. This will involve establishing a high-resolution record of carbon accumulation, combined with a whole basin reconstruction via GPR (Ground Penetrating Radar). At its deepest, almost 6 m of peat has accumulated in this basin, underlain by 2.4 m of clay, with peat initiation dated to ca. 9900 cal yrs. BP. Preliminary investigations suggest that fire has been a recurrent feature of this landscape, with several episodes throughout the Mesolithic and Neolithic periods, and in recent years, which is accompanied by a reduction in carbon accumulation. Future work will focus on reconstructing water table fluctuations and establishing a robust chronological framework, in order to develop a wider environmental context and history of carbon dynamics.

The Determination of Palaeotemperatures form Speleothems using Clumped Isotope and Traditional Isotope Palaeothermometry

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Palaeotemperature proxies are analysed in order to understand temperature variations over geological time, with δ18O analysis the current primary palaeotemperature reconstruction tool of choice; however, increasing interpretational uncertainties surrounding this palaeotemperature tool have reduced the confidence of derived temperatures. This study applied the clumped isotope palaeothermometer to the speleothem LH-70s-1; extracted from Lancaster Hole, Cumbria, and sought to identify the Younger Dryas Stadial; previously unobserved in the UK bulk isotopic record. In addition to detecting variations in cave temperatures from Δ47 signals observation, this study identified the temperature profile presented is concurrent with accepted profiles of surface temperature during the Younger Dryas; although slightly warmer and delayed. It also demonstrated that for the location examined, the analysed calcite was precipitated under equilibrium conditions with respect to δ18O and Δ47, and concluded that the elevated temperatures along with the delayed onset of the Younger Dryas are due to the thermal buffering provided by the surrounding country rock. The study demonstrates the successful application of clumped isotope analysis to a speleothem sample and the generation of a plausible temperature evolution profile of an event hitherto not recorded by traditional stable isotope thermometry. In addition the collected data validates previously undertaken fluid inclusion analysis of LH-70s-1 by Atkinson and Hopley (2013). It is suggested that the speleothem palaeoclimate archive examined here, may record valid precipitation temperatures and not experiencing a warm bias as suggested by papers including Daëron et al. (2011) and Kluge et al. (2013) and proposes that further examination should be undertaken to ascertain whether the conclusions derived from this location are applicable to other speleothem archives.

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Constraining the influence of the Southern Hemisphere Westerlies on the past, present and future behaviour of the Monte San Lorenzo ice cap, Patagonia

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The Southern Hemisphere Westerlies are a critical component of the Southern Hemisphere climate system, responsible for bringing precipitation to Patagonia, the Sub Antarctic and the Antarctic Peninsula, and for driving oceanic circulation. Past latitudinal variations in the Southern Hemisphere Westerlies may have driven Holocene glacier advances in Patagonia, but the timing of these advances and glacier-climate relationships are poorly constrained. Records of palaeo-precipitation, which could act as a proxy for variations in the strength of the Southern Hemisphere Westerlies, are particularly lacking.

Under a warming climate, the Southern Hemisphere Westerlies are predicted to migrate further south, which has potential consequences for future glacier response to climate change. In light of this, improving our understanding of this major airflow and its interactions has implications for not only ice masses in Patagonia but also ocean circulation and wider interconnected systems. Glaciers of small ice caps around the periphery of larger ice fields are likely to have short response times and high climate sensitivity. Modelled glacier reconstructions can be used to understand past changes in atmospheric circulation. A critical question is under what climatic conditions did past glacier advances occur, and how will these glaciers behave under various future climate change scenarios?

This project will aim to determine controls on the mass balance of outlet glaciers from the Monte San Lorenzo ice cap, Patagonia, through the Holocene and predict their behaviour under different climate scenarios on into the next century. Valleys of past outlet glaciers to the north and east of the ice cap contain significant glacial geomorphological features, lake terraces and deposits which currently lack detailed study. This study will utilise detailed geomorphological mapping (from field surveys and high resolution remote sensing) to reconstruct past glacial processes and the relative event stratigraphy. Cosmogenic nuclide dating from glacially transported boulders will reveal a detailed chronological record of Holocene glacier fluctuations. A glacier flowline numerical model, dynamically calibrated to match glacier observations and forced by observed climate data from the last three decades, will be used to test theories of climate forcing through the Holocene, with the chronological record of glacier fluctuations as a point of reference. Holocene runs will be forced with proxy and modelled temperature data, and extensive sensitivity experiments will define an envelope of uncertainty around model parameters.

Quantifying carbon accumulation and loss in afforested peatlands

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Over the course of the Holocene the development of peatlands has led to the storage of up to 600 Gt carbon globally. There is a growing recognition that these deposits are of international importance, and must be understood and conserved. This was not always so. The Flow Country of northern Scotland is one of the largest blanket bogs in the world. During the late 20th Century the development of new planting techniques combined with tax incentives to encourage forestry across large areas peatland.

The effects of this planting are poorly understood. As many of the stands reach harvesting age, the question arises of whether the bogs should be restored. To address this it is of critical importance to quantify the loss of carbon from the peat, and evaluate it against the accumulation of carbon in trees.

Tephrochronology can be an important tool as part of a stock-based approach to quantify carbon in such systems. Peat deposits in the Flow Country are known to contain several layers cryptotephra originating from eruptions in Iceland (most notably Hekla 4). Recently developed core scanning techniques using x-ray fluorescence and x-radiography allow for rapid identification of these layers. The tephra may then be used to delineate isochrones in the peat, allowing for comparison between cores from forested stands and unplanted bog.

This interdisciplinary project uses paleoenvironmental techniques to answer current conservation questions. It will also provide one of the most complete records of tephra in the north of Scotland.

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University Park Campus

Nottingham Conferences

Conference delegate buildings

Chemistry Building	28
Coates Building	36
Coates Road Auditorium	51
East Midlands Conference Centre	58
Engineering & Science Learning Centre	54
George Green Library	24
Hallward Library	9
Highfield House	10
Humanities Building	55
Keighton Auditorium	56
Law & Social Sciences	7
Lenton Grove	5
Medical School	46
Music Building	33
Nottingham Conferences Cottage	59
Nottingham Lakeside Arts Centre	49/50
Pharmacy Building	26
Physics Building	22
Pope Building	27
Portland Building	15
Psychology Building	29
Sir Clive Granger Building	16
The Hemsley Building	8
Trent Building	11
Vaughan Parry Williams Pavilion	47

Other facilities

Cafés	7/8/9/11/15/16/36/49/50 & Cavendish Café
Bank/Shops/Food Court	15
Chemist	15/19
Library	9/24

NORTH ENTRANCE
Satnav code: NG7 2RD

bus stop

accommodation

conference venue

ice breaker

bus stop

tram stop

SOUTH ENTRANCE
Access in from the Beeston direction only. Exit towards the city centre only

WEST ENTRANCE
Satnav code: NG7 2QE

Wollaton Park

David Ross Sports Village

Swimming Pool

Sports pitch

Sherwood Hall

Derby Hall

Lincoln Hall

Lenton & Wortley Hall

Rutland Hall

Cripps Hall

Hugh Stewart Hall

Orchard Hotel

Interim Sports Centre

East Midlands Conference Centre

Millennium Garden

Sir Clive Granger Building

Nightingale Hall

Law & Social Sciences

Highfield House

Portland Building

Humanities

Cavendish Hall

Ancaster Hall

Willoughby Hall

Trent Building

Florence Boot Hall

Lakeside Arts Centre

Highfields Park

Nottingham City Council Tennis Centre

Nottingham Hockey Centre

Highfields Sports Ground

Vaughan Parry Williams Pavilion

Nottingham University Hospitals NHS Trust Queen's Medical Centre (QMC)

Jubilee Campus

Dunkirk

Priory Island

To M1 Jcn 25 (5 miles)

To M1 jcn. 26 (4.5 miles)

To Jubilee Campus (1 mile)

To Jubilee Campus and Innovation Park

To city centre (2.5 miles)

To city centre (3 miles)

To King's Meadow Campus (0.5 miles)

To M1 Jcn 24 (11 miles)

To Beeston

To Long Eaton

A52 Derby Road

A52 Clifton Boulevard

A6514 Middleton Boulevard

A6200 Derby Road

A6005 Abbey Street

A6005 University Boulevard

A6464

Broadgate

Beeston Road

Ring Road

Triumph Road

Cloister Street

Lenton Hall Drive

Library Road

Science Road

East Drive

Cut Through Lane

Jubilee Avenue

Lakeside walk

Pedestrian/cycle route to Jubilee Campus

- Conference delegate buildings
- Conference accommodation
- Sports facilities
- Other University buildings
- Conference parking zones
- P Conference parking
- Blue-badge parking
- PD Pay & Display parking
- Hopper bus stop
- Public bus stop
- Footpaths
- Tram stop
- One-way traffic

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0 metres 200

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Nottingham Conferences Walking Guide

nottingham city centre

parks mart

Nottingham City Council

Safe r, cleane r, ambitious
Nottingham
A city we're all proud of

Where do I find?

Information points

Broadmarsh Shopping Centre	(J7)	1
NCT Travel Centre	(H6)	2
Nottingham Railway Station	(L8)	3
Nottingham Tourism Centre	(H7)	4
Victoria Centre	(F7)	5

Shopping

Bridlesmith Gate	(I7)	
Broadmarsh Shopping Centre	(J7)	1
Clumber Street	(G7)	
Derby Road	(G2)	
Exchange, The	(H7)	6
F H Mall	(H7)	7
Hockley	(H10)	
Lister Gate	(J7)	
Victoria Centre	(F7)	5

Entertainment

Albert Hall	(G4)	8
Broadway Media Centre	(G9)	9
Cornerhouse, The	(G6)	10
Lace Market Theatre	(I8)	11
Nottingham Arts Theatre	(H8)	12
Nottingham Playhouse	(H4)	13
Rock City	(F4)	14
Royal Centre - Royal Concert Hall, Theatre Royal	(G6)	15
Sky Mirror	(H3)	16
Trent FM Arena	(H10)	17

Places of Interest and Key Attractions

Bonington Art Gallery	(E5)	18
Brewhouse Yard Museum	(K5)	19
Brian clough Statue	(H6)	20
Castle Gatehouse	(J5)	21
Castle Museum and Art Gallery	(K4)	22
City of Caves	(J8)	23
National Ice Centre	(H10)	17
NCCL Gallery of Justice Museum	(J9)	24
Nottingham Castle	(K4)	25
Nottingham Contemporary	(J8)	26
Old Market Square	(H6)	27
Robin Hood Statue	(J5)	28
Speakers' Corner	(H6)	29
Victoria Clock Tower	(E7)	30
Ye Olde Trip to Jerusalem	(K5)	31

Public Offices, Community Centres and Facilities

BBC East Midlands	(K10)	32
Central Library	(H5)	33
Citizens Advice Bureau	(L7)	34
Council House	(H6)	35
Crown and County Courts	(K8)	36
Fire Station	(E6)	37
Guildhall	(F6)	38
HMRC - Inland Revenue	(M4)	39
International Community Centre	(D6)	40
Job Centre (Canal Street)	(K9)	41
Job Centre (Parliament Street)	(G5)	42
Magistrates' Court	(L6)	43
NHS Walk in Centre	(K11)	44
Nottinghamshire Archives	(L6)	45
Police	(F6)	46
Post Office	(G6)	47
Public Toilets (Greyhound Street)	(H7)	48
Trading Standards	(E6)	49
Victoria Leisure Centre	(G11)	50
YMCA	(E7)	51

Centres of Learning

Castle College	(K6)	52
New College Nottingham	(H9)	53
The Nottingham Trent University	(F5)	54

Places of Worship

Central Methodist Mission	(G8)	55
Christian Centre	(F2)	56
Congregational Church	(I6)	57
Friends Meeting House	(E3)	58
Islamic Centre	(F9)	59
Nottingham Buddhist Centre	(H8)	60
St Andrew's with Castle Gate (URC)	(F5)	61
St Barnabas RC Cathedral	(G3)	62
St Mary's Church	(J9)	63
St Nicholas' Church	(J6)	64
St Peter's (& St James') Church	(I7)	65
Synagogue	(E5)	66
Unitarian Chapel	(I10)	67
William Booth Memorial Hall	(F9)	68

Transport Points

Bus Stations

Broadmarsh	(K7)	69
Victoria	(E7)	70

Train Station

Nottingham Railway Station	(L8)	3

Tram Stops

Lace Market	(H8)	B
Nottingham Trent University	(E5)	E
Old Market Square	(H6)	C
Royal Centre	(G5)	D
Station Street	(L8)	A

Car Parks

Arndale	(K6)	1
Broadmarsh	(K8)	2
Fletcher Gate	(I8)	3
Huntingdon Street	(E8)	4
Mount Street	(H4)	5
Nottingham Railway Station	(M)	6
Queen's Bridge Road	(M7)	7
St James's Street	(I5)	8
Stoney Street	(I9)	9
Talbot Street	(F4)	10
Trinity Square	(F7)	11
Upper Parliament Street	(G5)	12
Victoria Centre North	(E7)	13
Victoria Centre South	(F8)	14
Wollaton Street	(G5)	15

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