Quaternary Research Association

UNIVERSITY OF CAMBRIDGE

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

20th Annual Postgraduate Symposium

2nd - 4th September 2015

BETA

QRA
Quaternary Research Association

Welcome!

Welcome to the 20th Annual Quaternary Research Association Postgraduate Symposium at the Scott Polar Research Institute, Cambridge.

We are delighted to announce a fantastic line-up of talks and posters from postgraduate students studying Quaternary science across the country.

The QRA postgraduate symposium is a great opportunity for postgraduate students to present work in a relaxed environment and to meet fellow students researching a wide range of Quaternary topics. We hope that you really enjoy the next few days and make friends that will last throughout your academic career.

If there is anything that we can do to make your stay more enjoyable, please don't hesitate to get in touch with any one of us.

On behalf of all of us… thanks for coming along and enjoy Cambridge!

Your QRAPG committee ☺

Our numbers (in case you have any trouble finding venues)

Ashleigh Massam: 07889038088
Michelle McCrystall: 07761602434
Jenny Roberts: 07811073033
Tom Williams: 07971564538

Contents

QRA Postgrad Reps

My name's Chris Darvill. I'm the postgraduate representative on the QRA executive committee for 2013-2015. I work at the British Antarctic Survey, but I've recently finished studying for my Ph.D. at Durham University on the timing of glaciations in southern Patagonia. Before that, I did the Quaternary M.Sc. course at Royal Holloway and a B.Sc. in Geography at Exeter University. This is my fourth postgraduate symposium (they're great fun) and I've also been to various QRA Annual Discussion Meetings and Field meetings. I would really recommend attending these other sorts of meetings as well as the postgraduate symposiums, as they're always friendly and welcoming and are great ways to get to know academics at other institutions. Have a look on the QRA website to see all of the meetings being planned for the future.

As the QRA postgraduate representative, I attend meetings several times a year where I let the rest of the committee know what the postgraduate members think about the QRA (following the annual symposium), and also speak on behalf of postgraduates during decisions being made about the running of the organisation. This can be important given that some of the funding opportunities are only for postgraduate members, and we also form a large part of many QRA meetings and are (probably) the largest consumers of the QRA social media! The postgraduate representatives are in charge of the QRA facebook and twitter accounts and are the link between the QRA postgraduate community and the rest of the organisation – so let us know what you think of how it's run!

My name's Jack Lacey. I am currently entering into my fourth year of Ph.D. study at the University of Nottingham, looking at lakes, isotopes, and climate change in the Mediterranean region. I have the great privilege of being part of a large international multi-disciplinary project that is trying to better understand the influence of climate and geological events on biological evolution in lakes. However, more about that in my talk and poster! This will be my third QRAPG symposium, and I am very much looking forward to it as they are a great place to meet other postgrads and hear about such a wide variety of interesting research topics. For the past year I have been the junior postgraduate representative on the QRA executive committee, a role I would highly encourage everyone to consider nominating themselves for at the AGM. Apart from adding to the CV, this position enables you to see some of the inner workings of the QRA and get actively involved in discussions that shape the organisation. If you have any questions about becoming a PG rep or about the post, come find me at the symposium!

Wednesday 02/09/15

QRAPG15 on tour to the British Antarctic Survey

13:00	Coach Pick-up from Cambridge Railway Station
13:30	Coach Pick-up from Queens Road near the centre of town
14:00	Coach Arrives at BAS, Registration, Introduction in the Conference Room, Separation into four groups
14:15	Tour starts (Stations: Ice Cores, Fossils, Acquarium, MAGIC)
16:15	Tour ends in the Conference Room
16:30	Coach departs to town centre and Trinity College for check-in
18:30-20:30	**Ice breaker in the Sedgwick Museum of Earth Sciences, Downing Site, University of Cambridge**

Thursday 03/09/15

Welcome

09:00-09:30	Michelle McCrystall	Welcome, Introduction, Safety announcements

Ice cores/Antarctica

09:30-10:30	Robert Mulvaney	Ice core evidence of climate change and deglaciation in the Weddell Sea region
10:30-11:00	**Coffee Break**	**Foyer**
11:00-11:15	Pablo A. Heredia Barión	The reconstruction of glacial phases on the North-Western Antarctic Peninsula from on-land glacier-movement indicators

Ocean circulation

11:15-11:30	Rowan Dejardin	A deglacial and Holocene oceanographic record from the South Georgia region of the Southern Ocean: preliminary results from micropalaeontological and isotopic analysis
11:30-11:45	Jenny Roberts	Evolution of South Atlantic Density and Chemical Stratificaton across the Last Deglaciation
11:45-12:00	Tom Williams	Continuous Ventilation of the Southern Ocean during Quaternary Glacial-Interglacial Cycles
12:00-13:00	Babette Hoogakker	Determining past ocean oxygen concentration: an example from the North Atlantic
13:00-14:00	**Lunch**	**Foyer**
14:00-14:15	Jacob Howe	A 1.5 Myr history of Atlantic Meridional Overturning Circulation from Nd isotopes
14:15-14:30	Julia Gottschalk	Ventilation of the deep Southern Ocean and changes in atmospheric CO2 during the last deglacial and glacial periods

Palaeoclimate reconstructions (UK)

14:30-14:45	Kevin Schiele	Stratigraphic Evidence for Glacial Sedimentation on the Western Irish Shelf during the Quaternary
14:45-15:00	Della Murton	Reconstructing rates of palaeoenvironmental change during the last glacial period from glaciolacustrine sediments in the Vale of York, UK
15:00-15:30	***POSTERS***	**Foyer**
15:30-16:00	***COFFEE/POSTERS***	**Foyer**
16:00-17:00	***POSTERS***	**Foyer**

Dinner

18:30-21:30	***Conference Dinner***	**University Centre, Granta Place**

Friday 04/09/15

Palaeoclimate reconstructions (UK)

9:00-09:15	Melissa Marr	Climatic instability and ecomorphological change in *Microtus agrestis* and *Microtus arvalis* over the Pleistocene-Holocene boundary
9:15-9:30	Samantha Bromfield	Assessing the genesis of Periglacial Ramparted Depressions (PRDs) by characterising internal structures macroscopically and microscopically
9:30-9:45	Rachael Avery	Seasonally laminated sediments of Windermere, UK as a record of Devensian deglaciation

Palaeoclimate reconstructions (Eurasia)/Northern hemisphere quaternary

9:45-10:00	Sonja Felder	Geochemical insights into the Mid-Pleistocene Transition (MPT) in the Asian Monsoon (IODP Expedition 346, Site U1427, JapanSea)
10:00-10:15	Jack Lacey	The Lake Ohrid Drilling Project: initial interpretations of stable isotope data over the last 640 ka
10:15-10:30	Yajun Li	Evolution of Quaternary alluvial fans in the eastern margin of the Tibetan Plateau and implications for the controlling factors
10:30-11:00	**Coffee Break**	**Foyer**
11:00-11:15	Rachel Patterson	Reconstructing postglacial landscape evolution following the drainage of glacial Lake McConnell, Northwest Territories, Canada: insights from biological proxy data.
11:15-11:30	Alwynne McGeever	Population dynamics of *Pinus* and *Ulmus* in Europe during the Holocene
11:30-11:45	Margaret Smith	The Climatic Impact of Anthropogenic Land Use Change Throughout the Holocene
11:45-12:00	Josie Duffy	Stable Carbon Isotope Dendroclimatology in the Jotunheim region of central, southern Norway
12:00-12:15	Jennifer Adams	Investigating the extent of natural and anthropogenic disturbances within shallow lakes of the Selenga River Delta, Siberia
12:15-12:30	Donna Hawthorne	A Scorched Past: Investigating past fire regimes throughout the Holocene in Ireland
12:30-13:00	Lucy Gonzalez	Funding opportunities: The pot of gold at the end of the rainbow, and how to get at it
13:00-14:00	**Lunch**	**Foyer**

Palaeoclimate reconstructions of equatorial regions

14:00-14:15	Esther Githumbi	A 15000 year environmental history of the Eastern Mau Forest, Kenya.
14:15-14:30	Richard Smith	Amazonia under mid-Holocene drought
14:30-14:45	Heather Plumpton	Amazonia and the 6K drought
14:45-15:00	Jonathan Hassall	Static or dynamic? Reconstructing potential past movement of the South Pacific Convergence Zone

Presenter	Abstract title
Icecores/Antarctia	
Ashleigh Massam	Application of ultra-high resolution direct trace-element analysis on glacial ice from Weddell Sea deep ice cores, West Antarctica.
Magnus Makeschin	The potential of raised beaches for the reconstruction of glacial advances
Palaeoclimate reconstructions Southern hemisphere Quaternary	
Christopher Darvill	Evaluating the timing and cause of glacial advances in the southern mid-latitudes during the last glacial cycle
Palaeoclimate reconstructions (Eurasia)/Northern hemisphere quaternary	
Nick Primmer	Mid-low latitude Holocene climate change using varve analysis
C Rootes	What is a glacial trimline?
Jenni Robertston	A novel way of determining uplift over the late Quaternary: synchronous correlation between multiple palaeoshorelines and multiple sea-level highstands.
Jack Longman	The smelting of metals in the Romanian Carpathians throughout the Holocene
Poppy Harding	Ecosystem resilience to abrupt climatic and environmental change in southern Siberia since the Last Glacial Maximum
Laura Deeprose	Preliminary Results from Perlas Cave: Capturing Climate during the Neanderthal Demise
Jack Lacey	A high-resolution Late Glacial to Holocene stable isotope and geochemical record from Lake Ohrid (Macedonia/Albania)
Palaeoclimate reconstructions (UK)	
Samantha Bromfield	Assessing the genesis of Periglacial Ramparted Depressions (PRDs) by characterising internal structures macroscopically and microscopically
Lauren Knight	Timings and dynamics of glaciation in the Wicklow Mountains, Ireland
Dot McCarthy	Morphometric analysis of the erosional style of Younger Dryas ice in Scotland
Catriona Purcell	Establishing the indicative meaning of ice-rafted detritus: ice sheet advance, collapse, or both?
Geoffrey Richards	Holocene sea-level changes in Wales: a combined empirical and model-based approach
Francesca Falcini	Roughness of palaeo-ice stream beds
Laura Crossley	Assessing the safe operating space for nutrient loads to river estuaries: a palaeoenvironmental approach to estuary management
Ocean circulation	
Emma Freeman	Radiocarbon based evidence for a significant role of the Atlantic Ocean in deglacial atmospheric CO_2 rise

Keynotes

We are excited to announce the following keynote talks:

Rob Mulvaney
(British Antarctic Survey, Cambridge)
"Ice core evidence of climate change and deglaciation in the Weddell Sea region"

Robert Mulvaney leads the 'Ice Dynamics & Palaeoclimate' science team at the British Antarctic Survey. His expertise lies in analytical chemistry and palaeoclimatology; special interests include millennial-scale climate change, trace gases in ice and firn as evidence of anthropogenic changes to the atmosphere. He is responsible for the BAS ice core analytical programme, as well as for the BAS ice core drilling operations in Antarctica.

Babette Hoogakker
(Department of Earth Sciences, University of Oxford)
"Determining past ocean oxygen concentration: an example from the North Atlantic"

Babette Hoogakker is part of the 'Ocean Biogeochemistry' and 'Isotopes and Climate' research groups at the University of Oxford.Her career had auspicious beginnings with her participation in the Quaternary Research Association Postgraduate Symposium during her PhD. She now specialises in the use of foraminiferal isotope and trace metals to study the interaction between biogeochemical cycles, large-scale ocean circulation and climate change. Her recent work has seen her focus on novel proxy-based methods to reconstruct glacial-interglacial deep water oxygen concentrations and respired carbon.

Lucy Gonzalez
(Anglia Ruskin University, Cambridge)

"Funding opportunities: The pot of gold at the end of the rainbow, and how to get at it"

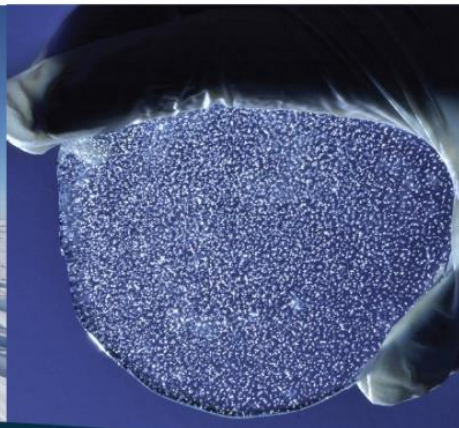
Having managed funded research projects at the British Antarctic Survey in Cambridge for several years, and now managing the European and International funding efforts at Anglia Ruskin University, Lucy Gonzalez is a tremendous source of information on all kind of funding opportunities that will be relevant and of interest for any post-doctoral researcher.

20th QRA Postgraduate Symposium

Tour of British Antarctic Survey

Wednesday 2nd September 2015

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

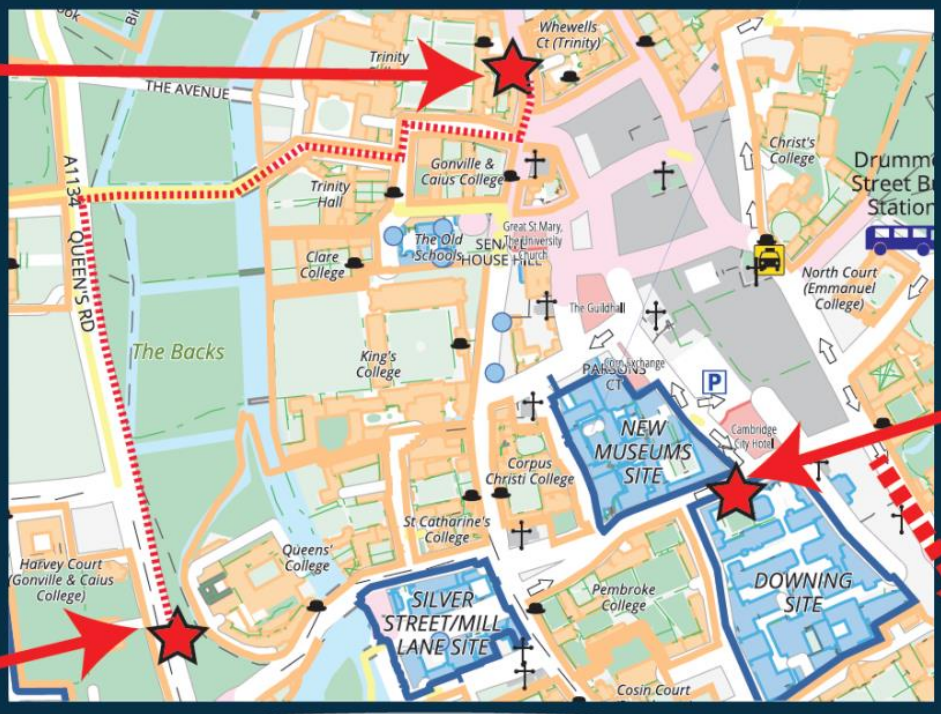


QRAPG 2015 would like to invite you to join us on a tour of the British Antarctic Survey – come and visit the facilities at a truly world class research institution! The tour will take in the ecosystems and evolutionary research aquarium facilities, as well as marine geology and ice core laboratories.

Coach pickup will be at 13:00 from directly opposite the entrance to Cambridge Railway Station on Station Road and 13:30 from Queens Road near the corner of Queens Road and Silver Street. The coach will be a brown Richmonds coach. There will also be a member of the conference committee to meet people at both the station and Queens Road stops.

Bags and luggage can be left on the coach and we will return into town at 16:30 – please bring something to eat if you think you might get hungry!

Trinity college accomodation



Icebreaker

Queens Road coach pickup at 13:30 / dropoff into town around 16:45

To Cambridge Railway Station

QRAPG.SOC.SRCF.NET
QRAPG2015@ESC.CAM.AC.UK

QRA Quaternary Research Association
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NATURAL ENVIRONMENT RESEARCH COUNCIL

Icebreaker!

Join us in the company of dinosaurs for a not-so-terrifying Icebreaker event in the Sedgwick Museum.

6:30-8:30pm

Wednesday 2nd September

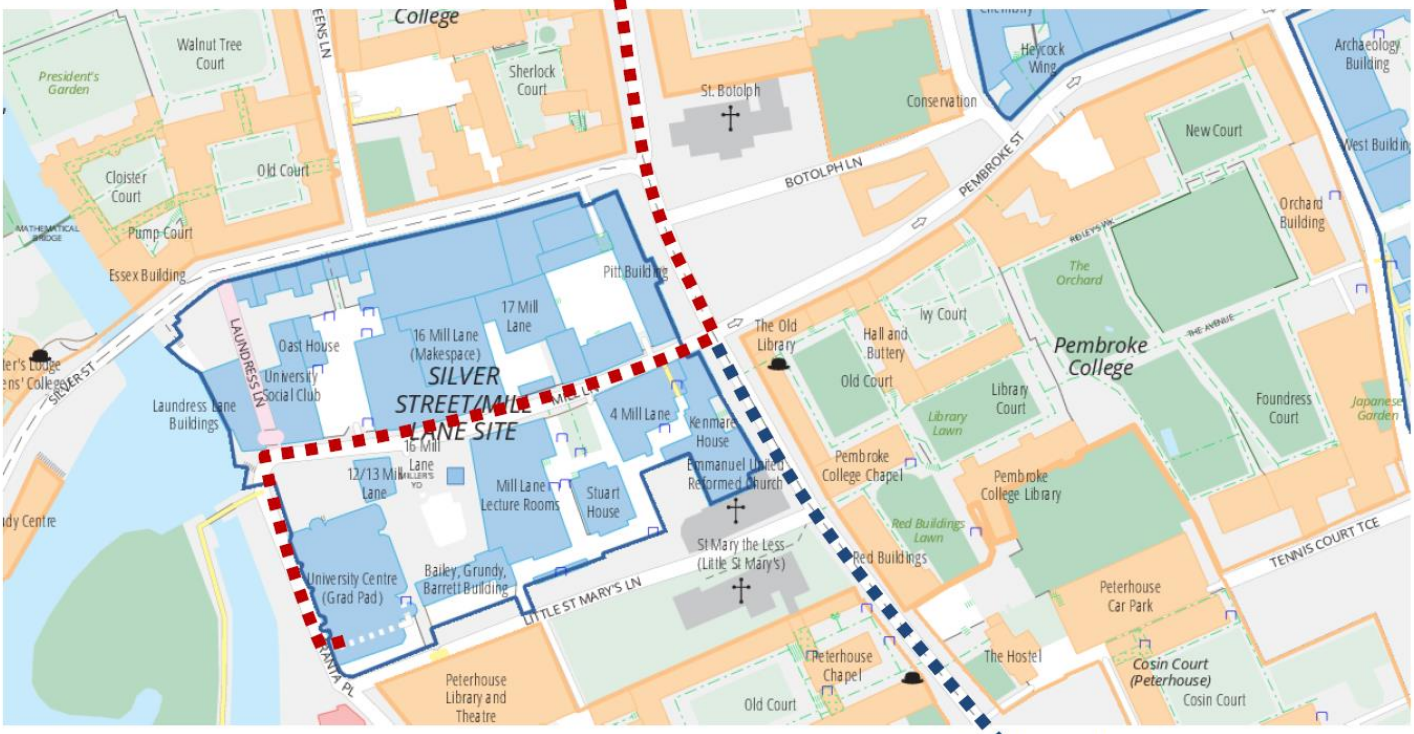
RIVERSIDE RESTAURANT

The conference dinner will be held in the Riverside Restaurant, part of the University Centre on **Thursday 4th September**.

6:30pm onwards...

We look forward to seeing you there!

From Trinity College



From the Scott Polar Research Institute

SESSION 1:

Ice Cores/ Antarctica

Chair: Ashleigh Massam

The reconstruction of glacial phases on the North-Western Antarctic Peninsula from on-land glacier-movement indicators

Pablo A. Heredia Barión[1,4,*], Magnus Makeschin[2,4], Jorge A. Strelin[3], Gerhard Kuhn[4]

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In contrast to off- and near-shore geomorphological and stratigraphical studies on former glacier dynamics on the Antarctic Peninsula, such studies on ice-free areas on-land are scarce. In order to contribute to the reconstruction of past glacial configurations and the deglaciation history of this region, further investigations should be conducted on correlating off-shore glacial landforms with glacial landforms on-land. Because of the retreating ice cover during the last 60 years, new coastal areas, bedrock outcrops, glacial landforms and their stratigraphic exposures have been exposed. The objective of this presentation is to show how glacial landforms on ice-free areas could be used as indicators for former glacier-movement on-land in the region of the North-Western Antarctic Peninsula, providing useful data to reconstruct former glacial configurations.

Field geomorphological mapping and remote sensing carried out on recent on-land ice-free areas on King George Island, South Shetland Islands, show glacial erosive and depositional landforms, such as glacial striae, grooves, roche moutonnées, drumlinoid and fluted forms, meltwater channels, U-shaped valleys and cirques as well as ice-marginal moraines. Those indicators were used to reconstruct the ice flow pattern and the extent of different glacial phases over time, based on their glaciological significance, cross-cutting relationships, orientation and location. Combining erosive and depositional landforms, it can be concluded that a glacier with subglacial load, ice-marginal deposition and active erosion at its wet based bed formed those glacial landforms. Furthermore, these glacial landforms, associated with those from adjacent off-shore areas of King George Island propose the existence of at least three glacial advances during the last 20 cal ka BP within the studied region, if correlated with already published (Del Valle et al. 2007, Ó Cofaigh et al. 2014) chrono-stratigraphical records.

References:

Del Valle, R. A., Montalti, D., Inbar M., y Boaretto E. (2007). Holoceno marino en la Península Potter, isla 25 de Mayo, Antártida. *Revista de la Asociación Geológica Argentina* 62 (1): 35-43.

Ó Cofaigh, C., Davies, B.J., Livingstone, S.L., Johnson, J., Smith, J., Anderson, J.B., Bentley, M.J., Canals, M., Dowdeswell, J.A., Evans, J., Glasser, N.F., Hillenbrand, C.-D., Hodgson, D., Larter, R.D., and Domack, E. (2014). Reconstruction of ice sheet changes in the Antarctic Peninsula sector since the Last Glacial Maximum. *Quaternary Science Reviews* 100: 87-110.

SESSION 2:

Ocean Circulation

Chair: Julia Gottschalk

A deglacial and Holocene oceanographic record from the South Georgia region of the Southern Ocean: preliminary results from micropalaeontological and isotopic analysis

Rowan L.S. Dejardin[1,2]*

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* *rowan.dejardin@nottingham.ac.uk*

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 in this ocean have varied since the last glaciation. Here, we present preliminary proxy records for productivity and temperature from a sediment core on the continental shelf east of South Georgia spanning the last 15 kyrs. South Georgia is of particular significance because it sits in the path of the Antarctic Circumpolar Current (ACC), between the Antarctic Polar Front (APF) and the Southern ACC Front (SACCF). The interaction of the SACCF with the South Georgia shelf is the primary nutrient source fuelling an intense phytoplankton bloom to the north-west of South Georgia, forming the largest seasonal sink of atmospheric CO_2 in the Southern Ocean (Jones et al., 2012). Determining past changes to primary productivity, driven by processes such as the interaction of the SACCF with the South Georgia shelf, deglacial out-washing and wind-driven dust, will provide insights into natural variability in the ACC from the deglacial to the present, and potentially about the bloom's sensitivity to variation in the Southern Hemisphere Westerly Winds (SHW) and the Southern Annular Mode (SAM).

Initial work has focussed on a single marine sediment core (GC666) collected by the British Antarctic Survey offshore South Georgia in 2012. Radiocarbon dating indicates a basal age of ca. 15000 cal. yr BP, with a very high initial sedimentation rate (~580 cm/kyr) that decreases to 16 cm/kyr towards the top of the core. Preliminary micropalaeontological (foraminiferal assemblage) and geochemical proxy data (foraminiferal $\delta^{13}C$ & $\delta^{18}O$), in addition to more complete XRF and organic carbon (TOC, TN, $\delta^{13}C$) data, from this core are interpreted here in terms of variation in temperature and productivity, revealing deglacial and Holocene variation in oceanographic conditions. Benthic foraminiferal assemblages are dominated by *Fursenkoina fusiformis* (which may be indicative of large pulses of phytodetritus (e.g. Gooday et al., 2012)), *Miliammina arenacea* (typical of the cold, saline waters around Antarctica (e.g. Peck et al., 2015)), *Globocassidulina crassa* and *Astrononion echolsi*. Ongoing work is currently increasing the resolution of the foraminiferal assemblage and isotope datasets, and future work aims to produce an alkenone sea-surface temperature (SST) record for the core.

References:

Gooday, A. J. et al. (2012). The influence of productivity on abyssal foraminiferal biodiversity. *Marine Biodiversity* 42(4): pp 415-431.

Jones, E. M. et al. (2012). Dynamic seasonal cycling of inorganic carbon downstream of South Georgia, Southern Ocean. *Deep-Sea Research II* 59: pp 25-35.

Peck, V. L. et al. (2015). Oceanographic variability on the West Antarctic Peninsula during the Holocene and the influence of upper circumpolar deep water. *Quaternary Science Reviews* 119: pp 54-65.

Evolution of South Atlantic Density and Chemical Stratification across the Last Deglaciation

Jenny Roberts[1,2] *, Julia Gottschalk[1], Luke C. Skinner[1], Victoria L. Peck[2], Sev Kender[3,4], Harry Elderfield[1], Claire Waelbroeck[5], Natalia Vázquez Riveiros[5], David A. Hodell[1]

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[2] *British Antarctic Survey, Cambridge;*
[3] *Centre for Environmental Geochemistry, University of Nottingham ;*
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[5] *Laboratoire des Sciences du Climat et de l' Environnement, Gif-sur-Yvette*
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Explanations of the glacial-interglacial variations in atmospheric pCO_2 invoke a significant role for the deep ocean in the storage of CO_2. Deep ocean density stratification has been proposed as a mechanism to promote the storage of CO_2 in the deep ocean during glacial times. A wealth of proxy data exists supporting the idea of a "chemical divide" between intermediate and deep water in the glacial Atlantic Ocean, which indirectly points to an increase in deep ocean density stratification. However, direct observational evidence of changes in the primary controls of ocean density stratification, i.e. temperature and salinity, remain scarce.

In this study, we present proxy reconstructions showing the evolution of the physical density gradient in high-latitude South Atlantic over the last deglaciation. Mg/Ca-derived seawater temperature estimates combined with salinity estimates determined from temperature-corrected $\delta^{18}O$ measurements on the benthic foraminifer *Uvigerina spp.* from deep and intermediate water-depth marine sediment cores are used to reconstruct the changes in density of sub-Antarctic South Atlantic water masses over the last deglaciation. Comparison is made between the evolution of the density gradient and benthic $\delta^{13}C$ and ^{14}C records from the two sites in order to assess the hypothesis of a causal link between the physical and chemical properties of the deglacial ocean.

Our records suggest that the major breakdown in the physical density stratification significantly lags the breakdown of the deep-intermediate chemical divide. The main chemical destratification event coincided with the early deglacial increase in atmospheric pCO_2, whereas the density destratification of the deep South Atlantic occurred at the onset of the Holocene. Our findings emphasise that the physical and chemical destratification of the ocean are not as tightly coupled as generally assumed. We argue that at least in the South Atlantic, physical ocean density destratification was not a major driver of atmospheric CO_2 change during the last glacial termination.

Continuous ventilation of the Southern Ocean during Quaternary glacial-interglacial cycles

Thomas J Williams[1,2*], Claus-Dieter Hillenbrand[1], Alexander M Piotrowski[2], David A Hodell[2], Claire S Allen[1], Thomas Frederichs[3], James A Smith[1], Werner Ehrmann[4]

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[2]*Department of Earth Sciences, Cambridge University, Downing Street, Cambridge CB2 3EQ, UK.*

[3]*Department of Geosciences, University of Bremen, PO Box 330 440, 28334 Bremen, Germany.*

[4]*Institute for Geophysics and Geology, University of Leipzig, Talstrasse 35, D-04103 Leipzig, Germany.*

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Changes in the concentration of carbon stored in the deep sea play a key role in past climatic change. Low carbon isotopic compositions observed in the Atlantic sector of the Southern Ocean (SO) during glacial periods suggest that this ocean was an important glacial-time carbon sink. Here we present carbon isotope data from planktic and benthic foraminifera at a site in the Amundsen Sea, Pacific sector of the SO that was bathed continuously by upwelling deep water throughout the last 800 kyrs. These records show that the carbon-rich glacial-time water mass was confined to the deep Atlantic and the SO's Atlantic and Indian sectors vertically by its high density and horizontally by bathymetric barriers. Much of the glacial SO outside of the Atlantic sector was well ventilated, reducing the capacity of glacial increases in biological productivity to account for decreased atmospheric CO_2.

A 1.5 Myr history of Atlantic Meridional Overturning Circulation from Nd isotopes

Jacob N. W. Howe*, A. M. Piotrowski[2]

[1] *Department of Earth Science, University of Cambridge, CB2 3EQ*
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Changes in Atlantic Meridional Overturning Circulation play an important role in modulating global climate by controlling northward heat transport in the surface ocean and carbon storage in the deep ocean. Here we present a new 1.5 Myr record of neodymium isotopes measured on uncleaned planktic foraminifera and fish debris from ODP Site 929 [6.0°N, 43.7°W, 4356 m] on the Ceara Rise in the western equatorial Atlantic Ocean. This record allows investigation of changes in Atlantic overturning across the glacial-interglacial cycles of the Quaternary. The record reveals fundamental changes in overturning across the Mid-Pleistocene Transition as well as providing new insight into the relationship between climate and ocean circulation during the period known as the "lukewarm" interglacials. The Nd isotope shifts broadly correlate with benthic foraminiferal $\delta^{13}C$ and $\delta^{18}O$ from the same core, however periods of significant decoupling between $\delta^{13}C$ and ε_{Nd}, particularly during glacial periods, indicate that deep Atlantic water mass mixing proportions and nutrient chemistry can vary independently of one another.

Ventilation of the deep Southern Ocean and changes in atmospheric CO_2 during the last deglacial and glacial periods

Julia Gottschalk[1*], Luke C. Skinner[1], Jörg Lippold[2], Samuel Jaccard[2], Hendrik Vogel[2], Norbert Frank[3], Claire Waelbroeck[4]

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The Southern Ocean is thought to have played a key role in atmospheric CO_2 ($CO_{2,atm}$) variations, both via its role in bringing carbon-rich deep-waters into contact with the atmosphere, and via its capacity for enhanced biologically mediated carbon export into the deep sea. The governing mechanisms of millennial scale rises in $CO_{2,atm}$ during the last deglacial and glacial periods have been linked controversially either with variations in biological export productivity, possibly driven by fluctuations in airborne dust supply, or to variations in southern high-latitude vertical mixing, possibly driven by changes in westerly wind stress or density stratification across the Southern Ocean water column. However, the impact of these processes on deep, southern high-latitude carbon sequestration and ocean-atmosphere CO_2 exchange remain ambiguous. We present proxy evidence for the link between deep carbon storage in the sub-Antarctic Atlantic with changes in $CO_{2,atm}$ during the last 70 ka from sub-millennially resolved changes in bottom water oxygenation based on the uranium accumulation in authigenic coatings on foraminiferal shells and the $\Delta^{13}C$ offset between epibenthic and infaunal foraminifera $\Delta\Delta^{13}C$. We compare our results with reconstructed opal fluxes and sediment model output data to assess the impact of physical and biological processes on Southern Ocean carbon storage. While variations in sub-Antarctic Atlantic export production are intrinsically linked with changes in airborne dust supply supporting the major impact of dust on the biological soft-tissue pump, they cannot account for observed changes in pore water organic carbon respiration indicated by increasing $\Delta\Delta^{13}C$ and therefore, bottom water oxygen changes in the deep sub-Antarctic Atlantic. This is in strong support of millennial-scale fluctuations in deep Southern Ocean carbon storage primarily controlled by the ventilation of the deep ocean by southern-sourced water masses, which emphasize the strong control of vertical mixing and upwelling of CO_2-rich water masses in the Southern Ocean on the ocean-atmosphere exchange of CO_2 and variation in $CO_{2,atm}$ over both glacial-interglacial and millennial time scales.

SESSION 3:

Palaeoclimate reconstructions

(UK, Ireland)

Chair: Tom Williams

Stratigraphic Evidence for Glacial Sedimentation on the Western Irish Shelf during the Quaternary

K. Schiele[1]*, S. Benetti[1], H. Haflidason[2], E. L. King[3], C. Ó Cofaigh[4], H. P. Sejrup[2], A. J. Wheeler[5], P. Dunlop[1]

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Previous studies show that the western Irish shelf has undergone major glaciations at least since the earliest Pleistocene. Evidence for grounded ice masses of the British-Irish Ice Sheet have been discovered on the seafloor of the western Irish shelf but are yet to be studied sub-surface.

This study investigates the Cenozoic seismic stratigraphy of the western Irish shelf using seismic data stretching from nearshore to portions of the outer shelf from west of Donegal Bay (55°N) to the Porcupine Ridge (51°N). The results facilitate an assessment of the dimensions and extent of major glaciations throughout the Quaternary period and their influence on sedimentary processes on the western European margin.

The dataset consists of 77 seismic lines that have been made available through the Irish Petroleum Affairs Division (PAD), the Marine Institute/INSS and were obtained on the R/V Håkon Mosby in 1997 and R/V Celtic Explorer in 2014, respectively. The seismic gear used include 20-3675 in^3 airgun arrays at frequencies of <150 Hz; a sparker system at frequencies of 750-2250 Hz and a pinger system at a frequency of 3.5 kHz. Vertical resolutions range from 0.2 m to ~10 m depending on the seismic source. Airgun data were processed and filtered by PAD. Both, sparker and pinger data were processed and analysed using the software CODA. Furthermore, geological data of 11 boreholes, accessed through PAD, were used for ground-truthing the airgun data. Intervals identified in borehole data were correlated to seismic units allowing an age estimate for the Cenozoic stratigraphy.

The last glaciation(s) left a rich geological and geomorphological record on the western Irish shelf such as moraines, basin infills and iceberg scours. The largest feature is a moraine found at about mid-shelf, which stretches from 54°04'N to 52°45'N (160 km) along the -160 m isobath about 160 km offshore Galway Bay. Airgun profiles crossing this 20 km wide moraine reveal its internal stratigraphy that consists of up to ~100 m thick sedimentary units, for the first time. In general, unconsolidated sediment units are rather thin towards the inner shelf as well as towards the shelf edge. On a smaller scale, incised features, in between seismic units, landward of the moraine are about 16 m high and 500 m wide and are thought to be created during a fall in relative sea level resulting in subaerial channelling of supposedly glacial diamicts and the formation of troughs. Infill of the troughs (low impedance reflectors) is thought to consist of marine muds deposited following eustatic rise in sea level due to deposition in low-energy environments. Prograding sedimentary sequences are identified in airgun data from the shelf edge NW off Donegal Bay. The entire sedimentary succession is ~80 m thick and is interpreted as a series of glacial advances towards the shelf edge that, based on correlations to borehole data, occurred basically during the Quaternary period.

Reconstructing rates of palaeoenvironmental change during the last glacial period from glaciolacustrine sediments in the Vale of York, UK

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Currently there exists a disparity between the terrestrial and marine records regarding the rates of growth and retreat of the British-Irish Ice Sheet (BIIS) during the last glacial period (Middle – Late Devensian substages, ~Marine Isotope Stages (MIS) 4–2). Models reconstructed from marine cores in the North East Atlantic Ocean have indicated that the BIIS may have: (1) been initiated c. 45 ka, with significant build-up from c. 28 ka, at the MIS 3–2 transition; (2) fluctuated with periodicities comparable to the Dansgaard–Oeschger cycles. These findings have yet to be corroborated within the terrestrial record.

Four near-continuous cores were drilled to bedrock through the basin fill in the Vale of York, the site of a former glacial lake (Lake Humber). High resolution sedimentary and geochemical analyses of these sediments, and of adjacent superficial deposits and bedrock lithologies, has enabled the first detailed, continuous record into the rates of palaeoenvironmental change in Britain during Middle – Late Devensian substages. A preliminary age model – determined by correlating colour reflectance data with the $\delta^{18}O$ records from NGRIP and Hulu Cave, China – suggests sedimentation began in the former lake basin at ~42 ka, consistent with the off-shore records. These basal silty sands are overlain conformably by glaciolacustrine sediments: laminated to massive silt and silty clay, and interbedded silt and silty sands. Primary sedimentation continued until at least 16.5 ka.

Provenance of the basin fill has been investigated using end-member modelling of the geochemical and reflectance data. Critically, this approach indicates the possibility of distinguishing sediments primarily derived from periglacial processes acting on the surrounding non-glaciated terrain, from those emplaced by glacial meltwater. Applied to the basin fill, our results indicate: (1) an ice lobe occupied the North Sea during much of the Middle – Late Devensian (~MIS 3–2), releasing meltwater that episodically drained westwards into the Vale of York; (2) a southerly-flowing ice lobe advanced into Lake Humber almost at the end of the lake's recorded history.

Climatic instability and ecomorphological change in *Microtus agrestis* and *Microtus arvalis* over the Pleistocene-Holocene boundary

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The interaction between genotype and environment is recognized as a major factor responsible for the generation and maintenance of phenotypic variation within and among populations. As a key component of a species' environment, climate is considered a strong driver of biological evolution and is known to exert selective pressures on particular morphological features. While climate-driven evolution in Late Pleistocene megafauna has been relatively well studied, less is known about the effects of climatic instability on micromammal populations over millennial time-scales. As keystone species largely unaffected by anthropogenic activity, and with rapid generational turnover, small mammals represent an excellent model to use to probe the effects of abrupt changes in climate on morphology at the population level.

This study focuses on two micromammal species, the short-tailed field vole (*Microtus agrestis*) and the common vole (*Microtus arvalis*), collected from cave sediments at Gully Cave, Ebbor Gorge – a key site in SW England with faunal remains dating from the Late-glacial (*c.* 15 000 cal BP) into the Holocene (commencing *c.* 11 500 cal BP). This interval is characterised by extreme and rapid climate fluctuations, but the effects of this variation on small mammal fauna remain largely unknown. As coordinated phenotypic variation can provide strong evidence for adaptation to local conditions any ecomorphological change observed in these species would strongly suggest an adaptive response to climate change.

Particular substructures in the molars of Arvicoline rodents have been shown previously to have a rapidly evolving form. Thus, changes in the shapes of the lower first molars of both species are investigated here. The 3D morphology of the molars was captured by micro-computed tomography (microCT) and a geometric morphometric approach using constellations of landmarks and semi-landmarks employed to capture the 3D geometry of these molars' triangular prisms and structure of the anterior cap. Procrustes alignment, PCA-based dimensionality reduction and CVA-based discrimination were used compare suites of tooth characters and document their co-variation with specific climatic factors against a null hypothesis of random variation.

This preliminary study represents the first time such techniques have been applied to Late Pleistocene/Early Holocene British small mammal fauna. Continued investigation will yield important insights into the effects of rapid climate change on morphological variation.

Assessing the genesis of Periglacial Ramparted Depressions (PRDs) by characterising internal structures macroscopically and microscopically

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Perennial frost mounds developed across northern Europe following the retreat of the Late Quaternary ice sheets (>10 ka BP). Their relict forms (Periglacial Ramparted Depressions - PRDs) comprise depressions with surrounding ramparts. Although PRD surface geometry is well-documented, their genetic origin is less well-understood. In addition, relict PRDs are sometimes difficult to identify because they are geomorphologically similar to features formed by non-frost processes (e.g. solution hollows, iceberg gravity craters).

Various methods have been used to examine PRDs in the U.K. including macroscopic sedimentological analysis, geomorphological mapping, Electrical Resistivity Tomography (ERT) surveys, Ground Penetrating Radar (GPR) and seismic refraction surveys. However, there is still little agreement on:

i) definitive identification of PRDs,
ii) PRD formation processes,
iii) the relationship between different frost mound types (*e.g.* pingo, palsa and lithalsa).

This research characterises PRDs by examining their internal structures at macro- (*e.g.* coring, logging) and micro-scales (thin sections). Micromorphology is an innovative and original approach for characterising PRDs because frost processes create distinctive and resilient micro-scale features indicative of sediment deformation processes and environmental setting.

PRDs are investigated at 1) Cledlyn Valley, mid-west Wales; 2) Walton Common, Norfolk; 3) the Ardennes (Belgium-German border), 4) the London Basin and 5) the Hampshire Basin.

This research will:

i. identify and characterise PRDs, particularly where surface features (*e.g.* ramparts) are missing due to burial or decay,
ii. provide a better understanding of the genesis of PRDs, potentially enabling classification of different types of ice-cored hills,
iii. inform palaeoenvironmental reconstruction, since ice-cored hills are diagnostic of former permafrost (frozen ground conditions),
iv. inform civil engineering projects where sediments are disturbed by PRD development (*e.g.* heave and subsidence).

No other known investigation macroscopically and microscopically characterises the internal structure of PRDs, making this research a unique and original contribution to knowledge.

Seasonally laminated sediments of Windermere, UK as a record of Devensian deglaciation

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Seasonally laminated sediments from Windermere in the English Lake District provide a high-resolution record of the last deglaciation of the British-Irish Ice Sheet from the English uplands, with regional palaeoclimatic implications. The varved sequence is capable of producing a record of interannual to interdecadal climate variability throughout the deglacial and Lateglacial, and marks abrupt climate shifts within this period. The record from Windermere is the first glaciolacustrine varve record from a currently active British or Irish lake thus representing a spatial 'stepping-stone' between the annually resolved ice-core records of Greenland and the varved sequences of Central and Eastern Europe, both representing different regional climate regimes. The excellent resolution and location of the Windermere varve record creates the potential to further constrain the diachroneity of deglacial and Lateglacial climate changes and identify leads and lags with respect to Greenland and Continental Europe.

The core sequence is undergoing detailed scanning electron microscope analysis to identify sub-mm scale varve boundaries, complemented by X-radiography and ITRAX XRF analysis. In addition the sediment is being analysed for Icelandic tephra in order to establish isochrons, forming part of a climate-independent chronology for the cores based on earliest-Holocene radiocarbon dates, varve counts and a reconstructed magnetic palaeosecular variation curve. In addition we have recovered a full Windermere Interstadial sequence for pollen succession analysis. Here we present some preliminary results of the ongoing work on the deglacial and Lateglacial varved Windermere sequence with a view to better understanding the nature of the last deglaciation of northern Europe.

SESSION 4:

Palaeoclimate reconstructions (Eurasia)

Chair: Jenny Roberts

Geochemical insights into the Mid-Pleistocene Transition (MPT) in the Asian Monsoon (IODP Expedition 346, Site U1427, Japan Sea)

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Major changes to the global climate variability took place during the Mid-Pleistocene Transition (MPT). The frequency of the global climate variability changed from 41 ka to 100 ka in the absence of major changes in astronomical parameters. The Asian Monsoon has been proposed as an internal feedback mechanism to the MPT, however, the detailed mechanisms are poorly understood.

During IODP Expedition 346 sediments from the Japan Sea, including Site U1427, were recovered. This site was chosen due to its high sedimentation rates and the good preservation of foraminifera shells. Analysis underway and planned are sediment and foraminifera geochemistry (bulk sediment $\delta^{13}C$, %C, %N, benthic and planktonic foraminifera species specific $\delta^{13}C$ and $\delta^{18}O$). This data will be used to correlate this site to the global reference records (e.g. Lisiecki & Raymo, 2005) to provide the age model. In addition the data will provide information on freshwater input and salinity changes as forced by the Asian Monsoon variability.

Initial observation show there are significant fluctuations in all the geochemical parameters, suggesting that this marginal-marine setting (southern Japan Sea) most likely records some aspect of the MPT, with the expected change in frequencies (likely driven by Milankovitch forcing). While there is an overall correlation of the different geochemical records (own and shipboard data, Tada et al., 2015), there appear to be some intervals where records deviate from each other or even anti-correlate. These deviations are likely due to environmental changes specific to the Japan Sea, such as salinity variability through freshwater input.

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The Lake Ohrid Drilling Project: initial interpretations of stable isotope data over the last 640 ka

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The Scientific Collaboration on Past Speciation Conditions in Lake Ohrid (SCOPSCO) project is an international multi-disciplinary research initiative to better understand the influence of major geological events and climate change on the generation of endemic populations. The target site is ancient Lake Ohrid situated on the Balkan Peninsula, which is thought to have continuously existed since the Pleistocene and is renowned for having an extraordinary degree of endemic biodiversity. In 2013 Lake Ohrid was drilled as part of an International Continental Scientific Drilling Program campaign and over 2100 m of sediment was recovered from four different sites. The master 'DEEP' site is located within the central basin, where seismic data indicated a thick succession of undisturbed sediments. Six parallel holes were drilled at DEEP and the total composite field recovery amounted to 545 m. The SCOPSCO cores will (1) provide a record of climate and environmental change, (2) deliver evidence for the impact of major geological and environmental events on evolutionary patterns and endemic biodiversity as a matter of global significance, (3) provide a record of past seismotectonic activity in the region and (4) give more precise information about the age and origin of the lake. Initial data from borehole logging, core logging, and geochemistry indicate that the DEEP succession provides a continuous record (99% recovery) and covers the last 1.2 million years. Total Inorganic Carbon (TIC) content is shown to be a sensitive proxy for short-term and long-term climate change from pilot cores from Lake Ohrid, and is found to be abundant (up to 80% calcite) in interglacial sediments throughout the DEEP profile. Calcite is generally absent in glacial deposits, however discrete layers of higher TIC are present (<2%), which have been confirmed to be siderite using XRD, SEM-EDX, and FTIR. Here, we present new stable isotope data ($\delta^{18}O_{calcite/siderite}$ and $\delta^{13}C_{calcite/siderite}$) on endogenic calcite and authigenic siderite through the first 640 ka of the DEEP site record (equivalent to the last 15 Marine Isotope Stages). To compare the calcite and siderite isotope data, we assess lakewater conditions at the time of formation for each carbonate mineral and reconstruct $\delta^{18}O_{lakewater}$. Variations in isotope data between and within individual interglacials show prominent hydroclimate fluctuations, including periods of exceptional aridity and potentially lower lake levels. Our results provide new evidence for long-term climate change in the northern Mediterranean region, which will form the basis to better understand the influence of major environmental events on biological evolution within the lake.

Evolution of Quaternary alluvial fans in the eastern margin of the Tibetan Plateau and implications for the controlling factors

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The study focus on the evolution of alluvial fans in Goulinping, a catchment in the eastern margin of the Tibetan Plateau in China. By conducting a series of field works including geomorphic mapping, sedimentary logging and OSL dating, the study discovered the respective behaviors of valley incision and aggradation in time scales of glacial-interglacial, millennial and decadal spans. It is found that in millennial and decadal scales, either aggradation or incision can happen while in the long time spans, there exist a broad trend in which valley were incised during the interglacial periods while were aggradated during glacial periods.

Reconstructing postglacial landscape evolution following the drainage of glacial Lake McConnell, Northwest Territories, Canada: insights from biological proxy data.

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Reconstructions of meltwater routing following the retreat of the Laurentide Ice Sheet, 10,000-8,000 cal BP, include a significant northwest drainage outlet e for glacial Lake Agassiz, via glacial Lake McConnell, into the Arctic Ocean. In the Great Slave Lowlands of the central Northwest Territories, clay-rich sediments from glacial Lake McConnell are widespread and commonly overlain by silty and sandy sediments derived from ancestral Great Slave Lake and its inflow streams. Despite the regional significance of this proglacial lake, limited palaeoecological knowledge exists, and few studies extend back to the early postglacial period. Knowledge of the timing, character and impacts of the final phases of proglacial lakes and the impact of sudden changes in lake discharge on regional vegetation dynamics thus remain poorly understood. To address these issues, a series of peat and lake sediment cores were collected from the Great Slave region. High-resolution analysis of pollen and sub-fossil chironomids, combined with radiocarbon dating constrain the timing and nature of palaeoenvironmental changes associated with the later stages of lake sedimentation, vegetation colonisation and peatland initiation.

In this paper, we present palynological data from two peatland sites and chironomid data from one small lake. White Truck bog (informal name) and Cameron River bog are both situated within the maximum extent of glacial Lake McConnell, and Matthew's Lake is located ca. 200 km beyond the former glacial lake limits. The peat cores show an abrupt transition from fine grained minerogenic sediments at White Truck bog and sandy facies at Cameron River bog to organic sediments. Peat initiation at White Truck bog and Cameron River bog are dated to 7738-7943 cal BP and 6990 – 7134 cal BP, respectively. *Betula* pollen dominates the base of the pollen record at each site, (>60% of the Total Land Pollen), suggesting that dense birch shrub cover prevailed in the earliest phases of peat formation. Both peatland records exhibit evidence of a fen-bog transition with early peaks in Cyperaceae pollen (20-40%) followed by a sharp decline. The palaeoecological record from the two sites also show a number of differences, which likely relate to local variation in hydrological conditions.

The chironomid record from Matthew's Lake shows that oligotrophic and cold stenothermic taxa prevailed during the earliest phases of clastic sediment deposition with a high species diversity. A transition from fine grained clay to gyttja is dated to 8423-8585 cal BP and correlates with a decline in cold-adapted species and the dominance of *Corynocera ambigua*. This study aids in understanding the landscape evolution in the Great Slave region, whilst constraining the timing of vegetation colonisation and peatland development following proglacial lake inundation.

Population dynamics of *Pinus* and *Ulmus* in Europe during the Holocene.

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This work investigates and compares the population dynamics of *Pinus* and *Ulmus* in Europe, during the Holocene, at varying temporal and spatial scales, by using recently developed and novel modelling methods.

The first component characterises the European-wide post glacial rise and mid-Holocene decline experienced by both genera. Pollen data was extracted from 330 sites on the European Pollen Database (EPD). The depth of rise and decline events for each genus in each site core was defined by applying a spline curve, to remove stochastic noise from the pollen data, and identifying the range of depths along which the pollen values increased or decreased. The R package Bchron was used to calibrate radiocarbon dates and produce an age-depth model for each site, using stochastic linear interpolation and Monte Carlo methods. The age-depth model data was applied to the event depth range to produce a probability distribution of when the rise and decline events occurred.

The second component characterises *Ulmus* and *Pinus* when they were abundant on the European landscape. Depth and magnitude data of maximum pollen values for both genera were gathered from the EPD. The age-depth models were used to determine the age of the maximum pollen value depths.

These data were then plotted on maps and natural neighbour interpolation was used to characterise the spatial and temporal dynamics of these population events in the two tree genera.

This work, therefore, presents novel techniques to quantifying tree population dynamics, and also provides insight into the specific dynamics of two major tree genera in Europe.

The Climatic Impact of Anthropogenic Land Use Change Throughout the Holocene

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The first agricultural societies were established around 10ka BP and had spread across much of Europe and S.E. Asia by 5.5ka BP with resultant anthropogenic deforestation. In this study, global earth system model simulations are used to examine the influence the biogeophysical effects of this regional, human-induced, land cover change have had on the climate, both globally and regionally, throughout the mid to late Holocene. The period under consideration is from 8ka BP to pre-industrial (1850). Snapshot simulations have been run at 1,000 year intervals to examine when the first signature of anthropogenic climate change can be detected both regionally, in the areas of land use change, and globally, including any influence on large-scale climate systems such as the Inter Tropical Convergence Zone.

Two experiments were performed utilising the Hadley Centre Climate model (HadCM3) with coupled dynamic vegetation (via the TRIFFID model) and alternative descriptions of past vegetation: (i) potential natural vegetation simulated by TRIFFID but no anthropogenic land-use changes, and (ii) where the anthropogenic deforestation model, KK10, of Kaplan et al, (2009 & 2011) has been used to set the HadCM3 crop regions. Results indicate that, in the June/July/August season, detectable temperature changes outside the normal range of variability are encountered from 7ka BP in regions of early land disturbance such as Europe and S.E. Asia and throughout the entire annual cycle by 3ka BP in Europe and 2ka in S.E. Asia.

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Stable Carbon Isotope Dendroclimatology in the Jotunheim region of central, southern Norway

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Two 412-year stable carbon isotope ($\delta^{13}C$) chronologies developed from living Scots pine (*Pinus sylvestris* L.) trees growing in Jotunheimen, central, southern Norway, are presented in this research, for the period AD 1600 to 2011. The three-site chronology is based on 28 trees with a mean sample depth of 11 and the two-site chronology is based on 18 trees with a mean sample depth 8. The chronologies are annually resolved, pooled and built using distinct periods of series overlap, in which the sample depth is highest.

The $\delta^{13}C$ chronologies are calibrated against instrumental data from meteorological stations and gridded instrumental data. Palaeoclimatic reconstructions of July to August summer temperature are developed based on the understanding that mechanistically, photosynthetic rate is the dominant factor controlling $\delta^{13}C$ values from tree ring cellulose in Jotunheimen. Different reconstruction methodologies are tested and the variation in sites contributing towards the individual records is considered.

Reconstructions are compared to additional temperature records from different archives both locally and regionally to discern the reliability of the isotope-based signal. The reconstructions are considered to represent a stronger record of past summer temperature compared to ring width research previously conducted at the site. Possible sub-regional variation, relating to the mechanisms controlling $\delta^{13}C$ values in tree rings, is discussed and the subsequent implications for the development of a regional understanding of dendroclimatology are examined.

Investigating the extent of natural and anthropogenic disturbances within shallow lakes of the Selenga River Delta, Siberia

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Wetlands are productive transitional systems between freshwater bodies and their terrestrial watersheds. Shallow lakes are often an important component of wetland floodplains, and may comprise up to 50% of the total surface area. Lake Baikal is a World Heritage Site in Siberia, with high levels of biodiversity and endemicity. The Selenga River is the principal source of inflow to Lake Baikal, entering the lake through a floodplain wetland, the Selenga Delta. The Selenga Delta is a designated Ramsar Site, and provides crucial habitat for wildlife populations of migratory birds and spawning fish due to high levels of habitat heterogeneity. The Selenga Delta also contains hundreds of shallow lakes with varying levels of connectivity. Twentieth century anthropogenic activities, including agriculture, mining, industry, hydrological modifications, introduced species and climate change, have increased the vulnerability of the lake ecosystems. Multi-proxy palaeoecological reconstructions from sediments of Selenga Delta lakes will allow for the examination of ecosystem impacts and sensitivity related to human-mediated pressures.

Sediment cores from two Selenga Delta lakes connected to the Selenga River, but on opposing sides of the Delta, were analyzed for algal pigments and trace metals. Unofficially named SLNG04 and SLNG05, the lakes are small and shallow with maximum depths less than 1.5 m. Chronologies were constructed using ^{210}Pb and ^{137}Cs activities. There is a lack of pigment presence in SLNG04 prior to 48 cm depth, after which time pigments representing all algae (Chl *a*) and chlorophytes are present at low concentrations until 39 cm. The biological changes coincide with changes in the lithology and magnetic susceptibility of the core, and likely reveal the developmental history of SLNG04 from terrestrial or ephemeral pond to the current shallow lake, as a result of an 1862 earthquake. Pigments representing a wide range of algae appear in the sediment record post-39 cm, with peak pigment concentrations occurring in the late 1950s/early 1960s (26-24 cm), and in the most recent decade. Enrichment factors for several trace metals in SLNG04, including Hg, Cu, Cd, and As are ≥ 3 beginning in the late 1950s/early 1960s, indicating recent anthropogenic contamination of SLNG04.

The SLNG05 record shows peak LOI_{550} and As, Br, Mn, and Fe concentrations concurrent with minimum wet and dry densities and concentrations of Ni, Cu, Zn, Pb, Al, Ti, and Si in the early 1960s. The observed changes in the SLNG05 sediment record coincide with the construction of the Irkutsk Dam on the Angara River (Lake Baikal's outflow), which resulted in extensive flooding of low-lying land surrounding the lake. It is likely that changes evident in the SLNG05 record reflect alterations to the hydrological connectivity of the lake within the Selenga Delta, and that prior to the flood events SLNG05 was a closed-basin, infilling lake. These results highlight the importance of hydrology and connectivity within the floodplain delta wetland and the sensitivity of these systems to changes in hydrology and regional anthropogenic activities.

A Scorched Past:

Investigating past fire regimes throughout the Holocene in Ireland.

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Globally, in recent years there has been an increase in the scale, intensity and level of destruction caused by wildfires. This can be seen in Ireland where significant changes in vegetation, land use, agriculture and policy, have promoted an increase in fires in the Irish landscape. This study looks at wildfire throughout the Holocene and draws on paleolimnological records from eight sites spread across Ireland. It addresses four main questions; what is the nature of wildfire in Ireland in the past? What impacts did wildfire have on the surrounding vegetation, landscape and people? Does Ireland's record of wildfire tie in with any regional, national or global trends in wildfire? And finally does wildfire have a significant impact on biodiversity? Charcoal, Pollen, XRF, Loss on Ignition and Archaeological data are utilised from lacustrine sediment to reconstruct the past fire regime at each of the study sites and interpret its interaction with vegetation, climate and people. This work uses new methods and techniques in fire history reconstruction; An Ensemble-Member approach to select the required smoothing method, a Gaussian mixture model to decompose the charcoal record to identify significant fire events, and various statistical methods to reconstruct fire frequency and fire return intervals. The charcoal record is validated using a Signal to Noise Index, Goodness of Fit model and Charcoal Peak Screening method. The Global Charcoal Database and Palaeofire package are used to examine any correlation between wildfire in Ireland with records from the UK, Europe, and across the Globe. Vegetation reconstructions are carried out to examine the interactions between wildfire and the surrounding vegetation. Finally biodiversity is reconstructed at each site throughout the Holocene and the effect of wildfire quantified through a statistical analysis. This research is the culmination of four years' work as part of the Earth and Natural Sciences Doctoral programme, and presents the first chronological comparison of regional fire activity in Ireland, providing an important base line level of data which can be drawn on in future scenarios when fire frequency is expected to increase.

SESSION 5:

Palaeoclimate reconstructions of equatorial regions

Chair: Michelle McCrystall

A 15000 year environmental history of the Eastern Mau Forest, Kenya.

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The current state of the ecosystem and landscape is attributed to the legacy of historical human and natural climatic processes as well as current human land-use and climate change impacts on ecosystems. The diversity and strong ecosystem gradients in East Africa require additional high-resolution datasets to fully quantify and understand the processes influencing these systems and to maintain sustainable ecosystem services and conservation goals. There have been few studies of the palaeoecology of the Mau Forest ecosystems, which have been critical timber regions in Kenya, serve as a 'water tower' for downstream water supplies, and are under pressure for conversion to agriculture.

A 537 cm core from Nyabuiyabui Swamp from the Eastern Mau highlands 2900m asl has been examined to understand the nature of past environmental variability and to quantify and examine the relationships between natural and anthropogenically influenced earth system processes. Eight radiocarbon dates have been obtained and used to develop an age-depth model using BACON. Geochemical information was collected by ITRAX core scanning of elemental compositions and show significant variation down core associated with changes in sediment accumulation rates at 2449±35 and 7616±33 cal yr. BP. Pollen and charcoal data are used to understand the vegetation composition changes over time and associated fire regime variability. A core consideration of the project is how societies, landscapes and ecosystems have responded to climate change at a high temporal resolution. The data will be combined with archaeological and socio-anthropogenic findings to provide biophysical and social information on the human environment interactions over time that will be useful for land use management decisions in these ecosystems.

Amazonia under mid-Holocene drought

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Most climate models simulate increased long-term drought for Amazonia in the next century. The projected decrease in precipitation coupled with rising temperatures is likely to create ecosystem feedbacks, such as forest dieback, that intensifies the drying (Malhi et al. 2008). Moisture availability, particularly during the dry season, affects tropical forest productivity more than any other climatic variable. Therefore, the projected increase of drought represents one of the biggest climatic threats to Amazonia and the ecosystem services it provides (Meir and Woodward 2010).

The effects of short-term (sub-decadal) droughts in the region are relatively well understood. Ecological monitoring projects captured information about the 2005 and 2010 Amazonian droughts, showing an increase in tree mortality and, in the short-term, the region switching from a carbon sink to source (Doughty et al. 2015). However, the effects of long-term (decadal to centennial) droughts are poorly understood. Earth system models (ESMs) have been used to simulate what affect long-term drought will have on forest ecosystems, with most predicting increased forest dieback. However, huge uncertainty exists over the scale of the dieback (Malhi et al 2009). This uncertainty limits our knowledge of what the consequences of climate change might be for Amazonian biodiversity, ecosystem services and functioning.

This NERC 'SCENARIO' DTP project will both synthesise existing palaeoecological data, as well as generate new palaeo-data (pollen and charcoal), to help improve our understanding of the impact of long-term drought upon Amazonian forests. During the mid Holocene (ca. 6,000 years ago), Amazonia has been shown to be significantly drier than the present (Baker et al. 2001). Palaeoecological data can help us understand how forests reacted to the dry climate at this time, thus increasing our knowledge of how forests may react under future drought. This project will also use these palaeo-data as a validation tool for testing various ESMs' ability to simulate past drought induced vegetation changes. This can potentially reduce the uncertainty of the ESMs' simulations of drought-induced dieback for the future. This presentation will give a more detailed overview of the project, talk about our recent fieldtrip (July 2015) to the Bolivian Amazon, and explain what data was collected and what will be done with that data.

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Amazonia and the 6K drought

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I am comparing the geographic distribution and floristic composition of southern Amazonian transitional forests under today's humid climate versus the significantly drier climate of the mid Holocene (ca. 6,000 years ago, 6 ka BP) [1]. This knowledge will provide important insights into the scale of forest die-back that can be expected under future enhanced drought simulated by several climate models [2–5], especially in climatically-sensitive ecotonal areas such as lowland Bolivia at the southern margin of Amazonia. Huge uncertainty exists over the geographic scale of the die-back, with model predictions ranging from negligible to basin-wide [6–8]. Although an imperfect analogue for the future, mid-Holocene Amazonia constitutes the best available 'natural experiment' for exploring the long-term impact of increased drought upon Amazonian forests.

In order to investigate the dynamics of the ecotonal shift in SW Amazonia 6kaBP, I am collecting multi-proxy palaeoecological data (pollen, phytoliths, charcoal, stable isotopes) from lake-sediment cores and soil profiles along a NW-SE transect. Preliminary results from a lake sediment core from Acre State, Brazil, will be presented, and discussed in the context of existing published data [9,10]. The combination of lake sediment and soil pit samples along my transect will enable me to address issues of spatial scale. My transect will include several forest types (including humid evergreen Amazonian forests and seasonally-dry semi-deciduous Chiquitano forests) and soil types, to allow me to assess how these factors affect vegetation responses to drought.

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Static or dynamic? Reconstructing potential past movement of the South Pacific Convergence Zone

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The South Pacific Convergence Zone (SPCZ) is the most extensive convective cloud band in the Southern Hemisphere (Kiladis *et al*., 1989; Vincent, 1994). Understanding this climate phenomenon is of global significance as, due to its size, the latent heat the SPCZ releases leads to an important dynamical response through the excitation of Rossby Waves that influences climate on a global scale (Matthews, 2012). It is known that on interannual to interdecadal timescales pan-Pacific climate phenomena such as the El Niño-Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO) cause the SPCZ to shift position (Vincent, 1994; Folland *et al*., 2002). Marine records, specifically coral records, have suggested that the SPCZ has moved position over the past 400 years in phase with the IPO. However, movement of the SPCZ over longer timescales – specifically thousands of years – has not yet been constrained. To this extent lake sediment cores have been obtained from from Lake Lanoto'o (13°54.620S 171°49.639E), Samoa, and Lake Teroto (20°00.575S 158°07.410W), Atiu, Cook Islands. These sites bracket the potential movement of the SPCZ, and provide long, undisturbed sediment archives from which a climate history can be reconstructed. A range of proxies have been utilised to elucidate the past movement of the SPCZ, with the timing of potential SPCZ movement being constrained with the development of a robust chronology.

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Poster Abstracts:

Application of ultra-high resolution direct trace-element analysis on glacial ice from Weddell Sea deep ice cores, West Antarctica.

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Current standard laboratory practices offer a relatively coarse-resolution trace element analysis. Sub-annual profiles are principally reserved for the upper depths of ice cores where compaction due to vertical strain has not reduced the annual layer thickness to values smaller than the typical sampling resolution. After this threshold is reached, it is necessary to reconstruct climate profiles by applying modelling techniques.

Recent developments in direct trace-element analysis using laser ablation inductively-coupled plasma mass spectrometry (LA ICP-MS) confirm the viability of making ultra-high resolution measurements on ice cores. Alternatively, a second method capable of extracting a chemical profile at a higher resolution than standard laboratory techniques analyses discrete samples cut using a microtome at mm-resolution by ion chromatography. Sections of ice from deep ice cores drilled at Fletcher Promontory (FP) and Berkner Island (BI), Weddell Sea, have been analysed using these two methods and present a sub-annual profile of Antarctic climate during the last glacial period.

The high-resolution results are compared with annual layer thickness values estimated using a combination of modelling techniques. The outcomes of this study are: (i) an assessment of modelling techniques by cross-comparison with observed data; (ii) the construction of a more robust age-depth profile for the Berkner Island ice core; and (iii) an improved understanding of the relationship between surface temperature and the amplitude of accumulation change during the last glacial cycle. The impact of this research significantly improves chronological reconstructions of ice cores which currently rely on untested glaciological modelling.

The potential of raised beaches for the reconstruction of glacial advances

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This study takes a closer look at raised beaches adjacent to the Bellingshausen Dome on Fildes Peninsula, King George Island. One result of the overall retreating ice cap since the LGM is a shrinking weight on the island, causing an isostatic rebound and therefore a local falling relative sea level (RSL). Thus, raised beaches have slowly been revealed and partly been reworked by glacial readvances and/or overlaid by periglacial products and glaciofluvial sediments. The purpose of this study is to investigate whether characteristic marine, glacial and periglacial deposits could be recognised in the composition of these beach sediments. The information could then serve to narrow down the local maximum ice extent since the raised beaches were formed about 8,000 years ago.

The sediments were examined due to their grain size, shape, composition and degree of sorting. Striated rocks and ice rafted boulders were also taken into account. The observations were then coded and digitalised on ARC GIS. Results suggest that the Collins Glacier has not advanced further than 400 metres from its current location in the past 8,000 years, as rounded and well sorted, clast-supported cobbles between 20 and 60 mm speak against any perturbation since they were formed and deposited by marine processes in this distance. However, towards the glacier the deposits become increasingly supported by sand and fine gravels that have been transported from frost weathered outcrops adjacent to the beach. Lastly, direct glacial perturbation close to the present ice margin becomes apparent, where a wide range of shapes, sizes and therefore a poor degree of sorting characterises the reworked raised beaches. In conclusion, this study could show that all criteria combined can be a useful tool for tracking glacial footprints.

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Evaluating the timing and cause of glacial advances in the southern mid-latitudes during the last glacial cycle

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Advances of glaciers in the southern mid-latitudes during the last glacial cycle (ca. 110-10 ka) were controlled by changes in temperature and precipitation linked to several important climatic systems, so the timing of advances can yield important insights into the mechanisms of southern hemisphere climate change. This is particularly important given that several recent studies have demonstrated significant glacial advances prior to the global Last Glacial Maximum (gLGM) in Patagonia and New Zealand, the causes of which are uncertain. The large increase in recent chronological studies in these regions offers the chance to robustly compare regional trends in glacial activity. Here, we compile two 10Be exposure dating chronologies from previously published glacial records in Patagonia and New Zealand to ascertain the broad pattern of mid-latitude glacial advances. We then evaluate whether pre-gLGM advances are a common feature, and examine whether they were synchronous between the two regions. The similarity between the chronologies from Patagonia and New Zealand suggests that they were driven by common factors during the Last Glacial Cycle from at least 45 ka. Comparison of glacier advances to forcing parameters suggests that the advances in Patagonia and New Zealand were probably driven by underlying orbital parameters, involving a combination of summer insolation, seasonality and winter duration, but the precise timing is likely to have been intrinsically linked to migration of the coupled ocean-atmosphere system.

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. As each varve contains a specific set of laminations which reflect the annual succession of limnic deposition (see Zolitschka *et al.* 2015), detailed reconstructions of palaeoseasonality can be made, including season length, intensity and characteristics. In this research, climatic reconstructions will be made using varved cores taken from closed lakes Nar Gölü, Turkey and Yaal Chac, Mexico. Both of these regions display highly seasonal climatic regimes and 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). The sub-annual capability of varves crucially represents an appropriate resolution for understanding climate change at a societal scale. 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.

By comprehensively understanding the annual depositional processes and drivers acting within the lake, gained from on-going lake monitoring, seasonal environmental change can be reconstructed utilising the varves' physical structure and composition. Thin section microscopy will be used to record changes to laminae thickness and sediment microfacies, with micro X-ray fluorescence (μXRF) additionally constraining the primary controls on the varve sedimentology. Previous work on Nar Gölü has identified the laminations to be organic-carbonate varves (e.g. Jones *et al.* 2005), and while no work has yet been published on Yaal Chac, its laminations are believed to be similarly composed. This research aims to further investigate the use of varve sedimentology as a palaeoclimatic proxy, and to reconstruct sub-annual climatic change from Turkey and Mexico and assess its impact on past societies.

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What is a glacial trimline?

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Glacial trimlines are glaciogenic landforms that are expressed as a horizon on the side of a glaciated or formerly glaciated valley. They can take many forms, such as vegetation trimlines, weathering contrasts and limits of glacial erosion or deposition. Glacial trimlines have been used to reconstruct recent changes in ice surface elevation in glacierised areas, such as the Alps (Kelly *et al.* 2004; Nussbaumer 2007), and are also used in Quaternary palaeoglacial reconstructions (Ballantyne 2010; Ballantyne *et al.* 1997, 2011; Fabel *et al.* 2012; Ballantyne and Stone 2015). There is no standardised method for the identification and interpretation of glacial trimlines, which has led to inconsistencies in their usage as noted by Ballantyne 2010. Such inconstancies hinder the comparison of reconstructions produced by different researchers and may be introducing uncertainty into glacial reconstructions. Specific and standardised investigation of the morphology, expression and interpretation of glacial trimlines should contribute towards resolving these issues and may shed light on the processes of trimline formation, potentially answering on-going debates in the literature. This poster reports on a new framework for the classification of glacial trimlines in order to improve identification and to encourage debate about the interpretation of trimline features in glacial or palaeoglacial settings. The classification is accompanied by mapped examples that aim to standardise the terminology used to describe different types of glacial trimline.

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A novel way of determining uplift over the late Quaternary: synchronous correlation between multiple palaeoshorelines and multiple sea-level highstands.

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Marine terraces provide a record of the relationship between eustatic sea-level changes and tectonic uplift (e.g. Lajoie, 1986), with elevations of their preserved inner-edges representing paleoshorelines formed during prominent sea-level highstands. Tectonically-deformed sequences of Quaternary marine terraces allow subduction and normal fault-related uplift rates, which span the late Quaternary, to be identified (e.g. Roberts et al., 2009; 2013). Consequently, slip rates and Earthquake Recurrence Interval (ERI) can be derived and used for long-term seismic hazard analysis.

Many authors correlate the ages of sea-level highstands with undated palaeoshorelines using a sequential method, whereby the next higher or lower paleoshoreline from a dated horizon is assumed to belong to the next older or younger sea-level highstand (e.g. Armijo et al., 1996). These ages are then used to determine an uplift rate. This approach fails to consider that palaeoshorelines from sea-level highstands that were lower than subsequent highstands are overprinted and destroyed by younger, and higher, sea levels. This 'removal' of palaoeshorelines means that any attempt to sequentially-correlate sea-level highstands to paleoshorelines will be unsuccessful and the resultant uplift signal flawed.

The development of a novel synchronous correlation method resolves this situation. Synchronous correlation exploits the fact that sea-level highstands are not uniformly spaced in time so palaeoshorelines will not be uniformly spaced in elevation given a uniform temporal uplift rate. Thus, a given uplift rate history, including examples where the uplift rate has changed through time, will produce a unique 'fingerprint' set of palaeoshoreline elevations. The uplift rate history can be derived by iterating the uplift rate and searching for best fits of predicted and measured palaeoshorelines. The expected and measured elevations are compared using linear regression analysis (R^2 value). This method can proceed from the simplest explanation (a constant uplift-rate through the time) to more complex hypothesis (varying uplift-rate through the time). We present examples from Calabria (South Italy) where faults active throughout the Quaternary have been deforming sequences of paleoshorelines.

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The smelting of metals in the Romanian Carpathians throughout the Holocene

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In Europe the characteristics, distribution and effects of recent pollution are well known, with monitoring observations existing at a continental scale. However, estimates of long-term pollution are restricted to central-western Europe, the British Isles and Scandinavia. In Eastern Europe in particular, the lack of such estimates has led to incomplete understanding of regional differences. When coupled to the insufficient knowledge of past emission sources and isotopic signatures of various ores, it is clear there are gaps in our knowledge of the history of pollution in this area. As a result, the causal relationship between humans and the environment are insufficiently explored, particularly within the Carpathian region- one with mineral wealth and a long history of human presence.

Peat bogs have long been used as an archive for environmental and climatic imprints, with research using climate indicators from bogs burgeoning in recent decades, and a range of proxies for past hydrological change have been developed. The potential for utilising the geochemistry of archives such as peat bogs to resolve the input of metals from the atmosphere has long been known, and has been used to distinguish the background levels from the anthropogenic imprint.

Here we present initial results from a multi-proxy study into the geochemical history of a collection of ombrotrophic peat bogs located in the Romanian section of the study region. These data display the first such study in the region and attempt to disentangle signatures related to natural cycling of elements over millennia, as well as anthropogenically-derived contributions through resource exploitation (land, forestry, ores), combustion, mining, and smelting activities.

Ecosystem resilience to abrupt climatic and environmental change in southern Siberia since the Last Glacial Maximum

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This poster outlines my PhD project 'Ecosystem resilience to abrupt climatic and environmental change in southern Siberia since the Last Glacial Maximum*'*. Siberia is highly sensitive to climatic change, with warming rates considerably higher than the global average over the last 50 years (Tingley & Huybers 2013), with potentially significant changes across Siberia, including in permafrost distribution (Gordov & Vaganov 2010). Thus there is a need to understand the long term variability in past Siberian climate and wider ecosystem responses. Climate variability in the Late Quaternary is dominated by long term orbital forcing and abrupt sub-Milankovitch events on the scales of millennia to centuries, driven by internal feedback mechanisms, volcanic forcing and solar activity (Lowe and Walker 2015). These are well documented in the North Atlantic region; however their scale is uncertain in Siberia, where, for example, the expression of events such as Heinrich 1 are uncertain. The region has the world's highest level of continentally (Mackay et al. 2011) and offers a key opportunity to understand climatic changes away from oceanic influences. Past climatic changes in central Asia also provide essential environmental context for early humans, for example at globally important sites such as Denisova cave (Krause et al. 2010), and megafauna extinctions (Stuart et al. 2004). Palaeoenvironmental studies in Siberia are focused around Lake Baikal, and less frequently smaller lakes including Lake Kotokel. Records from these sites are often conflicting, with a clear interstadial recorded in sites such as Kotokel between 14.5-14.0 kyrs and 13.3-12.8 kyr (Bezrukova et al. 2010), compared to a limited record in Baikal (Mackay et al. 2011). This demonstrates the need for further research to understand the complexities of the climatic system and ecosystem response in this region. This poster will outline the research framework, introduce the study site and its regional context, the key methods (particularly diatoms, biogenic silica and radiometric dating) and preliminary results from studies of high resolution records within the Baikal region that may offer a more detailed picture of the Late Quaternary palaeoclimatic setting and associated ecological responses.

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Preliminary Results from Perlas Cave: Capturing Climate during the Neanderthal Demise

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The causes of the Neanderthal extinction remain open for discussion with two key hypotheses being debated. The first invokes climatic instability during MIS3 as the cause of the Neanderthal demise (d'Errico and Sánchez Goñi, 2003; Finlayson and Carrion, 2007), whilst the second proposes the arrival of modern humans was responsible for the disappearance of the Neanderthals (Banks *et al*., 2008). At present, there is minimal evidence for climatic shifts on the Iberian Peninsula between 50,000 – 30,000 years ago, the period of the last Neanderthals. Speleothems from Perlas Cave (Northern Spain) have the potential to provide high-resolution, independently dated, terrestrial records of climate and environmental change during this period. The present study aims to create a palaeoclimate record using speleothems from Perlas Cave spanning the period of the last Neanderthals on the Iberian Peninsula. Cave monitoring is currently ongoing at Perlas Cave in order to determine how the external climate and environmental signal is transferred and preserved in the speleothem calcite. Initial cave monitoring results have provided insight into cave ventilation dynamics, drip rates and drip water chemistry. Uranium-series dating is being carried out on initial speleothem samples to identify those speleothems suitable for the study. Further uranium-series dating will be carried out in order to provide a robust chronology for the selected speleothem samples. Geochemical analyses, predominantly oxygen and carbon stable isotopes as well as trace elements, will be used as proxies for palaeoclimate and palaeoenvironment. Speleothems from Perlas Cave will be used to determine whether there is evidence for climatic shifts (e.g. Heinrich events) within Northern Iberia and this will provide the first high-resolution terrestrial palaeoclimate record in the region during this key period in human evolution.

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Laser Ablation U-Th as an age screening tool in carbonates: assessing travertine deposit ages in a natural analogue for Carbon Capture and Storage.

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U-Th disequilibrium dating is a well developed tool in the palaeoclimate community, offering the only method to get reliable absolute ages up to 600ka. Analyses are expensive and time consuming, so it is important to prioritise samples for analysis. For example, to achieve the 'best' ages material free of detrital contamination must be chosen, and sampling frequency must be chosen to produce age models for proxy records. To quickly assess the age of multiple samples, we have developed a laser ablation method allowing rapid determination of a samples age. The volume of sample required is far lower, sample preparation time is much quicker, but this is at the expense of precision (i.e. solution ages of this material are ~100 +/-0.5ka whilst laser ages are ~100ka +/- 6ka). Limitations of the technique are related to inter-element fractionation between U and Th in the laser and plasma, and are ultimately tied to the homogeneity of available standard materials.

The technique is tested using samples from Green River (Utah). This site is a natural analogue for Carbon Capture and Storage (CCS). Natural accumulations of CO_2 enriched fluids leak up the damaged zone of a fault in the core of an anticlinal trap, resulting in the deposition of travertine mounds, aragonite veins and gypsum veins. We want to understand the timescales which CO_2 escapes up fault systems causing these deposits, in order to assess the risks associated with CO_2 leakage. We also want to know the rate of fluid-rock reactions associated with these fluids. Previous studies show that the travertines preserve a record of these processes over at least ~400,000 years [1]. Their deposition is pulsed, with the greatest rates of fluid leakage coincident with the termination of glacial periods [2]. The use of laser ablation U-Th on these samples allows us to focus further higher resolution sampling in time-intervals of interest.

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A high-resolution Late Glacial to Holocene stable isotope and geochemical record from Lake Ohrid (Macedonia/Albania)

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Lake Ohrid (Macedonia/Albania) is an ancient lake and is renowned for its high degree of biological diversity. It is the target site for the ICDP SCOPSCO (Scientific Collaboration on Past Speciation Conditions in Lake Ohrid) project, an international research initiative to study the links between geology, environment and the evolution of endemic taxa. In 2011 a 10-meter core was recovered from the western shore of Lake Ohrid adjacent to the Lini Peninsula. Here we present high-resolution (c. 30-year) stable isotope and geochemical data from this core through the Late Glacial to Holocene to reconstruct past climate and hydrology (TIC, $\delta^{18}O_{calcite}$, $\delta^{13}C_{calcite}$) as well as the terrestrial and aquatic vegetation response to climate (TOC, TOC/N, $\delta^{13}C_{organic}$, Rock-Eval pyrolysis). The data identify 3 main zones: (1) the Late Glacial-Holocene transition represented by low TIC, TOC and higher isotope values, (2) the early to mid-Holocene characterised by higher TOC, TOC/N and lower $\delta^{18}O_{calcite}$, and (3) the late Holocene which shows a decrease in TIC and TOC. In general there is an overall trend of increasing $\delta^{18}O_{calcite}$ from 9 ka to present, suggesting progressive aridification through the Holocene, which is consistent with previous records from Lake Ohrid and the wider Mediterranean region. Several proxies show commensurate excursions that imply the impact of short-term climate oscillations, such as the 8.2 ka event and the Little Ice Age. This is the best-dated and highest resolution archive of Late Glacial and Holocene climate from Lake Ohrid and confirms the overriding influence of the North Atlantic in the north-eastern Mediterranean. The data presented set the context for the SCOPSCO project cores recovered in 2013 dating back to the Lower Pleistocene, and will act as a recent calibration to reconstruct climate and hydrology over the entire lake history.

Assessing the genesis of Periglacial Ramparted Depressions (PRDs) by characterising internal structures macroscopically and microscopically

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Perennial frost mounds developed across northern Europe following the retreat of the Late Quaternary ice sheets (>10 ka BP). Their relict forms (Periglacial Ramparted Depressions - PRDs) comprise depressions with surrounding ramparts. Although PRD surface geometry is well-documented, their genetic origin is less well-understood. In addition, relict PRDs are sometimes difficult to identify because they are geomorphologically similar to features formed by non-frost processes (e.g. solution hollows, iceberg gravity craters).

Various methods have been used to examine PRDs in the U.K. including macroscopic sedimentological analysis, geomorphological mapping, Electrical Resistivity Tomography (ERT) surveys, Ground Penetrating Radar (GPR) and seismic refraction surveys. However, there is still little agreement on:

iv) definitive identification of PRDs,
v) PRD formation processes,
vi) the relationship between different frost mound types (*e.g.* pingo, palsa and lithalsa).

This research characterises PRDs by examining their internal structures at macro- (*e.g.* coring, logging) and micro-scales (thin sections). Micromorphology is an innovative and original approach for characterising PRDs because frost processes create distinctive and resilient micro-scale features indicative of sediment deformation processes and environmental setting.

PRDs are investigated at 1) Cledlyn Valley, mid-west Wales; 2) Walton Common, Norfolk; 3) the Ardennes (Belgium-German border), 4) the London Basin and 5) the Hampshire Basin.

This research will:

v. identify and characterise PRDs, particularly where surface features (*e.g.* ramparts) are missing due to burial or decay,
vi. provide a better understanding of the genesis of PRDs, potentially enabling classification of different types of ice-cored hills,
vii. inform palaeoenvironmental reconstruction, since ice-cored hills are diagnostic of former permafrost (frozen ground conditions),
viii. inform civil engineering projects where sediments are disturbed by PRD development (*e.g.* heave and subsidence).

No other known investigation macroscopically and microscopically characterises the internal structure of PRDs, making this research a unique and original contribution to knowledge.

Timings and dynamics of glaciation in the Wicklow Mountains, Ireland

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Existing knowledge on the extent and timings of Midlandian (MIS 2) glaciation in Ireland remains limited. In particular, there is poor consensus concerning the former Wicklow Ice Cap, which is a key area for understanding regional ice mass behaviour and its interaction with the wider Irish Ice Sheet. This project aims to ascertain the extent, timings and dynamics of glaciation in the Wicklow Mountains from the Last Glacial Maximum (LGM; ~27 ka BP) to the Last-Glacial Interglacial Transition (LGIT; ~15-10 ka BP), including the Nahanagan Stadial (NS; 12.9-11.7 ka BP).

Specific PhD research objectives are to: (1) systematically assess evidence for former glaciation in the Wicklow Mountains and surrounding areas; (2) evaluate local and regional ice interactions at the LGM and during deglaciation; (3) establish patterns of recession and examine associated ice flow dynamics during the LGIT; and (4) determine ice extent, dynamics and associated links to palaeoclimate during the NS. To achieve this, a threefold approach is proposed: 1) extensive geomorphological mapping using remotely-sensed data and field surveys to identify evidence of the style and extent of former glaciation; (2) detailed sedimentological analysis to determine ice mass dynamics; and 3) relative and absolute dating to elucidate glacial chronologies.

Presently, work is focused on the systematic assessment of glacial geomorphological evidence in the study area. Mapping from remote sensing data (aerial photography, DTMs) in combination with field mapping undertaken during a four-week field season (August 2015) will help to produce the first regional glacial geomorphological map (1:10,000 scale). This will provide an important foundation for future investigations, including sedimentological and geochronological analyses, in order to assess the ice dynamics and timings of glacial events associated with the wider Irish Ice Sheet.

Although in its early stages, this research represents the first comprehensive investigation of glaciation in the Wicklow Mountains, and will significantly improve understanding of regional ice mass behaviour during the last glacial period.

Morphometric analysis of the erosional style of Younger Dryas ice in Scotland

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The characteristics of the ice cap which formed in Scotland during the Younger Dryas (YD) are not fully understood. Although considerable research has gone into defining the volume and extent of the ice, there has been little study into the effects YD ice had on topography. This study aims to determine if the YD ice in Scotland rejuvenated underlying topography, building relief, to what extent this occurred and the potential influence of lithology on the creation of relief. Understanding the style of ice erosion can give an indication of the climatic conditions under which an ice mass was formed, this study should subsequently enhance our understanding of the characteristics and influences of climate on the landscape of Scotland during the Younger Dryas.

The geochemical signature of the Irish Sea Ice Stream and the source of ice-rafted detritus flux in the deep ocean using XRF microscanner

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The Irish Sea Ice Stream was the largest ice stream that drained the British Irish Ice Sheet (BIIS) and as a consequence understanding its dynamic behaviour can help refine glaciological models of BIIS (Patton et al. 2013). The ice stream was grounded but had a large marine terminating margin with its limit the southernmost extension of the BIIS (Praeg et al. 2015). The ice stream was a major source of Ice Rafted Detritus (IRD) to the deep ocean reflecting retreat/re-advance phases of the ice stream (Scourse et al. 2009). We determine the geochemical signature of the ice stream's glacimarine sediment and its spatial variability using X-Ray Fluorescence with the aim to correlate these end members to the composition of the IRD flux in a deep sea core from the Goban Spur (MD04-2820CQ). We present initial results from the XRF analysis of Irish Sea Ice Stream end member sediments. Principle Component Analysis was used to characterise these end members into groups with a similar geochemical composition to trace the source of the IRD flux record in the deep ocean and how this reflects the position of the ice stream's calving margin.

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Holocene sea-level changes in Wales: a combined empirical and model-based approach

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Current predictions of sea-level change around the UK up to the year 2100 are based on geophysical models that are calibrated by past relative sea-level observations. These models are potentially unreliable as regional patterns of Holocene relative sea-level change, particularly in Wales, are poorly constrained. The aim of this work is to establish a new Holocene sea-level reconstruction for Wales from peat preserved in coastal freshwater back-barrier marshes at Abermawr in south Wales (Pembrokeshire) and Rhoscolyn in north Wales (Anglesey). These two sites are situated along an isostatic gradient as a result of Holocene subsidence of Pembrokeshire relative to Anglesey. This work builds on the approach by Gehrels and Anderson (2014) who first demonstrated the suitability of peat deposits in coastal freshwater back-barrier marshes for sea-level reconstructions. Methods to establish the stratigraphy of these sites include hand-drilled coring, ground-penetrating radar, electrical resistivity tomography and seismic surveys. Sea-level index points are collected from basal Holocene peat and are immune to sediment compaction. Groundwater monitoring will be used to determine if the back-barrier water table is controlled by tide levels. Groundwater modelling will test the influences of stratigraphy, peat permeability and marsh recharge on the relationship between groundwater level and sea level. Peatland testate amoebae will be used to reconstruct the historic mean annual water table of the back barrier marsh. The age of sea-level index points will be determined by radiocarbon dating. New data will be combined with existing regional data to present an amended and improved Holocene relative sea-level curve for Wales.

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Roughness of palaeo-ice stream beds

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Bed roughness is defined as the vertical variation of terrain over a given horizontal distance. It is one of a number of controls on ice stream location and flow, which also includes topography, meltwater routing, and subglacial geology. Ice streams are an important control on the behaviour of ice sheets – for example, in Antarctica, up to 90% of ice is discharged through ice streams and outlet glaciers. However, the inaccessibility of the bed beneath contemporary ice sheets has hampered research and caused bed roughness often to be overlooked. This has limited the understanding of ice stream behaviour, and consequently, the ability to accurately model ice sheets. Radio Echo Sounding (RES) profiles have enabled measurements of macro scale (> 10 km horizontal length) bed roughness underneath ice streams in Antarctica. This has shown that in general, smooth beds are located underneath fast flowing ice streams, whilst the bed is rougher beneath slower-flowing regions. However, RES profiles are limited because while they may provide data with an along-track resolution of ms-10s m, there is usually 10s of m or km between profiles. Derived roughness maps are therefore relatively coarse, which makes interpretation of bed roughness results difficult, and does not allow for a range of bed roughness scales to be measured. Palaeo-ice streams can be used as analogues of active ice streams and Digital Elevation Models (DEMs) such as NEXTmap (5 m resolution) provide a high resolution 3D data set which has the potential to produce roughness signatures for individual landform and bedform types. Despite this, only a handful of studies have looked at bed roughness of previously glaciated landscapes. This project will quantify bed roughness of palaeo-ice streams, and compare the bed roughness of different glacial landforms and bedforms. Bed roughness will be measured along the Minch palaeo-ice stream, NW Scotland, by applying amplitude and spacing parameters to a combination of NEXTmap DEMs and bathymetry data.

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

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Poole Harbour estuary, southern England, is an area of ecological importance with a history of long term eutrophication and is 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 for the harbour along with the sewage treatment effluent which enters to the north of the harbour 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 the 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 the nutrient and ecological history of Poole Harbour over the last ~250 years. The study will focus on the areas where the main sources of nutrients enter the estuary itself to identify the nutrient and ecosystem baseline. It can then be determined how the nutrient drivers affect 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.

Radiocarbon based evidence for a significant role of the Atlantic Ocean in deglacial atmospheric CO_2 rise

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Understanding the cause of the ~90ppm difference in atmospheric CO_2 during glacial versus interglacial periods remains a major challenge for palaeoclimate scientists. Whilst the cause is almost certainly related to a greater storage of carbon in the ocean, the mechanism remains unsolved. Radiocarbon based ventilation ages could shed light on this problem by helping to determine the distribution of carbon in the ocean as well as the partitioning of carbon between the ocean and the atmosphere. Despite this, deglacial Atlantic radiocarbon ventilation is very poorly constrained. Emerging new data however suggest an interesting story with a significant role for the Atlantic Ocean both in storing carbon during the last glacial maximum (LGM) and by triggering major releases of carbon over the last deglaciation.

The deep Atlantic Ocean was much more poorly ventilated at the LGM compared to today, most likely due to a reduced/altered Atlantic Meridional Overturning Circulation. This is expected to be associated with increased carbon storage due to reduced release of CO_2 to the atmosphere from a deep ocean that was receiving a continuous input of carbon via the biological pump.

Atmospheric CO_2 levels rose in a series of steps over the last deglaciation with a rapid jump at around 14.8kyrs BP (Marcott et al., 2014). A ventilation pulse of the entire intermediate and deep Atlantic (>1000m) looks to occur synchronously with this rapid increase in pCO_2. We therefore propose that it was during this time that the reduced/shoaled Atlantic Meridional Overturning Circulation observed at the LGM was reinvigorated and deepened resulting in the rapid release of deeply sequestered carbon to the atmosphere.

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Notes

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