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Welcome to the University of Leeds

Dear delegates, dear friends of the Quaternary,

It is our genuine pleasure to welcome you to Leeds for the 2020 Annual Discussion Meeting of the Quaternary Research Association. Surrounded by the lovely Yorkshire countryside where the impact of the Quaternary ice ages and records of intervening interglacials are hard to miss, we feel that Leeds is ideally suited to host, for the first time, this scientific meeting with such a rich tradition. We are particularly pleased to welcome so many early career scientists from around the UK - and whether this is your first QRA ADM or your 20th, we hope you will all have a great time.

With the meeting theme ‘Quaternary Earth System processes and feedbacks: challenges for society’, our aim is to highlight the interconnectivity of various parts of our Earth system, in particular over the last 2.6 million years up until the present day. No matter where you stand on the Anthropocene discussion, it is clear that a better understanding of our planet through the Quaternary can provide crucial insights into otherwise unrecognised climate feedbacks, tipping points and shifts in system states - and the importance of these issues has been highlighted by the IPCC, and by UKRI who are continually developing funding calls on these themes. All your research therefore provides case studies for understanding our currently evolving climate and projecting it into the future.

We are looking forward to an exciting line-up of keynote speakers covering six broad research topics that stand in the context of the Quaternary, but also of the Geological Society of London’s Year of Carbon 2019 (the Leeds QRA ADM is in 2020, but that's probably within the error of our age model).

Besides a range of excellent talks and posters, we also hope that you will be able to sample some of the rich social life and gastronomy Leeds has to offer, including the truly amazing cuisine at Tharavadu for our conference gala dinner.

Our sincere thanks go to all our sponsors, but especially to all of you - you are filling this meeting with purpose and life, and we will do our best to make it a positively memorable experience for you.

Welcome to Leeds, and we hope you enjoy the meeting!

The organising members of Leeds Quaternary and the Leeds hippo
Conference Organisers

Should you have any questions throughout the duration of the conference, please do not hesitate to approach one of the organisers.

Dr Natasha Barlow
Dr Christian März
Dr Paul Morris
Prof Graeme Swindles

Dr Ruza Ivanovic
Luis Rees-Hughes
Andy Emery
Niall Gandy

Thomas Sim
Jenna Sutherland
Dr Karen Bacon
(NUI Galway)
Keynote Speakers

Dr Natalya Gomez  (McGill University)  
*Ice Sheet - Sea Level - Solid Earth Interactions*

Dr Kirsty Penkman  (University of York)  
*Through the Looking-Glass, and What Amino Acids Found There*

Dr James Rae  (University of St Andrews)  
*High latitude controls on glacial CO₂ and climate*

Dr Angela-Gallego Sala  (University of Exeter)  
*Global peatland carbon: challenges and opportunities*

Prof Paul Valdes  (University of Bristol)  
*Learning lessons from the Past – Does Quaternary Science help predict the future?*

Prof Camille Li  (University of Bergen)  
*At the crossroads of atmosphere-ice-ocean mechanisms for abrupt climate change*
Getting to and from Campus

Walking

The University campus is a pleasant 20-minute walk from Leeds city station. Just follow the directions below and you'll be with us in no time at all:

Leave the station onto City square; with the Queens Hotel behind you, walk straight up Park Row. Continue up Park Row until the first major junction. Cross straight over The Headrow and continue up Cookridge Street. At the next set of lights, go straight on passing Millennium Square on your left and Leeds City Museum (home of the Leeds hippo) on your right.

Turn left onto Woodhouse Lane, a busy main road. You'll pass Leeds Beckett University on your left, and after another 100 m you'll arrive at our University campus on your left. To reach the Parkinson building, carry on up Woodhouse Lane to the white clock tower building.

By train

Leeds train station connects us with all major UK cities and has a fast and efficient London service. For train information and timetables, visit the National Rail Enquiries website.

By bike

If you're thinking about cycling to the University, we have secure bike racks and showers. For bike routes and information about cycling in the city, visit the Leeds City Council cycling pages. If you are visiting us by bike and have any questions or mechanical issues, our bike hub can help.

By bus or coach

Leeds coach station is where most long-distance coaches arrive into and leave the city. Main operators are National Express and Megabus. The coach station is right beside Leeds city bus station, where you can get local buses, including to the University. If you are traveling by train, buses 27 and 28 operate from directly outside the railway station and stop at Parkinson's Steps, outside the Parkinson Building.

For local bus information and timetables, visit the West Yorkshire Metro website and First Leeds and Arriva Yorkshire. There is also a city bus (number 5) which stops at the bus and train stations and the southern end of campus (near the back of Leeds General Infirmary A&E) every 10 minutes from 6.30 am - 7.30 pm Monday to Saturday. There is a taxi rank outside the bus and coach station. A taxi to the University takes about 10 minutes.
By car

If you are using satellite navigation, our address details for the main entrance to our site, near to Parkinson Building are:

University of Leeds
Woodhouse Lane
Leeds
LS2 9JT

*street listing can appear as Cavendish Road in some navigation systems

Leeds is linked to the M1 and M62. Parking on campus is very expensive for visitors (~£30 per day) and therefore you are best to use city car parks. However, please do contact us if you require a parking space on the campus for accessibility needs, where we can make alternative arrangements. We are also committed to reducing our carbon emissions, so we encourage visitors to walk or use alternative transport where possible.
Map from Leeds train station

Tharavadu (Conference meal)
Campus Map

A high-resolution campus map is available for download: https://www.leeds.ac.uk/downloads/download/9/campus_map_for_visitors

Campus Map

Key

18. Western Lecture Theatre
19. Leeds University Business School (LUBS)
22. Eilersie Hall
28. University House
29. Refectory
30. Lyddon Hall
44. Henry Price Residence
57. Great Hall
60. Parkinson Building
75. School of Music
78. Michael Sadler Building
86. Charles Morris Hall (Dobree House, Storm Jameson Court, Whetton House)
88. Staff Centre
89. Roger Stevens Building
100. Conference Auditorium
101. Sports & Exhibition Centre/The Edge

Car parks
- University car park (limited access)
- Other university car parks
- Public multi-storey car park

Other useful information
- CityBus Stop
- Bus Stop
- Taxi Rank
- Footpath
- Pedestrian Only Area
- Lawns

NB. Building numbers correspond to the University’s official maps which can be found on campus.
Inclusivity Statement

At the Leeds 2020 QRA ADM, we want every participant to feel welcome, included, and safe at the conference. Our goal is to create an inclusive, respectful conference environment that invites participation from people of all races, ethnicities, genders, ages, abilities, religions, and sexual orientations free from discrimination or harassment. We follow the guidelines provided by the 2019 INQUA Congress.

Expectations of attendees:

- Everyone involved with the Leeds 2020 QRA ADM is expected to show respect towards the attendees, venue staff, the Organising Committee, volunteers and all others participating with the meeting.
- The open exchange of ideas and the freedom of thought and expression are central to the aims and goals of the Leeds 2020 QRA ADM.
- The Leeds 2020 QRA ADM will be an environment that recognises the inherent worth of every person and group, that fosters dignity, understanding, and mutual respect, and that embraces diversity.
- We will do our best to accommodate specific needs such as accessibility or dietary requirements.
- The Leeds 2020 QRA ADM expects all interactions between attendees to be respectful and constructive, including interactions during the formal programme.
- Unacceptable behaviour will not be tolerated at the Leeds 2020 QRA ADM. Examples of unacceptable behaviour include, but are not limited to, bullying, intimidation, inappropriate physical contact or unwelcome sexual attention, continuous disruption of events or interference with participation or opportunity for participation of other people attending the meeting.
- We require attendees to follow this code during all of the Leeds 2020 QRA ADM and in all online interactions with the meeting (including social media and any other online facilities) and related social activities.
- The Leeds 2020 QRA ADM requests that all attendees abide fully with United Kingdom Equality Act in their participation in all meeting activities.
Wednesday 8th January 2020

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>0900-0955</td>
<td>Registration, Parkinson Building</td>
<td>Ice Sheet - Sea Level - Solid Earth Interactions</td>
</tr>
<tr>
<td>0955-1000</td>
<td>Welcome</td>
<td></td>
</tr>
<tr>
<td>1000-1030</td>
<td>Natalya Gomez</td>
<td>Ice Sheet - Sea Level - Solid Earth Interactions</td>
</tr>
<tr>
<td>1030-1050</td>
<td>Edward Gasson</td>
<td>Differences in the rates and character of the last two glacial terminations</td>
</tr>
<tr>
<td>1050-1110</td>
<td>Sarah Bradley</td>
<td>Fully coupled simulation of the Northern Hemisphere climate and ice sheets during the Last Glacial Maximum with CESM2.1/CISM2.1</td>
</tr>
<tr>
<td>1110-1140</td>
<td>Coffee, Parkinson Building</td>
<td></td>
</tr>
<tr>
<td>1140-1200</td>
<td>Kenji Izumi</td>
<td>Impacts of the PMIP4 ice-sheets on Northern Hemisphere atmospheric circulation during the last glacial period.</td>
</tr>
<tr>
<td>1200-1220</td>
<td>Jeremy Ely</td>
<td>An ensemble simulation of the last British-Irish Ice Sheet: Comparison with evidence and persistent model-data mismatch</td>
</tr>
<tr>
<td>1220-1240</td>
<td>Victor Cartelle</td>
<td>Buried glacial landscapes offshore the Netherlands: the southernmost limit of the Saalian ice sheet in the North Sea</td>
</tr>
<tr>
<td>1240-1300</td>
<td>Rachel Harding</td>
<td>The submerged Holocene landscape of the Brown Bank, North Sea and the search for evidence of Mesolithic inhabitation – a multi-disciplinary approach</td>
</tr>
<tr>
<td>1300-1400</td>
<td>Lunch, Parkinson Building</td>
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</tr>
<tr>
<td>1400-1420</td>
<td>Martina Conti</td>
<td>Molecular fossils inferring Quaternary sea-level changes</td>
</tr>
<tr>
<td>1420-1440</td>
<td>Sophie Norris</td>
<td>Rapid retreat of the western Laurentide Ice-Sheet driven by Bølling-Allerød warming</td>
</tr>
<tr>
<td>1440-1500</td>
<td>Jenna Sutherland</td>
<td>The impact of large proglacial lakes on past outlet glacier dynamics during the Last Glacial Maximum in New Zealand</td>
</tr>
<tr>
<td>1500-1530</td>
<td>Coffee, Parkinson Building</td>
<td></td>
</tr>
<tr>
<td>1530-1600</td>
<td>Kirsty Penkman</td>
<td>Through the Looking-Glass, and What Amino Acids Found There</td>
</tr>
<tr>
<td>1600-1620</td>
<td>Marc Dickinson</td>
<td>Intra-crystalline protein degradation dating of mammalian enamel: building geochronologies</td>
</tr>
<tr>
<td>1620-1640</td>
<td>Lucy Wheeler</td>
<td>Bringing amino acid geochronology of sea-level records up to date: investigating the intra-crystalline approach for foraminifera</td>
</tr>
</tbody>
</table>
1640-1700 Diana Sahy The age of methane-derived authigenic carbonates at seafloor cold seeps on the U.S. Atlantic Margin

1700-1800 Poster session and drinks reception, Parkinson Building

1800-1900 Quaternary Research Association AGM, including a presentation by INQUA President Thijs van Kolfschoten and medal presentations - Rupert Beckett Lecture Theatre, Michael Sadler Building

The red brick building on the right is the Michael Sadler Building. The white porched door gives direct entrance to the Rupert Beckett Lecture Theatre, down one flight of stairs.
<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
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<tbody>
<tr>
<td>0830-0900</td>
<td>Registration, Parkinson Building</td>
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</tr>
<tr>
<td>0900-0930</td>
<td>James Rae</td>
<td>High latitude controls on glacial CO₂ and climate</td>
</tr>
<tr>
<td>0930-0950</td>
<td>Charles Maxson</td>
<td>A Holocene carbon isotope record from Blue Lake North Stradbroke Island, Queensland, subtropical Australia</td>
</tr>
<tr>
<td>0950-1010</td>
<td>Craig Smeaton</td>
<td>Where’s the Carbon: Exploring the Spatial Heterogeneity of Sedimentary Carbon in Mid-Latitude Fjords</td>
</tr>
<tr>
<td>1010-1030</td>
<td>Ben Fisher</td>
<td>Implications of Carboxylic Acids for the Preservation of Iron associated Organic Carbon in the Seafloor</td>
</tr>
<tr>
<td>1030-1100</td>
<td>Coffee, Parkinson Building</td>
<td></td>
</tr>
<tr>
<td>1100-1130</td>
<td>Angela Gallego-Sala</td>
<td>Global peatland carbon: challenges and opportunities</td>
</tr>
<tr>
<td>1130-1150</td>
<td>Paul Morris</td>
<td>Spatiotemporal dynamics of Holocene fen-bog transitions in northern peatlands</td>
</tr>
<tr>
<td>1150-1210</td>
<td>Mariusz Galka</td>
<td>Long-term Sphagnum succession in mountain peatland ecosystems across Central and Western Europe: implications for peatland conservation</td>
</tr>
<tr>
<td>1210-1230</td>
<td>Richard Fewster</td>
<td>Drivers of Holocene palsa distribution in North America</td>
</tr>
<tr>
<td>1230-1400</td>
<td>Lunch and poster session, Parkinson Building</td>
<td></td>
</tr>
<tr>
<td>1400-1420</td>
<td>Dylan Young</td>
<td>Misinterpreting carbon accumulation rates in records from near-surface peat</td>
</tr>
<tr>
<td>1420-1440</td>
<td>Graeme Swindles</td>
<td>An oasis in a desert: A multiproxy palaeoecological record from a contemporary ‘refugium’ in Ilkley Moor</td>
</tr>
<tr>
<td>1440-1500</td>
<td>Rosie Everett</td>
<td>From the micro to the molecular: the challenges of contextualising multi-proxy taphonomic processes in understanding past ecosystem dynamics</td>
</tr>
<tr>
<td>1500-1520</td>
<td>Matt Jones</td>
<td>Palaeobenchmarking Resilient Agricultural Systems</td>
</tr>
<tr>
<td>1520-1550</td>
<td>Coffee, Parkinson Building</td>
<td></td>
</tr>
<tr>
<td>1550-1620</td>
<td>Paul Valdes</td>
<td>Learning lessons from the Past – Does Quaternary Science help predict the future?</td>
</tr>
<tr>
<td>1620-1640</td>
<td>Peter Hopcroft</td>
<td>Unlocking abrupt dynamics through optimisation of climate model parameterisations: Application to the termination of the African Humid Period</td>
</tr>
<tr>
<td>1640-1700</td>
<td>Paul Fish</td>
<td>Quaternary science supporting management of nuclear waste on the Cumbrian coast</td>
</tr>
<tr>
<td>1700-1720</td>
<td>Tom Berry</td>
<td>Relict periglacial hazards in the UK: engineering guidance for hazard mitigation</td>
</tr>
<tr>
<td>Time</td>
<td>Activity</td>
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</tr>
<tr>
<td>1800-1900</td>
<td>Optional visit to the Leeds hippo, Leeds City Museum. 25 people per session – please sign up at the registration booth by 1400. Postgraduates will lead groups to the Museum from Parkinson Building at 1745 and 1815.</td>
<td></td>
</tr>
<tr>
<td>1930-late</td>
<td>Conference dinner, Tharavadu (ticket must have been purchased in advance)</td>
<td></td>
</tr>
</tbody>
</table>

*Entrance to Parkinson Building, from Woodhouse Lane*
## Friday 10th January 2020

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>0830-0900</td>
<td>Registration, Parkinson Building</td>
<td>State shifts and abrupt changes – Rupert Beckett Lecture Theatre, Michael Sadler Building</td>
</tr>
<tr>
<td>0900-0920</td>
<td>Julian Murton</td>
<td>State shifts in permafrost environments since the Middle Pleistocene at the Batagay megaslump, Siberia</td>
</tr>
<tr>
<td>0920-0940</td>
<td>Adrian Palmer</td>
<td>Developing British distal glaciolacustrine varve records as high resolution archives of abrupt climate change</td>
</tr>
<tr>
<td>0940-1000</td>
<td>Jonathan Dean</td>
<td>Rapid shifts during the late glacial-Holocene climatic transition in the Eastern Mediterranean region, reconstructed from multiple proxies in central Turkish lakes</td>
</tr>
<tr>
<td>1000-1020</td>
<td>Alastair Curry</td>
<td>Secrets from the Lady of the Lake: an 11,000 year history of episodic talus erosion and resedimentation in the Brecon Beacons</td>
</tr>
<tr>
<td>1020-1040</td>
<td>Edd Armstrong</td>
<td>A Northern Hemisphere terrestrial climate dataset for the past 60,000 years</td>
</tr>
<tr>
<td>1040-1110</td>
<td>Coffee, Parkinson Building</td>
<td></td>
</tr>
<tr>
<td>1110-1140</td>
<td>Camille Li</td>
<td>At the crossroads of atmosphere-ice-ocean mechanisms for abrupt climate change</td>
</tr>
<tr>
<td>1140-1200</td>
<td>Louise Sime</td>
<td>The impact of abrupt sea ice loss on Greenland water isotopes during the Last Glacial Period</td>
</tr>
<tr>
<td>1200-1220</td>
<td>Lauren Gregoire</td>
<td>The role of ice sheet dynamics in the collapse of the early-Holocene Laurentide Ice Sheet: implications for the 8.2 kyr event</td>
</tr>
<tr>
<td>1220-1240</td>
<td>Mark Bateman</td>
<td>Evidence for abrupt shifts in ice advance of the British and Irish Ice sheet into Yorkshire during the MIS 3.</td>
</tr>
<tr>
<td>1240-1400</td>
<td>Lunch and departure, Parkinson Building</td>
<td></td>
</tr>
</tbody>
</table>
## Poster Presentations Programme

Available to view in Parkinson Building throughout the conference, with dedicated poster sessions alongside a drinks reception 1700-1800 Wednesday 9th, and during lunch on Thursday 10th.

<table>
<thead>
<tr>
<th>Presenter’s name</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abi Stone</td>
<td>Using portable luminescence readers to explore dryland dynamics</td>
</tr>
<tr>
<td>Alexander Jardine</td>
<td>Geomorphological and Archival Evidence of Coastal Storms</td>
</tr>
<tr>
<td>Andrew Mair</td>
<td>Spatial and temporal records of South Western Atlantic oceanography from the Uruguayan margin</td>
</tr>
<tr>
<td>Andy Emery</td>
<td>Down by the river: Terrestrial drainage network evolution at Dogger Bank during glacial to interglacial transition</td>
</tr>
<tr>
<td>Bing Liu</td>
<td>Ecology and paleoenvironmental application of testate amoebae in peatlands of the high-elevation Colombian páramo</td>
</tr>
<tr>
<td>Caitlin Nagle</td>
<td>Holocene relative sea-level changes in West Wales: data from the Dysynni Valley</td>
</tr>
<tr>
<td>Charlie Rex</td>
<td>Tracing state shifts from a terrestrial sequence spanning the last glacial-interglacial cycle in the Cheshire Basin, UK</td>
</tr>
<tr>
<td>Christopher Darvill</td>
<td>Retreat of the Cordilleran Ice Sheet and exposure of coastal islands during the last deglaciation in British Columbia, western Canada</td>
</tr>
<tr>
<td>Dale Tromans</td>
<td>The timing and spatial expression of Holocene rapid climate events: a view from the Dinaric Alps</td>
</tr>
<tr>
<td>Derek McDougall</td>
<td>Recent mountain glaciation and landscape development in the southern part of the Helvellyn Range, NW England</td>
</tr>
<tr>
<td>Emma Pearce</td>
<td>Modelling Firn: Is seismic Full Waveform Inversion the solution?</td>
</tr>
<tr>
<td>Eric Wolff</td>
<td>What happened to WAIS during the last interglacial? - how the new Skytrain Ice Rise core will help to answer that</td>
</tr>
<tr>
<td>Fiona Turner</td>
<td>Uncertainty and Emulation: Using Bayesian methods to learn more about past ice sheet shapes.</td>
</tr>
<tr>
<td>Graham Potts</td>
<td>Quantitative relationships between fault kinematics and glacial processes</td>
</tr>
<tr>
<td>Graham Rush</td>
<td>A high-resolution relative sea-level reconstruction from east Scotland to constrain the meltwater pulses that forced the 8.2 ka event.</td>
</tr>
<tr>
<td>Greg Rushby</td>
<td>Late Holocene Coastal Change at Malltraeth driven by sea level and anthropogenic change</td>
</tr>
<tr>
<td>Joshua Leigh</td>
<td>‘Little Ice Age’ maxima and glacier retreat in northern Troms and western Finnmark; northern Norway</td>
</tr>
<tr>
<td>Katie Cupples</td>
<td>Simulating anomalous enhanced North African precipitation during the mid-Holocene: a paleoclimatological enquiry using the isotope enabled HadCM3</td>
</tr>
<tr>
<td>Luis Rees-Hughes</td>
<td>Buried Beaches and Drowned Dunes: Reconstructing a late Holocene buried dune environment using 3D ground-penetrating radar imaging and image segmentation</td>
</tr>
<tr>
<td>Niall Gandy</td>
<td>Saddle Collapse of the Eurasian Ice Sheet in the North Sea caused by combined ice flow, surface melt and marine ice sheet instabilities</td>
</tr>
<tr>
<td>Ruza Ivanovic</td>
<td>The Last Deglaciation Meltwater Paradox</td>
</tr>
<tr>
<td>Name</td>
<td>Title</td>
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</tr>
<tr>
<td>Sean Gilgannon</td>
<td>Morphological analysis of large-scale glacial and glaciofluvial bedrock-incised landforms</td>
</tr>
<tr>
<td>Simon Hutchinson</td>
<td>Rediscovering Relicks Moss: an overview of a multi-proxy peat core record of Holocene environmental change at Delamere, Cheshire</td>
</tr>
<tr>
<td>Stephen Eaton</td>
<td>Palaeogeographic change in response to glacial/interglacial cycles: Middle and Upper Pleistocene stratigraphy of the southern North Sea</td>
</tr>
<tr>
<td>Stephen Gale</td>
<td>Dating European contact in Australia: the eastern Australian magnetic inclination anomaly</td>
</tr>
<tr>
<td>Thomas Sim</td>
<td>The response of permafrost peatlands in Arctic Sweden to late Holocene climate change</td>
</tr>
<tr>
<td>Trevor Faulkner</td>
<td>The importance of Greenland interstadial 2</td>
</tr>
<tr>
<td>William Roberts</td>
<td>Changes in storminess over the last deglaciation in the Southern Hemisphere</td>
</tr>
<tr>
<td>Yucheng Lin</td>
<td>Inverting the source and magnitude of meltwater pulse 1A using sea-level constraints</td>
</tr>
<tr>
<td>Yvan Romé</td>
<td>Ocean circulation mode transitions in North Atlantic during Marine Isotope Stage 3</td>
</tr>
</tbody>
</table>
Oral Presentation Abstracts

Session 1: Ice, oceans and sea-level
Ice Sheet - Sea Level - Solid Earth Interactions

Natalya Gomez*, David Pollard, Holly Han, Mike Weber, Peter Clark, Jerry Mitrovica, Robert DeConto, Jeannette Wan, Erik Chan, Konstantin Latychev, Evelyn Powell

*natalya.gomez@mcgill.ca

1 McGill University

Modelling past ice sheet and sea level changes has classically been approached either by inferring ice cover changes through applying sea level modelling and comparing to geological sea level records, or by modelling the dynamic response of ice sheets to past climate changes. More recently, we have developed coupled models that simultaneously predict dynamic ice sheet evolution, global sea level changes and deformation of the solid Earth, and the feedbacks that arise between ice dynamics and sea level changes. These coupled models represent a new tool for self-consistently capturing regional ice sheet dynamics and their contributions to near-field and far-field sea level changes globally, allowing for comparison to a wide range of geologic and geodetic datasets.

This talk will cover the physics of the interactions between ice sheets, sea levels and the solid Earth, and present recent work applying coupled modelling to give insight into ice sheet evolution and associated sea level changes over the last glacial cycle and during past warm periods such as the Pliocene. Results will focus on Antarctica, where there is extensive marine-based ice, and where complex, and laterally varying rheological structure of the solid Earth beneath the Antarctic ice sheet influences predictions of ice sheet evolution, sea level changes and modern glacial isostatic adjustment. The influence of sea-level change and solid Earth deformation on Northern Hemisphere ice cover variations, and the potential for inter-hemispheric teleconnections between ice sheets to arise through sea level change will also be discussed.
Differences in the rates and character of the last two glacial terminations

Edward Gasson*¹, Heather Stoll, Rob DeConto, Chris Clark

*e.gasson@bristol.ac.uk

¹ University of Bristol

Compared with the intensely studied interval of the last glacial maximum and termination, significantly less attention has been given to the preceding glacial period and Termination 2. This is perhaps understandable as the Greenland ice cores do not stretch this far back in time and the terrestrial record of the ice sheets has in part been lost during the subsequent glacial period. However, there are many questions remaining about how these two glacial intervals differed and whether this was important in driving some of the differences between the last interglacial and our current interglacial. Here I’ll focus on two aspects of the penultimate glacial and highlight some of the contrasts with the most recent glacial period.

Firstly, there is evidence for an Arctic ice shelf seen in extensive ice scouring on the Lomonosov Ridge in the central Arctic Ocean in water depths exceeding a kilometre. I’ll present modelling work that supports the interpretation that these features were caused by an ice shelf that extended across the entire Arctic Basin and discuss what significance an ice shelf may have had to the glacial Earth system. I’ll also discuss the dating of these features and why such a thick ice shelf may have formed during certain glacial stages and not others.

Second, I’ll focus on a new speleothem record from northern Spain which records the meltwater-driven d18O anomaly in the eastern North Atlantic and provides an absolutely dated chronology (U/Th) during the penultimate glacial and Termination 2. The character of which differs dramatically from a record for Termination 1 recovered from speleothems at the same site. I’ll discuss some possible reasons for the differences between the two glacial terminations recorded at this site and present model experiments to test these hypotheses.
Fully coupled simulation of the Northern Hemisphere climate and ice sheets during the Last Glacial Maximum with CESM2.1/CISM2.1

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We present preliminary results of a project aiming to produce the first transient fully coupled climate/ice sheet simulation of the last deglaciation using the newly released Community Earth System Model 2.1 (CESM2.1). The main goal of the project is to investigate the role of different feedbacks and dynamical processes in controlling the deglaciation of the Northern Hemisphere ice sheets. Key features of the CESM2.1 model setup are: (1) bi-directional coupling between the land and ice sheet model, where the surface mass balance (SMB) and near-surface air temperature fields are computed at multiple elevations and downscaled to the active ice sheet regions; (2) a new one-way coupling from the ocean to the ice sheet model, where the simulated depth-varying ocean temperature and salinity are extrapolated into ice shelf cavities and used to force a two-equation sub-shelf melting parametrisation.

The Earth system model is forced according to the protocols of the Paleoclimate Modelling Intercomparison Project 4 (PMIP4). However, the input palaeo-bathymetry and ice sheet reconstruction are generated using a global Glacial Isostatic Adjustment (GIA) model which combines the new and different empirically-constrained Eurasian Ice sheet reconstruction (developed as part of the BRITICE-CHRONO project) with the Greenland - North American ice sheet chronologies taken from Lecavalier et al., 2014. Additionally, a new and different LGM paleo vegetation reconstruction is incorporated generated from BIOME4. We will show results of the 1 Last Glacial Maximum (LGM 21 ka) CESM2.1 climatology generated using static Northern Hemisphere ice sheets, which will be evaluated against a range of empirical constraints.
Impacts of the PMIP4 ice-sheets on Northern Hemisphere atmospheric circulation during the last glacial period

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The Last Glacial Maximum (LGM; 21000 yr before present) is a target period of the paleoclimate simulations in the Coupled Model Intercomparison Project Phase 6 – the Paleoclimate Modeling Intercomparison Project Phase 4 (CMIP6–PMIP4) because of abundant in continental, ice, and marine indicators. The LGM was a period of low atmospheric trace gases, when large ice-sheet covered over the North America and Scandinavia. Paleoclimate reconstructions and modeling studies suggest that the Northern Hemisphere atmospheric circulation was substantially different from today. In this study we used HadCM3B-M2.1aD coupled atmosphere-ocean-vegetation general circulation model to investigate the impacts of the main LGM boundary condition changes. In particular, we use alternative ice-sheet reconstructions, following the PMIP3 and PMIP4 protocols, specifically Peltier ICE-6G\textsubscript{C}, Tarasov GLAC-1D, and the PMIP3 ensemble ice sheet. We show the mean state of the atmospheric circulation as represented 200-hPa and 850 hPa eddy geopotential height, 200-hPa zonal wind, and precipitation over the Northern Hemisphere extratropics. The wintertime stationary waves using ICE6G and PMIP3 show a fundamental difference compared to GLAC-1D. The larger ICE6g icesheet splits the westerlies and results in a pattern of change which is very different to the lower GLAC-1D ice sheet where the circulation is less deflected. This has significant further consequences in terms of sea ice cover and surface temperatures. In summer, the three simulations of stationary waves are more similar since the area of the ice sheets are also similar. This result shows that small differences in ice sheet elevation can have important impacts on the resulting climate. Furthermore, data-model comparison was performed at data sites to evaluate the simulations in regard to the realism of large-scale response features. The simulation with the ICE-6G\textsubscript{C} captures features of the LGM climate state better.
An ensemble simulation of the last British-Irish Ice Sheet: Comparison with evidence and persistent model-data mismatch

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New data from the BRITICE-CHRONO consortium project shows that the British-Irish Ice Sheet (BIIS) was highly dynamic; advancing and retreating in an asynchronous and highly spatially variable manner. This behaviour is a challenge to replicate in ice-sheet models. Here, we perform ensemble simulations of the BIIS using the Parallel Ice Sheet Model. The model is forced with output from a global climate model, corrected to account for glacioisostatic adjustment and empirically reconstructed ice sheet surface topography at one-thousand-year time intervals. Four small (n = 50) ensemble experiments are conducted, accounting for two methods of dealing with basal friction (prescribed and evolving due to basal hydrology) and two climate records (derived from Greenland and Antarctic ice cores). Each member of the ensembles is compared with three sources of data, the particulars of which require three separate tools: i) geochronological data, recording the timing of ice-free conditions; ii) flowsets of subglacial bedforms, recording ice flow direction; and iii) the position of moraines, recording ice-margin position and shape. These comparisons enable us to quantify the fit between the simulation and data. Our results show that persistent model-data mismatch occur. The advance of ice to the Celtic shelf break is difficult to replicate, perhaps due to missing surge-dynamics in the model. The model also often fails to correctly replicate the timing of retreat from the North-western continental shelf break, perhaps due to simplified ocean forcing in the model. Furthermore, the pattern of ice retreat in the North Sea is dependent upon the basal friction scheme used. Despite this, the model can replicate many of the characteristics of the inferred behaviour of the BIIS. To conclude, we present the best-fit simulation, showing a modelled reconstruction of the BIIS.
Buried glacial landscapes offshore the Netherlands: the southernmost limit of the Saalian ice sheet in the North Sea

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During the late Quaternary interglacial-glacial history of the North Sea, several ice sheets advanced into current offshore areas, leaving a clear imprint of erosion and infill of the basin. These deposits are interbedded with a wide range of fluvial, marine, coastal and terrestrial sediments building up a complex stratigraphic framework.

The acquisition of new high-resolution geophysical data to support offshore renewable energy development in the North Sea provides an invaluable opportunity to investigate the youngest Quaternary infill and to develop palaeoenvironmental models. Among these extensive windfarms, Holland Kust noord is close to the reported limit of the Saalian ice sheet offshore the Netherlands (Joon et al., 1990). The new data not only allows increasing confidence in defining the southernmost limit of this ice sheet in the North Sea, but also provides a great opportunity to unveil glacial buried landscapes.

The northern half of the surveyed area is dissected by NE-SW trending incised valleys, up to 40 m below the seafloor. These incisions correspond to subglacial meltwater channels (tunnel valleys) distinguished by a rising and falling thalweg, steep walls and abrupt endings. Their orientation is coherent with an ice advance in a southwestward direction during the Drente (MIS 6) glaciation. These valleys are filled with acoustically chaotic or transparent facies, possibly deposited during deglaciation. Some valleys also display acoustically well-laminated facies, deposited during later proglacial, transgressive and regressive stages. To the west of the study area, some of the wider valleys are filled by clinoforms with northwards dipping reflectors probably deposited through backfill upon glacial recession.

Glacial valleys become wider and shallower to the south, with less topographic variation. Several E-W oriented ridge-like deposits are preserved with some intervening channels or elongated basins. These deposits are intensively deformed and may represent glaciotectonized moraine complexes.

An extensive (> 14 km2) and relatively shallow depression is present in the southwest windfarm area. Infilling deposits are characterized by semi-continuous parallel reflectors, in some areas affected by high-amplitude acoustic anomalies revealing the presence of peat. Initial infill under proglacial conditions is likely, but these deposits mainly correspond to post-Saalian transgressive, Eemian interglacial and early Weichselian regressive sediments. Peat layers are tentatively attributed to the warm Eemian interglacial. Further integration of borehole and cone penetration.
The submerged Holocene landscape of the Brown Bank, North Sea and the search for evidence of Mesolithic inhabitation – a multi-disciplinary approach

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The Brown Bank, an elongated, 30 km-long sand ridge roughly 100 km due east from Great Yarmouth and 80 km west of the Dutch coast, and the surrounding area have long been suspected of containing evidence of prehistoric settlement. Over the decades, a concentration of archaeological material, including bone, stone and human remains, have been dredged up by trawlers and fishing vessels. The Naaldwijk Formation (Fm), comprising tidal channels and flats, was deposited in the early Holocene under a transgressive sea-level regime and has been identified as the potential feeder bed for Mesolithic age archaeological and palaeontological finds.

In 2018, an INNOMAR parametric echo sounder was used to acoustically image below the seabed at cm-scale resolution. Alongside the geophysical data, palaeoenvironmental and SedaDNA analysis and C14 and OSL (optically stimulated luminescence) dating of vibrocore samples has identified correlatable early Holocene land surfaces within the Naaldwijk Fm. In 2019, the team returned to the Brown Bank, using the latest maps of where the Naaldwijk Fm/Holocene sediments outcrop near the seabed to determine dredge locations with the highest prospectivity for Mesolithic archaeological finds.

Here, we share the results for the area around core VC45, near the boundary between the UK and Dutch sectors. A palaeovalley and distinct peat layer ~34 m below current sea level have been imaged and confirmed by sedimentological analysis. The dredging campaigns have discovered terrestrial material including peat and ancient wood. These finds strongly suggest an ancient woodland stood at this location at the end of the Mesolithic at around 9000 BP. Along with ongoing geophysical mapping of the region, this work is providing new insights into the fluvial palaeogeography and the timing of transgression at the end of the last glacial in the southern North Sea.
Molecular fossils to study transgressions from the Quaternary

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Targeted analysis of organic matter in soils and sediments is useful for evaluating past environmental conditions, as specific compounds may be directly linked to organisms and hence to the conditions in which they inhabited the environment. Variations in molecular fossil distributions have become a powerful tool for understanding changes in palaeoclimate conditions. This work uses molecular fossils to give an insight into the impact of transgression events on primary producers inhabiting the studied basin, and hence a more detailed record of sea-level change.

The cores studied consisted of unconsolidated immature sediments from the mid-late Pleistocene (< 500,000 years) and the Holocene. Molecular fossils, such as chlorophyll pigments and lipids, exhibit fluctuations as a response to changes in palaeoenvironmental conditions, providing a useful marker for sea-level changes. Fluctuations in the pigment and n-alkane distribution reflect changes in primary producer activity, while the GDGT-based index of branched and isoprenoid tetraether lipids (BIT) differentiates between terrigenous and marine organic matter inputs. Lipids were analysed by GC-FID and HPLC-MS while analysis of chlorophyll pigments was carried out using a new UHPLC-DAD method.

The results from biomarker analyses show excellent time-resolved agreement with previous lithological and ecological studies, but enabled a more sensitive response of different primary producers to changing conditions to be observed. Linking the pigment and lipid record with more secure dating will enable a more accurate record of Quaternary sea-level change.
Rapid retreat of the western Laurentide Ice-Sheet driven by Bølling-Allerød warming

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The timing of Laurentide Ice Sheet deglaciation, along its southwestern margin, controls the evolution and drainage of large glacial lakes and has implications for the migration of early humans into the Americas. Accurate reconstruction of the ice sheet’s retreat also constrains glacial isostatic adjustment models and is imperative for our understanding of ice sheet sensitivity to climate forcings. Despite its importance, much of the retreat history of the southwestern Laurentide Ice Sheet is still poorly constrained by minimum limiting 14C data. Here, we present a database of 24 10Be surface exposure ages from glacial erratics spanning southwestern Alberta to northwestern Saskatchewan, Canada. We combine these data with regional geomorphic mapping and pre-existing luminescence, 10Be surface exposure ages and ‘high quality’ minimum radiocarbon chronologies, exclusive of dates on bulk sediments, terrestrial shells or mixed assemblages, to provide an updated chronology for the retreat of the southwestern Laurentide Ice Sheet. Our compiled dataset of cosmogenic, luminescence and minimum radiocarbon dates present a consistent retreat record. These data suggest that initial detachment of the southwestern Laurentide Ice Sheet from its coalescence with the Cordilleran Ice Sheet occurred at ~15.0 ka BP, concurrent with, or possibly somewhat before the abrupt warming at the onset of the Bølling-Allerød, and retreated >1200 km to its Younger Dryas position in ~2000 years or less.
The impact of large proglacial lakes on past outlet glacier dynamics during the Last Glacial Maximum in New Zealand

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Proglacial lakes are known to affect the stability of mountain glaciers and can partly disengage glacier behaviour from climatic perturbations. Ice-contact proglacial lakes are pervasive across New Zealand and 33\% of the country’s perennial ice terminates within lake-calving glaciers. Proglacial lakes have been recognised as an integral part of the onset and progression of ice sheet deglaciation. It has been suggested that the retreat of glaciers in the Southern Alps immediately after the Last Glacial Maximum (LGM, c. 30–20 ka BP) could have been relatively rapid, not only because of climate forcing, but in addition to the widespread formation of large proglacial lakes. Ice-contact proglacial lakes formed during deglaciation from LGM ice advance limits, infilling their overdeepenings. These lakes would have caused a shift from land-terminating to lacustrine-calving glacier termini, and that would have accelerated ice margin recession in many valleys and consequently ice mass loss. Despite the importance of glacier-lake interactions in influencing deglaciation, these mechanisms are generally ignored by ice sheet model simulations. The importance of this omission has not been quantified.

We use BISICLES, a higher-order ice sheet model capable of adaptive mesh refinement, to study the impacts of a proglacial lake on glacier retreat. The lake boundary is treated in a similar way to a marine calving margin. We perform idealised experiments to present a simulation of the Tasman Glacier since the LGM. We look at the effect on the glacier margin by running two simulations, once with, and once without the presence of a lake under a constant hypothetical climate forcing to isolate the effects of lake-terminating processes. The Tasman Glacier has abundant empirical data and is well chronologically constrained at the LGM, which is used to inform, validate and analyse our numerical modelling simulations in this study. The influence of a proglacial lake accelerates recession due to the development of a calving ice margin (a physical effect due to mass flux from the ice to the lake by calving). This explains the early amplified retreat and the failure for this difference to increase through time. These results highlight the importance of including ice-contact proglacial lakes in palaeo-ice sheet modelling, as well as the need for a coherent regional model of ice-lobe and palaeo-lake evolution that reconciles all dating evidence in order to elucidate the pattern of retreat following the LGM in New Zealand.
Session 2: Recent advances in Quaternary Geochronology
Through the Looking-Glass, and What Amino Acids Found There

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Chronology underpins our understanding of the past, but beyond the limit of radiocarbon dating (~60 ka), sites become difficult to date. Amino acid geochronology uses the time-dependent breakdown of proteins in biominerals, with the racemisation reactions (conversion between mirror-images) of amino acids having the potential to date the whole of the Quaternary. Recent studies have shown that a very small fraction of ‘intra-crystalline’ protein within mollusc shells, opercula, coral, eggshell and enamel forms a closed system, and if this is targeted, the difficulties due to leaching, contamination and environmental factors are removed. The analysis of a coherent calcite intra-crystalline system has enabled the development of a chronology back to at least 2.8 Ma, while enamel proteins allow time resolution well into the Pliocene.

Our research is now focusing on building chronological frameworks on a wide spatial and temporal scale, from Europe to Africa, Asia and Australia. Ever expanding the range of materials we are testing, we are also gaining an unprecedented understanding into biomineralisation, and the palaeoenvironmental signal that can be contained within the fossil protein. We present here both the potential and the limitations of the technique.
Intra-crystalline protein degradation dating of mammalian enamel: building geochronologies

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Accurate age estimation of mammalian remains is imperative to understanding a range of palaeontological enquiries. Direct dating of mammalian remains is extremely difficult beyond the limits of radiocarbon dating (~50 ka). Analysis of the predictable breakdown of proteins and amino acids in wide variety of calcium carbonate (CaCO3) based biominerals has been a powerful tool for Pleistocene age estimation (back to ~2.5 Ma), but to date, its application to mammalian remains has been challenging. By targeting a proteinaceous fraction found within the crystalline structure of biominerals (the intra-crystalline fraction), the difficulties associated with contamination, leaching and environmental influences are circumvented. We have assessed the suitability of tooth enamel for intra-crystalline protein decomposition (IcPD) dating by testing both the protein breakdown and the intrinsic properties of the inorganic crystal structure of enamel through simulated degradation experiments. We have found that a fraction of amino acids can be successfully isolated from enamel that are expected to remain stable over long time scales.

Geochronologies based on the extent of IcPD in proboscidean enamel have been constructed from known age material, which shows the technique successfully dates material from the Plio-Pleistocene from eastern to Western Europe. It is therefore now possible to provide direct age estimation for unknown age proboscidean material from the same temperature regions where we have developed frameworks. Enamel IcPD dating has the potential to be expanded to a range of mammalian species and additional geographic regions. One such region is Africa where we are planning to build frameworks based on several mammal species, targeting important archaeological sites in southern and eastern Africa.
Bringing amino acid geochronology of sea-level records up to date: investigating the intracrystalline approach for foraminifera

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Amino acid racemisation dating (AAR) is one of a range of techniques used to date Quaternary deposits. Recently, significant improvements in AAR have been made by focusing on the “intracrystalline” fraction of proteins from certain biominerals (e.g. mollusc shells, corals, enamel). This fraction effectively acts as a closed system, therefore removing external influences on racemisation rate, as well as minimising contamination and leaching of native biomineral proteins [1]. This approach has been used to constrain the ages of interglacial sea-level deposits using freshwater snail opercula [2], but where opercula are absent (e.g. marine sediments), this limits the technique’s application.

Calcareous foraminifer tests, which are widespread in marine sediments, have been a target for AAR since the earliest days of the technique [3]. However the intra-crystalline approach has not been extensively tested for this class of biomineral, with standard pretreatments typically designed only to remove exogenous contaminants.

In this research modern and Pleistocene tests of Haynesina germanica and Ammonia spp. have been analysed using a recently developed ultra-high performance liquid chromatography (UHPLC) method and a range of chemical pre-treatments, to investigate whether the intra-crystalline approach shows similar improvements compared to wholeprotein analysis as seen in other biominerals. Future work will extend these experiments to a wider range of species of foraminifera in order to develop an optimised AAR protocol for this class of biomineral. This method will then be applied to a range of interglacial sea-level deposits to develop a foraminifera-based avenosstratigraphy to complement the existing avenosstratigraphic framework of the British Quaternary.

References:

The age of methane-derived authigenic carbonates at seafloor cold seeps on the U.S. Atlantic Margin

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Seafloor cold seeps venting methane-rich fluids are ubiquitous along continental margins, and are often associated with methane-derived authigenic carbonates (MDACs), a byproduct of anaerobic methane oxidation in the shallow subsurface. U-Th dating of MDACs, which are archives of past methane emissions, can be used to assess the timing and drivers of fluid flow. However, the logistics of sampling MDACs typically preclude the assembly of datasets with sufficient geographic coverage and resolution to investigate the processes triggering and sustaining methane seeps on a regional scale. Here we present the first results of a collaborative project led by the British and US Geological Surveys aimed at understanding methane emission patterns over the last 20 ka along a 1000 km stretch of the US Atlantic Margin. MDAC samples were collected from the seafloor at eight active seep fields in water depths between 300 – 2200 m below sea level (mbsl) by the Deep Submergence Vehicle Alvin in 2015 as part of the SeepC Program led by C. Van Dover (Duke University). Samples consist of 30 – 80% calcite and/or aragonite cements encasing detrital silicates ranging from silt to gravel. Interconnected voids within the MDACs, which likely represent fluid conduits, are partially filled with layered, clean (>90%) aragonite. The U-Th dating of MDAC poses several challenges. Samples contain a significant amount of initial 230Th, both as detrital Th carried by silicates, and hydrogenous Th adsorbed from seawater. Consequently, corrections applied to account for initial Th are water depth dependent, and must be quantified for each site. MDAC are also relatively porous, which increases the chances of open system behaviour (i.e. an exchange of U and/or Th between the MDAC and its environment over time). Using a robust interpretive framework based on agreement between age data and textural relationships within each MDAC, and comparing calculated initial (234U/238U) with mean seawater values to screen for open system behaviour, we were able to produce a dataset of ~100 U-Th dates. We found that shallow continental shelf seeps (300 – 400 mbsl) have been active since ~16 ka, while deep-water seeps (>1000 mbsl) are mostly younger than 4 ka. When placed in a regional geological context, this age distribution suggests that position relative to the boundaries of the gas hydrate stability zone, the presence/absence of underlying salt diapirs and fractures, and proximity to the formerly glaciated New England margin were the main controls on methane seepage along the US Atlantic margin.
Session 3: Quaternary carbon cycling
High latitude controls on glacial CO$_2$ and climate

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Rapid CO$_2$ and climate change have long been linked to changes in high latitude ocean circulation and biogeochemistry. Thanks to new paleoceanographic tracers, our understanding of these fascinating fluctuations is rapidly evolving. Here we present new records of boron isotopes in benthic and planktic foraminifera and deep sea corals to reconstruct pH and CO$_2$, paired with trace elements, radiocarbon, and sediment composition, to examine the roles of circulation and the biological pump in CO$_2$ and climate change over glacial cycles. These data demonstrate a key role for the Southern Ocean in glacial CO$_2$ change, and that, despite its size, circulation and CO$_2$ in this basin can flip rapidly between different states during millennial and centennial-scale climate change events. However we also find important roles for the northern basins, with a persistent Atlantic-Pacific seesaw in ventilation and biogeochemistry in each of the rapid climate change events of the last glacial cycle, likely linked through atmospheric teleconnections.
A Holocene carbon isotope record from Blue Lake North Stradbroke Island, Queensland, subtropical Australia

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Holocene climate is crucial to understand because the trends seen will underpin our understanding of climate in the next 100 years. This is especially true in sub-tropical Australia due to the under representation of the region in Holocene climate studies. Blue Lake (Kaboora) on North Stradbroke Island (Minjerribah), Queensland, Australia is a groundwater window lake of major ecological and cultural significance. The strong connectivity with the regional groundwater underpins stability in the hydrology and ecology of the lake, rendering Blue Lake sediments an ideal tracer of subtle changes in the climate and regional environment. Here, we report a new, ~7,500-year high resolution C/N and carbon isotope record, which shows an abrupt shift at ~4 ka from terrestrially dominated sources of organic matter to predominantly in-lake sources. Furthermore, these records are compared to modern FTIR data to identify specific plant groups that contribute to lake sediment organic matter through this shift to better understand what occurred. The shift is interpreted to reflect a decline in rainfall on the island, as is evident in a quantitative rainfall reconstruction from nearby Swallow Lagoon. This carbon isotope record is the starting point for further contemporary and palaeoclimatic research at the site. The monitoring aims to define the relationship between climate, hydrology, and the carbon and oxygen isotopic composition of Blue Lake sediments. The modern process study focusses on oxygen isotope variation and will determine the pathway of oxygen isotopes from initial precipitation to uptake by plants in the lake. Using this as a foundation, we will create a high-resolution rainfall record that will build on previous studies of pollen, macrophytes, and diatoms from the island and the broader region that suggest a mid-Holocene drying. Quantitatively defining such a shift will enable a more thorough investigation into the impacts of climate drivers such as ENSO in eastern Australia.
Where’s the Carbon: Exploring the Spatial Heterogeneity of Sedimentary Carbon in Mid-Latitude Fjords

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Fjords are recognized as globally significant hotspots for the burial and long-term storage of marine and terrestrially derived organic carbon (OC). By trapping and locking away OC over geological timescales, fjord sediments provide a potentially important yet largely overlooked climate regulation service. Currently, our understanding of the spatial distribution of OC within the surficial sediments of fjords is limited and this potentially implies an overestimation in the global estimates of OC buried in fjords as current calculation methods assume a homogenous seabed. Using the mid-latitude fjords of Scotland and Ireland as a natural laboratory, we have developed a multi-tiered methodological approach utilizing a spectrum of data ranging from freely available chart data to the latest multibeam geophysics to determine and map the seabed sediment type. Targeted sampling of fjord sediments was undertaken to establish a calibration of sediment type against OC content. The results show that fjord sediments are highly heterogeneous both in sediment type and OC content. Utilizing the tiered mapping outputs, first order estimates of the surficial (top 10 cm) sediment OC stock within Scottish fjords (4.16 ± 0.5 Mt OC) and Irish systems (2.09 ± 0.26 Mt OC), when normalized for area the surficial sediments of Scottish and Irish fjords hold 2027 ± 367 and 1844 ± 94 tonnes OC km-2 respectively far exceed estimates for the continental shelf, again highlighting fjord sediments as hotspots for the capture of OC. This tiered approach to mapping sediment type is ideally suited to areas of the marine environment where data availability and quality is a limiting issue. Further understanding of the spatial heterogeneity of these sediments provides a foundation to re-evaluate global fjord OC burial rates and to better understand the role of fjord sediments in regulating the global climate.
Implications of organic ligand dependent preservation of iron in the seafloor for marine carbon cycling

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The biological carbon pump represents a key feedback cycle in the Earth’s climate system. Organic carbon (OC) export to the seafloor by marine phytoplankton in the upper ocean accounts for ~0.2–0.4 Pg per annum, representing a significant sink for atmospheric carbon. Coupling of OC and Fe is known to create a “rusty sink” for metastable carbon preservation in the seafloor, a process comparable to the protection of terrestrially derived organic matter promoted by iron in soils. With ice sheet extent representing a control on the export of both OC and Fe to the seafloor, the glacial-interglacial cycles of the Quaternary are likely to have created significant alterations in the OC and Fe fluxes; and thereby in the preservation of sedimentary OC. Despite the potential importance of the Fe-OC coupling in the Quaternary carbon cycle, there is limited knowledge about the nature of the Fe-OC coupling, and methods to quantify the amount of carbon trapped in the “rusty sink” are poorly constrained and uncalibrated.

In this study, we explore how the structure of a common carbon compound associated with iron minerals affects their organomineral stability as an indicator of their ability to preserve carbon within the seafloor. Organic carbon-free marine sediments were spiked with known amounts of synthesized Fe-OC co-precipitates designed to represent natural compounds covering a range of Fe to OC affinities (i.e., ferrihydrite co-precipitated with carboxylic acids, replicating the end product of degraded amino acids). These were subject to standard extraction procedures for the iron mineral phases and associated OC, and measured for Fe and OC extraction efficiency. We find that the extractability, and thus the stability, of iron organominerals is dependent upon the structure and quantity of organic carbon associated with iron. Specifically, those organominerals containing a greater concentration of carbon appear to suffer from greater structural disorder, and thus less stability. This leaves the OC associated with these phases more vulnerable to microbial degradation and therefore liberation of OC from the seafloor as CO2. Crucially this shows that iron organominerals cannot be considered a ‘bulk phase’ and behave differently dependent upon the specific structure of organic molecules associated with the iron mineral. This represents a potentially significant ‘tipping point’ in carbon storage in the seafloor, whereby iron minerals associated with a high weight % of OC are likely to retain OC for a shorter period of time compared to low % OC organominerals.
Session 4: Ecosystems
Global peatland carbon: challenges and opportunities

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Peatlands store large amounts of carbon, with recent estimates doubling \([1]\) previous estimates \([2]\). Not only there is uncertainty on the carbon inventories, but more importantly, in how carbon exchange between peatlands and the atmosphere will change in the future. Previous work has suggested increases in the carbon sink for high latitude peatlands and possible decreases in the tropics with warming \([3]\). This has been corroborated by expert survey results, although experts also suggest that gains at high latitudes may be offset by regional carbon losses from permafrost thaw, peat fires, and drought \([4]\). On-going work will test the hypothesis that peatlands will expand into the Arctic and increase carbon accumulation rates and therefore help mitigate some of the carbon releases expected at high latitudes (ICAAP, a NERC funded project). In the tropics, carbon accumulation rates may decrease in the future \([3]\), and experts suggest that carbon losses are already underway and are likely to increase as a result of warmer temperatures, drought, land-use and fire \([4]\). This expert survey has also highlighted the importance of not only restoration but managing and preserving current stores as a key factor in decreasing emissions from tropical peatlands in the future. In summary, if we want to use peatlands as a possible nature based climate solution, then we need to increase our understanding of global peatland functioning and carbon cycling at high and low latitudes to better safeguard these important ecosystems and use their full potential to store carbon in the future \([5]\).

References:


During the course of their development, peatlands commonly transition from wet, nutrient-rich, methane-emitting fens; to drier, nutrient-poor, carbon dioxide-emitting bogs. These changes in wetness and trophic status represent decreasing hydrological connection between a peatland and local sources of surfacewater and shallow groundwater. Such hydrochemical changes also cause pronounced shifts in plant assemblage along a semipredictable successional gradient, and are thus identifiable in plant macrofossil records from peat cores. It is currently unclear whether fen-bog transitions are an inevitable consequence of continued peat development raising the growing surface above local hydrological influences; or whether transitions are triggered by external drivers such as climate change. Spatial gradients in modern distributions of fens and bogs would appear to suggest a climatic control, meaning that future warming may cause changes in their distributions through altered peat accumulation rates and trophic status, with implications for greenhouse gas budgets and biodiversity. However, until now, no comprehensive database of fen-bog transitions has been available, and primary palaeoecological studies rarely consider more than a handful of sites, hindering the identification of general principles. We present interim results from an ongoing effort to develop a comprehensive database of published fen-bog transitions from around the world that will provide a basis to study the drivers of this phenomenon. Our secondary database mainly comprises study sites from North America and northern Europe, but also contains sites across Asia, Patagonia and southern Europe. In the majority of study sites, high quality plant macrofossil records reported in the primary literature allow us to identify a three-stage sequence of rich fen, poor fen, bog. In other cases, lower quality data allow us only to distinguish between herbaceous and bryophytic macrofossil zones. In all cases, we have estimated the ages of transitions by respecifying age-depth relationships using the original chronometric data reported alongside macrofossil records. Once completed, our database may become a valuable resource for peatland palaeoecologists. We plan to analyse the database to identify the drivers of fen-bog transitions.
Long-term Sphagnum succession in mountain peatland ecosystems across Central and Western Europe: implications for peatland conservation

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The development of ombrotrophic peatland ecosystems located in various biogeographic zones was substantially affected by climate change in the Holocene. Disturbances due to increased human activities intensified in the past several centuries and include peat excavation, fires, as well as deposition of minerals such as nitrogen on peatland surfaces. This combination of natural and human disturbances has led to direct hydrological and biochemical disturbances that triggered changes in vegetation, including the decline of Sphagnum peat-forming species in peatland ecosystems such as blanket bogs or Baltic raised bogs in European lowlands and highlands.

There is still little understanding about the development of the small peatlands located across mountain ranges in Europe. Understanding the various factors that have influenced the development of these ecosystems in the past is critical for predicting the response of ecological communities to ongoing climate change and potential negative human activities. Assessing the resilience of peatland organisms to disturbance is an important and significant task to aid further protection and management of the entire range of ombrotrophic peatlands found in the European mountains, from destroyed to pristine.

We undertook high-resolution, multi-proxy (biotic and geochemical analyses) palaeoenvironmental reconstructions with replicate cores from five ombrotrophic peatlands where peat-forming process is active. Studied peatlands are located along an east west gradient in the Central and Western Europe: Carpathian Mts., Harz Mts. and Schwarzwald Mts. and Vosges Mts. In our palaeoecological studies we aimed to: i) reconstruct local (mainly Sphagnum populations) and regional (forest communities) vegetation changes at and around selected bogs and assess their resilience to disturbance; ii) reconstruct longterm palaeohydrological signals in these bogs; iii) assess ecosystem resilience to climate and disturbance by fire events and human impact (deforestation, dust and pollution). Based on our results, we found that: i) Sphagnum populations are indicative of pristine, ombrotrophic conditions that can repeatedly self-regenerate via autogenic processes following disturbance such as pollution; ii) Sphagnum fuscum and Sphagnum medium/divinum were the main peat-forming Sphagnum species during ombrotrophic stage; iii) recent climate warming has stimulated spreading of some Sphagnum species; iii) fires did not play a significant role in development or maintenance of Sphagnum communities. Results from our study show that palaeoecological analyses, and particularly plant macrofossil reconstructions, constitute an important tool for the determination of present ecosystem conservation stage and reference conditions for the restoration of ombrotrophic peatlands.
Drivers of Holocene palsa distribution in North America

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Permafrost peatlands represent a globally important, organic carbon store which is particularly sensitive to climatic change. The distribution of permafrost within peatlands at coarse spatial scales is evidenced by the presence of palsas and peat plateaus. Frozen temperatures render these ecosystems largely inert, but thaw and the development of saturated conditions significantly enhances carbon dioxide (CO2) and methane (CH4) emissions, presenting positive feedback mechanisms which threaten to accelerate future climate change. Although predictive models of permafrost degradation are well-developed for mineral soils, the thermal properties of organic soils complicate the response of peatland permafrost to climatic changes. The extent and severity of future thawing has remained highly uncertain at hemispheric scales, as confident simulations of permafrost peatlands are only currently available for Fennoscandia. Our preliminary analyses indicated that bioclimate models of palsa distribution in Fennoscandia perform poorly in North America, suggesting that the climatic controls on permafrost development within peatlands may display interregional variability. The lack of a generally applicable palsa distribution model currently prevents scientists from simulating past or future permafrost peatland distributions outside of Europe.

We developed a catalogue of palsa and peat plateau distribution in North America (> 350 sites). We related these loci to modern climate data using binary logistic regression to develop a bioclimate model that can be used to predict the current bioclimatic envelope of palsas and peat plateaus. We then incorporated outputs from palaeoclimate simulations using the HadCM3 General Circulation Model to simulate spatiotemporal dynamics of North American permafrost peatlands throughout the Holocene. To constrain our climatically-informed predictions we used several non-climatic plausibility filters, including the timing of peat initiation, deglaciation and sea level change. Our results indicate that the climatic envelope suitable for palsas and peat plateaus has remained almost stationary in western Canada and Alaska since the early Holocene. In eastern North America the climatic envelope has shifted northwards since 11.5ka, although environmental constraints moderated the movement of palsa lines. Peat availability appears to have primarily limited palsa and peat plateau development. Our simulations of past palsa and peat plateau distributions provide new evidence with which to constrain the timing of permafrost aggradation and degradation in peatlands, enabling comparisons with estimates from traditional palaeoecological techniques. An improved understanding of permafrost peatland developments throughout the Holocene will also enhance the reliability of projected future permafrost peatland distributions under anthropogenic climate change.
Misinterpreting carbon accumulation rates in records from near-surface peat

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Peatlands are globally important stores of carbon (C) that contain a record of how their rates of C accumulation have changed over time. Recently, near-surface peat has been used to assess the effect of current land use practices on C accumulation rates in peatlands. However, the notion that accumulation rates in recently formed peat can be compared to those from older, deeper, peat is mistaken – continued decomposition means that the majority of newly added material will not become part of the long-term C store. Palaeoecologists have known for some time that high apparent C accumulation rates in recently formed peat are an artefact and take steps to account for it. Here we show, using a model, how the artefact arises. We also demonstrate that increased C accumulation rates in near-surface peat cannot be used to infer that a peatland as a whole is accumulating more C – in fact the reverse can be true because deep peat can be modified by events hundreds of years after it was formed. Our findings highlight that care is needed when evaluating recent C addition to peatlands especially because these interpretations could be wrongly used to inform land use policy and decisions.
An oasis in a desert: A multiproxy palaeoecological record from a contemporary ‘refugium’ in Ilkley Moor


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Crawshaw Moss (a small area within Ilkley Moor, West Yorkshire) contains a high diversity of plant species (including Sphagnum mosses), and is actively peat-forming. This is in stark contrast to most other areas of Ilkley Moor, which have been severely damaged by intense burning, grazing and drainage over many decades. Thus, we consider Crawshaw Moss to be an ecological ‘refugium’ within the wider degraded landscape of Ilkley Moor. In this presentation we will describe our White Rose University Consortium-funded project that focusses on investigating the ecology, hydrology, biogeochemistry, stratigraphy, palaeoecology and archaeology of this important Yorkshire site. Our study fuses measurements of contemporary processes (decomposition rates, geochemistry, peatland hydrology and hydraulics, and vegetation composition) with multi-core, multi-proxy palaeoecological data (pollen, plant macrofossils, testate amoebae, geochemistry, and carbon accumulation rates) to understand why this ‘refugium’ has persisted. Initial data show that Crawshaw Moss was an Alder-dominated wetland forest as recently as ~2,000 years ago (two-sigma range for the end of the Alder phase = 2459-1592 cal. BP, median age= 2080 cal. BP). Our findings support a previous study from Lanshaw Moss (3.5 km ESE of our site) that revealed the presence of wet Alder-dominated forest up until the Iron Age. Both studies suggest the Iron Age was a period of widespread deforestation and agricultural expansion across Ilkley Moor.
From the micro to the molecular: the challenges of contextualising multi-proxy taphonomic processes in understanding past ecosystem dynamics

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The value of multi-proxy and multi-disciplinary input into Quaternary research cannot be disputed, and remains fundamental to pushing the extent of knowledge and understanding of past ecosystems forward. With the emergence of novel tools such as sedimentary DNA (sedaDNA), and its application as a complementary and addition to traditional proxy data such as pollen and diatoms, the resolution and the scale in which Quaternary environments can be studied, has taken a leap forward.

However, as demonstrated in the research development of traditional proxies in Quaternary research, the relationship between the sedimentary record, archive preservation and the wider context relating to fundamental principles on taphonomic processes, are never straightforward. Integrating individual archives into a coherent multi-proxy assessment of a palaeoenvironment, whilst applying these fundamental principles can produce divergent and conflicting results.

Using recent data from the submerged landscape of Doggerland (the southern North Sea), this paper aims to explore key questions in taphonomic research, such as source and preservation, and contextualise it within the wider context of how this feeds into a process of reconstructing past ecosystem dynamics. In particular, it will examine the method and tools used in the approach on individual proxy records (pollen, diatoms and sedaDNA), and demonstrate the complexity of synthesising individual outputs, for a coherent and valuable approach for Quaternary research.
Session 5: Quaternary Science for the Earth’s Future
Agricultural resilience has been a challenge for societies for >11,000 years. Archaeological and geological records describe the successes and failures of the past and recent societal unrest in the Fertile Crescent, the first home of agriculture, demonstrates the complex and changing, social, economic and environmental landscapes that can lead to a lack of resilience. To improve our understanding of over 11,000 years of agricultural resilience scenarios and maximise the lessons we can learn from these, this new project is investigating past, present, and projected agricultural systems in centres of agricultural origins, particularly in Latin America and the Fertile Crescent. We aim to work towards the interdisciplinary, holistic approach, necessary for understanding systems in their full complexity, without which projections of future agricultural resilience cannot be robust.

The project aims to further understanding of how plants respond to climatic stress within their past, present and projected agricultural systems, considering the impact of environmental, biological, economic, and social variables towards improving productivity and sustainability of future agriculture. It places Quaternary Science at the centre of work concerned with projections of future systems. Using a Holocene timeframe we aim to integrate new Quaternary Science data, particularly records of vegetation and hydrological change, with work on traditional agricultural knowledge, field-scale environmental monitoring, and phenotyping and genetics from laboratory experiments.

Crops are particularly vulnerable to increasing unpredictability in climate, such as extremes in temperatures and/or drought, which can impact both small and large agricultural stakeholders. We require an understanding of crop varieties with both high stress tolerance and yield stability and how to optimise these in changing, or changed, climate states. In natural habitats, wild plant populations, locally adapted minor crops and certain major crop varieties already demonstrate such solutions; indicating that traits for resilience and yield stability exist. Our palaeobenchmarking approach opens up more than 11,000 years of data from which to model future system scenarios and utilise natural and/or early agricultural variation to identify novel traits for crop improvement.
Learning lessons from the Past – Does Quaternary Science help predict the future?

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Research on Quaternary Earth System processes and feedbacks is flourishing with a vibrant community investigating many aspects of change. Such research is frequently motivated by concerns about Earth’s future but how does the past really feed into future projections? It is not as easy as it at first sounds. The talk will discuss many aspects of this challenge and will particularly focus on the role that climate and Earth System modelling plays in translating our knowledge of the past into predictions of future change and adaptation.
Unlocking abrupt dynamics through optimisation of climate model parameterisations: Application to the termination of the African Humid Period

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The Holocene ‘greening’ and subsequent, possibly abrupt desertification of the Sahara is among the most studied environmental transitions of the Holocene. It was ultimately driven by the gradual decline in summer insolation and was likely reinforced by land-atmosphere coupling to the monsoon system, mediated by vegetation. However, the majority of general circulation models (GCM) cannot produce enough precipitation to sustain a ‘Green’ Sahara, and the termination has therefore only been studied with a few models. We present a suite of transient GCM simulations with HadCM3 covering the entire Holocene, which optionally sample optimised versions of the atmospheric convection and vegetation moisture stress parameterisations. We aim to better understand how well state-of-the-art GCMs can reproduce abrupt transitions, and to explore the dynamical underpinning of the Saharan ‘greening’ and desertification. With both optimised convection and vegetation parameterisations, the simulation shows a convincing ‘greening’ followed by a series of abrupt oscillations in vegetation cover that culminate in an abrupt collapse at around 6000 years before present, in agreement with available reconstructions. We apply the theory of critical slowing to evaluate this response, and explore the impact of these model changes when simulating the response to a ‘future-like’ climate with elevated carbon dioxide. Our results show that stability of climate models is intimately tied to chosen parameters and formulations. We conclude that novel methods of inferring suitable model state-space regions from observations are required.
Implications of organic ligand dependent preservation of iron in the seafloor for marine carbon cycling

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The biological carbon pump represents a key feedback cycle in the Earth’s climate system. Organic carbon (OC) export to the seafloor by marine phytoplankton in the upper ocean accounts for ~0.2–0.4 Pg per annum, representing a significant sink for atmospheric carbon. Coupling of OC and Fe is known to create a “rusty sink” for metastable carbon preservation in the seafloor, a process comparable to the protection of terrestrially derived organic matter promoted by iron in soils. With ice sheet extent representing a control on the export of both OC and Fe to the seafloor, the glacial-interglacial cycles of the Quaternary are likely to have created significant alterations in the OC and Fe fluxes; and thereby in the preservation of sedimentary OC. Despite the potential importance of the Fe-OC coupling in the Quaternary carbon cycle, there is limited knowledge about the nature of the Fe-OC coupling, and methods to quantify the amount of carbon trapped in the “rusty sink” are poorly constrained and uncalibrated.

In this study, we explore how the structure of a common carbon compound associated with iron minerals affects their organomineral stability as an indicator of their ability to preserve carbon within the seafloor. Organic carbon-free marine sediments were spiked with known amounts of synthesized Fe-OC co-precipitates designed to represent natural compounds covering a range of Fe to OC affinities (i.e., ferrihydrite co-precipitated with carboxylic acids, replicating the end product of degraded amino acids). These were subject to standard extraction procedures for the iron mineral phases and associated OC, and measured for Fe and OC extraction efficiency. We find that the extractability, and thus the stability, of iron organominerals is dependent upon the structure and quantity of organic carbon associated with iron. Specifically, those organominerals containing a greater concentration of carbon appear to suffer from greater structural disorder, and thus less stability. This leaves the OC associated with these phases more vulnerable to microbial degradation and therefore liberation of OC from the seafloor as CO2. Crucially this shows that iron organominerals cannot be considered a ‘bulk phase’ and behave differently dependent upon the specific structure of organic molecules associated with the iron mineral. This represents a potentially significant ‘tipping point’ in carbon storage in the seafloor, whereby iron minerals associated with a high weight % of OC are likely to retain OC for a shorter period of time compared to low % OC organominerals.
Relict periglacial hazards in the UK: engineering guidance for hazard mitigation

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Most areas of the UK have been affected by periglacial during the Quaternary and the inheritance of relict periglacial geohazards can be a significant technical and commercial risk for future civil engineering projects, if not recognised early and managed appropriately. This paper describes the processes and products associated with periglacial in the relict periglacial landscape of the UK with a specific focus on the hazards they pose to engineering projects and how they might be monitored and mitigated.

The periglacial land systems classification proposed by Murton and Ballantyne (2017) is applied to the assessment of ground engineering hazards to show how it can be used to support development of engineering ground models. We discuss techniques for the early identification of a site’s susceptibility to periglacial geohazards, which includes interpretation of high-resolution aerial imagery and LiDAR, ground investigations and site reconnaissance and geomorphological mapping. We then describe the implications of periglacial geohazards to engineering works. Finally, we outline the strategies for monitoring and remediation or periglacial geohazards supported by industry experience.
Session 6: State shifts and abrupt changes
State shifts in permafrost environments since the Middle Pleistocene at the Batagay megaslump, Siberia

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The Batagay megaslump, in the Yana Uplands of northern Yakutia, is the largest known retrogressive thaw slump in the world and preserves some of the oldest known permafrost. The slump exposes a remarkable sequence of Middle Pleistocene to Holocene permafrost deposits that record the interaction of colluvial, aeolian and permafrost processes on a hillslope episodically forested during the last several hundred thousand years. Numerous bones, teeth and occasional carcasses of ice-age and Holocene vertebrates have been recovered from the permafrost. The stratigraphy indicates repeated shifts in permafrost environments between, on the one hand, aeolian sedimentation and syngenetic permafrost growth and, on the other, thermokarst activity.

The megaslump itself has developed over the course of several decades in three stages: (1) gullyng, (2) thaw slumping and (3) megaslumping. After disturbance to the taiga vegetation cover in the 1940s to 1960s, a hillslope gully formed by the early 1960s. The gully initiated thaw slumping along its central part during the 1980s, with the slump enlarging to megaslump (>20 ha) proportions during the 1990s. By 2018, the area of the slump reached nearly 77 ha and its headwall was up to about 52 m high. The main geomorphic processes of slump growth are headwall ablation and thermal erosion, producing a distinctive terrain of icy badlands. Though much of the megaslump is rapidly growing at present, it will likely stabilize eventually as an irregular terrain characterized by sandy ridges and sand-filled elongate depressions formed by the degradation of the badlands.
Developing British distal glaciolacustrine varve records as high resolution archives of abrupt climate change

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The glaciolacustrine varve archives of the major Northern Hemisphere ice sheets enable annually-resolved chronologies of cryospheric response during the last deglaciation to be developed. To date, in the UK, there have been relatively few studies that integrate varve chronologies into such glacier reconstructions (Palmer et al., 2010; MacLeod et al., 2011; Avery et al., 2019). Consequently, the higher chronological precision afforded by these records and improved understanding of glacier advance and retreat rates during periods of abrupt climate change are underutilised. Here, as an example of the potential of these archives, we present new varve data for the Lochaber Master Varve Chronology that provides further refinement to our understanding of the timing and nature of glacier retreat during the Loch Lomond Stadial and Early Holocene.

The Lochaber lake systems that developed in Glen Roy and Glen Spean lie to the north of Rannoch Moor, which was one of the ice sources that contributed to the ice dam permitting glacial lake formation in these valleys. Ice advance (retreat) can be identified through increases (decreases) in lake level in Glen Roy that caused additional sites of varve sedimentation to be activated. The original varve thickness chronology of 515 years was used to infer the position of the ice margin (Palmer et al., 2010), but new data from an increased spatial network of sites within Glen Roy and Glen Spean now allow refinement of this chronology when combined with tephrochronological developments. These new data provide a more accurate and precise timing for deglaciation and supports the previous assertion that this ice retreat was initiated during the later stages of the LLR but prior to the rapid warming thought to be associated with the onset of the Holocene, although glacial ice persisted into the early Holocene. This information contributes to the debate for the timing of deglaciation on Rannoch Moor (Bromley et al., 2014, Small and Fabel, 2016; Lowe et al., 2019) by casting doubt on the Bromley et al. (2014) early deglaciation hypothesis. The data also provides an insight into how the Loch Lomond Stadial ice cap responded to climatic forcing such as enhanced atmospheric warming driven by oceanic warming during the latter stages of the YD (Bakke et al., 2009; Lane et al., 2013).
Rapid shifts during the late glacial-Holocene climatic transition in the Eastern Mediterranean region, reconstructed from multiple proxies in central Turkish lakes

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High-resolution climate reconstructions from the Greenland ice cores have shown rapid climate changes during the late glacial-Holocene transition. However, much less is known about the speed of the changes at this time away from the North Atlantic. This time is of particular interest in the Eastern Mediterranean region as this is when agriculture was first being developed. Establishing how rapidly climate, especially hydroclimate, changed here therefore allows us to better understand how climate influenced humans at this key early stage in the development of civilisation, as well as to better understand global climatic teleconnections.

Here we present high-resolution oxygen isotope ($\delta^{18}O$) data from endogenic carbonates, along with pollen and charcoal data, from two volcanic maar lakes 25 km apart in Cappadocia, Turkey, from ~15-11 ka BP. The two sedimentary sequences are partly or wholly laminated, allowing calculation of rate of change during key transitions. By using multiple proxies from two archives that are subjected to the same forcings, we are better able to disentangle external, climate forcings from localised, within-lake forcings on the proxy records.

$\delta^{18}O$ from both records show a rapid transition from a drier Younger Dryas to a wetter early Holocene, with varve counting allowing for a very precise estimate of its time duration; at Nar lake the hydroclimate transition takes c.200 years, with over half the magnitude of the $\delta^{18}O$ shift occurring in just 9 years. Eski Acıgöl $\delta^{18}O$ data show a similarly rapid shift. From the pollen records, we confirm the commonly seen pattern from the region of trees not re-appearing in large numbers until several millennia after the start of the Holocene. However, our high resolution data show there was a rapid switch from Artemisia-chenopod to grass steppe concomitant with, and of a similar rapidity to, the change in $\delta^{18}O$. Charcoal records from both lakes show wildfires were sharply reduced during the cold, dry Younger Dryas, and increase at the start of the Holocene as the amount of biomass increased, suggesting fuel load was the dominant control on wildfires at this time.

Therefore, our high-resolution data show that there was a rapid hydroclimate and vegetation shift in the Eastern Mediterranean region at the start of the Holocene, at the time when agriculture was first developing here, of a similar rapidity to the changes seen in the North Atlantic region. This highlights the strong links between changes in the North Atlantic region and Eastern Mediterranean hydroclimate.
Secrets from the Lady of the Lake: an 11,000 year history of episodic talus erosion and resedimentation in the Brecon Beacons

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The incidence and impact of recent extreme storm events on hillslope systems in upland Britain has received widespread attention in research and wider media. Growing concern focuses on future amplification of the magnitude and frequency of such formative events. Significant gaps remain, however, in our understanding of the long-term chronological context and causes of hillslope erosion during the Holocene. In particular, there is continued debate as to whether episodes of erosion are broadly synchronous within and between regions, and whether they represent local anthropogenic influences, general climatic trends, and/or an increase in the frequency or intensity of localised extreme rainstorms, conditioned by internal, stochastic or complex response.

This research provides the first database of montane debris flow activity for southern Britain. Terrestrial deposits (debris fans and gully sidewalls) and lacustrine sediments were analysed at the foot of incised talus slopes on the Mynydd Du (Black Mountain) sandstone escarpment in south Wales.

Episodic erosion and resedimentation of talus is evident in the form of buried in situ organic-rich horizons intercalated with stacked sediment units. Radiocarbon dating of 35 samples recovered from debris cones and lake cores suggests that gully erosion and redeposition of talus represents asynchronous debris flow and slopewash activity within the past 8-9 cal kyr, though a marked increase in magnitude and frequency of erosional events is interpreted to have occurred at ~4.4-4.0 cal kyr BP.

There is some support for possible clustering of events at ~4.8-4.2, ~2.2-1.8 and at ~0.7-0.3 cal kyr BP. Climatic and human impact scenarios may explain the periodic breaching of geomorphic stability thresholds at Mynydd Du. Preliminary palynological and charcoal analyses, together with wider archaeological and documentary evidence of local landscape history, suggest that the step-change in event magnitude at ~4.4-4.0 cal kyr BP may reflect anthropogenic disturbance of natural vegetation covers in the wider area by Neolithic farmers, which included continued declining woodland, the introduction of grazing livestock, and cultivation. Such perturbations may have initiated a general intensification of Late Holocene hillslope erosion at this site, lowering the threshold for subsequent storm events. The pattern of hillslope erosion at Mynydd Du is further discussed in relation to comparable datasets from northern Britain and models of talus evolution, with a view to informing management strategies in sensitive upland landscapes.
A Northern Hemisphere terrestrial climate dataset for the past 60,000 years

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The last glacial period witnessed significant fluctuations in global climate, reconstructing climate change over this period has important uses in a wide range of academic research. Here we present a continuous land-based climate reconstruction dataset extending back 60 kyr from 0 BP (1950) at 0.5° resolution on a monthly timestep for 0°N to 90°N. It has been generated from 42 discrete snapshot simulations using the HadCM3B-M2.1aD ocean-atmosphere-vegetation coupled general circulation model. We incorporate Dansgaard-Oeschger (DO) and Heinrich events to represent millennial scale variability, based on a temperature reconstruction from Greenland ice-cores, with a spatial fingerprint based on a freshwater hosing simulation with HadCM3B-M2.1. Interannual variability is also added and derived from the initial snapshot simulations. Model output has been downscaled to 0.5° resolution (using simple bilinear interpolation) and bias corrected. Here we present surface air temperature, precipitation, incoming shortwave energy, minimum monthly temperature, snow depth, wind chill and number of rainy days per month. Comparison against a wide range of ice-core and observational data shows that our simulated dataset is consistent with observations. This is one of the first open access climate datasets of this kind and can be used to study the impact of millennial to orbital-scale climate change on terrestrial greenhouse gas cycling, northern extra-tropical vegetation, and megaflora and megafauna population dynamics.
At the crossroads of atmosphere-ice-ocean mechanisms for abrupt climate change

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The Dansgaard-Oeschger events of the last glacial period are among the best studied abrupt climate changes. The prevailing view is that they are caused by low-frequency variability of the Atlantic Meridional Overturning Circulation (AMOC). Recent modelling studies suggest a different possibility: that D-O events may be an unforced or "spontaneous" oscillation of the coupled atmosphere-ice-ocean system. Evidence from reanalysis data, climate model simulations, box models, and idealized ocean GCMs point to the supbolar North Atlantic as a key coupling region - the crossroads where vigorous winds encounter the southernmost extension of sea ice and most variable currents in the basin. We explore the idea that, under special conditions, the system hits a sweet spot for feedbacks between winds, sea ice cover and ocean circulation to amplify and sustain perturbations towards warm (stadial) or cold (interstadial) conditions, thereby producing D-O-like variability.
Greenland ice cores provide excellent evidence of past abrupt climate changes. However, there is no universally accepted theory of how and why these Dansgaard Oeschger (DO) events occur. Several mechanisms have been proposed to explain DO events, including sea ice, ice shelf build-up, ice sheets, atmospheric circulation, and meltwater changes. DO event temperature reconstructions depend on the stable water isotope $d^{18}O$ and nitrogen isotope measurements from Greenland ice cores: interpretation of these measurements holds the key to understanding the nature of DO events. Here, we demonstrate the primary importance of sea ice as a control on Greenland ice core $d^{18}O$: 95% of the variability in $d^{18}O$ in southern Greenland is explained by DO event sea ice changes. Our suite of DO events, simulated using a general circulation model, accurately captures the amplitude of $d^{18}O$ enrichment during the abrupt DO event onsets. Simulated geographical variability is broadly consistent with available ice core evidence. We find an hitherto unknown sensitivity of the $d^{18}O$ paleothermometer to the magnitude of DO event temperature increase: the change in $d^{18}O$ per K temperature increase reduces with DO event amplitude. We show that this effect is controlled by precipitation seasonality.
The role of ice sheet dynamics in the collapse of the early-Holocene Laurentide IceSheet:implications for the 8.2 kyr event

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During the last stages of its deglaciation (~10000 to 7000 years ago), the Laurentide Ice Sheet (LIS) experienced extraordinary changes when the collapse of the ice dome that covered the Hudson Bay generated a rapid acceleration of melt (the Hudson Bay Saddle Collapse; Gregoire et al., 2012). This likely caused the 8.2 ka event, an abrupt northern hemisphere cooling of several degrees that lasted for ~160 years, by slowing down N. Atlantic Ocean circulation. This climatic event would provide the ideal test case to benchmark the sensitivity of the ocean circulation simulated in climate models. However, this requires better knowledge on the evolution of the Laurentide Ice Sheet, its rate of melting and the interaction with the sudden drainage of proglacial Lakes Agassiz and Ojibway. The evolution of the Laurentide Ice Sheet during this period was likely influenced by marginal lakes and the ocean and by its major ice stream, which exported ice towards Hudson Strait. Accurately simulating these processes requires a latest-generation ice sheet model such as BISICLES, which is capable of accurately and efficiently resolving ice stream dynamics and marine margin retreat (so-called grounding line migration) thanks to the combined use of complex physics and adaptive refinement of the resolution.

We use BISICLES with a new simple sub-glacial hydrology scheme, to simulate the Early Holocene demise of the Laurentide Ice Sheet. BISICLES is driven using a positive degree day mass balance scheme with monthly precipitation and temperature from the HadCM3 climate model under climatic conditions from 10,000 to 8,000 years ago. The model simulates the ice sheet evolution with unprecedented detail and accuracy compared to reconstructions of ice sheet extent. We evaluate plausible rates of ice sheet melt and associated sea level rise caused by the Hudson Bay saddle collapse and the sensitivity of this to uncertain initial conditions, and model parameters. We find that dynamical processes are important for accurately simulating the pattern of ice retreat. Rates of meltwater discharge during the Hudson Bay saddle collapse depend on basal sliding and surface mass balance parameters.
Evidence for abrupt shifts in ice advance of the British and Irish Icesheet into Yorkshire during the MIS 3

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For many years it was thought the North Sea Lobe (NSL) of the last British and Irish Icesheet (BIIS) extended south from Scotland and northern England to its maximal position in Norfolk and then retreated north again. More recent work has shown the NSL was far more dynamic, abruptly advancing, oscillating and retreating in the period 22-17 ka. Controversy remains with regards to NSL advances prior to this in MIS 3. Did they happen, if so when and for how long? Crucial to this has been arguments surrounding the age of the Basement Till on the East Yorkshire Coast. Does it represent a pre-Devensian Ice advance (MIS 6 or older) or is it of Devensian age and relating to an earlier ice advance of the NSL in MIS 3-4? First described by Lamplugh in 1882, its stratigraphic position under the MIS 5e raised beach at Sewerby was proposed by John Catt in 1963 based on field observations of the till exposed on the present-day wave-cut platform within 70 m of the raised beach section. Despite much effort, this stratigraphic association has not been proven. Lamplugh originally mapped the Basement Till above the beach deposits and Eyes et al (1994), based on amino acid dating, attributed the Basement Till as exposed at Dimlington to the MIS 2. This implies a separate BIIS ice advance earlier to that responsible for the Skipsea and Withernsea tills. This paper presents new work dating the Basement Till and reviews other new evidence from the Humber Gap, Vale of Pickering and offshore in the North Sea which shows the NSL of the BIIS did have multiple abrupt shifts within both MIS 3 and 2.
Poster Session Abstracts
Using portable luminescence readers to explore dryland dynamics

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Reconstructing environmental change in sand-rich drylands, locations where aeolian dunes interact with fluvial systems and lake shorelines, requires wide spatial coverage and dense chronologies. This is extremely time-consuming and resource intensive if based only upon laboratory-based luminescence dating of samples. Portable luminescence readers (POSL) (Sanderson and Murphy, 2010) provide a useful means of generalising chronologies within simple systems, and of helping to understand more complex systems through a combination of in situ analyses and laboratory procedures. Here we explore datasets from: (i) 148 dune and 135 lake shoreline samples across southern Africa and (ii) dune damming sediments (DDS) within the Negev, Israel (Roskin et al., 2017), where insights into bleaching histories, sediment luminescence sensitivity and sample age can be gained through a combination of simple POSL profiling and laboratory calibration of luminescence-sensitivity, coupled with SEM analysis.

The southern African datasets show that POSL signals from bulk samples regressed against laboratory-based ages on quartz can be used to calibrate POSL signals into first-order age estimates, and that a regionally-specific approach is needed for different dunefields across the subcontinent (r2 of 0.99, 0.93, 0.81 and 0.52) (Stone et al., 2019). Sample composition, such as quartz to feldspar ratios, account for the largest spatial contrasts, and sample luminescence-sensitivity may also influence signals. For the lake shoreline data, factors other than sample burial age are contributing to driving the POSL signals but with no clear single factor. Contrasts in POSL signal characteristics between individual dunefields and lake shorelines systems are also providing interesting insights into sediment provenance and geomorphological processes across southern Africa.

The Negev case study shows an example of reflexive geomorphology in a more complex DDS setting using POSL alongside laboratory irradiation and SEM analysis. The different DDS could be identified at this vegetated linear dune (mostly stabilized since the Younger Dryas), after accounting for: (i) luminescence sensitivities through calibration, (ii) inherited luminescence signals based on depletion rates and (iii) stratigraphic position. Apparent ages for emplacement of both fluvial and aeolian units can be established providing a coherent basis for interpreting the environmental history of the DDS.

Overall the POSL approaches discussed here provide cost- and time-effective means of generalising chronostratigraphies over large areas in both simple and complex systems, in order to reconstruct Quaternary environmental changes.
Geomorphological and Archival Evidence of Coastal Systems

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Coastal storms pose a significant hazard to the coastal populations of Britain and are predicted to increase in frequency and magnitude throughout the 21st century. This interdisciplinary research, which utilises geomorphological analyses and written evidence, seeks to determine how trends in the frequency and magnitude of coastal storms have changed over the last 300 years and examine how the consequences and responses to storms have evolved over this period.

Fieldwork undertaken in the Three Rivers estuary, Carmarthen bay included detailed lithostratigraphical analyses and surveying. Potential storm surge horizons were identified at altitudes of 2.16 – 2.66 mOD and 2.77 – 3.14 mOD following field, geochemical and particle size analyses. Coincident increases in the abundance of calcium and strontium (probable offshore marine indicators) relative to the conservative elements iron and titanium within the stratigraphy suggested that the horizons were indications of major storm surge events which significantly influenced the coastal environment. The enhanced enrichment of zirconium compared to titanium relative to the baseline of ‘average shale’ in the potential storm surge deposits, also provides further evidence that the deposits were likely to be of offshore marine, rather than terrigenous origin. The abrupt increase in the relative abundance of potassium and silicon (respective indicators of quartz and feldspar) and the increase in the particle size of the sediments in correspondence with the short medium-grained sand horizons also support this hypothesis. The principal component analyses which exhibited a combination of the calcium, strontium and grain size distinguished the abrupt medium-grained sand horizons from the surrounding clays and silts providing further evidence that the horizons indicate the occurrence of past storm surge events.

The written records from the 18th and 19th centuries concerning meteorological observations highlighted the regular occurrence of storm surge events in Camarthen Bay and their changing influences on the coastal population. Storm surge skew tidal gauge data will be used to bridge the two forms of research and provide quantitative support for the written analysis which will enable the creation of a highly accurate record of coastal storms in South-west Wales. Ensuing 210Pb and 137Cs dating will allow the identification of a temporal correspondence between written and geomorphological records.
Spatial and temporal records of South Western Atlantic oceanography from the Uruguayan margin

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The Brazilian-Malvinas Confluence (BMC) is sited off the Uruguayan margin and represents an important oceanographic heat exchange between the warm Brazilian Current and cool Malvinas Current, thermally regulating the South Atlantic Ocean between the tropics and Antarctica. A primary control on planktonic foraminiferal species occurrence is the water temperature in which that species dwells, the contrasting water mass temperatures within the BMC therefore influence the proportion of subtropical vs. subpolar species within the foraminiferal assemblages. The mixing of these two thermally contrasting water masses leads to a rapid shift in the proportion of planktonic foraminiferal species present across the margin.

This project utilises a series of thirty-two core tops spread across the margin to map the transition between warm and cold foraminiferal assemblages based on known species preferences. This map forms a ‘modern’ baseline against which to assess temporal variation of foraminiferal assemblages, and in turn determine whether this is indicative of north/south BMC migration. Previous sediment provenance studies have suggested the potential for BMC migration in line with glacial-interglacial cycles, alternating between Brazilian and Malvinas Currents bathing the Uruguayan margin. Down core assemblage studies and isotopic analysis seek to confirm this pattern using the most northern core of the collection, UPC 028, to determine shifts from the present warm-subtropical status.

Initial findings map a latitudinal preference to the core tops that largely follow expected temperature gradients and map a contact between those sites bathed preferentially in Brazilian vs. Malvinas waters. Down core sampling of planktonic foraminiferal assemblages and collection of isotopic data suggests that temporally UPC 028 experiences variable water mass temperatures, impacting the foraminiferal communities present and implying potential BMC migration and oceanographic change.

This project utilises a dense collection of core tops to map in high resolution the ‘present’ planktonic foraminiferal communities across the Uruguayan margin and tests how spatially variable communities are in line with water mass temperature. Additionally, this study investigates past changes to the current oceanographic status quo, using planktonic foraminiferal assemblages and isotope analysis to assess BMC migration.
Down by the river: Terrestrial drainage network evolution at Dogger Bank during glacial to interglacial transition

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Dogger Bank, in the Southern North Sea, was covered by the British-Irish Ice Sheet prior to its deglaciation by approximately 23 ka BP. Subsequently, it was exposed subaerially, before marine transgression at approximately 8.5 ka BP. During this window of subaerial exposure, the Dogger Bank area experienced climatic warming after deglaciation, which may have altered the sedimentary environments and drainage basin characteristics. The vulnerability of drainage networks to changes in the palaeoclimate may provide insight into future hydrological changes under projected climate warming.

Investigation of an integrated dataset of high-resolution seismic reflection data and Cone Penetration Tests, acquired for windfarm site investigation, has revealed a channel network, incising glacial and proglacial lake sediments, which sits below coastal and shallow marine sediments. These channel-fills are interpreted to represent terrestrial drainage networks. When mapped out, the morphology and sinuosity of the channel forms reveal two distinct sets of channels. The first set comprises two straight, wide (400 m) channels that contain macroforms interpreted to be braid and side bars. The long profile of these channels show flow direction was from north to south in one channel, and west to east in the other channel. These channels are interpreted to be proglacial rivers, draining the ice sheet margin to the north. The second set of channels are more sinuous and all have heads within the study area. These channels form a tributary subdendritic network that flows into the proglacial rivers. These channels are interpreted to have formed later, based on their differing morphology and channel long profiles that incise down towards the proglacial channels.

The timing of channel formation lacks direct constraint. However, the first set of channels, the proglacial rivers, must have formed as the ice sheet was still on Dogger Bank, before 23 ka, to supply meltwater to the rivers, but after the filling of the proglacial lake basin with fine-grained lake sediments. Palaeoclimate modelling was used to generate precipitation profiles for Dogger Bank, and this shows a cold and dry period after the ice sheet retreat and until 17 ka. After this, precipitation increased, which would have allowed the second set of channels to form, draining precipitation from the land surface. These rivers were then active until marine transgression at around 8 ka. This landscape evolution provides unique insights into the changes in drainage of the North Sea Basin during climate warming.
Ecology and paleoenvironmental application of testate amoebae in peatlands of the high-elevation Colombian páramo


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We investigated the ecology and paleoecology of testate amoebae in peatlands of the Colombian páramo to assess the use of testate amoebae as paleoenvironmental indicators. Objectives were to (1) identify environmental controls on testate amoebae, (2) develop transfer functions for paleoenvironmental inference, and (3) examine testate amoebae in a Holocene peat core and compare our findings with other proxy records. Results from 96 modern samples indicate that testate amoebae are sensitive to pH and surface moisture, and cross-validation of transfer functions indicates potential for paleoenvironmental applications. Testate amoebae from the Triunfo Peatland in the Central Cordillera provided a proxy record of pH and water-table depth for the late Holocene, and inferred changes were correlated with peat C/N measurements during most of the record. Comparison with a lake-level reconstruction suggests that at least the major testate amoeba–inferred changes were driven by climate. Our work indicates that testate amoebae are useful paleoenvironmental indicators in high-elevation tropical peatlands.
Holocene relative sea-level changes in West Wales: data from the Dysynni Valley

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This research reconstructs Holocene sea level changes in west Wales in order to better understand anthropogenic impacts on the landscape. The Dysynni Valley in west Wales provides a valuable case study due to the well-preserved estuarine sediments and a rich archaeological record, from prehistory to the medieval period.

Fieldwork, including stratigraphic analysis, sampling, and geomorphological mapping, was undertaken at three sites, Penllyn, Perfeddnant and Gesail, in order to establish the vertical and horizontal extent of marine inundation in the valley. Laboratory work included loss on ignition, particle size, diatom and foraminifera analyses to establish the salinity and geophysical properties of the sediments enabling sea level fluctuations and changing sedimentary dynamics to be established.

The stratigraphy at Penllyn revealed a basal peat dated to between 7787-7665 cal BP, overlain first by blue-grey clay, and then by a woody peat dated to 6402-6297 cal BP. The diatom analysis at Penllyn revealed that the clay was dominated by marine and brackish species such as Nitzschia navicularis, Diploneis interrupta, Diploneis didyma and Diploneis stroemi. A marine-estuarine intertidal environment existed at this site during the mid-Holocene and this correlates with the Main Postglacial Transgression in the area.

At Perfeddnant, a similar stratigraphy revealed a basal peat dated to 9885-9547 cal BP, overlain by blue grey clay. At the base of the profile, freshwater diatoms were found such as Eunotia praerupta and Pinnularia major. However, the clay was dominated by poorly preserved, broken diatoms, with some valves of Diploneis interrupta and Nitschia navicularis identified. However, foraminifera were found, with high and mid marsh foraminifera Jadammina macrascens and Trochaminna inflata dominating the profile. The clay was overlain by a woody peat dated to 4782-4420 cal BP. A short core of grey alluvium overlying glacial gravel was recovered from Gesail, at the head of the valley. The diatom profile was dominated by freshwater species such as Pinnularia major, indicating that marine conditions did not reach the top of the valley.
Tracing state shifts from a terrestrial sequence spanning the last glacial-interglacial cycle in the Cheshire Basin, UK

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The last glacial-interglacial cycle was a period of dynamic climate change in the North Atlantic, with short-term variations in temperature (stadials and interstadials) superimposed on the dominant shifts between glacial and interglacial conditions. These variations in climate ought to have provoked environmental change in the British Isles. However, the record of past ice sheet fluctuations and environmental conditions is limited by poor chronological control and the erosion of pre-existing deposits during the Last Glacial Maximum. Hence, British environmental change remains weakly contextualised in North Atlantic climate change. This study focussed on the development of a chronostratigraphic framework using the sequence of Quaternary sediments at Arclid Quarry, Cheshire, to better constrain palaeoenvironmental change in the British Isles during the last glacial-interglacial cycle. This was conducted by applying stratigraphic techniques and optically stimulated luminescence (OSL) dating to the sequence. Two tills bracketing the sequence were dated to before ~77 ka and after ~29 ka, providing evidence for two separate ice sheet advances into the Cheshire basin and contesting evidence for Marine Isotope Stage 4 glaciation. The age of the upper till sediment was found to be consistent with the age of underlying sand unit. The two tills were separated by fluvo-aeolian sand and dense amorphous peat lenses. Portable optically stimulated luminescence analysis provided evidence for one phase of fluvial and one phase of aeolian conditions during the deposition of the upper 20 m of sand. The peat lenses were deposited between ~77 ka and ~48 ka, likely during a relative warm period, with implications for the Early Devensian (Chelford and Brimpton) interstadials. Our results indicate state changes resulting in prominent (albeit shortlived) environmental shifts in the Cheshire Basin. This suggests that environmental conditions in the British Isles were sensitive to subtle variations in North Atlantic climate during this period. The resultant framework may now be considered a reference for the rest of the British Isles.
Retreat of the Cordilleran Ice Sheet and exposure of coastal islands during the last deglaciation in British Columbia, western Canada

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Reconstructions of Cordilleran Ice Sheet retreat add to our understanding of ice sheet demise, sea level change and the peopling of the Americas. Recent work shows deglaciation along the west coast of North America was complex, with diachronous retreat of different ice margins, and there remain important chronological gaps along this coastline. Here, we present 52 terrestrial cosmogenic Be-10 nuclide exposure ages from islands along the western margin of British Columbia, Canada. We find that ice retreat occurred by at least 18.1 ka, exposing low-lying parts of Banks Island and Calvert Island by ca. 17.7 ka. Several of our study sites record a still-stand (or re-advance) of ice at ca. 17.6–16.6 ka on Aristazabal Island, Hunter Island and Calvert Island, correlating with a significant advance of the Puget Lobe and several other glacial records at this time. We find that the ice sheet may have thinned markedly between ca. 16.6 and 13.4 ka but remained extensive, with coastal sites still being exposed by around 14.5–13.4 ka. Our exposure ages fit with an emerging model of early deglaciation along this coastline compared to previous ice sheet reconstructions. The new data support radiocarbon dating of sediments from Haida Gwaii showing ice advanced at 30.0 ka and retreated by 19.4 ka, with significant implications for a coastal human migration route into the Americas. Consistent ages from several sites around the former Cordilleran Ice Sheet at ca. 17.6–16.6 ka may imply a regional response to hemispheric change during Heinrich event 1. Our findings also contribute towards a developing story of ice sheet thinning by around 14.0 ka, during which time the Cordilleran Ice Sheet is thought to have contributed around 2.5–3.0 m to eustatic sea-level rise. Further work will contribute towards the emerging picture of coastal human migration and will better constrain the contribution of the Cordilleran Ice Sheet to global sea-level during the last deglaciation.
The timing and spatial expression of Holocene rapid climate events: a view from the Dinaric Alps

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A greater understanding of past natural climate variability is essential to allow insights into system responses to rapid warming, and to help determine possible future impacts. Quasi-periodic rapid climate events are known to pervade the last glacial period, but the extent and nature of Holocene millennial-/centennial-scale climate instability is less well understood. This PhD research project aims to determine whether the terrestrial central Mediterranean region experienced rapid climate changes in response to variability in large-scale ocean (AMOC) and atmospheric (Siberian High) circulation systems. A 10 m core has been retrieved from Lake Barno Jezero, located in the Dinaric Alps, Montenegro (1490 m asl; 43°9’22’’N, 19°5’33’’E). The lake is expected to be sensitive to even muted climate variability; it is situated close to the mountain treeline, experiences winter ice cover and located in a relatively remote area with a low historical population. Prospective coring has revealed a lake sediment record that is thought to extend into the last glacial. Preliminary organic and carbonate content analysis of the 10 m core reveal multiple oscillations, while initial diatom analysis has begun. We await the completion of further analysis (Stable oxygen isotope analysis and 14C dating) to assess the nature and tempo of lake and catchment changes during the Holocene.
Recent mountain glaciation and landscape development in the southern part of the Helvellyn Range, NW England

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The southern part of the Helvellyn Range, which is situated in the English Lake District, is well-known for its alpine-style glaciated terrain, with textbook examples of cirques, arêtes, troughs and hanging valleys. Glaciers were last present during the Loch Lomond Stadial, 12.9 – 11.7 ka BP, when ice masses developed in the cirques and valleys to the east and northeast of high ground. J.B. Sissons considered the downvalley extents of these glaciers to be delineated by prominent, sharply-defined moraines. He also noted the presence of other moraines in the area but believed these pre-dated the Younger Dryas on account of their larger size and more rounded appearance – the latter interpreted as evidence for prolonged weathering and erosion under severe periglacial conditions. As such, he excluded them from his geomorphological maps.

This poster presents the results to date of ongoing research into glaciation and landscape development in this area. There are two main drivers for this work. Firstly, work elsewhere in the Lake District has shown that some of the cirque and valley glaciers mapped by Sissons were in fact outlet glaciers draining icefields that developed on broad, rounded summits, with associated implications for our understanding of landscape development and paleoclimates. This may also have been the case in the Helvellyn Range, at least locally. Secondly, this project looks at the abundant assemblages of glacial depositional landforms not mapped by Sissons. Assuming these pre-date the Loch Lomond Stadial, geomorphological mapping may be able to shed some light on the final stages of Late Devensian deglaciation in the vicinity of the Helvellyn Range.

Preliminary geomorphological mapping reveals that the landform record is somewhat more complex than previously supposed. Sissons’ reconstruction appears to be broadly correct, however, with the exception that limited summit glaciation occurred (but not on Helvellyn itself). These glaciers retreated actively for most if not all of their lengths. Perhaps more interestingly, there is abundant and remarkably detailed geomorphological evidence for the active retreat of mountain glaciers that extended beyond the published limits of the glaciers mapped by Sissons. This most likely represents evidence for pre-Lateglacial deglaciation.
Modelling Firn: Is seismic Full Waveform Inversion the solution?

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The transformation of snow into ice is a fundamental process in glaciology. The yearly accumulation of fresh snowfall increases the overburden pressure, changing the snow’s properties such that it transitions into firn and pure glacier ice thereafter. Therefore, firn characteristics provide a tool for evaluating past and present climate conditions relating to the amount of snow accumulation, melt, temperature conditions and the subsequent preservation of the snow.

Due to the importance of relationships between firn and other glaciological processes (e.g., settling, sublimation, recrystallization and other deformation processes) it has not been possible to develop a theoretically-based model which accurately predicts firn properties with depth. Therefore, methods of measuring firn are either intrusive or rely on (potentially unreliable) empirical conversions. Full Waveform Inversion (FWI) may offer a new standard for glaciological seismic modelling, mitigating issues within current seismic modelling techniques and paving the way for the recovery of elastic properties, including density.

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What happened to WAIS during the last interglacial?
How the new Skytrain Ice Rise core will help to answer that

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Sea level records combined with constraints on the size of the Greenland ice sheet demand that 2-7 metres of sea level equivalent was lost from Antarctica at some point in the last interglacial (LIG). Most concern has centred on the West Antarctic Ice Sheet (WAIS), and modelling experiments using still-unproven physics can produce the required retreat during the LIG. It seems astonishing that we cannot yet point to any convincing evidence that WAIS either collapsed or survived. Here we will discuss how the ERC project WACSWAIN aims to remedy this. In the field season 2018-19 we drilled a core to bedrock (651.04 m) at Skytrain Ice Rise, which sits behind the Ronne Ice Shelf. The ice there is nicely layered to the bed, and we have evidence that last interglacial ice will be preserved in the lowest 30 m of the ice. The core is ideally located to sense the retreat of the Ronne Ice Shelf and the reduction of the WAIS, if and when they occurred. Analysis is still underway, but we will present what data we have.
Uncertainty and Emulation: Using Bayesian methods to learn more about past ice sheet shapes

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Understanding how warming can affect ice sheets is vital for accurate projections of climate change. A better understanding of how the Antarctic ice sheets shape and size have changed in the past would allow us to predict more accurately of how they will adapt in the future; this is of particular relevance in predicting future global sea level changes. This research performs a Bayesian analysis with previous ice sheet reconstructions and proxy data from ice cores to create a model of the Antarctic ice sheet at the Last Glacial Maximum (LGM). We do this by finding the relationship between the ice sheet shape and water isotope values.

We developed a prior model which describes the variation between a set of ice sheet reconstructions at the LGM. A set of ice sheet shapes formed using this model were determined by a consultation with experts and run through the general circulation model HadCM3. This provides us with paired data sets of ice sheet shapes and water isotope estimates. The relationship between ice sheet shape and water isotopes is explored using a Gaussian Process emulator of HadCM3, building a statistical distribution describing the shape of the ice sheets given the isotope values. We then use MCMC to sample from the posterior distribution of the ice sheet shape and attempt to find a shape that creates isotopic values matching as closely as possible to the observations collected from ice cores. This would allow us to create a more accurate estimate of the ice sheet at the LGM, and to quantify the uncertainty in the shape and incorporate expert beliefs about the Antarctic ice sheet during this time period.
Quantitative relationships between fault kinematics and glacial processes

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The fluvioglacial Quaternary sands and gravels exposed near Lleiniog (Anglesey, North Wales) have been deformed by several different mechanisms including faulting [1, 2]. Based on the offset of bedding and sedimentary structures Lee et al. (2015) identified both normal and reverse faults. During recent fieldwork at Lleiniog orientations of faults were supplemented with detailed measurements of bedding and laminations in the immediate vicinity of the fault surfaces.

The aim of this work is to directly relate the results of detailed geometric and kinematic analyses of these faults to sub- and proglacial processes. Based on current fault dips and fault cut-off angles (i.e. the angle between a fault and bedding) two, possibly three families of faults can be identified. These faults are characterised by either:

(a) low dips and moderate cut-off angles;
(b) moderate dips and moderate cut-off angles;
(c) steep dips and large cut-off angles.

Subsequently, the kinematics of the three geometries have been modelled assuming that the fault blocks are rigid bodies, so called rigid domino model of faulting. Within these blocks fault cut-off angles are preserved and movement along the faults must be accompanied by rotation of the faults and fault block itself.

Initial results from this modelling indicate that there are faults that display high to moderate amounts of rotation as well as faults with limited to no rotation. Greater amounts of rotation are associated with greater amounts of horizontal extension or contraction, possibly linked to subglacial processes. High angle faults with small amounts of rotation are most likely to be a consequence of vertical collapse features with little or no translation, possibly formed in a pro-glacial setting.

Quantitative modelling of the type presented here may provide new insights into ice sheet dynamics, unrestricted by the age or geographic location of the deposits.

References:


A high-resolution relative sea-level reconstruction from east Scotland to constrain the meltwater pulses that forced the 8.2 ka event

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The ‘8.2 ka climate event’ is recognised as the largest magnitude Holocene cooling event in the North Atlantic region. Freshwater input from the retreating Laurentide Ice Sheet drove a slowdown of the Atlantic Meridional Overturning Circulation (AMOC) which subsequently caused the observed climatic shift. A 160 year period of temperature cooling of 3.3 ± 1.1 °C and reduced precipitation are observed in Greenland, with contemporaneous climate shifts recognised in many other records around the North Atlantic region and notably further afield. A new high-resolution sea-level reconstructions from the east coast of Scotland will be presented with the aim of resolving the history of the meltwater input(s) prior to the 8.2 ka event.

Litho- and bio-stratigraphic data alongside high-precision radiocarbon dates have been collected from the Ythan Estuary (NE Scotland) for the centuries prior to the 8.2 ka event. Results of a foraminifera based transfer function and multiple high-precision radiocarbon dates will be presented to produce the robust reconstruction. A rapid multi-stage sea-level rise is demonstrated that is compared to existing records to analyse the likely source and magnitude of the meltwater pulse(s).

Identifying the freshwater source(s) and quantifying melt-water input allow climate models to be tested in order to apply them more confidently to future AMOC responses to scenarios of warming and ice melt. Thus, this work ultimately will help to improve understanding of the impacts of Arctic ice melt on oceanic changes and future climate, especially in the North Atlantic region.
Late Holocene Coastal Change at Malltraeth driven by sea level and anthropogenic change

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In order to properly understand flood risk at the coast it is vital to understand the frequency with which storm surges have occurred in the past. Bateman et al. 2018 found that through use of portable luminescence profiling and particle size analysis it is possible to find evidence for past storms within coastal dune profiles. This work expands upon this study with the addition of GPR profiles of dunes in North Wales in attempt to better understand this record and how it may be used to reconstruct specific storm events.

This work also builds upon this by comparison of dune reconstructions with a 3300 year old relative sea-level reconstruction in an adjacent back barrier salt marsh (Rushby et al. 2019) along with 400 years of historic maps. This is done in order to elucidate how the onset of modern rates of sea-level rise and anthropogenic forcing may be driving the coastal evolution of the Malltraeth estuary and the implications this may have for future coastal change in the estuary.
Glaciers are key indicators of climate change and observations across the globe are reporting increasing rates of mountain glacier recession. Here we document ~200 years of change in mountain glacier and ice cap extent in northern Troms and western Finnmark, northern Norway. This is achieved through geomorphological mapping, lichenometric dating, and remote sensing that uses both satellite imagery and aerial orthophotographs. Lichenometric dating in the Rotsund Valley reveals that the Little Ice Age (LIA) maximum occurred as early as AD 1822 (±39 years), and before the early-20th century LIA maxima proposed on the nearby Lyngen peninsula, but clearly younger than the maximum LIA limits in southern and central Norway (ca. 1740-50). Since the LIA maximum and AD 1989, the studied glaciers (n = 15) shrunk a total of 3.86 km² (39%). All glaciers which decreased in area by more than 50% are now fronted by proglacial lakes. Subsequently, glaciers of northern Troms and western Finnmark shrank by ~35 km² between AD 1989 and 2018 (n = 219). Furthermore, very small glaciers (<0.5 km²) show the highest relative shrinkage. As of AD 2018, 90% of mapped glaciers within our study area are now <0.5 km².
Simulating anomalous enhanced North African precipitation during the mid- Holocene: a paleoclimatological enquiry using the isotope enabled HadCM3

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The mid-Holocene climate of North Africa is characterised by an anomalous precipitation response to orbital forcing – which is seasonally inhomogeneous. During this time, the Sahel and much of the Sahara was transformed into a mesic landscape – home to an abundance of shrub and grasslands – as well as variable galleries of tree cover. In order to assess the climatological drivers and boundary layer processes fuelling this anomalous precipitation-vegetation response, this study makes use of the isotope-enabled HadCM3 model suite. Three experiments (pre-industrial, mid-Holocene (orbital) and mid-Holocene (with vegetation prescribed over the Sahara)) are performed, each tasked with the diagnosis of annual and seasonal mean climate states. Here, evidence is provided that moisture is sourced from the equatorial Atlantic, and is advected across the continent due to the occurrence of anomalous anti-trade winds. Also clearly simulated, is the presence of the African Easterly Jet. A positive-oscillatory-atmosphere-vegetation feedback is apparent – whereby increased soil moisture content, transpiration and precipitation amount act to sustain local moisture recycling. In terms of δ18O, this research finds that the magnitude of precipitation change is not simply scalable to the magnitude of change in δ18O – and thus, the sole attribution of this anomalous precipitation field to the ‘tropical amount effect’ would be unreasonable. Finally, a model-data comparison has led to the questioning of the robustness of simulated change in δ18O – and suggest that model sensitivity to δ18O may need to be reconsidered.
Buried Beaches and Drowned Dunes: Reconstructing a late Holocene buried dune environment using 3D ground-penetrating radar imaging and image segmentation

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During the last two decades, geophysical methods, specifically Ground-Penetrating Radar (GPR) have grown in popularity for acquiring high-resolution images of the stratigraphy, internal structure and wider context of geomorphic landscapes, as well as the reconstruction and evolution of buried landscapes. GPR offers centimeter-scale resolution of the buried subsurface, allowing 3D visualization of abrupt changes in Quaternary environments. However, for all these advantages GPR data interpretation can be non-intuitive with the technique seldom giving images that immediately resemble the expected subsurface geometry. Interpretations can be especially challenging when handling the large 3D data volumes that are commonly available with modern GPR technology.

In this paper, we outline the first steps toward the development of a user-friendly, automated GPR analysis tool that utilizes the image processing techniques Edge Detection and Thresholding. Developed initially for medical image analysis, we investigate them as a means of assisting the analysis of GPR data for subsurface geomorphic features. By segmenting and extracting the primary reflections of interest, such algorithms provide a methodology which can categorize the evolution of buried environments, highlighting abrupt changes in lithology, structure and extent of subsurface depositional environments. Combining 3D GPR, image segmentation methods and field data, represents an innovative approach to reconstructing Quaternary environments.

We present a 500 MHz GPR dataset collected over a buried aeolian Holocene coastal environment in Llanbedr, Gwynedd, North Wales, which has since been reclaimed for use as an airfield. The complexity of the buried structures and rapid changes from sand to silty-organic units as identified in cores (maximum depth ~ 2 m) means 3D GPR offers a powerful tool to reconstruct this dynamic and evolving landscape. When viewed in a top-down “depth-slice” view, the 3D architecture of the subsurface is easily visualised, facilitating the reconstruction of the evolution of the site.

We conclude that utilising a sedimentological and geophysical approach to characterize the evolution of a late Holocene dune field is an effective methodology. This presentation demonstrates the capability of GPR as a method of imaging the palaeo signature of Quaternary landscapes, presents a new algorithm by which to segment the data to efficiently characterize the GPR image, and categorizes the morphological evolution of a late Holocene aeolian landscape.
Saddle Collapse of the Eurasian Ice Sheet in the North Sea caused by combined ice flow, surface melt and marine ice sheet instabilities

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Despite growing empirical evidence, the pattern of, and mechanisms that led to, deglaciation of the North Sea sector of the Eurasian ice sheet remains unresolved. The sector is dominated by the large Norwegian Channel Ice Stream that had a width comparable to the contemporary Thwaites glacier. Reconstructing the deglaciation of the North Sea is thus important to provide insights into marine ice sheets, the behaviour of large retreating ice streams, the subsequent marine transgression of the North Sea, and future sea level changes in the region. Numerical simulations of the deglaciation of the North Sea have struggled to capture the confluence and separation of the British-Irish and Fennoscandian Ice Sheets as shown by the empirical data.

We ran an ensemble of 70 experiments simulating the deglaciation of the North Sea between 23-18ka BP using the BISICLES ice sheet model. We employed mesh refinement capability to target the North Sea. Experiments are forced with HadCM3 climate simulations of the last deglaciation, varying initial ice sheet geometry and model parameters to account for uncertainty in climate, ocean, and ice dynamics. We then compared model outputs to empirical data for ice flow, extent and retreat ages using a suite of quantitative model-data comparison tools to identify the range of plausible scenarios for North Sea deglaciation.

In the ensemble members that best match the empirical data, the North Sea deglaciated through the collapse of the marine-based Norwegian Channel Ice Stream, unzipping the confluence between the British Irish Ice Sheet and the Fennoscandian Ice Sheet. Thinning of the Norwegian Channel Ice Stream causes surface temperature feedbacks, rapid grounding line retreat, and ice stream acceleration, further driving the separation the British Irish and the Fennoscandian Ice Sheets through the saddle collapse mechanism. The results allow for further work comparing model data to sea level records to create a Bayesian calibrated model reconstruction of North Sea deglaciation.
The Last Deglaciation Meltwater Paradox

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In recent years, the ability of complex climate models (such as general circulation models, GCMs) to perform fully transient simulations of the Last Deglaciation (21 – 9 ka BP) has advanced greatly, leading to exciting advances in our ability to investigate mechanisms of abrupt climate change during this period. The first GCM simulation to do this was the TRACE-21k simulation\(^1\), but it presents an often overlooked problem: the simulated abrupt events are produced using impossible climate forcings that are not in accord with palaeoclimate records. Specifically, TRACE-21k uses a very unrealistic ice sheet meltwater scenario to drive Heinrich Stadial, Bolling Warming and Younger Dryas temperature and ocean circulation changes.

Here, we present more realistic GCM simulations of the last deglaciation based on observations of greenhouse gases, ice sheet evolution and global mean sea level; comparing and contrasting the results with the TRACE 21k scenario. Using a realistic meltwater discharge produces a small weakening of the Atlantic Meridional Overturning Circulation (AMOC) after the onset of Heinrich Stadial 1 and a large weakening at Meltwater Pulse 1A. The resulting surface climate signal over Greenland is inconsistent with the ice core record. However, if we use the TRACE-21k meltwater scenario, then we successfully simulate abrupt events such as the Bolling Warming, confirming the original result of Liu et al (2009) using a different climate model.

This leads to the paradox. If we use the large meltwater forcing of TRACE-21k (which is not consistent with glaciological reconstructions), then we successfully simulate the climate change over Greenland during the Last Deglaciation. However, if we use a more glaciologically realistic meltwater history, then the climate response does not accord with the data. Ideas to resolve this paradox will be discussed.

References:

Morphological analysis of large-scale glacial and glaciofluvial bedrock-incised landforms

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Understanding the controls on focused glacial erosion is important given the potential impact on ice sheet development and dynamics. Previous work undertaken in this area has assumed that large glacial erosional landforms such as troughs and overdeepenings are morphologically distinct from glaciofluvial landforms such as tunnel valleys. However, there are many examples of large-scale glacial bedrock incisions that are difficult to categorise as either glacial or subglacial fluvial, and process-based morphological criteria for distinguishing between the two are lacking.

We present morphological analyses of overdeepened bedrock-incised landforms present on the Northern Swiss Foreland (NSF), focusing on the cross-profile morphology and comparability to that of similar features in other settings, and end member examples of erosion. This work combines methods implemented previously by Hirano and Aniya[2] (1988), Harbor[3] (1995), and Zimmer and Gabet[4] (2018). The findings of the cross-profile analyses seem to indicate that features such as those seen in the NSF are formed as palimpsest features, being influenced by both glacial and subglacial fluvial erosion.

The preliminary findings of this work can be used to help develop criteria to assess the relative contribution of glacial versus subglacial-fluvial erosion in the formation of such features, and therefore inform understanding and numerical modelling of subglacial conditions and processes.

References:


Rediscovering Relicks Moss: an overview of a multi-proxy peat core record of Holocene environmental change at Delamere, Cheshire

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Late Glacial deposits and post-glacial remains characterise the landscape of west Cheshire. However, historically, many wetlands in this region have been ‘lost’ to human activities; yet it has also featured a number of palaeoenvironmental studies, although many earlier studies were single proxy and tended to span only the late Holocene. Located close to regionally important archaeological remains along the Mid Cheshire Ridge, the former Marley Tile Works’ change in land use has facilitated an investigation of the potential of the site’s peat deposits as an archive of environmental change and human impact. A ca. 3.5 m peat core was subjected to pollen, charcoal and macrofossil analysis alongside mineral magnetic and geochemical investigation with an AMS 14C and 210Pb chronology. A multi-proxy approach allows a reconstruction of mire development and landscape change. In common with other palaeoenvironmental studies of the Late Glacial to mid Holocene, natural drivers dominate the environmental history of the site recording a transition from shallow lake to fen and bog environment, the timing of which is in line with the seral development of mire environments regionally. However, it also appears to provide evidence of an early short cold phase; the Younger Dryas Stadial. A range of local to regional, and both direct and indirect human impacts have also been identified. The site is advantageous in that it spans a longer time frame than many other local studies providing a full Holocene perspective. Mesolithic human impact is apparent in the changes in tree cover, disturbance indicators and the evidence of fire as charcoal particles, and is consistent with other studies although from a lowland site. A Mesolithic to Neolithic transition is observed, and Bronze to Iron Age impacts on the environment (seen as forest cover changes and evidence of agricultural activities) align with the archaeological record for the hillfort most local to the site (Eddisbury), but show some variations in comparison to lake sediment records in the region. Subsequent relatively recent land use change impacts on the site are also apparent, including the demise of Delamere Forest and local to regional industrial activity. However, the latter may also have degraded the recent environmental record of the peat profile. Despite the recent history of this former industrial site, this multi-proxy record reveals the ‘lost’ mire of Relicks Moss. Whereas, despite the relative abundance of potential palaeoenvironmental archives in the region, locally there remains a paucity of dated, multi-proxy studies.
Palaeogeographic change in response to glacial/interglacial cycles: Middle and Upper Pleistocene stratigraphy of the southern North Sea

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The Middle to Late Pleistocene (MIS19 to MIS2) period is characterised by considerable global climatic instability, with repeated cycles of glaciation and high amplitude relative sea-level changes. Recently acquired industrial quality high resolution seismic, core and geotechnical data from the southern North Sea form a valuable archive of mid-latitude palaeogeographic change during this period. Three major stratigraphic units have been identified using seismic mapping, seismic facies analysis, core logging and interpretation of cone penetration test (CPT) data.

The lowermost stratigraphic unit (approximately MIS 19 to MIS 13) is predominantly fluviatile and overlies the marine deltaic successions characterising the Early Pleistocene. Channel-fills within this unit are orientated approximately north-south and northeast-southwest, and display variable channel fill architecture, and provide direct evidence for large-scale Middle Pleistocene fluvial networks North of 52° in the southern North Sea. These fluvial networks are interpreted to be a consequence of the evolution and increasing influence of mainland European and British river systems in response to climatic changes. A series of north-south trending tunnel valley-fills, provide evidence for subglacial conditions at this location, and are thought to have formed during the Anglian Stage glaciation (MIS12). There appears to be a sedimentary hiatus with sediments from MIS 5d and 4 then dominating the survey area. These deposits are predominantly sheet-like and composed of silts and clays with indications of iron sulphide and marine shells supporting a low energy, restricted marine environment. Dune-scale bedforms and variation in the geomechanical properties (CPT) of the fill provide evidence for changes in the rate of relative sea-level fall and the evolution of a dynamic and complex coastal landscape during this time.

Analysis and interpretation of the southern North Sea Quaternary stratigraphy using this high resolution dataset provides critical information informing ice sheet extent, landscape response to glacial/interglacial cycles and regional sea-level fluctuations.
Dating European contact in Australia: the eastern Australian magnetic inclination anomaly

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In settler societies such as those of north America, parts of south America, Australia and New Zealand, where technologically advanced farming was imposed on an environment that had experienced little or no agriculture, we see what Griffiths[1] (1997) has referred to as, ‘one of the great ecological ... encounters of all time’. And of all the settler societies, Australia may display these impacts most clearly. Australia’s later colonisation and its relatively undisturbed pre-colonial environment saw the imposition of industrial farming on an untilled and untrampled landscape, providing perhaps the most extreme example of agricultural modification experienced anywhere in the world.

Understanding this impact requires detailed records that extend back not only to the arrival of the first stock or the turning of the first sod, but to well before the point of contact, for without such a record, it is impossible to establish a pre-impact control against which to judge the impacts of agricultural activity.

Unfortunately, dating this part of the geological timescale presents us with severe challenges. Written records of all but the most prosaic information are rare until the middle years of the 19th century and almost non-existent before official colonisation in AD 1788, whilst, with the exception of 230Th/234U methods, the use of which is restricted to rather specific depositional environments, there is no established geochronometric tool capable of dating more than a fraction of this most recent part of the geological timescale at a resolution adequate to tackle the environmental issues of this period.

An alternative approach to dating the recent past, and one that has not so far been widely exploited, involves matching the palaeomagnetic secular variation signatures of recent sedimentary sequences with the known record of geomagnetic field fluctuations. This work reports a precisely dated magnetic inclination anomaly identified in sedimentary and archival records that allows us to date late 18th century sedimentary sequences. This event is of great significance because it encompasses the period immediately preceding the point of European contact in Australia, offering the potential to date perhaps the most critical episode of the continent’s environmental history.

References:

The response of permafrost peatlands in Arctic Sweden to late Holocene climate change

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The lowland areas surrounding Abisko in Northern Sweden are characterised by extensive permafrost peatlands. Permafrost peatlands store a disproportionate amount of carbon for their land area and on a hemisphere scale store globally-important amounts of carbon (C). This carbon has remained largely inert for millennia because of frozen soil conditions suppressing decomposition by soil biota. However, in the last century Abisko has experienced >2.5°C warming, with mean annual temperatures now regularly exceeding 0°C. The observed and projected increase in temperatures at high-latitudes is associated with increased permafrost thaw, exposing the C stored to decomposition and subsequent emission to the atmosphere as greenhouse gases. Nevertheless, the global warming potential from increased decomposition may be partially or entirely outweighed by increased C sequestration and accumulation of peat from enhanced ecosystem productivity; however, the magnitude of this effect remains unclear. Alongside the degradation of permafrost, shifts in hydrology and vegetation have been identified as key areas of uncertainty in the prediction of permafrost carbon dynamics. Increasing our understanding of the response of permafrost peatlands to warming is essential in determining whether these ecosystems will accelerate or partially mitigate future global warming. In the absence of long-term monitoring data we are using a palaeoecological approach to reconstruct past hydrology (testate amoebae), vegetation (plant macrofossils) and carbon accumulation in 10 cores from eight sites near Abisko. These permafrost peatlands are at various stages of permafrost degradation and reconstructions span roughly the last millennium. The cores are being dated using 210Pb, 14C and tephrachronology. In this poster we will present preliminary results suggesting that recent warming may coincide with ecosystem shifts in these permafrost peatlands and discuss the possible implications for future carbon dynamics.
The Importance of Greenland Interstadial 2

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GI 2 comprises two narrow peaks, GI2.2 and GI2.1, separated by a short 200-year stadial, GS2.2, from 23340–22900 years b2k, when δ18O rose from c. −40‰ to −38‰ [2]. These warm peaks and their corresponding Ca2+ values approach or exceed all subsequent records before the start of the Lateglacial Interstadial. This overall GI2 warming probably impacted the waxing and waning of the northern icesheets and eustatic sea levels during the LGM, following the lowest sea level at c. 27ka [1], but this has hardly been studied. Indeed, the latest results from BRITICE-CHRONO reported at INQUA 2019 imply a mainly continuous eastward retreat of the BIIS to the western coastlines of Ireland and Scotland.

However, a growing body of physical evidence suggests that the LGM was separated into a shorter extensive and a longer, less extensive, phase before and after GI2. There is unrefuted evidence for two LGM peaks from a) Scandinavia and North America, published as early as 1973; b) Norway, of abrupt recession and partial re-advance of the coastal icesheet; c) the depths of coral reefs on the Great Barrier Reef of Australia; d) possible correlation of the later longer peak with the Wester Ross Re-advance in Scotland and the Donegal Bay Moraine in Ireland, supported by strong evidence of major re-advance moraines in western Ireland seen on field trips to Connemara and Clare Island at INQUA 2019; e) the work of Raistrick and others in northern England.

The absence of BRITICE-CHRONO records for a major early recession and re-advance and any other D-O oscillations within the LGM might arise from dating uncertainties and a rather coarse 1000-year modelling interval. The project primarily used marine records, whereas the re-advances in Ireland and Scotland primarily terminated on land. Any re-advance moraines on the sea bed were perhaps indistinguishable from recessional moraines. Because of continuous eustatic sea level rise after the first peak, the tidewater icesheet did possibly retreat continuously, whilst glaciation on land advanced. Hopefully, the British and Irish marine records will eventually become reconciled with terrestrial and other evidence, and the extent of local altitudinal deglaciation at GI2 will become understood, by new climate models and by dating to an accuracy of ±100 years, following incorporation of more precise tephra chronologies.

References:


Changes in storminess over the last deglaciation in the Southern Hemisphere

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Exciting new proxies of climate variability have been developed which can shed light on how stormy past climates were (Buizert and Severinghaus 2016). To set the stage for what changes we might expect these proxies to show, we present climate model results that show how the storminess around Antarctica may have changed at points during the last deglaciation.

Around West Antarctica there is a reduction in the storminess in a 10ka simulation compared to the modern. During the LGM a reduction in storminess near West Antarctica is simulated. This reduction can be attributed mostly to the increased elevation of Antarctica at this time.

During cold periods in the North Atlantic, there is an increase in storminess. It is possible to relate these changes in storminess to the position of the poleward edge of the Southern Hemisphere mid latitude jet during wintertime. This jet is known to be sensitive to changes in the North Atlantic climate. So a physical explanation for the link between storms in the Southern Hemisphere and cooling in the Northern Hemisphere can be given.
Inverting the source and magnitude of meltwater pulse 1A using sea-level constraints

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The understanding of Meltwater Pulse 1A (MWP-1A), the largest and most rapid global sea-level rise event during the last deglaciation, happened approximately between 14,650 to 14,000 yrs before present, is important for understanding large ice sheet stability, the global sea-level budget and climate change. However, the source and magnitude of this event is still debated, especially whether Antarctica can make a significant contribution to this event. Here we use a joint method of Monte Carlo linear regression and sea-level fingerprints constrained by six sites with sea-level observations through this interval to investigate the source and magnitude of MWP-1A. By considering uncertainties in both age and depth, we found a significant 9.18 ± 3.42 m Antarctic contribution to MWP-1A. This result shows good agreement with some Antarctic palaeo proxies but it is inconsistent with most Antarctic ice sheet (AIS) reconstructions derived from glacio-isostatic adjustment (GIA) modelling studies, which either do not hold enough ice at the Last Glacial Maximum (LGM) to make a significant contribution to MWP-1A, or do not show rapid melting during MWP-1A. If Antarctica only contributed ~10 m to post-LGM sea-level rise, as most GIA models predict, then the post-LGM sea-level rise is not balanced by the total amount of ice that melted since the LGM. We quantify this ‘missing ice’ using a Monte Carlo simulation method, which shows there is 11.2 ± 12.3 m ice still unaccounted for. We compare observational (glaciological) constraints with GIA models and conclude that the Weddell sea is the region with the sparsest observational constraints and the greatest misfit between observed and modelled ice thickness change during the LGM. This region could potentially hold some of the ‘missing ice’ and contribute significant sea-level rise during MWP-1A. More marine and terrestrial glacio-geological data, especially constraints on past grounding line positions, as well as more sea-level records across MWP-1A, especially from the intermediate-field (e.g. Central and South America), are needed to test our hypothesis. In addition, in order to better understand transient AIS discharge during MWP-1A, it will be necessary to consider the role of atmospheric and oceanic heat transfer in controlling ice sheet dynamics.
Ocean circulation mode transitions in North Atlantic during Marine Isotope Stage 3

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A substantial number of abrupt climate change events (Dansgaard-Oeschger and Heinrich events) are witnessed during the last glacial period. However, the underlying dynamical processes behind these D-O events remain unknown. Transitions between weak and strong modes of the Atlantic Meridional Overturing Circulation (AMOC) are assumed to have played a crucial role.

Based on a MIS3 equilibrium simulation of climate at 38ka BP with the Norwegian Earth System Model (NorESM), we study the potential for triggering spontaneous abrupt climate transitions given different background climate conditions. In particular, we investigate the relationship between sea ice extent and the strength and location of deep water formation sites, as well as the impact of AMOC changes on North Atlantic climate.

The stability of the AMOC and sea ice shows little response to atmospheric CO2 and ice sheet topography, suggesting that these boundary conditions are less important than previously thought for the occurrence of spontaneous AMOC mode shifts. On the other hand, adding freshwater to the surface of the Northern Atlantic triggers a shift to a weak AMOC mode, and a cooling of the North Atlantic region.

By including freshwater from a dynamic iceberg model, simulating a Heinrich event from the Laurentide ice sheet, we show that the AMOC is highly sensitive to the location of the forcing. We find that a simulated Laurentide sourced Heinrich event is very different form a freshwater influx to the Nordic Seas, which in the NorESM accounts for most of the changes in the AMOC and dominates the regional climate response.

These results question the results based on simple, classical freshwater hosing experiments applied to a broad area of the North Atlantic and indicate the importance of precise iceberg modelling for simulating the climate impact of Heinrich events.
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