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Quaternary Newsletter

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QUATERNARY NEWSLETTER

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Instructions to authors

Quaternary Newsletter is issued in February, June and October. Articles, reviews, notices of forthcoming meetings, news of personal and joint research projects etc. are invited and should be sent to the Editor. Closing dates for submission of copy (news, notices, reports etc.) for the relevant issues are 5th January, 1st May and 1st September. These dates will be strictly adhered to in order to expedite publication. **Articles must be submitted at least 6 weeks before these dates in order to be reviewed and revised in time for the next issue of QN, otherwise they may appear in a subsequent issue.**

Suggested word limits are as follows: obituaries (2000 words); articles (3000 words); reports on meetings (2000 words); reports on QRA grants (800 words); reviews (1000 words); letters to the Editor (500 words); abstracts (500 words). Authors submitting work as Word documents that include figures must send separate copies of the figures in .eps, .tif or .jpg format (minimum resolution of 300 dpi is required for accurate reproduction). Quaternary Research Fund and New Researchers Award Scheme reports should limit themselves to describing the results and significance of the actual research funded by QRA grants. The suggested format for these reports is as follows: (1) background and rationale (including a summary of how the grant facilitated the research), (2) results, (3) significance, (4) acknowledgments (if applicable). The reports should not (1) detail the aims and objectives of affiliated and larger projects (e.g. PhD topics), (2) outline future research and (3) cite lengthy reference lists. No more than one figure per report is necessary. Recipients of awards who have written reports are encouraged to submit full-length articles on related or larger research projects

NB: Updated guidelines on the formatting of contributions are now available via the QRA webpage and from the editor.

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COVER PHOTOGRAPH

View looking westward down Glencoe during the Quaternary of the West Grampian Highlands QRA Field Meeting, September 2021.
Photo credit Chris Francis.

OBITUARY

ROBERT WILLIAM CHARLES WESTAWAY

25th March 1959 (Falmouth) – 13th August 2021 (Durham)

The sudden death in August of Rob Westaway has deprived the Quaternary community of a great character and innovator, who had been active for nearly two decades in the QRA as well as its offshoot, the Fluvial Archives Group (FLAG). A first degree in physics (albeit with maths, geology and material science) and a PhD in geophysics (earthquake seismology), both at Cambridge, were not obvious routes into the Quaternary, which perhaps explains why Rob's contribution to our subject came late in his career. Indeed, he remained highly active in other fields such as computer science and structural and engineering geology.

Rob held early lectureships at Reading, Liverpool and Durham, also teaching in secondary schools in Durham and the NE, before joining, in 1999, the Open University as an Associate Lecturer and Regional Tutor, covering computing, engineering and, lately, environmental courses. From 2012, he held a concurrent part-time post as Senior Research Fellow in the School of Engineering (Energy

Engineering Group) at the University of Glasgow, where he worked with Paul Younger and, following the premature death of Prof. Younger, with Gioia Falcone. At the time of his death, he was engaged in projects at Glasgow working to develop and improve geothermal energy. In 1995 Rob had established a consultancy company, 'Technoscience Ltd' (working in computer science and training), which remained active at the time of his death.

Rob's contribution to Quaternary science stemmed from his realisation that certain landscape and sedimentary archives from the Pleistocene recorded progressive but fluctuating uplift that he believed to have been driven by mobility of the lower crust, which flowed into uplifting areas, thickening their crust from its base and thus maintained the increased elevation, providing a feedback mechanism that enhanced erosional isostasy. Rob believed that fluctuations in such uplift were closely related to palaeoclimatic change, with the greater severity of the Quaternary glacials, especially since the 100 ka cycles began, leading to accelerated surface processes and, therefore, more rapid uplift, with a time-lag that was related to crustal properties. Indeed, he developed a mathematical computer model that matched the patterns of uplift recorded by staircases of river terraces and raised beaches to palaeoclimatic records. The power of these ideas is their ability to explain features of the Quaternary record that cannot otherwise be understood.

Rob was extremely generous with his time, as reported by collaborators and graduate students who have worked with him. However, he was no respecter of status and could be highly critical of work that he felt to be flawed. Many would fear his acerbic questioning at conferences, which could appear to some as rudeness and occasionally led him into trouble. He was knowledgeable about many things, ranging from science fiction to history and world affairs, not to forget (and here is something that will gel with many QRA members of a certain age) railways: Rob could quote from memory the code number of every class of multiple unit on the British railway network, past and present.

Rob was author of almost 200 publications and numerous unpublished technical reports, with many more to follow posthumously, as his various collaborators in disparate fields seek to publish the fruits of their work with him. With Paul Younger, in 2014, he published the first realistic quantitative assessment of the nuisance that might arise as a result of ground vibrations caused by earthquakes induced by fracking as part of a hypothetical future UK shale gas industry. The selected bibliography below highlights some of the highlights amongst his contribution to Quaternary science, as well as some from his broader activities.

R. Westaway selected bibliography

Sole author:

2020. Late Cenozoic uplift history of the Peak District, central England, inferred from dated cave deposits and integrated with regional drainage development: A review and synthesis. Quaternary International 546, 20–41.

2017. Isostatic compensation of Quaternary vertical crustal motions: coupling between uplift of Britain and subsidence beneath the North Sea. Journal of Quaternary science 32, 169–182.

2016. The importance of characterizing uncertainty in controversial geoscience applications: induced seismicity associated with hydraulic fracturing for shale gas in northwest England. Proceedings of the Geologists' Association 127, 1–17.

2012. A numerical modelling technique that can account for alternations of uplift and subsidence revealed by Late Cenozoic fluvial sequences. Geomorphology 165–166, 124–143.

2011. A re-evaluation of the timing of the earliest reported human occupation of Britain: the age of the sediments at Happisburgh, eastern England. Proceedings of the Geologists' Association 122, 383–396.

2011. The Pleistocene terrace staircase of the River Thame, central-southern England, and its significance for regional stratigraphic correlation, drainage development, and vertical crustal motions. Proceedings of the Geologists' Association 122, 92–112.

2010. The relationship between initial (end-Pliocene) hominin dispersal and landscape evolution in the Levant; an alternative view. Quaternary Science Reviews 29, 1491–1500.

2010. Improved age constraint for pre- and post-Anglian temperate-stage deposits in north Norfolk, UK, from analysis of serine decomposition in *Bithynia* opercula. Journal of Quaternary Science 25, 715–723.

2010. Implications of recent research for the timing and extent of Saalian glaciation in eastern and central England. Quaternary Newsletter 121, 3–23.

2009. Active crustal deformation beyond the SE margin of the Tibetan Plateau: constraints from the evolution of fluvial systems. Global and Planetary Change 68, 395–417.

2009 Quaternary vertical crustal motion and drainage evolution in East Anglia and adjoining parts of southern England: chronology of the Ingham River terrace deposits. Boreas 38, 261–284.

2009. Quaternary uplift of northern England. Global and Planetary Change 68, 357–382.

2007. Late Cenozoic uplift of the eastern United States revealed by fluvial sequences of the Susquehanna and Ohio systems: coupling between surface processes and lower-crustal flow. Quaternary Science Reviews 26, 2823–2843.

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1994. Evidence for dynamic coupling of surface processes with isostatic compensation in the lower crust during active extension of western Turkey. Journal of Geophysical Research 99, 20,203–20,223.

Collaborative papers:

Bridgland, D.R., **Westaway, R.**, Hu, Z., 2020. Basin inversion: a worldwide Late Cenozoic phenomenon. Global and Planetary Change 193, 103260.

Westaway, R., Burnside, N.M., 2019. Fault "Corrosion" by Fluid Injection: a Potential Cause of the November 2017 ^{Mw} 5.5 Korean Earthquake. Geofluids 2019, doi.org/10.1155/2019/1280721

Demir, T., **Westaway, R.**, Bridgland, D., 2018. The influence of crustal properties on patterns of Quaternary fluvial stratigraphy in Eurasia. Quaternary 1, 28. doi.org/10.3390/quat1030028.

Bridgland, D.R., Demir, T., Seyrek, A., Daoud, M., Abou Romieh, M., **Westaway, R.**, 2017. River terrace development in the NE Mediterranean region (Syria and Turkey): patterns in relation to crustal type. Quaternary Science Reviews 166, 307–323.

Westaway, R., Bridgland, D.R., White, T.S., Howard, A.J., White, M.J., 2015. The use of uplift modelling in the reconstruction of drainage development and landscape evolution in the repeatedly glaciated Trent catchment, English Midlands, UK. Proceedings of the Geologists' Association 126 480–521.

Westaway, R., Bridgland, D.R., 2014. Relation between alternations of uplift and subsidence revealed by Late Cenozoic fluvial sequences and physical properties of the continental crust. Boreas 43, 505–527.

Seyrek, A., Demir, T., **Westaway, R.**, Guillou, H., Scaillet, S., White, T.S., Bridgland, D.R., 2014. The kinematics of Central-Southern Turkey and Northwest Syria revisited. Tectonophysics 618, 35–66.

Westaway, R., Younger, P.L., 2013. Accounting for palaeoclimate and topography: A rigorous approach to correction of the British geothermal dataset. Geothermics 48, 31– 51.

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Bridgland, D.R., **Westaway, R.**, Howard, A.J., Innes, J.B., Long, A.J., Mitchell, W.A., White, M.J., White, T.S., 2010. The role of glacio-isostasy in the formation of post-glacial river terraces in relation to the MIS 2 ice limit: evidence from northern England. Proceedings of the Geologists' Association 121, 113–127.

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Westaway, R., Cordier, S., Bridgland, D., 2009. Étude du soulèvement pléistocene dans le nord-est de la France et le sud-ouest de l'Allemagne d'après les terrasses du bassin de la Moselle: relation avec les propriétés crustales. Quaternaire 20, 49-–61.

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THE JAMES CROLL AWARD

JAMES CROLL AWARD – PROFESSOR PAULA REIMER

The James Croll Medal is the highest award of the QRA and is named in honour of James Croll (1821-1890). Croll is most closely associated with fundamental work on the astronomical theory of the ice ages, but he also made seminal contributions on the glacial geology of Scotland, on the mechanisms that drive ocean circulation and the impact of that circulation on recent climate, on tidal theory and the rotation of the Earth. These are all major issues that occupy Quaternary scientists to this day. Croll was effectively self-taught. His work and example demonstrate that any individuals from all backgrounds can rise to national eminence and generate science of lasting and major international impact, and that it is not who you are or where you come from but what you do that is important. These are the qualities that the QRA seeks to celebrate in the award of the James Croll Medal.

The Medal is therefore normally awarded to a member of the QRA who has not only made an outstanding contribution to the field of Quaternary science, but whose work has also had a significant international impact.

The QRA is pleased to announce that this year's recipient of the James Croll Medal, the senior medal of the QRA, is Professor Paula Reimer.

Paula J. Reimer received her Ph.D. in Geological Sciences from the University of Washington in 1998 working under the supervision of Professor Minze Stuiver in the Quaternary Isotope Lab. She then took up a postdoctoral research fellowship in School of Archaeology and Palaeoecology at Queen's University of Belfast, Northern Ireland, followed by three-years at the Center for Accelerator Mass Spectrometry at Lawrence Livermore National Laboratories. She established the international radiocarbon calibration working group (IntCal) which she chaired from 2002-2020. Since 2004 Paula has been the Director of the 14CHRONO Centre for Climate, the Environment, and Chronology and ^{14}C AMS facility at Queen's University Belfast.

For three decades now, Paula has been at the forefront of radiocarbon (^{14}C) dating, especially as the "flag bearer" of ^{14}C calibration. Soon after developing ^{14}C dating in the 1950s, Willard Libby (Nobel Prize 1960) noted that fluctuations in the concentration of atmospheric ^{14}C necessitated the ^{14}C dating of material of independently known age, in order to produce calibration curve that enable placing of ^{14}C dates of unknown material on the calendar scale. Paula's PhD supervisor Minze Stuiver led the production of the first internationally agreed ^{14}C calibration curves (e.g., Stuiver and Suess 1966 Radiocarbon 8: 534-540). From the late 1970s Paula worked as a programmer in Minze's lab, and there she wrote the software for the influential publication by Stuiver and Reimer 1986. For a mere $5, users were to be sent a floppy disk with the calibration program, and the authors promised that they would "update the program if time and budget permitted it".

That is exactly what Paula has done since then. Over the decades, the ^{14}C calibration curves have become ever more precise and accurate, have been extended ever further back in time, so, under Paula's watch, the IntCal calibration curves have now more than doubled in length to include the last 55,000 calendar years, based on nearly 13,000 multi-disciplinary data points ranging from dendro-dated tree-rings via U/Th-dated corals to varve-counted lakes and ocean basins. The IntCal curves (IntCal98, IntCal04, IntCal09, IntCal13, IntCal20, SHCal13, SHCal20, Marine98, Marine04, Marine09, Marine13, Marine20) have clearly become the world-leading standard, unifying what used to be a confusing array of competing calibration approaches into a scientifically underpinned framework compiled by experts from across the world who agreed to, share, improve and integrate a wide range of datasets. Much of this cat herding has been made possible through Paula's gentle but determined and rigorous leadership. The vast majority of all ^{14}C dates worldwide are now calibrated using the IntCal curves, and Paula's own calibration papers have amassed over 40,000 citations so far. Her efforts have enabled countless Late Quaternary archaeological and palaeoecological sites to be placed on a secure, common and widely accepted calendar scale, vital for these studies, and crucial for understanding the climatic and environmental background to current climate change.

Together with her husband Ron she maintains and updates the on-line radiocarbon calibration program http://calib.org which attracts thousands of users from across the world to calibrate their radiocarbon dates. Also provided is http://calib.org/CALIBomb for calibration of post-bomb dates, and users of marine dates can calculate and apply regional age offsets for their marine samples using http://calib.org/marine. This unique and invaluable database is used by many researchers across the world.

Through her work on ^{14}C calibration and dating, Paula has been involved in numerous collaborative projects, and has also successfully supervised to completion 14 PhD students, at least five of whom have continued as postdocs and lecturers. Since setting up ^{14}CHRONO, one of only 4 AMS labs in the UK, Paula has enabled many UK and international projects and collaborations, thereby providing a role in training ECR scientists. Paula was also instrumental in securing the School of Geography, Archaeology and Palaeoecology's Silver Athena-SWAN award. Paula also supports the QRA's ^{14}CHRONO Radiocarbon Date Award, which allows undergraduate, masters and early stage PhD students to apply for up to three radiocarbon dates and provides an important means of supporting students starting out in Quaternary research.

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Response

I am absolutely thrilled to receive the James Croll Medal from the QRA! The previous medal winners have all been very distinguished Quaternary scientists and I'm exceedingly proud to join their ranks. Thank you very much for selecting me for the 2022 James Croll Medal! Since my work on radiocarbon calibration has been highlighted in the citation, I want to acknowledge the contribution of all the earth scientists, radiocarbon specialists, statisticians and archaeologists who have collaborated with me over the years to update the calibration curves, especially my colleagues in the IntCal Working Group. Thank you all!

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THE LEWIS PENNY MEDAL

LEWIS PENNY MEDAL – DR BENJAMIN CHANDLER

This medal, which is named after Lewis Penny, a Quaternary geologist and founder member of the QRA, is awarded to a young or new researcher who has made a significant contribution to the Quaternary stratigraphy of the British Isles and its maritime environment.

The QRA is pleased to announce that this year's recipient of the Lewis Penny Medal is Dr Benjamin Chandler.

Ben is a Quaternary scientist who specialises in glacial process-geomorphology and sedimentology. He has made a number of important and critical contributions to our understanding of British Quaternary palaeoglaciology and glacier-climate relationships using modern analogues. Ben studied for a BSc in Geography at Queen Mary University of London graduating in 2013. Here he developed an interest in the Quaternary glacial history of Scotland and inspired by Sven Lukas and then-PhD-student Clare Boston, he completed a BSc dissertation on the Loch Lomond Stadial (Younger Dryas) glaciation of Ben More Coigach, in northwest Scotland. This was awarded the British Society of Geomorphology Marjorie Sweeting Dissertation Prize (2014), and the research was published in Journal of Quaternary Science.

Ben went on to undertake an MSc (by Research) in Geography at Durham University, under the supervision of Dave Evans and Dave Roberts. His MSc research project concerned the formation of ice-marginal ('annual') moraines in Iceland, and also introduced him to research in modern glacial environments. This research contributed to five publications, including two chapters in the Glacial Landsystems of Southeast Iceland field guide (2018).

In 2014, Ben returned to Queen Mary University of London to undertake a PhD under the supervision of Sven Lukas and Clare Boston. The project focused on the extent and dynamics of former glaciation in the Gaick, Central Grampians, Scotland. The research challenged the widely accepted paradigm of extensive Loch Lomond Stadial (Younger Dryas) glaciation in this region and presented a model of restricted plateau icefield glaciation of the Gaick during the Loch Lomond Stadial.

After completing his PhD in 2018, Ben spent a year as a Visiting Researcher at the University of Portsmouth, before being awarded a Leverhulme Trust grant to undertake postdoctoral research at Stockholm University (2019–2021) where his research focused on the application of near-surface geophysics to glacial environments. Ben is currently an Assistant Professor in Geomorphology at the University of Nottingham.

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HONORARY MEMBERS

Every year we nominate individuals for Honorary Membership of the Quaternary Research Association in recognition of significant, long-standing contributions to the QRA and to Quaternary science more widely. This year I am delighted to say that we have awarded Honorary Membership of the QRA to Peter Coxon, Kevin Edwards and David Horne.

PROFESSOR PETER COXON

A module on 'The Quaternary Period' taught by Rendel (RBG) Williams at Sussex in 1976 converted Pete from a would-be plant physiologist into someone fascinated by unravelling past environments through the medium of Quaternary geology. An undergraduate dissertation project on the 'Late-glacial and Holocene non-marine Mollusca of the Cuckmere Valley. Sussex' firmly set his interests in the Quaternary sphere. At Rendel Williams' suggestion, Pete joined the QRA in 1976, receiving a two page hand-written letter from the then Secretary John Catt welcoming him to the QRA.

Pete went on to a PhD in the Subdepartment of Quaternary Research at Cambridge under the supervision of Richard West. In 1979, the opportunity of a lectureship arose in 'Quaternary Geomorphology' at Trinity College Dublin giving Pete his first aeroplane flight and his first job interview experience. He got the post and worked at TCD until he retired 41 years later in 2020. Pete taught a range of modules in the Geography Department and he estimates that he took over 3200 students on departmental and geog/geol society field courses in Ireland and abroad.

Pete had the opportunity to work closely with and learn from Frank Mitchell and to carry out work on a wide range of Quaternary topics from mapping a whole offshore island (Clare Island) for an IQUA field meeting in 1982, to unravelling the archaeology buried by peat in SW Ireland, bog failures, Tertiary landscape evolution and vegetation history, interglacial deposits and periglacial and glacial geomorphology. Much of his work is summarised in a range of journal publications, review articles, book chapters, QRA, IQUA and INQUA field guides and recently an edited book. Pete was elected to Fellowship at TCD in 1992 (the year of the College's quatercentenary), elected as a Member of the Royal Irish Academy in 2002 and awarded IQUA's 'Frank Mitchell Award for Excellence in Research and Teaching' in 2011.

Pete has supported the QRA throughout his career, attending his first QRA Annual Field Meeting at Bristol in 1977, and he was awarded an engraved tankard at Aberystwyth on the occasion of his 25th consecutive QRA AFM. He held posts on the Executive Committee as an Ordinary Member (1988-91), Secretary (1994-98), Vice-President (2004-2008) and President (2014-2017). During these terms he attended every committee meeting. He also served on the Editorial Board of the *Journal of Quaternary Science* for over ten years, including as Special Issues Editor. As Secretary he set up the first QRA website and created a membership database greatly improving the management of the QRA membership and subscriptions. He has run field meetings for the QRA, IQUA and INQUA producing and/or co-authoring 14 field guides as well as contributing to others.

Pete also served the Irish Quaternary Association (IQUA) as Secretary (1983-1986) and Chair (2001-2005 and 2008-2011) as well as holding the post of INQUA Secretary-General for two intercongress terms (2003-2007 and 2007-2011). These experiences led Pete to suggest to IQUA that Ireland should bid for the 2019 Congress. The success of that bid and the resulting 2019 INQUA Congress held in Dublin was for Pete, a career highlight.

PROFESSOR KEVIN J. EDWARDS

Kevin attributes his interest in Quaternary science to a geography field trip to a Fife bog on a cold winter's day, where he was mesmerised by the experience of coring through peat into underlying lake sediments and Lateglacial clays and later, viewing the slides under the microscope. He says "Fossil pollen did not just look magical, but yielded indications of flora, climate, soil change, woodland removal and agriculture – a Rosetta Stone for local and wider environments".

Kevin undertook a PhD at the University of Aberdeen on the palaeoenvironments and archaeology of the Grampian foothills supervised by Rod Gunson, then moved on to a lectureship at Queen's University Belfast in 1975. He participated in the early meetings of the Irish Association for Quaternary Research (IQUA), compiling their Field Guide on Co. Tyrone (1980) and jointly editing The Quaternary History of Ireland (1985). Posts at the Universities of Birmingham and Sheffield followed before returning to Aberdeen as Professor of Physical Geography in 2000, retiring as Emeritus Professor in 2018. He is currently at the University of Cambridge where he is Senior Fellow of the McDonald Institute for Archaeological Research, Emeritus Associate of the Scott Polar Research Institute, and a Fellow Commoner of Clare Hall.

Kevin's research ranges from single site investigations through to macro-scale continental and global-scale studies, largely on Lateglacial to Holocene timescales, and especially concerning human-environment interactions. His contributions include methodological and theoretical contributions to palynology, period-based studies in Britain and Ireland; and an interest in the history of science.

Kevin's has contributed to numerous QRA Field Guides, co-organised the Annual Discussion Meeting in Sheffield (1996) and most recently an on-line celebration of the life and work of James Croll (2021). He has served on many panels and committees, including both the NERC Radiocarbon Steering Committee and the Oxford University Radiocarbon Accelerator Dating Service, and as editor or editorial board member of many journals. He became a Fellow of the Royal

Society of Edinburgh in 2002 and in 2018 he was made an Honorary Fellow of the Royal Scottish Geographical Society and was also awarded the Society's Research Medal.

PROFESSOR DAVID HORNE

Dave Horne is Emeritus Professor of Micropalaeontology at Queen Mary University of London, following his retirement in 2020. Dave is a micropalaeontologist with particular expertise in ostracods. His PhD, completed in 1980, investigated living Ostracoda in the Severn Estuary. Initially his research focused on taxonomic revisions of British living and Pleistocene fossil ostracods, including co-authorship of a marine and brackish water ostracods volume (for the Linnean Society's Synopsis of the British Fauna series) in 1989. He collaborated on the Non-marine Ostracod Distribution in Europe, or NODE, database that now underpins the Quaternary palaeoclimate work that has been his main focus since joining Queen Mary University of London in 2003.

His Mutual Ostracod Temperature Range (MOTR) method, brought opportunities to collaborate with archaeologists to develop palaeotemperature reconstructions for British Palaeolithic sites. He has also developed a multi-proxy consensus approach in collaboration with other specialists, comparing palaeotemperature reconstructions using ostracods, beetles, chironomids and other proxies in order to test and refine their results. One such application involved developing a novel Mutual Climatic Range method for plant macrofossils from Happisburgh Site 3, the oldest known site of human occupation in Britain, validating and refining beetle MCR results for that site. He continues to be active in research; current collaborative projects include a multi-proxy MIS11 palaeoclimate reconstruction at Hoxne, as well as taxonomic harmonisation of North American, European and

East Asian ostracod databases to improve calibrations of species' temperature ranges for use in palaeotemperature reconstructions.

Dave has run many field meetings for students and research groups and he has participated in QRA field and discussion meetings. He may also be found at Marks Tey, exploring the upper part of the lacustrine succession. He has encouraged and supported a number of undergraduate and postgraduate students to undertake micropalaeontological investigations of this important Middle Pleistocene site and some of this work was published in the QRA's Lower Thames and Eastern Essex field guide.

ARTICLES

MEGAFOSSILS: EVIDENCE FOR THE NATURE OF HOLOCENE LOWLAND WOODLAND IN ENGLAND AND WALES

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Abstract

Tree remains, megafossils, associated with former land surfaces, which subsequent became buried and preserved beneath Holocene coastal sediment, have long been used as a source of evidence as to the nature of lowland woodland during the Holocene. Nevertheless, in the debate that has accompanied the Vera hypothesis (that grazing pressure resulted in areas more closely resembling wood-pasture than closed canopy woodland) the focus has largely been upon the interpretation of other lines of evidence, particularly pollen. Here the megafossil evidence from this stratigraphic context from the Fenland basin, which influenced the views of authors such as Godwin on the structure of Holocene woodland, is reviewed alongside more recent detail palaeoecological investigations of such remains from coastal exposures. Whether these megafossils, and the closed canopy conditions they evidence, are likely to be representative of vegetation across a wider region is then discussed, along with the potential and difficulties for future palaeoecological investigations using such megafossils.

Introduction

The proposal by Vera (2000, 2002) that the early and mid-Holocene vegetation of lowland Europe as a consequence of grazing pressure more closely resembled wood-pasture, rather than the long held view of a closed canopy of tall trees, has generated considerable discussion. Despite extensive reviews of the available evidence (e.g. Hodder *et al*. 2005) debate, particularly over the interpretation of proxy evidence, notably pollen (e.g. Mitchell 2005,Birks 2019), but also including beetles (e.g. Whitehouse and Smith 2010) and fungal spores (e.g. Baker *et al*. 2013), has continued. In part this has been driven by the proponents of the hypothesis desire to promote naturalistic grazing in conservation management and rewilding schemes (e.g. Tree 2018). One possible line of evidence, the physical remains of trees, 'plant megafossils', has however been rather overlooked in recent years with Hodder *et al*. (2005) claiming that they "provide little evidence for the nature of woodland away from wetlands".

In the lowlands of England and Wales tree remains are commonly, though not exclusively, found exposed along the coastline or former coastal areas where their origin and preservation is linked to rising ground-water under the influence of relative sea-level (see for example Waller and Kirby 2021). Many occur within peat deposits, which when exposed on foreshores have consequently been termed 'submerged forests'. Others grew on dry land ('pre-Holocene') surfaces and were preserved by the accumulation of later sediments that often include a 'basal' peat. This important division of megafossil remains, based on stratigraphic position, has consistently been made since the early descriptions of these deposits by authors such as Skertchley (1877), Miller and Skertchley (1878), Reid (1913), Swinnerton (1931) and Godwin *et al*. (1935). In the context of trees that grew on pre-Holocene surfaces the frequently used term 'bog oak', which Godwin (1978) described as being 'collective', is unhelpful as they did not originate in bogs and neither are they all necessarily oak.

Here I review the megafossil evidence available to provide information on the nature of mid-Holocene lowland woodland; that is remains associated with former dry surfaces and the immediately overlying deposits. The initial focus is on the Fenland region of East Anglia, as the abundant megafossil remains exposed in this former embayment as a result of drainage in the 19th and early 20th centuries appears to have had a major influence on ideas in Britain on the structure of natural Holocene woodland. This is followed by a review of more recent palaeoecological studies of megafossils that have been undertaken from coastal exposures of basal Holocene deposits. Whether the megafossil remains preserved in these situations can be regarded as representative of lowland woodland and the potential and difficulties of further exploiting this resource are then discussed.

Megafossil remains in the Fenland basin

In the Fenland basin, Skertchley (1877) gives an indication of the large quantities of tree remains exposed as a consequence of the accelerated drainage and reclamation work that followed the introduction of steam-driven pumps in the early 19th century. Some of the detail is second-hand and lacks stratigraphic information, such as remains reported from near Bardney (Figure 1) which included a tree "90' (27.4m) long in the bole, 16' (4.9m) in the girth", and "70' (27.4m) before a branch went off". Elsewhere, Sketchley (1877) reports first-hand, such as at Wood Fen (near Ely) where "at the base of the peat, with roots in the Kimmeridge Clay a forest of oaks is found". "Some of these trees are of fine proportions measuring 3' (0.9m) in diameter, are quite straight, and very seldom forked". Accompanying tables and figures indicate the presence of tree remains at the base of the Holocene from

Stickney on the northern fen edge in Lincolnshire to Soham in Cambridgeshire and over a variety of solid lithologies (clay, sand, gravel). Sketchley records oak, elm, yew, hazel and birch from the basal layers though the basis for these identifications is unclear, aside perhaps from reference to bark being preserved on the underside of some of the trunks.

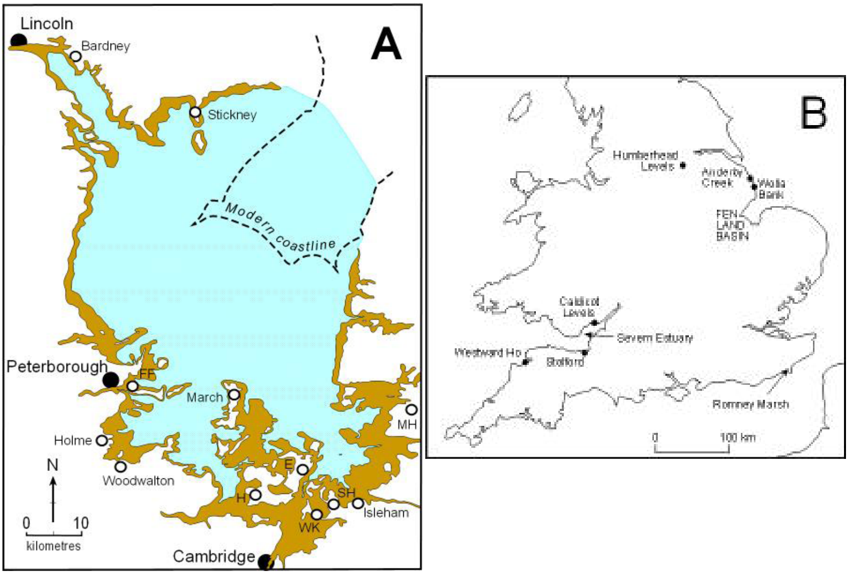

Figure 1. Places mentioned in the text. Figure 1A Also depicting the Fenland 'skirtland'; areas of Holocene sediment, largely peat (brown) but with some shell marl and alluvium, that overlie pre-Holocene surfaces beyond the maximum landward limit of Holocene marine incursions (blue). Data from Waller (1994). FF= Flag Fen, H= Haddenham,E = Ely, SH = Soham, WK = Wicken, MH = Methwold. Figure 1B Non-Fenland locations.

Tree remains were still a common feature of southern Fenland in the early 1930s, found in drainage cuts, peat cuttings and as a result of peat wastage "especially in a belt a few miles wide extending seawards from the margin of the Fens against the upland" (Godwin 1978), that is in areas where peat forms the surface sediment over pre-Holocene surfaces, beyond the inland limits of marine sedimentation (Figure1). This period saw the establishment of the Fenland Research Committee. Although now better remembered for the early use by Sir Harry Godwin of pollen analysis, megafossil remains were one of the initial focuses of its investigations, as is evident from Godwin's final account (Godwin 1978) of his and the Committee's work. Godwin (1978) provides a sketch of the primeval high forest that he believed "covered the British Isles before the advent of Neolithic man". Reference is made to "the aspect of the woodland that is represented by the basal layers of buried trees", namely that as a result of competition for light "the majority of the trees have straight unbranched boles". Such remains are said to be not uncommonly as much as 90' (27.4m) in length without branching, a rooted yew in Isleham Fen was reported as having a girth of 14' 6" (4.4m) and great quantities of timber "300 tons of Black Oak" were said to have been removed from a single small farm. Basal trees are recorded as being "firmly rooted in the solid clays of the fen floor mostly Gault, Kimmeridge or Oxford Clay or in Boulder Clay". Differences between remains in the peat and the basal trunks are noted both in stature, smaller in the peat, and the root systems, horizontal in the trees from the peat and vertically penetrating for the basal trunks. The species composition of the basal forest is discussed though, in contrast to the yew and pine remains said to be abundant on sandy substrata adjacent to Breckland, it is unclear whether references to wych elm and large and small-leaved lime are based on megafossils.

Additional evidence for the prevalence of tree remains in southern Fenland in the first half of the 20th century is provided by Bloom (1944). In an effort to improve the drainage of adjacent land owned by Bloom and increase the wartime production of food, Adventurers' Fen south of Wicken, was requisitioned and reclaimed in 1941. Amongst the difficulties encountered (the work was filmed, the video 'Reclaimation' can viewed via the East Anglian Film Archive at the University of East Anglian, Cat. No. 77) were the "bog-oaks" found just below the surface of the peat, some of which were said to be over a 100' (30m) long. Excavation involved saws and explosives, with the remains eventually dragged out by tractor. By the end of the process "we had a heap over 200 yards (180m) long, five yards (4.5m) wide and eight feet (2.4m) high in places, all from eighteen acres (7.3 ha) of land" (Bloom 1944). A more recent, though undated, film of the removal of a substantial megafossil from arable land near Woodwalton Fen is also available via the Great Fen website (www.greatfen.org.uk/about-great-fen/heritage/bog-oak).

The dimensions of the Fenland megafossils also influenced the ideas of Rackham (1980) and Peterken (1981) on the structure of natural woodland. Both authors refer to remains found beneath peat with Peterken (1981) reporting on the dendrochronological examination of a Fenland oak trunk 1m in diameter and 6.5m in length. Said to be 5000 years old, the tree grew for at least 340 years and exhibited growth rates "very similar to that of modern oaks grown in densely stocked high forest in France" (Peterken 1981).

Most of the trunks likely to be associated with the pre-Holocene surface in Fenland that have been dated (Table 1) range in age from *c*. 5500 to 4300 cal. yrs BP (all the dates quoted here have been calibrated in Clam, Blaauw 2010). This reflects the altitudinal range of the former land surfaces that have been exposed/disturbed

Figure 2. Fenland 'bog oaks' dredged from a dyke in an area of surface peat near Holme Fen (TL215881) in 1990 *(Photos: Rog Palmer)*.

Site/Lab No/ altitude	Radiocarbon age(^{14}C BP)	Calibrated age (2σ range)/ Absolute Age BP/(*BC*)	Publication	Stratigraphic details from original publications
Flaggrass March, Q-532	4055 ± 110	4285-4840 (*2335-2890*)	Godwin and Willis 1961	Wood peat from base of a peat bed resting upon the gravels of Island of March
Adventurer's Fen Wicken, Q-129	4380 ± 140	4580-5445 (*2630-3495*)	Godwin and Willis 1961	Roots of an oak tree growing in Gault Clay beneath the black fen peat
Methwold Severals Fen		*c*. 4570 BP (*c.2620 BC*)	Norfolk Geodiversity Partnership 2013	13.4m oak trunk, dated by dendrochronology
Queen Adelaide Bridge, Ely Q-589	4495± 120	4850-5330 (*2900-3380*)	Godwin and Willis 1961.	Outer rings of an oak tree 7' (2.1m) in girth and with a 70' (21.3m) trunk, almost certainly from the basal forest bed, found in fen clay during river-drainage. Illustrated in Godwin and Deacon (1974) and Godwin (1978)
Adventurer's Fen Wicken, Q-130	4605 ± 110	4980-5580 (*3030-3630*)	Godwin and Willis 1961	Outer rings of prostrate oak from basal forest layer beneath fen peat, exposed alongside Q-129
Holme Fen, Q-1296 (c.-5.00m OD)	6600 ± 120	7280-7670 (*5330-5720*)	Switsur and West 1975	Oak wood from outer rings of tree lying horizontally, 12m long and 0.6m diameter, on bed of unoxidized aquatic peat overlying a floor of reworked boulder clay

Table 1. Dates from Fenland of tree remains likely to be derived from, or close to, the base of Holocene sediments. Radiocarbon calibrations performed in Clam (Blaauw 2010) using the statistical software R (R Development Core Team 2013).

(to a depth of *c*.-3.40m OD, Waller 1994) in southern Fenland over the last *c*. 90 years. Deep excavations have rarely been undertaken in Fenland, with the outlier (Q-1296), derived from such a setting (Godwin and Vishnu-Mittre 1975). While older deeper land surfaces remain buried, younger high surfaces have also have been exposed. However, here the presence/availability of megafossils for dating is likely to have been influenced both by decay (any remains being exposed earlier and for longer) and by woodland clearance, which the pollen evidence suggests occurred extensively (though not exclusively) in southern Fenland from *c*. 3700 cal. yrs BP (Waller 1994).

By the 1980s, decomposition, as a result of the prolonged lowering of the ground water table, had rendered organic material found at or close to the modern surface in southern Fenland largely structureless (Waller 1994). Nevertheless, large tree remains were still regularly exposed as a result of 'dyke cutting'. During such ditch deepening and cleaning operations the trunks encountered were extracted (thereby making the in situ position of individual remains difficult to determine) and the generally badly decayed wood piled up along dyke sides and in fields (Figure 2). A similar situation prevails today, with only large well-preserved, and therefore valuable (for carpentry) remains, attracting attention (e.g. BBC News 26th September 2012, Norfolk).

Palaeoecological studies of basal megafossil remains from coastal exposures

Many palaeoecological studies have been undertaken from organic deposits on the foreshores of England and Wales (see for example Tooley 1978, Fulford *et al*. 1997). However, following early workers such as Reid (1913) and Godwin and Godwin (1934), most have applied pollen and plant macrofossil analysis, rather than focussing on the tree remains. Exceptions to this have not necessarily included work on basal deposits and, with those that have, a large amount of information is only available in PhD theses (Heyworth 1985, Clapham 1999, Timpany 2005).

Heyworth (1985) pioneered the use of dendrochronology on submerged forests, and was able establish overlapping sequences of well preserved oak trunks at Stolford, Somerset. The mid-Holocene remains examined here appear to have included trees rooted in limestone (Lias) and an overlying peat. Rather than indicating the sudden demise of large number of trees, this analysis demonstrated death occurred over a prolonged period, which was attributed to a gradually rising water table.

The work of Clapham (1999) included investigations of basal deposits (overlying Boulder Clay) found at two locations on the east Lincolnshire coast. At Anderby Creek 51 stumps over 2090 m2 area were mapped and at nearby Wolla Bank, 20 stumps over 604 m2. Maximum dimensions of associated prostrate trunks were 5m long and 0.6m in diameter. Oak remains dominated, though Fraxinus, Betula, Alnus and Salix remains were also recorded. Associated radiocarbon dates range from *c*. 5600-5100 cal. yrs BP. Significantly, Clapham (1999) used the information obtained on the spatial distribution of the stumps to provide insights into woodland structure and disturbance regimes. Measurements of tree density and girth were compared against those recorded from old-growth forests in the United States and Europe. Clapham (1999) used this evidence along with the lack of a large number of small stems, to argue that the closed canopy stands were likely to be either in a state of advanced regeneration or at the old-growth stage. However, as he acknowledges the density measurements assume that the stumps and trunks present are contemporary, which could not be demonstrated by dendrochronology at these sites due to poor preservation.

The work of Timpany (2005) alongside that of Bell *et al*. (2001, 2002, 2003) combines the spatial analysis and measurement of megafossils with the use of dendrochronology. Timpany (2005) mapped basal remains (overlying Pleistocene sands) at two sites, Goldcliff East and Redwick, on the Caldicot Levels in the Severn Estuary. Tree-ring analysis of Quercus remains revealed woodlands, dating from *c*. 8150 to *c*. 7700 cal. yrs BP, that existed for at least 330 years at Goldcliff East and 430 years at Redwick (Nayling in Bell *et al*. 2001, 2003). This analysis also indicated that the trees did not all die as a result of a sudden event, but that senescence occurred over a period of 100 years or more. At Goldcliff East 21 trunks and 8 stumps were recorded from a pre-Holocene land surface and a thin lower peat. Between 1-12m long, most of these trees had diameters between 0.2-0.4m. Bands of narrow ring growth were often recorded from the trees with the smaller girths, which along with the morphology of the remains, was taken to indicate that these trees were struggling to grow under a canopy. At Redwick more than 100 Quercus megafossils, 56 trunks and 48 stumps, were recorded from a pre-Holocene surface. Two trunks had lengths over 11m, with the maximum diameters mostly between 0.1-0.6m, though the largest, a stump, was 2.24m in diameter with a potential age of 450 years. That few of the trunks (only 13) showed evidence of branching was taken to indicate this largely occurred high in the canopy. Timpany (2005) concluded that the Caldicot Levels remains indicate the presence of a closed canopy Quercus woodland, with an understorey of Corylus avellana.

Discussion

Both the general morphology of the remains and the more detailed palaeoecological investigations undertaken on megafossils from coastal exposures, provide then compelling evidence for the presence of some closed canopy woodland in lowland England and Wales during the period *c*. 8000-4000 cal. yrs BP. So are these remains likely to be representative of vegetation across the wider region, in terms of species composition and structure?

In terms of species composition, in both southern Fenland and the other exposures that have been investigated in detail, there is a preponderance of oak, despite these megafossils being recorded across a wide range of solid lithologies and therefore soil types. This certainly contrasts with the mixed woodland with abundant lime (which is palatable to many browsing herbivores, Pigott 2012), suggested by the pollen evidence, both from adjacent deposits (e.g. Godwin and Vishnu-Mittre 1975, Waller 1994) and for much of lowland England (e.g. Birks *et al*. 1975, Moore 1977, Greig 1982, Bennett 1989). Indeed Rackham (1980) comments that lime (megafossils) "ought to have been consistently commoner than oak". Explanations have included the selective removal of lime and elm during the Neolithic (Godwin 1978), with the earliest pollen evidence of human woodland inference in Fenland dating to c. 6200 cal. yrs BP (Peglar in Evans and Hodder 2006), and preservation bias (with oak more resistant to decay). However, in contrast to assumptions that coastal megafossils were killed by a sudden rise in the water table (e.g. Rackham 1980), the dendrochonological work of Heyworth (1985) and Nayling in Bell *et al*. (2001, 2003) demonstrate that senescence was prolonged. Radiocarbon dates from the base of basal peats in Fenland (and therefore not prone to sediment compaction) indicate ground water-levels rose gradually, at a rate of *c*. 2mm yr-1, over the period 5350 and 4400 cal. yrs BP (data in Waller 1994). Species tolerant of high water-levels, notably oak, would then, relatively, have survived longer (particularly where basal peat formed) and their remains are therefore much more likely to be preserved than that of lime or elm. Significantly, pollen records from basal Fenland sequences from the mid-Holocene consistently have lime dominated assemblages in the sub-soil beneath peat (Waller 1994). Differences in the timing of death within species are likely in part to reflect local variations in topography. That in the mid-Holocene a Fenland megafossil 0.6m in diameter falling onto the pre-Holocene surface at the onset of peat formation would not be completed buried for *c*. 300 years explains comments made by Skertchley (1877) regarding bark being preserved on the underside of trunks and indicates preservation bias is also an important factor. Well preserved remains, such as the oak recovered near the Queen Adelaide Bridge Ely (see Table 1) are likely to have fallen into pre-existing deposits, as is suggested for this particular megafossil from the context given in Godwin and Willis (1961). Consequently, it can be argued that in terms of species composition these basal megafossils are not representative of the mixed deciduous dry woodland of the mid-Holocene but rather a transitional stage towards the development of wet woodland.

In terms of structure, it is possible that some of the disturbance factors that have the potential to influence woodland structure (e.g. wind, fire, human activity and the browsing of large herbivores) had a differential impact in areas in close proximity to the coast. Increased wind damage, as a result of the greater frequency of major storms and the influence of moist soils (see Allen 1992), could be expected to influence age structure, resulting in patchwork of even-age stands (Peterken 1996).

Allen (1992) examined prostrate trees, predominantly of oak and alder rooted in peat from Severn estuary to elucidate past wind régimes. The presence of root-balls (indicating windthrow) and the apparent age of the remains (judged to be mainly "youthful to early mature" on the basis of size), were taken to indicate storm-damage, with the fall patterns reflecting the prevailing wind direction. Similarly, Timpany (2005) found evidence for wind disturbance in the intercalated peat deposits, though indicates, for the basal oaks on the lower foreshore, that wind may have acted as a proximate factor, toppling trees that were dead or dying. The megafossils at Wolla Bank and Anderby Creek did not fall in a consistent direction and as Clapham (1999) comments wind disturbance did not prevent the woodland at these locations from reaching a "later developmental stage".

Fire may also have played a role in woodland dynamics in coastal/estuarine settlings. Extensive charcoal spreads and charred oak trees have been recorded from the Late Mesolithic at Goldcliff East (*c*. 7400 cal. yrs BP) and Westward Ho in Devon (Bell *et al*. 2000; 2002), while on Thorne and Hatfield Moors on the Humberhead Levels extensive burnt tree remains (mainly of Pinus sylvestris and Betula) of mid and late Holocene age have been recorded from basal deposits (Whitehouse 2000). The latter were attributed by Whitehouse (2000) to natural fires. Studies of fire history from microscope charcoal from coastal areas such as the Romney Marsh region also indicate disturbance in the early Holocene (Grant and Waller 2010). Here a decline in fire occurrence occurs during the mid-Holocene which, compared to the Humberhead Levels, may reflect differences in peatland species composition (with Pinus absent). However, it seems unlikely that away from peatland areas, natural fires would be more prevalent in areas close to the coast compared to inland, though the megafossils remains themselves could provide further insights into fire frequency through the use of fire scars (e.g. Lageard *et al*. 2000). There is certainly no reason to believe that prehistoric human activity in proximity to coastal/estuarine areas might differentially favour the development of closed-canopy woodland. Here impacts on woodland might be expected to be earlier and greater with the wider range of resources available an attraction. There is certainly archaeological evidence for human activity in the Fenland basin spanning the period covered by the presence of the megafossils (see Hall and Coles 1994), as well as pollen records suggesting phases of woodland disturbance (e.g. Godwin and Visnu-Mittre 1975; Waller 1994; Peglar in Evans and Hodder 2006).

Archaeological excavations have shown large quantities of wood were used for construction. While in some cases wetland areas may have been exploited e.g. alder and other wetland species were used for the earliest timbers in the Bronze Age platform at Flag Fen (Pryor 2001), elsewhere timbers with similar characteristics to the larger megafossils were exploited, e.g. oak planks 1.3m wide and at least 4m long were used in the construction of a Neolithic long barrow found near Haddenham (Evans and Hodder 2006). Importantly, evidence for the presence of wild herbivores (including red deer and aurochsen) in the form of footprints, faecal and skeletal remains have been recorded from basal and subsequent coastal peat layers (e.g. Bell *et al*. 2001; Godwin 1978, Gee 1993). Even for fen woodland it seems unlikely then that the relatively wet conditions posed particular limitations on the activities of large herbivores, and their ability or otherwise to influence vegetation development.

While megafossils are increasingly being used in palaeohydrological and palaeoclimatic studies (e.g. Edvardsson *et al*. 2016), as a palaeoecological resource in England and Wales they appear to be underutilized. Further studies of the megafossil archives discussed here would improve our understanding of the early and mid-Holocene lowland vegetation of England and Wales. Information on the species present (based on an examination of wood structure) and basic residual dimensions (length, girth) could usefully be collected from all repositories of megafossil remains. Large coastal exposures afford the opportunity to investigate spatial patterns; mapping the distribution of stools to determine tree density, with contemporeneity established through dendrochronology. The latter technique can also provide information on age structure, growth patterns, longevity and patterns of senescence and so disturbance régimes. The work of Clapham (1999) and Timpany (2005) demonstrate the potential, nevertheless there are significant difficulties to be overcome by those wishing to undertake systematic investigations. With coastal megafossils these include practical problems associated with sampling inter-tidal environments such as short exposure time, wood degradation, along with insecure contexts and eroded surfaces (contemporeneity cannot be assumed). Many of these issues could be avoided by the use of remains exposed by the excavation of buried land surfaces now inland. Currently, however, at least in the Fenland basin, the removal of many trunks from their growth position on discovery and the limited extent and unpredictable occurrence of ditch exposures are deterrents to systematic investigation.

Conclusion

That the vegetation of lowland England prior to widespread human inference consisted largely of areas of closed canopy woodland went largely unchallenged through the 20th century. While the reputation of early proponents, particularly Godwin, must have played a part in this, it should not be forgotten that this proposition was based in part on evidence "more eloquent than the pollen statistics" (Rackham 1980). Old photographs and videos of unbranching trunks and substantial stumps, alongside occasional new inland finds and coastal exposures of megafossils rooted in pre-Holocene sediment, are a testament to the former presence of areas of closed-canopy woodland in lowland England and Wales.

If the vegetation of the Holocene is to be used as a baseline for future landscapes in rewilding schemes (e.g. Lorimer *et al*. 2015) then the palaeoecological evidence discussed here cannot be ignored. Appropriate rewilding options for lowland England and Wales would include the creation of mixed species closed-canopy woodlands and, in former peatlands, areas where the accumulation of plant biomass is not retarded by heavy grazing (see Waller and Kirby 2021). Such projects would not just recreate conditions from one period in our past but also provide additional ecosystem services, notably enhanced carbon storage.

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RENEWED THOUGHTS ON THE TRENT 'TRENCH' AND THE LINCOLN 'GAP'

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Introduction

In his recent article (2021), Rob Westaway expressed support for Shotton's vision (1953, 1983) of glacial (Wolstonian) MIS 8 and fluvial events in the Midlands and concluded that north-eastward 'proto Soar' drainage persisted to Nottingham thence to Lincoln and the Wash, until the Wragby/Ridgeacre/MIS 8 glaciation (White, *et al*. 2017). His argument relating to the Midlands is based on firm sedimentological and geomorphological evidence, but any extension from Nottingham to the Wash must be speculative because it relies on both a 'trench' and 'gap' being present in pre-MIS 8 times for which the MIS 8 glaciation has left little, if any, sedimentary evidence. It is argued below that these features are not bound to have existed before the Wragby/MIS 8 glaciation, and that a model put forward by the writer almost 60 years ago (Straw, 1963, 1979a) negates an early Trent proceeding north-east from Nottingham to Lincoln. It attempted to show that before the Wolstonian glaciation (MIS 8) Midland drainage, confluent around Long Eaton, proceeded eastward to the Ancaster gap and Wash receiving mainly left-hand tributaries, that part of its valley was destroyed during the Wragby Glaciation, and that it was deglacial meltwaters, later the Trent, that eroded the 'trench' and then set a course to Lincoln. This paper reassesses this model in the light of more recent research.

The Trent 'trench'

This unique landform is a major feature of the Trent drainage system. More of a 'tray' than a trench or a gorge, it is a straight, wide (2-3km), steep-sided, gravel-floored valley extending for almost 40 km between Long Eaton and Newark across the Triassic Mercia Mudstone dipslope (Figure 1). It is generally accepted as having been initiated by meltwaters, either on a newly-exposed, sub-glacial surface (Bridgland *et al*. 2014, 2015; Howard *et al*. 2009) or as a deglacial marginal channel (Posnansky, 1960; Straw, 1963) but during which glaciation, Anglian (MIS 12) or Wragby (MIS 8), is still a matter of controversy.

Straw (1963, 1979a, 2002) associates it with deglaciation during the Wragby Glaciation and, like Posnansky (1960) and Lamplugh and Gibson (1910), regards it as a channel formed along the north-west side of a mass of stagnant, down-wasting ice residual in the Vale of Belvoir. Its erosion could have been rapid because, for the first time, the rivers Dove, Derwent, Erewash, Trent and proto-Soar combined to flow north, and the 'trench' became the conduit for a large Midland catchment (Figure 1). The highest surviving sediments to link through the 'trench' are those of the Etwall – Eagle Moor Terrace, with a surface declining from *c*.60 m OD near Derby to *c*. 30 – 35 m OD near Lincoln and regarded as late MIS 8 (White *et al*. 2007b, 2010; Bridgland *et al*. 2014; Westaway, *et al*. 2015). Lower terraces are younger, and the Trent has continued to occupy the 'trench' to the present day.

By contrast, Bridgland *et al*. (2007, 2014, 2015, 2019) interpret the deposits on Wilford Hill (SK 582352) at c.91m OD as Anglian outwash or high terrace and, noting similar heights of the south-east side of the 'trench', imply the former existence of a late-Anglian deglacial surface on which a new drainage system arose. This follows Howard *et al*. (2009) who envisaged the 'trench' as initiated by englacial streams superimposed onto a sub-glacial, bedrock surface, at *c*. 80-90 m OD, when Anglian ice dissipated. However, the Wilford outlier has an ambiguous status. It need not relate directly to the 'trench' at all, for it lies on the east side of the break in the flank of the 'trench' east of Clifton that was most likely the pre-'trench' course of the river Leen (see below), close to its postulated confluence with the proto-Trent (Figure 1).

South-east of the 'trench', the severed portion of the Mercia Mudstone dipslope forms an asymmetrical ridge; the steeper north-west slopes overlook the river (Bridgland and White, 2007) and the gentler south-east ones fall toward the river Smite valley which drains the south-west part of the Vale of Belvoir (Figure1). The crest of the ridge is undulating and reaches heights of 78 m OD between East Bridgford (SK 691431) and Kneaton (SK 710460) and 80 m OD near Radcliffe-on-Trent (SK 645392). North-east of Kneaton, a wide col exists in line with the Dover Beck valley west of the 'trench'. South-west of Nottingham, the flanks of the 'trench' are discontinuous but, on the north-west side lengths of steep slopes remain in the city beneath the castle and through Beeston, and on the south-east side at Gotham (SK 537301) (98 m OD) and Clifton (SK 552341) (86 m OD).

Around Long Eaton the rivers Soar, Derwent and Erewash are confluent with the Trent and are gathered at the south-west end of the 'trench'. However, a wide break in the south-east flank at Barton-in-Fabis (SK 522328) in line with the Erewash, leads to a long tract of low country through Ruddington (SK 572332), Tollerton and Cotgrave (Figure1). Another break, north of Ruddington, is in line with the river Leen flowing south through the city and contains Wilford Hill. These alignments and the tract of low ground suggested to the writer (Straw, 1963) that, prior to formation of the 'trench', the Erewash, Leen, and Dover Beck to the north-east had formerly joined a river, the proto-Trent, that occupied the low tract and headed east toward the Ancaster gap. Although subsequently modified by ice, meltwaters and gypsum dissolution this depression remains a real feature in the landscape (Figure 1), even though Howard *et al*. (2009) dismissed it as highly speculative because of the extent of post-glacial erosion. On its north side ground rises to 80 – 86 m OD at Clifton and Radcliffe-on-Trent, and 91 m OD

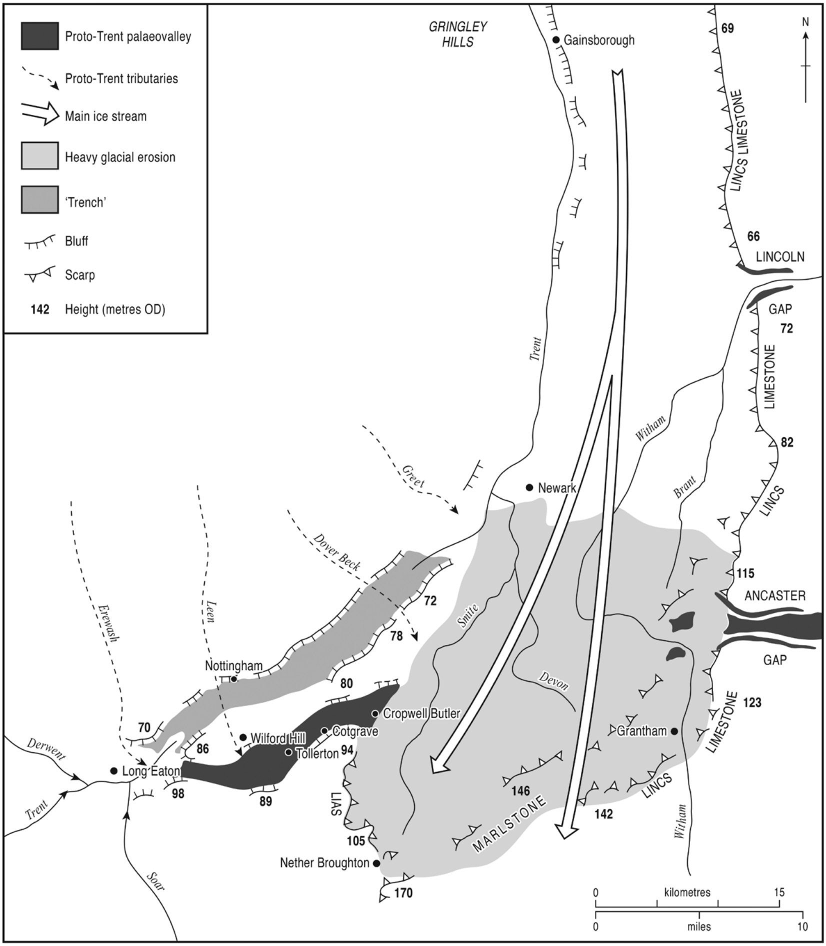

Figure 1. Three successive stages in landscape development around and east of Nottingham. 1. Proto-Trent palaeovalley. 2. Glacially-extended Vale of Belvoir. 3. Meltwater-initiated 'trench'.

at Wilford Hill. On the south side the land rises to more than 90 m OD south of Bunny (SK 583297), to 85 m OD in Keyworth (SK 614308) and to 78-94 m OD south of Cotgrave in the form of the basal Lias scarp. The 'floor' of the depression is 2 km wide at the west end, 3 km between Cotgrave and Radcliffe, and 3 km again at Cropwell Butler at the east end. Around Barton-in-Fabis (SK523328), Ruddington, and between Tollerton and Cotgrave the 'floor' has been lowered, in part by the dissolution of underlying gypsum deposits (Howard *et al*, 2009), but wide extents of ground at *c*.50-55 m OD survive between Ruddington and Cotgrave retaining a cover of glacial till (Howard *et al*. 2009), and north and south of Cropwell Butler. This long depression can be referred to as the Cropwell Butler gap and, given that its sides rise to heights equivalent to those of the 'trench', there is no reason why this proto-Trent palaeovalley should not have arisen on the late-Anglian surface, in exactly the way proposed by some for the 'trench', waters being attracted eastward by the Ancaster gap which had survived the Anglian glaciation.

Bridgland *et al*. (2007, 2014, 2015) and White *et al*. (2007a, b) misinterpreted this model. They refer to the Cropwell Butler col, a small feature occupied by the old Grantham canal, at Berry Hill north-west of Cropwell Bishop (SK 686355). They dismiss the col as too high to take the Trent to the Vale of Belvoir after the MIS 8 glaciation and reject the view that the Trent then flowed down the Smite valley. But this view was never expressed by Straw (1963, 1979a, 2002) who has always maintained that the 'trench' was the Trent's post -MIS 8 course.

The notion of a proto-Trent river flowing to Ancaster remains plausible (Straw, 1963,1979a). The former floor of the Cropwell Butler gap at 50 – 55 m OD compares with the 45 m OD rock floor of the Ancaster gap some 27 km distant (gradient *c*.0.4 m/km) and, if the proto-Trent did follow this course, it implies continued occupation and downcutting of this gap since at least Anglian times. The breaching of this course was manifestly a MIS 8 event, when Ice advanced south over the Mercia Mudstone, Penarth and Scunthorpe Mudstone outcrops of the Vale of Belvoir and its eastern part surmounted the Marlstone scarp south-west of Grantham (Straw, 1979a, 2021) (Figure1). Its western part was deflected south-south-west and flowed strongly on toward Loughborough, directly across the proto-Trent palaeovalley (Straw, 1963,1979a, 2021). The valley of the river Smite and its tributaries has visibly replaced the proto-Trent valley east of Cropwell Butler and today forms the south-west part of the Vale of Belvoir (Figure 1). Particularly noticeable in this area is the marked north-east/south-west lineation of streams and low interfluves: note the Smite, Car Dyke, the Whipping and Rundle Beck between slight ridges occupied by roads and villages. This linearity is in large part a reflection of the strike of the underlying, alternating mudstones and limestones of the Scunthorpe Mudstone Formation but its topographic expression is the consequence of MIS 8 ice flowing along the same alignment, and much erosion and moulding by ice south of Newark should be accepted (Straw, 1979a, 2011).

Only a few kilometres to the east ice was tearing large lumps of Marlstone and Lincolnshire Limestone from the escarpment, and to the south vast quantities of till were piled up to form the Nottingham Wolds. Although Howard *et al* (2009) accepted that ice had flowed along the Vale, the scale of glacial erosion has been underestimated in the past (but see Rice, 1968). The 25-30 m difference in height at Cropwell Butler between the 'floor' of the proto-Trent depression and the general level of the Smite valley which cuts across it, is probably a minimal measure of such erosion. Northward, the ground would have been higher, probably drained by a south-flowing tributary to the proto-Trent. Today, the Smite/Devon valley declines north so that in the area south-east and south of Newark, for example, some 40-50 m of bedrock could have been removed, and it is suggested that this northward descent is largely the consequence of scour by MIS 8 ice, and not the combined effort of low-gradient streams. South of Cropwell Bishop to Nether Broughton the scarp of the Lias Barnstone Member has been pared back into re-entrants and promontories. It is claimed here therefore that the Smite valley, south of Newark, is essentially a glacial feature, and was eroded lower than the 'floor' of the Cropwell Butler gap. During deglaciation, this surviving stretch of the palaeovalley and the new Smite valley were both occupied by stagnant ice and, as melting proceeded, englacial streams became superimposed over the low valley-ridge relief, resulting in the discordant elements visible in the Smite/Devon system today.

To summarise at this point, the case has been made for Midland drainage to have been directed east from Long Eaton through a still partly distinguishable palaeovalley to the Ancaster gap (Straw, 1963, 1979a, 2002) until the MIS 8 glaciation. Westaway (2021) prefers to direct it through the 'trench' toward the Lincoln gap. This requires the 'trench' to be a pre-MIS 8 feature. Howard *et al*. (2009) suggest it was probably initiated on an Anglian deglacial surface, endorsed by White *et al* (2010) and Bridgland *et al*. (2014). This carries three implications: that fluvial incision proceeded through MIS 11, 10 and 9; that the 'trench' was glacierized during MIS 8, and that late in that glaciation the Trent was forced to reoccupy the 'trench' presumably guided by waning Vale ice.

The Anglian deglacial surface, on soft-rock areas, was considerably higher than present (probably at least 50 m) and any fluvially-eroded 'trench' incised into it a relatively shallow feature compared with today. Bridgland *et al*. (2014) and White *et al*. (2007a, 2010) proposed that during MIS 8 ice flowed up the 'trench' rather than along the Vale of Belvoir, there-after to expand widely in the Derby area. This is glaciologically unlikely, because the wide Vale floor adjacent to its north end would have been of similar height to the 'trench' floor and was more in line with the Vale of York, source of the ice (Figure 1). The passage of ice over the Lias, Penarth and Trias outcrops, its destruction of part of the former proto-Trench valley, and its deposition of thick deposits to the south have been stressed above. It is also pertinent if ice did pass up it to seek evidence for glaciation of the ‘trench’ acknowledging that later use would probably remove glacial sediments as it did the higher terraces (Bridgland *et al*. 2014, 2015) and that the side slopes would be ‘freshened up’ as migratory meanders or braid-plain streams impinged on them. The crest of the detached south-east portion of the dipslope shows no sign of moulding and a col remains on the ridge north-east of Kneaton probably related to Dover Beck. The Mercia Mudstone dipslope north-west of the ‘trench’ is dissected by valleys (dumbles) energized by its downcutting, and no till survives. The spur-ends forming bluffs to the ‘trench’ show no evidence of smoothing even though ice could not have kept to its confines. It may also be relevant that tributaries to the ‘trench’ on the north-west side (there are none on the south-east) as at Lowdham, Gonalston, Thurgarton and Rolleston all follow easterly courses. Had the ‘trench’ been subject to ice flow over hundreds or a few thousands of years then tributaries directed south or south-west might be expected. There is therefore, for whatever reason, no sign of glacial modification of the ‘trench’ by MIS 8 ice, and no evidence therefore that it was in existence when that ice arrived. A post-Anglian ‘trench’ is therefore a speculation and, in the absence of a ‘trench’ at the onset of this Wragby glaciation, the likelihood of strong flow of ice along the Vale of Belvoir is much increased. Before MIS 8 the Vale was probably drained by a south-flowing tributary to the proto-Trent valley, responding originally to the slope of a post- Anglian surface. The length of such a tributary would depend on the presence or otherwise of a catchment focussed on the Lincoln gap. Were there no gap and catchment here, then a divide with Humber drainage exists at Gringley Hills, Gainsborough (Figure1) but, if there was a Lincoln river, then a more southerly divide with the proto-Trent system has to be assumed as also its destruction by MIS 8 ice. The alternatives are such that if the ‘trench’ is post- Anglian and a course north to the Humber was denied by the Gringley Hills, then a Lincoln gap becomes imperative to take Midland drainage to the sea but, if the ‘trench’ is MIS 8 and the proto-Trent was routed before glaciation to Ancaster, then the Vale drained to it and no Lincoln gap was requisite.

The Lincoln gap

The Lincoln gap is an enigma. Why is it at Lincoln and not a few kilometres north or south? Why does it transect a straight, north/south, almost horizontal scarp crest (at 66 m OD) of the Lincolnshire Limestone? The Humber gap, some 30 km north, most noticeably cuts the Chalk, but also the Lincolnshire Limestone to the west. It is associated with known north-west/south-east faults and lies at the north end of a downwarped section of the Chalk and Middle Jurassic cuestas determined at the south end by the Grasby monocline (Swinnerton and Kent, 1976). This section has long carried eastern Pennine drainage to the North Sea and has permitted glacier ice to penetrate west on at least three occasions (Straw (1979b). The Lincoln gap, by contrast, seems to bear no relationship to structural features.

As recounted above, the Wragby MIS 8 ice was so efficient that no sedimentary evidence for drainage through a Lincoln gap before that glaciation survives, nor indeed evidence of any sort for the presence of a pre-Wragby gap. By contrast, MIS 8 ice flowed over the Humber gap and its meltwaters utilized the Ancaster gap, proving their pre-MIS 8 existence. So, when claims are made that a Lincoln gap was an integral part of a pre-MIS 8 drainage system, they could well be ill-founded.

However, if a Lincoln gap did not exist before MIS 8 but most certainly did afterwards, there must have been conditions existing during glaciation for one to be created. Harmer (1907) clearly foresaw that when ice closed the Humber gap and advanced down the Vale of York, the Pennine and Don river waters would be ponded up in front of the ice and along the Lincoln Cliff of the time. He suggested that both the Lincoln and Ancaster gaps were overflow channels. A precondition had to be that ground was generally low enough west of the Cliff and that higher ground existed to the south for ponding to take place, but the notion remains feasible. Three factors could have been involved – the surface level of the lake, the height of the scarp crest, and the position of the ice front. For overflow to take place, the lake level had to exceed the scarp height, and such a situation might have occurred at any position of the ice front as it was advancing south and covering up the gently rising scarp crest. By chance this was at Lincoln, which accounts for the 'hit and miss' location of the gap, where the height of the still uncovered scarp crest was crucially matched for the first time by the level of the lake water. Had water level equalled scarp height when the ice was further north, the gap would have been notched there. If the ice had got south of Lincoln then the water level would have had to rise higher before topping the scarp. Any channel cut by overflow erosion had to be sufficiently large to withstand submergence and possibly some erosion by the ice and yet be available for meltwater use at the Eagle Moor stage during deglaciation. Of course, this process might have happened at Lincoln during the Anglian glaciation but, if the above scenario is at all realistic and noting that it would presage the formation of Shotton's Lake Harrison and its overflows deeper in the Midlands later in the same glaciation, production of a glacial phase gap is patently feasible. Although one might have been eroded during deglaciation by drainage of a lake, as suggested by the Skellingthorpe Clay (Bridgland *et al*, 2014), and by meltwaters issuing from the 'trench' and forming the several terraces so focussed on Lincoln, it is more likely that a gap produced during the advance of the ice proved later to be attractive to surficial and perhaps englacial meltwaters, as did the Ancaster gap to the late Anglian proto-Trent. It is proposed therefore that conditions conducive to formation of a gap during the MIS 8 glaciation did exist and that the notion of an older Lincoln gap is dispensable.

Conclusion

This paper has presented again the situation where a proto-Trent flowed from Long

Eaton to Ancaster through MIS 11, 10, and 9 until the MIS 8 Wragby Glaciation and has sought, by describing extant geomorphological features in the landscape east of Nottingham, to reduce speculation regarding the course of the Trent at that time. It is claimed that some 17 km of a former proto-Trent valley can be identified east of Long Eaton, with tributaries, and that a longer, 26 km, stretch of this valley was completely obliterated by MIS 8 ice and replaced, at a lower level, by the valley of the river Smite which now forms the south-west part of the Vale of Belvoir (Figure 1). It has been argued also that the 'trench' was formed by meltwaters during MIS 8 deglaciation so that advance of ice up the 'trench' was not possible. But ice did flow strongly south, particularly along the Lias and Penarth outcrops, with sufficient strength to remove tens of metres of rock from the ground in front of the Marlstone scarp and from that crossed by the eastern section of the proto-Trent valley.

Because there is no tangible evidence for the proto-Trent flowing to Lincoln before the Wragby Glaciation, there is no requirement for a Lincoln gap at that time, nor earlier. Swinnerton (1937) proposed a sequence of events that involved a Late Pliocene 'Lincoln river' occupying a gap. Such a long history may apply to the Humber and Ancaster gaps, but not to the low Lincoln gap and the 'trench'. Their histories begin during MIS 8, and viable mechanisms for their initiation during the Wragby Glaciation have been put forward.

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NIEDERSCHÖNHAGEN, DETMOLD, GERMANY: A 170 M LONG EARLY QUATERNARY LAKE RECORD FROM A SUBROSION STRUCTURE

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Abstract

The first results from an ongoing interdisciplinary cooperation to investigate an almost 170 m thick Lower Pleistocene lake sediment succession is presented here. Core drilling in a subrosion depression recovered these sediments at Niederschönhagen in Germany. According to pollen analysis, the sediments range in age from Gelasian to Calabrian. Globally, numerous warm and cold phases occurred within this time frame. So far, the palynological investigations have identified two distinct warm phases, the younger of which is likely to be assigned to the Waalian interglacial. Various other microfossil groups were also found in samples analysed so far. The most informative of these are the ostracods, which allow detailed palaeo-ecological conclusions, such as water chemistry, water depth and structure of a waterbody. The lowest and the uppermost part of the drilling are normally magnetized, which, considering the palynological information, suggests a classification into the Gauss normal Chron and the Olduvai-subchron, giving a timeframe of ~2.7 – 1.9 Ma. The research is to be continued.

Introduction

Early Quaternary sediments and local paleoclimate records are sparse in Europe north of the Alps, although some are present (e.g. Scheidt *et al*., 2020). Here we present first results from a ~170 m core drilled in a subrosion structure in Germany, which preserves Lower Pleistocene sediments. This geoarchive may increase our understanding of the Earliest Quaternary in Continental Europe.

In the Weser Uplands, a low mountain range in northwest Germany, numerous subrosion structures evolved at different times since the Cenozoic. They owe their origin to the leaching of saline rocks (rock salt, gypsum and anhydrite) in the subsurface (Farrenschon, 1998). During their formation, the subrosion depressions act as sediment traps; they facilitate the preservation of sediments because the latter were comparatively well protected from erosion. To date, dozens of subrosion depressions, filled by Oligocene, Miocene, Pliocene, lower, middle or upper Pleistocene sediments have been discovered in the Weser Uplands (Farrenschon, 1986, 1998). The thickest proven thickness was found within a subrosion depression called "Vahlhauser Senkungsfeld" (Vahlhausen sinking area). Since leaching of rocks in the deeper subsurface was recognized as the cause, in this case mainly Permian rock salt and calcium sulphate, it was also referred to as the "Subrosionssenke von Mosebeck" (Mosebeck subrosion depression). It is located about 7 km northeast of downtown Detmold and has an area of about 2.5 by 1.8 km. In 1976, the drill hole "Mosebeck 1/76" was cored in this subrosion depression. This revealed a surprisingly thick sequence of sediments reaching stratigraphically from Waalian to the Cromerian complex (Deutloff & Stritzke, 1999; ca. 1.6 – 0.85 Ma). Mesozoic rocks were encountered 139.15 m below the surface. More than 40 years later, the drilling core of this important reference locality is no longer available. The sparse archive data and a too low-resolution sampling of pollen from a recent perspective did not allow a satisfying re-investigation. In 2019, the Geological Survey of the federal state of North Rhine-Westphalia (Geologischer Dienst Nordrhein-Westfalen – Landesbetrieb –; GD NRW) therefore organized a new core drilling called "Niederschönhagen" within the Mosebeck subrosion depression.

Lithology and sedimentology

The borehole opened up an old Pleistocene limnic sequence under a 2.8 m holocene backfill, which extends over the technically determined final depth at 170 m, approx. 4 m below sea level. The underlying Mesozoic bedrock was not reached. The sequence consists mainly of silt and clay in varying proportions (see Figure 2). In the upper half of the sequence, between 31.8 and 64.1 m, humus-rich depth intervals occur, some of which merge into silty peat with wood residues. They are indications of a tendency towards aggradation. There are layers of well-sorted clay and marlstone clasts ranging in size from sand to fine gravel over the entire column. Their provenance are rocks from the Middle and Upper Keuper (Triassic) and Lower Jurassic, which occur in the immediate vicinity of the subrosion depression. Many depth intervals are free of coarsely clastic components. This is particularly the case at those depths where a very

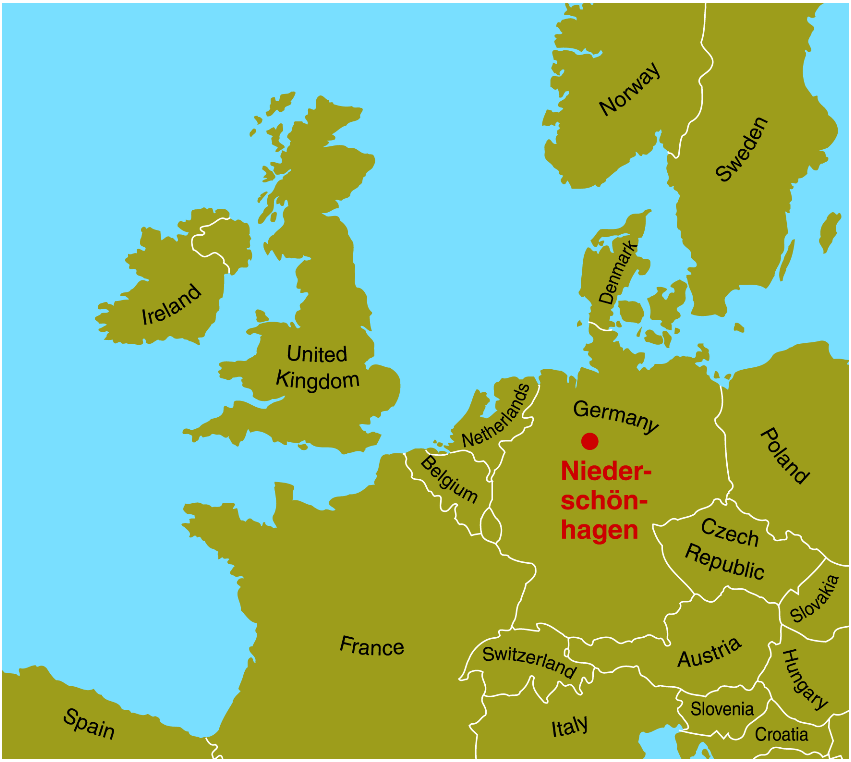

Figure 1. Overview map showing the position of drilling Niederschönhagen.

fine silt-clay banding indicates the lack of strong water movement (84.4 – 89.8 m and 115.2 – 148.8 m). These areas are certainly associated with deeper water depositional environments. Overall, the sequence of layers is very fine-grained and largely tectonically undisturbed.

First investigations and results

The GD NRW, the initiator of the drilling, is carrying out a number of different investigations on the core. Some investigations are partly still in progress, for example from the fields of heavy minerals, grain sizes and chemistry. A summary evaluation of these data will be provided later.

The palaeopalynological analysis is carried out under the leadership of GD NRW in cooperation with partners at the University of Göttingen and from the private sector. First palaeomagnetic investigations by the Leibniz Institute for Applied

Geophysics and its palaeo- and rock magnetic laboratory in Grubenhagen, have already been carried out. Micropalaeontological investigations of the various other (non-pollen) microfossil groups are in preparation under the leadership of a working group from the University of Jena.

We expect that the core will be an important reference profile for the Lower Pleistocene in Western Europe after the investigations are completed.

Rock- and paleomagnetic analyses

Rock- and palaeomagnetic analyses were carried out at the LIAG in the magnetic laboratory Grubenhagen. Natural remanent magnetization and alternating field demagnetisation was carried out using a 2G enterprises cryogenic magnetometer and a MAGNON AFD 300. The magnetic susceptibility was measured using a MAGNON VFSM; we analysed 334 samples.

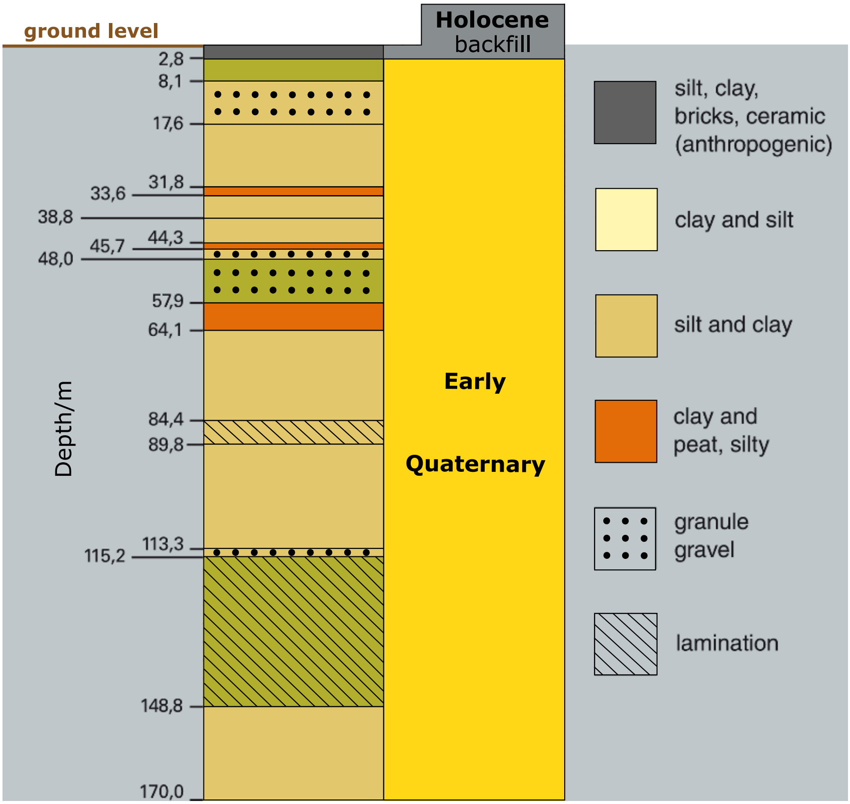

Figure 2. Schematic lithostratigraphy of the Niederschönhagen drill core.

Stepwise demagnetisation resulted in stable and in our opinion in reliable palaeomagnetic directions for 235 samples, samples without stable palaeomagnetic directions are not shown. For higher demagnetisation steps (above 60-80 mT), some samples showed increasing intensities indicative for the iron sulphide greigite (Snowball, 1997). While it is known that greigite forms after deposition, we see a general pattern in the palaeomagnetic directions: the lowermost and uppermost parts are magnetised in reverse direction of the recent magnetic field, and the part in between is mostly magnetized in direction of Earth's recent magnetic field (Figure 3). We regard this pattern to represent properties of Earth's magnetic field in the past, although recording may not be exactly synchronous with deposition (Tauxe *et al*., 2006). Some depth intervals are hard to interpret. Given the information from pollen analyses (see below), it seems most likely that the normal top part represents the Olduvai subchron, and the normal polarity at the base of the core represents the Gauss normal Chron (ending ~2.6 Ma ago; (Ogg, 2020)). This interpretation would give the core a time span of >600,000 years at the beginning of the Quaternary.

Temperature-dependent magnetic susceptibility measurements confirm a contribution of iron sulphides. Magnetic susceptibility properties need to be interpreted with great caution because of a sulphide content, which is indicative for the dissolution of at least some of the originally deposited magnetic minerals.

Palynological analyses

For the palynological analyses, samples were prepared according to a common method using hydrofluoric acid. In most cases, more than 500 pollen grains per sample were counted using a light microscope (Figure 4).

Palynological investigations show that even in the youngest sections of this drilling the Cromer I period is not recorded and thus Gelasian and Calabrian early Quaternary sediments are present at the surface, a difference to the old drilling. Since the Olduvai subchron ends at the Eburon-Tegelen boundary (Cohen & Gibbard, 2019) at 1.8 Ma (cp. http://www.stratigraphie.de/std/Bilder/5_2.pdf), it can be assumed that longer sections of the younger Tegelen/Gelasian are preserved. Pollen analytical results suggest that sediments of lower Tegelen age lie below the beginning of the drill core at Niederschönhagen; relevant amounts of Neogene species and *Fagus* are missing (compare Zagwijn, 1992).

The deposition time covered by the Niederschönhagen drilling is therefore likely to be somewhat more than 1.0 million years. Globally, numerous warm- and cold phases occur in this time frame. Up to now only two distinct warm phases are identified in the Niederschönhagen record, at depths around 90 m and 145 m; the most pronounced being at depth about 90 m. In this climatic optimum, *Larix*, *Quercus*, *Tilia*, *Carpinus*, *Corylus*, *Eucommia* and *Alnus* successively spread

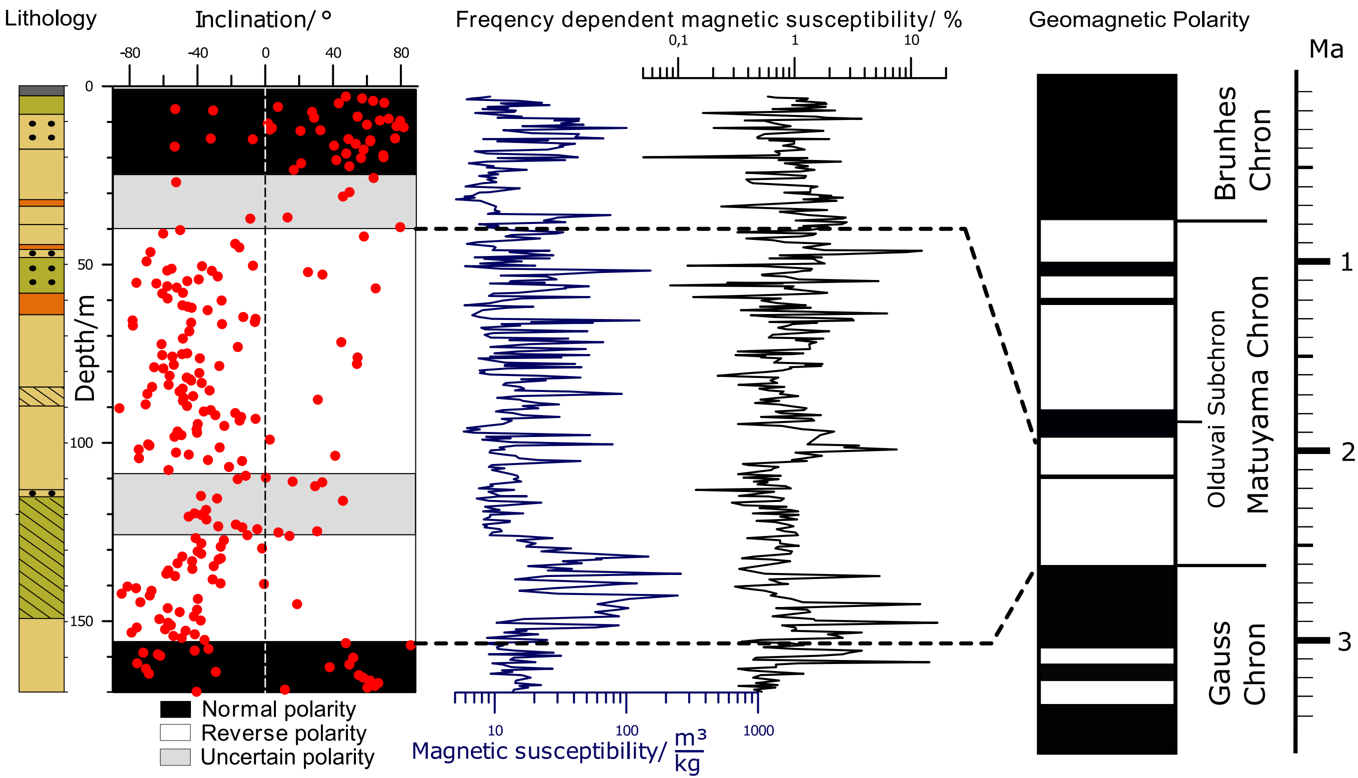

Figure 3. Magnetic polarity from individual samples is shown on the left together with our interpretation regarding normal/ reversed polarity. Several intervals cannot be assigned a polarity, and we are uncertain if more samples can clarify the polarity of these intervals. In the centre, magnetic susceptibility properties are shown, and the right panel shows our interpretation regarding age of the geoarchive.

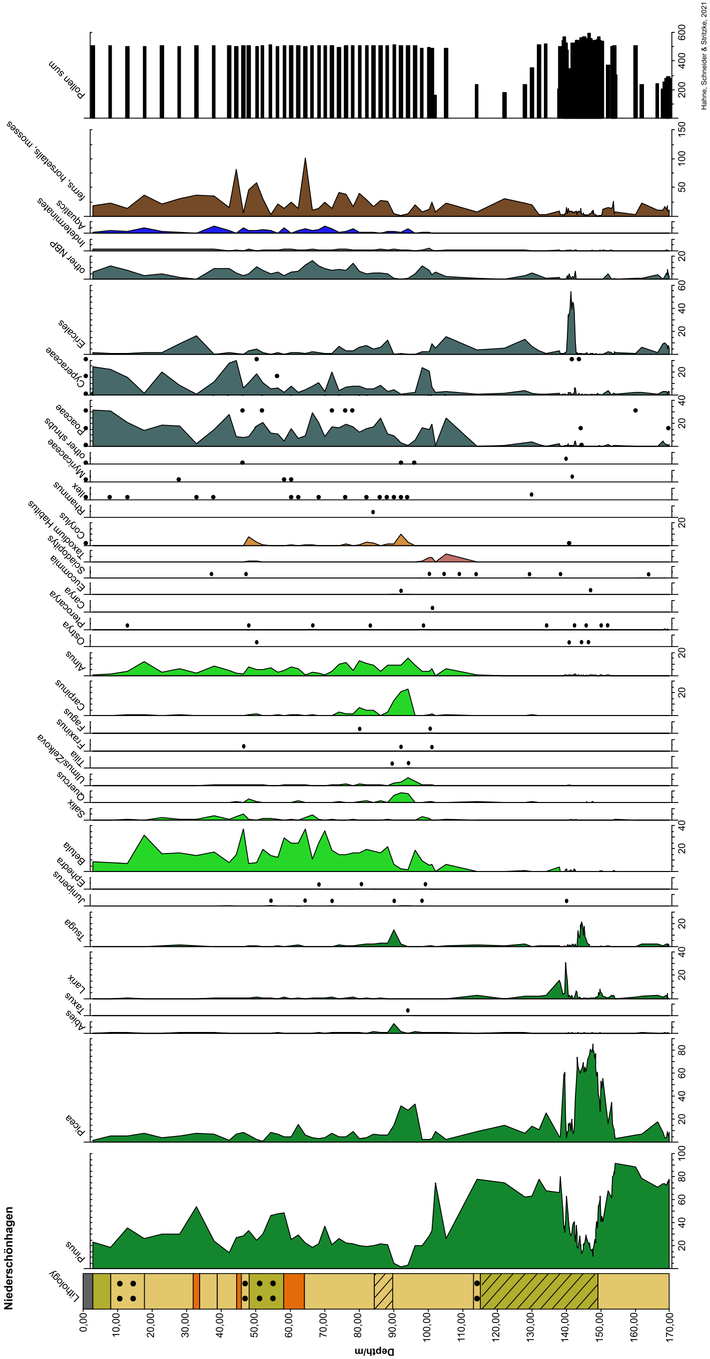

Figure 4. Pollen diagram from the Niederschönhagen drilling.

(Figure 4). According to the palynostratigraphical schema of (Zagwijn, 1992) this warm phase should be assigned to the Waalian interglacial. The evaluation of the pollen analytical data will be continued.

Micropalaeontological analyses

The microfaunal analyses were carried out on samples which were taken previously for the palynological and malacological investigations. After wet sieving, the micro- and macrofauna were picked and counted using a light microscope. For the pilot study about 20 test samples from the lower 100 m of the core were selected. Ostracoda are the main micropalaeontological group present in the studied samples. There is a low diversity gastropod fauna as well besides gyrogonites of Charophyta, fruits and seeds, bones and teeth of fishes and reworked pre-Quaternary microfossils, especially Foraminifera. At depths around 170, 150 and 130 m the dominance of the ostracod species *Cytherissa lacustris* indicates a lake in cold climatic conditions. The presence of freshwater gastropods, like *Valvata* species, gyrogonites and fish remains also points to permanent limnic conditions but rather shallow water (Glöer, 2002; Frenzel, 2019). The ostracod *Cytherissa lacustris* is a typical glacial species and widely distributed during the glacial phases, whereas it is rare in the interglacial warm periods (Löffler, 1997; Meisch, 2000). A second ostracod assemblage, dominated by *Candona* spp., indicates moderate to warmer conditions around 96 m core depth. This corresponds roughly to the upper warm phase. Reworked marine foraminifers, ostracods and gastropods suggest a stronger input of pre-Quaternary sediments. Further microfauna analyses are in progress. The next steps will be an increase of time resolution by further reduction of sampling distances especially for the warm phase and more detailed palaeoecological interpretation. A clear differentiation of glacial and interglacial phases based on microfossils is already recognisable.

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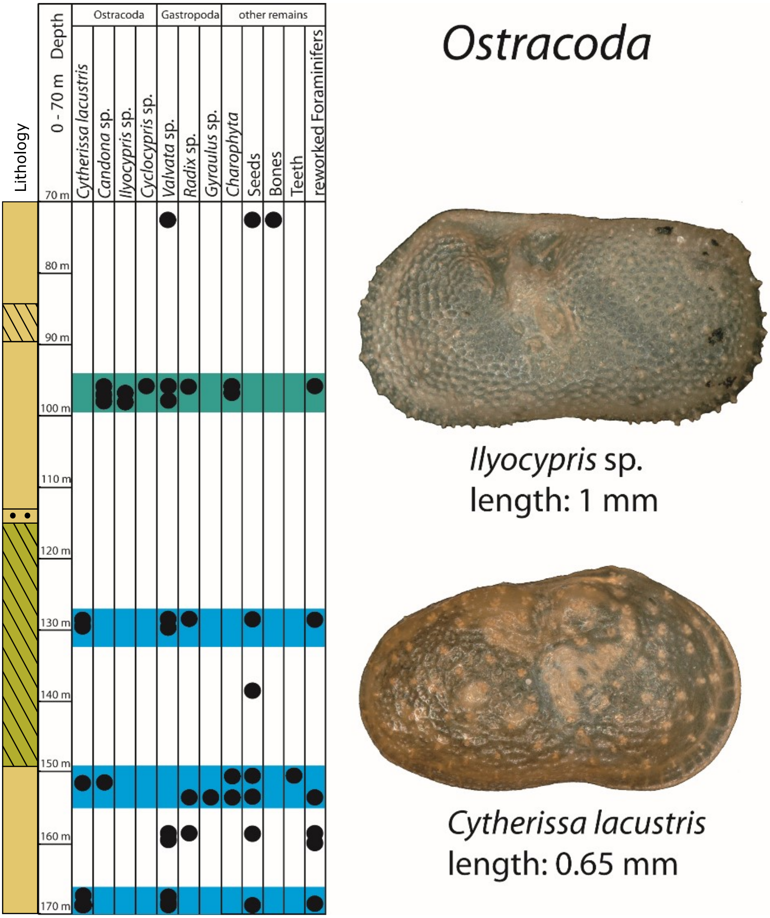

Figure 5. Distribution of ostracods and other microfossils as well as gastropods from the Niederschönhagen drilling. Blue bars: cold lake conditions; green bar: warm lake condition. *Ilyocypris* sp., left valve, sample 97.25 – 97.40 m; *Cytherissa lacustris*, right valve, sample 196.25 – 196.60 m.

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INSECT ARMAGEDDON: BRIDGING THE GAP BETWEEN MONITORING DATA AND PALAEOECOLOGY

Background and rationale

Recent studies report dramatic decreases in insect numbers (ca. 75%) as well as in the diversity of insect populations, a trend that has been dubbed "Insect Armageddon" in the media. Insect Armageddon is believed to be threatening ecosystem functioning and global food security (e.g. Cardinale et al., 2012; Hallmann et al., 2017). All observations of declines in insect diversity are based on ecological monitoring data which typically span no more than a few decades. Due to this relatively short time-window of data availability, it is unclear what the main driver of the ongoing decrease in insect diversity is, as it is not possible to disentangle effects of e.g. climate warming, anthropogenic land-use change, or long-term natural trends.

Palaeoecological datasets such as those derived from lake sediment records have the potential to provide information on ecosystem functioning on decadal to millennial timescales. Chironomids or non-biting midges are among the few insect families for which identifiable parts are preserved in lake sediment records where they are ubiquitously present. Chironomids provide an excellent opportunity to study shifts in the invertebrate fauna of any lake and to reconstruct changes in climate (e.g. Brooks, 2006), environmental conditions (e.g. Engels et al., 2012), human impact (e.g. Tóth et al., 2019) or in chironomid diversity (e.g. Engels et al., 2016). Engels et al. (2020) show that on millennial timescales there is a robust relationship between chironomid diversity and temperature. However, little observational data on recent changes in chironomid diversity is available (Engels et al., 2020) and it is unclear whether chironomids follow the general trend toward lower diversity as shown for other insect families (Hallmann et al., 2017).

The main aim of this research project is to bridge the gap between the decadal-scale monitoring data of insect population dynamics on the one hand, and the long-term records available through palaeoecological studies on the other. Field data from the 1990s provide unique observations of the chironomid fauna for a set of Norwegian lakes (Brooks and Birks, 2001). A detailed comparison between the samples taken in the mid-90s and modern-day samples would allow to assess whether ongoing climate change has already started to affect the chironomid fauna of these lakes, and can further be used to analyse the impact of spatially heterogenic changes in land use across the last 25 years. To achieve these goals, a 15-day fieldwork was carried out in southcentral Norway supported by the Quaternary Research Association and the Birkbeck Research Innovation Fund. A subset of the 157 lakes that were included in the Brooks & Birks (2001) dataset were revisited in August/September 2019 and multiple sediment samples were retrieved from each lake basin.

Figure 1. Field pictures: (a) picture of lake Stigedalsvatnet sampled in September 2019; (b) picture of the gravity core obtained from lake Stoylsvatnet

Results

We retrieved gravity core samples from 20 lakes in the area around Bergen (NO) that were originally sampled by Brooks & Birks (2001). The lakes are broadly located in two regions: first, we sampled eight lakes in the area near Røldal (Table 1). The landscape in this region is characterised by relatively steep slopes, barren rock surfaces, and (especially in the higher altitudinal regions such as those around lake Holebudalen) sparse vegetation dominated by birch and coniferous trees. An additional 12 lakes were sampled in the area around Førde, which compared to the Røldal region showed more agriculture (mostly pastures) and other human impact on the landscape, had a more undulating aspect, and better-developed soils.

For each site, the bathymetry of the lake was explored from a rubber dinghy using a hand-held echo sounder. Subsequently, a gravity core was obtained at the same sampling location and/or sampling depth as originally sampled by Brooks & Birks (2001). The top three centimetres of sediment were subsampled in consecutive 1-cm-thick intervals in the field, and typically the bottom-sample of the gravity core (the depth of which varied depending on penetration of the corer) was sampled as well. A second gravity core was obtained for most of the lakes, typically focussing on a different, more shallow, depositional environment, and sampled for its top sediments. Finally, we subsampled the entire core retrieved for one lake in the Røldal region (Lontjørnane) and one from the Førde area (Stoylsvatnet; Figure 1).

Significance

The surface sediment samples obtained for the 20 Norwegian lakes will allow to establish by how much the diversity of the chironomid fauna of these sites has changed since they were first sampled ca 25 years ago. A long-term perspective on these recent changes will be obtained from analysing one or both of the sediment sequences (Lontjørnane, Stoylsvatnet). A comparison against a nearby sediment record from lake Svartatjønn that was radiometrically dated (Larsen, 2000) suggests that our ca 30-cm-length cores could span several centuries. We will produce a detailed record of changes in chironomid diversity across this time interval, and using a range of numerical techniques, the combined results will be compared to long- and short- term climate (Sarva et al., 2018) and land use data (Bryn et al., 2018) to determine the main driver of changes in chironomid diversity on decadal to centennial scales.

The retrieved core samples allow for further research to be carried out. Proposed studies could for instance include the analysis of other proxy-indicators based on material from the same core-tops as the chironomids, it could include an in-depth comparison of the chironomid fauna from the littoral of a lake versus the fauna from the profundal of the lake, or it could allow for a top-bottom comparison in order to estimate changes in the chironomid fauna over centennial rather than millennial scales. We very much welcome interested people to contact us to discuss opportunities for cooperation and are happy to make sediments available, particularly to students in Quaternary Geology or other relevant fields.

Acknowledgments

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Common name (abbr.)	Sediment core	Latitude (°N)	Longitude (°E)	Water depth (m)	Sampled: Top (T) Bottom (B) Entire core (E)
Dalevatnet	Dlv19-A	61°29’37.8”	005°32’07.0”	14.5	T & B
	Dlv19-B	61°29’35.6”	005°31’55.8”	0.8	T
Dalevatnet (#2)	Dl2_19-A	61°28’47.8”	006°02’59.8”	13.6	T & B
	Dl2_19-B	61°28’35.3”	006°03’04.9”	3.0	T
Flotatjørn	Flo19-A	59°36’34.5”	006°20’43.6”	6.8	T & B
	Flo19-B	59°36’30.7”	006°20’44.5”	1.0	T
Fullskjeggevatnet	Ful19-A	61°41’30.9”	005°48’15.2”	13.7	T & B
	Ful19-B	61°41’30.1”	005°48’01.1”	1.8	T
Grastjørn	Gra19-A	59°54’48.5”	006°33’17.8”	10.3	T
	Gra19-B	59°54’48.3”	006°33’12.2”	3.0	T
	Gra19-C	59°54’48.0”	006°33’16.3”	10.6	T & B
Holebudalen (unofficial name)	Hol19-A	59°50’28.5”	006°59’31.1”	8.0	T & B
	Hol19-B	59°50’31.8”	006°59’34.9”	2.3	T
Konsdalsvatnet	Kon19-A	61°52’11.0”	005°04’29.2”	6.6	T & B
	Kon19-B	61°52’03.8”	005°04’31.4”	2.3	T
Kråkenesvatnet	Kra19-A	62°01’39.7”	005°00’18.4”	2.6	T & B
	Kra19-B	62°01’35.5”	005°00’05.2”	6.4	T
Lintjørna	Lin19-A	59°31’51.2”	005°39’22.0”	7.7	T & B
	Lin19-B	59°31’49.2”	005°39’18.6”	2.3	T
Litlevatnet	Lit19-A	61°34’06.1”	005°36’27.8”	11.8	T & B
	Lit19-B		005°36’20.9”	1.4	T
Litlevatnet (#2) (unofficial name)	Lt2_19-A	61°24’39.2”	005°52’53.1”	9.2	T & B
	Lt2_19-B	61°24’40.7”	005°52’51.4”	2.3	T
Lontjørnane	Lon19-A	59°54’44.2”	006°36’19.6”	8.8	E (34cm)

	Lon19-B	59°54’43.7”	006°36’22.2”	2.8	T
RådalstjØrna	Rad19-A	59°38’33.3”	005°35’12.7”	14.0	T
	Rad19-B	59°38’32.0”	005°35’09.9”	3.9	T & B
Røyrtjørna	Roy19-A	59°31’34.6”	005°41’24.7”	13.5	T & B
	Roy19-B	59°31’32.6”	005°41’32.2”	3.7	T
Stangavatnet	Sta19-A	61°23’30.8”	005°44’11.7”	11.2	T & B
	Sta19-B	61°23’27.5”	005°44’09.2”	1.9	T
Stigedalsvatnet	Sti-19A	61°58’41.3”	006°06’42.3”	15.0	T & B
	Sti19-B	61°58’35.5”	006°06’38.8”	1.7	T
Stølstjørna	Sto19-A	61°20’32.9”	006°11’09.2”	8.6	T & B
	Sto19-B	61°20’33.2”	006°11’22.9”	1.9	T
Stoylsvatnet	Stv19-A	61°49’17.7”	006°02’07.8”	8.3	E (28cm)
	Stv19-B	61°49’15.8”	006°02’02.5”	2.0	T
Svartevatnet	Sva19-A	61°49’53.8”	005°26’50.2”	26.1	T & B
	No B-core retrieved				-
Vatnedalsvatnet	Vat19-A	59°43’54.0”	006°03’05.4”	22.7	T & B
	Vat19-B	59°43’53.5”	006°03’14.1”	14.9	T

Table 1. Lakes sampled: common names as available on www.norgeskart.no or otherwise following previously published names; sediment core codes; latitude (°N), longitude (°E) and water depth (cm). Right-hand column indicates what samples were retrieved: T = top samples located between 0-1 till 2-3cm below sediment-water interface; B = bottom 1-cm-thick sediment sample from deepest part of the retrieved core (depth varies per core); E = entire core sampled, with core length in parentheses.

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REPORT ON THE QUATERNARY OF THE WEST GRAMPIAN HIGHLANDS QRA FIELD MEETING 2021 BASED AT FORT WILLIAM, SCOTLAND.

Figure 1. The meeting group at the Glen Roy viewpoint. Photo: Chris Francis.

The first QRA Field Meeting since the start of the pandemic was held between 15th and 19th September 2021 in Fort William and was led by **Adrian Palmer (AP), Ian Matthews (IM) and John Lowe** (**JL**; Royal Holloway). The meeting's aim was to consider both established and new reconstructions of Late Devensian glacial activity, sea-level and palaeoenvironmental change in the West Grampian Highlands area. The group assembled in the Ben Nevis Inn, Fort William, on the evening of the 15th for initial introductions and finalisation of logistics.

Day One

The group convened at the Commando Memorial near Spean Bridge where AP, IM and JL introduced the themes of the meeting with magnificent views of the Great Glen Fault and the Nevis Range imparting a sense of the scale of the Loch Lomond Readvance (LLR) ice mass that accumulated in this basin, a recurrent theme during the meeting.

A short drive took us to a quarry adjacent to Creag Aoil within the Lundy Channel where **Andy Russell** (Newcastle) described his work on the dynamic behaviour of the LLR ice mass as it retreated from the Spean into the Great Glen. Andy illustrated the complex geomorphological relationships between late-LLR retreat moraines and massive sediment fills within the Lundy channel that had been reconstructed using sediment exposures and the novel use of ground penetrating radar.

After driving along Loch Linnhe to the Rannoch plateau, a picnic lunch was taken at the White Corries Ski Centre with picturesque views. **JL** provided an overview of research that has played a crucial role in our understanding of the build-up of ice during the LLR and the timing of deglaciation from this major ice dispersal centre. Recent research based on radiocarbon dating suggests that the maximum age of deglaciation from the Rannoch was much earlier than previously supposed, but this conflicts with other recent research based on a combination of cosmogenic radionuclide and radiocarbon dating supported by tephrochronology, which suggest the ice did not vacate this area until ~11.5 ka BP. A detailed discussion developed concerning the accuracy and precision of the available age models and their interpretation. The next stop afforded stunning views of Glencoe, where **JL** introduced the work of Peter Thorp who used geomorphological evidence to reconstruct the vertical and lateral limits of LLR ice in this and adjacent valleys (Figure 2). The concept of glacial 'trimlines' as markers for the upper surfaces of former glaciers prompted some detailed discussion. This valley also displays excellent evidence for a paraglacial landscape, as well as some of the best developed debris cones and fans in Scotland, which **Colin Ballantyne** (St Andrews) expertly described.

Figure 2. The view looking westward down Glencoe. Photo: Chris Francis.

The final stop overlooked Castle Stalker and the Sound of Shuna where stretches of the Lateglacial Main Rock Platform (MRP) and Postglacial raised beaches could be observed (Figure 3). **Alastair Dawson** (St. Andrews) gave a detailed account of key arguments concerning the Lateglacial sea-level history in this vicinity and explained why the weight of evidence suggests that the MRP developed partly or wholly during the Loch Lomond Stadial. Ensuing discussions centred on whether a platform of this magnitude could form in such a short period of time, while requiring an equilibrium between rates of isostatic rebound and eustatic sea-level rise. **IM** presented preliminary results of current investigations of subaqueous ice-marginal landforms preserved on the floor of Loch Linnhe that lie beyond the limits of outwash fans that mark the maximum LLR ice limit in Loch Linnhe.

The absolute age of these landforms is not known, but current investigation of a Lateglacial sequence preserved on the Isle of Lismore, led by **IM**, suggests that retreat of the Late Devensian ice sheet from this vicinity dates to ~14.1 ka BP, or shortly before.

Day Two

The sea-level and glacial history themes were revisited with the group taking the drive west from Fort William to Arisaig, where the themes of the day were introduced by **IM** and **Dorothy Weston** (**DW**, Royal Holloway) in a classic area for research on isolation basins. The height of the basin sills, and the palaeoenvironmental evidence they contain provide critical data on the timing and scale of sea-level variations following local deglaciation. At the nearby site of Loch Torr a'Beithe, **IM** described the litho- and bio-stratigraphy previously obtained from the basin, whilst a demonstration core was recovered. **DW** explained her forensic stratigraphic procedures which included detailed tephrochronological analyses, the results providing an independent test of the chronology of the sequence. An interesting discussion led by **Tim Atkinson** (UCL) then developed concerning the taphonomy of cryptotephra shards and their reliability in developing chronologies of isolation times, whilst **Louise Callard** (Newcastle) and **Dave Evans** (Durham) encouraged the dating of any shells preserved in the cores.

Figure 3. Alistair Dawson discussing aspects of the sea-level history in the Loch

Due to wet weather, lunch was consumed in the vehicles as we transferred through beautiful landscapes to the Ardtoe area on the Ardnamurchan peninsula to examine a second isolation basin (Figure 4). While another demonstration core was being extracted, **IM** and **DW** explained the reasons for re-investigating two sites with different sill heights to develop more secure chronological constraints for the timing of isolation at different sites using tephrochronology. The ensuing discussions illuminated the complexity of the tephra records, but also how the existing age models could still be refined. Despite a testing midge bombardment mid-afternoon, a lively debate was sparked concerning alternative strategies for generating more precise isolation chronologies and how tidal regimes may have changed throughout the LGIT, with **Alastair Dawson** suggesting that the area may have been susceptible to mega-tides during the deglaciation period, with possible implications for reconstructed sea-level curves, while current sea-level reconstructions may not be adjusted for differential isostatic rebound. As the weather closed-in or waterproofs began to leak, we sought refreshment in a café in the small hamlet of Acharacle for welcome recuperation.

Figure 4. John Lowe describes a core extracted from the lower Ardtoe isolation basin. Photo: Chris Francis.

Day Three

The day started with drizzle as the group headed toward Glen Spean and Glen Roy to review the evidence for old and new models of local LLR glaciation reflected in the varved records that accumulated in ice-dammed lakes which formed in these valleys. Starting in Glen Spean, the group was led by **AP** to the varved sequence at Loch Laggan West (LLW), made accessible by the unusually low level of the loch. **AP** then introduced the original model for ice dynamics and maximum ice limits in the Roughburn/Fersit area and presented new geomorphological evidence from LiDAR data that indicates that the local ice margin oscillated in a more active manner than previously envisaged. The significance of the well exposed LLW varved record was then explained, as well as how it links to a longer sequence at Loch Laggan East, which led to discussion of the processes of varve formation and their linkages through varve thickness variations.

Next stop was at Fersit at the mouth of the Treig valley to view the Treig moraines and well-preserved kames and eskers and a large fan/delta. **Doug Benn** (St. Andrews) presented his new thesis based on mapping of the local landforms, that the Laire-Treig ice lobe may have surged when it reached its maximum limits. This could explain the asynchronous glacier behaviour of the Lochaber ice lobes. **JL** then described how pollen- and tephro-stratigraphic evidence obtained from sediments preserved in kettle holes in the Fersit area and in the Roy-Spean catchment indicate that the area became ice-free by ~10.8 ka BP, thus providing a limiting age for the demise of the local glacial lake systems in Lochaber.

A quick coffee and lunch break at the Darwin's Rest café at the mouth of Glen Roy preceded our trip to the Viewpoint as the sun began to win its battle with the clouds. **Colin Ballantyne** pointed out the large Rock Slope Failures within Glen Roy‑some of which clearly post-date the formation of the lake shorelines. It is not clear what controlled their formation within the short interval since the Dimlington Stadial, but some could have been triggered by the formation of the lake systems or by isostatic rebound-induced seismic events. It was concluded that this fell into the 'needs more work' category.

AP then outlined the new Lochaber Master Varve Chronology (LMVC19), which spans a total of 518 years, and its implications for our understanding of the timing and duration of the Lochaber lake systems. The most significant implication of the new model is that no varve sites have been found in Glen Roy that can be linked directly to the early 260 m lake stand. It is proposed that the Laire-Treig Ice Lobe reached its maximum limits before ice in the Great Glen blocked the westward drainage of the Roy and lower Spean. When the Great Glen escape route was eventually blocked, the first lake to develop in Glen Roy was at the 325 m level. This represents a significant departure from the established model of the lake sequence proposed by J.B. Sissons. Some time was spent discussing the implications of this new finding, particularly concerning the implied rates of lake shoreline formation, which the model suggests could form in well under 100 years, which rekindled the discussion held on Day One concerning the formation of the Main Rock Platform. Another new finding is the first robust detection of the Vedde Ash in the LLW varve sequence which anchors the LMVC19 record to an absolute timescale, from which it can be deduced that the local LLR ice margin persisted at its maximum position between ~12.14 and ~11.62 ka cal BP.

The party then moved up the Roy valley to the iconic and enigmatic Glen Turret Fan (Figure 5) to consider the controversial issues of the mode and timing of its formation. **AP** pointed out the key features and outlined previous interpretations of this large fan and the adjacent ice-marginal landforms, and how these link to the three major shorelines in the immediate vicinity. Particularly puzzling, if the limit is considered to date to the LLS, is the low altitude of the glacier lobe‑by comparison with currently inferred regional LLR ELA's, although this might be possible if the glacier had surged. **AP** argued that within the new LMVC paradigm of delayed ice growth in the Great Glen, it is possible for the fan to have formed subaerially (as proposed by J.D. Peacock) but during the early LLS. **JL** then led the party to the site of Turret Bank to explain how the sequence preserved at this site supports the contention that the Turret Fan and adjacent ice-marginal features were likely to date to the LLS. A key part of the argument is the presence of glaciolacustrine varve sediments and early Holocene tephras in the sequence that link to the LMVC. **AP**, on behalf of **Neil Ross** (Newcastle), then presented some recent Ground Penetrating Radar data obtained from the lower Turret valley, and these were complemented by new GPR lines ran by **Louise Callard** and **Andy**

Russell (Newcastle) during this meeting: the combined results reveal a complex subsurface architecture suggestive of subaqueous moraines and clinoform structures perhaps charting the retreat of a glacier into the head of Glen Turret. After a long but engrossing day in the field, the group returned to Fort William for a convivial evening in the Ben Nevis Inn.

Figure 5: The group wanders down from the surface of the Glen Turret Fan towards the Turret Bank site; the GPR lines referred to in the text were ran along the main valley floor; at the right-hand side of the image, an ice-marginal moraine ridge curves from the inner edge of the Turret fan and gradually rises against the eastern flank of the Turret valley. Photo: Chris Francis

Day Four

The final day took us to the area of the Pass of Drumochter and the Upper Truim valley. **Doug Benn** (St Andrews) led a short walk westwards from the Balsporran car park to describe the geomorphological features of the West Drumochter Hills and the glacier reconstructions they support. He envisaged an active retreating ice margin with regular oscillations of a greater scale than those typical of other parts of the West Grampian Icefield. He also compared the reconstructed ELA's of this inferred ice mass with those of smaller ice masses around the margins of the West Grampian Icefield. **JL** then summarised how the limits of the West Drumochter Icefield could be assigned to the LLR based on an 'inside' site (contains Holocene deposits only) located in the Pass of Drumochter, and an 'outside' site (contains a Lateglacial sequence) located at Loch Etteridge (see below).

A short drive north took the group to Loch Etteridge for the final stop (Figure 6). It is a classic site with a superb suite of kames, kame terraces and eskers deposited during the Late Devensian Ice Sheet retreat, while a Lateglacial lake sediment sequence is preserved beneath the loch. **IM** outlined a chronology for the sequence based on tephra isochrons, as well as the complex litho- and biostratigraphy of this highly variable sediment sequence. **Charlotte Perry** (Royal Holloway) presented detailed plant macrofossil data that suggest that this part of Scotland was highly sensitive to climatic forcing factors during the LGIT. **Alice Carter Champion** (Royal Holloway) also presented μ-xrf data for the Loch Lomond Stadial part of the sequence. These new findings were discussed in the context of recent proposals for a mid-Younger Dryas shift in climatic conditions using the Vedde Ash as a tie point for comparing with records from other sites in Scotland.

Figure 6: Ian Matthews describes the highly variable lithological changes in the LGIT sequence from Loch Etteridge. A wealth of biological and lithological proxies with an improved chronological model are now available for this site generating new insights into the Lateglacial palaeoclimatic history of Scotland. Photo: Chris Francis

The trip was drawn to a close by **AP** who thanked everyone for their participation. Everyone agreed that, after a relatively long, COVID-induced hiatus, it was fantastic to be able to hold a QRA gathering in a classic Quaternary field area, and to debate new research results that are challenging existing paradigms. **Andy Russell** closed the meeting by offering a vote of thanks to the organisers, before farewells were made and the group of old and new friends dispersed, homeward bound.

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QRA POSTGRADUATE SYMPOSIUM 2021

The QRA Postgraduate Symposium of 2021 ran on 30-31 August. Because of the ongoing pandemic and just like last year, this year's Symposium was held online. There were a total of 11 postgraduate students in attendance, of which 9 people gave a presentation, equal to the number of presentations last year. Most people checked in from the UK, I attended the conference from my fieldwork location in the northeast of Iceland. As can be expected from the QRA, presentation topics were varied, from identification of small mammal fossils to the deglaciation of Tierra del Fuego.

The conference started off with a key-note presentation by Dr Althea Davies (University of St Andrews). She talked about the contributions of palaeoecological research to modern policy, and how the number of palaeoecological contributions can be increased or improved. Presentations filled the rest of the day, presenters and their topics were as follows:

- Emily Watt (National History Museum, University College London) – The shape of things: shape-based identification of small mammal postcranial fossils.
- Harry Roberts (University of Lincoln) – Quantifying carbon composition in relation to environmental drivers in a temperate peat bog.
- Sarah Ferrandin (Queens's University Belfast) – Investigating the timing and causes of nitrogen cycle changes in Bronze Age Ireland.
- Hannah Wynton (University of Cambridge) – Explosive volcanism in the Kenyan Rift: a tephrostratigraphic perspective.

The second day started with an informal discussion among the attendees, before the rest of the presentations were held. Creating a fun and inviting atmosphere was difficult due to it being held online, but during this second day, questions were more easily asked and discussions went on for longer. There were 5 presentations, the details of which are outlined below.

- Holly Norton (University of Lincoln) – A history of climate and disease in Early-Modern Lincolnshire, UK.
- Willem Koster (University of St Andrews) – Detecting uncertainties and heterogeneity in pollen records – using Icelandic pollen records as an example.
- Oliver Thomas (University of Manchester) – Understanding the nature and timing of deglaciation in the Tierra del Fuego, Patagonia.
- Olivia Verplancke (Keele University) - Understanding the origin and palaeoglaciological significance of Herefordshire's Ice Age Ponds using semi-automated GIS methodologies.
- Sarah Walton (Sheffield Hallam University) – Climate and environmental change in Southeast Iceland.

As can be seen from the titles of the presentations, topics were quite varied, and there was a wide range of experts in different topics. Despite this there were interesting discussions or questions and it seemed to have been an educational experience for attendees and they seemed to have enjoyed themselves. Attendees expressed that the online Symposium made it much easier to attended, but the lack of good opportunities to properly talk to people, in between, and after presentations was a major downside. I hope that next year's Postgraduate Symposium can and will be organised as it used to be organised: in person and with the added fun of a field trip.

In conclusion, this Symposium was a mixture of interesting postgraduate research work in a slightly less than ideal and perhaps slightly awkward setting. I fully agree with last year's organiser Dale Tromans who said that in person Postgraduate Symposia are far more valuable for postgraduate students and allow for more interaction necessary to creating contacts and discussing Quaternary research. I would like to thank all those who attended and presented at the Symposium and I hope to see you again at next year's Symposium

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ABSTRACTS QRA DISSERTATION PRIZE

QRA UNDERGRADUATE DISSERTATION PRIZE 2021

It is our great pleasure to announce that the winner of this year's QRA Dissertation Prize is Sylvie Hodgson Smith (University of Cambridge) for her thesis on "Reconstructing the global climate effects of the volcanic eruption of Mt. Samalas, 1257 AD".

Sylvie's project comprises a sophisticated analysis of tree-ring-derived palaeotemperature and hydroclimate records to examine the impacts of a large tropical eruption, including the coherency of records at regional to global scales. Sylvie's interpretation was thoughtful and balanced, and included a critical evaluation of climate models that simulate the climate behaviour following the eruption. The thesis stood out in terms of its very high standard of presentation and is worthy of publication. We congratulate Sylvie on an outstanding piece of undergraduate research.

We wish to commend three other students for their high-quality research that demonstrated their command of their respect investigations.

Tom Garrod (University of Sheffield): A glacier reconstruction of Younger Dryas glaciers in the Nordfjord region of western Norway using GIS and geomorphological mapping.

Catherine Dorey (University of Nottingham): The changing landscapes of the southern mid-latitudes throughout the Holocene

Jack Crouch (Royal Holloway): Exploring valley glacier environments and change through Structure from Motion in Kaunertal, Austria

We congratulate all the nominated students this year, whose work testifies to complex and interesting projects, many of which were based on creative and successful use of secondary data sources.

Judges:

Mary Edwards
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Gill Plunkett
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RECONSTRUCTING THE GLOBAL CLIMATE EFFECTS OF THE VOLCANIC ERUPTION OF MT. SAMALAS, 1257 AD. A COMPARISON OF TREE-RING DATA AND CLIMATE MODEL SIMULATIONS.

Despite intensive research, the global climate impacts of the Mt. Samalas eruption in Indonesia in 1257 AD are still unknown. Uncertainties in sulfur deposition dating in bi-polar ice cores and poor parameterisation of aerosol microphysics in climate models contribute to disagreement between colder simulated and warmer reconstructed summer temperature following the largest volcanic eruptions. To reconstruct global climate following the Samalas eruption, this dissertation uses a network of 249 tree-ring width chronologies from all continents except Antarctica, spanning the entire 13th century which are sensitive to predominantly temperature or precipitation. Northern Hemisphere mid-latitude chronologies reveal summer cooling in 1258 AD, whereas Scandinavian and Siberian chronologies show the strongest cooling in 1259 AD. Southern Hemisphere and high-latitude North American chronologies show summer warming in 1258 AD, challenging assumptions of a globally coherent cold spell following the Samalas eruption. Precipitation chronologies reveal a precipitation dipole response in Europe which differs from the hydroclimate response to the Tambora 1815 AD eruption, challenging assumptions that similar magnitude events produce comparable hydroclimate changes. Precipitation chronologies indicate southward shifts in the ITCZ following the eruption. Precipitation anomalies strengthen in Europe, Central Asia and Australia in 1259 AD, revealing persistent hydroclimate effects. Although the tree-ring width network is biased towards North America and Europe and suffers from several limitations, the results provide insight into heterogeneous global climate changes following the Samalas eruption. The tree-ring width reconstruction was compared to PMIP3 model simulations. Models show good agreement with mid-latitude cooling in the Northern Hemisphere but fail to simulate warming in the Southern Hemisphere and Northern High-latitudes in 1258 AD, or global temperature recovery in 1259 AD. Although models simulate precipitation patterns in Europe, they do not reproduce heterogeneous responses in North America. Differences in forcing datasets, aerosol parametrization in models and the influence of natural patterns of climate variability are suggested as reasons for this disagreement.

Sylvie Hodgson Smith
University of Cambridge

GLACIER RECONSTRUCTION OF YOUNGER DRYAS GLACIERS IN THE NORDFJORD REGION OF WESTERN NORWAY USING GIS AND GEOMORPHOLOGICAL MAPPING

This study investigated Younger Dryas glaciation in the region of Nordfjord, Western Norway. With a focus upon the identification of palaeo icefield evidence. This investigation was conducted by gathering high-resolution datasets to perform comprehensive geomorphological mapping and the use of the GlaRe Toolset in ArcGIS to perform numerical modelling of the proposed Younger Dryas glaciation. The evidence compiled through these methods were then cross-referenced and analysed to provide evidence for whether the site in question was home to icefield outlet glaciation or cirque glaciation. The study found that in several sites, the numerical modelling strongly supported the existence of icefield and outlet glaciation instead of cirque glaciation, with geomorphological evidence supporting the findings of the numerical modelling, although geomorphological evidence was limited. In conclusion, this study found evidence that supported the existence of icefield and outlet glaciation during the Younger Dryas in Nordfjord in regions stated as home to cirque glaciation in the Younger Dryas by past literature. Accordingly, this study proposes new Younger Dryas icefield outlet glaciation sites previously believed to have been home to cirque glaciation. However, further work is still required to increase understanding of the glaciation within Nordfjord during the Younger Dryas

Tom Garrod
University of Sheffield

THE CHANGING LANDSCAPES OF THE SOUTHERN MID-LATITUDES THROUGHOUT THE HOLOCENE

A reconstruction of the landscapes of the southern mid-latitudes over the Holocene (~12,000 Cal yr. BP) has been produced to better understand the role that the climate modes governing the region play in environmental change. Using Tasmania and Southern South America as study areas, pollen and charcoal data has been extracted from online databases and analysed to investigate fire histories and subsequent vegetation changes. It was found that in the early Holocene (12-8ka), a warm and dry period across the Southern Hemisphere mid-latitudes brought about domination of taxa characteristic of aridity in both regions. Through the mid-Holocene (7-4ka), moist conditions across the region prevailed which saw the domination of rainforest during this time. At 6ka, the onset of ENSO variability has created greater heterogeneity across the Southern Hemisphere mid-latitudes. However, there is general agreement of a recent warming and drying trend. Analysis shows that the southern mid-latitudes are tele-connected, with vegetation changes being analogous across the region. Although the main driver of environmental change in the southern mid-latitudes throughout the Holocene has been climate, the influence of humans in the anthropogenic era should be acknowledged. This has become a greater contributing factor in recent years.

Catherine Dorey
University of Nottingham

EXPLORING VALLEY GLACIER ENVIRONMENTS AND CHANGE THROUGH STRUCTURE FROM MOTION IN KAUNERTAL, AUSTRIA

The role of digital imaging technologies in mapping glacial landforms is paramount to understanding glacial dynamics and regime changes. Density and types of glacial-erosional landforms will determine a glacial setting's past environment and inference what the future holds for an environment, as seen as glaciers recede. Whilst dominated by techniques like Landsat and LiDAR, Structure from Motion (SfM) has shown to be a contender in its sub-cm image resolution and has seen use in mapping erosional landforms. In this report, a collation of images taken at a recently exposed rockface at Kaunertal, Austria, was digitised into a point cloud and mapped onto a DEM using SfM software, accompanied by clast analysis rose plots of landforms. Interpreting the landforms reveals that the area featured a temperate climate, where ice flowed north-westerly down the valley. The presence of meltwater and varying levels of erosional landforms indicates a variable stress regime at Kaunertal, characterised by thin ice cover and a mix of high basal pressures and low-medium pressure that facilitated detachment of the rockface. Secondly, the diverse range of diamicton at the site suggests subglacial transport of debris and the reworking of rock-sized debris suggesting glacial erosion and forms part of rapid change in the region. Whilst SfM has proven well for analysing glacial environments; current technological restraints limit the widespread use it in academia. This report concludes that SfM should be considered an option alongside digital mapping techniques.

Jack Crouch
Royal Holloway, University of London

OUTSTANDING PAPER IN THE JOURNAL OF QUATERNARY SCIENCE BY AN EARLY CAREER RESEARCHER

CHRONOLOGY OF THE MEDITERRANEAN SEA-LEVEL HIGHSTAND DURING THE LAST INTERGLACIAL: A CRITICAL REVIEW OF THE U/TH-DATED DEPOSITS

JOURNAL OF QUATERNARY SCIENCE (2021), 36(7), 1174-1189

Francesca Pasquetti, Monica Bini, Biagio Giaccio, Andrea Ratti, Matteo Vacchi, Giovanni Zanchetta

Relative sea-level (RSL) evolution during Marine Isotopic Stage (MIS) 5 in the Mediterranean basin is still not fully understood despite a plethora of morphological, stratigraphic and geochronological studies carried out on highstand deposits of this area. In this review we assembled a database of 323 U/Th-dated samples (e.g. corals, molluscs, speleothems) which were used to chronologically constrain RSL evolution within MIS 5. The application of strict geochemical criteria to the U/Th samples indicates that only ~33% of data available for the Mediterranean Sea can be considered 'reliable'. Most of these data (~65%) refer to the MIS 5e highstand, while only ~17% could be related to the MIS 5a. No attribution to MIS 5c can be unequivocally supported. Nevertheless, the resulting framework does not allow us to define a satisfactory RSL trend during the MIS 5e highstand and subsequent MIS 5 substages. Overall, the proposed selection of reliable/unreliable data would be useful for detecting areas where MIS 5 substage attributions are not supported by confident U/Th chronological data and thus the related reconstructions need to be revised. In this regard, the resulting framework calls for a reappraisal and re-examination of the Mediterranean records with advanced geochronological methodologies.

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QUATERNARY RESEARCH ASSOCIATION

The Quaternary Research Association is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. The majority of members reside in Great Britain, but membership also extends to most European countries, North America, Africa, Asia and Australasia. Membership (currently *c.* 1,200) is open to all interested in the objectives of the Association. The annual subscription is £20 with reduced rates (£10) for students and unwaged members and an Institutional rate of £35.

The main meetings of the Association are the Field Meetings, usually lasting 3–4 days, in April, May and/or September, a 2-3 day Discussion Meeting at the beginning of January. Short Study Courses on techniques used in Quaternary work are also occasionally held. The publications of the Association are the *Quaternary Newsletter* issued in February, June and October; the *Journal of Quaternary Science* published in association with Wiley; and the QRA Field Guide and Technical Guide Series.

The Association is run by an Executive Committee elected at an Annual General Meeting held during the Annual Discussion Meeting in January. Current officers of the Association are:

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