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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 numbers are 1st 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 (500 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 or .jpg format. In case of the latter, a 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.

N.B: Detailed guidelines on the formatting of contributions are now available via the QRA webpage and from the editor, including an EndNote style file to help with the formatting of bibliographies for submissions to *QN*

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COVER PHOTOGRAPH

Large latero-frontal moraines and associated meltwater channels near the plateau edge of the Monadhliath in Scotland, demonstrating that these were formed by an outlet lobe of a large plateau icefield; part of the field party of the Field Meeting in April 2013 for scale (photograph by John Groves; see related report by Groves and Pearce in this issue).

EDITORIAL

This first issue of *QN* in 2014 is the first of three celebrating the QRA's 50th anniversary and follows on from a very successful – and plainly amazing – ADM at the start of this year. I hope that the medal citations that make up much of this issue of *QN* are both a fitting reminder of this event (for those who were there) and convey some of the vibrancy of the event (to those who could not be there).

One of many planned activities to celebrate the 50th anniversary of our association is the creation of a list of the 50 most important sites for Quaternary Science in Britain. Please submit your favourite site, so that we have a good and representative selection to choose from.

As ever, I would like to thank all those who contribute to *QN* with their stimulating articles, discussions, reports etc. and continue to show that the Quaternary community in the UK is a very active one. I would also like to thank all of those who have reviewed articles and discussion pieces submitted to *QN* in a very constructive manner over the last year.

With the best wishes for a successful year 2014,

Sven Lukas

ANNOUNCEMENT

QRA50: Top 50 UK Quaternary Sites Nomination Form

As part of the 50th year celebrations of the QRA, it seems fitting to highlight some of the key sites and localities that have been fundamental to our understanding of the Quaternary landscape around us.

Over 2014, we are looking to compile a list of the 50 most significant Quaternary sites within Britain as nominated by you, the QRA community. These top 50 sites will be published at the end of the year in the form of a QRA50 full colour booklet and ultimately as a web-based resource available through the QRA web site.

More information as well as downloadable nomination forms are available from www.qra50.org. Alternatively, please ensure that your nomination contains the following information:

- Nominator
- Address
- Email
- Site Name
- Grid Reference
- Photo title and credits
- Site Description (250 word limit not including key references)
- Key references that should be formatted following the Quaternary Newsletter guidelines (available on the QRA website or directly from the editor of QN, Sven Lukas: S.Lukas@qmul.ac.uk)

Any Quaternary site within Britain is eligible and you are welcome to submit more than one site if you have several favourites. Submissions should be accompanied by a photo if possible including any credits.

Please submit your nomination **by 30 September 2014** either by post to (QRA50 c/o Dr Emrys Phillips, British Geological Survey, Murchison House, West Mains Road, Edinburgh, EH9 3LA) or electronically by email to: mytopsite@qra50.org.

If you have any questions, please contact either Barbara Silva (pollenbird@hotmail.com) or Emrys Phillips (erp@bgs.ac.uk).

...and if you need some inspiration, here is our first nominated site by Dr Emrys Phillips from the British Geological Survey.

Site Name: Overstrand, North Norfolk [National Grid reference TG 256 405]



Photo: Rafting of chalk bedrock at Overstrand on the North Norfolk coast (photograph taken by Emrys Phillips)

Overstrand is truly one of the classic sites in the UK for glacitectonic deformation within the Middle Pleistocene glacial sequence exposed on the north Norfolk coast, eastern England. Glacial rafts or ‘megablocks’ are dislocated slabs of bedrock and/or unconsolidated sedimentary strata that have been transported from their original position by glacial action. Such rafts are typically composed of relatively thin slabs of material that may have been transported over distances ranging from tens of metres to hundreds of kilometres. They generally occur as single, horizontal slab-like features, but may be stacked within conspicuous ice-pushed hills of various types. The section at Overstrand is dominated by a large raft comprising Cretaceous chalk bedrock overlain by pre-glacial marine sands and gravels of the Wroxham Crag. The raft is approximately 20-25 m thick and 100 m in length, and was detached, transported and finally emplaced by a major ice sheet flowing from the north, down the North Sea. The chalk and Wroxham Crag within the raft are deformed by a southerly verging anticline which occurs within the hanging-wall of a thrust forming the prominent detachment at the base of the raft. This southerly direct thrust and

the deformation associated with the emplacement of the raft are well exposed at the base of the cliff section.

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JAMES CROLL AWARD

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. The Medal is normally awarded to a member of the QRA who has made an outstanding contribution to the field of Quaternary science, and whose work has had a significant international impact. In this 50th Anniversary year, the QRA is delighted to award not one, but two Croll medals to two members who have not only made an outstanding individual impact on Quaternary science but whose names are inextricably linked through their many joint activities: John Lowe and Mike Walker. What follows are two separate citations and then a short statement on their joint contribution to Quaternary science, as it is hard to disentangle their work completely! I hope I have done justice to both the individual and collective contributions of both these giants of Quaternary science.



Mike Walker and John Lowe

John Lowe

John's research has had a huge impact across a range of areas of Quaternary geology and global environmental change. He is especially well known for his research work on the glacial-interglacial transition and the development and application of new chronological approaches. His work over the last 40 years has helped put the UK Quaternary science at the forefront of research in these fields. Beyond his individual contributions to the science, John has been extremely active in developing new initiatives for a broader Quaternary science community through development of research programmes, journals, and on national and international committees. John holds the Royal Geographical Society's Victoria Medal, the Geological Society's Coke Medal, and the University of Helsinki Medal for contributions to earth science. In INQUA, he was President of the Palaeoclimate Commission, INQUA Vice-President and is now Senior Vice President.

John's career began with a First Class MA in Geography from the University of St Andrews, and the award of the Royal Scottish Geographical Society Medal and the George Cumming memorial prize. He undertook a PhD at Edinburgh, before taking up his first academic post at City of London Polytechnic in 1973. His first two publications were both in *Nature* (Lowe and Walker, 1976; Sissons *et al.*, 1973), the former being the first of a whole series of Lowe/Walker or Walker/Lowe collaborations. His early work on the Lateglacial and Holocene vegetation history of Scotland covered a wide range of locations and contexts and showed that there was abundant terrestrial evidence for the termination of the last glaciation and its impact on vegetation and landscape (Lowe, 1982a, b; Lowe and Walker, 1981). The importance of accurate and sufficiently precise chronologies became apparent as this work progressed, and with the emergence of Accelerator Mass Spectrometry (AMS) radiocarbon dating, it was possible to look more critically at chronologies and begin to define dating requirements to address critical questions of timing and correlation (Lowe *et al.*, 1988). In 1989, John moved to Royal Holloway and in 1992 was appointed Professor of Quaternary Science of the University of London, and his attention was drawn towards southern Europe and consideration of the broader geographical pattern of rapid climate change at the end of the last glacial (Lowe, 1992). The North Atlantic Seaboard Programme (Lowe, 1994) took this work forward looking at the glacial-interglacial transition patterns across the whole of the North Atlantic (Lowe *et al.*, 1994). Throughout the 1990s, John also worked very productively with others on different proxies and methods to develop a better understanding of the spatial and temporal patterns of climate variability (e.g. Brooks *et al.*, 1997; Lowe *et al.*, 1995; Ponel and Lowe, 1992). The discovery of the Vedde ash within the Younger Dryas in Scottish lake sediments presented a new opportunity to improve chronology and correlations between deposits in the North Atlantic region (Lowe and Turney, 1997). The development of the INTIMATE (Integration of Ice core, Marine and Terrestrial Records)

programme took this work forward and highlighted the need for clear and critical use of chronologies for correlation (Lowe *et al.*, 2001). Further work with his colleagues and PhD students focused especially on the development of tephrochronology (e.g. Blockley *et al.*, 2005; Davies *et al.*, 2001), assisted by financial support including grants from the Leverhulme Trust and a NERC consortium project (RESET: RESponse of humans to abrupt Environmental Transitions). The work on tephrochronology has been especially influential in further development of correlations across Europe and the North Atlantic (Lowe *et al.*, 2008) and is still continually developing as new sites are studied (e.g. Housley *et al.*, 2013). Finally, this brief summary of John's contributions to Quaternary research cannot go without mention of the large number of students that have benefited from his supervision and wisdom through the 78 Masters projects, 24 PhD students and 15 post-doctoral researchers he has supervised and mentored. Many of these people are now taking forward the science in new directions.

Mike Walker

Mike's research has been enormously influential in developing interest and application of Quaternary science across a broad range of disciplines. Work on the Lateglacial and the last glacial-interglacial transition has been a continuing theme, but he has also been especially influential at the interface between palaeoenvironmental research and archaeology, as well as leading major initiatives on stratigraphy of the late Quaternary through the INQUA Commission on Stratigraphy and Chronology, and the Subcommission on Quaternary Stratigraphy (SQS) of the International Commission on Stratigraphy (ICS). Over the years he has been very active promoting Quaternary science in national and international groups and committees (e.g. NERC committees), as well as serving on journals and professional organisations including INQUA and the QRA. He is a Fellow of the Society of Antiquaries and an Honorary Professor in the Institute of Geography and Earth Sciences, University of Aberystwyth. Mike's career began with a BA (Hons) from Oxford, followed by an MSc (Calgary) and a PhD at Edinburgh. His first academic post was as a Lecturer in Geography at St David's University College, Lampeter in 1974, where he rose to a personal chair in Geography (1995) and then became Professor of Quaternary Science in the Department of Archaeology (2000). He subsequently served as the University Director of Research and became Professor Emeritus in 2008.

Mike's early publications are marked out by a series of papers in *Nature* (Lowe and Walker, 1976; Sissons *et al.*, 1973; Sissons and Walker, 1974; Walker, 1980) on a range of sites and aspects of Lateglacial climatic and environmental change. To focus only on these *Nature* papers would be wrong however, as behind these relatively brief papers was a large amount of detailed palaeoecological data that characterises much of Mike's work. The series of papers on Rannoch Moor (Walker and Lowe, 1977, 1979, 1981) and the Brecon Beacons (Walker, 1980,

1982a, b) are typical. The joint Walker/Lowe and Lowe/Walker publications on Mull and Skye were further 1980s highlights, and again it is characteristic that the first paper in the series was published in *Nature* (Walker and Lowe, 1982), with a raft of publications following this up (Lowe and Walker, 1986a, b; Walker *et al.*, 1988; Walker and Lowe, 1985, 1987, 1990). Mike had also been working on a range of other sequences during this time, such as the pre-Devensian sequences in northern Scotland (Walker *et al.*, 1992), reflecting wider interests that he continues to the present day, especially in relation to archaeology (e.g. Walker *et al.*, 2006). The North Atlantic Seaboard and INTIMATE programs, placed all of the UK Lateglacial work in a much wider context and demonstrated that there was much more to be gained in terms of understanding of climate and environmental change from bringing together different proxies (Walker *et al.*, 1993) from multiple locations (Lowe *et al.*, 1994; Walker, 1995). Arising from these wide ranging international projects, Mike took a leading role in the formalisation of stratigraphy of the Lateglacial and early Holocene using the ice cores as the template (Björck *et al.*, 1998; Walker *et al.*, 1999) and then proposed ways in which other terrestrial records might be linked to this template (Walker, 2001; Walker *et al.*, 2001). This led to the designation of a global stratotype section and point (GSSP) for the base of the Holocene (Walker *et al.*, 2009; Walker *et al.*, 2008). The latest proposal is for formal division of the Holocene (Walker *et al.*, 2012). Mike's diverse publication record is marked especially by his exceptional contributions to textbooks that bring Quaternary science to the wider attention of students and other research communities. Besides the now classic *Reconstructing Quaternary Environments* (with John Lowe, see below), he has published *Late Quaternary Environmental Change: Physical and Human Perspectives* (with Martin Bell, 1992, 2005) and *Quaternary Dating Methods* (2005).

The Lowe/Walker, Walker/Lowe partnership

It is especially apposite in this 50th year of the QRA, that James Croll medals are awarded to both John Lowe and Mike Walker, because as well as being Quaternary scientists of international repute in their own right, both have contributed hugely to the work of the Association. Both are past Presidents, past Editors of the *Journal of Quaternary Science* and both are honorary members of the QRA. As the selection of references listed below makes clear, their work has been closely entwined over much of their careers to date. Of all their joint work, perhaps most prominent is the book *Reconstructing Quaternary Environments*, a text that has probably done more than any other publication to bring the attention of Quaternary science to vast numbers of students and send many of them on their way to a future career in the field. Following earlier editions in 1984 and 1997, it is now about to appear in its 3rd edition in 2014, and there is every sign that this will be even more popular

than previous editions. It is certainly hotly awaited by students and staff in Universities around the world!

In summary, John and Mike are, individually and collectively, world leaders in their field and two of the most outstanding members of the QRA. They have placed the UK at the forefront of research on the last glacial-interglacial transition and a variety of related fields, and made an enormous contribution to Quaternary science education through their joint and individual efforts. The QRA are absolutely delighted to award the James Croll Medals for 2013 to John Lowe and Mike Walker.

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Dan Charman
President of the QRA
January 2014

LEWIS PENNY AWARD

THE 2013 LEWIS PENNY MEDAL

We are delighted to announce that, in its eighth year, the Lewis Penny medal is awarded to Andrew Finlayson of the British Geological Survey, in recognition of his outstanding work on Quaternary geomorphology and palaeoglaciology. The Lewis Penny Medal is in memory of Lewis and his contributions to Quaternary science and his support of the QRA, and was made possible through the generosity of many of Lewis's former students, friends and colleagues. The prize is intended to recognise a young or new research worker who has made a significant contribution to the Quaternary stratigraphy of the British Isles and its maritime environment, including adjacent areas of continental Europe that have relevance to the British Isles.

Andrew Finlayson

Andrew Finlayson combines an extremely diverse and unusual set of approaches to tackle the Quaternary stratigraphy of the British Isles, and especially towards our understanding of the glacial history in Scotland. His expertise includes geomorphology, sedimentology, geochronology, and 3-D modelling, which are combined to understand glacial sediments and landforms in the UK.

Andrew is a graduate of the University of St Andrews (BSc. Hons, Geography, 2001) and Royal Holloway University of London (MSc., Quaternary Science, 2004).

He has recently submitted his PhD to the University of Edinburgh (School of Geosciences), which he has been working towards part-time alongside his position at the British Geological Survey (Edinburgh). He has published 11 journal articles, contributed to two QRA Field guides and four policy reports, as well as an explanation of glacial history in a British Mountaineering Club Map.

Andrew has most notably focused his efforts on understanding glacial sediments and landforms in several areas Scotland to shed light on the timing and processes of glacial events and stratigraphy during the Devensian (Finlayson,



2006, 2012, 2013a; Finlayson *et al.*, 2010, 2011, 2013). His research combines several approaches of traditionally-disparate fields to achieve a unique and holistic understanding that is unprecedented by combining geomorphological, sedimentological and geochronological evidence with 3D-modelling approaches (adopted from hydrogeology) and glaciological theory (e.g. Finlayson, 2012, 2013a; Finlayson *et al.*, 2013). Applying this unique combination of approaches to the Clyde Basin has enabled him to challenge traditionally-accepted concepts such as that subglacial till is far-travelled (Finlayson, 2012), but also to advance our understanding of groundwater flow in this region. In addition, he has been able to quantify rates of sediment flux over larger areas for the first time and investigate the implications for the use of former valley glacier and ice sheet beds, themselves key input parameters to any glaciological model, in palaeoglaciological modelling (Finlayson, 2012, 2013a). His contributions have advanced our understanding of glacial processes beyond the ordinary and have allowed the quantification of former subglacial processes with greater accuracy than was possible before.

Andrew has also contributed to two QRA field meetings in written form and through presentations in the field through his research in Scotland, most notably his MSc research (Finlayson, 2006; Finlayson and Golledge, 2008) and subsequent work in NW Scotland (Bradwell *et al.*, 2010). Andrew's presentation at the 2012 QRAADM in New Forest showcased how knowledge in Quaternary Science can be used to inform policy decision-making. His work for the BGS in this regard has bridged the gap between science and communication to policy decision makers (e.g. Finlayson, 2013b; Finlayson *et al.*, 2012; MacDonald *et al.*, 2007; Smith *et al.*, 2007).

In summary, as an early career researcher Andrew has made a significant contribution to many areas of UK Quaternary science by bridging the gap between different approaches in order to understand more fully the Quaternary stratigraphy of Scotland. The QRA is delighted to recognise his achievements with the award of the 2013 Lewis Penny medal.

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GLACIAL GEOLOGY IN SCOTLAND

Andrew Finlayson (British Geological Survey)

Introduction

Firstly, I'd like to sincerely thank the QRA for awarding me the Lewis Penny Medal. It is an honour to have my research recognised in this way, and to join the list of existing recipients. The catalyst for my interest in Quaternary studies was Colin Ballantyne's enthusiastic lectures on the Quaternary geomorphology of Scotland, while I was an undergraduate at St Andrews. Upon graduating in 2001, I based myself in the amazing landscape of the Canadian Rockies where I became convinced that a geomorphology-related career was the path for me. In 2004 I completed the excellent MSc in Quaternary Science at Royal Holloway, led at the time by John Lowe, and made thoroughly enjoyable by a positive peer group. I was employed by BGS the following year, where I was fortunate to join a growing Quaternary team in the Edinburgh Office. My work at BGS led me onto investigating landforms and stratigraphic sequences in the Scottish glacial record. In 2009 Tom Bradwell suggested that I talk with David Sugden about starting a part-time PhD at Edinburgh University, and the project took off immediately. Tom and David's advice, enthusiasm and confidence made it an extremely rewarding experience, and I submitted the PhD at the end of last year.



My main research interests since joining BGS fall under three broad themes.

Palaeoglaciological reconstructions

There is a strong history of palaeoglaciological research in Britain and Ireland (e.g. Charlesworth, 1955; Penny, 1964; Ballantyne, 1989, 2007; Evans *et al.*, 2005). Perhaps one of the most significant contributions in recent years was the compilation of the BRITICE database (Clark *et al.*, 2004), which triggered a renewed focus on British-Irish Ice Sheet (BIIS) research. By presenting an up-to-date synthesis of existing geomorphological evidence at an ice-sheet-wide scale, the BRITICE work provided an initial template from which larger-scale ice sheet reconstructions, similar to those of the former Laurentide and Fennoscandinavian Ice Sheets, could be based. The synthesis also highlighted sectors of the BIIS where little evidence had been described, and therefore could be used to direct new work that could subsequently contribute to a detailed, whole ice-sheet reconstruction.

My work initially took me to the Creag Meagaidh range in the western Grampian Highlands, where I became interested in ice field configuration during the Loch Lomond Readvance, and the signature of ice sheet retreat prior to the readvance (Finlayson, 2006). This work extended to the Beinn Dearg range in NW Scotland where collaboration with Tom, Nick Golledge and Derek Fabel allowed the comparison of a numerically simulated and empirically reconstructed former ice cap (Finlayson *et al.*, 2011). The key outcomes were: that areas of glacier inception and ice retreat were not necessarily the same; that wind redistribution of snow played an important role in ice cap configuration, which we attempted to quantify; and that soft-sediment landforms from an earlier deglacial stage had survived under ice cap outlet glaciers.

I also became interested in ice-sheet scale problems, and through collaborative work, presented an interpretation of the last ice sheet cycle in western Scotland (Finlayson *et al.*, 2010, 2014). Having spent almost every childhood summer holiday on the Island of Arran, field work in this part of the world was an enjoyable experience and a nice opportunity to revisit some of my favourite places under the pretence of ‘work’! The research in western Scotland highlighted the important influence of subglacial topography on dynamic and stable zones of the former ice sheet, and provided evidence for significant changes in ice sheet flow that were brought about by the growth and collapse of a marine-terminating sector. Our work also recognised that many features in the landscape relate to an early restricted mountain ice sheet configuration – thought to have been the dominant glacial mode in the early and middle Quaternary (Lee *et al.*, 2012).

Three-dimensional geological modelling

I was introduced to three-dimensional geological modelling through working on urban geology projects. My original involvement in this work related to the

development of shallow subsurface geology models that could be interrogated to inform urban planning and sustainable urban regeneration projects in Glasgow. However, I quickly realised that the models also have significant potential to inform us about the volumes of sediment that were deposited by glacial and post-glacial processes. Incorporating thousands of borehole records, I developed a catchment-scale three-dimensional Quaternary geology model for the Clyde basin, and linked with an ice sheet reconstruction to elucidate patterns and quantify volumes of sediment moved during the last glacial cycle (Finlayson, 2012a). The results suggested that, in the Clyde basin, ice marginal and sub-marginal processes were key agents of sediment movement, while sediment transfer under the ice sheet was far more restricted. The models also allowed layers, or packages, of sediment to be ‘peeled off’ the land surface to reveal buried landscapes. One application of this was to test how quantitative palaeoglaciological studies, based on modern topographic data, can be affected by a ‘mask’ of postglacial sediments in lowland, depositional environments (Finlayson, 2013a).

I believe there is a lot of potential for new three-dimensional geological modelling or mapping techniques in Quaternary studies, and recent software developments have made it a relatively user-friendly and accessible tool. As an example, in Iceland I have been applying the technique to model the internal structures of a modern glacier, based on structural glaciological measurements, radar data and terrestrial LiDAR scans (Phillips *et al.*, 2013). This has been part of a larger field project led by Jez Everest, and has involved particularly enjoyable work with Emrys Phillips – a self-confessed bedrock geology convert who has now turned to the ‘dark side’ of Quaternary studies!

Applied Quaternary Geology in Scotland

My job has always involved elements of applied Quaternary geology, which I find very rewarding. In the UK ongoing development places increasing demands on the underlying landscape (e.g. energy supply, waste storage, transport networks, aggregate resources). To inform planning decisions, a good understanding of the likely surface and subsurface ground conditions is required. In formerly glaciated terrain, a landsystems approach (Eyles, 1983; Evans, 2005) can play an important role in planning ground investigations and interpreting the results. The costs of putting geologists on the ground are very small compared to overall site investigation costs, yet the benefits can be significant. By working with colleagues, such as Clive Auton and Jon Merritt, I have been able to see how Quaternary geologists can add real value to large-scale infrastructure projects.

Since joining BGS, I have been involved in providing Quaternary geological input to projects at Hunterston, Dounreay and Drigg, relating to radioactive

waste storage and site restoration (Golledge *et al.*, 2009; Finlayson, 2010; Smith *et al.*, 2010). I have contributed to geological site assessments for buried power cable routes (Finlayson *et al.*, 2012) and wind farm sites (Barron *et al.*, 2011; Finlayson, 2013b), and have included Quaternary geological information in approximately 50 desk-based site assessments for private and public sector clients. Around the River Clyde in west central Scotland, I am involved in work, led by Diarmad Campbell, generating three-dimensional Quaternary and bedrock geology models which are helping planners to anticipate ground conditions and identify contaminant pathways for a variety of brown-field regeneration projects (Campbell *et al.*, 2007; Finlayson, 2012b). A particular early highlight for me at BGS was contributing to work by Alan MacDonald, Clive Auton and others, characterising the Quaternary sediments and groundwater flow in a flood prone part of north-east Scotland (MacDonald *et al.*, 2007, 2012). The results informed design of a flood alleviation scheme, resulting in huge savings through prevented groundwater flooding damage.

These types of projects continuously remind me that the work of Quaternary scientists, in understanding the processes that have shaped our land surface over the last 2.6 million years, is important; and it is necessary for continued sustainable development on our landscape.

Acknowledgements

I am lucky to be part of a stimulating Quaternary research group at BGS and this award is very much a reflection on the positive research environment here. I am surrounded by people with wide ranging expertise, who have had an extremely positive influence on my career so far. In particular I'd like to acknowledge Tom Bradwell, Clive Auton, Mike Brown, Diarmad Campbell, Dayton Dove, Jez Everest, Tim Kearsey, Jon Lee, Maarten Krabbendam, Jon Merritt, Emrys Phillips, Chris Thomas and Katie Whitebread. I have also benefitted from the expertise of numerous researchers outside BGS, especially Derek Fabel (Glasgow), Nick Golledge (Wellington), Sven Lukas (QMUL), and David Sugden (Edinburgh). Finally, thanks to S-J, Holly and Jamie for providing perspective by keeping life outside work so entertaining!

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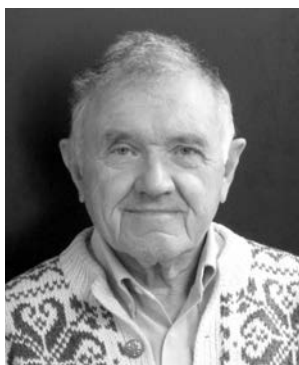
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HONORARY MEMBERS

Honorary Membership of the QRA is bestowed on individuals who have given distinguished and career-long service to Quaternary science and/or effective contributions to the activities and development of the QRA itself, and who are on the cusp of professional retirement or who have already retired. I am delighted to announce that we are awarding honorary memberships in 2013 to four individuals from a range of constituencies of the QRA.

John T(homas) Andrews

John Andrews has been a Quaternary scientist for over 50 years. He originates from Cumbria (then Cumberland), being born and raised in the small iron and steel town of Millom. He elected to go Nottingham University where he studied Geography, History, and Geology, graduating in 1959. He then moved across the Atlantic to McGill University in Canada where he spent 1959-1960 at the McGill Sub-Arctic Research Station in Schefferville, completing his MSc thesis on the Glacial Geology of an area of the Labrador coast in 1961. His amphi-Atlantic early career is demonstrated by his first paper



was on the strength of lake ice and his second on the Wasdale screes. John's early career also included some fine sporting achievements, especially on the rugby field where he played at national level as a schoolboy and somehow found a place to play in Canada throughout the 1960s!

From 1961-1968 John worked for the Department of Energy Mines and Resources in the Geographical Branch and the Geological Survey of Canada. His research was concentrated on Baffin Island (then NWT) with an emphasis on glacial history and glacial isostatic rebound. In 1964-1965 he went back to Nottingham for his PhD under the supervision of Professor Cuchlaine King, and attended his 1st QRA meeting in 1965 at the Annual Discussion Meeting in Durham where he spoke about his work on Baffin Island. In 1968 he moved to the University of Colorado, Boulder, to the Department of Geological Sciences and he was also attached to the Institute of Arctic and Alpine Research (INSTAAR), where he has remained for the rest of his career, becoming Professor Emeritus in 2003. His research initially continued in the Eastern Canadian Arctic, but in 1978 he "went to sea" and has worked ever since then on marine Quaternary glacial issues in the waters of Baffin Bay, the Labrador Sea, and the western Nordic Seas. During his career, he supervised 75 graduate students, including

35 PhD students, many of whom will be familiar names such as Giff Miller, Art Dyke, John England, Peter Clark, Anne Jennings, and Aslaug Geirsdottir. His association with the QRA has been long, although distance has prevented attendance at a large number of meetings. His main contribution has been as an active member of the Editorial Board of the JQS since the inception of the journal. He has contributed a number of papers including two invited papers on Heinrich events (1998) and the MIS3 and MIS2 history of the Iceland Ice Cap and the Greenland Ice Sheet (2008). His most recent contributions were published in 2012 and 2013. In sister organizations, John has served as Past President of the Quaternary and Geomorphology Division of the Geological Society of America (GSA) and Past President of the American Quaternary Association (AMQUA). We are by no means the first to recognise John's contributions and (amongst others) he has been previously awarded Distinguished Career Awards of both AMQUA and the GSA. For all his past, present and future contributions to Quaternary science, the QRA is delighted to add Honorary Membership of the QRA to this list of honours!

Clive Auton

Clive grew up in South Wales where, as a schoolboy, he became enthralled by the huge variety of rocks and minerals exposed along the southern margin of the South Wales coalfield and in the coastal cliffs of south Glamorgan. This led him to a geology degree at the University of Liverpool, where he began to take an interest in Quaternary sediments and landforms, fuelled by field excursions led by Geoff Thomas to the till cliff sections of the Wirral and the gravel pits of North Wales and the Cheshire Basin. On graduating, Clive accepted a Liverpool University grant to undertake research on the sedimentology and palaeoecology of Upper Ordovician limestone reefs in central Sweden, also working at the Rijksmuseum, Stockholm, under a British Council fellowship. Clive joined the Leeds office of the Institute of Geological Sciences in 1977 to survey parts of the south Yorkshire coalfield, before transferring to the Minerals Assessment Unit in Keyworth, where he spent seven years mapping and supervising drilling complex Quaternary sequences in East Anglia. It was at this time that Clive joined the QRA and made his first contribution to the QRA field excursion to the Gipping and Waveney valleys, led by Peter Allen and Jim Rose. Subsequently, he and Martin Clarke published some of the first evidence of the deposition of pre-Anglian fluvial gravels derived from the East Midlands, which were exposed at Ingham, north of Bury St. Edmunds.



Clive moved from Keyworth to Edinburgh in 1985, where he and Jon Merritt studied the Quaternary sequences of much of north east Scotland. His work focused on systematic surveys of Aberdeenshire and Moray, as well as the Highland Border, the central Grampian Highlands and latterly Caithness. He also worked extensively on Quaternary investigations and modelling work associated with nuclear power stations in western Cumbria and Dounreay in Caithness. Clive became a member of the QRA Executive Committee in 1989, acted as meetings officer between 1990 and 1992, and led the Beaulay-to-Nairn QRA field meeting in 1990. He also contributed to or led a number of other field meetings on the Pliocene-Middle Pleistocene of East Anglia (1988), the Banffshire Coast and Buchan (2000), the Western Highland Boundary (2003) and latterly to the Monadhliath (2013). During his career, Clive's mapping has appeared on 18 published maps, he has co-authored four memoirs, more than 80 major reports and more than 50 refereed papers and book contributions. He became District Geologist for the Highlands and Islands in 2003, but he also continued to work on both pure and applied aspects of Quaternary geology throughout Scotland and Northern England. Latterly, much of his work was focused on a wide variety of geological issues, but Clive remained a Quaternary field scientist at heart and he was leading BGS surveying efforts around Inverness and the Great Glen, until he retired in July 2013. In the future, Clive aims to continue as a very active member of the QRA, which he feels was fundamental to the development of his career, and he intends to participate in many more field excursions in the coming years. The QRA is pleased to make Clive an Honorary member for his contributions to British Quaternary geology and the life of the QRA.

Andy Currant

Andy Currant was raised in Bedfordshire and acquired a fascination for natural history in his early childhood, spending much of his free time digging for fossils in his garden. His first contact with the Natural History Museum came through the Museum's enquiry service, where he would take his schoolboy collections of fossils to be identified. After a brief diversion painting hospital wards, Andy applied for a junior curatorial position at the Natural History Museum in 1971. He maintains that his interviewers mistook his schooling at Wallington County Grammar for the rather grander public school of Wellington and that he was initially deployed on the Fossil Mammal



Section not by choice, but rather because he looked a “likely lad for shifting heavy bones”. After a career in Quaternary mammals spanning over 40 years, it was clearly a prescient move!

Andy developed his own role as Curator of Fossil Mammals at the Natural History Museum, taking a part-time BSc in Geology and Zoology at Birkbeck College, gaining merit awards for his research and curation and authoring more than 100 publications. His curatorial work focussed on upgrading the quality of information associated with museum specimens and promoting the care and use of nationally important collections, including helping to restore the fossil mammal collections at Taunton Museum. He developed an exceptional knowledge of the thousands of specimens in his care, their collectors and histories, and was a constant source of information, support and generosity to the researchers, students and members of the public who came through the doors. The job gave him considerable latitude to pursue interests as diverse as the Piltdown Forgery and Patagonian ground sloths but it was in the establishment of the history of the British mammal fauna that he made his name. Andy was an active fieldworker throughout his career, with particular expertise in excavating cave assemblages at key palaeontological and archaeological sites such as Westbury-sub-Mendip and Gough’s Cave in Somerset, Tornewton Cave in Devon, and Bacon Hole and Minchin Hole on the Gower coast. He also played a major role in the excavation of the Gibraltar Caves and in the analysis of the assemblages from Pontnewydd Cave in North Wales, as well as contributing to research projects in the Thames valley, East Anglia, the Bytham River and the Solent. A strong supporter of the QRA, he has made numerous contributions to Quaternary Newsletter and to QRA fieldguides from the 1970s to the 2000s, leading excursions to sites and participating in discussion meetings.

In 1989, Andy published a seminal paper on the identification of temporally discrete groupings of mammals that would become the foundation for future British Quaternary mammalian biostratigraphical research. Since 2001 and working with his great friend, the late Roger Jacobi, he published several refinements to the Late Pleistocene mammalian biostratigraphy in Britain, based on research undertaken as part of his core role in the flagship Leverhulme Trust-funded Ancient Human Occupation of Britain project. An instantly-recognisable figure, Andy also became sought-after for media appearances, particularly on *Time Team*. The QRA is delighted to make Andy an Honorary member for his contributions to British Quaternary palaeontology and the life of the QRA.

John A. Matthews

John Matthews graduated with a BSc in Geography from King's College, University of London in 1969. He completed his PhD at King's College under the supervision of the distinguished botanist and lichenologist, Dr. Francis Rose, and was appointed a Demonstrator in Physical Geography at the University of Edinburgh in 1972. He became a Lecturer in Geography at the University of Wales, Cardiff, in 1977 and moved to Swansea University to take up a Chair of Physical Geography in 1994. He has been Emeritus Professor of Physical Geography at Swansea since 2007, having chosen to retire aged 60 in order to devote himself more fully to research, and has successfully increased his rate of output since retirement!

Throughout his career, John's research has focused on glacier forelands and Holocene environmental change. His approach has been empirical and field-based. He has carried out field research in Finnish Lapland, northern Sweden, Kenya, Austria and the Brecon Beacons (Wales), but his main focus has been on the mountains of southern Norway, for which he has organised and led 42 annual Jotunheimen Research Expeditions, which still continue. This means that he has spent around six years of his life in a tent! He received the Ness Award of the Royal Geographical Society in 1988 for these expeditions and the importance of the Anglo-Norwegian links was recognised in 2005 when he was invited by the Queen to the State Banquet to honour the King and Queen of Norway at Buckingham Palace on the 100th anniversary of Norwegian independence. He shared this honour with his wife of 30 years - who has never stayed a night in a tent!

Two main themes have dominated his research: first, the investigation of chronosequences (the time zones of different ages in front of retreating glaciers) as a methodological device to understand better the biophysical landscape; and, second, the reconstruction and dating of Holocene glacier and climatic variations and their effects on the landscape. After beginning as a biogeographer/ecologist from a PhD on plant succession on the Storbreen glacier foreland in Jotunheimen, his research interests broadened in scope and shifted in emphasis



towards dating techniques and reconstructing glacier variations. This began with lichenometry, and later developed through radiocarbon dating and the establishment of the Swansea Radiocarbon Dating Laboratory with Quentin Dresser. Research focused particularly on age-depth relationships in soils buried beneath moraines, and rare near-continuous records of Holocene glacier variations, and reconstruction of debris flow, especially in collaboration with Wibjörn Karlén, Atle Nesje, Sven-Olaf Dahl, and Matti Seppälä. More recently, John has been instrumental in the development and application of Schmidt-hammer exposure-age dating (SHD) for dating rock surfaces.

John has published over 150 research publications, including nine books. Beyond his personal research, his most important contribution to Quaternary science has been to found and edit *The Holocene*, an international journal focusing on recent environmental change. This journal has probably done more than any other publication to develop and cement links between Quaternary science and wider aspects of environmental and climate change, particularly raising awareness of Quaternary climate change as a context for future anthropogenic climate change. He was also co-ordinating editor of the book series *Key Issues in Environmental Change* and the *Encyclopaedic Dictionary of Environmental Change*. These contributions reflect his belief in physical geography and Quaternary science as part of a larger nascent discipline of 'environmental change', which ranges from the geological record to the latest manifestations of anthropogenic effects on the Earth's geo-ecosystems. These views are further developed in his latest books: the *Handbook of Environmental Change* (2012), and the forthcoming *Encyclopedia of Environmental Change* (2014). For all his past, present and future contributions to Quaternary science, the QRA is delighted to award John Honorary Membership of the Association.

Dan Charman
QRA President

Danielle Schreve
QRA Vice-President

REPORTS

QRA FIELD MEETING THE QUATERNARY OF THE MONADHLIATH MOUNTAINS AND THE GREAT GLEN

Fort Augustus, 17th – 20th April 2013

Introduction

'The Monadhliath Mountains in central Scotland are dominated by a large dissected plateau area which until recently has received very little research attention.' This sentence and the prospect of visiting Scotland pre-midge season stirred the Quaternary community to attend the QRA field meeting organised by **Clare Boston** (Exeter), **Sven Lukas** (QMUL) and **Jon Merritt** (BGS, Edinburgh). 40 people from all over the UK (Brighton to Aberdeen, Durham to Belfast) assembled in the beautiful Fort Augustus, at the southern end of Loch Ness, to taste the local ale and listen to introductory presentations from Clare Boston, Jon Merritt and Callum Firth (Brighton).



Figure 1. Group photo

Day 1: The northern Monadhliath Mountains: Glen Killin and the Great Glen

The group assembled on a chilly April morning ready for a Quaternary packed day. Unfortunately, we had to bid a temporary adieu to one member synonymous with Quaternary geomorphology, Clive Auton, who had an 'incident' the previous day resulting in a lost wing mirror. Once out of sight, the meeting began at the south-western end of Loch Ness with an introductory talk by **Callum Firth** (Brighton) on the Quaternary geology and geomorphology in and around Fort Augustus. The group were surrounded by landforms and deposits including, drift limits, kame-and-kettle topography and raised shorelines, all of which provide important information for interpreting Lateglacial events. In particular the features allow calculations on re-depression of the Earth's crust by the build-up of ice in the Western Highlands during the Younger Dryas (YD) and provide evidence for a major jökulhlaup within the Great Glen. The field evidence suggests the loch level was *c.* 29 m OD during the early part of the Younger Dryas and on reaching its maximal extent, the glacier at Fort Augustus exhibited oscillatory behaviour before retreating *c.* 2 km, by which time the loch level stood at 32m OD. When the glacier had retreated *c.* 4 km, the ice-dammed lake in Glen Spean drained catastrophically beneath ice occupying the Great Glen to produce large outwash spread known as the Auchteraw Terrace. Discussion emphasised that although some questions remain concerning the precise series of events, the general consensus supported a major Younger Dryas jökulhlaup event. **Andrew Turner** (Northumbria) supplemented the visible landform evidence with data from five geophysical surveys in Loch Ness providing a valuable insight to LGM glaciation and the Younger Dryas jökulhlaup. The data revealed a complex sediment stratigraphy within two large basins divided by a bathymetric high, suggested to be a moraine (Foyers Rise moraine), marking a major standstill and grounding line system during LGM deglaciation. A *c.* 16m thick sediment package overlies proglacial sediments and progressively thins from the southern end of the basin until it onlaps the Foyers Rise. The reflection characteristics, locations and distribution of this deposit are interpreted as representing a Younger Dryas jökulhlaup gravel deposit emanating from the southern end of Loch Ness. Andrew's discussion provided the first conceptual model of ice retreat through the deep tectonic trough of the Loch Ness Basin and its depositional evolution, which would have exerted a significant control on localised ice sheets dynamics and geometry of the British-Irish Ice Sheet and further understanding Younger Dryas deglaciation.

Now fully awake and wet, the group moved northwards to Glen Killin to investigate evidence for a Late Devensian ice-dammed lake in, and around, Loch Killin led by **Clare Boston**. This meant the group had to navigate unconsolidated material, thanks to the previous nights rain, to visit the first *c.* 11 m high section followed by an easier access road-side *c.* 4 m section. The sediments are interpreted as

representing subaqueous deposition within a former glaciolacustrine environment. Some debate ensued regarding the location and direction of ice flow at the time of lake formation, with the majority of participants favouring down-valley ice flow and localised ponding. Following from this, the group later became immersed in discussion over a flat-topped hill found on top of the Monadhliath plateau, which contains Gilbert-type deltaic sediments, providing evidence for the likely altitude of the former lake *c.* 646 m. The key question arising as to whether this lake height corresponded to the altitude of a nearby col, implying an extensive ice-dammed lake, or whether the two were unrelated and the flat-topped hill was again evidence of more localised ponding.

The group continued to walk up-valley to investigate the geomorphological evidence for a Younger Dryas plateau icefield to the south of Loch Killin. **Clare Boston** led a discussion on the relative chronology of the main Killin Valley. Moraines of varying shape and size were identified in the surrounding valleys with alluvial fans prevalent in Glen Markie and prominent lateral moraines in Coire an Eich. A significant amount of sediment had accumulated in Glen Odhar with several large (*c.* 50 m) sections, moraines and incised ice-marginal meltwater channels accompanying terrace assemblages on the southeastern valley side. Using geomorphological data from other neighbouring valleys, it was concluded that the head of Glen Killin and the upper half of Coire Easgainn were occupied by glaciers during the YD to around 350 m. The upper limit of sediment accumulation in Glen Killin can be followed up-valley into Glen Markie and Glen Odhar indicating a coalescence of the Markie, Odhar and Eich tributary glaciers a short distance from the terminus. This geomorphological evidence coupled with ice-thickness modelling indicates the existence of an ice-field which supplied valley glaciers with ice from the main Monadhliath plateau to the south.

Following a satisfying lunch stop, **Sven Lukas** discussed the genesis and significance of two prominent YD moraine sections in the Killin Catchment. Despite the enthusiastic and sustained efforts of Lukas and entrenching tool, such exposures are unfortunately rare in the Monadhliath. The Easgainn Moraine is interpreted as an ice-contact scree slope due to the friable, clast-supported nature of the diamicton combined with the presence of large boulders within the distal side. In addition, the significant height (*c.* 20 m) of the moraine indicates a stable ice-margin for a substantial time period. A second moraine opposite Stronelairg Lodge displayed a more complex sequence of three diamictons interpreted as a mixture of debris-flow deposits or sedimentation within an ice-contact fan; similar assemblages are noted elsewhere in Scotland in hummocky or ice-marginal moraines. This sedimentological evidence indicates that outlet glaciers deposited large ice-contact fans during oscillatory retreat during the second half of the YD. The lack of evidence for dead-ice meltout and the proximity of these sections to the YD maxima again indicates a rapid switch from stable conditions to a temperate and changeable environment; this complex and dynamic evidence adds to our understanding of plateau ice field behaviour in glaciated and glacierised terrain.

The final stop on the Killin area wet weather tour was facilitated by **David Jarman** and took advantage of the group's proximity to the only rock slope failure (RSF) cluster in the Monadhliath. The clustering of four RSFs around the outer head of the Killin trough affects around 0.6 km² of a 20 km² area and interestingly all occur immediately outside the proposed Younger Dryas glacier limits. David suggested that this indicates a more concentrated erosion of bedrock (CEB) during the LGM relative to other nearby sites, followed by rock slope failure as a paraglacial response to this erosion. David argues that here the CEB is not driven by glacial breaching as for other RSF clusters, but that Glen Killin is still adapting to ice discharge and could be classed with other 'late-developing' side troughs. After some innovative route finding and a brief optional paddle to cross a more vigorous than usual stream, the group arrived back just in time to sample the vibrant cultural offerings of the greater Fort Augustus area.

Day 2: The eastern Monadhliath Mountains: the upper Findhorn Valley

To the disbelief of the entire group, the second day was punctuated by good weather and unsurprisingly, spectacular surroundings; all cobwebs were blown away as the next stop was the Findhorn Valley where the day was to begin.

The upper part of this valley, between Coignafearn and Dalbeg, is commanded by a sequence of river terraces and alluvial fans emerging from the Deamhaidh, Challich and Elrick tributary catchments. As the group walked up-valley, **Clare Boston** explained the significance of these striking terraces as components for assessing YD glacial limits and constructing a relative chronology for the area. Mapping suggests the grading of several fans into terraces indicating contemporaneous formation during the YD; talus-blanketed moraines overlying this terrace are likely Late Devensian. This chronology correlates with YD alluvial fan formation in Glen Roy likely due to increased sediment availability following deglaciation. This evidence connecting alluvial architecture with glacial events during the Last Glacial Interglacial Transition reflects allogenic forcing and additionally suggests that the upper Findhorn Valley remained ice-free during the YD.

Following a brief lunch stop, the group powered on to the head of the Findhorn Valley where **Clare Boston** continued to explain the glacial geomorphological evidence for glaciation during the YD. The group agreed that features such as sharp-crested moraine mounds, ridges (with a high proportion of boulders) and associated meltwater channels provided a convincing case for the presence of YD ice at the head of the Findhorn catchment sourced from the Monadhliath plateau to the southwest.

Day 3: The southern Monadhliath Mountains: Glen Banchor

The final day commenced and the group assembled, after a late night, ready for one last stimulating day of Quaternary geomorphology before commencing the long drive home. The day started in Glen Banchor, an approximately 5 km-

long valley to the south-east of the Monadhliath Mountains that runs parallel to the Upper Spey Valley, west of Newtonmore. This valley is joined by five tributary valleys, which drain the Monadhliath plateau and have recently been subject to detailed geomorphological mapping and cosmogenic radionuclide (CRN) dating. The interpretation from the mapped landsystems carried out by Boston (2012) and Trelea-Newton and Golledge (2012) both agreed that the upper glacial landsystem, at the heads of these tributary valleys, was most likely of Younger Dryas age based on similar dated landsystems elsewhere in Scotland. However, **Clare Boston** highlighted differences arose in the exact down-valley limits of the former outlets, most likely due to the issues with landform preservation due to post-glacial processes. **Ian Evans** also emphasised the importance of terminology when using the phrase ‘plateau’ in a geomorphological context. *Plateau*, suggests an upland area which is predominantly flat-topped, when in fact, for the Monadhliath Mountains and other U.K. locations, ‘plateau’ is more accurately described as undulating high ground consisting of numerous interconnecting summits.

As the group huddled together from the chilly north-easterly wind, looking more like Antarctic penguins than hardened Quaternary scientists, discussion progressed to the revised surface exposure ages derived from CRN dating by **Delia Gheorghiu**. The CRN dates were published subsequent to the mapping of Glen Banchor and far from clarifying the sequence of events, in fact, introduced considerable ‘head scratching.’ Gleann Chaorainn, a south-facing, 5 km-long valley, which is connected to the south-east corner of the plateau, formed the basis for the start of a somewhat heated discussion over the CRN dates, despite the group still being located within Glen Banchor at this stage. The geomorphology indicates ice extended from the plateau into the valley and the its morphostratigraphic context implies a Younger Dryas age. However, three CRN dates obtained from *in situ* boulders on moraines span a longer time period of 19.3 ± 1.1 ka, 16.8 ± 0.9 ka and 13.7 ± 0.8 ka, thus implying the moraines relate to an older phase of local/plateau glaciation. Lengthy discussion over the numerical and relative-age disparities produced an unexpected turn of events, witnessing the majority of the male Quaternary cohort keeping a low-profile, leaving the all-female headliners to sort out the chronology! **Clare Boston** and **Mihaela Trelea-Newton** suggested there may be an issue with the dates and politely refuted the decision of Delia Gheorghiu to favour the ‘central’ age. The discussion ended with a few smiles and all agreeing that a more comprehensive dating programme is required to produce a consistent set of absolute dates. With not a rain drop in sight the group walked c. 5 km up-valley into Gleann Ballach via the neighbouring Gleann Fionndrigh.

Clare Boston introduced the geomorphology within Gleann Ballach, which showed a clear Younger Dryas landsystem. Similar to Gleann Chaorainn the reconstructed down-valley limits differ between Boston (2012) and Trelea-Newton and Golledge (2012) with the latter placing the limit c. 45 m up-valley.

Clare Boston argued for a two-phased Younger Dryas advance, with an early advance to the outer limit followed by retreat and stabilisation up valley at the Trelea-Newton and Gollodge (2012) propped limit. Revised CRN dates by **Delia Gheorghiu** were also presented for this valley which supports Younger Dryas glaciation within the head of the valley. The dates for the two moraines debated above have been revised to 13.0 ± 0.7 ka and 11.4 ± 0.6 ka, respectively, but taking into consideration the error margins, the idea of early advance and later stabilisation during the Younger Dryas may still be applicable.

Discussion subsequently moved to a large cross-valley flat-topped ridge, which occurs at c. 495 m OD and is c. 60 m in height, standing out as significantly larger than and of a different morphology to the moraines up-valley of it. Clive Auton described recent research conducted examining the sands which make up the ridge, suggesting they relate to deposition within an ice-dammed lake formed during LGM deglaciation of the Strathspey outlet glacier. The debate centred on evidence for subsequent deformation of the ridge by ice and the direction of ice flow. **Delia Gheorghiu** suggested the CRN date from this feature of 11.2 ± 1.1 subsequently revised to 13.2 ± 0.8 ka, implies that Younger Dryas ice (flowing southwards) abutted the lake sediments to deposit the dated boulders, although accepting original deposition of the lake sediments from regional ice flowing northwards up the valley. This clearly has implications for the down-valley limit of Younger Dryas ice in Gleann Ballach, and Sven Lukas initiated a lively discussion on the possibility of exhumation of the boulders on the ridge as an explanation for the potentially young CRN ages. The group settled to tuck into a well deserved lunch break following a thorough examination of flat-topped ridge glaciolacustrine sediments, and said goodbye to David Jarman who, within five bites of a sandwich, was already a dot on the mountain side after spotting a rather good looking RSF! The group made their way back to the vehicles discussing the exciting geomorphology on the way and with much reluctance bid farewell until the next QRA meeting.

On behalf of the QRA and the delegates we would like to thank **Clare Boston**, **Sven Lukas** and **John Merritt** for organising the first QRA field meeting to the Monadhliath Mountains. The sites and discussion were stimulating and, as always, the company most enjoyable.

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QRA FIELD MEETING REPORT

THE QUATERNARY OF NORTHUMBERLAND, DURHAM AND NORTH YORKSHIRE

17th – 20th September 2013

Introduction

Northeast England, comprising Northumberland, Durham and North Yorkshire, was last visited by the QRA in 1999. Since then, and particularly in recent years, a great deal of Quaternary research has been conducted in the region, including three doctoral theses (Yorke, 2008; Davies, 2009; Livingstone, 2010) and numerous associated publications. The QRA field meeting held in September 2013 was an opportunity to take stock of this new research. It was led by **Bethan Davies** (Aberystwyth University), **Lynda Yorke** (Bangor University), **David Bridgland** and **Dave Roberts** (both Durham University) and comprised 29 members from across the UK.



Figure 1. Group photo of the QRA members present at the meeting.

Tuesday 17th September (evening)

The meeting began with an introductory lecture at Durham University. **Bethan Davies** gave a great pitch for the northeast as one of the few places in the UK exhibiting mid-Pleistocene glaciation (at Warren House Gill). **Lynda Yorke** introduced us to outwash terrace sites that we would be visiting (and some we would not be able to see!) and **David Bridgland** was particularly keen for visitors to take a look at the spectacular Durham meander during their stay – a great example of post-glacial fluvial incision. The following three days covered three distinct topics: the glaciation of eastern County Durham; ice disintegration in the lower Tyne valley and (pre-) Holocene terraces; and the deglacial basins of the Swale-Ure washlands, north of palaeo-lake Humber.

Wednesday 18th September

We had stunning weather for the first day in the field and drove straight out to Whitburn Bay on the coast of County Durham. **Bethan Davies** and **Dave Roberts** began by explaining the glacial history of the area. Key to this is the theory that two ice lobes moved over the coastline during the Last Glacial Maximum (LGM), firstly, a lobe from the Tyne Gap flowing east and secondly a lobe from the North Sea flowing south. These two lobes deposited the Blackhall till and the Horden till, respectively, whose provenance is determined by erratic clasts within the tills.

Perhaps the most intriguing feature of the site was a striking boulder pavement, which can be seen at certain points along the contact between the two tills and which provoked much discussion among the group. **Dave Roberts** suggested that it was probably a lag deposit at the base of the ice, with meltwater moving amongst the boulders and winnowing finer material away, whilst **Derek Teasdale** highlighted the striations on two large, adjacent boulders. It is possible that the two sets of striations on one of the boulders were caused by different ice masses flowing in different directions, suggesting that both ice lobes interacted with the boulder pavement.

Elsewhere in the section, **Dave Roberts** talked us through a system of pipe structures where the lower Blackhall till was reworked or removed due to hydrofractures as a result of high groundwater pressure in the underlying bedrock, prior to the emplacement of the upper Horden till. This created vertical pipes through the till of varying grain size which may have seeded the formation of gravelly channels below the ice. In case this was all getting a bit much, we then took a pause from glacial sedimentology to have an early lunch of Whitburn fish and chips à la tourist board advert and overlooking the sea.

After lunch, we moved on to Easington raised beach, a small but important site nestled on a Cliffside above Shippersea Bay on the County Durham coast. It is one of the most northerly interglacial deposits to have been reported, with well-sorted, cemented sands and imbricated gravel beach sediments sitting on Magnesian Limestone bedrock. **Bethan Davies** explained that the exposure contains Magnesian Limestone pebbles but no coal or sandstone, indicating that they were removed due to high-energy beach processes. It also contains a number of exotic pebbles most likely reworked from older glacial deposits. The beach has been dated to around 200 ka using Optically Stimulated Luminescence (OSL) on the sands and an MIS 7 age using Amino Acid Racemisation (AAR) on gastropod shells. U-series analysis of the cement gave scattered ages between ca. 7 ka and 39 ka, perhaps suggesting that some cementation occurred during the Holocene. Importantly, the beach sits at roughly 33 m O.D., which over the last 200 ka agrees with the ca. 0.19 mm a⁻¹ of progressive regional uplift of northern England proposed by **Rob Westaway** (more on this later...).

This was also an opportunity to walk over to Hawthorn Dene, the smaller of many incised valleys in the area. Heading down into the deep gorge, **David Bridgland** informed us that it is cut into bedrock, much like the Durham meander. This has allowed a unique wildlife refugium to develop and the site is now managed by the National Trust and Durham Wildlife Trust. For those not taken by the rare plants, the Durham Coast railway line crosses this gorge on a spectacular viaduct (much to the delight of some).

The final site of the day was Warren House Gill. This was not, as we were led to believe, the set of a crucial scene in the 1971 thriller '*Get Carter*' (it was actually filmed at Blackhall), though the Quaternary history of the site has been studied since the early twentieth century. It has also been mined heavily for coal, preventing further study until recent excavations by **Bethan Davies**. She talked us through several pits in which could be seen a sequence that represents Middle and Late Pleistocene glaciation. The lowermost sediments contain pebbles and microfossils derived from Scotland and the far northeast of the North Sea basin, as well as some granite erratics likely originating from Norway. This is overlain by interglacial estuarine silts. The upper part of the stratigraphy relates to three phases of Devensian ice-sheet flow: first the Tyne Gap ice stream, then Scottish ice and finally the North Sea lobe. Intriguingly, the Peterlee Member at the top of the sequence contains thick sand deposits that are dyed red from the Triassic Red Marl offshore, presumably relating to an advance of the North Sea lobe.



Figure 2. A sequence excavated by Bethan Davies at Warren House Gill.

Thursday 19th September

The second day of the field meeting took us inland to the Upper Tyne Gap to look at postglacial river terrace sediments. The weather had turned to a steady drizzle by the time we arrived to look at a gravel section exposed in a meander bend near Fourstones. **Lynda Yorke** highlighted the T_0 , T_1 and T_2 terraces visible at this location, which are part of a sequence of six distinct terraces along the valley. T_0 and T_2 are of Holocene age, supported by OSL dates of ca. 6 ka and 8.1 ka respectively (T_1 remains undated). Lynda also pointed out that the Tyne Valley till here may contain Lake District indicators, which are absent in equivalent sediments by the coast.

We then took an early lunch in Corbridge, which was somewhat delayed by slow service to those who went to the pub. Fortunately for the rest of us, service in the Co-op was significantly quicker!

The afternoon focussed on the alluvial history of the valley. **Lynda Yorke** continued to tell us about the terrace sequence, which provoked discussion of their formation, with two hypotheses proposed: either they were pre-glacial, with sediments completely filling the valley prior to subsequent incision, or they formed laterally alongside an actively retreating ice margin. Whilst continuing this discussion, we walked to Farnley Haugh, near Corbridge, where we were able to see the exposed sands and gravels of terrace T_3 in more detail. It was suggested that this incision may represent >20 m of down-cutting and refilling during the Loch Lomond Stadial given that OSL dating of the top sediments gave an average age of 10.3 ka.

This naturally led on to discussion over whether there is a climatic signal associated with the incision or whether it just represents a self-adjusting system. What ensued can only be described as a monumental [good-hearted] argument. Basically (and it became a tad convoluted as the hours passed), the crux of the argument was this: there appears to be a consistent, 30 m high terrace across the glacial valleys of the northeast, but it is not clear as to what caused it. For simplicity, we will divide the argument into two camps according to the most vocal proponents, (**Rob**) **Westaway** / (**David**) **Bridgland** and (**Dave**) **Roberts** / (**Derek**) **Teasdale**.

The **Westaway/Bridgland** model proposes that the terraces indicate 30 m of uplift, much of which had occurred prior to full deglaciation. On the other hand, **Roberts/Teasdale** suggested that the terraces are not simply a response to uplift, but are (also) likely to have formed as a result of the complex interplay between deglacial/postglacial drainage pathways and ice marginal/valley infill distribution. Fortunately, the debate was eventually diffused by mention of a very nice, old railway bridge nearby (trains again).

The group then headed back to the Corbridge for a group photo in the suitably non-Quaternary carpark (see Figure 1). We ended the day looking at a postglacial sequence at the former Merryshields Quarry, now a farm, led by **Lynda Yorke**. The area consists of ice disintegration topography, formed close to the ice margin, and sedimentary sections indicate frequent changes in discharge and are a good example of hyper-concentrated flow. That finished the day off nicely and allowed us time to get back to Durham before the formal evening dinner at Hatfield College.



Figure 3. Lynda Yorke describing the sediments at Merryshields

Friday 20th September

Our last day took us south to visit the Swale-Ure washlands, beginning with a trip to Marfield quarry which contains some spectacular glacial sediments. **Dave Roberts** began by talking us through this sequence of lacustrine sediments overlain by coarse bedded gravels, then a subglacial till, followed by coarse sands and gravels in a sandur deposit and capped by a readvance till. This upper till was suggested to relate to a thrust moraine that can be seen skirting one end of the quarry. It was suggested that the upper sandur may correspond to the now-infamous 30 m terrace, and that this terrace is therefore a consistent sandur deposit across the area, but proceedings were swiftly moved on before the argument could get going again. There is much evidence of glaciotectionism at the site, with lake clays being folded and thrust and large-scale mounds representing thrust blocks produced during local ice readvance. As part of this

explanation, **Dave Roberts** brought forth a boulder to indicate striations, but dropped it to reveal a stunning *Productus giganteus* fossil inside. This caused much excitement.

Lunch was at Snape (which amused Harry Potter fans) in a small country pub where we had a spread of sandwiches laid on. This was conveniently close to Snape Mires where we then visited to look at the pro-glacial and post-glacial sediments. **David Bridgland** and **Jim Innes** talked us through a body of research that they have been conducting. This includes work on rare Lateglacial/early Holocene tufas at Mill House and shelly marls at Ings lane, both overlying glacial lake clays. **Tom White** also informed us that local mollusc assemblages have revealed *Myxas glutinosa* and *Pisidium pseudosphaerium* species, both of which are extremely rare in British sequences.

The trip ended on a high with a visit to the Thornborough henges. These are spectacular remnants of a tripartite henge monument, likely constructed around 2800 BC, and our visit was suitably dramatic. Arriving the day before the solstice, we entered into a druid camp. Adorned in strange clothing and spouting some pretty wacky ideas, the QRA cohort clearly appeared rather odd to the druid community.

The field meeting stimulated much discussion into the Quaternary of the northeast region and was a timely summary of the great quantity of research that has recently been conducted in the region. It was an excellent meeting, and much is owed to all contributors, but particularly to the hard-work and organisation of **Bethan Davies**, **Lynda Yorke**, **David Bridgland** and **Dave Roberts**.

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ADVANCED WORKSHOP: MICROMORPHOLOGY OF SEDIMENT DEFORMATION, SCHOOL OF GEOGRAPHY, QUEEN MARY UNIVERSITY OF LONDON (QMUL)

This 5-day workshop (7-11 October), organised and run by **Simon Carr** (QMUL), **Jaap van der Meer** (QMUL) and **Emrys Phillips** (British Geological Survey (BGS)), was hosted in the Centre for Micromorphology (CfM) at QMUL. The workshop was aimed at researchers who could demonstrate a good working knowledge of sediment micromorphology, and/or those who had attended previous International Workshops on Micromorphology of Glacial Sediments. It comprised a series of informative lectures and practical training sessions examining the application of micromorphology to (glacial) sediments including a review of the processes and mechanisms of sediment deformation. The main focus however, was on exciting recent developments in the collection, manipulation and analysis of micro-scale properties of deforming sediments.

Lectures by Simon covered a comprehensive back-to-basics review of subglacial sediment deformation and current issues associated to its understanding; the quantification and digital mapping of plasmic fabrics using Metripol birefringence imaging; and recent progress in the generation of large 3D microfabric datasets using 3D computed x-ray tomography, including some excellent motion visuals. Jaap described and explained some challenging compositional and diagenetic features commonly encountered in thin sections of sediments associated to cold environments, as well as polyphase deformation and strain signatures in glacial deposits including details of several impressive, large and small scale, hydrofracturing systems. Finally, Emrys gave a series of detailed talks on the deformation, sedimentation, and liquefaction of soft-sediment beds during basal sliding; the use of micromorphology in assessing hydrofracture systems in glacial sediments; the application of digital, microstructural mapping; the value of sediment composition and provenance in micromorphology; and the analysis of deformation and liquefaction associated with mass flow deposits. Short presentations were also given by each of the workshop delegates throughout the week. On the first day of the workshop **Sam Roberson** (BGS, Northern Ireland) introduced an interesting project investigating soft-sediment glacial deformation in a drumlin field in County Down, Northern Ireland. **Lorna Linch** (University of Brighton, UK) followed with a summary of several micromorphological projects she has led from both glacial and iceberg scoured environments, and how she hopes to apply micromorphology to future research. On the second day, **Ewelina Lipka** (Adam Mickiewicz University, Poland) summarised her extensive use of micromorphology, particularly during the analysis of deformation below ploughing boulders and as part of a project investigating liquefaction in subglacial sediments. **Edouard Ravier** (University of Burgundy, France) then talked



Figure 1. Workshop participants in the Centre for Micromorphology, School of Geography, Queen Mary University of London (from left to right: Włodzimierz Narloch, Jaap van der Meer, Lorna Linch, Edouard Ravier, Emrys Phillips, Ewelina Lipka, Sam Roberson, Andis Kalyāns, Simon Carr).

about his impressive PhD research investigating soft-sediment deformation in both glacial and turbidite deposits. Later in the week **Włodzimierz Narloch** (Nicolaus Copernicus University, Poland) presented micromorphological findings on subglacial till formation processes and implications for ice sheet dynamics in north central Poland, stimulating a lively discussion. Finally, **Andis Kalyāns** (University of Tartu, Estonia) introduced a novel and unique statistical approach to microfabric examination in thin sections from glacial till.

Between lectures, workshop delegates worked collaboratively in pairs as part of six intensive practical methods training sessions run by the convenors. These sessions covered ‘Thin Section Description’ and ‘Diagenesis and Texture’ (Jaap); ‘X-ray Tomography’ and ‘Metripol Analysis’ (Simon); and ‘Microstructural Mapping’ and ‘Compositional Analysis’ (Emrys). During these highly practical, hands-on sessions, delegates were able to access and analyse over 1500 thin sections (stored in the CfM archive) using high specification Leica microscopes with in-built image capture and storage software; as well as apply the Metripol birefringence imaging system and the 3D x-ray tomography scanner to a variety of samples of their choice. In addition, delegates were given an exciting opportunity to collect and analyse data in both 2D and 3D from their own thin sections and block sediment samples as part of their personal research projects, using all the specialist equipment available to the CfM facility.

Finally, delegates were allocated each a thin section from the deeply incised, fault-guided valley of Coire Mhic-sith, located near the Drumochter Pass, central Scotland. This site preserves a sequence of fine-grained glaciolacustrine sediments which were overridden by ice during a minor readvance, and therefore preserve ample evidence of glacial deformation. Alongside the methods training sessions and lecture slots (and as part of on-going research after the workshop) delegates were given the task of describing their allocated thin sections using the range of methods utilised in the workshop. It is anticipated that all outcomes from the analysis of the Coire Mhic-sith thin sections and block sediment samples will result in a co-authored paper with all workshop participants, to be published in an international, peer-reviewed journal.

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***QRA*¹⁴ CHRONO AWARD**

RECONSTRUCTION OF SALTMARSH DEVELOPMENT DURING THE HOLOCENE: PRELIMINARY RESULTS OF A RADIOCARBON-DATED SEDIMENT CORE FROM TOLLESBURY, ESSEX

Background and rationale

Coastal saltmarshes provide ecosystem services in conservation (Doody, 2008), coastal flood defence (King and Lester, 1995), sequestering carbon (Mitch and Gosselink, 2000) and feeding and breeding/nesting grounds for fish and birds (Boorman, 1992). It is threatened by sea level rise (SLR) with an average rise estimated at 1.6 mm/year. For example, over the last 50 years a continuing erosion of 40 ha saltmarsh per year, equivalent to two thirds of the total UK saltmarsh loss was detected in south-east England (Hughes and Paramor, 2004).

Regarding literature, saltmarshes form through facilitation succession where the marsh prograde towards the sea (Adam, 1990). A competing hypothesis, proposed in my PhD project, suggests that with SLR saltmarshes develop differently, leading to marsh migration towards the hinterland. To test this, foraminifera assemblages from sediment cores are used (Bockelmann *et al.*, 2002) to reconstruct saltmarsh development. The specific aim of this QRA-¹⁴CHRONO Centre Radiocarbon Dating Award was to date plant remains from a sediment core taken at the main site near Tollesbury in the Blackwater estuary, Essex. The knowledge of the sediment age is imperative for the understanding when saltmarsh formed and how it develop in response to sea level changes.

Methodology and results

In November 2012 a 4 metre core was drilled with a percussion corer and liner sampler from a saltmarsh near Tollesbury (Figure 1). The sediment is a decalcified, unlaminated, greyish-blue silty clay which changes to a sandy silt at 3.5 metre. The top sediment is brownish in colour due to oxidation and also enriched plant horizons/lenses and roots are found. Funded by The Haptonema Charitable Trust, six samples from this core will be dated with optical luminescence dating method (OSL) at Queen Mary University of London (Wintle, 2008). Although, two test samples showed good signals, no OSL method was used before to date sediment such young as this, except for sand dunes by Ballarini *et al.* (2003).

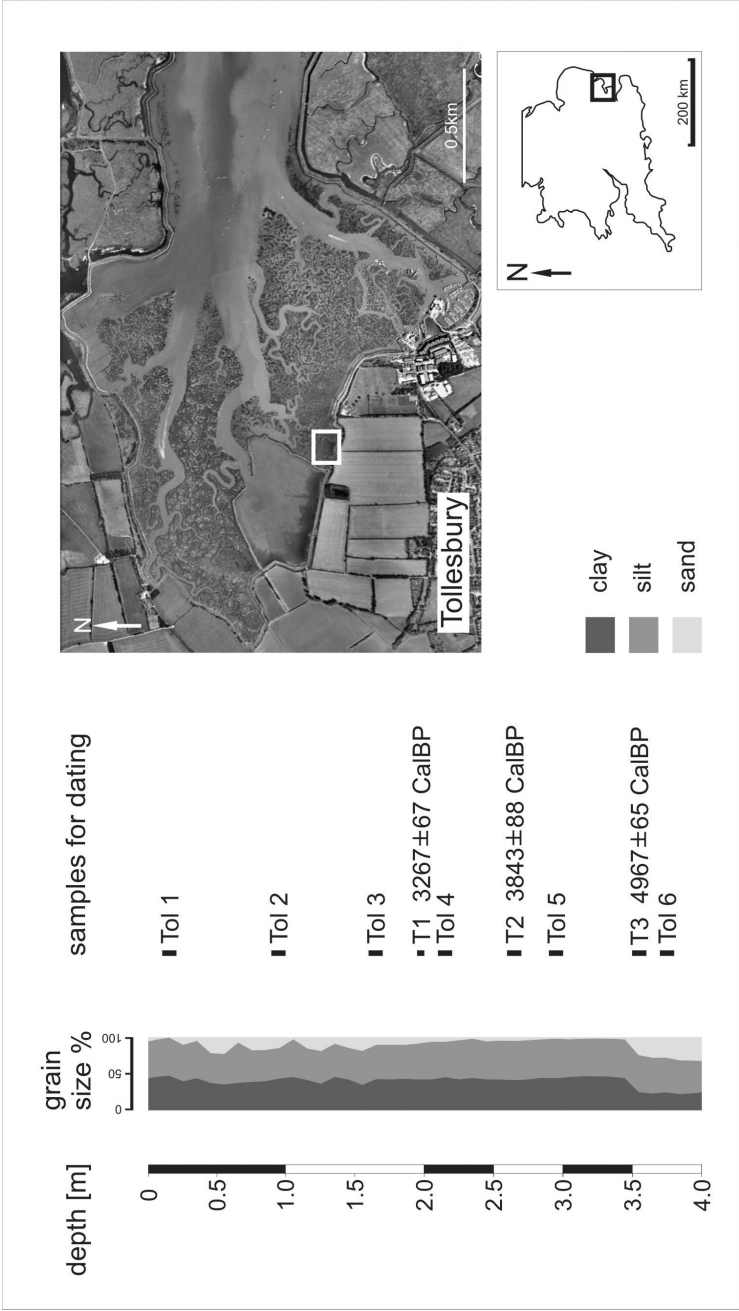


Figure 1. Location of the 4 meter saltmarsh core near Tollesbury in the Blackwater Estuary, Essex (Google Earth). Shown are the grain size analysis from the core with calculated ages of the radiocarbon samples (T1 to T3). Also the position of the six OSL samples (Tol1 to 6) are indicated.

Therefore, radiocarbon dating is needed for cross-calibration with the OSL dates. For the three samples, plant bulk samples were analysed via extracted humic acids following Lowe *et al.* (2004) at the Chrono Centre Lab at Queens University Belfast. At a depth between 195-200 cm the plant sample T1 was dated to 3267 ± 67 CalBP (UBA-23424). This plant horizon was also identified in a nearby 2.5 metre core at the same depth. At 270-280 cm depth (T2) the sediment contained less plant material which could be dated to 3843 ± 88 CalBP (UBA-23425). The water content drops below 30%. The last sample (T3) from 350-360 cm depth was dated to 4967 ± 65 CalBP (UBA-23426). There, the sediment was nearly water free, extreme dense and plant remains were very sparse, but roots were still present.

Significance

The radiocarbon dated core sediments from the saltmarsh near Tollesbury indicate that the saltmarsh was formed over 4967 ± 65 CalBP ago. This can be assumed because a 5 metre core from the same marsh contains saltmarsh foraminifera throughout and the grain size analysis shows similar results. This means that the marsh is older than the assumed 4000 years BP due to archaeological findings from the Essex coast (Wilkinson and Murphy, 1986). All three dates also show that the growth rate of the marsh was nearly constant with an calculated accretion of 1 mm per half a year.

The additional OSL samples in combination with the found foraminifera will divided the core in more sections where trans- and regressions can be identified, dated and the marsh development can be reconstructed regarding to sea level fluctuations. Also correlations with the Holocene Stratigraphy from the southern Crouch estuary estuary will be possible where a saltmarsh core show a similar age of 4100 ± 70 years BP (Wilkinson and Murphy, 1986).

Acknowledgements

I am gratefully acknowledge the QRA and the Chrono Centre, QUB for awarding me with the 2012 QRA-¹⁴CHRONO Centre Radiocarbon Dating Award. I would also like to thank Dr Sven Lukas for supervising me with the OSL and radiocarbon samples. Thanks also goes to Professor Paula Reimer from QUB with helping me process and sending off the radiocarbon samples. I am also grateful to my supervisors Dr Rob Hughes and Dr David Horne for their continued support. Also, I am thankful to my colleagues Harold Lovell and Gregory Carey without their help I would not been able to carry out the field work. At last, I also would like to acknowledge The Haptonema Charitable Trust for funding me six OSL samples.

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NEW RESEARCHERS AWARD SCHEME

LATE – GLACIAL / HOLOCENE VEGETATIONAL HISTORY OF FUEGO – PATAGONIA, SOUTHERN SOUTH AMERICA (53 - 54°S)

Background and rationale

Southern South America (SSA), is an ideal location due to its subantarctic physical setting, topography and climate for the reconstruction of changes in past vegetation communities from which climatic conditions may be inferred. In Fuego-Patagonia, the subantarctic *Nothofagus* (Southern Beech) forests have been the dominant type and may have persisted in refugia during the Last Glacial Maximum (LGM) (Premoli *et al.*, 2010).

The distribution of the Fuego-Patagonian vegetation is governed by the southern westerlies (SWW) along the Andean mountains. This results in a strong west-east precipitation gradient, which is reflected in the wet subantarctic *Nothofagus* forest in the west to the dry steppe in the east. These ecotones are particularly sensitive to environmental changes and are, therefore, important as ecological indicators of global changes.

The present project seeks to assess the establishment and the presence of refugia of subantarctic *Nothofagus* forest across Fuego-Patagonia during the Late-glacial / Holocene transition from which local and regional climatic signals may be inferred. Two field campaigns have obtained seven long cores from peat lands, three have been selected for high-resolution pollen analysis, supported by lithostratigraphic analysis, radiocarbon dating and tephrochronology.

Fieldwork

Study sites are located along the present ecotonal boundaries of *Nothofagus* forest and the steppe zone on Fuego-Patagonia. Two fieldwork seasons were carried out; during the first in January 2012 in Tierra del Fuego (53° - 54°S), two sites were sampled: Punta Yartou and Lago Lynch (Figure 1). The Punta Yartou core was obtained from a small kettle hole basin formed during ice retreat after the LGM (McCulloch *et al.*, 2005). The Lago Lynch core was from an open peat bog, within an area of small lakes and bogs within a zone of hummocky drift probably formed during the LGM. The second fieldwork season was carried out in February 2013 and a third core was collected at north east coast in Dawson Island, near to “Rio Grande” (Figure 1).

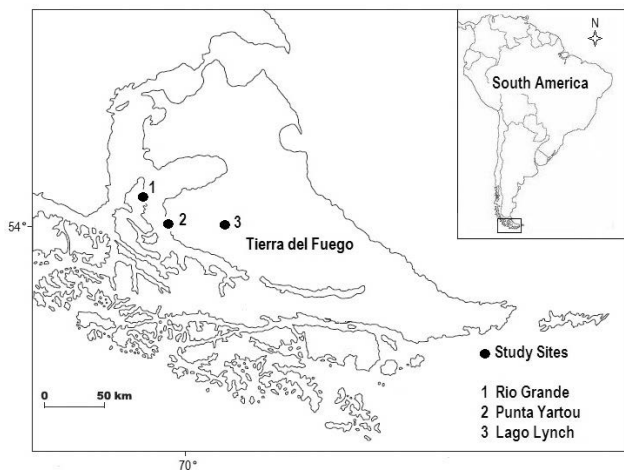


Figure 1. Study sites, Southern South America.

Preliminary results

The stratigraphy of the Fuego –Patagonia cores show the presence of blue-grey clay glacial sediment at the base. Preliminary interpretations based on the minimum ^{14}C ages suggest ice retreat sometime before *c.* 15,000 Cal yr BP. The Fuegian pollen records indicate the continuous presence of *Nothofagus* pollen, providing evidence for the persistence of *Nothofagus* forest during the Late-glacial/Holocene transition. This evidence is consistent with plant genetic data that suggests that within the south – eastern region of Tierra del Fuego *Nothofagus* may have persisted in refugia during the Quaternary ice ages and may have served as colonisation sources during the interglacials (Premoli *et al.*, 2010). Three visible and three microscopic tephra layers have also been found in the each core. Four of the tephra layers have been registered in previous work in Tierra del Fuego (Stern, 2008). Geochemical analyses will be used to describe and identify all the tephra layers found, in order to extend the tephrochronology of the region and to improve the age-depth models for the cores.

Acknowledgments

The author would like to thank the QRA for financial support for the second field season. This work would have not been possible without the help of my supervisor Dr. Robert D. McCulloch (University of Stirling, Scotland) and Dra. Flavia Morrello (Centro del Hombre Austral, University of Magallanes, Chile).

Also thanks to Jonathan Kitchen and James Blaikie for assistance in the field.

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INVESTIGATING MODERN CALIBRATIONS FOR METHANE IN HIGH-LATITUDE THERMOKARST LAKES

Background and rationale

Northern-latitude thermokarst lakes (TKLs) have recently been identified as sources of methane (CH_4), which are not currently included in regional or global CH_4 budgets due to the uncertainty associated with variability of ebullition (bubbling) within the lakes (Walter *et al.*, 2006). The current model for TKLs evolution suggests CH_4 is generated through seeps at the expanding margins, therefore if a record of CH_4 activity is preserved in lake sediments, its temporal and spatial distribution will alter depending on the location of a core.

Recent studies have shown the ability of some chironomid (non-biting midges) taxa to utilise CH_4 oxidising bacteria (MOB) as a viable food source within lakes (see Jones and Grey 2011 for details). Biogenic CH_4 produced in lakes has a highly depleted $\delta^{13}\text{C}$ isotopic signal in comparison to its source material and other potential food sources within the lake and studies have shown taxa such as *Chironomus anthracinus*-type and *Chironomus plumosus*-type have been observed with highly depleted $\delta^{13}\text{C}$ values (Jones and Grey, 2004). Further studies have suggested that a CH_4 signal can be determined through chironomid head capsules (Van Hardenbroek *et al.*, 2010).



Figure 1. A typical thermokarst lake. Slumping margins are seen in the foreground.

Methods and Study Area

This fieldwork aimed to test the relationship between chironomid larvae and CH₄ in TKLs with samples taken from lakes in central Alaska. The NRWA provided support for the fieldwork, which was completed during the summer of 2012. Surface samples were collected from two TKLs in order to address the aim above.

Ten 0-5cm surface samples were taken from two distinct areas within the lakes; the thermokarst zone and non-thermokarst zone, in order to establish differences in chironomid communities associated with methane generation and oxidation.

Samples were picked for both larvae and chironomid head capsules and sent to the NERC Isotope Geochemistry Laboratory at the British Geological Survey for stable isotope analysis.

Preliminary Results

Initial stable isotope measurements of chironomid larvae and head capsules have shown little to no added depletion in $\delta^{13}\text{C}$ values in comparison to bulk sediment and macrophyte values. A 1-2‰ offset in a more negative direction is observed in the larvae which is likely to be attributed to fractionation due to vital effects. The $\delta^{13}\text{C}$ values show that chironomid larvae show little to no evidence for the contribution of MOB in their diet, or at least that ingestion of MOB has had any effect of the stable isotopic composition of the chironomid larvae.

Acknowledgements

I would like to thank the QRA for their contribution of funds towards the fieldwork costs. I would also like to thank Geography and Environment, University of Southampton for funding the overall research project, to Professor Mary Edwards and Dr Peter Langdon for their supervision throughout the project and generous help in the field. Financial support from the NERC Isotope Geosciences Facilities steering committee for support (IP-1273-1111) is also gratefully acknowledged.

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INVESTIGATING THE TEMPERATURE- $\delta^{18}\text{O}$ RELATIONSHIP OF BRITISH FRESHWATER MOLLUSCAN SHELL: MODERN ANALOGUE STUDIES AND THE SIGNIFICANCE FOR UNDERSTANDING INTERGLACIAL CLIMATES

Background and rationale

The $\delta^{18}\text{O}$ of freshwater carbonates has been demonstrated to be controlled largely by air/water temperatures in temperate, mid-latitude regions such as Britain (Andrews, 2006; Candy *et al.*, 2011), therefore has potential to provide quantitative climatic information from Quaternary deposits that contain carbonate material. In Britain, these deposits typically are rich in aragonitic freshwater mollusc shells (e.g. Preece, 2001); however the $\delta^{18}\text{O}$ composition of these shells has infrequently been studied. This is due to a lack of modern analogue studies, thus an understanding of the relationship between mollusc shell $\delta^{18}\text{O}$ composition ($\delta^{18}\text{O}_{\text{shell}}$), the $\delta^{18}\text{O}$ composition of water ($\delta^{18}\text{O}_{\text{sourcewater}}$) from which they have mineralised and water temperatures.

This study was conducted to address the relationship between these variable for selected taxa in three lowland fluvial systems in southern Britain with the aim of elucidating the modern temperature- $\delta^{18}\text{O}_{\text{shell}}$ relationship in freshwater gastropods. This will build upon previous single-catchment studies (Waghorne *et al.*, 2012, Davies, 1999) and help ascertain if this relationship is regionally consistent.

Methodology

Three lowland fluvial sites were selected for study: R. Thames, R. Colne and R. Wey. Monthly water spot samples from the sites were collected between November 2011 - December 2012 and the $\delta^{18}\text{O}$ composition analysed. Concurrent water and air temperature data for each was obtained from Environment Agency. Living shells were collected after the sampling period and their shells were prepared for $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ analysis following standard methods (Waghorne, 2012). Results are presented from one gastropod taxon: *Bithynia tentaculata* (L).

Preliminary Results

The $\delta^{18}\text{O}_{\text{sourcewater}}$ and $\delta^{18}\text{O}_{\text{shell}}$ from each site are presented in Table 1. The $\delta^{18}\text{O}_{\text{sourcewater}}$ from all three sites shows consistent values across the year. The lack of seasonal variation suggests that the $\delta^{18}\text{O}$ composition is driven primarily by isotopically homogenised groundwater recharge rather than air temperature

fluctuations, as suggested by Darling (2003) and observed in other lowland rivers systems (Waghorne *et al.*, 2012; White *et al.*, 1999).

The $\delta^{18}\text{O}_{\text{shell}}$ values from each indicate that *B. tentaculata* shells are mineralised in isotopic equilibrium with source water as previously established by Waghorne *et al.* (2012). Deviations of $\delta^{18}\text{O}_{\text{shell}}$ composition therefore, are primarily the result of temperature-controlled isotopic fractionation, thus can be used to infer water temperature at the time of mineralisation. Using White (1999) palaeotemperature equation, these the $\delta^{18}\text{O}_{\text{shell}}$ composition suggests mineralisation at a temperature range of 10-16°C, which is broadly consistent with spring-summer water temperatures recorded at all three sites. However, there is some intra and inter-site variability in $\delta^{18}\text{O}_{\text{shell}}$ values, which may suggest some site-specific influences affecting $\delta^{18}\text{O}_{\text{shell}}$ composition.

Table 1. Descriptive statistics for water and shell $\delta^{18}\text{O}$ composition analysed from the River Thames, Colne and Wey. Shell values are expressed relative to PDB; water values relative to SMOW. Calculated temperatures based on White (1999) palaeotemperature equation, temperature range calculated from standard deviation of both water and shell dataset

	Water $\delta^{18}\text{O}$ (‰ V-SMOW)			Shell $\delta^{18}\text{O}$ (‰ V-PDB)			Calculated °C	°C Range
	N	Average $\delta^{18}\text{O}$	S. D (1 σ)	n	Average $\delta^{18}\text{O}$	S. D (1 σ)		
Thames	12	-6.56	0.23	5	-4.65	0.61	12.1	1.8
Colne	12	-6.81	0.17	5	-4.64	0.84	10.9	3.2
Wey	12	-6.54	0.18	5	-5.30	0.09	15.7	0.5

Significance

Preliminary results from this study indicates that *B. tentaculata* shell mineralisation occurs in isotopic equilibrium with $\delta^{18}\text{O}_{\text{sourcewater}}$ at water temperatures experienced in spring-summer months, suggesting the potential for $\delta^{18}\text{O}_{\text{shell}}$ to be used as a temperature proxy in Quaternary deposits that yield freshwater molluscs. There is however some variability in this relationship which needs to be assessed prior to use. Further work will focus on this and also testing the modern $\delta^{18}\text{O}_{\text{shell}}$ - water temperature relationship for other freshwater taxa.

Acknowledgements

The author would like to thank the QRA NWRA you funded the water $\delta^{18}\text{O}$ analysis as part of this study. Water samples were analysed at NIGL, Keyworth, and shell samples analysed in the Department of Earth Sciences, RHUL. The Environment Agency is acknowledged for the supply of water and air temperature data. Thanks are also extended to all of those that helped with sample collection.

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ABSTRACT

THE MID-TO-LATE PLEISTOCENE PALAEOENVIRONMENTS OF THE GORDANO VALLEY, NORTH SOMERSET

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This study constitutes the first reconstruction of Pleistocene palaeoenvironmental change from the Gordano Valley, a low-lying valley marginal to the Severn Estuary in southwest England. The valley lies at the limit of Pleistocene glacial expansion and the threshold of terrestrial, marine and fluvial environments. An axial alignment opposite to that of the Severn Estuary provides a regionally unique preservational environment for valley floor Pleistocene sediments. These sediments potentially contain an important archive of palaeoenvironmental information yet they have received limited attention from previous researchers.

Data from 489 manual cores are used to determine the aerial extent, surface morphology and geometry of the uppermost minerogenic sediments. These reveal a patchwork of sands, silts and gravels with a hummocky surface topography and a central basin or channel. Stratigraphic, sedimentological and palaeontological analysis of eight percussion cores reveals thinly bedded, very poorly sorted gravel, silt and sand units with an altitude range of *c.* -2.5 to +3 m OD. Two units record abundant temperate freshwater and intertidal fossil material. Using a multi-faceted methodology, detailed analysis of relatively small volumes of material from core samples of the Gordano Valley's minerogenic sediment archive has identified complex sequences of depositional and post-depositional environmental change. The sediments are characterised as representing a range of Pleistocene palaeohydrological environments interspersed with a number of periods of non-deposition, and involving a number of processes (aeolian, colluvial, pedogenetic, various fluvial, intertidal). Radiocarbon and optically stimulated luminescence dating and amino acid geochronology indicate Mid-to-Late Pleistocene deposition. A revised model of the Pleistocene Gordano Valley, presented here, suggests a landscape in which alluvial fans formed close to the valley margins and freshwater streams and interconnected pools which were open to tidal influence formed along the valley axis. The elevation of intertidal deposits appears to provide terrestrial validation for a low late-MIS 7 sea-level, in terms of known global sea-level, without recourse to a regional uplift model.

This thesis has demonstrated the potential to produce high-resolution reconstructions of environmental change from relatively small volumes of material, contributing an enhanced geochronology of landscape response to Mid-to-Late Pleistocene climate change in the Bristol Channel/Severn Estuary region that has wider national importance in the context of coastal lowlands.

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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.

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