

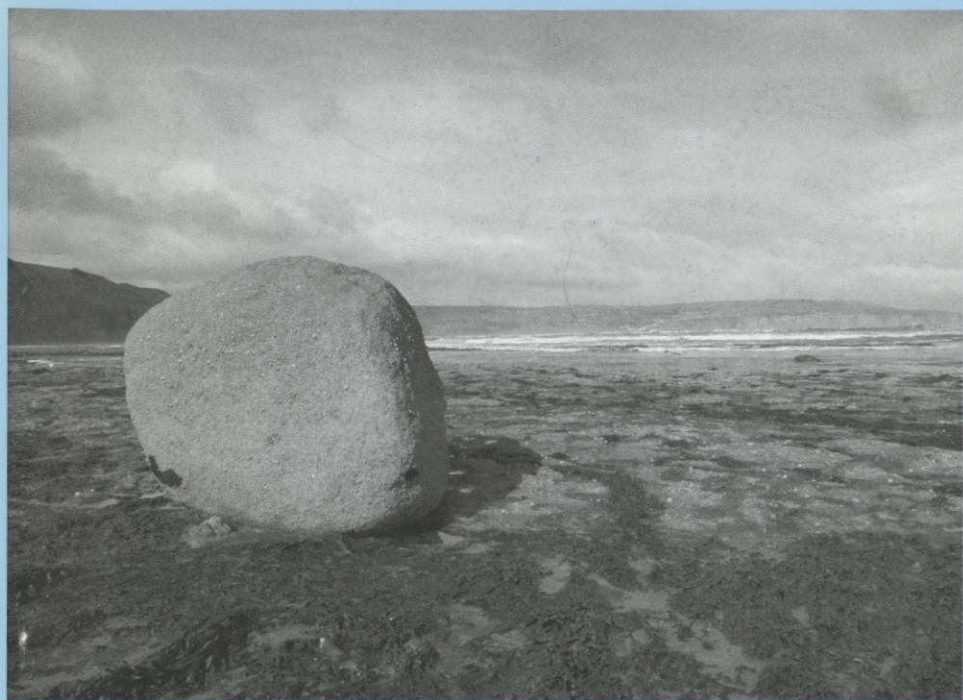
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# QN

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 1<sup>st</sup> January, 1<sup>st</sup> May and 1<sup>st</sup> 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 Jpeg format. Quaternary Research Fund and New Research Workers 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.

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## COVER PHOTOGRAPH

Coverphoto caption: Shap Granite glacial erratic on wave cut platform in Robinshood bay, East Yorkshire (photo by Mark Bateman).

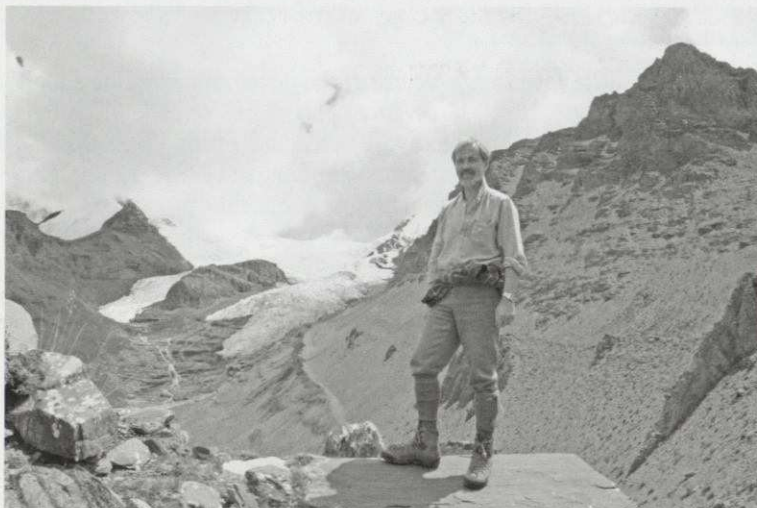
# **JAMES CROLL AWARD**

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## **THE INAUGURAL JAMES CROLL MEDAL (2011)**

The James Croll Medal has been instituted by the QRA in 2011 as its senior award and is named in honour of James Croll (1821-1890). Croll is most closely associated with fundamental work on the astronomical theory of the ice ages, but he also made seminal contributions on the glacial geology of Scotland, on the mechanisms that drive ocean circulation and the impact of that circulation on recent climate, on tidal theory and the rotation of the Earth. These are all major issues that occupy Quaternary scientists to this day. Croll was effectively self-taught. His work and example demonstrate that individuals from all backgrounds can rise to national eminence and generate science of lasting and major international impact, that it is not who you are or where you come from but what you do that is important. These are the qualities that the QRA seeks to celebrate in the award of the James Croll Medal. The Medal is therefore awarded to a member of the QRA who has not only made an outstanding contribution to the field of Quaternary science, but whose work has also had a significant international impact.

For anyone working in the fields of glaciology, glacial geomorphology and Quaternary glaciation it is impossible to be unaware of the seminal contribution of Geoffrey Boulton. This is aptly reflected in the long list of accolades to the man and his research. These include a D.Sc. from the University of Birmingham, his election as Fellow of the Royal Society and of the Royal Society of Edinburgh, the awards of the International Glaciological Society's



Seligman Crystal and Geological Society's Lyell Medal, and most impressively an OBE for his contribution to science and higher education. The Geological Society regards Geoffrey as one of the most influential Earth scientists of his generation, based on both the enormous scientific impact of his research and widely cited papers as well as his more recent appointments as adviser on science policy to Westminster, the Scottish Parliament and Europe. The QRA hereby adds its own accolade to the career achievements of Geoffrey Boulton through the award of its newly-established James Croll Medal. This is recognition of Geoffrey's monumental contributions to the understanding of the geological and geomorphological record of Quaternary glaciation.

Throughout his career Geoffrey has been at the forefront of developments in his science, largely because his meticulous observations have been paired with significant theoretical and conceptual breakthroughs. His early work on glacial geology and glaciology in Svalbard in the 1960s and 1970s resulted in seminal papers on process-form relationships in glacial sedimentology, systematically elucidating the ways in which complex sequences of tills and associated stratified sediments could be produced in a single glaciation. The implications of this research for Quaternary stratigraphy were explained by Geoffrey in the little known journal *Cambria* in 1977 in a paper on the sequence exposed in the coastal cliff at Glanllynau on the Llŷn Peninsula in North Wales, a benchmark contribution that laid the foundations for recognizing subglacial and melt-out tills. The importance of Geoffrey's early work is amply illustrated by the number of times his papers have been cited by subsequent publications on glacial topics. Notable in this respect are Boulton (1967, 1968, 1970a, 1971, 1972a, 1972b, 1975) on the processes and patterns of glacial debris release on modern glaciers, Boulton (1974, 1979a) on glacial erosion, Boulton (1970b, 1978) on debris transport pathways in glacier systems, and Boulton (1976, 1982) on subglacial bedforms.

In the 1980s Geoffrey was at the centre of the development of the subglacial deformation paradigm, based in no small part on his remarkable subglacial tunnel experiment at Breiðamerkurjökull in Iceland. From this work came the hugely influential papers of Boulton and Hindmarsh (1987), Boulton (1987) and Boulton and Dobbie (1998), which linked real-time process observations with theoretical models of drumlin formation. With the aid of very able colleagues, Geoffrey then scaled up the implications of his research findings to craft thought-provoking reconstructions of whole ice sheets (e.g. Boulton *et al.*, 1977, 1985; Boulton and Jones, 1979; Boulton and Clark, 1990a, b) and to construct benchmark conceptual models on the relationships between regional glacial sedimentology and ice dynamics (Boulton, 1996a, b). At the same time Geoffrey was developing further seminal output on subglacial drainage networks, producing models of ice sheet drainage (Boulton and Caban, 1995; Boulton *et al.*, 1995) and conducting yet more fascinating experiments with real glaciers

(Boulton *et al.*, 2001a, 2007a, b). Geoffrey has also been active in tackling smaller-scale geomorphic and stratigraphic problems, often in collaboration with a vibrant and productive postgraduate research team, delivering widely cited papers on glacetectonics (e.g. Hart *et al.*, 1990; Hart and Boulton, 1991), moraine construction (e.g. Boulton and Eyles, 1979; Boulton, 1986; Boulton, *et al.*, 1996, 1999), glacimarine sedimentation (e.g. Boulton, 1990) and regional Quaternary stratigraphy (e.g. Boulton, 1979b, c; Boulton *et al.*, 1982). Whole ice sheet palaeoglaciology is now the order of the day in Quaternary glacial research and again Geoffrey has been at the forefront of its development, as demonstrated by (Boulton *et al.*, 2001b) on the European Ice Sheet and Boulton and Hagdorn (2006) and Boulton (2010) on the British Ice Sheet.

The true reflection of the impact of this body of research by Geoffrey and his colleagues is ultimately in its citation, which is indeed impressive. The citation records speak for themselves; more than 25 of Geoffrey's authored and co-authored papers have been cited more than 50 times. No review paper or textbook with glacial content is without at least one Boulton diagram, typically consisting of a carefully crafted synopsis of spatial and temporal change in a complex system.

It seems singularly appropriate that Geoffrey should be the recipient of this, the inaugural James Croll Medal. Though we're not aware that Geoffrey has ever been employed as a janitor, as Croll was at the Andersonian College in Glasgow, in other respects their profiles coincide: fundamental and enduring research contributions to the understanding of Quaternary glaciation and stratigraphy, and careers set amidst the deep traditions of Scottish geology. Geoffrey has also been a very long-lasting, and active member, of the Quaternary Research Association, serving as one of its most influential recent Presidents between 1991 and 1994. The QRA are delighted to be able to honour Geoffrey with the award of the first James Croll Medal.

**Dave Evans**  
**QRA Vice-President**

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## RESPONSE FROM GEOFFREY BOULTON ON HIS AWARD OF THE JAMES CROLL MEDAL

It is a delight and an honour to have received the first James Croll Medal from the Quaternary Research Association. I am immensely fond of the QRA. It is an extraordinary organization. It has succeeded over the forty-six years of its life in retaining a freshness and a continual capacity to reinvent itself in addressing contemporary scientific imperatives that many other scientific bodies might envy. Part of its strength has been its refusal to adopt the top-heavy bureaucracy or formalized structures that many organizations feel they should create as they grow. A consequence of this is reflected in the QRA's capacity to respond to the fresh insights of successive generations from the great variety of disciplines that contribute to our understanding of the evolution of the recent Earth.

I am almost certainly the only one here who was present at the meeting in Birmingham in 1964 that created the Quaternary Field Study Group, which changed its title to Quaternary Research Association four years later. At that time, true inter-disciplinary studies were almost unknown in science, and it is a tribute to the QRA's founders that from the start it attracted, and has retained, the enthusiasm of brilliant exponents from a wide variety of disciplines with a common interest in fusing their different strands of knowledge to create syntheses that are greater than the sum of the disciplinary parts. In its earliest years, the opportunity to talk, discuss and argue in the field with the likes of Fred Shotton and Russell Coope from geology, Richard West and Harry Godwin from botany, Donald Baden-Powell and Gail Sieveking from archaeology, Alec Skempton, one of the "greats" from civil engineering, Eric Brown and Brian Sissons from geomorphology, John Wymer from palaeoanthropology and Nick Shackleton from the emerging discipline of palaeo-oceanography were inspirations to many a young scientist.

One of the great strengths of the QRA has been its focus on field excursions. It is a remarkable index of the progress of science that in returning to the same sites in each generation we find new insights derived from advances in contributory disciplines. But it has the weakness of tempting us to be parochial, rather than using the Thames terraces, Highland moraines, or East Anglian vertebrate fossils as a basis for globally applicable general understanding.

The early excursions of the QRA were innocent affairs, based merely on the natural historian's delight in understanding the world we live in, largely unrelated to any utilitarian motives. But this innocence began to be lost after the demonstration by Hays, Imbrie and Shackleton in 1976 of the correctness of James Croll's insight about the astronomical cause of Ice Ages, developed further by Milankovitch, with the conclusion that orbital changes were the

pace makers of long term climate. It was realised that the orbital signal needed to be amplified to explain the magnitude of Quaternary climate change, that atmospheric carbon dioxide could be the amplifier and that its recent anthropogenic increase could be the cause of changes that could throw future climates off their natural trajectory. Quaternary science had now become central to a growing need to understand how and why the mosaic of climate and environment changes, how the human species might be influencing change, and how we might need to change our behaviour if humanity is to live optimally in its planetary home. As Mark Twain, a great intuitive geologist, commented, "if the past does not repeat itself, it at least rhymes."

Quaternary science, often unwittingly and unwillingly, now finds itself thrust into a problematic political and policy arena. Many object strongly to the idea of major human impact on climate, on any limits to growth and the idea that the human economy is a wholly-owned subsidiary of the environment. At the same time, the demands for predictive certainty in view of the massive costs of mitigation and adaption pose a great challenge to us in finding useful ways of contributing to the public and policy debate that avoid the temptation of unjustified certainty. George Porter once said that "there are only two sorts of science; applied and not yet applied". Quaternary science has made that transition.

It is very timely therefore that next year's annual discussion meeting is concerned with the contribution of Quaternary science to public policy. As someone who has been heavily involved in science policy for Government, I recognize the challenge. It will be to avoid rhetorical statements about the variability of climate and environment, but to find how to engage with policymakers and public in ways that they recognise to be important and relevant to their interests and concerns.

However, the underlying motivation for most of us remains the excitement and the frustration of doing science, in its "wholesale return of conjecture out of such a trifling investment of fact", and the obsessive need to poke further into the unknown and tell others of our discovery in yet another paper, which will of course be the best we have ever written. This happens without thought of prizes or medals, but if they come from bodies that we admire, they are profoundly satisfying. But the antidote to foolish pride, which I cannot resist repeating, was provided by the late, great Billy Wilder, that "honours are like haemorrhoids, if you wait long enough, every asshole gets one!"

**Professor Geoffrey Boulton**  
**School of Geosciences**  
**University of Edinburgh**  
**Edinburgh EH9 3JW**

# LEWIS PENNY AWARD

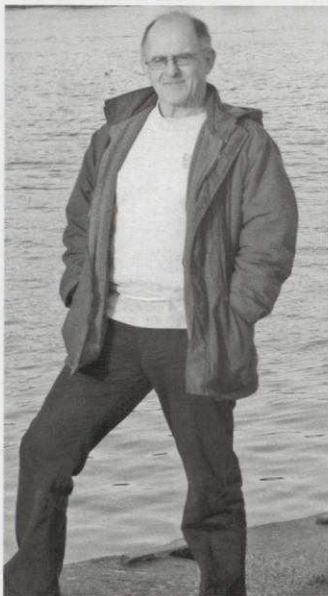
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## THE 2011 LEWIS PENNY MEDAL

We are delighted to announce that the fifth, the 2011, Lewis Penny Medal is awarded to Dr Paul Butler of Bangor University. The offering of this medal, in memory of Lewis and his contributions to Quaternary science and his support of the QRA, was made possible through the generosity of many of Lewis's former students, friends and colleagues. The prize is intended to recognize 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.

Paul Butler is both an exceptional and unusual recipient for the Lewis Penny Medal; exceptional in terms of his abilities, impact and his central role in the rapidly developing field of molluscan sclerochronology and scleroclimatology; unusual in that, now aged 56, his research career has developed following a return to academic study in 2001 following a career as a systems analyst. He has therefore risen to his current status in marine palaeoclimate research from a standing start as an undergraduate within nine years.

Sclerochronology is analogous to dendrochronology on land. Many molluscan bivalve species, notably *Arctica islandica*, contain annual increments akin to tree-rings. It has been demonstrated that increment variability is common to the individuals within a population, so these series can be cross-matched to generate absolute records of the marine environment that can extend potentially over thousands of years. Furthermore, through calibration with instrumental series, it has been demonstrated that increment variability is often a function of marine climate, such as summer sea temperatures. These series in themselves therefore provide ultra-high-resolution records of marine climate variability, they can be interrogated geochemically (stable isotopes, trace elements) to



generate detailed palaeoclimatic data and can be used to calibrate marine radiocarbon. Records of such resolution and potential have not before been available from the middle and high latitude oceans; such records are critical for reducing uncertainty in model simulations of future climate.

Paul Butler has been centrally involved in these developments. He returned to full-time study in 2001 and was awarded a First Class Degree in Ocean Sciences at Bangor University in 2004. He was then awarded the Cemlyn Jones Studentship for his Ph.D. on *A. islandica* sclerochronology in the Irish Sea, awarded in 2009, and is now employed as a Research Fellow in the School of Ocean Sciences at Bangor. His record is exceptional. He has 1. generated the first multi-centennial *A. islandica* series (Butler *et al.*, 2010 QSR), 2. generated a continuous marine reservoir calibration for the last 450 years from the Irish Sea (Butler *et al.*, 2009 EPSL), 3. published the first high-resolution record of the Suess effect from the temperate ocean (Butler *et al.*, 2009 EPSL), 4. demonstrated that the common growth signal is coherent across distances up to 80 kilometres in the North Sea (Butler *et al.*, 2009 *Paleoceanography*), 5. undertaken detailed appraisal of different detrending methods applied to shell series (Butler *et al.*, 2009 EPSL), 6. established that  $\delta^{13}\text{C}$  can be used as a reliable palaeoenvironmental indicator in the mature increments of *A. islandica* (Butler *et al.*, online, P3), 7. contributed to significant technical developments in sclerochronology (Wanamaker *et al.*, 2009; Karney *et al.*, 2011) and 8. was centrally involved in the discovery of the longest-lived non-colonial animal known to science (Wanamaker *et al.*, 2008). He is currently working on a 1,500-year series from Icelandic waters that will be published in a high profile journal. The key to this success is Paul's ability to "read" shell series, to decode these records, and to apply advanced statistical methods derived from dendrochronology to cross-match and cross-date to correlate them together. He is therefore a code-breaker. This is above all a stratigraphic endeavour, and it is in chronology construction that Paul's expertise is paramount. The focus of this work has been in reconstructing the Late Holocene palaeoenvironments and stratigraphy of the seas adjacent to the UK. It was clear from the 2<sup>nd</sup> International Conference on Sclerochronology (Mainz, July 2010) that Paul is widely respected as *the* authority on cross-matching of shells. To have attained this status in nine years is extraordinary and thoroughly deserving of the award of the Lewis Penny Medal.

**James Scourse**  
**QRA President**

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## RECENT ADVANCES IN SCLEROCHRONOLOGY

Dr Paul G. Butler (School of Ocean Sciences, Bangor University)

### Introduction

First of all, I'd like to thank the QRA Awards Committee for honouring me with the Lewis Penny Medal. In a way, I feel a bit of a fraud, since it's clearly intended for a "young" researcher, the extra clause allowing for "new" researchers having possibly been added after consultation with m'learned friends. At the age of 57 ( $\pm 2$ ) I feel neither young nor particularly new, but I have to admit it's less than two years since I was awarded my PhD. Well, it takes some of us longer than others .... The truth of the matter is that I'm "new to scientific research", since I returned to academia in 2001 after a career as a computer consultant to study for a BSc in Ocean Sciences at Bangor, so I guess I'm batting for the small community of people who have undertaken a radical career change at quite a late stage in their life.

I was fortunate after finishing that BSc to be offered the chance to apply for the Cemlyn Jones Studentship, an award funded by a legacy to the School of Ocean Sciences (SOS) at Bangor whose remit is the study of the marine history of the locality. The project on offer came out of what seemed a fairly obscure field: sclerochronology, a marine version of dendrochronology which uses the annual growth increments in the shells of long-lived marine clams as an equivalent of tree-rings. But one thing I'd learnt while studying the climate change debate was that the lack of high resolution archives for the marine environment represented a significant gap in the proxy record and I appreciated that this studentship could, if successful, constitute a significant step towards completing the picture.

It's important at this point to acknowledge my mentors at Bangor, leading scientists in their respective fields who have been a source of enormous inspiration to me and who had enough confidence in my abilities to steer me towards my research field. Sclerochronology is something of a multidisciplinary field and its application requires insight into the biological, ecological and climatological drivers of shell growth and interpretation of the geochemical, morphological and structural properties of the shell. We are very fortunate at SOS to have on the research staff Professor Chris Richardson (a pioneer of research into the biological aspects of shell growth) and Professor James Scourse (who is well known to all of you for his work on ice sheet dynamics and North Atlantic palaeoceanography). I've been told that their interest in sclerochronology resulted from a chance meeting during a coffee break which subsequently led to the inclusion of a sclerochronology element in an EU 5<sup>th</sup> Framework project on Late Holocene shallow marine environments around

Europe (“HOLSMEER”). This work led to the development of the proposal for my studentship, a 1,000-year shell-based chronology using growth increments in the shell of the bivalve clam *Arctica islandica* from the Irish Sea.

## Research

*Arctica islandica* has turned out to be a quite remarkable beast, most famously because of its extreme longevity. When I started work on the studentship back in 2004, Chris and James were working on a floating chronology which included a 267-year old specimen from the North Sea. At the time, this was thought to be the longest-lived non-colonial animal known to science (Scourse *et al.*, 2006), but even before their paper had been published, our German colleague and sometime rival Bernd Schöne reported a 374-year old from Icelandic waters (Schöne *et al.*, 2005a). Since then, the record has been pushed out even further, but more of that anon. The main scientific benefit of the longevity of *A. islandica* is not in breaking records, but in the fact that it can be used to build an absolute timescale for the marine environment. This is because (a) its lifespan is recorded in annual increments in the shell, (b) the increments show distinct variability from year to year and (c) the shells grow synchronously within populations. The implications of this last point are profound, for it constitutes *prima facie* evidence that the shells are recording a common environmental signal, and at the same time it enables them to be crossdated back in time so that shell material in dead collected shells can be absolutely dated if their patterns of growth can be matched with similar patterns in live collected shells with a known date of death. The characterization of *A. islandica* as the “Tree of the Sea” (Witbaard, 1997) is apposite.

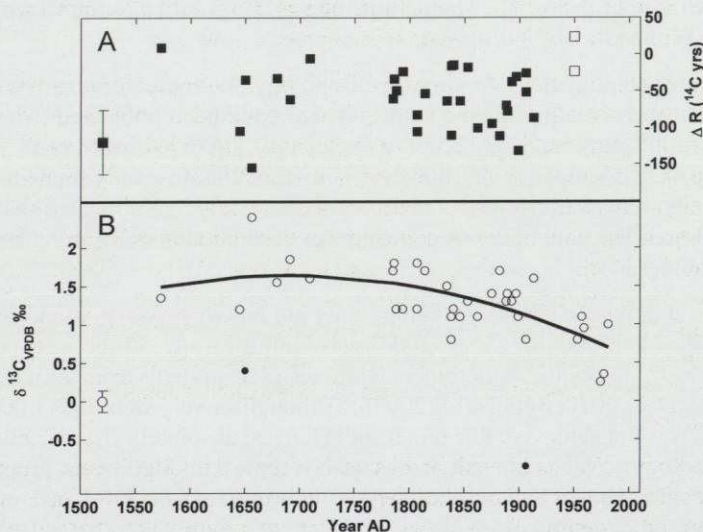
Thus the potential of *A. islandica* for chronology development was already well known, and some pioneering studies had already been published (Marchitto *et al.*, 2000; Schöne *et al.*, 2003; Scourse *et al.*, 2006; Witbaard *et al.*, 1997). These were limited in scope, however, sometimes because only small numbers of shells were available and sometimes because only live-collected shells had been used. The goal of the studentship was considerably more ambitious than any of these.

In the end, the Irish Sea chronology only got halfway to its goal. A 489-year crossdated chronology (1516–2004) was built for a site off the west coast of the Isle of Man using 58 increment width series from shells from 42 specimens (Butler *et al.*, 2010; Butler *et al.*, 2009b). Although the very ambitious 1,000-year target was not achieved, this remains the longest absolutely-dated shell-based chronology so far published and as such it represents significant progress in the development of high resolution proxy archives for the marine environment. So, what did we find out?



## Applications

One key benefit of having an absolutely dated chronology for the marine environment is that it gives us the ability to calibrate the radiocarbon timescale. Radiometric analyses of marine samples are compromised because the radiocarbon would have spent an unknown amount of time in the marine reservoir between its formation in the atmosphere and its incorporation into the sample. The measured radiocarbon content is depleted by an amount corresponding to the date of the sample plus the time in the reservoir. The problem is that the amount of time spent in the reservoir is an unknown function of water mass transport and mixing, and consequently an accurate determination of the date of the sample is impossible. For practical purposes, the excess depletion is modelled by an ocean-atmosphere box diffusion model (Hughen *et al.*, 2004) which yields a time-varying estimate ( $R(t)$ ) of the mean oceanic mixed-layer  $^{14}\text{C}$  age (Stuiver *et al.*, 1986), but which takes no account of regional hydrography. For any given region of the ocean, the reservoir age is defined as  $R(t) + \Delta R$ , where  $\Delta R$  is a correction term which can only be known if the precise calendar age of the sample is known. This may seem circular, since the traditional procedure is to use the radiocarbon age to determine the approximate calendar age, but in practice the determination of  $\Delta R$  in this way has two powerful applications. First, if the value of  $\Delta R$  at a location is known, accurate radiometric dating of other marine samples from the same location becomes possible. Secondly, changes over time in  $\Delta R$  can be reconstructed by



**Figure 1:** Time series of (A)  $\Delta R$  and (B)  $\delta^{13}\text{C}$  based on the Irish Sea *Arctica islandica* chronology. Reproduced from Butler *et al.* (2009).



analysing material from different parts of the chronology, allowing conclusions to be reached about changes in the age of regional water masses. In the case of the Irish Sea, the age of the water (an arm of the North Atlantic Current) does not appear to have changed during the past 400 years (Figure 1a).

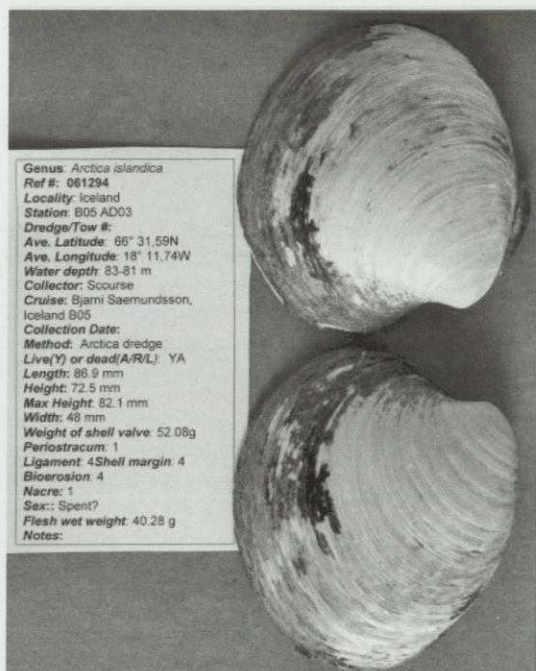
It is also possible to build a time series of the stable carbon isotope ratio  $\delta^{13}\text{C}$ .  $\delta^{13}\text{C}$  is a rather enigmatic proxy, which isn't easily interpreted in terms of environmental variables, but for the more recent period of accelerating emissions of  $\text{CO}_2$  from fossil fuels it can be used as a tracer of anthropogenic carbon. This is because plants preferentially take up  $^{12}\text{C}$  when they photosynthesize, so that carbon derived from fossil fuels can be identified by its relative depletion in  $^{13}\text{C}$ . This effect (known as the  $^{13}\text{C}$  Suess effect) has been identified in ice core samples (Francey *et al.*, 1999). In the marine environment, it is less easy to detect because of fractionation at the air-ocean boundary, water mass mixing and (in the case of shell material) further fractionation during carbon uptake and shell secretion. The signal is therefore muted and the variability is much greater. It is, however, readily detectable in the Irish Sea *A. islandica* shells (Figure 1b). In the context of the determination of the role of the oceans as a sink or source for  $\text{CO}_2$ , this has some potential, since it may be possible to use  $\delta^{13}\text{C}$  in the shell as a proxy for the  $\delta^{13}\text{C}$  of the dissolved inorganic carbon in the seawater.

Indications of connections between shell growth and seawater properties are as yet unclear. There appear to be positive correlations between growth and sea surface temperatures (Butler *et al.*, 2010), but this relationship is complicated by the influence of surface temperature on food supply. It is therefore necessary to be cautious when interpreting these apparent links.

Sclerochronology is still a very new discipline, but we have been able to cut some corners because of the many similarities with the much more developed field of tree-ring research. The involvement of the Bangor sclerochronology group in the European FP6 project MILLENNIUM – a multiproxy-based investigation of European climate of the past 1,000 years – enabled us to develop collaborations with leading groups of dendrochronologists at Swansea University and the Swiss Federal Research Institute (WSL) in Zurich. As a result, we have been able to apply dendrochronological techniques with confidence to our shell chronologies, and we have been told on several occasions that the strength of the statistical correlations between the growth increment patterns in the shells compare very well with the equivalent relationships in tree-ring chronologies.

MILLENNIUM has moved the discipline forward in other ways. The project included a significant marine element concentrated on the North Atlantic Ocean, and as part of this aspect the Bangor group were charged with the development of a 1,000-year *Arctica islandica* chronology for the North Icelandic shelf. I was still working on my doctorate when this project was starting, so we took on an American geochemist, Al Wanamaker, to carry

out the major part of the shell processing and chronology construction. The eventual successful completion of an absolutely dated chronology going back to AD 649 (1,356 years) was very much a joint exercise between Al and myself. Using estimates of  $\Delta R$  derived from the Icelandic shells, we have been able to chart the history of hydrographic changes north of Iceland, where Arctic- and Atlantic-sourced water masses contend around the Polar Front. That research is still being prepared for publication, but one spectacular result that has been widely reported - and not just in the scientific press - was the measurement of the lifespan of one of the Icelandic clams at a truly remarkable 507 years, making it the longest-lived non-colonial animal known to science whose age has been precisely determined (Wanamaker *et al.*, 2008) (Figure 2).



**Figure 2:** Icelandic *Arctica islandica* specimen 061294, aged by increment counting and crossmatching at 507 years.

## The way forward

The practicality of using the shell of *A. islandica* to build long crossdated chronologies has been confirmed only over the past three or four years. Sclerochronology has now reached a very exciting stage in its development, and the way forward is likely to take it in multiple directions:

(a) The creation of networks of *A. islandica* chronologies – very much along the lines of recent work with tree-ring chronologies (eg Briffa *et al.*, 2002) – will allow us to reconstruct changes in marine environments on large spatial scales. As a pilot, I have already developed a small network for the northern North Sea (Butler *et al.*, 2009a), and there is no doubt that this is a realistic future prospect for the North Atlantic Ocean, where *A. islandica* is common on the shelf seas and around mid ocean islands such as Iceland and the Faroes.

(b) Another exciting development will be the use of different species for chronology building. No other suitable species is quite as long lived as *Arctica*, but my colleague David Reynolds has been having some success with another bivalve clam, *Glycymeris glycymeris*, which can live up to 200 years, which complements *Arctica* in its habitat type and distribution, and which can be found in many other parts of the world outside the Atlantic region.

(c) Moving to geochemistry, the reconstruction of bottom water temperatures using stable oxygen isotope ratios ( $\delta^{18}\text{O}$ ) has already been pioneered by Bernd Schöne (Schöne *et al.*, 2004; Schöne *et al.*, 2005b), but in a new development the Bangor group have recently been awarded NERC funding to carry out stable isotope analyses on the long Iceland *Arctica* chronology.

(d) Another important focus, this time in the ecological/biological domain, is the acquisition of a detailed understanding of the drivers that influence shell growth. This aspect is essential if we are to make reliable process-based interpretations of increment widths; in addition to very detailed environmental monitoring of wild populations, we will need to design and implement a range of well-controlled laboratory and field experiments.

## Acknowledgments

First, I should mention colleagues at the School of Ocean Sciences at Bangor University, who have always been encouraging and very supportive and pretended to laugh at my jokes: James Scourse, Chris Richardson, Al Wanamaker, David Reynolds and Nicole Fraser. I've also found the sclerochronology community outside SOS very willing to collaborate, cooperate and answer my queries, no matter how naïve they might have seemed – I want to mention in particular Rob Witbaard, Bernd Schöne and Bryan Black. Tree-ring researchers are showing great interest in what we are doing, and I've worked with and gained valuable advice from (here are just a few from what could easily be

a much longer list of names) Mary Gagen, Giles Young, Neil Loader and Iain Robertson at Swansea, Ulf Büntgen and Valerie Trouet at WSL and Rob Wilson at St Andrews. Colleagues on the MILLENNIUM project who have welcomed me into their "family" include Danny McCarroll, Bill Austin, Jan Heinemeier, Sheila Hicks, Jon Eiriksson, Karen Luise Knudsen, Alex Cage and many others. And finally, I want to thank Keith Briffa, who gave me a torrid but fair time when I defended my thesis but who eventually decided to let me out into the wide weird world of Quaternary science.

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# HONORARY MEMBERS

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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 recently retired.

I am delighted to announce that both proposed nominations for new Honorary Members of the Association were warmly and enthusiastically endorsed at the Annual General Meeting of the Association held at the University of Liverpool on 5<sup>th</sup> January 2011.

## Professor Valerie Hall

Valerie Hall has a very distinguished research record in the field of Quaternary palaeoenvironmental and climatic change. She has been a pioneering influence in the recognition of ash layers of Icelandic volcanic origin in a variety of European environmental archives (peat bogs, lakes, ice cores, marine sequences), notably across Ireland, but also further afield. The science of tephrochronology is now very well established and Valerie is one of a number of few individuals in Europe, recognised by the wider Quaternary community, whose work and influence has had a seminal role in this development.



Valerie's early love for botany was stimulated by the proximity of the Belfast Botanic Gardens to her childhood home, and lead to a degree in Botany at Queen's University Belfast. During this time she took a course in palaeoecology taught by Alan Smith; in Valerie's own words "we worshipped him" and she was hooked, undertaking a final year research project on 19<sup>th</sup> century Irish agriculture. Following Queen's, Valerie taught, married and had two daughters. In her mid-thirties she was invited to undertake a Ph.D. back in the Botany Department at Queen's but research was delayed when Valerie was diagnosed with cancer. Her illness was severe and she underwent tough bouts of radio- and



chemotherapy. She was only finally able to embark on a part-time Ph.D. at the age of 39 following her recovery. Her research was on the vegetational history of Ireland over the last two millennia under the supervision of Jonathan Pilcher. Valerie was awarded her Ph.D. in 1989 after only four years part-time study.

In the same year Valerie was awarded a Junior Fellowship in the Queen's Institute of Irish Studies and continued the pollen work in the palaeoecology labs, at which time the early volcanic ash studies were being undertaken at Edinburgh and at Queen's. NERC funding in 1990 provided a three year Research Fellowship to work on tephra in north Irish peat sequences. During this time Valerie rose to the challenges of geochemistry using electron microprobes. Valerie was awarded her first lectureship in the Institute of Irish Studies at the age of 48. Hope for all late starters! Throughout this time, she worked closely with many scientists who are – in her own apt words again – “the ‘vertebrae’ in the backbone of the QRA”. She has great memories of fieldwork with John Lowe and Mike Walker, notably with Mike on Tregaron Bog in Wales on a miserably wet Whit Monday. John and Mike dug the late-glacial section at Sluggan Bog with Valerie. The material retrieved revolutionized dating this obdurate time period and tephra was discovered in the Younger Dryas section. She also recalls fondly trips around New Forest bogs with Keith Barber and his team, and to Tor Royal with Dan Charman and Rewi Newnham; “those lads really know their stuff”. In the mid 1990s, John Lowe sent one his young, promising Ph.D. students to Valerie for ‘tephra training’ - a youngster called Chris Turney. Other students from Royal Holloway have passed through Valerie's hands and gone on to greater things, notably Siwan Davies now at Swansea University. Indeed, Valerie's role as mentor of younger scientists and colleagues has been outstanding. She is committed to others, selfless, an encourager, a wise counsellor to colleagues and students alike. During my time as Editor of the *Journal of Quaternary Science* Valerie was a swift and ultra-reliable referee; were that there were more like her!

Valerie has been at the crux of the development of multidisciplinary Quaternary research in Belfast and the reputation that Queen's now enjoys in the palaeoenvironmental field owes much to her insight, intelligence and commitment. In retirement she continues research on Irish sites, and with Jonathan Pilcher and Mike Baillie she is engaged in searching the Greenland ice cores for their tephra signals, supported by the ice core scientists in Denmark.

## Professor Ann Wintle

Ann Wintle has had a profound impact on the development of luminescence dating techniques and their application to Quaternary geochronological problems over a 35-year career. She has been involved in many of the most significant technical breakthroughs in the field, and the current status of luminescence as an established dating technique in Quaternary science owes much to her influence. The overriding impression of Ann is as a researcher who, on the one hand, brings the utmost scientific rigour and exacting questioning to every problem she addresses, but who, on the other, also brings an infectious sense of fun to everything she does.

Ann took her Ph.D. in the Research Laboratory for Archaeology and the History of Art at the University of Oxford under Martin Aitken in 1974, on the physical properties of luminescent minerals. Her background was in physics, but it was to sediments that she gravitated, setting up a laboratory dedicated to the luminescence dating of loess and other deposits. After a spell working with David Huntley at Simon Fraser University in Canada between 1977 and 1979, she set up the luminescence dating laboratory in the Godwin Laboratory in the Sub-department of Quaternary Research at Cambridge. It was during this period, between 1979 and 1987, that Ann first attended QRA meetings. She recalls "several hours propping up a bar in Cornwall with David Keen" and the famous excursion to Normandy notable for the magnificent lunches laid on by Jean-Pierre Lautridou. Scientific highlights of the trip were the loess and raised beach sections discussed in collaboration with John Catt and Nick Shackleton. My own research on the Isles of Scilly might have taken a completely different course if, in 1981, Ann had not tipped me off about some potentially interesting organic sequences underlying loess on the islands.

In 1987 Ann had just completed employment as a research assistant in Cambridge and was facing unemployment. As the result of a bet with Nick Shackleton, she turned up at a QRA meeting in London dressed in a fancy dress costume that she had worn at the Godwin Laboratory Christmas party the month before. Ann went dressed as a loess section, complete with loess dolls





glued to the palaeosols. It clearly worked because David Bowen duly invited Ann to apply for a lectureship at Royal Holloway College to which she was eventually appointed. From there she moved to Aberystwyth in 1989 where she remained for 20 years until her recent retirement.

Ann's research and publication record is outstanding. Over 170 refereed papers, somewhere around 5000 citations, six papers in *Nature*, one in *Science*, and co-authorship of the book *Optically Stimulated Luminescence Dosimetry*. She has provided support to the academic community through service on the editorial boards of *Quaternary Science Reviews*, *Boreas*, *Radiation Measurements* and *Ancient TL*, and her distinction has been recognised by the award of an Honorary D.Phil. from Uppsala University (2001) and of the Appleton Medal and Prize of the Institute of Physics (2008).

Less readily quantifiable has been Ann's immense influence in encouraging, supervising and mentoring young researchers and senior collaborators alike. Many, if not most, of the active luminescence labs around the world are run by individuals who have been directly taught or otherwise strongly influenced by Ann. Their tribute was a retirement party held at the 12<sup>th</sup> International Luminescence and ESR Dating Conference held in Beijing, and the Special Issue of *Quaternary Geochronology* published in her honour in 2009. To these significant accolades we add Honorary Membership of the QRA.

James Scourse  
QRA president

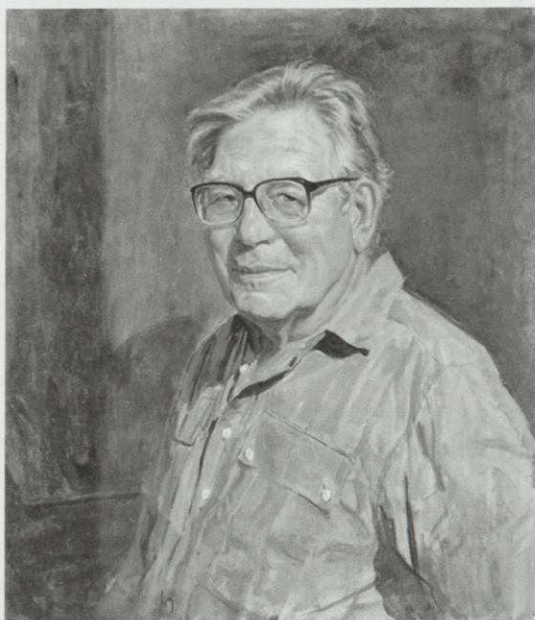
# OBITUARY

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## PROFESSOR TJEERD HENDRIK VAN ANDEL

1923-2010

Professor Tjeerd van Anel, the eminent earth scientist, Quaternary geologist and geo-archaeologist died peacefully on Friday 17th September 2010, aged 87 in Cambridge. Throughout his long and varied career, which spanned over 60 years, he made substantial contributions in geophysics, sedimentology, and oceanography, before he shifted his attention to geo-archaeology. He enriched the understanding of both earth scientists and archaeologists and advanced the study of geology and human behaviour in its broadest sense.



Oil painting of Professor Tjeerd van Anel by Anastasia Sotiroupolis.

Although Tjeerd was born in Rotterdam in 1923, he spent much of his youth in the Dutch East Indies where he visited Hindu remains with his parents. On his return to the Netherlands, this experience inspired him to take up Archaeology when he entered the University of Groningen in 1940. Here he became a student of the Dutch prehistorian A.E. van Giffen, who was an early pioneer of biological archaeology and who, among other things, encouraged Tjeerd in the study of what we now call science-based archaeology.

However before he could complete his studies, the Germans closed the University during the War. Returning afterwards many of the older staff were no longer in post, so Tjeerd pursued a course in Quaternary geology, which he hoped would lead him back towards Archaeology. However, at Groningen the Geology institute was led by the highly influential Anglo-Dutch geologist Philip Kuenen, who apparently tried but failed to dissuade Tjeerd from taking up the subject. The path was then set. Tjeerd continued at Groningen to take his PhD *Provenance, transport and deposition of Rhine sediments* in geology (1950) under Kuenen's supervision. Shortly afterwards he was appointed by the Bataafse Petroleum Maatschappij (Den Haag), a subsidiary of Shell Petroleum N.V., as a sedimentologist for their South American operations.

As many will know, Kuenen was a highly acclaimed marine geologist and his influence gave Tjeerd the opportunity to study modern marine sedimentation and through that to gain a position at Scripps Institution of Oceanography in California where he worked on continental-margin marine sediments. Over the next few years he turned increasingly to the study of mid-ocean ridge plate boundaries, at a time when the plate-tectonics revolution was fast developing.

At much the same time, the Deep-Sea Drilling Project was established by the major American oceanographic institutions and Tjeerd was involved in the running of the project as the representative of Scripps on the planning committee. He moved to Oregon State University to establish a new ocean science institute where his palaeoceanography group achieved considerable recognition. Through his involvement during this period, with the International Decade of Ocean Exploration and his service on the National Science Foundation, he had the chance to support and foster the greatly influential CLIMAP project. This major co-operative project involved an elite team of several of the most innovative researchers in palaeoceanography. Its results provided the first glimpse of how the glacial world temperature distribution would have looked and triggered an exciting revolution in Quaternary science from which whole new visions of climate change and its implications became apparent.

But Tjeerd had not completed his discoveries in oceanography by this time. During the 1970s he continued participation in mapping of the Mid-Atlantic Ridge and at the same time he moved to Stanford University to become Professor of Ocean Sciences. His continued co-operation with colleagues led to the peak of his achievement as he saw it. To quote him "together with Dick von Herzen of Woods Hole, the Alvin expedition enabled me, on the 17th of February 1977, at 11 in the morning, to be the first to see the now famous deep-sea hot springs". Popularly known today as 'black smokers', the discovery of these springs initiated whole new research areas in evolution and especially the concept of the development of early life.

Once at Stanford Tjeerd immersed himself in the teaching of general geology, which he confided greatly enriched his life and made him into an earth sciences generalist. At Stanford by chance he met Michael Jameson, a classical archaeologist who invited him to join an archaeological survey in Greece. This reignited his enthusiasms from his past: van Giffen's training, early interest in Quaternary geology and palynology, practical laboratory skills, and an interest in sea-level changes. It is Jameson whom he credited with giving him the opportunity to devote the last 25 years of his research career to the interface where archaeology meets geology in the understanding of distant human history.

Tjeerd's most important contribution to geoarchaeology was the study of sea-level changes and their effects on human settlement and land use, particularly in the Mediterranean region. His study of the interaction of humans and their physical environment has been influential. In particular, his analysis of the timing and intensity of soil erosion resulting from anthropogenic activity initiated discussion among geo-archaeologists world-wide in the 1980s.

This remarkable change in direction from oceanography back to his earliest roots in archaeology reflected Tjeerd's broadening major interest in Earth processes. Most readers who know him will do so through his best-selling book *New Views on an Old Planet* (Cambridge University Press). Aimed principally at a general readership, the book was first published in 1985 and now, several editions later, is still in production and is widely used as a recommended text for undergraduates. Its success is testament to Tjeerd's ability to reach a wide audience, a skill that he also employed in his many public lectures. It was also seen in his regular thoughtful and stimulating contributions in the journal *Terra Nova*.

In 1988 Tjeerd took early retirement to move from Stanford to the University of Cambridge where he was awarded an Honorary Professorship in Earth History, Quaternary Science and Geo-Archaeology in the Department of Earth Sciences. His wealth of experience and enthusiasm injected a welcome energy to the fields of Archaeology and Geology alike and in particular, it drew in the greater Cambridge Quaternary community, offering a welcome new focus for palaeoenvironmental research in the University.

In the last two decades Tjeerd was an energetic contributor to the Geosciences in Cambridge, both in research and teaching. Apart from continuing his general research while at the University, his most significant contributions was in his role in the reorganisation of Quaternary research. The break up of the Subdepartment of Quaternary Research (SDQR), then under the leadership of Nick Shackleton was enacted by the University in 1994. This potentially traumatic event could have been highly damaging for Quaternary research in the University by undermining a reputation for excellence established over 70 years. That the constituent research groups survived and initially at

least, prospered, was due in no short measure to Tjeerd taking the lead in this delicate operation. The Godwin Institute of Quaternary Research, the extra-departmental umbrella organisation that succeeded the SDQR, was effectively Tjeerd's creation. The initial strength of the new institute was reflected in the success of the outstanding Stage 3 Project which involved all the Cambridge Quaternary community together with archaeologists and a very large group of workers from around the world to examine the environmental change and human history in Europe 70-20 ka years ago.

Tjeerd's life was indeed an exciting and influential one, starting from his initial inspiration in archaeology, passing by way of geology, oceanography and Quaternary science, and finally turning full-circle to bring him back to archaeology. The irony of this was not lost on him. In his own words, it was "a journey full of unexpected detours, none of which I regret".

Tjeerd leaves his wife Kate Pretty, his first-wife Marjorie, and his children Charlotte, Barbara, Jessica, Carolyn, Chris and Jeff.

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# ARTICLE

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## THE SAALE GLACIATION OF EASTERN ENGLAND

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### Introduction

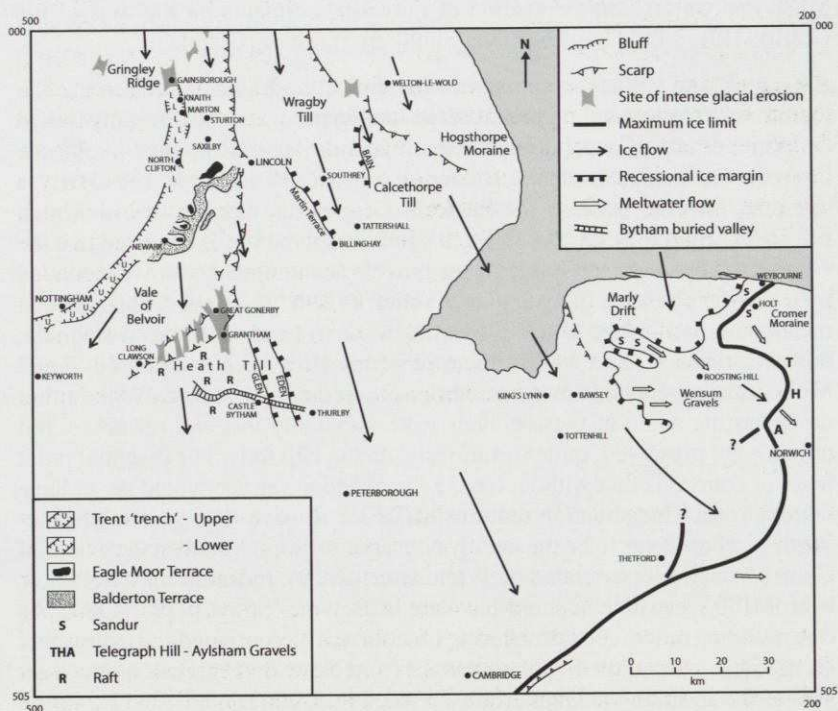
Recently, two papers have been published each expounding a case for glaciations of eastern England in Marine Isotope Stage (MIS) 8, referable to the Saale glaciation of the continent. White *et al.* (2010) concentrate on a review of evidence from the Trent basin discussing the terrace sequence in particular. Westaway (2010) considers a wider region, referring also in some detail to sedimentary and geomorphological evidence in Norfolk, the Fens and the Midlands. Both papers conclude that glaciations of parts at least of eastern England occurred within that post-Anglian/pre-Devensian period, anomalously called the Wolstonian, most probably in MIS8. This gives considerable satisfaction to the writer who, for over 50 years, has claimed just such a glaciation to have been responsible for much of the glacial sediment of the region, for creation and modification of landforms, and many adjustments to drainage systems. The papers do not however reach consensus on the southern limits of the ice incursion nor, in the case of that by White *et al.* (2010), have some implications of Trent terrace formation and the significance of related landforms been thoroughly explored. The writer seeks therefore to provide a commentary on the two papers, and to draw attention to certain features pertaining to the courses of the Trent variously to Lincoln and Gainsborough and to underestimation of the extent of MIS8 ice. He also offers views on the southern limits of both the MIS8 ice and, because of its impact on Trent and Fenland drainage, the extent of Devensian ice in MIS2 (Last Glacial Maximum).

### The Trent terraces

Over the past 5 years the Trent basin has been subject to surveys by the Trent Valley Palaeolithic Project of an intensity not previously conducted, and much new material bearing on its Quaternary history has been acquired. Yet the writer is concerned that some features have not been given sufficient prominence or even considered, and that the bearing of circumstances surrounding formation of the highest terrace on ice extent has not been appreciated. Comments follow therefore on the Eagle Moor Terrace, the Trent 'trench', and ice limits in central Lincolnshire.

In the paper by White *et al.* (2010) there is no reference to the special conditions pertinent to the deposition of the Eagle Moor Terrace gravels (MIS8), situated

as they are on a number of separate hill tops. One is left to assume that the gravels, transported by meltwaters from the middle and upper Trent areas, were deposited along a shallow rock-based depression that stood no lower than 40 to 30 m OD. In this situation somewhat higher ground must have existed northward and southward of this depression which allowed waters to reach the Lincoln gap. Today, remnants of the Eagle Moor Terrace occupy anomalous positions on the tops of the Graffoe Hills, a group of four eminences between Newark and Lincoln on more-resistant beds within the Lower Lias (Fig. 1). These Hills now stand higher than any ground west of the Oolite scarp from Gainsborough in the north for some 30 miles to the middle Vale of Belvoir in the south. Part of the present, low relief, land surface is occupied by the Balderton Terrace, dated to MIS6, which lies between 20 and 10 m OD. The lowering of a vast area, including separation of the Graffoe Hills, by the order of 15 to 20 metres would therefore have had to have been achieved during MIS7 (but by what processes in an interglacial?). However, two serious objections can be made against the concept of a widespread Eagle Moor land surface.



**Figure 1.** Postulated extent, flow direction and erosional features of the Saale icesheet; recessional margins; meltwater flow; the Trent 'trench' and terraces.



First, an area of till claimed by White *et al.* (2010) as MIS8 survives east and southeast of Gainsborough, but its southern parts lie at only 8 to 10 m OD near Sturton, considerably lower than the Eagle Moor Terrace remnants. Even allowing for some glacial erosion before lodgement of the till the parent ice was clearly entering a land surface parts of which at least were well below any putative Eagle Moor surface. On deglaciation meltwater movement would most likely have been below the tops of the Graffoe Hills, and in these circumstances it is difficult to see how meltwaters from the Gainsborough ice could have contributed sediment to the Terrace.

Second, the Vale of Belvoir has been heavily ice-eroded, in places by the order of 30 m, as witnessed by the huge quantities of Liassic till south of the Oolite scarp (Fig.1; Straw, 1963, 1979a; Rice, 1968). This erosion was pre-Eagle Moor Terrace and if it was MIS12 (Anglian) then the Graffoe Hills were already eminences by MIS8 time. If erosion was MIS8 (Wolstonian) then the Hills could well have been created as part of the subglacial relief through differential erosion. In either case on deglaciation, lower ground was again available for MIS8 meltwaters, and deposition of outwash sediments on the tops of the Graffoe Hills would have been very unlikely if not impossible.

A general land surface at and somewhat above the Eagle Moor Terrace can therefore be regarded as a figment of the imagination, and the difficulty (noted by White *et al.*) of accounting for the relatively large difference in altitude between the Eagle Moor and Balderton Terraces disappears. Yet clearly a dilemma persists, because the Eagle Moor gravels, like the Gainsborough till, seem firmly to belong to MIS8. It can be resolved if it is accepted that the Graffoe Hills, when the Eagle Moor gravels accumulated, were surrounded by ice being elements of a subglacial relief. In 1963 the writer proposed that meltwaters had indeed coursed from Newark to Lincoln across a stagnant, downwasting ice mass and, as the tops of the Hills became exposed, Eagle Moor gravels were laid down on a composite ice/bedrock surface. With further downwasting some of these gravels were inevitably lost and reworked, but others were preserved, quite fortuitously, on the Hill tops. The essential point here, of course, is that without ice the Eagle Moor Terrace would never have materialized. This situation requires MIS8 ice to have flowed much further south of what seems to be the unduly conservative limit based on the extent of Gainsborough till postulated by White *et al.* (2010). Indeed it may well have been MIS8 ice which scoured the Vale of Belvoir (Straw, 1979a, 1983). As downwasting proceeded water flow to Lincoln was discontinued and meltwaters seem to have found their way northward from Newark (Fig.1) along the west side of the shrinking ice mass (Straw, 1963, Fig.3, 2002a).

Upstream of Newark the Trent today is confined to a straight, sharply-defined valley generally referred to as the Trent 'trench'. The 'trench' actually begins at Long Eaton and Barton-in-Fabis and trends northeast eccentrically across



the Mercia Mudstone dipslope. It appears to end at Newark from where terrace gravels spread northeast toward Lincoln. However, from North Clifton to Gainsborough the Trent again cuts across the dipslope in a straight, confined valley just as wide as that above Newark. Though less visually obvious it retains, on its east side at North Clifton, Marton, Knaith and Gainsborough, significant bluffs on eminences of Mudstone higher than the MIS2 gravels (Holme Pierrepont Terrace) and the southern parts of the Gainsborough till to the east (Straw, 1963, 2002a). 'Removal' of alluvium and gravel would reveal a form analogous to the 'trench' above Newark. In no way are the form and alignment the consequences of capture by a Humber tributary, but this valley was adopted by the Trent when, in taking its present course northward from North Clifton, it avoided the MIS2 gravel tract between Saxilby and Torksey.

Like the 'upper trench' this 'lower trench' was most probably cut by waters guided across the Mudstone dipslope, held against rising ground by some obstruction, presumably ice. But Devensian ice never reached this 'lower trench', so the feature is pre-Devensian and was most likely excavated along the west side of decaying Gainsborough till ice when, as claimed above, the Eagle Moor Terrace was abandoned (Straw, 1963). It confirms movement of 'Trent' meltwaters toward the Humberhead area at a stage (early in MIS7) long before its present occupation by the Trent. White *et al.* (2010) however, regard the present Trent course to the Humber, commencing during MIS2 when gravels were aggrading to c.7 to 8 m OD in the Saxilby area, as the first time Trent waters had taken such a route. But they do not acknowledge that connection with the Humber could only occur if there were available a low gap at Gainsborough through the prominent, west-east, bedrock Gringley ridge (38+ m OD). As it happened, such a gap did exist in line with the 'lower trench' (Fig.1); its formation too must have been pre-Devensian (probably by glacial erosion – Straw, 1979a, b) and it was low enough in MIS2 for Trent waters to pass northward. A connection with the deep, now buried, valleys under the 25-foot Drift north of the ridge (Gaunt, 1994; Straw, 2002b) and the possibility of Devensian glacio-isostatic depression would make this likely.

The presence of both this gap and the 'lower trench' should not be ignored in any account of Trent history, but they were not considered by White *et al.* (2010). Their existence and significance provide reason why this writer has consistently argued for Trent drainage having passed toward the Humber on more than one occasion. The earliest northward drainage, through MIS7 time following disappearance of MIS8 ice, along the 'lower trench' came to an end when the Trent built the Balderton Terrace from Newark to Lincoln, a diversion and event which might be taken as consequences of ice blockage of the Humber in MIS6.

In central Lincolnshire the Martin Terrace, correlative of the Eagle Moor Terrace, lies on the southwest side of the River Witham below Lincoln between

about 23 to 14 m OD. Of glaciifluvial origin, White *et al.* (2010) suggested it formed along the western margin of a 'Wragby Till' ice mass, though where the water and sediment went south of Billingham is not known (Fig.1). The writer regards it as an episode during downwasting of a more extensive icesheet that occupied all central and north Lincolnshire and when the Bain valley was being initiated on its eastern side (Straw, 1966). There is no field evidence for ice margins east and west of the Oolite cuesta north of Lincoln, as shown on Figure 1 in White *et al.* (2010) and Figure 2 in Westaway (2010), which with a relative relief of less than 40 m would have been ice covered.

### **The extent and limit of MIS8 ice**

It is obvious from the above discussion that MIS8 ice occupied more of the Graffoe Hills/Vale of Belvoir area than indicated by White *et al.* (2010) and Westaway (2010), and under the guise of 'Wolstonian' it may have reached the Midlands, the southern Fens and central Norfolk. Various authors, including this writer, have placed various limits in various locations and, in the light of these two papers, some further comment seems appropriate.

In their Figure 1, White *et al.*'s postulated ice limit in west Norfolk peters out north of Totternhill, but Westaway (2010; Fig.1b) carries the line east from northward of the Nar valley to the Wensum, thence north to the coast near Weybourne. This accommodates much of the Marly Drift of northwest Norfolk and permits numerous sandar (at Houghton, Great Bircham, Syderstone, Holt and Kelling) to be regarded as MIS8 outwash features. Westaway reassesses the organic deposits at Roosting Hill in the Wensum valley as of MIS7 date, and to be resting on till and gravels referred to MIS8. In 1973 the writer mapped and defined a system of convergent outwash trains (Wensum Gravels) descending from the sandar, the forerunner of the Wensum drainage, claiming both outwash and Marly Drift as representative of a 'Wolstonian' glaciation. The ice limit in this area was placed northwest of Norwich, against a tract of east-grading outwash sands and fine gravels designated the Telegraph Hill–Aylsham Gravels that seems to be contemporaneous with the Holt sandur north of the Cromer Ridge (Fig. 1). The Marly Drift is lithologically similar to the Calcethorpe Till of east Lincolnshire, both being emplaced by ice passing south over the Chalk outcrop south of Flamborough Head (Straw, 1965, 1967, 1979b).

In the Fen region both White *et al.* (2010) and Westaway (2010) consider penetration by central Lincolnshire ice as far south as Peterborough, but Gibbard *et al.* (2009) take it closer to Cambridge and Straw (1979a,b) found reason to place it along the Chalk scarp of Suffolk. Whichever limit is close to the actual one the ice involved had flowed down central Lincolnshire, scouring the Upper Jurassic clays and eventually depositing the Wragby Till, largely composed of such materials, on the eroded bedrock surface which passes beneath the Fen alluvium. On the east side of central Lincolnshire a diffluent stream of

Calcethorpe Till ice breached the head of the Bain valley but, while retaining its integrity, was constrained by the Wragby Till ice to flow southeast to the Fen edge east of Tattershall. This ice, part of the Calcethorpe Till/Marly Drift icesheet, would have reached west Norfolk around Bawsey (Fig. 1) north of Narborough, and could have been responsible for the large quantities of flints at Totternhill and Blackborough End.

It was shown above that the MIS8 limit determined by the Gainsborough till and figured by White *et al.* (2010) was unduly restrictive and that formation of the Eagle Moor Terrace required the presence of ice around the Graffoe Hills. The quantity and constituents of the large areas of till on the Heath south of the Oolite scarp points to widespread scraping at some stage of the floor of the Vale of Belvoir, by as much as 30 m in places. MIS8 ice not only reached the Graffoe Hills but must have passed some way south in order to provide a higher ice surface when the Eagle Moor Terrace was being deposited. The presence alone of MIS8 ice in the Vale of Belvoir is however no proof that it was responsible for the erosion of the Lias clays and emphasis of the limestone ridges, though it could account for the superimposition of the stream network overlying those ridges, and Vale erosion together with the breaching of the anterior Marlstone scarp and carriage of huge rafts of bedrock into the Heath tills might be ascribed to an earlier, probably MIS12 glaciation. But this writer finds it unlikely, if the Trent 'upper trench' is a MIS8 feature, that MIS8 ice penetrating as far as Keyworth did not also surmount the Oolite scarp southwest of Grantham it being a powerful stream of ice emanating from the Vale of York. Noting the presence of Oadby Till in Leicestershire with a substantial chalk and flint content, it can also be argued that northern MIS8 ice pushed deep into the Midlands. The writer (1983) offered a model for ice-flow into the Midlands and a mechanism for the transport of north Lincolnshire chalk and flint far to the southwest, and still prefers this situation, but accepts that an MIS8 limit might be recognized along the Oolite scarp from Great Gonerby to Belvoir and Long Clawson, and thence to Gotham and Barton-in-Fabis. In this latter case a contemporary limit for the western Fen ice could be marked by the line of the Glen valley, cut as it is across a number of till-buried former valleys including the Bytham valley.

### **The limit of MIS2 ice (LGM)**

Westaway (2010) considers the MIS2 limit to be well-established, indicating on Figure 2 the presence of Devensian ice through east Lincolnshire and across the mouth of the Wash to north Norfolk, and its existence in the lower Trent valley west of Scunthorpe. White *et al.* (2010) show the same coverage on their Figure 1, concluding that although ice did not impinge directly on the Trent catchment it did have an impact on the drainage system. This latter point cannot be understated because Devensian ice obstructed free-flow through the

Humber gap on two occasions, with corollaries being the formation of 'Lake Humber' and diversions of the Trent to Lincoln (Straw, 1963, 2002b, 2008). If inland Devensian ice had reached as far south as Doncaster (Gaunt, 1976) meltwaters would almost certainly have been discharged south of the Gringley ridge, but there is no tangible proof that, in the Vale of York, Devensian ice ever advanced south of the Trias hills of Hambleton Hough, Brayton Barff and Holme-on-Spalding Moor near Selby (Straw, 2002b). The Wroot-Thorne Gravels, claimed as ice-marginal (Gaunt, 1976) are more likely residual pre-Devensian deposits, on pedestals of Sherwood Sandstone, with a 'Carb-Permian' lithology quite at variance with the York-Esrick materials. As a final observation, the LGM is believed by this writer to be represented by the Esrick Moraine and in east Lincolnshire by the Hogsthorpe Moraine (Straw, 2008).

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# A RESPONSE TO 'THE SAALE GLACIATION OF EASTERN ENGLAND'

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We are delighted that Professor Straw has taken the opportunity to comment on our ideas about an East Coast glaciation during Marine Isotope Stage (MIS) 8, particularly since he has long been an advocate of just such an event. His contribution reflects his incomparable knowledge of the area in question and the evidence that he has observed during a long career as a geomorphologist with an interest in such matters. In the two papers to which he refers by White *et al.* (2010) and Westaway (2010), the recognition of a glaciation later than the Anglian and prior to MIS 7, with MIS 8 as the best fit, arises from consideration of river terrace sequences, in particular those of the Fenland Basin. Amongst the latter, we would include the palaeo-Trent, which drained into the Wash system prior to the Late Devensian. Professor Straw arrived at his views from his observations of geomorphology and glacial sediments and so will have different perspectives. In asking by what processes could the Eagle Moor terrace have been incised during an interglacial, he seems unaware of the plethora of publications in the past few years attributing river terrace formation in Britain to climatic forcing (against a background of uplift), with most British incision events coinciding with warming (glacial to interglacial) transitions (see Bridgland, 1994, 2000, 2010; Maddy, 1997; Bridgland & Westaway, 2007a, b). Within that paradigm the Eagle Moor to Balderton incision event would be easily explained, were it not (1) for the slight excess in height difference in comparison with other terrace pairings that represent a single Milankovitch cycle and (2) the fact that a glaciation has occurred in the vicinity, which means that the normal climatic forcing effect need not be invoked (see Maddy & Bridgland, 2000). The heights of the outcrops and meltwater features that Professor Straw cites in the Gainsborough area are indeed well below the modelled MIS 8 and 6 fluvial levels, which would suggest that they must result from emplacement in glacially overdeepened locations. Whether the Eagle Moor gravel was emplaced as a result of meltwater flowing through the Saalian ice sheet or whether (as White *et al.* (2010) and Westaway (2010) suggested) it flowed around the margin of the ice is an interesting speculation but not of fundamental importance.

As for the Vale of Belvoir as ice-eroded, we note that newer BGS maps no longer show the low-level till in the Vale, this having been reclassified as gravels of various types (see Howard *et al.*, 2009). During the Trent Valley Palaeolithic Project (TVPP) we dug within the old mapped outcrops in the Smite valley and found neither till nor always the gravel that appears on the new maps. Our

view, however, is that the Vale has been lowered by the combined efforts of the various streams that drain it, which have kept pace with downcutting by the Trent, forming a wider lowland than is occupied by the main river because the rocks are generally softer. Odd stream courses through ridges of hard bedrock can surely be attributed to superimposition of fluvial drainage lines during this phase of down-cutting.

We dispute rather more strongly the suggestion that the Trent Trench extends beyond where we have mapped it. Professor Straw considers that there are morphological features upstream of Nottingham that constitute a continuation of the Trench. In our view these do not bear comparison and, in any case, the crucial distinction is that downstream of Nottingham there are no terraces (other than the youngest) and the implication is that the Trent has cut the Trench as an incised reach during the course of several climate cycles (Bridgland and White, 2007). In contrast, upstream of Nottingham there are terraces outside of what Professor Straw wants to call the Trent Trench, showing that the river has not been so tightly constrained there. Professor Straw's 'lower trench' seems unlikely to be pre-Devensian, since that would not fit with the uplift paradigm: it would, if Middle Pleistocene in age, have to represent the bottom of a glacially overdeepened trough. However, given that we might need to invoke that type of reasoning to explain the above-mentioned till outcrops around Gainsborough, this is an idea worthy of consideration (see below). Nonetheless, we consider it equally possible that fluvial erosion, perhaps during drainage of Lake Humber, could have cut this feature much later, perhaps in the Devensian.

We see no strong evidence in support of Professor Straw's suggestion, which pre-dates this contribution to QN, that the Trent had an earlier (Pleistocene) course to the Humber and, indeed, that it might have been diverted repeatedly between that route and the Lincoln Gap. In contradiction of that, we point to the clear evidence that during MIS 7 (when Professor Straw would have it cutting his 'lower trench') the Trent was routed through the Lincoln Gap, as shown by the sediments it laid down at Southrey and in the Tattershall area (even though in the latter case the interglacial evidence is from the Bain tributary, it is clear that there was a confluence with the main Trent just to the SW). However, we cannot rule out a Humber course for the Trent between the glaciations of MIS 12 (which destroyed the Bytham River drainage) and MIS 8 (after which the Trent flowed via Lincoln). The depth of the Trent Trench suggests, from the modelling of incision in adjacent reaches (Westaway, 2007), that progressive downcutting since MIS 12 is represented; unfortunately there are no terrace deposits preserved in areas downstream of the Trench that are older than MIS 8 (assuming our attribution of the Eagle Moor Terrace to that stage is correct), so we don't know whether the continuation was via the Humber or via Lincoln. It is quite possible that it was the former and that the low-level Gainsborough

till reflects an overdeepened MIS 10–9 Trent valley that was overrun by the MIS 8 ice sheet, the advance of which might well have diverted the river into the Lincoln Gap. The absence of high-level terrace remnants in the vicinity of the Lincoln Gap, such as might record Trent drainage during MIS 10, might be argued as weak evidence in support of the more northerly Humber route, along which no preservation could be expected. As an analogy of the ‘missing’ deposits, there are high-level sediments upstream of, and parallel with, the Ancaster Gap, apparently recording a pre-Anglian river flowing by that route, which was inherited by the extended Slea (incorporating the Upper Witham) after the Anglian (Bridgland *et al.*, 2007). The evidence is slender, but an earlier Humber Trent can perhaps be envisaged, although it pre-dates that proposed by Professor Straw.

In respect of queries about ice margins east and west of the Oolite cuesta north of Lincoln, we point out that White *et al.* (2010) were looking for the smallest dimensions of the ice mass that could account for the evidence; the rather less cautious Westaway (2010) paper suggests that the ice may well have been more extensive. Between them it would seem that these studies cover the range of possibilities, not all of which are agreed upon by all three of us; in addition it is interesting to see Professor Straw’s up-to-date views on this. In addition to his contribution to QN, we have benefitted from correspondence with Professor Straw, whose comments and advice will be valuable in finalizing the text of our forthcoming monograph for Oxbow Books (Bridgland *et al.*, in press).

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# REPORTS

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## QRA FIELD MEETING: THE QUATERNARY OF THE SOLWAY LOWLANDS AND PENNINE ESCARPMENT

29<sup>th</sup> September to 2<sup>nd</sup> October 2010

At the end of September 2010, 26 delegates attended the QRA Field Meeting to the Solway Lowlands and Pennine Escarpment, organised by **Stephen Livingstone**, **Dave Evans** and **Colm Ó Cofaigh** (Durham). The last QRA visit to Cumbria was in 1994 and since then there have been a number of significant advances within the fields of remote sensing and geomorphological mapping, in Britain aided by the acquisition of the NEXTMap dataset, which have revolutionised the way we think about the British-Irish Ice Sheet (BIIS) as a now highly dynamic system. It is now understood that the region around the Solway Lowlands was affected by competing ice flows from the Southern Uplands, Pennines, Lake District and Irish Sea Basin, the dominance of which fluctuated spatially and temporally to produce a highly complex geomorphic signature. In light of this new research, it was time for the QRA to re-visit the central sector of the BIIS.

The field meeting began on the evening of Wednesday 29<sup>th</sup> September in Cockermouth Youth Hostel. **Stephen Livingstone** (Durham) kicked off the meeting with an introductory talk highlighting his work on the mapping and identification of flowsets, which were used to reconstruct the changing Late Devensian ice flow patterns in the region, identifying four major flow phases. Phase I is depicted by a dominant ice flow into the region from Scotland, which forced ice from the Lake District eastwards; within Phase II, both Scottish and Lake District ice flowed eastwards through the Stainmore Gap and Tyne Gap; Phase III is characterised by westerly ice flow into the Solway Lowlands, caused by the draw down of ice into the Irish Sea Basin (Blackhall Wood Re-advance); and Phase IV concerns the advance of Scottish ice across the Solway Firth (Scottish Re-advance).

### Day 1: Thursday 30<sup>th</sup> September

The day started out with good weather as we arrived at the first stop; Faugh sand pit. The site is located within the Brampton Kame Belt and quarrying has exposed several units of sand, silt, clay and gravel of varying architecture, which **Stephen Livingstone** has interpreted to represent glaciofluvial sedimentation within an ice-walled lake plain.

We then continued southwards to the meltwater channels on the western side of the Pennine Escarpment. A winding drive up the escarpment provided us with spectacular views of the channels as we headed towards the viewpoint at the top. After a chance to stock up on provisions/tea and coffee at the café, **Stephen Livingstone** outlined the three main types of meltwater channels formed during the deglaciation of the Penrith sandstone ridge; subglacially formed channels orientated parallel to ice flow with undulatory profiles, ice-marginal channels which flow parallel to the slope contours, and 'chute' channels, formed by meltwater flowing directly downslope into the subglacial system from the margin. **Dave Evans** suggested that some of the channels may be polygenic, having captured subglacial drainage followed by sub- to ice-marginal meltwater.

The lunch stop, for anyone who had resisted the temptation of food at the café, gave us an excellent view of the Brampton Kame Belt. Here **Stephen Livingstone** described its morphology, identifying three main features: depressions, interpreted as kettle holes; ridges, formed as part of the sub-glacial to ice-marginal drainage system; and flat-topped hills, interpreted ice-walled lake plains. Stephen then revealed his idealised model for the formation of the Brampton Kame Belt, suggesting that it was deposited by stagnating ice, which led to the development of an enlarging glacial karst and the time-transgressive evolution of sediment deposition to create the depressions, ridges and flat-topped hills seen today. **Dave Evans** added to this suggesting that the area was a suture zone, representing a stable longstanding drainage network and that therefore ice stagnation was not necessary to initiate the formation of the kame belt, but would have contributed to the final morphology of landsystem.

After lunch we moved on to the somewhat muddy Blackhall Wood section (although for those who attended GLWG 2008, it was comparatively dry!), located on the southern bank of the River Caldw. The section contains an important tripartite sequence, recording a change from a subglacial to proglacial environment, and the formation of a proglacial lake, before ice re-advanced into the area. From micromorphological analysis of the varve sequence, **Stephen Livingstone** proposed that the lake existed for at least 261 years, and suggested that the subsequent re-advance (now Blackhall Wood Re-advance) pre-dated the Scottish Re-advance, owing to its location within a SE-NW trending drumlin, part of his late flow stage 'LT5'. A lively discussion then ensued: **Jon Merritt** (BGS) posed the question as to whether the more consolidated nature of the lower tills compared to the upper till was due to different subglacial conditions, whilst **Dave Roberts** (Durham) mused over the processes of drumlin formation; **John England** (Alberta) asked whether saturated deformable sediment combined with a cold snap would have been enough to cause the "last gasp" of the ice sheet, but **Stephen Livingstone** and **Dave Roberts** thought that the re-advance was more likely to have been triggered by the 19 ka BP meltwater pulse.

The final Day 1 site was at Carlton, within the hummocky/ribbed moraine topography of the Petteril Valley. **Stephen Livingstone** suggested that the lower gravel and sand units were deposited as a delta during the retreat of a late flow phase (LT5), and were then tectonised by a subsequent readvance of ice. Stephen has found the upper till to be geochemically similar to Scottish Re-advance till at Plumpe Farm, implying a Scottish Re-advance age for the upper till, although a correlation with the Blackhall Wood Re-advance has not been ruled out.



**Figure 1.** The group at the Blackhall Wood section by the River Caldew (Photo: Dave Evans).

### **Day 2: Friday 1<sup>st</sup> October**

With the anticipation of heavy rain, the second day started at the Powfoot Boulder Pavement, near Annan on the northern coast of the Solway. **Jon Merritt** (BGS) introduced the site with **Andrew McMillan** (BGS), describing the pavement as a collection of bullet- and flatiron-shaped clasts which are exposed intermittently at low tide, depending on changes in the deposition or removal of beach sands. The clasts are striated with a consistent WNW-ESE direction, matching the ESE flow in the area identified by **Stephen Livingstone**. With this in mind, we set out towards the last known location of the boulder pavement, and at this point, sure enough, the rain descended on us! Despite our best efforts and perseverance in the rain, we found very little evidence for the boulder pavement, the most compelling being an isolated greywacke

sandstone boulder with 112° orientated striations on it. Following some brief discussions in groups on the mechanisms of boulder pavement formation, its preservation, and the pavement's location within the stratigraphy we made a hasty exit back to the vehicles and out of the rain.

**Jon Merritt** introduced the second stop, a section at Plumpe Farm, which provides evidence for the Scottish Re-advance in the form of glaciotectionised sands and silts capped by a till. By then the rain had turned to drizzle and the discussion turned to the minimal amount of disturbance within the sands which, to quote **Dave Evans**, was "quite remarkable". The discussions that followed concluded that despite the lack of evidence for strain, the water escape structures within it left no doubt that it was a glaciotectionite.

The much anticipated and needed pub lunch at the Black Lion in Durdar was a chance to dry off and reflect on the morning's sites. Before we left, **Stephen Livingstone** took the opportunity to present a large hill-shaded NEXTMap DEM of the Solway Lowlands, which allowed us to put into context both the sites we had already seen and those yet to come.

As we left the pub, the skies brightened and the group headed to Overby Quarry, located within the Holme St Cuthbert glaciofluvial complex. **Stephen Livingstone** characterised the regional geomorphology, explaining how the complex would have been deposited by ice flowing across the Solway from the north-west and how it is superimposed on top of NE-SW trending drumlins. **Dave Evans** remarked that the water escape structures within the sand lithofacies demonstrate significant loading and fast deposition, suggesting that the complex was produced over a very short period of time.

The final site of the day was at Swathy Hill, where **Stephen Livingstone** showed us evidence for the glaciotectionisation of pre-existing glaciofluvial and glaciolacustrine sands within a NE-SW trending drumlin assigned to the Blackhall Wood Re-advance. Within this lithofacies we were able to see some fantastic deformation structures, including convolute bedding, flame structures, and faults, as well as some clastic dykes, and the party divided into a number of smaller groups in order to discuss the finer details.

### **Day 3: Saturday 2<sup>nd</sup> October**

A blustery Day 3 began at the St Bees Moraine. **Jon Merritt** introduced us to the geomorphology, sedimentology and previous debates at the site. We had congregated on the cliff top, and the discussion that ensued focussed on a typical tripartite sequence of peat interbedded with laminated muds, documenting infilling of a depression on the top of the moraine during the Lateglacial. Although the depression has originally been interpreted as a kettle hole, **Dave Evans** proposed an alternate view that it and other depressions are due to dips in the strata of the moraine due to glaciotectionic folding.



The group then descended the cliffs and from beach level we were able to see some of the evidence for this glaciotectionism. **Dave Roberts** took the opportunity to draw our attention to the impressive folding within the laminated sands and gravels at the base of the cliffs before the group then moved on to an area of the cliff where the St Bees Till occurs. After a brief description of the till from **Jon Merritt**, **Dave Roberts** continued the discussion, providing food for thought on the possibility of a link between the St Bees Moraine and the Killard and Bride moraines in Ireland, therefore correlating the Scottish Re-advance to the Killard Point Stadial. However, the timing of formation of the St Bees Moraine is still unconstrained and Dave also commented that if the St Bees Moraine does represent a Scottish Re-advance limit, then its signature is very different to the Holmes St. Cuthbert ice-contact delta found further north.

Following a short drive down the coast we stopped at Drigg. **Jerry Lloyd** (Durham) highlighted the importance of this area of coastline for testing models of past sea-level and glacio-isostatic rebound, since it lies between glacio-isostatic uplift to the north and subsidence to the south. After a chance to examine the Drigg Beach Till, we headed away from the cliffs to an area of peat on the foreshore, which contains remarkably well-preserved tree logs. Calculations by Jerry place relative sea-level at around 4.5 m lower than present in order for woodland to have been established. No dates have been recovered from this site so far, however.



**Figure 2.** Group photo at Swathy Hill (Photo: Matt Strzelecki)

The final stop was at Holme Bridge, just inland from Drigg. Cores recovered at this site by **Jerry Lloyd** have provided radiocarbon dates of around 15.5 and 16.5 cal. ka BP from a peat layer about one metre below the surface. This surprisingly old age is supported by the pollen record which is dominated by Lateglacial fauna and implies that mean sea-level at this location was 2m OD during the Lateglacial, with implications for current geophysical models. After a successful coring attempt using a gauge corer, Jerry was persuaded to put the Russian corer into action. Despite less than ideal sediment conditions, Jerry, with the aid of a few helpers, demonstrated an effective (and also highly entertaining) coring technique and two near-immaculate cores were recovered displaying the full sequence. After some discussion and much photo taking, the meeting was then brought to a close. While the group was still gathered, **John England** took the opportunity to thank the organisers and contributors, particularly **Stephen Livingstone**, for an excellent field meeting and the chance to see some superb sections and geomorphology, sentiments which I'm sure were very much felt by the rest of the party.

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## QUATERNARY VERTEBRATE RESEARCH GROUP CONFERENCE 2010

Thursday 7<sup>th</sup> and Friday 8<sup>th</sup> June 2010

The 6<sup>th</sup> Annual meeting for the Quaternary Vertebrate Research Group (QuaVer, <http://www.ljmu.ac.uk/RCEAP/85952.htm>) was held at the Natural History Museum, London (NHM). The group, set up and organised by **Hannah O'Regan**, at Liverpool John Moores University, is a great way to keep in contact with colleagues working in a similar field, and once a year arranges a small, free conference to share ideas, network, and encourage new ideas for future research.

### Small, smaller, smallest

**Victoria Herridge**, at the NHM, started the day's talks giving an enthusiastic discussion about her PhD findings on dwarf Sicilian and Maltese elephants. Historically there have been two species of dwarf elephants recognised; the 'small' dwarf elephant, *Palaeoloxodon falconeri* and the 'large-sized' dwarf elephant, *P. mnaidriensis*. There was a third species, *P. melitensis*, which was identified as a 'medium-sized' dwarf elephant; this species however, has fallen out of usage. It has been assumed that these three species were all found at Malta and Sicily. Victoria attempted to identify the validity of the species using coefficient variation on the M3 teeth measurements, and demonstrated three different sized taxa at Malta and Sicily; *P. melitensis* and *P. mnaidriensis* are valid as good species; *P. falconeri* and *P. melitensis* are synonymous species, with *P. melitensis* taking priority. The third species Victoria identified is currently being assigned a species.

### A mouthful of jaw

**Marc Jones**, at University College London, presented preliminary results of a study on tuatara jaw shape he carried out with his student, Emma Humphries. Tuatara are reptiles represented by just two living species, *Sphenodon punctatus* and *S. guntheri*, that are currently restricted to islands off the coast of New Zealand; their Holocene record has been largely overlooked. They were previously distributed widely on both the North and South islands which have been effectively separated by the Cook Strait since about half a million years ago. Marc and Emma used landmarks and geometric morphometrics to compare over 150 dentaries from several sites across the two major islands to assess geographic variation. Results demonstrated that jaws from different localities do show differences in shape such as relative jaw depth, but it is unclear whether this relates to differences in genetic phenotype or differences of bone remodelling in response to variation in prey hardness.

## **The variation of assemblages**

**Mark Ruddy**, at Royal Holloway, University of London, discussed the potential variation discovered at different fossil sites in Europe. Fossils can offer the opportunity to identify discrete events in the past; however, a similar assemblage at a different site may contain a mixture of cold and warm fauna due to its different accumulation rates, and deposition; so some sites may give distorted results. Well dated sites, over a small period, and deposited over a short period should show low variation; whereas sites not excavated well with no clear stratigraphy may show more variation. At any site, the results need to take into account the taphonomy of the site, the history of its collecting and the known information about the palaeoenvironment. This may seem like common sense, but mis-reading the result can lead to erroneous conclusions.

## **A Mammoth site**

**Katharine Scott**, from St Cross College, Oxford, discussed a site at Stanton Harcourt, Oxfordshire, which she and Christine Buckingham have excavated for almost 10 years. The site is a series of channel deposits dated to Marine Isotope Stage 7 (around 200,000 years ago) and represents a former course of the River Thames. The majority of the remains are of Mammoth but there are also other large mammals, including elephant, lion and bear. The Mammoths are attributed to the 'Ilford' Mammoth, now considered to be a late form of steppe Mammoth, with some primitive features including thicker dental enamel. The Stanton Harcourt Mammoths demonstrate a maximum shoulder height of only 2.4 metres whereas woolly Mammoths and modern elephants attain a maximum shoulder height of 3.5 metres. The possibility that these specimens are small because they represent only females is unlikely, as the bones were excavated over a wide area and there was no evidence of a single catastrophic event killing a matriarchal herd. Further research is underway on the other mammal remains and on the taxonomy of the small Mammoth.

## **Fishy deposits**

**Hannah Russ**, from University of Bradford, demonstrated results from her PhD project, which is analysing fish remains from cave sites across Europe to see if these remains can be reliably attributed to human occupation. Part of Hannah's research is assessing how reliable fish bone identifications are from different cave sites, and if they are collected at all. To see how bones from their skeletons survive an experiment was carried out with three species of fish; trout, European chub and pike. Three of each species were de-fleshed using Bio-tex solution, sieved through 500 $\mu$ m sieve and dried for 48 hours. A basic 'trampling' experiment was carried out to replicate human and animal movement in caves; elements which were identifiable were picked out and tallied after 25 steps, 75, 175 and 375 steps. The results showed the trout bones

survived best, whereas the pike and chub bones did not survive as well. The results do show that just because one species is present at a cave site does not mean that other fish species were not present. It also highlighted the possibility of a sampling bias, where some bones may not be picked out by the collector, as they are not immediately identifiable as fish.

## **Big and small Carnivores**

**Hannah O'Regan**, from Liverpool John Moores University, discussed the morphology of carnivore remains from several Pleistocene sites in the Cradle of Humankind, South Africa. In particular the different models of evolution and dispersal for the sabretoothed cats of the genus *Dinofelis* were considered. How these felids, along with many other large carnivore species, could have co-existed in the South African Pleistocene, was considered using a basic ecological model based on data from the modern Kruger Park. Using these data it appears possible that the animals could have fitted together, although some species would have to have been in very low numbers. However, time averaging at particularly species rich sites would also account for apparently high numbers of co-existing taxa, and appears the more parsimonious explanation. The model and ideas about the South African Carnivora were developed in collaboration with Dr Sally Reynolds and published in the *Journal of Human Evolution* in 2009.

## **Cleaning bones**

The next talk, given by **Ian Smith**, at Liverpool John Moores University, described the importance of the matrix adhering to bones from cave sites which were not subject to a soil sampling strategy. The matrix contained in bone cavities and fossae, or adhering to rough areas of bone, may contain important information relating to the depositional environment in the form of mollusc shells, bones from microfauna or partially digested fragments of bone. The colour, texture and consistency of the matrix may also provide an indication of the original context of individual bones that have been redeposited and so is one of the factors (alongside the many taphonomic indicators) to take into consideration when attempting to sort bones from bioturbated contexts.

## **A sabre-tooth mystery**

An intriguing talk about the history of excavated material was given by **Ross Barnett**, from the University of Durham. Ross was looking at *Homotherium* sp. remains in the UK; from Kent's Cavern, Devon, and from Cromer, Norfolk. After initial excavation, the specimens from Kent's Cavern were subsequently dispersed to several museums around the UK. Thorough research has shown that there are two canines held at the British Geological Society, one in the NHM, London, one in the Oxford University Museum of Natural History and one at

the Royal College of Surgeons (this specimen has unfortunately been lost in the 2<sup>nd</sup> World War). The canine from Oxford is currently missing (although it has been photographed). One incisor specimen is held at the NHM and the other at the Royal Albert Museum, Exeter. This talk highlighted how historically specimens were often dispersed to different museums and the importance of contacting different museums when researching certain sites is invaluable.

### **The decline of the Mammoth**

The final talk for the conference was given by **Adrian Lister**, from the NHM. Adrian discussed research he was working on with Tony Stuart, illustrating the decline in the Mammoth across Europe and Siberia. Animals can react to environmental change by adapting to the different environment, changing their range, phenotypic plasticity, or becoming extinct. During the last glaciation there was a large area of dry steppe-tundra which was replaced by forests and tundra in the Holocene. There are currently two schools of thought on Mammoth extinction; modern tundra, such as that in Siberia for example, is boggy and not very biologically productive, which would not have sustained the needs of the Mammoth feeding habits; or the overkill theory.

Looking at Mammoths which had been dated, Adrian and Tony have been able to reconstruct the final range of the Mammoths. Until about 21 ka (thousand years ago), the range of Mammoths was across northern and central Europe and Siberia. Fewer Mammoths date from the period of the Last Glacial Maximum (LGM, 21-19 ka), demonstrating a refugium in Siberia. They then appear to re-expand, but to shrink again at 14 ka into North Siberia and re-expand for a brief period during the Younger Dryas (12.9-11.7 ka). The last record of Mammoths on Wrangel Island date to 4 ka. It appears that the Mammoths were reacting to changing vegetation; as the grasslands were replaced by forests, the Mammoths retreated to the small pockets of vegetation where they could survive. From here, perhaps due to additional pressures (such as human hunting), they became extinct.

The research demonstrates that during the climatic changes within the Pleistocene Epoch, the Mammoth adapted to the stresses on their environment, and that both the changing climate and human hunting may have together assisted in the extinction of these giant mammals. During the Glacial periods, the Mammoth's range was large, covering much of Northern Europe and Siberia. As the lush grasslands shrunk in response to the interglacial climate, the Mammoths retreated to small pockets where they could survive. Coincidentally, humans appear to have arrived at the same time these large mammals were in their refugia, and the small populations of the large mammals could not respond to human hunting. It should be noted that the research has been carried out by using currently dated Mammoths (included many dated on Tony and Adrian's

project). There are untapped specimens in museums which currently have not been dated, and could shed more light on this theory.

There was an opportunity to view several posters during the lunch breaks which ranged from highlighting the importance of microfauna and isotope analysis on various microfauna teeth to an interactive poster by exploring the methods museums and universities use to interact with the public. The conference attendees were also fortunate enough to partake in several behind the scenes tours at the NHM. These included visiting the spirit preserved specimens, the Quaternary fossils, and were fortunate enough to observe some of the museums hi-tech equipment, including scanning electron microscopes creating 3D images of specimens, the Alicona imagining machine, which can be used to measure cut marks on bones, and a macro scanner for 3D imaging of large specimens.

### **Summary**

The conference was well attended with students and professionals from different fields of vertebrate Quaternary Science. There were a variety of topics throughout the two days, through the talks, posters and the tours, which highlighted the importance of linking the different research fields. Networking with colleagues presented a plethora of opportunities to discuss new ideas and potentially collaborate on research projects. One topic that came up several times was the importance of museum specimens for research. Many museums across the UK, large and small, hold Quaternary specimens that can assist researchers to unlock the secrets of this recent past.

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**ANNUAL FIELD MEETING TO THE WEST SUSSEX  
COASTAL PLAIN, ARUNDEL OF THE INQUA NORTH AND  
WEST EUROPE WORKING GROUP OF THE COASTAL AND  
MARINE PROCESSES COMMISSION**

**July 4<sup>th</sup> – 7<sup>th</sup> 2010**

What would you ideally desire in a coastal field meeting in Southern England? Consider that. If you do, you probably have grasped the essence of Arundel's 2010 INQUA field meeting. The author, a debutant to such events, arrived at the venue in the Sunday afternoon, to marvel at the picturesque surroundings, and to be greeted by the mastermind behind all this: **Phill Teasdale** (University of Brighton). It had begun. And slowly but steadily, all other participants gravitated to the Norfolk Arms Hotel, which consequently filled up with British and Dutch scholars, and one exceptional Flemish lady. This bilingual blend soon found itself at the ice breaker: a fine stage for the new and the established to mingle, quite like the excellent dinner.

The next day was dedicated to theory. Most of the ~20 participants had signed up for a presentation, and we gathered under the painted yet watchful eye of the alleged Duke of Norfolk for four sessions of presentations. **Martin Bates** (Lampeter) kicked off with an extensive overview of the Quaternary history of the coastal plain we resided on, and **Colin Whitehead** talked us through Black Rock, which seems to contain French clasts, after which we could let all that knowledge settle in over coffee. For after the break there was no rest: all extremities of the coastal British Isles and their geographical relevance were discussed. **David Smith** (Oxford) tackled sea level in Scotland, in combination with prehistoric cultures; **Roland Gehrels** (Plymouth) toppled over some previous theories about Irish sea-level evolution; **Phill Teasdale** discussed radiometric dating in Scotland and all its complications, and **Jason Kirby** (Liverpool John Moores) took us back to Southern England to enlighten us on how the sea had played with the Dungeness gravel barrier. Then it was time for lunch, which was quite splendid.

After lunch we embarked on a longer journey; **Martin Bates** started nearby, discussing non-analogue faunas as found in the earlier discussed southern coastal plain, after which **Cecile Baeteman** (Belgian Geological Survey) took us to the Belgian coast, and their tidal inlets. **Malcolm Bray** (Portsmouth) introduced some Mediterranean spirit elaborating on Maltese boulders; tsunami deposits? **Henk Weerts** (Cultural Heritage Agency, Netherlands) then brought the grain size resolutely back to sand, and specifically a Dutch beach barrier with an unexpected Roman harbour in it. We then reactivated our digestive systems with coffee, tea and cake.

Last but not least there was a final session, kicked off by the author, who spoke of Icelandic sea level, **Sytze van Heteren** (Deltares, Netherlands) discussing the Dutch shoreface and transgression casually dethroning the “Bruun Rule”; **Peter Vos** (Deltares) blaming many processes previously seen as natural on man and praising medieval safety, and **Natasha Barlow** (Durham) gloriously closing the ranks with the problematic sea-level history of the Solent. All these excellent speakers now had deserved a pint! Luckily there was time to explore the abundant pubs of Arundel before dinner.

The next morning we tried to trace all locally preserved raised beaches in chronological order; we started out with a small exposure of Goodwood/Slindon raised beach gravels, and moved on to where the Aldingbourne raised beach could be clearly distinguished in the landscape. Some previously retrieved cored material illustrated the wide gestures of expert Martin Bates. We then went down to the modern beach at Selsey, where wave erosion ate away at a cliff of not entirely certain age, and unseen channel fills lurked in the depths.



**Figure 1.** Fieldtrip leaders Martin Bates and Phill Teasdale on the beach at Selsey.

The next stop was at West Wittering in the Chichester Harbour. This large area contains many interesting features: a tidal delta, very rapid changes in aeolian sand deposition, moving sand bars, a spit, and an ice cream van, just to name a few. As soon as the packed lunches had vanished in the apertures of the assembled intelligentsia **Malcolm Bray** showed us the greater picture, where the river Solent would have run, and what modern tides do with the sediments. He then showed us a very recent and very small row of dunes in



front of "Millionaire's Row". A kind gift from nature, providing protection, but also a detested incursion on dearly paid views, and horticultural tidiness.

We proceeded to the spit, of which the migrations were well-documented. Some sand bars on their way to join it could be seen, as well as the location where it had been breached in 2004. We walked all around, which also allowed us a glance on the salt marsh that the spit protected. It had been, and may continue to be, a test lab for small-scale method validation studies. On the other side of the sea arm we found another cliff face with alleged marine sediments, with a nice ice wedge in them. Just seaward of this cliff London Clay was exposed; this yielded some pretty fossils.

Those who expect the report of this day to end soon: think again! We managed to jam quite some coastal geography in this one modest day. So fearlessly we continued, past yet another spit-with-saltmarsh, and to a barren mudflat that had been a flowering *Spartina* field. Every *Spartina* plant had by now gone to meet its maker. And the *Spartina* might have given up, but we hadn't. Our energy was illustrated by Michael Tooley, who found a swing, and could not restrain himself, much to the dismay of David Smith. Not all of us were so inexhaustible, though; here and there some desire for a pub could be discerned. But all in its own time; first we wanted to have a look at a marsh that had a community of *Spartina* that still thrived; why this difference? Shout if you know the answer. Then we had seen enough for one day, and hastened to the pub.

The next morning the road took us to Elmer, where an innovative array of small breakwaters had been constructed a few years back. This was another expression of affluent people living near the shore; this makes elaborate coastal defence lucrative. We walked along the breakwaters to the east, where the breakwaters are replaced by groynes. The last groyne showed a difference of several meters in sediment heights on both sides...

The last excursion point was the levied Adur in Shoreham. Phill Teasdale told some wild tales of waves battering his equipment, and of research methods that looked so decidedly dodgy that the police came to have a look in large numbers. And on that spectacular note we called it a field meeting. We said goodbye, and I think I can rightly say we all went in our preferred directions feeling slightly melancholy. It had been a good meeting! May future organisers of this event fare as well as the gentlemen responsible for this one were. We thank Phill and his co-organisers Callum Firth (Brighton), Malcolm Bray and Martin Bates for a splendid field meeting.

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# QUATERNARY RESEARCH FUND

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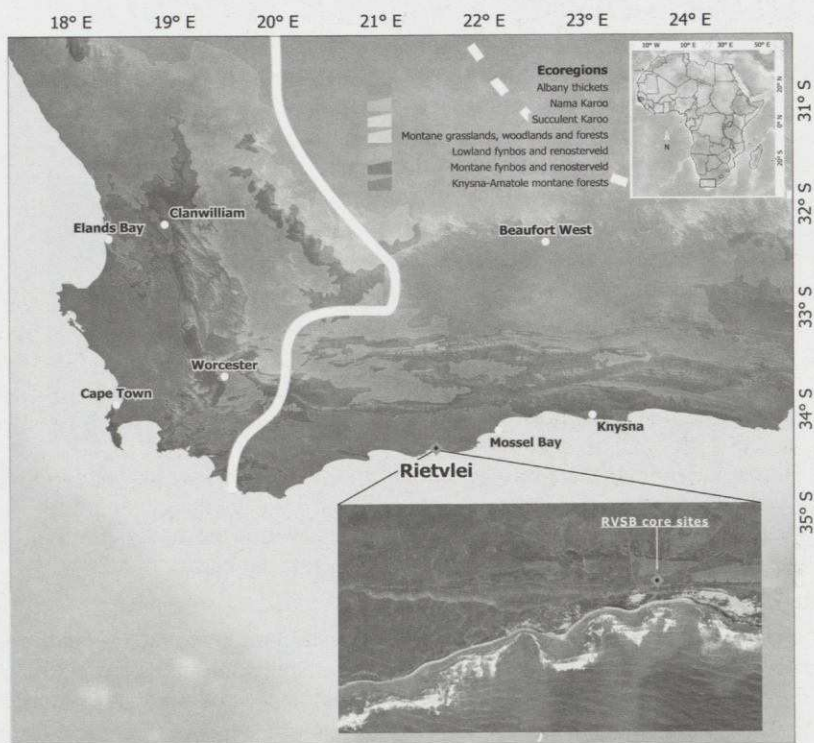
## LATE QUATERNARY PALAEOECOLOGICAL AND PALAEOENVIRONMENTAL DYNAMICS OF THE STILL BAY REGION, SOUTH AFRICA

### Background and rationale

The southern Cape coast of South Africa spans the transition between southern Africa's winter and summer rainfall regimes. These contrasting climatic zones reflect the continent's latitude, and the seasonal migration of the sub-tropical high pressure cells. In light of the region's clear palaeoclimatic significance, and its important Middle Stone Age archaeological heritage (e.g. Henshilwood *et al.*, 2002) the area has seen a growing palaeoenvironmental and archaeological research effort. However, the majority of terrestrial palaeoecological archives are frustratingly short and fragmentary (Chase and Meadows, 2007). Recent fieldwork concerning the wider geomorphic history of the southern Cape coast identified a number of promising sites for palaeoecological study, including Rietvlei, an interdune wetland near to the town of Still Bay (Figure 1). The wetland has formed between a Last Interglacial barrier dune system and the remnants of an older cemented dune system, possibly relating to the penultimate interglacial (Figure 2: see Roberts *et al.*, 2008). Luminescence ages from the basal outer barrier provide a maximum age for the formation of the wetland of c. 125 ka (MIS 5e). Funding from the QRA supported fieldwork for preliminary coring of the Rietvlei site to assess the potential palaeoenvironmental and palaeoecological record preserved.

### Results

Two cores from the eastern margins of the lake, RVSB1 and RVSB2, reached depths of 2.75 and 3.60 m respectively. Both cores comprise organic-rich black to very dark brown silty sands. Three initial radiocarbon ages from RVSB2 span the period 1,260 <sup>14</sup>C years BP to 27,630 <sup>14</sup>C years BP. A clear increase in sedimentation rate and organic matter accumulation is apparent during the last 10,200 <sup>14</sup>C years BP (corresponding to a depth of c. 2.5 m; Figure 3a). Variation in TOC and C/N ratio is accompanied by significant fluctuations in  $\delta^{13}\text{C}_{\text{TOC}}$  (-25 to -21 ‰), with a tendency for more depleted values during much of the Holocene. We are currently using compound-specific stable isotope analyses to disentangle the causes of this  $\delta^{13}\text{C}$  variation, which may reflect changes in the wider terrestrial vegetation (e.g. presence of  $\text{C}_4$  vegetation), and/or variation in local macrophyte and algal inputs.



**Figure 1.** The location of the Still Bay area and the coring site, Rietvlei. The solid white line marks the limits of the winter rainfall zone of the Western Cape Province; the dashed white line marks the transition from a year round/mixed regime to a fully summer rainfall dominant climate.

We have also applied the less well-known technique of pyrolysis-GC/MS (gas chromatography mass spectrometry), which we have used to characterise the macromolecular (insoluble) organic matter (OM) within the samples (Carr *et al.*, *in press*). This approach reveals clear changes in the fundamental composition of the organic matter within the cores; including distinct fluctuations in the relative significance of algal and higher plant-derived organic matter. The technique also provides insights into the extent of OM preservation and the mechanisms underlying OM degradation. For example, figure 3b shows down-core variations in the concentration of lignin-derived pyrolysis products. The rapid decline in lignin abundance in the upper 0.5 m reflects its sensitivity to post-depositional degradation within what is a warm, relatively arid environment. Interestingly, further down the core a secondary lignin peak is observed at 1.5 m, which is commensurate with rising trend in TOC and declining  $\delta^{13}\text{C}$  (not shown).



**Figure 2.** View of the Reitvlei wetland looking south (ocean visible to the left) from the crest of a (Marine Isotope Stage 7?) cemented dune ridge. The wetland, visible in the middle ground, has formed within the topographic hollow between this ridge and the prominent last interglacial barrier dune system.

This is probably indicative of enhanced terrestrial organic matter delivery to the wetland. This approach is also providing insights into the contribution of specific lignin types (related to angiosperms, non-woody angiosperms and gymnosperms) and fluctuations in organic matter provenance (e.g. the varying contribution of algal biomass). We aim to refine these data in conjunction with ongoing palynological and charcoal analyses, along with additional chronological control.

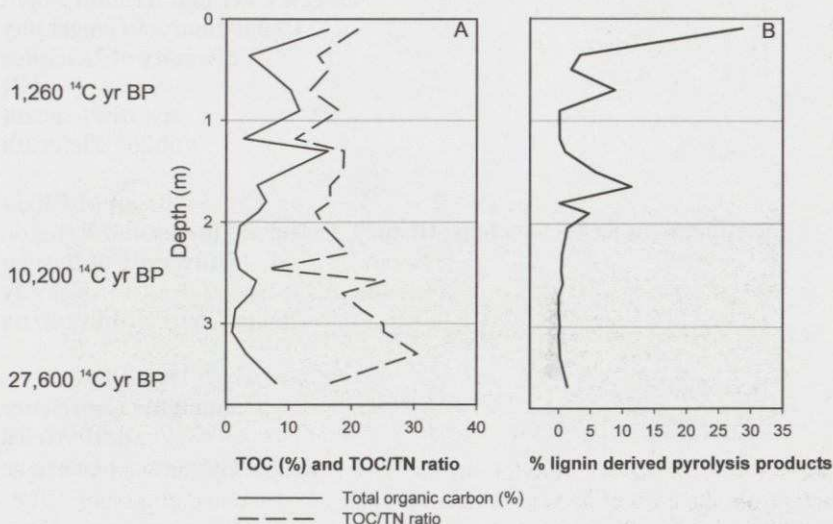
### **Wider significance**

The extraction of such an organic-rich (in the Southern African context) and apparently long record suggests that the site holds great promise. The site potentially holds on one of the longest palynological records for the region's unique Cape Flora (Chase and Meadows, 2007). Initial results confirm the persistence of this water body throughout at least the Late Quaternary, which probably accounts for diverse trace fossils preserved in the nearby aeolianites. These trackways preserve evidence for a wide variety of fauna, most notably the African Elephant, as well as various Antelope, and Equids (Roberts *et al.*, 2008).

### **Acknowledgments**

The QRA are thanked for supporting this research. Guy Gardner is thanked for his hospitality and granting access to the site.





**Figure 3.** Preliminary data from core RVSB2: Graph a) shows the total organic carbon and C/N ratios for core RVSB2. Graph b) displays the relative concentration of lignin-derived organic matter for the same core, as derived via pyrolysis-GC/MS.

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# **NEW RESEARCHERS AWARD SCHEME**

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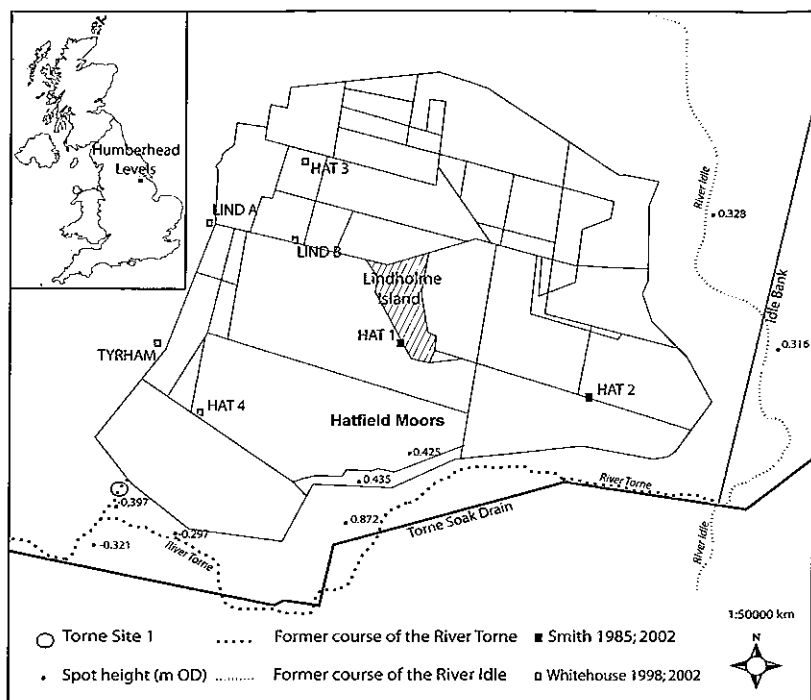
## **SUB-FOSSIL COLEOPTERAN REMAINS FROM THE FORMER TORNE RIVER COURSE, NEAR HATFIELD MOORS, HUMBERHEAD LEVELS**

### **Background and rationale**

The Torne River was canalised in the seventeenth century (Cory, 1985); prior to this the river closely skirted the southern margins of Hatfield Moors (one of the largest lowland raised mires in Eastern England and now an SSSI) in the Humberhead Levels region of South Yorkshire (Fig. 1). Alluvial clay, silt and fen peat deposits are associated with the river floodplain, providing a complimentary archive of Holocene environmental history away from the neighbouring raised mire. In comparison to the mire, limited palaeoenvironmental research has been carried out on the river floodplains. Investigations on Hatfield Moors have revealed the nature of the mires environmental history from around 3000 cal BC (Boswijk, 1998; Boswijk and Whitehouse, 2002; Smith 2002; Whitehouse, 2004; Geary, unpublished); Figure 1 shows the locations of previous study sites. Hatfield Moors is a sensitive mire system with a good record of later Holocene environmental, climatic and hydrological changes. Peat initiation is centred on 3000 cal BC; Coleoptera and plant macrofossil analyses, testate amoebae and pollen stratigraphical investigations highlight a series of environmental changes. Recurrence surfaces (periods of increased surface wetness) have been recorded on the mire, while changes in woodland composition and pulses of peat growth are well documented and dated (Boswijk, 1998; Boswijk and Whitehouse, 2002; Smith 2002; Whitehouse, 2004). Sea-level change, climatic fluctuations and human activity have been recognised as potential forcers of environmental change in the Humberhead Levels region, which likely affected both mire and floodplain ecosystems (Buckland and Smith, 2003).

Few investigations have attempted to examine any relationships between floodplain and mire ecosystems within a wider landscape context, as well as their combined connections and responses to environmental change- the subject of this project. Testing whether or not the systems react to change in a similar manner (e.g. synchronous or not) or at the same magnitude (or not) may allow us to view Holocene environmental change and system responses to processes such as 'tipping points' from a holistic landscape perspective. Thus, it may also be possible to ascertain the major forces of change that apparently cause these ecosystems to breach their thresholds. This may allow us to begin to understand the connections between the two different ecosystems and provide greater clarity on responses to climate and associated environment changes





**Figure 1.** Location of Hatfield Moors and the Humberhead Levels, South Yorkshire. Previous palaeoenvironmental research locations are shown, together with former river courses and the primary sampling location for this study (Torne Site 1).

during the Holocene in a particular region (i.e. Humberhead Levels), which would have important implications to our understanding of system processes to long and short term change.

Sub-fossil Coleoptera, pollen stratigraphical investigations and analysis of the sedimentary archive have been used to reconstruct the environment on the River Torne Floodplain. The identification of Coleoptera from one sampling site (Torne Site 1) was undertaken at the University of Birmingham, this was facilitated by a New Researchers Award Scheme grant from the Quaternary Research Association.

## Results

Coleoptera were extracted and identified from one floodplain site (Torne Site 1) on the former course of the River Torne (Fig. 1). In total, 991 individuals were identified across a 3m stratigraphic sequence (clay and humified fen peat deposits), representing 24 families, 81 genera and 74 species from a total of 45

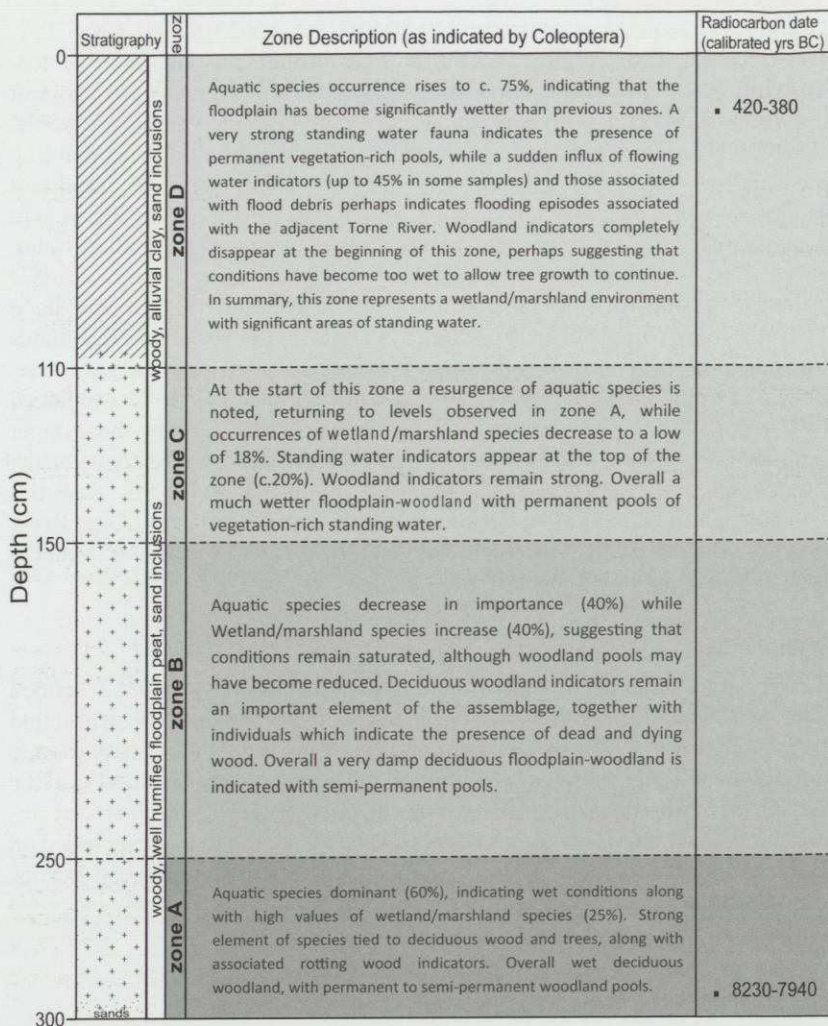
samples. The sequence dates from 8230-7940 (UBA-10633) to 420-380 (UBA-10630) cal BC; Fig. 2 summarises the major environmental changes recorded. The early Holocene period, represented by Zone A (Fig. 2) consists of very wet deciduous woodland, with permanent and semi-permanent woodland pools. Zone B represents a slightly drier phase in ecological development, enabling the deciduous woodland to flourish as woodland pools became less important in the environment (Fig. 2). By Zone C the floodplain appears to increase in wetness once again, with permanent pools of vegetation-rich standing water, although the woodland remains a significant element of the ecosystem. Zone D represents the most dramatic change in ecosystem dynamics (Fig. 2). Woodland indicators have completely disappeared by the start of this period; the deciduous forest in this locality probably declined as a direct result of increasing wetness, indicated by the surge of aquatic Coleopteran species. This is accompanied by a major stratigraphic change with clay deposits characterising these upper sediments, suggesting that the floodplain environment had changed dramatically. The occurrence of species associated with running water in this zone (D) perhaps indicates flooding episodes associated with the adjacent Torne River (Fig. 2). A marshland environment with significant areas of standing water is likely to have prevailed thereafter.

### Significance

Sub-fossil Coleopteran analysis (together with pollen analyses- not described here) of floodplain deposits has produced a palaeoenvironmental reconstruction from the Torne River in the Humberhead Levels (Fig. 1). Broad-scale environmental changes have been highlighted in Figure 2; further dating of the sequence is currently taking place, which will provide a chronology to the events observed. Once this is complete, events can be compared to those recorded on Hatfield Moors and other palaeoecological sites in the Humberhead Levels, thus allowing the aims (set out in the introduction of this report) associated with the wider research project to be addressed.

### Acknowledgements

The author would like to thank the QRA for its financial support provided through the New Research Workers Award. Field work associated with this report was also funded by the *Thorne and Hatfield Moors Conservation Forum (THMCF)*. Radiocarbon dates were awarded by the <sup>14</sup>CHRONO centre, Queen's University, Belfast. Dr. Nicki Whitehouse, Dr. Ben Gearey and Dr. Helen Roe are to be thanked for their continued supervision and support. Also Dr. David Smith for his assistance in Coleopteran identifications. Finally Mr. D. Chappell of Boston Park Farm for access to land and also Helen Kirk (*THMCF*) for her helpful assistance with various aspects of this project.



**Figure 2.** Summary of major environmental changes interpreted from sub-fossil Coleoptera recovered from the Torne River floodplain (zonation has been ascribed visually), together with recorded stratigraphy and radiocarbon dates (cal yrs BC).

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# A PALAEOENVIRONMENTAL RECONSTRUCTION FROM THE HOOGLAND BASAL FLOWSTONE, SOUTH AFRICA

## Background and Rationale

The late Pliocene-early Pleistocene represents an important period in African climate history because of its association with early hominin evolution. However, a paucity of climatic data from terrestrial localities hampers high-resolution palaeoenvironmental interpretations. Presented here is stable isotopic data from a flowstone from the South African cave site of Hoogland. Dating to the aforementioned time period, the data provides an insight into the vegetation, and in turn climate, local to the site at the time of speleothem formation.

Hoogland (25°48'48.30" S, 28°0'20.40" E) lies to the northeast of the Cradle of Humankind World Heritage site, 20 km west of Pretoria, and is today situated in a transitional zone between grassland and bushveld savanna vegetation regimes. The Hoogland deposit consists of a ~2 m deep basal flowstone, overlain by ~5 m of fossil-bearing siltstone and gravel deposits, which are separated into 6 accumulation units by thin flowstone layers.

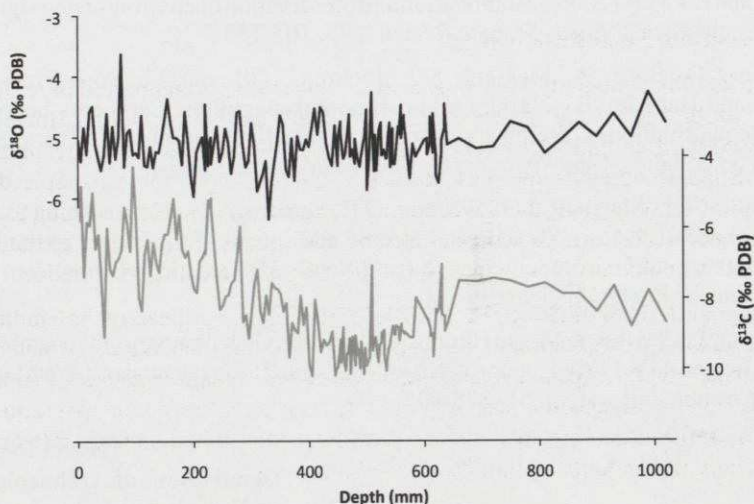
As part of a wider programme of research, and with the help of this QRA grant, stable isotope analysis was conducted on the upper 1.2 m of the basal speleothem. The isotopic composition of speleothems has been demonstrated to reflect the isotopic composition of its source water, which in turn can be linked to overlying environmental/climatic conditions (Fairchild *et al.*, 2006). Oxygen and carbon isotope values were examined as proxies for rainfall and vegetation respectively.

## Result

$\delta^{18}\text{O}$  values range from -6.35‰ to -3.63‰ (mean = -5.12‰), while  $\delta^{13}\text{C}$  values range from -10.18‰ to -4.26‰ (mean = -8.09‰) (Figure 1). No significant trend is present in the oxygen results but the range of values is similar to that seen in other South African speleothems of a similar age (e.g. Hopley *et al.*, 2007). The proportion of  $\text{C}_4$  vegetation at the site can be estimated from the  $\delta^{13}\text{C}$  results, as varying from 0% at ~400-600mm depth, to around 40% at 0-200mm depth, using the method outlined by Genty *et al.*, 2001. The calculation assumes soil  $\text{CO}_2$   $\delta^{13}\text{C}$  values of -25‰ and -11‰ for 100%  $\text{C}_3$  and  $\text{C}_4$  vegetation respectively, and a bedrock component of 15%, which has a local  $\delta^{13}\text{C}$  value of  $-0.9 \pm 0.7\text{‰}$ . (Veizer *et al.*, 1992).

## Significance

$\delta^{13}\text{C}$  results show notable temporal variation in the proportion of  $\text{C}_4$  vegetation present in the Hoogland area. Such change most likely represents a response



**Figure 1.**  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  results from the Hoogland basal speleothem. Data is plotted as depth below the top of the flowstone.

to modifications in the local climatic regime, however it is not yet possible to infer whether these climatic changes operated at a regional or global scale.  $\delta^{18}\text{O}$  results are more difficult to interpret. The lack of a clear trend in the data presents two possibilities: either the signal is a true reflection of climate, with rapid fluctuations operating at a local scale, or the original climatic signal has been altered by post-depositional processes. Direct dating of the speleothem will provide a basis for more robust interpretation of results.

### Acknowledgements

I would like to thank the QRA and ECRC for their financial assistance with this project, and Dr Kruger for allowing access to the site. I am grateful to my supervisor Dr. Phillip Hopley for his guidance throughout the project, and to Dr Andrew Herries, Jason Hemmingway and Florian Stark for their help with fieldwork.

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# STABLE ISOTOPE ANALYSIS OF BIOGENIC CARBONATE WITHIN THE INTERNAL GROWTH INCREMENTS OF THE MARINE BIVALVE *GLYCYMERIS GLYCYMERIS*

## Background and Rationale

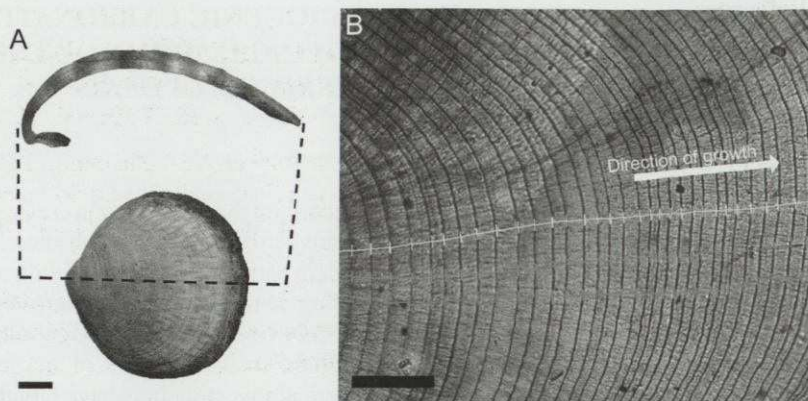
The shells of many bivalve molluscs contain records of their ontogeny in the form of periodic growth increments. These increments can be used to build absolutely dated chronologies by cross-matching equivalent patterns in coeval individuals using techniques derived from dendrochronology. Such chronologies have the potential to become powerful tools for palaeoenvironmental investigations, facilitating annually and sub-annually resolved reconstructions of marine and aquatic change. Thus far sclerochronological investigations have largely focused on the marine bivalve *Arctica islandica* due to its great longevity (>400 years, Wanamaker *et al.*, 2008), proven periodicity (Witbaard *et al.*, 1994) and synchronicity of growth line formation (Butler *et al.*, 2009). The distribution of *A. islandica*, however, is constrained by water depth and sediment type and therefore cannot be used to investigate many regions of key hydrographic and oceanographic interest. It would therefore be beneficial to broaden the spectrum of sclerochronological archives, incorporating species which occur in many different habitats and environments. The dog cockle, *Glycymeris glycymeris*, (Figure 1) has the potential to be one of these species; its preferred habitat and distribution complements those of *A. islandica*, and with a maximum longevity of ca. 200 years and annual growth increments (Berthou *et al.*, 1986) it seems to be suitable for chronology construction. In addition, *G. glycymeris* has been shown to be an accurate recorder of anthropogenic impacts on marine benthic communities (Ramsay *et al.*, 2000).

## Methodology

We examined the stable isotopic composition of one *G. glycymeris* collected live from the Tiree Passage (west Scotland), in 2006. Growth increment widths were digitally recorded and compared with a statistically robust *G. glycymeris* master sclerochronology. Annually resolved aragonitic calcium carbonate samples were micromilled from 28 of the most modern growth increments. The resulting  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  records were then analysed with respect to the raw growth increment measurements as well as local sea surface temperatures (SST).

## Preliminary Results and discussion

A statistically significant positive correlation was identified between annually resolved  $\delta^{18}\text{O}$  values and sea surface water temperatures ( $r=0.53$   $p<0.001$ ), opposite in sign to the established (negative) relation for aragonite. Conversion of the  $\delta^{18}\text{O}$  values to bottom water temperatures using the aragonite palaeo-



**Figure 1.** A) A complete *G. glycymeris* shell sectioned along the axis of maximum growth (dashed line) valve. Scale bar = 10mm. B) Photomicrograph of annually resolved growth lines within *G. glycymeris* complete with series of measurements. Scale bar = 100µm.

temperature equation suggests a strongly stratified water column during the season of peak shell growth. The  $\delta^{13}\text{C}$  determinations over the same 28 year period indicate a significant linear trend towards more depleted  $\delta^{13}\text{C}$  values overlaid with a cyclic 7-8 year oscillation. Linear regression analysis of the  $\delta^{13}\text{C}$  values with the raw growth increment measurements as well as comparison with other  $\delta^{13}\text{C}$  values over the same period suggests that this decline likely combines an ontogenetic element with a secular trend due to the  $^{13}\text{C}$  Suess effect.

### Acknowledgements

I would like to thank the QRA's New Research Workers award for providing financial support. A special thanks must go to Dr. Alan Wanamaker for supporting both the technical work as well as accommodating myself allowing me to complete the micromilling and running of the samples. Thanks must also go to Prof. James Scourse and Prof. Chris Richardson for their guidance and supervision as well as providing the opportunity to carry out the work, as well as reading the manuscript. Final thanks must go to Dr. Paul Butler for his valuable comments.

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# CONSTRAINING THE LONG-TERM UPLIFT OF NOEL HILL, KING GEORGE ISLAND, SOUTH SHETLAND ISLANDS, ANTARCTICA

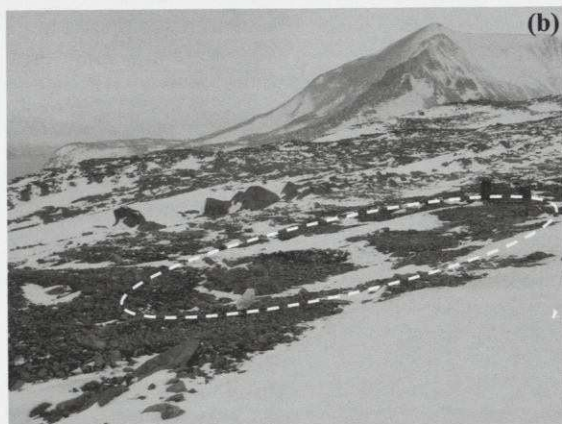
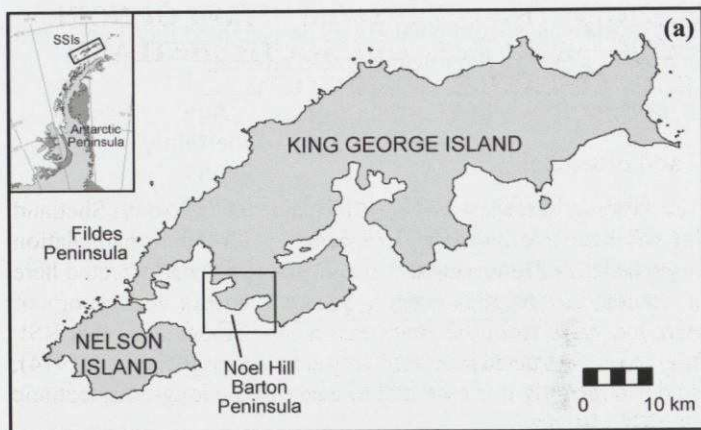
## Background and rationale

A new high resolution relative sea level (RSL) curve for the South Shetland Islands (SSIs) has been produced by integrating evidence from isolation basins and raised beaches. However, RSL reconstruction is complicated here by the role of tectonics, as the islands lie on a plate boundary with reports of neotectonic activity. Work from the Huon Peninsula demonstrates that RSL can successfully be reconstructed in tectonically active areas (Chappell, 1974), but in order to do so robustly it is essential to quantify the long-term tectonic contribution to RSL change.

It is proposed to use cosmogenic exposure dating of previously reported high altitude pre-Holocene "residual beach" deposits to estimate the long-term tectonic uplift rate of the SSIs. The deposit sampled is on Noel Hill, King George Island, SSIs (Figure 1), at 134 m above mean sea level (amsl), in an area where the Holocene marine limit is < 20 m amsl. The deposit has previously been described, although not dated, by John and Sugden (1971). It forms a terrace-like surface at the base of a ~15 m cliff and consists of well-rounded pebbles and cobbles. The original strategy was to date the clasts using multiple cosmogenic isotopes ( $^{10}\text{Be}$ ,  $^{26}\text{Al}$ ,  $^{21}\text{Ne}$ ) to allow consideration of the complications associated with multiple periods of ice cover. However, there were no quartz-bearing clasts and therefore the dating strategy was revised to the use of chlorine-36.

## Results

$^{36}\text{Cl}$  analysis was carried out at the University of Edinburgh and SUERC, and ages were calculated following Schimmelpfennig *et al.* (2009). Four samples were dated (Table 1) and the overall age of the deposit is taken as the error weighted mean and 1-sigma standard deviation of the four ages, to reduce the influence of ages with large uncertainties. The weighted mean age of the Noel Hill deposit is  $6872 \pm 966$  yr BP, assuming zero erosion of the samples.

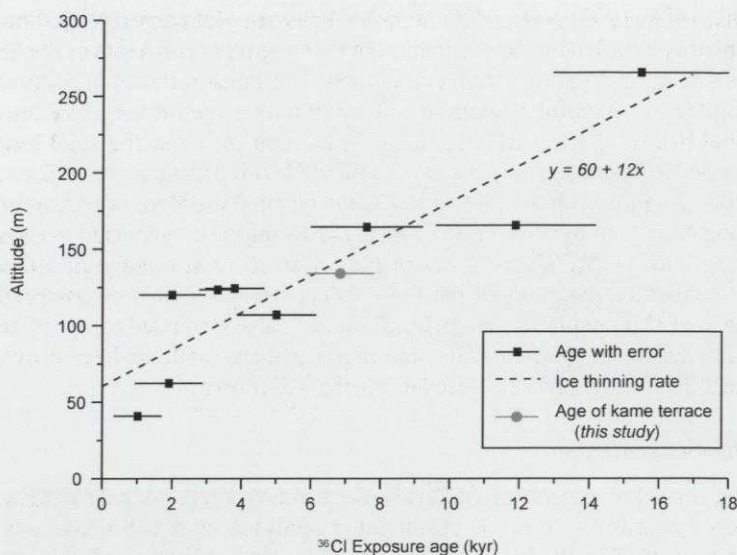


**Figure 1.** (a) Location of Noel Hill and the South Shetland Islands; (b) Terrace-like surface (~10x25 m) wrapped around the base of an ice-moulded hill (off photo to right) at 134 m amsl on the side of Noel Hill; (c) Surface of the terrace consisting of well-rounded and sorted pebbles and cobbles.



**Table 1.**  $^{36}\text{Cl}$  exposure ages from Noel Hill. The weighted mean age of the four samples is  $6872 \pm 966$  yr BP, assuming zero erosion.

Sample	$^{36}\text{Cl}$ with 1 $\sigma$ error (atoms/g)	Age (yr)	Age uncertainty (yr)
NH1	$47000 \pm 48200$	<b>5497</b>	6979
NH2	$51500 \pm 9490$	<b>5764</b>	1440
NH3	$77300 \pm 84100$	<b>8764</b>	10823
NH8	$108000 \pm 9260$	<b>7849</b>	1337



**Figure 2.**  $^{36}\text{Cl}$  exposure ages of glacially striated surfaces on Barton Peninsula, King George Island from Seong *et al.* (2009). The date on the kame terrace deposit from this study (red) fits closely with the proposed ice thinning rate of Seong *et al.* (2009).

## Significance

A depositional age of *ca.* 7 ka BP differs enormously from the age estimated by Pallàs *et al.* (1997) of *ca.* 250 ka, and suggests the original hypothesis that the dated deposits are beach sediments deposited at sea level and subsequently uplifted probably needs revising. The first alternative that the deposits mark

the Holocene marine limit can be discounted as this does not fit with evidence from isolation basins in this wider study that places RSL below 15 m at 6.5 ka BP. The second possibility is that this deposit is a much older residual beach that has remained ice-covered until the final deglaciation. However, this is not consistent with the extensive (100s of metres wide, kilometres long) wave-cut platforms across the SSIs at elevations up to 290 m amsl, which were cut during non-glacial intervals.

A third possibility is that the deposits are actually glaciofluvial kame terraces. They closely resemble the description of a kame terrace at 160 m amsl at Tumbledown Cliffs, James Ross Island of "well-rounded stones in a sandy to gravelly matrix forming a small terrace-like step in the valley side". The deposit also closely resembles kame terraces found around polythermal glacier margins elsewhere in Iceland and on Ellesmere Island, Canadian High Arctic (Evans, 1988, 1990, 2005). Although this does not yield any information on RSL history or aid in the determination of the long-term uplift rate of the SSIs, this is still an interesting discovery as reports of kame terraces in Antarctica are limited to a handful of locations. In addition, an age for the kame terrace on Noel Hill of *ca.* 7 ka BP also helps further constrain the deglacial history of Barton Peninsula, and agrees extremely well with previous work (Seong *et al.*, 2009; Figure 2). In order to address the original problem of constraining the long-term tectonic uplift rate, marine platforms have been used as proxies for long-term uplift. Where suites of platforms occur at a range of altitudes at the same location, ages of the most recent interglacials were assigned to increasingly higher platforms. An uplift rate was also estimated by considering the fault system around the SSIs, and together these methods have provided the tectonic correction factor needed for the RSL curve.

### Acknowledgements

I gratefully acknowledge the QRA New Research Workers' Award for financial support towards the cost of cosmogenic analyses, and the University of Edinburgh and SUERC for running the analyses, in particular Dr Steve Binnie for assistance with the labwork and processing of results. This work forms part of a PhD funded by a British Antarctic Survey Collaborative Fund studentship. Thanks to the crew of HMS Endurance and BAS Field Operations staff for logistical support during fieldwork, and to my PhD supervisors Mike Bentley, Dom Hodgson, Rob Larter, Jerry Lloyd and Steve Roberts for their support.

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**Department of Geography**  
**Durham University**

# REVIEWS

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## **CUSHENDALL (SHEET 14)<sup>1</sup>, NEWTOWNSTEWART (SHEET 25)<sup>2</sup> : BEDROCK AND SUPERFICIAL DEPOSITS, NEWTOWNSTEWART (SHEET 25)<sup>3</sup> : BEDROCK (NORTHERN IRELAND)**

**Published by : British Geological Survey 2009<sup>1</sup> 2008<sup>2,3</sup>**

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1:50,000 sheets £8 each; 25 % discount for academic institutions when ordered from : **Sales Desk, Geological Survey of Northern Ireland – GSNi, Department of Enterprise, Trade & Investment, Colby House, Stranmillis Court, Belfast, BT9 5BF** Tel: 028 9038 8462 (ext: 82662) Web: [www.detini.gov.uk](http://www.detini.gov.uk) (prices exclude post and packing at cost).

The Cushendall sheet (14) fills a significant gap in the coverage of the Antrim coast, even if the out of print Giant's Causeway (7) and Ballycastle (8) sheets require remapping with photogeological interpretation and ground checking - as demonstrated by this newly published map for this neighbouring district. Northern Irish geological 1:50,000 maps are published in a slightly more popular style than those for England and Wales, even if they have similar sheet lines, and so the latest editions have a **Landscapes from Stone** section in their margins. This text provides a brief introduction to the local geology and notable features with key names and terms highlighted in bold, illustrated with selected colour photographs and the occasional diagram.

With the Cushendall map, I have an occasional quibble with this style of presentation. Even if writing clearly and informatively for the interested layman is no mean feat, I take issue with the district being covered by "a sheet of ice that originated from Northern Europe" rather than Scotland, nor is it made clear that evidence of previous ice sheets has been obliterated by the last one, along with any signs of older Quaternary deposits. The main map has numbered 5mm wide circles relating to these photographs, which are unnecessary, as the excellent captions in the Landscapes from Stone section quotes these grid

references, and the third circle even manages to obscure locally important detail. However, the neatly drafted map shows the complex distribution of superficial deposits which blanket most of the local bedrock, with peat covering higher ground and till along upland streams, plus significant areas of morainic deposits and glaciofluvial material further away from the uplands. Drumlins are marked in dark blue, and glacial meltwater channels are indicated, while along the coast below the edge of the Antrim Lava Plateau a series of major landslips is marked.

The Newtownstewart sheet (25) covers an eastern portion of county Tyrone and a small portion of the Republic of Ireland, and is published as two editions, so that one shows only the bedrock geology. Unfortunately, the other one, including the superficial deposits that blanket the area does not simplify this line work, as done on this version of the new pair covering the Rochdale sheet (*Quaternary Newsletter* No. 121, 57-60), so areas underlain by Neoproterozoic metamorphic rocks have dense patches of near parallel lines that are highly distracting. However, with a separate bedrock edition the Landscapes from Stone section could go into relatively greater detail about the areas Late Quaternary history.

Though only relatively few types of superficial deposit occur in the district, in places they are quite complex and are associated with various glacial features neatly shown with a combination of ten distinct types of lines, and dark blue and red for drumlins and kettleholes. The annotated simplified 1:125,000 land system map shows the glaciofluvial (sand and gravel) deposits, moraines and drumlins in relation to selected meltwater channels and eskers, though 200 m and 300 m contours are only provided for the eastern half of the sheet, when in any case 50 m intervals would have been more informative. With two extra folds (25 cm) it would have just been possible to incorporate on the same map the Northern Irish part of the Killeter sheet (24) to the west. Now this is too late, it could be produced in an unusual combination with the also as yet unpublished map for Strabane (17) to the north of Newtonstewart. In any case, contemporary Northern Irish publications provide great potential teaching material which are notably cheaper than their British equivalents and yet produced to the same high standards.

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## QUATERNARY RESEARCH ASSOCIATION

The Quaternary Research Association is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. The majority of members reside in Great Britain, but membership also extends to most European countries, North America, Africa, Asia and Australasia. Membership (currently c. 1,000) is open to all interested in the objectives of the Association. The annual subscription is £20 with reduced rates (£10) for students and unwaged members and an Institutional rate of £35.

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

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

**President:** *Professor D. J. Charman*, Department of Geography, University of Exeter, Rennes Drive, Exeter EX4 4RJ, UK  
(email: d.j.charman@exeter.ac.uk)

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**Editor, Journal of Quaternary Science:**

*Professor A.J. Long*, Department of Geography, University of Durham, Durham, DH1 3LE. (e-mail: a.j.long@durham.ac.uk)

**Publicity Officer:** *Dr F. Marret-Davie*, Department of Geography, University of Liverpool, Liverpool L69 3BX. (e-mail: f.marret@liverpool.ac.uk)

All questions regarding membership are dealt with by the **Secretary**, the Association's publications are sold by the **Publications Secretary** and all subscription matters are dealt with by the **Treasurer**.

The QRA home page on the world wide web can be found at:

<http://www.qra.org.uk>

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Quaternary Research Association

# CIRCULAR HIGHLIGHTS

## FEBRUARY 2011

### 1. INQUA 2011: <http://www.inqua2011.ch/>

The QRA is a member of the International Union for Quaternary Research - INQUA (<http://www.inqua.tcd.ie/>), which unites scientists from all over the world. The next (XXVIII) INQUA Congress will be held in Bern, Switzerland 20th July - 27th July, 2011.

Please note that Early bird registration closes on 31<sup>st</sup> March 2011 and costs CHF 750 (CHF 550 for PhD students), equivalent to ca. £490 and £360 respectively, based on current exchange rates. Later registration is even more expensive.

The QRA website has information about obtaining travel grants for the 2011 INQUA congress and an application form can be found at <http://www.qra.org.uk/grants/8>. Note that the deadline for receipt of applications is **15<sup>th</sup> February 2011**

### 2. QRA AWARDS NOMINATIONS: <http://www.qra.org.uk/grants/awards>

The QRA sponsors several prizes in recognition of excellence in the field of Quaternary research. The **Undergraduate Dissertation Prize** is awarded annually and is administered by the RGS-IBG. The **Lewis Penny Medal** is awarded to a young or new research worker who has made a significant contribution to our understanding of the Quaternary stratigraphy of the British Isles. Our senior award, the **James Croll Medal**, is awarded to a member of the QRA who has not only made an outstanding contribution to the field of Quaternary science, but whose work has also had a significant international impact.

We invite the membership to make nominations for these awards. Application procedures and forms can be found on the QRA website <http://www.qra.org.uk/grants/awards> and have a deadline of **15<sup>th</sup> May 2011** for the Lewis Penny and James Croll medals.

### 3. Minutes of the 45th Annual General Meeting of the QRA, Liverpool, 2011

These minutes were distributed in the February Circular in previous years, but as we now just distribute current QRA Highlights in this circular flier, with main content limited to the QRA website, these minutes will now be available on the website at: <http://www.qra.org.uk/publications/circular>

### 4. QRA PUBLICATIONS: <http://qra.org.uk/publications>

Do not forget to check the latest publications from the QRA website including field and technical guides. You can download an order form from the website and view a summary of contents for each published guide. New 2010 guides (members prices):

**The Quaternary of Western Sutherland & Adjacent Areas (Lukas & Bradwell) £14.00**

**The Quaternary of the Solway Lowlands & Pennine Escarpment (Livingstone et al) £14.00**

## 5. CALENDAR OF QRA MEETINGS: [www.qra.org.uk/meetings](http://www.qra.org.uk/meetings)

Offers to arrange meetings are always welcome. Please contact the Meetings Officer: Dr Eleanor Brown ([Eleanor.Brown@naturalengland.org.uk](mailto:Eleanor.Brown@naturalengland.org.uk)) to discuss your proposal.

### April 2011 **Quaternary of the Exe Catchment & Blackdown Hills**

This meeting is now full at a capacity of 45.

### September 2011 **Field meeting/workshop: Glaciotectonics/Norfolk**

Contact: Emrys Phillips, [erp@bgs.ac.uk](mailto:erp@bgs.ac.uk); Jon Lee, [jlee@bgs.ac.uk](mailto:jlee@bgs.ac.uk)

### September 2011 The Geologists' Association - **Geoconservation for Science and Society: An Agenda for the 21<sup>st</sup> Century**

Venue: University of Worcester

Contact: David Bridgland ([D.R.Bridgland@durham.ac.uk](mailto:D.R.Bridgland@durham.ac.uk)) & Eleanor Brown ([Eleanor.Brown@naturalengland.org.uk](mailto:Eleanor.Brown@naturalengland.org.uk))

### Nov 2011 **Marine Tephrochronology (Co-sponsored meeting)**

Venue: Burlington House, Geol Soc

Contact: Bill Austin, St Andrews ([wena@st-andrews.ac.uk](mailto:wena@st-andrews.ac.uk))

### Jan 2012 **ADM: Quaternary Science and Society**

Venue: Southampton/New Forest

Organisers: Peter Langdon ([p.g.langdon@soton.ac.uk](mailto:p.g.langdon@soton.ac.uk)) & Tony Brown ([tony.brown@soton.ac.uk](mailto:tony.brown@soton.ac.uk))

## 6. UPDATES TO THE QRA WEBSITE

The site will have increased functionality from early 2011, including:

- Online payment for membership, field and technical guides
- QRA on the map (an interactive map with QRA field guides linked to sites)
- Photo gallery (with the interactive map)
- Links with JQS, QSR and Boreas

Furthermore we will improve the database management of the website and also produce an annual membership card which will be sent to each QRA member. This will be necessary for any of the membership who want to visit and use the facilities at the RGS, with whom we are now affiliated.

## 7. QRA NEWS HEADLINES: <http://www.qra.org.uk/news>

Please check the QRA website regularly for any news updates.

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A reminder: this flier replaces the circular and identifies key upcoming activities within the QRA. All specific details can be found on the QRA website. For any enquiries regarding QRA activities please consult [www.qra.org.uk](http://www.qra.org.uk) or contact the Secretary, Dr Pete Langdon, [p.g.langdon@soton.ac.uk](mailto:p.g.langdon@soton.ac.uk). School of Geography, Highfield, University of Southampton, Southampton, SO17 1BJ



February 2011

## Publications



Quaternary Research Association

	Title	Date	Editor(s)	Price to Members*	Retail Price inc p&p UK only
<b>FIELD GUIDES</b>					
	The Quaternary of the Solway Lowlands & Pennine Escarpment	2010	Livingstone <i>et al.</i>	£14.00	£20.00
	The Quaternary of Western Sutherland & Adjacent Areas	2010	Lukas & Bradwell	£14.00	£20.00
	The Quaternary of the Trent Valley & Adjoining Regions	2009	White <i>et al.</i>	£10.00	£16.00
	The Quaternary of the Solent Basin & W Sussex Raised Beaches	2009	Briant <i>et al.</i>	£14.00	£20.00
	The Quaternary of Northern East Anglia	2008	Candy <i>et al.</i>	£16.00	£22.00
	The Quaternary of Glen Roy and Vicinity	2008	Palmer <i>et al.</i>	£14.00	£20.00
	North of Ireland	2008	Whitehouse <i>et al.</i>	£14.00	£20.00
	Quaternary of The Brecon Beacons	2007	Carr <i>et al.</i>	£14.00	£20.00
	Quaternary of Somerset	2006	Hunt & Haslett	£14.00	£20.00
	The Isles of Scilly	2006	Scourse	£12.00	£18.00
	Quaternary of The Rossendale Forest & Greater Manchester	2005	Crofts	£10.00	£16.00
	Quaternary of Central Western Ireland	2005	Coxon	£12.00	£18.00
	Nene Valley	2005	Langford & Briant	£12.00	£18.00
	Quaternary Mammals of S & E England	2004	Schreve	£12.00	£18.00
	Central Grampian Highlands	2004	Lukas <i>et al.</i>	£12.00	£18.00
	Isle of Man & North West England	2004	Chiverrell <i>et al.</i>	£12.00	£18.00
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	South-West Ireland	2002	Harrison & Mighall	£9.00	£15.00
	Central Germany (Thuringia)	2002	Meyrick & Schreve	£9.00	£15.00
	East Yorkshire & North Lincolnshire	2001	Bateman <i>et al.</i>	£7.00	£14.00
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	Banffshire Coast and Buchan	2000	Merritt <i>et al.</i>	£7.00	£14.00
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	Central East Anglia & the Fen Basin	1991	Lewis <i>et al.</i>	£3.00	£6.00
	Beaulieu to Nairn	1990	Auton <i>et al.</i>	£2.00	£5.00
<b>TECHNICAL GUIDES</b>					
No. 7	Description & Analysis of Quaternary Stratigraphic Field Sections	1999/2007	Jones, <i>et al.</i>	£8.00	£14.00
No. 8	Non-marine ostracods and Quaternary Palaeoenvironments	2000	Griffiths & Holmes	£9.00	£15.00
No. 9	The Identification of Testate Amoebae in Peats	2000	Charman <i>et al.</i>	£9.00	£15.00
No. 10	The Identification and Use of Palaeartic Chironomidae Larvae in Palaeoecology	2007	Brooks <i>et al.</i>	£14.00	£20.00

**The Quaternary of Western Sutherland and Adjacent Areas (£14/20)**  
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