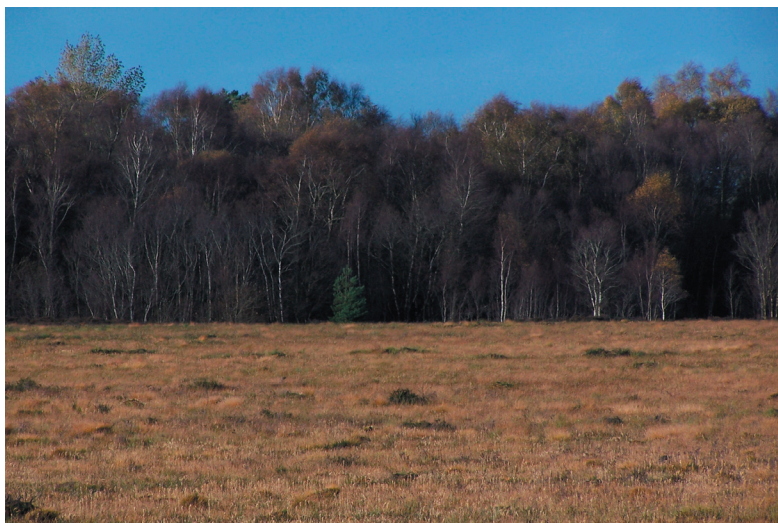

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Quaternary Newsletter



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QUATERNARY NEWSLETTER

EDITOR:

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Instructions to authors

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

Suggested word limits are as follows: obituaries (2000 words); articles (3000 words); reports on meetings (2000 words); reports on QRA grants (500 words); reviews (1000 words); letters to the Editor (500 words); abstracts (500 words). Authors submitting work as Word documents that include figures must send separate copies of the figures in .eps 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

Moninea bog in County Fermanagh, Northern Ireland. An extensive fire damaged this lowland raised bog in 2005. Photo provided by Graeme Swindles.

ANNOUNCEMENTS

PROFESSOR DAVID KEEN

Readers will have heard of the premature death of former president David Keen. Part of the February QN will be devoted to David. To help compile this, those who knew him are invited to send relevant anecdotes and stories, please, to Danielle Schreve (by the end of November):

Danielle.Schreve@rhul.ac.uk

INQUA 2011

As a result of a proposal sent to the QRA Executive Committee by members of the School of GeoSciences at the University of Edinburgh and the British Geological Survey, a committee has been formed to put together a bid to host the INQUA Congress 2011 in Edinburgh. This committee is formed from members of the QRA, IQUA, Scottish Universities and representatives from Universities and Institutions in Ireland, Norway, Denmark and Iceland. As many of you who have attended previous INQUA congresses will be aware, field excursions are an important part of the programme. To help formulate the Edinburgh bid we are calling for volunteers to submit a field excursion, which they would run if the bid is successful. Please send any proposal (title and very brief details) to either Stephen McCarron or Tim Mighall so we can include a list of possible excursions when our bid is presented to INQUA in Cairns 2007. Thank you for your support.

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CONSTRAINING THE AGE OF SPHEROIDAL CARBONACEOUS PARTICLE (SCP) STRATIGRAPHIES IN PEATS USING TEPHROCHRONOLOGY

Graeme T. Swindles and Helen M. Roe

Introduction

A number of recent studies have compared peatland palaeohydrological records spanning the past ~200 years with instrumental climate data (Charman *et al.*, 2003; Hendon and Charman, 2004; Schoning *et al.*, 2005). Such studies are of fundamental importance for elucidating the climatic inferences that can be made from longer palaeohydrological records generated from peat profiles (Schoning *et al.*, 2005). The majority of these studies have used spheroidal carbonaceous particles (SCP) to provide chronological control for the records. SCP are a type of fly-ash formed from the high-temperature combustion of fossil fuels and are typified by a wide range of particle sizes (Rose *et al.*, 1995). These particles have also been used previously to reconstruct atmospheric pollution histories from lakes (Clymo *et al.*, 1990; Rose *et al.*, 1995) and blanket peat profiles (Yang *et al.*, 2001a, b). SCP-derived chronologies have particular importance to peat-based studies as radiometric methods, most commonly lead-210, americium-241 and caesium-137, may be particularly problematic for ombrotrophic peat profiles due to marked displacement and downwash effects (Oldfield *et al.*, 1995).

The chronology of SCP concentration changes since the nineteenth century has been established for the UK and Ireland using radiometric dating of multiple lake cores (e.g., Rose *et al.*, 1995). These high-quality data are now freely available on the Carbydat online database (<http://www.geog.ucl.ac.uk/ecrc/carbynet2/carbydat.htm>). However, there is scope to independently date the SCP concentration changes in peat profiles and address the possibility of SCP mixing and displacement in the peat acrotelm. A crypto-tephra layer derived from the eruption of Hekla in AD 1947 (Larsen *et al.*, 1999) has been found in Irish bogs and forms a distinct isochron for the 20th century (Hall and Pilcher, 2002; Hall and Mauquoy, 2005). The aim of this investigation is therefore to test the reliability of SCP-derived chronostratigraphies in peats utilising this tephra isochron, which will consequently provide independent dating for part of the SCP record.

Methodology

Cores were extracted from lawn microforms at three raised bogs in Northern Ireland using a Russian D-section corer (Figure 1). The study sites comprise Dead Island ASSI, Co. Derry (Irish Grid Reference: C931053); Slieveanorra NNR, Co. Antrim (D132265) and Moninea ASSI, Co. Fermanagh (H299215). SCP were extracted from the sub-sampled cores following a modified version of the method proposed by Rose (1990), using nitric acid instead of hydrogen peroxide (Rose, 1994; Rose *et al.*, 1995). After washing the residues, the SCP were mounted on slides and counted under light microscopy ($\times 400$ magnification). The particle concentrations were expressed as number of particles per gram of dry mass (gDM^{-1}). Tephra was detected through light microscopic analysis of the burnt peat samples and shards were extracted for geochemical identification using a hot acid digestion technique (Hall and Pilcher, 2002). The tephra shards

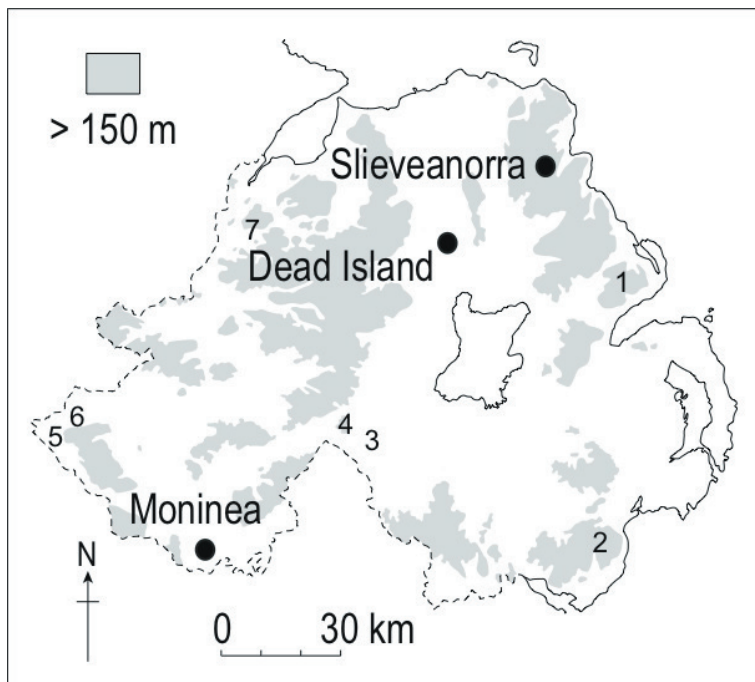


Figure 1. Map showing the location of the three peatlands and the lakes providing the regional SCP data (Carbydat). The lakes comprise: (1) Lough Mourne, County Antrim; (2) Blue Lough, County Down; (3) Lough Brantry, County Armagh; (4) Lough Creeve, County Armagh; (5) Lough Melvin, County Fermanagh; (6) Broad Lough, County Fermanagh; (7) Lough Ash, County Tyrone.

were geochemically analysed using wavelength dispersive electron microprobe analysis at the Tephrochronology Analytical Unit at Edinburgh University.

Results and significance

Three main features are registered in the seven existing SCP records from Northern Ireland lakes (Figure 1). These include i) the start of the SCP record which generally occurs in the 1850s; ii) the rapid increase in SCP concentration commonly occurring in the 1950s; and iii) the peak concentration at ~1979. However, it is evident that there are some slight differences in the timing of these SCP concentration changes. The three features tend to occur slightly later in the western sites, which may be somewhat related to their distance from the power stations in Belfast and on the northeast coast. However, this regional approach aims to reduce site-specific effects that could be introduced from concentrating on one lake record alone. The Hekla 1947 tephra (cf. Hall and Pilcher, 2002) was identified within the top 10 cm of each peat profile (Figures 2 and 3). Unfortunately, no geochemical information was obtained for the Moninea profile, although it is inferred that the tephra layer is Hekla 1947 from the optical characteristics of the shards and its stratigraphic position.

The position of the 1947 tephra and the rapid increase of SCP are contemporaneous or stratigraphically close in the peat profiles (Figure 4). The presence of the markers in the same 1 cm horizon at Slieveanorra and Moninea, denotes that the accumulation of this section overlaps the 1940s and at least part of the 1950s, which is in agreement with typical raised bog accumulation rates of ~10 yrs cm⁻¹ or greater (e.g. Charman, 2002). The 1 cm spacing between the two events at Dead Island may represent i) the faster accumulation rate of this small lowland raised bog and ii) an effect relating to the core sub-sampling strategy. The lack of chronological reversals or severe smearing of

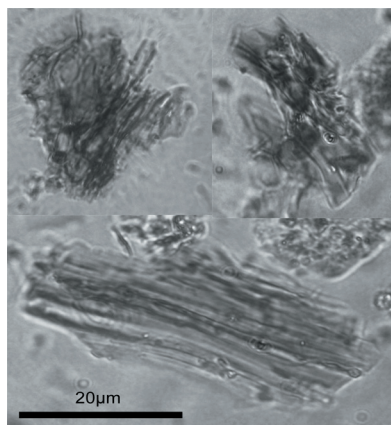


Figure 2. Photographs of tephra shards from the eruption of Hekla in 1947 (Dead Island). The shards are typically orange-brown in colour and have fluted or vesicular morphologies.

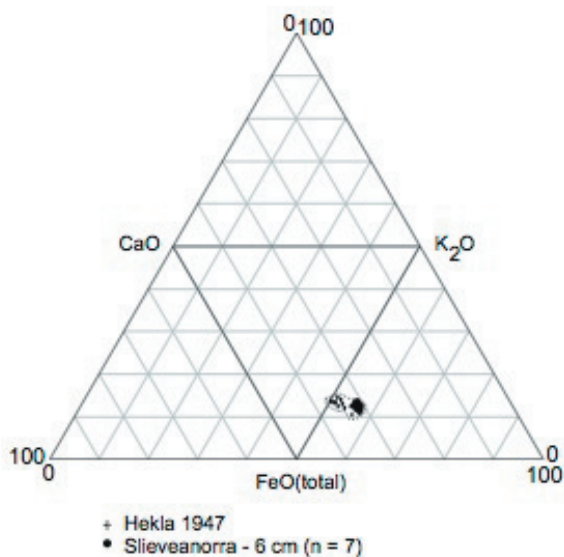
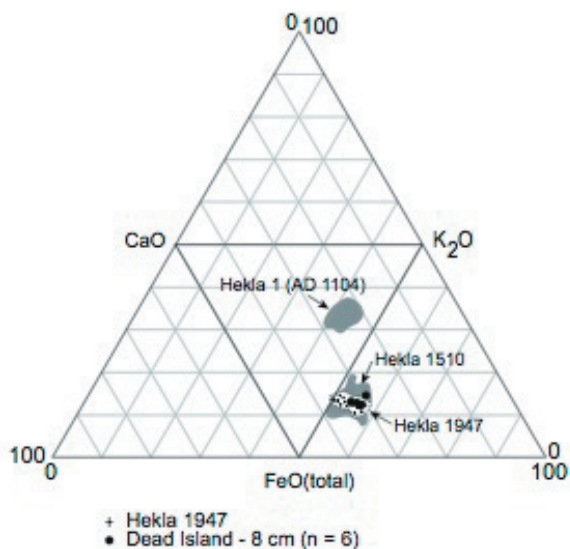


Figure 3. Ternary plots of major oxide suites (expressed as percentages) from the Hekla 1947 tephra recorded at Dead Island and Slieveanorra. The crosses indicate the previous analyses (Larsen *et al.*, 1999; Hall and Pilcher, 2002). The geochemical envelopes for Hekla 1 (AD 1104) and Hekla 1510 are shown for comparison (grey shading).

the chronological indicators suggests that there are no marked differential displacement effects for the two particles and that peatland SCP profiles are probably reliable. The SCP rapid increase is clearly associated with the peak in tephra concentrations and it can therefore be assumed that it occurred at, or more likely just after 1947, which corroborates the 1950s date previously inferred from the lake records.

The Hekla 1947 tephra provides a very important isochron for correlating recent palaeoenvironmental records from peat profiles and the combination of tephrochronology and SCP stratigraphies provides a robust method for dating such profiles, in light of the possible difficulties of radiometric methods (Oldfield *et al.*, 1995). Currently, this tephra has been found in Iceland (Larsen *et al.*, 1999) and Ireland (Hall and Pilcher, 2002; Hall and Mauquoy, 2005), although it will be probably encountered in other northwest European countries in the future. One important issue in regard to the Hekla 1947 tephra is that it is similar geochemically to the older Hekla 1510 tephra (Figure 3), although they can usually be separated stratigraphically. Using a converse approach, the rapid increase of SCPs could indeed be used to identify the Hekla 1947 tephra at other European sites.

There is great potential for further investigations, for instance it may be possible to cross-check the early part of SCP records in certain regions using the Askja 1875 tephra which is present in a number of northwest European countries (van den Bogaard and Schmincke, 2002; Schoning *et al.*, 2005).

Acknowledgements

Many thanks to Neil Rose, Peter Hill, Anthony Newton, Valerie Hall, Gill Plunkett, Yoma Megarry, John McAlister, Roy Tomlinson, John Meneely, Phil Sansum and Lorraine Mooney. This work was carried out during a DEL-NI doctoral scholarship (GTS). Acknowledgements are given to EHS-NI for allowing access to the protected sites.

The regional SCP data were obtained from the Carbydat website (<http://www.geog.ucl.ac.uk/ecrc/carbynet2/carbydat.htm>). The new geochemical data for Hekla 1947 will be made available on Tephabase (<http://www.geo.ed.ac.uk/tephra/>), although direct requests to the authors are welcomed.

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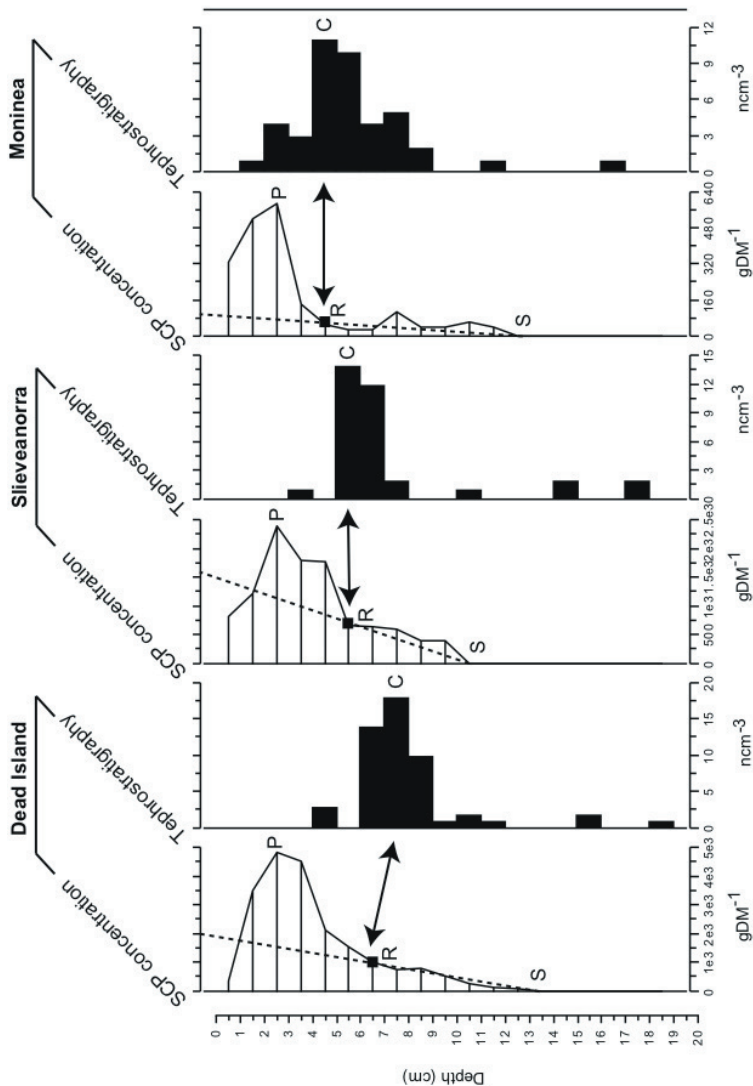


Figure 4. Diagram illustrating the SCP concentrations and the tephrostratigraphy of the three peat profiles. A number of features are identified: S represents the start of the SCP record (1850s), R is the rapid increase in SCP concentration (1950s), P is the peak concentration (~1979) and C is the maximum tephra concentration (Hekla 1947). Dashed lines and black squares are used to illustrate where the SCP concentration increases in a non-linear fashion. The arrows illustrate the correlation of the rapid increase in SCP concentration with the Hekla 1947 tephra.

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POSSIBLE EXPLANATIONS FOR THE TRANSITION FROM PALAEO SOL TO TUFA DEPOSITION AT SOME HOLOCENE SITES IN THE MENDIP AREA, SOMERSET

Trevor Faulkner

Introduction

Deposits of tufa at Ston Easton (ST634542, 100–130m OD) and Rodney Stoke (c. ST476497, 15m OD) on and beside the Mendip Hills were visited on 4 April 2006, during the QRA / INQUA ‘Quaternary of Somerset’ field meeting (Davies *et al.*, 2006; Tetlow *et al.*, 2006). The 2–5m-thick tufa deposits of calcium carbonate have formed below risings that emerge from the bases of outcrops of Jurassic and Carboniferous limestones, at catchment areas that rise above 260m OD, by chemical processes reviewed by Baker and Simms (1998). Each deposit is *underlain* by 10–20cm of a dark palaeosol that covers a stratum of coarse gravels that is interpreted to represent periglacial outwash from a late stage of the Devensian glacial period. The beginning of tufa deposition at Ston Easton is attested to be prior to 8500BP, from preliminary molluscan analysis (Davies *et al.*, 2006, p61). Assuming that the palaeosol and the tufa both developed after climatic amelioration, why did the tufa not start to form immediately, rather than after an interval of palaeosol accumulation?

Permafrost

Because there is no evidence of a local Devensian icesheet, as confirmed during the field meeting, it is likely that the Mendip Hills were permafrosted at glacial maxima to depths up to 100m (e.g. Boulton *et al.*, 1996). This would prevent the movement of groundwater, causing snowmelt and summer precipitation to flow across the surface of the limestone and other outcrops, depositing the various periglacial sediments. The effective end of the Devensian glacial on Mendip was shown in the field meeting to be at the start of the Bølling interstadial [Greenland Interstadial G1-1e], from a light yellow-brown clastic-rich peat in sediment core GVVH17 in the Gordano Valley dated at 15060–14840cal. years BP (Hill *et al.*, 2006, p124), agreeing with the significant warming at a similar time recorded at an infilled kettle-hole at Llanilid, South Wales (Walker *et al.*, 2003). Almost continuous peat deposits in the Gordano core confirmed a subsequent return towards the present interglacial conditions, with the Younger Dryas stadial apparently marked locally only by a minor hiatus. Because it would take a significant time for the deeper parts of the limestone aquifers to unfreeze, vegetation and palaeosols probably had time to develop on the surface around Mendip before groundwater flow regimes were re-established in the endokarst, and therefore before tufa could be deposited.

Calcium carbonate chemistry

A delay in the deposition of tufa should also arise from the chemistry of calcium carbonate dissolution and precipitation. The amount of calcite that can be dissolved increases with the amount of carbonic acid in solution. This depends on the partial pressure of the carbon dioxide that is present in the water that enters the limestone. Atmospheric P_{CO_2} is presently c. 0.038%, although it was <0.02% before the start of the Holocene (e.g. Petit *et al.*, 1999, Fig.3), giving a maximum calcite saturation then of c. 10mglitre⁻¹. Beneath vegetated soils, P_{CO_2} can increase to 1–5% atmospheres, when the calcite saturates at concentrations of 60–200 and 70–300mglitre⁻¹ in closed systems at 10 and 0°C (Ford and Williams, 1989, p57). When the water discharges at the surface, the dissolved calcite can reach a high saturation ratio and precipitate as tufa, if CO_2 is degassed from solution to equilibrate with a lower atmospheric P_{CO_2} . Assuming little local vegetation immediately after periglacial conditions ameliorated, any meteoric water with a P_{CO_2} of only 0.02% that flowed into near-surface fractures in the limestone above the level of permafrost would have no opportunity to degas on its return to the surface. Hence, no tufa could be deposited initially from the early risings.

The re-establishment of vegetation may have started at warmer lower altitudes above thicker periglacial deposits, before its appearance in upper catchment areas, and it may also have been promoted on lower, acid, rocks rather than on upper carbonate rocks. A palaeosol could therefore continue to accumulate below karst springs without tufa being precipitated for another significant time interval. After vegetation was established on the catchment area and on the limestone, the P_{CO_2} of the recharge would increase, steadily increasing the possible dissolved load. A limestone aquifer consisting of long narrow fractures would immediately discharge spring water saturated with calcite at low flow rates, which could then precipitate as tufa if the spring water degassed, thereby inhibiting further soil and peat production below the springs. However, if the aquifer contained shorter larger fractures and / or karst conduits, the discharge might remain aggressive at higher flow rates and tufa production could be delayed until increasingly concentrated autogenic recharge beneath forests caused the saturation ratio at the spring to increase sufficiently.

After tufa production started, the hydrogeological system probably remained fairly dynamic, with the effects of the limestone chemistry being determined by variations of annual precipitation and temperature and by the growth, and possible anthropogenic clearing, of vegetation. Tufa growth, aided by turbulent spring flows and biological processes that both also tend to remove CO_2 , would be promoted by rather low annual precipitation at a steady rate, especially with autogenic recharge beneath forests, because the aquifer would then remain saturated, and short and infrequent bursts of rainfall would displace the saturated water already stored in the aquifer, but still allow time for saturation to return.

Mean summer air temperature is higher than mean spring water temperature, which also promotes tufa by reducing maximum calcite saturation and by increasing evaporation. However, this effect is partly reversed in winter, when existing tufa could be dissolved. Heavy continuous rainfall and floods of allogenic recharge, especially from non-forested catchments, would reduce the groundwater P_{CO_2} , thereby reducing the maximum calcite saturation, and would additionally reduce the saturation ratio at the spring to make the water more aggressive, especially if the recharge was from non-carbonate catchments into well-developed karst conduits. In these cases, tufa precipitation might be interrupted and existing tufa could be removed, both by chemical dissolution and by mechanical erosion. If such conditions persisted long enough, tufa production would cease and soil and peat development below the springs could be re-established.

Comparison with Holywell Coombe, Folkestone

The Mendip examples contrast with the stratigraphy of Late Glacial–Holocene deposits in dry valleys at the chalk escarpment of Holywell Coombe, Folkestone, where *none* of the extensive buried tufa deposits below two prominent palaeo springs are immediately underlain by palaeosols, rather than by chalky colluvium or by organic muds and silts (Preece and Bridgland, 1999). Indeed, one such deposit lies beneath an ‘Allerød Soil’ dated to $11530 \pm 160^{14}CaBP$ and probably represents warming soon after the short Older Dryas cold interval. The explanation for tufa deposition in advance of palaeosols at Holywell Coombe is probably that a) permafrost was less persistent close to the English Channel, giving an early establishment of calcite-saturated groundwater flow in the highly-fractured chalk aquifer, and b) complete forestation, initially by birch, occurred soon after each climatic amelioration on the lower altitude catchment areas that only reach 136m OD. Consequently, the reasons for the delay in tufa production at Mendip may not apply at coastal chalklands.

Conclusion

At least three mechanisms may complement each other in delaying the start of tufa deposition in the Mendip area: the persistence of permafrost in the inland and upland aquifers, the ‘bottom-up’ establishment of vegetation on to the Mendip plateau, and the time taken for the aquifers to become sufficiently saturated with calcite. Indeed, Griffiths and Pedley (1995, Fig.1) indicated that (inland) British tufas were commonly not deposited until the start of the Holocene, i.e. several thousand years after the Bølling–Allerød amelioration. Similar mechanisms should also cause a delay in the major deposition of underground speleothems after deglaciation and the return to an interglacial climate. These possible explanations for the transition from Mendip palaeosol

to tufa deposition and its subsequent continuing production (as discussed by Griffiths and Pedley, 1995 and by Baker and Simms, 1998) should be testable by further biotic and isotopic analysis and by dating of the various observed sediments.

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Dr. Andy Baker (University of Birmingham) and Dr. Paul Davies (Bath Spa University) both provided useful comments on an earlier draft of this article. An anonymous reviewer is thanked for his thoughtful suggestions.

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REPORTS

QUATERNARY VERTEBRATE RESEARCH GROUP (QUAVER) - SECOND ANNUAL MEETING

11th-12th April 2006

Following the success of the inaugural meeting held last year at Liverpool John Moores University, the Quaternary Vertebrate Research Group (QUAVER) met for its second meeting at Oxford University on the 11th-12th April 2006. Hosted and introduced by **Kate Scott**, this meeting gathered together speakers from a diverse range of disciplines and institutions, and testifies to the scope of skills and interests implicit in Quaternary Science.

The presentations started with **Hannah O'Reagan** (Liverpool John Moores University) discussing her work on the out of Africa mammal movements during the Plio-Pleistocene Afro-Eurasian migration (3 Ma BP – 500 ka BP). This work has shown that taxa moved alone rather than in pulses of migration and that Europe received far more taxa than it contributed to global migration. **Christine Buckingham** (Oxford) then highlighted how the sedimentary context of mammal bone finds in the fluvial record can be used to predict the location of mammal remains in other analogous locations, illustrated using a river meander at Stanton Harcourt and deposits at Lynch Hill.

Adrian Lister (UCL), with his presentation on early Pleistocene elephant evolution in Europe, steered the discussion towards specific taxa and his opinion that the change in elephant taxa (*Mammuthus meridionalis* replaced by *M. trogontherii* and *Palaeoloxodon antiquus*) were instances of immigration rather than sympatric speciation. Following on from this, **John Stewart** (UCL) presented the findings from his work on non-analogue faunas of the Pleistocene. Rather than being a rarity, non-analogue faunas were commonplace in the Pleistocene and data from the study site in the Ardennes (Trou Al'Wesse) suggest that metapopulations became extinct leaving no descendents and mark the importance of climate in these studies. This presentation prompted a spirited discussion revolving around other influences and restrictions on non-analogous fauna, including the importance of warm-bloodedness, vegetation and food abundance. **Andrew Currant** (Natural History Museum) then presented some alterations to the late Pleistocene mammalian biostratigraphic framework to incorporate the unique faunal composition found at Brean Down in Somerset. This site is now believed to be OIS 4, and observations of sea-level during OIS 5 indicate that OIS 5a fauna was an island isolate of that found in OIS 5b,

illustrating that cold stage fauna were present in the United Kingdom during a warm stage high sea-level period. Kate Scott added that two open sites near Oxford support these findings. **Roger Jacobi** (AHOB project) then updated the meeting on his work and the application of ultrafiltration in radiocarbon analysis. This technique improves the removal of bone contaminants, and has significantly altered the ages of previously dated material, such as woolly rhinoceros (*Coelodonta antiquitatis*) from Pin Hole redated to 43,700 k BP (from 22,500 k BP). Further information will be provided in his co-authored papers *in press*. **Kate Scott** (University of Oxford) gave an interesting talk on the nature of Pleistocene *Hyaena dens*, and described the defining features of a den. *Hyaena* activity, predominantly gnawing and grinding of bone, is a recurrent phenomenon facing Quaternary Palaeontologists but is not always a welcome one. Kate Scott reminded the audience that all evidence left by Pleistocene *Hyaena* is indicative of particular behaviours and is thus useful. **Rhiannon Stevens** (University of Nottingham) reported on her work reconstructing the palaeoclimate at Tuckwells using stable isotope analysis. It would appear that the climate at this proposed OIS 5a site was warm and arid, which prompted a change in grazing habits of reindeer at this site. An invitation was made by **Neville Hollingworth** (Centre for Ecology and Hydrology) for research to be carried out at the gravel pits of the Cotswold Water Park. These pits have already yielded Pleistocene mammal remains (most famously mammoth) and more pits are set to be excavated in the future. **Bob Eeles** reviewed the material found in Sutton Courtenay, including a substantial amount of woolly rhinoceros and also some fossil bison. There are also environmental remains and some remarkable worked flint. The flint was of a very high quality and similar in morphology to that seen in continental Europe. Specimens of this material were on display and drew many admiring comments.

The final session of the day began with **Sylvia Gonzales** (Liverpool John Moores University) discussing her work on the Giant Deer of the Isle of Man. These specimens are found in the Pingo basins and kettleholes of the island and represent the only Pleistocene mammals found there so far. Of particular note was the apparent small size of the body relative to antler size, which was thought to possibly indicate dwarfism that occurred before the Isle of Man became fully detached from the English mainland. Reasons as to why this would occur whilst the isthmus was still complete were proposed in the ensuing discussion. **Derek Yalden** (formerly of the University of Manchester) gave the final presentation of the day, on his work compiling data for a book on the Archaeological history of birds in the British Isles. This book is designed to be an accompaniment to his previous book on mammals, and in researching it has highlighted the difficulties in separating domestic and wild fowl when using the literature of other authors.

The session ended with summations by Kate Scott and Hannah O'Reagan,

in which the importance of collaboration and communication between palaeontologists and geologists in vertebrate research was emphasised. The morning of the second day comprised a field excursion to view fossils from Sutton Courtenay and Stanton Harcourt, followed by a visit to the Lynch Hill Quarry. As if on cue, two pieces of mammal bone were found at Lynch Hill during the visit, as well as *Gryphaea*, ammonites and belemnites that were identified by Neville Hollingworth.

Thanks are extended to Kate Scott and Christine Buckingham for organising such an interesting and successful meeting, and also to the QRA for its support of QUAVER.

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THE ISLES OF SCILLY QRA SHORT FIELD MEETING

9-13th May 2006

If golf is the best way to ruin a good walk, one of the best ways to *enhance* one is a leisurely round of key Quaternary sites of the Isles of Scilly, with spring flowers in abundance, golden wiry lichen (top clean air indicator), swallows swooping, gently lapping waves, dramatic granite tors, accessible sections - and absolutely *no* crowded coaches, cramped minibuses, wet anoraks or muddy boots. Get the picture? The science wasn't bad too. What a treat! Unfortunately, with 29 sites to cover and a word limit of 2000 your *rapporteur* must be selective: he can hope only to give a flavour of this excellent meeting.

Participants assembled in Hugh Town, St Mary's, just 20 years after the original Scillies QRA meeting, for a communal evening meal at the Atlantic Inn, followed by a comprehensive introductory talk, at the Isles of Scilly Museum, by **James Scourse** and most of his co-leaders, **Dave Evans**, **John Hiemstra**, **Charlie Johns**, **Danny McCarroll**, **Ed Rhodes** and **Rob Scaife** (unfortunately **Ian Foster** was unable to be present). James began on a sombre note, with an image and memory of David Keen, a former President of the Association, who sadly died shortly before the meeting. He will be sorely missed.

The meeting had a sharp thematic focus, a controversial ice margin, but arguably the most clear-cut in Britain in the opinion of **Dave Evans**. From this we delved into surging(?) glacier dynamics, extra-glacial landscape evolution, sea level fluctuation, vegetation colonisation and destruction, human occupation and marine hazards, the whole potentially confounded by unusually difficult dating (^{14}C , TL, OSL and ^{10}B) circumstances necessitating a brief commentary on 'radiometric ages' by the Field Guide editor (Scourse, 2006, p. v).

Day 1: a punctual 9 a.m. start (it gets earlier later) aiming to visit eleven varied sites, during a 10 km circuit of St Mary's, illustrating the simpler, extra-glacial, 'Southern' Scillies stratigraphy, and some attractive archaeology.

At Porthloo, **James Scourse** introduced the type-site of the Porthloo Breccia, probably the most extensive deposit on the Scillies. Here, a coarse component, comprising angular granite clasts with a granular matrix, obviously derived from local bedrock, is interbedded with finer sediment from the same source, and rests on raised beach material (Watermill Sands and Gravels). Few would argue with its interpretation as a periglacial slope deposit but its complex stratigraphical and structural relationships suggest that terms such as solifluction and, more specifically, gelifluction, hardly begin to describe the processes responsible for this key element in Scillies stratigraphy. In view of its close stratigraphical links with both the Scillies Till and the so-called Sandloess, there is still plenty

of scope for detailed analysis of this widespread unit.

At Carn Morval, **James Scourse** pointed out that the Porthloo Breccia, here associated with a channelled granite bedrock, contained beds of largely derived organic material, comprising mostly amorphous humus. With **Rob Scaife**, he discussed the pollen, which indicated open grassland; not distinctly Arctic, yet very different from Holocene pollen spectra. Both TL dates (18 ka BP) and ^{14}C dates on humin residues (21 and 24 ka BP) and humic extracts (19 ka BP) were consistent, notwithstanding potential contamination by modern roots, percolating groundwater and tunnelling solitary bees.

A delightful coastal walk brought us to Halangy Down where our Iron Age and Romano-British forebears had chosen to settle. **Charlie Johns** introduced Bant's Carn, an entrance grave containing mainly Bronze Age pottery but with some Neolithic material. **Rob Scaife** reported pollen analyses carried out previously by G.W. Dimbleby. The virtual absence of trees and shrubs was consistent with colluvial/hillwash layers in the nearby cliff, some containing medieval pottery, resulting from undated but probably late-prehistoric to recent soil erosion. Juxtaposition of human occupation and the current coastline prompted a discussion of sea level rise and the timing of the inundation of the lowlands separating the present Isles of Scilly. **James Scourse** considered that rapid sea level in the Scillies area negated Thomas's (1985) model of island separation in historical times. Further north, at Pendrathen, **Jackie Melville** described "a heap of rubble", the eroded remains of a round cairn, containing both Bronze Age pottery and Neolithic flint, as difficult to interpret. Site protection, in the context of rising sea levels was a pressing issue.

The archaeological story was continued at Bar Point (**Rob Scaife**) and Innisidgen (**Charlie Johns**). At Bar Point **Ed Rhodes** had obtained 'reliable' OSL dates from the Holocene blown sand overlying podzolic soils supporting heathland after abandonment of prehistoric fields. English Nature was collaborating with English Heritage in the 'Ways of Heath' project, in an effort to manage sites for the benefit of former heathland, rather than the current tangle of gorse and bracken.

Watermill Cove, is described in the Field Guide as "the most important Pleistocene site south of the glacial limit on the Scillies" (Scourse, 2006, p. 66). It played an important part in the stratigraphic scheme of Mitchell and Orme (1967), and was the focus of the short-lived Page (1972)/Shotton (1973) Hoxnian controversy. Page ^{14}C -had dated the Hoxnian Stage as c. 22 ka, on the basis of Mitchell and Orme's stratigraphical interpretations, and Fred Shotton (1973) had fired an uncompromising reply. **James Scourse** demonstrated the complex stratigraphy of the site – raised beach deposits, head, organic material and more head. The site contained the basal Pleistocene sequence of Scilly except possibly an isolated deposit at 30 m near the Garrison at Hugh Town. The

raised beach was assumed MIS 5e equivalent in age, quite feasible in relation to humin residue dates of 33 and 26 ka BP, obtained from the organic material of beds 3a and 3c, respectively. But OSL dates, reported by **Ed Rhodes**, were confusing, given results of 112 and 82 ka BP on unmodified raised beach sand and 93 and 71 ka BP on fluorosilicic acid-treated samples, expected to be older! Was the landscape stable after MIS 5e until the crossing of an environmental threshold later in the Devensian initiated solifluction which ponded drainage as indicated by organic deposits with aquatic pollen?

In the afternoon **Rob Scaife** discussed Holocene pollen at Higher and Lower Moors. The former contained the most continuous Holocene vegetation data for the Scillies beginning with the middle Holocene Atlantic period (FI.II). There was evidence of Neolithic woodland clearance, but the most important clearance event, with evidence of pastoral and arable agriculture, was probably late Bronze or early Iron Age, though ^{14}C dates were inconclusive! A second Higher Moors section spanned the Devensian/early Holocene transition with the first evidence of early Holocene woodland.

At Peninnis Head, **James Scourse** introduced the party to a spectacular extra-glacial landscape dominated by three of four distinctive tor forms – horizontal, vertical and hillslope – markedly different from a rounded, eroded fourth type within the glacial limit. **Danny McCarroll** discussed cosmogenic isotope dating, employed to differentiate rock surfaces inside and outside the Scillies glacial limit. A ^{10}Be determination of >113 ka BP from Peninnis Head, outside the ice limit and others, of 68 and 80 ka BP, from within the limit, exemplified potential errors. The first date could only be a minimum age since weathering removes ^{10}Be -enriched rock; the others may be aberrantly old, the surface having presumably retained a residual signal due to insufficient rock removal at the ice margin. Such are the hazards of ‘absolute’ dating!

Finally, at Porth Cressa, on the outskirts of Hugh Town, **James Scourse** introduced a representative exposure of sandloess, a complex deposit with four facies, “too coarse to be defined as true loess, but too fine to be defined as coversand” (Scourse, 2006. p. 91). Sandloess facies D, was characterised by deformation structures interpreted as ‘mass-flow’ or ‘colluvial’ in origin, but in my opinion possesses features indicative of soft sediment loading rather than lateral movement. A small example of this facies, exposed at the northern end of St Martins, appeared to support this interpretation.

Day 2 possessed an added *frisson* of anticipation - of the first boat trip, and of the ice sheet margin. The boat trip passed without a hitch; some details of the ice margin elicited slightly more concern. Once disembarked at Lower Town Quay on St Martin’s, the party again relied of ‘shanks’ pony’ to visit eight sites, this time with the focus on the ice margin, before re-embarkation at New Quay,

Higher Town, for the return to 'The Quay' on St Mary's.

James Scourse introduced Porth Seal, as another of those contentious key locations where Frank Mitchell (Mitchell and Orme, 1967) had worked. Contrary to the impression given in the Field Guide (Scourse, 2006, p. 5), Frank had remained unconvinced of the Scourse (1991) views. Mitchell and Orme (1967) had recognised two raised beaches, interpreted as Hoxnian and Ipswichian. Bowen (1981) saw the rounded pebbles of the upper beach as soliflucted granite corestones; not a beach at all. James believed that the upper beach material was a soliflucted equivalent of the lower beach. Dating was critical yet again presented problems. A first series of ^{14}C dates from the surface of organic material above the raised beach gave 11 ka BP to c. 18 ka BP. A second series, obtained from within the exposure to circumvent contamination gave 25 ka BP for humin residues and c. 34 ka BP for a humic extract. Jane Hart wondered whether Frank Mitchell would have interpreted the latter date as 'infinite'. At this point **Danny McCarroll** laid most of his cards on the table: ^{14}C was OK; there was likely to be a range of dates, but were they 'ball park' or 'infinite'? In his view "we have enough results already to date the glaciation. This is the key scientific question". Mike Walker concurred. But we still had not seen evidence of the ice margin!

This was presented at the next two sites, Pernagie Bar and White Island Bar, where bouldery marine tombolos link St Martins with offshore islands in a pattern of partially submerged ridges reminiscent of ice lobe moraines. **Dave Evans** believed the relatively poor sorting of the boulders, continuity of the ridges inland, and their till core justified this interpretation. **James Scourse** convinced most of the reality of the Scilly Till, when he retrieved it from beneath the bouldery spread (Fig. 1). However, not everyone, including, I think, our leader, seemed totally convinced by the sandy ridge with isolated surface boulders, above the beach, even though **Dave Evans** was able to point to its traceability uphill. Could the surface blocks be archaeological in origin? Trenching was desirable but problematic. Nevertheless, for your *rapporteur* the till itself, the structural relationships of the Bread and Cheese section (see below) and most of the morphology was sufficient justification for a grounded glacial margin around the northern edge of the Scillies.

Chad Girt, on White Island, is another key site, chosen by Barrow in 1906 as his type site for the Pleistocene of the islands, and by Mitchell and Orme (1967) as the type-site of their 'Chad Girt', lower, erratic-free raised beach. **James Scourse** accepted the interpretation of the raised beach and solifluction deposits but not Mitchell and Orme's timing of events, nor their interpretation of the rounded erratics as a glacial meltwater sediment. **John Hiemstra** had recognised evidence for ice lensing and silt capping, typical periglacial micromorphological features, in thin sections of the erratic-bearing material, but **Jane Hart** seemed unconvinced that we were not looking at till in its

primary context. **Danny McCarroll** pointed out that a ^{10}Be date of 68 ka BP from *within* the assumed ice margin on White Island was “too old” for the rock to have been completely zeroed by erosion; the glacier here had just “stroked” the Scillies. **Charlie Johns** spoke briefly about the archaeology on White Island before the party moved swiftly on to avoid being marooned by a rising tide.

At Burnt Hill, the promontory forming the western side of Bread and Cheese Cove, **Charlie Johns** also explained the controversy surrounding the extensive archaeological remains: was it an Iron Age cliff castle or the site of an unenclosed settlement? Unfortunately, “the dead are missing” so was this ever a residential site?

And so to Bread and Cheese Cove, another key Mitchell and Orme (1967) site, considered “the most important Pleistocene site on the Isles of Scilly” (Scourse, 2006, p. 111), and the scene of recent additional work (Hiemstra *et al.*, 2006) on its glacial sediments. **James Scourse** provided an historical outline: open grassland pollen had been obtained from recently discovered organic material near the section base. **Dave Evans** outlined convincing macro-structure (fold and shears) and clast fabric data of the Scilly Till sediments, **John Hiemstra** the micromorphological details (e.g. birefringence, water-escape structures). Discussion developed around models of a surging Irish Sea ice sheet associated with the H2 event or the LGM. **Danny Mc Carroll** was not impressed by existing ice sheet modelling, which failed to account for thick ice over Ireland which provided the driving mechanism for an extensive Irish Sea glaciation. As to when all this happened, humic extract ^{14}C dates of 7.8 ka BP and a humin date of 9.7 ka BP were considered to be “clearly aberrant” (Scourse, 2006, p. 122) and indicative of ground water contamination induced by the subjacent impermeable granite bedrock shore platform. An OSL date of 49 ka BP from the Porthloo Breccia below the glacial sediments provided a maximum age for the glacial event, according to **Ed Rhodes**. He considered that three samples, giving dates of 130 ka, 108 ka and 82 ka, from close to the prominent shear zone *within* the Scilly Till, could be explained as indicating the pre-glacial age of the sediments, while inverted dates reflected the inverted glaciotectionised stratigraphy. However, one continues to wonder about the present efficacy of OSL dates from other than pure, aeolian, quartz sediments. Technical refinements are clearly desirable.

The party stopped briefly at Chapel Down for **Charlie Johns** to explain its archaeological importance, and at Perpetch where **James Scourse** pointed out the lack of erratic material in both the lower and upper Porthloo Breccia and the Old Man Sandloess, indicating that the site lies beyond the ice margin.

The programme allowed about two hours back on St Mary’s for refreshment before an evening excursion to the now uninhabited island of Nornour, where

Charlie Johns, on behalf of the QRA, was delighted to welcome **Sania Butcher**, a resident of St Mary's. She had maintained her interest in this fascinating site since her initial excavations in the 1970s and outlined the key elements of a settlement of eleven huts erected and modified between the Bronze Age and the Romano-British Period. A remarkable collection of finds including coins, rings, religious figurines and brooches (viewed the previous evening in the museum), but almost no domestic material, suggested an adjacent shrine.

And so to **Day 3**. Time and tide wait for no man, apparently, so we had no option but to rise even earlier for a prompt departure from the Hugh Town Quay at 08.30 and the short cruise to Old Grimsby Harbour on the northeast coast of Tresco. At Gimble Porth, **James Scourse** outlined the day and introduced the site. At the southern end of the bay Old Man Sandloess, here laminated as in the best French limon à double, separated upper and lower units of erratic-free Porthloo Breccia. At the opposite end of the bay, the sequence was Porthloo Breccia, Hell Bay Gravel (glacial outwash), Bread and Cheese Breccia (erratic-rich), an indication that we had crossed the glacial margin. Again, discussion revolved around glacier surging and the advanced position of the Irish Sea ice sheet, whether the two-fold H2 event, indicated by the double peak of calving iceberg debris, was also reflected in ice margin behaviour. **Dave Evans** reckoned that two or three pulses of moraine at the Devensian maximum could be recognised throughout the UK. He also urged caution in the use of the term Hell Bay *Gravel* as this unit was often diamictic – a reworked glacial deposit? – rather than well sorted. Hell Bay *Member* was his preferred nomenclature. Incidentally, 'Breccia', 'head' and Sandloess' are other terms used in the Scillies, which do not always adequately describe the sediments in question.

Beyond Gimble Porth, beneath Castle Down, the Battery section exposed a sequence of sands and gravels, according to **James Scourse**, the "finest exposure on Scilly of meltwater sediments" (Scourse, 2006, p. 136). These are interbedded, erosionally, with head deposits. Attempts to OSL date the Tregarthen Member at this site proved inconclusive, both untreated and treated samples resulting in inverted dates. The nature of the 'Battery' sequence and its structural complications were discussed at length. There is undoubtedly scope for further analysis, including a detailed drawing of this important section. As the party crossed Castle Down towards King Charles Castle, members could observe ploughing blocks of indeterminate age, evidence for mobile sand with implications for sea level fluctuations and/or human occupation (environmental v social factors), extensive spreads of erratics, smoothed tors, and a fine example (according to Charles Turner) of *Asplenium marinum*, the Sea Spleenwort, in an abandoned tin adit. The hill-top location of King Charles' Castle afforded excellent views of Cromwell's Castle beneath, and

New Grimsby harbour, which it was built to defend. Unfortunately, angles of declination were all wrong and Cromwell's Castle became the only viable means of defence. It also provided **Charlie Johns** with an excellent vantage point from which to address the troops, assembled beneath at Castle Porth, the western equivalent of Gimble Porth.

After lunch at the New Inn, New Grimsby, Tresco, it was a short distance by boat to Bryher. Here, **Charlie Johns** described rampart remains of an Iron Age cliff castle that protected Shipman Head, the location of a boulder moraine discovered only in 2002. Regrettably, for tidal reasons, the party could not gain access to this critical site. If access had been possible, we would have seen, according to **Danny**, one particularly large (>3 m thick) boulder with a deeply incised dendritic drainage network, similar to those on top of extra-glacial tors, crucially on its underside, suggesting inversion during emplacement in the moraine. If this is the case, the present top of the boulder should provide cosmogenic isotope evidence devoid of residual cosmogenic isotopes and the potential to over-estimate the age. If anything the true age might be underestimated due to possible post-depositional weathering losses indicated by the less well developed drainage features on the present top of the boulder. Even so the preliminary ^{10}Be age of 19.8 ka BP, was considered to place the overturning of the boulder firmly in MIS 2 with obvious implications for the status of the traditional southwest peninsula ice margin. **Danny** was at pains to compare the apparent success of this dating procedure with the difficulties associated with the OSL technique.

The party transferred to St Agnes. A planned meal at the Turk's Head allowed time for observation of an excellent raised beach site at Porth Killier, a doubtful tsunami site at the Big Pool, reputedly related to the Lisbon earthquake of 1755, more spectacular extra-glacial tors, and further organic sediments at Little Porth Askin, where **Charles Turner** offered a vote of thanks to the organiser, James Scourse. We had seen outstanding sections and been given excellent scientific explanations by individual contributors. The archaeological interest had also expanded his understanding of the Scillonian environment. We had also benefited greatly from the assistance of Brian Long, James Scourse's assistant, and many others who had worked tirelessly behind the scenes. Finally, he thanked all those who had contributed to the excellent discussions. For **James Scourse**, replying, it had been 'a real pleasure' to return to the Scillies. He had enjoyed being with everyone and wished to thank his assistants on Scilly, Julie Love and Dave Mawer from the Isles of Scilly Wildlife Trust, Amanda Martin from the Isles of Scilly Museum, and, most especially, Brian who had been party to everything from Field Guide preparation to section cleaning. Replete, after a very good meal, the group returned to Hugh Town as dusk was falling.

It is difficult to fault the logistics. Although we were not all based in the same accommodation, the scale of Hugh Town is such that assembly and departure

each morning were achieved without delay and critical tides were not missed. This, of course, was down to meticulous planning by the leader, but also relied upon the cooperation of a number of Scilly islanders, as well as party members, each of whom deserve praise for punctuality. James and his collaborators deserve our hearty congratulations.

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QUATERNARY RESEARCH FUND

LATE DEVENSIAN GLACIATION OF THE ISLES OF SCILLY: TESTING THE HYPOTHESIS

Introduction and background

The following is a report for a QRA Research Fund grant awarded in 2005 to James Scourse and Danny McCarroll.

In 1991 Scourse presented data which indicated that the glacial deposits of the northern Isles of Scilly are of Late Devensian age. This revised chronology was in accord with data from the offshore zone in the Celtic Sea (Scourse *et al.*, 1990) and is important because of the implications for ice stream activity in the southern Irish Sea (Scourse and Furze, 2001), Late Devensian ice thicknesses and deglaciation history (cf. Eyles and McCabe, 1989; McCarroll, 2001) and Heinrich event IRD phasing (Scourse *et al.*, 2000). Funding from the Quaternary Research Fund in 2002 enabled the authors, in conjunction with David Evans and John Hiemstra (then at Glasgow, now at Durham and Swansea respectively), to undertake a sedimentological investigation of the Scilly Till (Hiemstra *et al.*, 2006) and to collect samples for OSL and cosmogenic dating to test the Late Devensian model. Preliminary geochronological results have been published in Scourse *et al.* (2004).

The high quartz content of Scilly granite makes it suitable for both ^{10}Be and ^{26}Al cosmogenic techniques. In 2002 we obtained a preliminary ^{10}Be age of 113 ka from an extra-glacial granite tor at Peninnis Head, St Mary's (Scourse and McCarroll, 2006). The most promising site was located on the northern end of Bryher, at Shipman Head. Our interpretation here is that the glacier just reached this point, so that the end of the headland lay beyond the ice limit but along the northern edge there is a linear accumulation of large boulders interpreted as an ice-marginal moraine. On this moraine there is one extremely large block of rock ($>3\text{m}^3$) that has been completely inverted. On the underside there is a clear and deep dendritic drainage network, similar to those seen on the many tors that lie beyond the ice limit. The top of the block also displays drainage features but they are much less developed. If we are right in assuming that this large block was inverted and incorporated into the moraine at the ice margin, then there is no danger of any residual cosmogenic isotopes and the surface will not over-estimate the age of the glacial margin. This has yielded a preliminary ^{10}Be age of 19.8 ka (McCarroll *et al.*, 2006). Both these ages support the chronology proposed by Scourse (1991).

Methods

We used the Research Fund grant to return to Scilly in April 2005 in order to sample a large erratic of olivine basalt reported from Great Crebawethan by Dr J.R. Hawkes (pers. comm., 1983, in Scourse, 1991) and to undertake reconnaissance fieldwork on the other uninhabited western islands, including the Western Rocks, Mincarlo and Gweal. These islands had never been visited by the authors and, as they are situated across the proposed ice limit, it was suggested may well support boulder spreads of the kind discovered at Shipman Head Down. Any boulders discovered would be sampled for cosmogenic dating.

After frustrating delays caused by the simultaneous breakdown of two British International helicopters followed by 36 hours of dense sea fog which prevented any flying, we finally hired a boat and visited the localities of interest on Wednesday 13th April. We were accompanied by Dave Mawer and Julie Love of the Isles of Scilly Wildlife Trust since Great Crebawethan is a bird and seal reserve and consideration had to be given to potential habitat disturbance by any geological work. Despite an intensive search by all four individuals, we failed to trace the reported basalt erratic. Great Crebawethan, despite its name, is very small; approximately 450 m by 250 m, mostly consisting of bare granite outcrop covered by large granite boulders within the inter-tidal zone. At the time of the visit the island was populated by a large population of seals. One very small area in the central part of the island rises above the inter-tidal zone and supports some soil and vegetation (mostly grasses); there are some small sections here exposing Porthloo Breccia (solifluct derived from the local granite) overlain by Old Man Sandloess (Scourse, 1991). Not only were we unable to locate the basalt erratic, but we found no trace of erratics associated with the Old Man Sandloess. Though based on negative evidence, this suggests that this island lies outside the ice limit on Scilly (Figure 1). It was evident from the burial of washed-up anchor cable beneath very large granite boulders (in excess of 3 m by 3 m) that most of the inter-tidal boulders covering the majority of the island are actively mobile during storms. So, even if we had been able to find the erratic, there would have been significant doubts about whether it had been stationary since deposition by glacier. This potential recent mobility clearly compromises any sampling for cosmogenic dating. Though this landing therefore resulted in a largely negative outcome, it was nevertheless useful to have set foot on a part of the archipelago which is very rarely visited and to have observed the geomorphology and very thin Pleistocene cover.

We then took the boat close to Mincarlo, Great Minalto, Castle Bryher, Illiswilgig and Maiden Bower. These islands must lie close to, or across, the ice limit, and we were able to observe that they all lack the boulder spreads characteristic of Shipman Head on Bryher (McCarroll *et al.*, 2006). There is no positive evidence that these islands lie within the ice limit. We then landed on Gweal, a small island (500 m by 250 m) immediately to the west of Bryher.

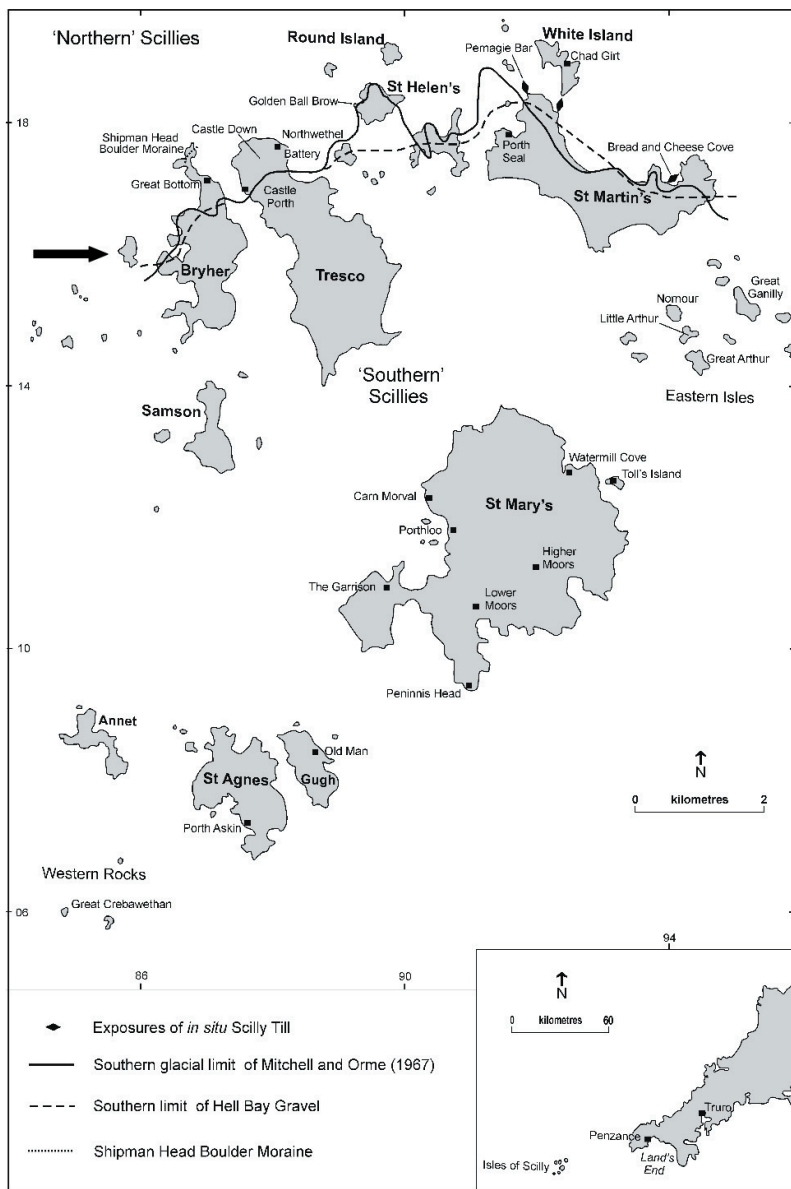


Figure 1. The Isles of Scilly: ice limits. Large black arrow indicates the island of Gweal.

This island rises to over 30 m and is much more substantial in terms of soil, vegetation and Pleistocene cover than Great Crebawethan. We observed and recorded Pleistocene sections around the island, noting that there are good exposures of the Porthloo Breccia and Hell Bay Gravel (Scourse, 1991), the latter containing abundant erratics, many striated. The Hell Bay Gravel is present in sections right around the island, indicating that Gweal clearly lies within the ice limit.

Significance

The negative evidence from Great Crebawethan, and the positive evidence from Gweal, has enabled a revision of the ice limit published in Scourse (1991), presented here as Figure 1. This revised ice limit is also published in new QRA Field Guide for Scilly (Scourse, 2006). The ice limit now no longer extends as far to the south and west as Great Crebawethan, nor does it cross Mincarlo. The line clearly passes to the south of Gweal (as indicated in Scourse, 1991) but now stops at an indeterminate point south of Gweal. Offshore geophysical (boomer, side-scan sonar) survey by the RV *Prince Madog* during September 2005 (unpublished) in the channel immediately to the southwest of Gweal failed to provide any evidence relating to the ice limit in this vicinity.

During the survey of Gweal an organic site on the southeast coast (SV867150) was discovered. A body of chocolate-brown to black humic organic material was found within the basal Porthloo Breccia below the erratic-rich Hell Bay Gravel. The lithology and stratigraphic position of this organic deposit is identical to the other Middle and Late Devensian organic sequences reported from Scilly by Scourse (1991); it is significant, however, because it is one of only two organic sites that lie north of the ice limit. The other is Bread and Cheese Cove on St Martin's, a site which has proven extremely problematic in terms of radiocarbon dating. The Gweal site may therefore prove to be important; it was sampled during the visit but remains to be investigated in detail.

Acknowledgements

The landings on these uninhabited islands would not have been possible without the help, local knowledge and expertise of Jeremy Phillips, chair of the Isles of Scilly Boatmen's Association, and the assistance and advice of Dave Mawer and Julie Love of the Isles of Scilly Wildlife Trust. We thank the QRA for their financial support for this project which also facilitated the arrangements for the Short Field Excursion to Scilly in May 2006.

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SAND-WEDGE DEVELOPMENT, TUKTOYAKTUK COASTLANDS, WESTERN ARCTIC CANADA

Background and Rationale

Ice-wedge casts in Quaternary sediments are widely used to reconstruct former air temperatures or, more cautiously, ground thermal regimes (Murton and Kolstrup, 2003). For such reconstructions to be useful, however, it is important to know over what period of time the wedges developed. Wedges developing during 10–20 years and then melting provide a very different environmental record from those developing over hundreds or thousands of years and experiencing episodes of climate change, partial melt and re-growth. Thus data on wedge growth rates from regions of contemporary permafrost are needed to help us interpret the palaeoenvironmental significance of relict wedges from mid-latitude Quaternary deposits

Data on ice-wedge growth during periods of ~20 years are provided from J. Ross Mackay's pioneering monitoring studies in tundra of western Arctic Canada (summarised in Mackay and Burn, 2002). Data for 10^2 – 10^4 -yr periods (Payette *et al.*, 1986; Vasil'chuk and Vasil'chuk, 1998) are inferred indirectly from radiocarbon dating of organic material within deposits that host upward-growing ice wedges in sub-Arctic Quebec and across Siberia. But direct dating of wedge development over such periods of time requires analysis of the wedges themselves. A promising method of direct dating is by applying luminescence techniques to windblown sand within Arctic sand wedges (Murton *et al.*, 1997); such wedges develop where sand, rather than ice, infills thermal contraction cracks in permafrost to produce vertically-laminated bodies of sand that have a high preservation potential (Murton *et al.*, 2000). This method has the advantage of being able to directly date the time when the sand was last exposed to sunlight, which, within the error of the dating method, coincides with the time when the wedge cracked and the sand was blown into the crack. Moreover, the sediments hosting the Arctic sand wedges are themselves often of aeolian origin, and therefore can also be dated (Bateman and Murton, in press).

With support from the Quaternary Research Fund, we are applying optically-stimulated luminescence (OSL) dating to determine growth rates of Arctic sand wedges. During summer 2005, we collected sand samples from a number of large sand wedges in the Tuktoyaktuk Coastlands of western Arctic Canada. This is a region where wave erosion exposes permafrost along tens of kilometres of coastal bluffs, facilitating analysis and sampling of large stratigraphic sections.

Preliminary results

We sampled two types of sand wedges. The first type is 1–21 cm wide, ≤ 9

m high, and has a narrow, chimney-like shape (Figure 1A). Such wedges are thought to grow vertically upward during aggradation of aeolian sand sheets, and so are termed 'syngenetic'. The second type is unusually wide (2.3–3.9 m maximum true width), often has vertical to overturned strata beside its top, and underlies a prominent erosion surface (Figure 1B). This type of wedge is thought to grow vertically downward during erosion (deflation) of the ground surface, and is termed 'anti-syngenetic', following J. R. Mackay's (1990) classification of ice wedges. Dating of the sand wedges and their host sand is currently being undertaken. The expectation is that syngenetic wedges should become younger towards their tops, whereas anti-syngenetic wedges should become younger towards their centres, other things being equal. Preliminary dating of the host aeolian deposits and some adjacent epigenetic sand wedges indicates that the wedges developed between marine isotope stage 3 and the Last Glacial-Interglacial Transition (Bateman and Murton, in press), before and after the region was covered by ice streams from the northwest margin of the Laurentide Ice Sheet.

Significance

Successful completion of the dating will provide the first long-term growth rates for syngenetic and anti-syngenetic sand wedges in permafrost regions. The accompanying stratigraphic observations will provide a new touchstone for understanding the origin and palaeoenvironmental significance of relict sand wedges in Pleistocene cold-climate aeolian sand deposits in mid-latitude regions such as the 'sand belt' of northwestern Europe.

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Figure 1. Relict sand wedges, Tuktoyaktuk Coastlands, western Arctic Canada. (A) Syngenetic sand wedge 8.6 m high, 2–20 cm wide, within aeolian sand-sheet deposits. The sides of the wedges are inscribed for clarity. Person for scale.



Figure 1. Relict sand wedges, Tuktoyaktuk Coastlands, western Arctic Canada. (B) Anti-syngenetic sand wedge with a maximum width, measured orthogonally to the axial plane of the wedge, of 3.9 m. The top of the wedge is truncated by an erosion surface that has been traced along kilometres of coastal bluff. Beside the spade, strata in the host sand are vertically upturned.

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CONFIRMATION OF THE EXTENDED BRISTLECONE PINE CHRONOLOGY

Background and rationale

The White Mountains of California are home to the ancient bristlecone pine (*Pinus longaeva* D.K. Bailey) forest which provides a unique natural archive of information on past climate. Bristlecone pines are the oldest living trees on earth, with the world-renowned 'Methuselah' tree dating to over 4700 years. The rings of these trees contain an unrivalled, annually-resolved record of climatic change. Growing at an altitude of *ca.* 3000-3500m, the trees manage to survive in the poorly nourished, alkaline soil with arid conditions and a relatively short growing season.

Throughout the world, the ring-widths of trees have been used extensively both to calibrate the radiocarbon timescale and to reconstruct past climates. The well-replicated 8,700 bristlecone pine chronology offers the potential to examine the exact nature of past climatic events. As cross-dated ring width samples are accurate to the nearest year and chronologies, once developed and verified, rarely require revision, past climatic events can be determined without the uncertainties inherent in other, often less well-resolved proxies. The use of long-lived trees to reconstruct past climates also minimises the problems which may arise from using short time-series overlapped back in time (Cook *et al.*, 1995). In a pioneering study, LaMarche, Jr. (1974) was able to reconstruct warm season temperature over the last 5500 years from the differing response of timberline bristlecone pine trees to climate, demonstrating the climatic sensitivity of the record and its value as a palaeoclimatic archive.

Objectives

The aim of this research was to extend the existing 8700-year old tree ring chronology to bridge the gap with the older 3000-year old floating chronology and to increase sample depth during this critical period. The long-term objective of this research is to determine stable isotope values (carbon, hydrogen and oxygen) on absolutely-dated samples to reconstruct past climates with a high degree of confidence and to examine the nature of rapid climatic change events in this region.

Methods

As part of the University of Arizona Bristlecone Pine Project, 5mm diameter cores or small discs were obtained from remnant bristlecone pines at an elevation of *ca.* 3000m in the White Mountains (37°23'N, 118°09'W). The samples were sanded with progressively finer grades of abrasive paper to reveal any

visible growth rings. Cross dating was achieved using skeleton plotting and the program CROSSDATE 4.0 (Lazear and Harlan, *pers. comm.*).

To confirm cross dating where the chronology sample depth and levels of replication were low, samples were dated at the Swansea Radiocarbon Dating Laboratory using standard techniques. The wood samples (*ca.* 10g) were split into matchstick size pieces and pre-treated with dilute acid, alkali and dilute acid respectively to remove soluble organic components, such as humic acids. Combustion and subsequent purification yielded methane for gas proportional counting. Radiocarbon dates were calibrated using OxCal 3.10 (Bronk Ramsey, 2001) and the INTCAL04 terrestrial dataset (Reimer *et al.*, 2004).

Results

Although many samples were dated, one particular sample warrants further attention. Sample 2004-064 was cross dated using skeleton plotting to yield a date of 6828 BC to 6407 BC. A sub-sample of 48 rings (6708 BC to 6660 BC) was dated using conventional radiocarbon dating (SWAN-657). The radiocarbon age of this sample (7770 ± 80 BP) was calibrated using OxCal and the INTCAL04 dataset to yield a calendar age of 6830 cal BC to 6440 cal BC with a 95.4% (2_σ) probability of occurrence (Figure 1).

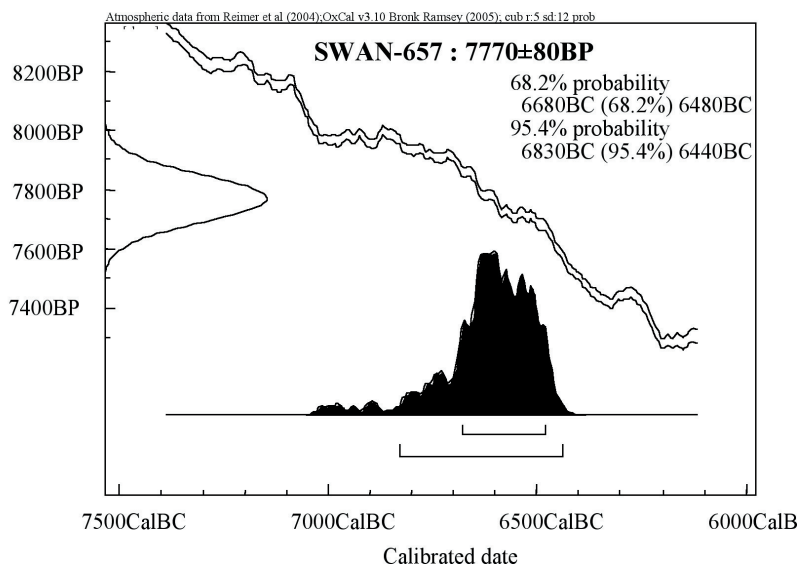


Figure 1. Calibration of the radiocarbon date from a sub-sample of 2004-064 (SWAN-657) using OXCal (Bronk Ramsey, 2003; Reimer *et al.*, 2004.). The one-sigma and two-sigma range of calibrated dates are illustrated.

Clearly, the close agreement between the calibrated radiocarbon date (6830 cal BC to 6440 cal BC) and the date obtained by skeleton plotting in a region with low sample replication (6708BC to 6660BC), confirmed the dating of sample 2004-064. This study confirms that the extension of the bristlecone pine chronology by 126 years to 6828BC. The quest now continues to find further remnant samples to bridge the gap with the floating chronology.

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THE ^{210}Pb CHRONOLOGY OF DEPOSITION IN Tocal HOMESTEAD LAGOON, EASTERN AUSTRALIA

Tocal Homestead Lagoon is a lateral (Hutchinson, 1957, p. 115) or blocked valley lake (Blake and Ollier, 1971), lying adjacent to the Paterson River, a major left-bank tributary of the Hunter River in central eastern New South Wales, Australia (Figure 1). The lake represents one of the few geomorphic features in the region in which sedimentary records of environmental change may be preserved. In an attempt to exploit this record, the sediments in the lake were cored along a 50 m grid. The most complete and highest resolution record came from site TCA9, which was chosen as the location of the master core. In order to obtain a detailed record of deposition in the lake over the last few centuries (the period since and immediately preceding the time of European contact), the excess ^{210}Pb activity of 44 samples from the top 1.26 m of the master core was determined by alpha spectrometry. Five different models were applied to the $^{210}\text{Pb}_{\text{excess}}$ activity profile in an attempt to establish the chronology of deposition at the site. The modelled chronologies were tested against a range of independent dating methods. These included:

1. The activity of ^{137}Cs in the sediments. Cesium-137 is an anthropogenic nuclide derived from atmospheric testing of nuclear weapons. In Australia, it is usually assumed that the first occurrence of ^{137}Cs at detectable levels dates from the late 1950s (Brunskill *et al.*, 2002).
2. The incidence of elemental lead in the sediments. Except in the vicinity of metal smelters and mines, the first detectable increase in the concentration of elemental lead above background levels in Australia took place in 1932 with the introduction of tetraethyl lead into motor fuels (Cook and Gale, 2005).
3. The palaeomagnetism of the sediments. Studies of ships' logs, historical records, archaeomagnetic measurements and observatory data have revealed a sharp and short-lived peak in the inclination of the magnetic field in eastern Australia in the period c. 1690–1770.
4. Carbon-14 dating of the sediments. Accelerator mass spectrometric dating of closely-spaced samples of different organic fractions from those parts of the sequence immediately preceding European contact has enabled us to test the reliability of the ^{210}Pb models at their chronological limits.

Application of these four means of calibration has allowed us to select the ^{210}Pb model that fully matches the independent chronologies. This is shown in Figure 2. This sequence represents the most detailed and best supported chronology of post-contact sedimentation yet obtained in Australia. It promises

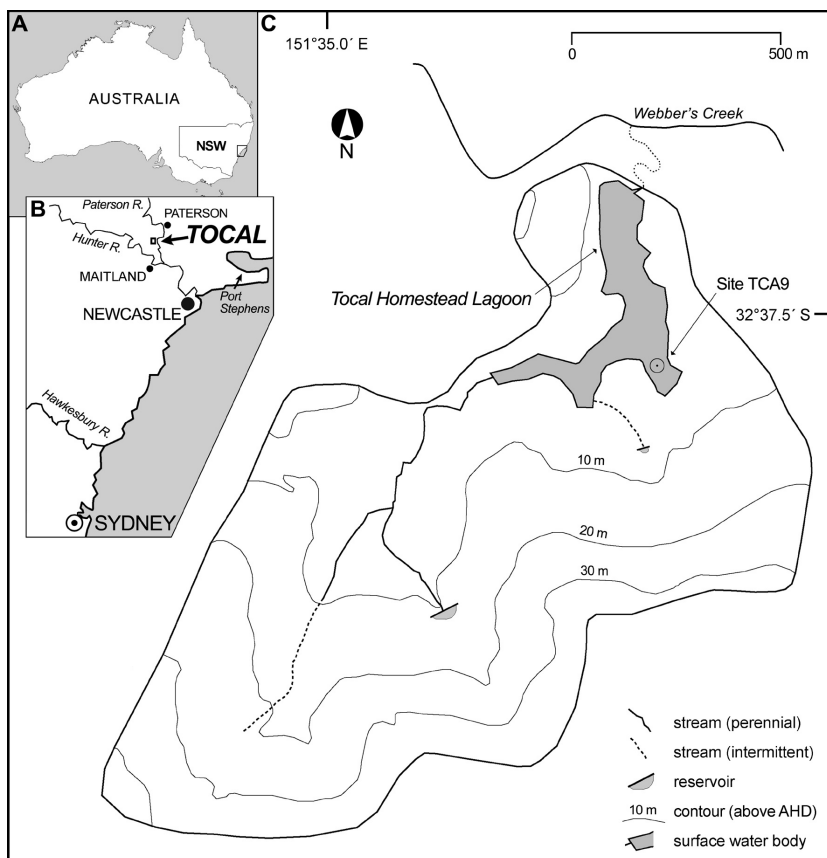


Figure 1. The catchment of Tocal Homestead Lagoon and its situation in central eastern New South Wales, Australia, showing the locations mentioned in the text. Mapping based on field surveys, 1993 aerial photographs and the unpublished Geographical Information System established for Tocal by Agriculture New South Wales (Cook, 2006).

to be of immense value in attempts to assess the impact of European land use on the natural environment, in validating models of human environmental encounters and in placing post-contact environmental records in a reliable chronological framework.

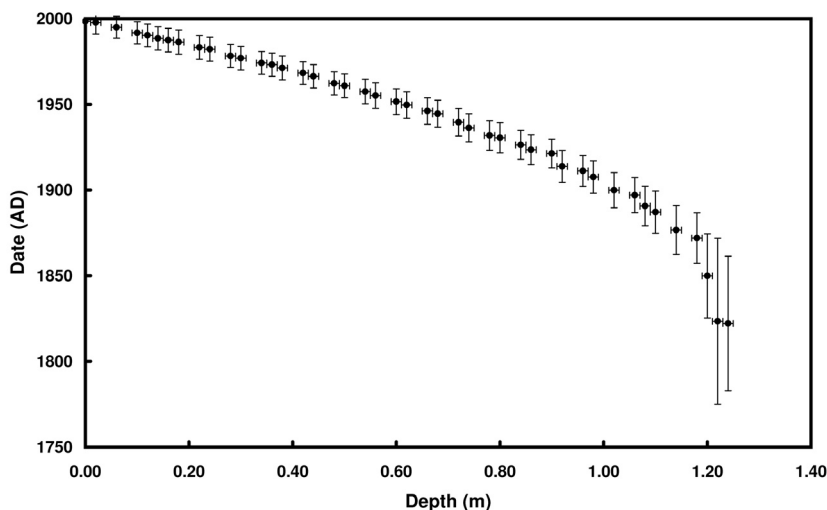


Figure 2. The ^{210}Pb chronology of core TCA9b, Tocal Homestead Lagoon, central eastern New South Wales, Australia (Cook, 2006).

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A LATE GLACIAL CHIRONOMID ASSEMBLAGE FROM SOUTHERN SWEDEN: PRELIMINARY RESULTS

Background and rationale

The pattern of late glacial climate change, characterised by rapid, short-term climate oscillations, is well established across Northwest Europe. In order to test the hypothesis of synchronous climate change, accurate correlation of records across the region and improvements in the resolution of proxy records is required. This will enable leads and lags to be identified in the system and to assess how the changes varied in magnitude across the region. Generating high resolution quantified temperature reconstructions is an important step towards achieving this goal. Chironomid analysis is an excellent proxy to use as chironomids have been proven not only to be sensitive indicators of Lateglacial and Holocene climate change (Walker and Mathewes, 1987, 1989), but multivariate statistical models have been developed which enable such changes to be quantified (Brooks and Birks, 2000, 2001). Several high resolution chironomid temperature reconstructions from Northern Europe have recently been published (for review see Brooks, in press).

The QRA New Research Workers Award contributed towards travel and accommodation to undertake fieldwork at Hässeldala port, southern Sweden. The site was chosen as previous work has identified several tephra horizons in the sequence, as well as 28 high-resolution radiocarbon dates and a pollen curve (Wohlfarth *et al.*, in press). Work is being carried out in collaboration with researchers at Stockholm University.

Methods and results

Fourteen 1m cores were extracted from the site using a 10cm diameter Russian corer, in order to carry out both chironomid and coleopteran analyses. Only the chironomid analyses are reported here. Cores were correlated to the master core previously taken from the site. One core was sampled at 10cm resolution for chironomid analysis, from 245-335cm, which covers the Late Glacial period. Samples were prepared using the method outlined in Brooks *et al.* (1997). Preliminary, low resolution, results of the chironomid analyses are presented here (Figure 1). The lithostratigraphy is based on the units identified by Wohlfarth *et al.* (in press).

The results show major chironomid assemblage changes occurring across the late

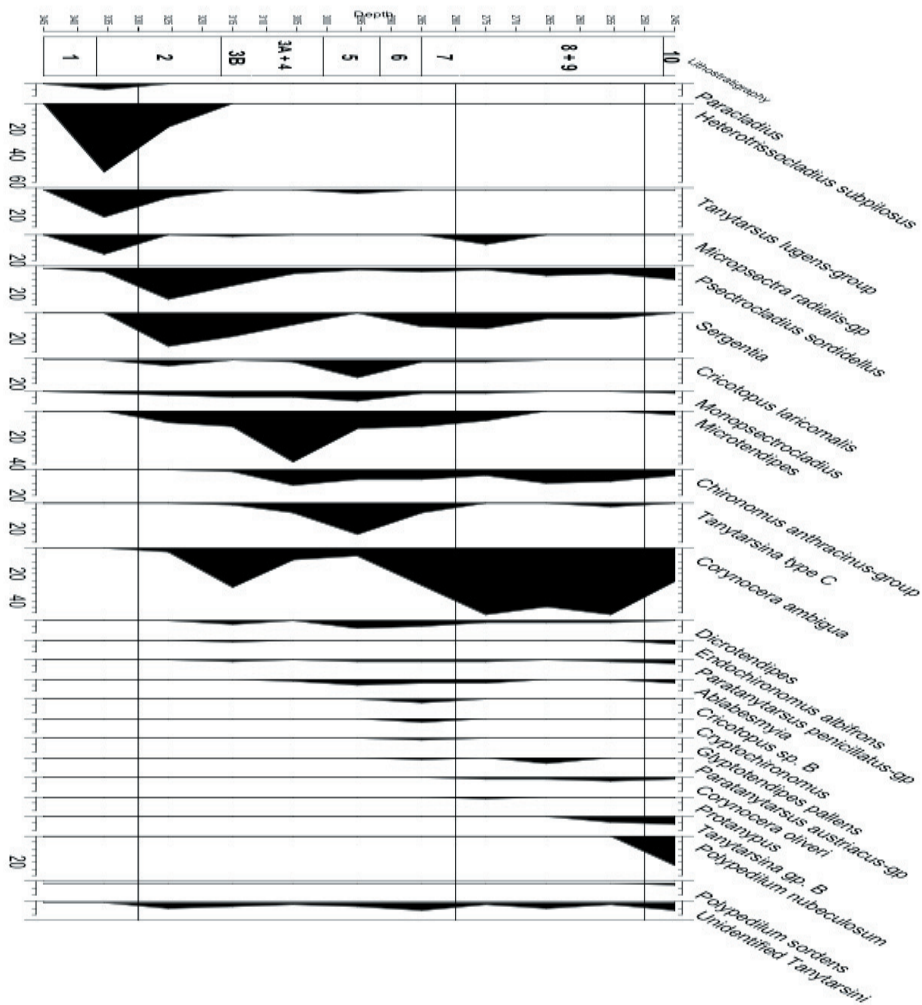


Figure 1. Simplified low-resolution chironomid diagram from Hässeldala port, showing dominant taxa. Taxa are expressed as a percentage of total head capsules. The diagram has been provisionally visually zoned on the basis of major chironomid faunal changes. The lithostratigraphy is based on that from Wohlfarth *et al.* (in press).

glacial. The base of the sequence (335cm) is dominated by *Heterotrissocladius subpilosus*, and *Tanytarsus lugens*, cold stenotherms which favour oligotrophic conditions. The following five samples (325-285cm) show an increase in taxa with a warmer temperature optima, including *Sergentia coracina*, *Psectrocladius sordidellus*-type and *Microtendipes pedellus*. Three samples extracted from unit 9 (275-255cm) demonstrate that the fauna had switched to one dominated by cold stenotherms, including *Micropsectra radialis* and *Corynocera ambigua*. The final sample, at 245cm (unit 10) charts a decline in cold stenotherms and an increase in warm stenotherms such as *Endochironomus albifrons* and *Polypedilum nubeculosum*.

Based on correlation with the master core, the base of the core (units 1 and the lower part of 2) is tentatively ascribed to the Older Dryas (GI-1d). Units 2-7 would then correspond to the Allerød (GI-1a-c), Units 8 and 9 to the Younger Dryas period (GS-1) and Unit 10 to the early Holocene. The changing chironomid faunal assemblages support these associations, and demonstrates good correlation to previously published chironomid diagrams from Northwest Europe (Brooks *et al.* 1997, Brooks and Birks, 2000, Brooks, in press).

Future work will increase the resolution of the chironomid analyses, to at least every 2cm. Coleopteran analyses will also be carried out. Quantitative temperature reconstructions will be carried out for both proxies at the site.

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THE USE OF PALAEOMAGNETIC ANALYSIS AS A SUPPLEMENTARY DATING TOOL FOR SALT-MARSH SEDIMENTS: APPLICATION IN SEA-LEVEL STUDIES

Introduction

Late Holocene sea-level studies are increasingly using data obtained from the analysis of salt-marsh sediment sequences. The chronology of these sediments has been traditionally provided by ^{14}C dates. Unfortunately, many UK and northern European salt-marsh sequences do not contain sufficient material suitable for ^{14}C dating (Edwards, 2001). To overcome the present reliance on the direct ^{14}C dating of salt-marsh sediments this project was conceived to investigate the application of a number of alternative dating methods, including palaeomagnetic analyses. Reported here is the investigation of palaeomagnetic analyses as a potential dating tool for salt-marsh sediments in the Taf Estuary, south Wales, UK (51° 46'N 004° 25'W).

Palaeomagnetic analyses have been used in both limnology and oceanic marine studies as a dating tool, but, as yet, have not been applied to salt-marsh sediments. Following some success with an initial palaeomagnetic analysis of a Taf sediment sequence collected in 2002, the award from the New Research Workers Scheme has been used to help fund the field collection and magnetic analysis of a second, replicate sequence collected in 2003.

Method

The two 1.2 m monoliths were taken from the vertical faces of separate pits in the Taf salt-marsh near the upper limit of spring tides. The 2003 pit was dug at the same ground surface elevation, about 10 m west of the 2002 pit. Stainless steel boxes were used to cut azimuth orientated sediment monoliths that were later sub-sampled in the laboratory using 2 cm³ overlapping plastic boxes. The natural remanent magnetism (NRM) in these samples was then measured at Southampton Oceanographic Centre (SOC) using a Cryotronic magnetometer following a step-wise demagnetisation procedure from 0 to 500 mT.

Results and discussion

Some structure was apparent in the declination and inclination records from both sections, but the NRM signal was locally noisy. The intensity signal preserved in some samples was apparently too low (less than 0.5 mA m⁻¹) for the reliable measurement of the direction vectors, and a number of obvious anomalous values were produced that were outside the possible range of declination and inclination values for the site. This was very evident with the

samples from the more organic-rich sediments above 20 cm and these were all excluded from the analysis.

After the removal of the data with low intensity values there was agreement between the two independent sets of declination data (Figure 1A; $r^2=0.59$, $p=0.000$). However, even after the removal of the unreliable data there was no significant correlation between the two sets of inclination data (Figure 1B). To test the validity of the analysis as a dating tool the Taf 2002 NRM data were aligned to the UK palaeomagnetic master curve of Thompson and Turner (1981) using the sequence slotting software SLOTDEEP (Maher, 1998). The suggested depth ages were then plotted in Figure 2 along with ^{14}C dates and ^{210}Pb data from a nearby sediment core (R. Gehrels, unpublished data).

The palaeomagnetic analyses produce a chronology that indicates an older age for the sediments than the ^{14}C dates. The difference in the chronologies may be an artefact of the palaeomagnetic method, or it may be indicating some contamination of the ^{14}C samples by younger carbon from downward growing

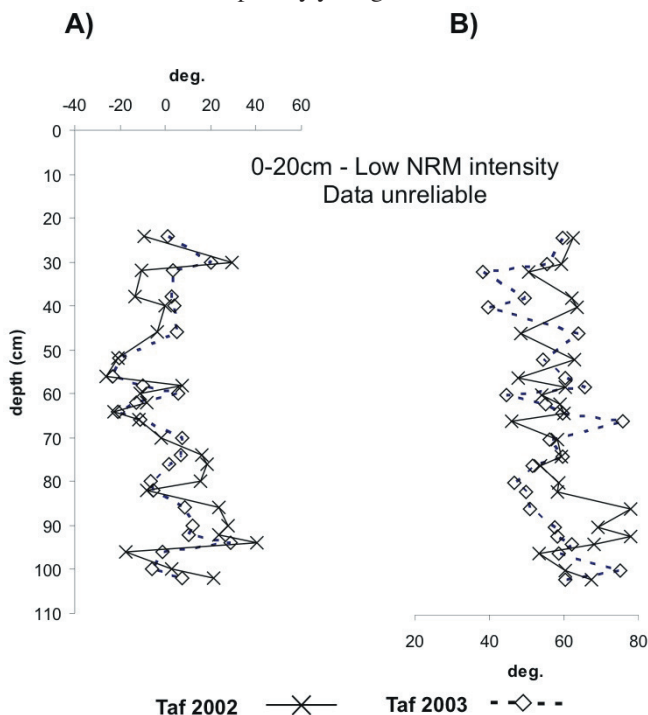


Figure 1. Taf 2002 and Taf 2003 declination (A) and inclination (B) curves. Declination records agree well ($r^2=0.59$, $p=0.000$). Inclination records do not agree ($r^2=0.01$, $p=0.655$).

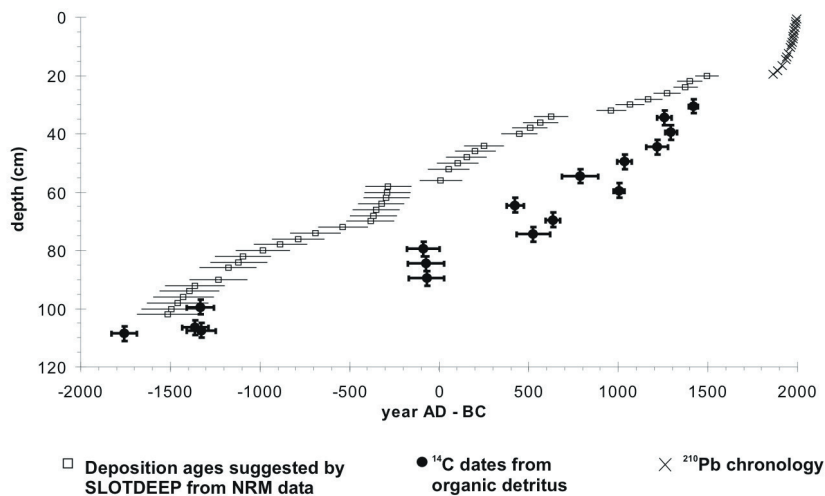


Figure 2. The Taf chronologies. AMS ^{14}C dates (From carbon detritus, R. Gehrels, unpublished data) and the ages obtained from aligning the Taf data with the UK declination data master curve of Thompson and Turner (1981) using SLOTDEEP (Maher, 1998). Error bars: Taf ^{14}C dates - two sigma uncertainty and sample depth range shown; Taf palaeomagnetic dates - two sigma uncertainty modelled from the Calib 5.0 (Stuiver *et al.*, 2005) re-calibration of the original published ^{14}C dates used by Thompson and Turner (1981).

roots. However, the level of agreement between the radiometric dates and the magnetic chronology does indicate that it is possible to obtain a geomagnetic palaeosecular variation record from salt-marsh sediments, and that this type of analysis may be useful as an independent dating method to supplement the ^{14}C dating of minerogenic sediments.

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This work forms part a PhD project funded by the School of Geography, University of Plymouth, and is supervised by Dr Roland Gehrels, Dr Hywel Evans and Dr Eric Achterberg (SOC). Palaeomagnetic analyses were conducted by Andrew Roberts (SOC). The Taf ^{14}C analyses were carried out by Klaas van der Borg (Utrecht University) in collaboration with Orson van de Plassche (Free University, Amsterdam) with funding from the National Institute for

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SEDIMENTARY AND SEISMIC SIGNATURES OF AN ICEBERG- SCoured LATE QUATERNARY SUCCESSION IN THE CENTRAL NORTH SEA

Background

The shallow sedimentary facies of the Witch Ground basin, central North Sea, are characterised by an extensively iceberg-scoured surface, which lies buried up to 25 metres beneath the modern-day seafloor (Figure 1A, B). The irregular scoured horizon was first identified by Stoker and Long (1984) on 2D boomer seismic and side-scan sonar profiles and has been tentatively dated to 17-18 ka B.P. It lies within a package of soft glacimarine muds, which form a regionally-extensive, upward younging late Quaternary sequence, dated from ~22 ka B.P. to Holocene (Sejrup *et al.*, 1994). The glacimarine package overlies till deposits laid down by an offshore ice sheet which is thought to have covered the North Sea basin during the late Weichselian glacial maximum (Marine Isotope Stage 2, 29-22 ka B.P., Sejrup *et al.*, 1994; Carr *et al.*, 2006).

Since the original study, the iceberg scours have received little attention, except for a brief note in Long and Praeg (1997). Studies of the sediments surrounding the ploughmarks have also evaded focus, and interest in them has only recently been renewed (Carr *et al.*, 2006).

As part of new research in the basin, the same set of iceberg ploughmarks have been identified and mapped on commercial 3D seismic data (Figure 1C). Plan view seismic images from the buried sequence confirm Stoker and Long's initial interpretations and further suggest that iceberg features are extensive across the entire Witch Ground region, formed both at subcrop and at seabed. Additionally, geomorphic signatures correlating with tills found beneath the iceberg scoured facies indicate that the basin was occupied by one or more palaeo-ice streams in the recent past (Graham *et al.*, In Prep; Figure 1D).

The present study investigates a new shallow core (BGS borehole 04/01), tied directly to 3D seismic datasets, and drilled through the Witch Ground late Quaternary succession, penetrating the interpreted iceberg scoured sediments at ~15-20 metres, as well as underlying till facies. The borehole has been analysed for a range of geophysical, geotechnical and sedimentological properties, with a view to better characterising the shallow stratigraphy and the sediments in which iceberg ploughmarks are developed.

As part of these analyses, grain size measurements (Particle Size Analysis-PSA) were funded by the QRA New Research Workers' Award. The data were collected using laser granulometry techniques, and carried out by the School of the Environment, University of Gloucestershire in October 2005.

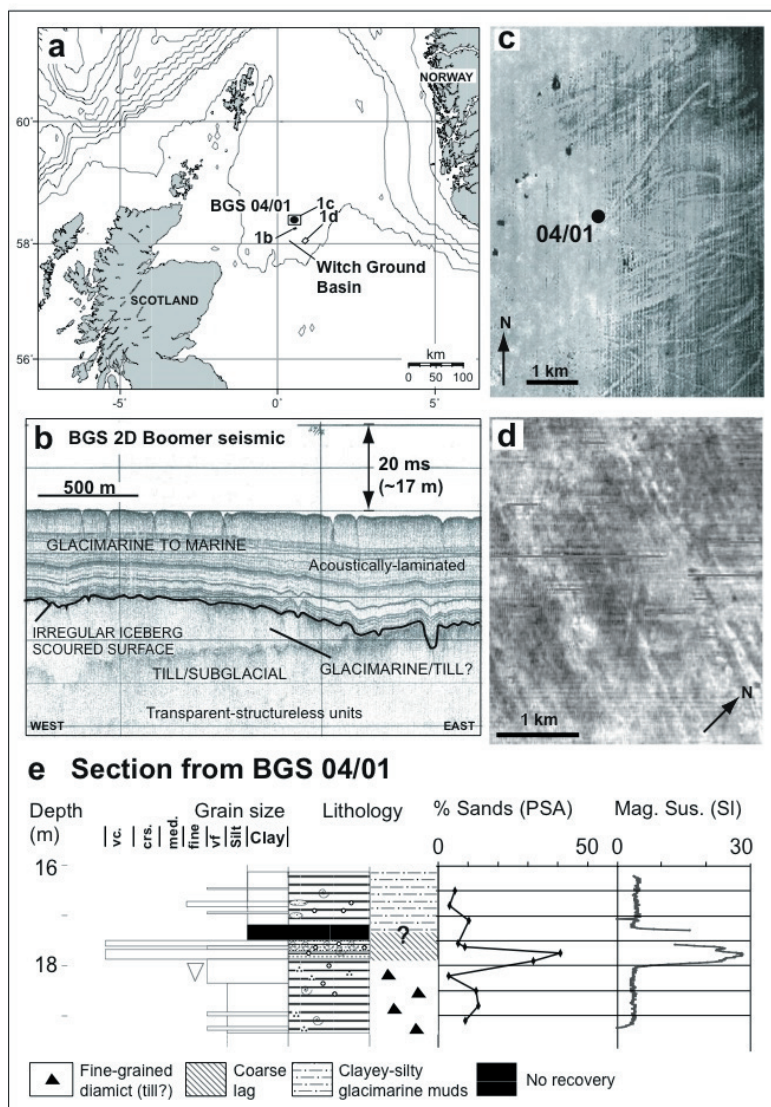


Figure 1. (a) Core location map; (b) Boomer seismic line through Quaternary succession showing the acoustic character of the iceberg scoured horizon and surrounding sediments. Plan-view seismic time slices through 3D seismic data, illustrating (c) iceberg ploughmarks around core site, at ~15 m below seabed; (d) mega-scale glacial lineations buried at ~30 m below seabed to the southeast of core site. See (a) for locations. (e) Core logs for BGS 04/01 at a level surrounding the iceberg-scoured lag deposit.

Preliminary results

Grain size data for the Witch Ground core reveal a fine-grained and lithologically indistinct succession, composed throughout of structureless muds, muddy-clayey silts and sandy silts. This is somewhat surprising given the heterogeneity implied by the seismic observations (Figures 1C and D). Sedimentary sequences of ice-stream related facies are commonly structureless and lithologically invariable in cored record. This has also proven the case in past shallow borings of the region (Long *et al.*, 1986).

The most interesting sedimentary unit comprises a single 30 cm thick shelly diamicton, observed at ~ 17.5 m depth in the core (Figure 1E), and which is tied tentatively to the irregular iceberg ploughed surface, seen on both 2D and 3D seismic datasets.

An iceberg-keel scoured interpretation for this horizon is supported in five lines of evidence:-

- (1) Grain size measurements for the deposit exhibit a high coarse input (Sand content up to ~ 40%, Figure 1E), inferring deposition in a relatively high energy environment (proximity to a glacial source).
- (2) The horizon contains a high concentration of larger clasts (1 to >5 mm diameter), which we interpret as rafted dropstones, iceberg rainout or iceberg basal debris.
- (3) A high magnetics peak in the deposit is thought to reflect a higher concentration of magnetised coarse grains, commonly associated with an increased flux of ice-rafted detritus in glacially-influenced marine settings (Figure 1E).
- (4) Shell fragments, which are commonly found broken and weathered in the deposit, might suggest that a degree of reworking has taken place at this level, and support an ice-keel contact interpretation.
- (5) The matrix of the deposit appears lithologically similar to that of the underlying sediments, suggesting that the horizon has been derived, in part, from pre-existing sedimentary units.

Our interpretation rests on a firm stratigraphic tie to the seismic data, which forms part of ongoing work in the basin.

Initial findings and significance

The shallow core has provided a new opportunity to characterise the sediments relating to the newly discovered offshore geomorphological record of this area. Grain size results show that borehole records of glacial activity in the North Sea reflect, on face value, wholly glacimarine processes, and do not reflect the

scale of erosional activity implied by the buried geomorphic signature. Even sediments interpreted as tills, at the base of the core, display a fine-grained character, suggesting that they were deposited primarily in a (glacial) marine setting, and were latterly remoulded by overriding ice. These findings have important implications for how 'large-scale' three-dimensional morphology is characterised in downcore (i.e. one-dimensional) profile, and how evidence for glaciation is recognised in submarine successions.

A diamictic 'lag' described in the core sequence is interpreted as an iceberg scoured horizon (iceberg turbate) and ties approximately to the erosion surface previously recorded by Stoker and Long (1984). The unit has gone some way to helping ground-truth the seismic and geomorphic observations in this part of the basin.

Further work on the core data seeks to integrate the sedimentary and geomorphic records into a late Quaternary event stratigraphy, in which ice sheets and subsequently icebergs were widespread across the central North Sea.

Acknowledgements

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ABSTRACTS

MID- TO LATE HOLOCENE RELATIVE SEA-LEVEL CHANGES IN THE NORTH OF IRELAND

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The mid- to late Holocene relative sea level (RSL) history of Ulster is poorly understood. This PhD study represents a first attempt to use microfossil records (foraminifera and diatoms), which are well-preserved in saltmarsh sediments, to reconstruct the recent RSL record.

Saltmarsh microfossils have proved to be accurate proxies for reconstructing accurate, high-resolution records of palaeo-RSL change, particularly in the late Holocene. However, this method has not as yet been exploited in the north of Ireland, an area where mid- and late Holocene RSL data is lacking. As this is a key period of study in terms of predicting near-future RSL trends, it is important that the recent geological history be determined, thus highlighting the significance of detailing RSL changes throughout the north of Ireland. Reconstructive models predict RSL variations for the late Quaternary, with a clear lack of data for approximately the last 3000 years.

A modern training set of contemporary microfossil and environmental data is produced for the north of Ireland and used to develop foraminiferal and diatom transfer functions. Elevation is found to be the dominant controlling variable on microfossil assemblages. The microfossil-based transfer functions are applied to five fossil sites (Mill Bay, Dorn, Cullintra, Strath's Farm and Maas), allowing inference of palaeo-RSL and consideration of its spatial variability across the north of Ireland.

Four new Sea-Level Index Points are generated from Dorn and Maas, which fit closely with the regional sea-level models of Carter (1982a). More recent chronologies are developed for four saltmarsh sites (Mill Bay, Dorn, Cullintra and Strath's Farm), based on ^{210}Pb supported by ^{137}Cs dating. Comparison of the recent saltmarsh microfossil record to local tide gauges suggests a comparative directional change but a discrepancy in rates of RSL, to a factor of ten. This is suggested to be a product of both the inaccuracies of local tide gauge records and of the limitations of the transfer function method. This highlights the need for more robust testing of such statistical models.

THE LATE-GLACIAL AND HOLOCENE RELATIVE SEA-LEVEL HISTORY OF THE SEYMOUR INLET COMPLEX, BRITISH COLUMBIA, CANADA

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This study examines the relative sea-level (RSL) history of a remote coastal region (Seymour Inlet Complex) of south-western British Columbia, Canada through the analysis of isolation basins and saltmarshes. Detailed litho- and biostratigraphic analyses of sediment cores from three isolation basins (Woods Lake, Two Frog Lake and Tiny Lake), ranging in sill elevation from 2.13-3.59 m MTL, provide new data from an area devoid of information on Late-glacial and Holocene RSL and environmental change. Diatom analysis reveals that the lake basins were flooded by the sea during the Late-glacial and were subsequently isolated at ca. 11,800 ¹⁴C years BP. RSL rose again during the early Holocene and breached the 2.13 m sill at Woods Lake at ca. 8,000 ¹⁴C years BP. In the late Holocene, RSL rose to a minimum of 1.49 ± 0.34 m MTL at ca. 2,400 ¹⁴C years BP. This was followed by a RSL fall, with the final isolation of Woods Lake at ca. 1,900 ¹⁴C years BP. Schwartzenberg Lagoon, with a sill of -0.3 m below MTL shows that RSL has not fallen below this level. The results have been used to produce a RSL curve for the Late-glacial and Holocene. This is compared with RSL predictions derived from geophysical models available for the region. This region shows a similar RSL history to that published for eastern Vancouver Island.

The diatom data show that during the Late-glacial, climatic conditions were cool and dry, with evidence of Younger Dryas cooling. This was followed by a warmer and drier climate in the early Holocene. The transition to the mid-Holocene was characterised by modern cool and moist conditions. The late Holocene was characterised by cool and wet conditions with evidence of Neoglacial cooling. This is supported by pollen data. The lake basins record a long-term natural lake acidification.

A diatom-based transfer function was developed using elevation (m) relative to MTL, for two local saltmarshes (Waump and Wawwatl saltmarshes), which were employed to quantitatively reconstruct changes in palaeo-marsh surface elevation. The results show that there have been significant recent changes in saltmarsh surface elevation during the last three centuries, which may be attributed to complex local processes and possibly to co-seismic submergence associated with a large magnitude regional earthquake. The data as a whole

are similar to tide gauge records from Port Hardy (the closest station), which records a general RSL fall during the historical period.

This research has provided important new information on the RSL and environmental history of the SIC. The results of the study demonstrate the potential of isolation basin data, multi-proxy and palaeoenvironmental techniques for local and regional studies of RSL and environmental reconstruction in British Columbia.

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 Annual Field Meeting, usually lasting 3–4 days, in April, and a 1 or 2 day Discussion Meeting at the beginning of January. Additionally, there are Short Field Meetings in May and/or September, while 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.

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