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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:

Arhomb porphyry erratic found by Harmer (1910, 111) in the 'North Sea Drift' at Catton brickyard (TG 33130), near Norwich, in 1909 (Norwich Castle Museum Accession Number NWHCM : 1909.36). Provided by Peter Hoare.

PRESIDENT'S ANNOUNCEMENTS

Recently departed members

Members are probably already aware of the sad news of the recent deaths of three prominent members of the QRA, Sir Professor Nick Shackleton, Dr. John Wymer and Professor David Keen. Not only did all three make significant contributions to science, but they were instrumental in their own ways in strengthening and integrating the UK Quaternary research community. Their interests were wide-ranging, inclusive and progressive. Their contributions at science meetings, whether indoors or out, were always lively and stimulating. Each exuded a spirit of approachability and conviviality that is very much in keeping with the QRA and its events. They will be sorely missed, by many. Obituaries will already have been published by the time this Newsletter is circulated. Hence, rather than repeating what has already been adequately summarised elsewhere, it is planned that future copies of the Newsletter will carry extended and separate articles which will recall their individual characters, as well as their contributions to Quaternary science.

Honorary Members

The nominations of three new Honorary members of the QRA were reported to, and approved at, the AGM of the QRA held in Cheddar in April, 2006. Honorary status is bestowed on all three in recognition of, and indeed salute to, their individual contributions to the continued success and development of the QRA, as well as to Quaternary science more generally.

Professor David Keen

It was cruel indeed that David died before he could enjoy, at length, the status of Honorary membership. I well recall the day I telephoned him to seek his approval for nomination. A Shakespearian actor could not have bettered his robust rendition (several times) of the word 'chuffed', during a warm and ebullient reaction. I have rarely felt so rewarded in the role of harbinger. There is comfort to be gained from the knowledge that David clearly viewed this invitation as a major accolade bestowed by his peers. Members will be aware of David's many publications on the Quaternary of several parts of the British Isles, but probably he is most often connected with progress in understanding of Quaternary events and stratigraphical details in the English Channel area and in the English Midlands. He was, of course, one of the UK's leading experts in Quaternary molluscan stratigraphy, and those who knew him well

will remember his unswerving dedication to all things malacological. David was Editor of the *Quaternary Newsletter* from 1981 to 1985, Secretary of the association from 1986 to 1990 and President of the association from 2002 to 2005. He was a regular participant in QRA field and conference meetings, and indeed organised, or co-organised, a number of them.

Professor Jan Mangerud

The QRA is blessed with a number of very active and influential overseas members who not only bring additional prestige to the association, but who provide external links and views that are greatly valued. Jan Mangerud has been a member of the association since the 1970's; he has attended a number of the association's field and discussion meetings, occasionally as a guest of honour/invited speaker. Jan is one of the leading Scandinavian Quaternary geologists of recent times, his name being recognised globally within the geology community. Based at the University of Bergen, Norway, since 1967, he was made full Professor there in 1977, and has served that august institution throughout his impressive research and teaching career. He has published extensively on many aspects of the Quaternary geology of Scandinavia and Greenland and adjacent seas, and is a member of several editorial boards of the top 'Quaternary' journals. He remains extremely active in research, having recently commenced some new projects based in Russia. He was elected as Fellow to the Royal Norwegian Society of Sciences and Letters in 1987, to the Norwegian Academy of Science and Letters in 1992, and to the Royal Academy of Science, Medicine and Technology (Sweden) in 1996. He was awarded the Reusch medal of the Norwegian Geological Society in 1971 and the Fram Committee Nansen Award for Polar Research in 1995.

Dr. Peter Allen

Peter Allen has published extensively on the Quaternary geology of East Anglia and the Lower Thames for more than three decades. During that time he has also been a stalwart and effective supporter of the QRA, selflessly giving up much of his time to the preparation and organisation of a considerable number of field meetings - unsurprisingly based mainly in East Anglia and the Lower Thames. He has contributed to, and co-edited, a number of the association's Field Guides. More recently he has made vital contributions to the recording of important Quaternary sites for the comprehensive Geological Conservation Review series, and is lead editor on a GCR volume dedicated to the Quaternary of East Anglia and The Midlands, which is due for imminent publication. Peter also served as a member of the QRA Executive Committee from 1995 to 1998 and as Treasurer of the association between 2000 and 2005. Among his

trade-mark assets count indefatigable *bonhomie* and a sharply humorous wit, maintained in fair weather and foul, which make him a welcome participant in the association's activities.

It is an honour and a pleasure to formally record the induction forthwith of all three to Honorary Membership of the Quaternary Research Association.

The timing of the QRA Annual General Meetings

The issue of the timing of, and attendance at, the association's AGMs has been discussed several times before, but is being raised again due to the dwindling attendances in recent years. The matter was brought into sharp relief by the attendance at this year's Cheddar AGM, which was attended by 17 persons, most of whom were members of the Executive Committee, and a few of whom (I am reliably informed) were not even members of the association! Clearly, this is an unsatisfactory state of affairs, and, as reported in the latest Circular, the Executive Committee considers that change is required.

A proposal made on previous occasions, that the AGM should be scheduled to take place during, or immediately adjacent to, the January Annual Discussion Meeting, is therefore being re-visited. The rationale for this is that there are normally around, or in excess of, 100 attendees at the ADMs, the majority of whom are QRA members. There is also a developing aspiration within the Executive that the ADMs should always address highly topical and important Quaternary matters and be based in accessible, major centres, so that a robust attendance is always guaranteed. In this way, we hope to maintain, and even surpass, the attendance records of recent ADMs. This raises questions about the scheduling of the AGMs within or around the ADMs, but the Executive does not consider this to raise insurmountable difficulty.

A formal proposal will be framed in time for presentation at the Spring AGM in 2007, with a view to instigating this change from January 2008 (when the ADM will be based at the RGS in London), if approved by majority vote. This notice is being brought to the attention of all members at the earliest possible time in order that the matter may receive the full scrutiny it warrants. The views of members are invited, and may be sent to the Secretary, or direct to me. If substantial objections are raised, these will be publicised in advance of the AGM, for open debate.

John Lowe
President, QRA
Royal Holloway
University of London

THE LEWIS PENNY MEDAL

THE 2005 LEWIS PENNY MEDAL

We are delighted to announce that the second Lewis Penny medal has been awarded to Dr Colm Ó Cofaigh of Durham University. Colm was presented with the medal and £100 prize money by the past President of the QRA, Professor David Keen, at the Annual General Meeting on April 7th at the Imperial Hotel in Galway, Ireland.

The offering of this medal, in remembrance of Lewis's contributions to Quaternary Science and his support of the QRA, was made possible through the generosity of many of Lewis's former students, friends and colleagues. The prize is intended to reward a young or new research worker who has made a significant contribution to the Quaternary Stratigraphy of the British Isles and its maritime environment, including adjacent areas of continental Europe that have relevance to the British Isles.

Colm graduated with a BA and an MSc from Trinity College Dublin (1991), before undertaking a PhD on Late Quaternary glaciation and sea level history of western Ellesmere Island at the University of Alberta in Canada. He is currently a member of the Quaternary Environmental Change research group and lecturer in the Department of Geography, Durham University. His research focuses on a wide range of aspects relating to Quaternary glacial depositional environments and ice sheet history in both polar and mid-latitude areas. His work in Britain and Ireland has focused on the sediments and landforms of the Last Glacial Maximum around the terrestrial margins of the Irish and Celtic seas, drawing together intensive sedimentological and stratigraphical investigations into the Irish Sea Till and associated sediments on the Irish coast. This has enabled the testing of reconstructions that depict LGM ice as far south as the Isles of Scilly and has called into question both the concept of an ice-free enclave in southern Ireland at this time and the status of the South Irish End Moraine. Further details of Colm's research and future objectives are given in his viewpoint article below.

**Danielle Schreve
QRA Awards Officer
Royal Holloway
UK**

LATE QUATERNARY GLACIATION OF SOUTHERN IRELAND AND THE CELTIC SEA

Colm Ó Cofaigh (Durham University)

Introduction and Rationale

Around the terrestrial margins of the Irish and Celtic seas, sedimentologically heterogeneous glacigenic deposits – the *Irish Sea Drifts* – deposited by the Irish Sea Ice Stream, have been a focus of investigation by glacial geologists since the nineteenth century (e.g. Darwin, 1842; Lamplugh, 1903; Wright and Muff, 1904; Eyles and McCabe, 1989; McCarroll, 2001). Within the Irish Sea Drifts, the term *Irish Sea Till* has been used to describe matrix-rich diamicts containing marine micro- and macrofauna. In the absence of ice-marginal landforms, the Irish Sea drifts have been used to demarcate the extent of the Irish Sea Ice Stream along the coasts of Wales, Ireland and the Scilly Isles. Along the south coast of Ireland, Irish Sea Till crops out discontinuously westward to Cork Harbour, and comprises a fine-grained diamict facies containing erratics of northern Irish Sea Basin provenance, including flint and Ailsa-Craig micro-granite, as well as shell fragments and foraminifera. Interpretations of the age of the south coast sequence range from Late Midlandian (Devensian) (Warren, 1985; Gallagher and Thorp, 1997; McCabe, 1999), through to mid-Midlandian (Bowen *et al.*, 2002) to Anglian (Mitchell *et al.*, 1973; Synge, 1981; McCabe, 1987).

Since the publication of a paper by Eyles and McCabe (1989) that advocated a glacimarine origin for the Irish Sea Drifts, the genesis of these sediments has been a major source of debate (e.g. McCarroll and Harris, 1992; Van der Meer *et al.*, 1994; McCarroll, 2001). Traditionally, along the south coast of Ireland, the Irish Sea Till and overlying glacigenic sediments have been interpreted as terrestrial tills (e.g. Wright and Muff, 1904; Synge, 1981; Warren, 1985). However, Eyles and McCabe argued that the Irish Sea Till was in fact a distal glacimarine mud deposited by suspension settling from meltwater plumes and iceberg rafting. A difficulty with much of the previous work on the south coast has been that sedimentological investigations of the Irish Sea Till have tended to be very limited and typically of a reconnaissance nature. Indeed much of this previous research has concentrated on the stratigraphic correlation of the diamict units based on erratic content and reconstruction of former ice limits, rather than detailed, sedimentologically-based, reconstructions of the depositional environment. Resolution of this debate is important because conflicting interpretations of the Irish Sea Till in southern Ireland and the Celtic Sea have different implications for the southward extent of the Irish Sea Ice Stream which, in turn, is a key input to models of the last British-Irish

Ice Sheet and its associated relative sea-level fluctuations. Previous modelling reconstructions of the last British-Irish Ice Sheet show southern Ireland lying outside the maximum ice limit (e.g. Lambeck, 1996) and thus imply a more restricted glacier extent in the Celtic Sea during the last glaciation. The validity of these reconstructions rests largely on the genesis and age of the Irish Sea Till.

In an attempt to resolve this debate for the sequences along the south and south-east coasts of Ireland, sedimentological examination of coastal outcrops of Irish Sea Drift was carried out. The principal aims of the research were firstly to determine the depositional origin of the Irish Sea Drifts, and in particular the Irish Sea Till, in this region, and secondly to determine the timing of the ice advance which deposited the Irish Sea Till and overlying sediments along the south coast of Ireland.

Research Findings

The major results from this research have been:

- Late Quaternary glacial sediment sequences along the south coast of Ireland between Cork Harbour and the Screen Hills in County Wexford preserve evidence for the onshore advance of a grounded Irish Sea Ice Stream which cannibalised pre-existing marine sediments and re-deposited them onshore as deformation till (Ó Cofaigh and Evans, 2001a and b). Subsequent recession of the Irish Sea Ice Stream allowed the damming of ice-marginal lakes in embayments along the coast, into which glacial lacustrine sediments were deposited. This was followed by an advance of glacier ice of inland origin over these lake sediments, which glacially tectonised them and deposited deformation till over the top of the sequence.
- There is no supporting sedimentary evidence for deposition of the Irish Sea Till by glacial marine suspension settling and iceberg rafting between Cork Harbour and County Wexford. Neither is there any *in-situ* marine macrofauna that might support such an interpretation.
- Fast flow of the Irish Sea Ice Stream into the Celtic Sea was achieved by deformation of its bed. This reflects the abundance of deformable marine mud and glacial lake deposits over which the Irish Sea Ice Stream and local glaciers advanced. Such sediments were fine grained and probably saturated, and hence would have been easily deformed, eroded, and transported, thereby facilitating the development of deforming bed conditions (cf. Boulton and Jones, 1979; Alley *et al.*, 1986; Alley, 1991). However, subglacial sediment deformation was not pervasive as indicated by the presence of intact rafts of marine sediment within the Irish Sea Till (Ó Cofaigh and Evans, 2001b).

- Advance of a grounded Irish Sea Ice Stream along the south coast of Ireland appears to have occurred late in the last glacial cycle, and this is supported regionally by offshore marine geological evidence (Scourse *et al.*, 1990, 2000). This indicates extension of Late Midlandian/Devensian glacial ice beyond its traditional limits in the Celtic Sea and the South Irish End Moraine, and removes the stratigraphic basis for the Munsterian Glaciation as well as differentiation of surficial glacial drifts in southern Ireland (Ó Cofaigh and Evans, 2001a and b).
- Deposition of the Screen Hills complex along the coast of County Wexford was at least a partial response to ice marginal stabilisation as the Irish Sea Ice Stream retreated northwards from the Celtic Sea into the narrow corridor between Pembrokeshire and southeast Wexford. The complex sequences of multiple tills and glaciectonised stratified sediments, thrust block moraines/thrust ice-contact fans, pitted outwash and hydrofracture fills of the Screen Hills are, in combination, strongly indicative of a very dynamic ice stream margin (Thomas and Summers, 1983; Evans and Ó Cofaigh, 2003).
- The evidence for a dynamic and possibly short-lived advance of the Irish Sea Ice Stream into the Celtic Sea, late in the last glacial cycle, suggests that its rapid flow may have been a relatively transient feature during, or immediately prior to, deglaciation. In combination with evidence from other documented palaeo-ice streams for rapid flow switching and short-lived streaming events immediately preceding, as well as during, deglaciation (e.g. Ó Cofaigh *et al.*, 2005; Evans *et al.*, 2005; Stokes *et al.*, 2005) this suggests that ice streams are not necessarily steady-state features of full glacial ice sheets but rather may “switch on and off” rapidly towards the close of a glacial cycle.

Future Research

Research on the genesis of the Irish Sea Drifts and the Late Quaternary glacial history of southern and south-west Ireland is continuing. Specifically this research focuses on the following themes:

- Micromorphological investigation of the genesis of the Irish Sea Till from northeast Ireland southwards to Ballycroneen, County Cork (the southern limit of the Irish Sea Till in the Celtic Sea). The aim is to produce the most comprehensive micromorphological study of the Irish Sea Till to date and to further constrain its depositional origin.
- Bulk samples of the Irish Sea Till have been collected for geotechnical testing. These samples were collected where sedimentological evidence indicates a subglacial deformational origin for the till (e.g. Screen Hills,

County Wexford; Whiting Bay, County Waterford) and geotechnical testing will focus on determining the till rheology (i.e. viscous vs. plastic). This is currently a major research question in investigations of modern and palaeo-ice stream tills (e.g. Iverson *et al.*, 1998; Kamb, 2001; Bennett, 2003; Ó Cofaigh *et al.*, 2005) and the Irish Sea Till provides an excellent test in this regard.

- A persistent problem in investigations of Quaternary stratigraphy and glaciation in southern Ireland and the Celtic Sea has been the lack of absolute dating control. On-going research is attempting to constrain the timing of the advance of the Irish Sea Ice Stream into the Celtic Sea through radiocarbon and OSL dating.
- Investigations of glacial sedimentology and stratigraphy in County Kerry to test the traditional interpretation that this region supported a separate ice cap during the last (Late Midlandian) glaciation in Ireland (e.g. Synge, 1981).

Acknowledgements

I would like to sincerely thank the QRA for bestowing upon me the honour of the Lewis Penny Medal for my research.

I would like to particularly acknowledge the contribution of Dr. David J.A. Evans with whom much of this research has been carried out. I also thank my colleagues Dr. John Hiemstra (Swansea), Professor Pete Coxon (Trinity) and Professor Marshall McCabe (Ulster) who have contributed to this research in various ways over the years.

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THE EARLY PLEISTOCENE MODIFICATION OF THE REMNANTS OF THE TERTIARY DRAINAGE SYSTEM IN NORTHAMPTONSHIRE, U.K.

R.K.Belshaw, K.A.Smith and G.D.Hackney

Introduction

Very large quantities of sand and gravel of the Tertiary Milton Formation are preserved in the palaeovalleys of the Milton and Brigstock Rivers in Northamptonshire (Belshaw *et al.*, 2004, 2005). Two factors probably account for this preservation. Firstly, the development of the proto-Soar valley, south-westward along the strike of the clays exposed to the north west of the Northamptonshire Ironstone, captured the headwaters of the rivers (Rose *et al.*, 2002; Belshaw *et al.*, 2004, 2005) in the Late Pliocene to leave a low-gradient misfit stream network with a greatly reduced discharge below the Watford Gap on the dip slope of the Northamptonshire escarpment. Too little energy would have been available for fluvial processes to remove much of these sands and gravels. Secondly, the drainage in the Milton valley suffered substantial re-alignment from the Early Pleistocene due to fault-associated periglacial activity, leaving the main body of the Milton Formation on a bench south of the present valley of the Nene. The preservation is significant because the post-capture remains of the Pliocene Milton Formation are immediately capped by late Middle Pleistocene tills. There is no evidence for any intervening sedimentary input into the area for well over a million years. This paper focuses on the processes involved in the abandonment of the Milton valley in favour of the present course of the Nene through Northampton, and the Early and early Middle Pleistocene development of drainage within Northamptonshire. The implications of this are examined for the proposed course for the late Tertiary Letchworth River (Smith and Rose, 1997; Boreham and Langford, 2006).

The formation of the course of the River Nene through Northampton

The present Nene turns away from its former northwest–southeast Milton River course at Weedon (SP6259) to flow due east, cutting through high ground at Northampton into a wide basin that extends to Wellingborough (SP9066). This part of the new course is known to coincide with the line of the Northampton Fault. Faults in the Northamptonshire Ironstone Field are associated with valley bulging and plateau-edge cambering, and gulling (Hollingworth *et al.*, 1944; Hollingworth and Taylor, 1951). Deformation of clays by these processes to

depths in excess of 50 m is recorded. The typical cross-sections of cambering and valley bulging (Hollingworth *et al.*, 1944) imply a considerable loss of clay from the area.

The Northampton Fault, a complex of fractures, also coincides with a tunnel valley (Early, 1956; Horton, 1970). The term “tunnel valley” covers a wide variety of morphologies and sedimentary contents in eastern England, including sub-glacial melt-water channels with pipe flow deposits (Cornwell and Carruthers, 1986), subaerial valleys with fluvial deposits (Cox, 1985) and glacially eroded valleys containing glacial and fluvial deposits (Horton, 1970; Woodland, 1970). An analysis of site investigation borehole records held by the Northamptonshire County Council by Manning (1989) showed that the Northampton tunnel valley is strongly linear in plan, unlike other examples. It is a shallow trough over 14 Km in length with sub-parallel sides about 1 Km apart while the floor appears to be flat at about 30 to 40 m AOD (15 to 20 m below the current valley floor). The sides are very steep, exceeding 45 degrees in places. A network of very close cores extracted in the late 1980s for the Bedford Road flyover just east of Northampton (SP7759) showed small cusp-shaped landslip scars along the north edge. Using information from early boreholes, Horton’s sections through the tunnel valley (1970, figures 3 and 4) show the channel filled with finely laminated lacustrine calcareous silts overlying thick un-bottomed Chalky Till. However, later more detailed borehole investigations showed that the underlying clay was Lias clay rather than Chalky Till (Manning, 1989). Lenses of diamicton and sands and gravels occur very irregularly in the lacustrine silts. There is a surface layer of late Middle and Late Pleistocene fluvial sands and gravels and floodplain silts (the Nene Valley Formation), usually 2 to 3 m thick, but locally thicker, which extends onto the wider valley floor on either side of the tunnel valley, masking the presence of the feature (Figure 1).

Hollingworth (in a written comment in Early, 1956) pointed out that the coincidence of the tunnel valley with the Northampton Fault was significant. The downthrow to the north brings the Middle Lias Marlstone Rock Bed against the Middle Lias Silt and Clay, and the Lower Lias Clay at about the altitude of the base of the tunnel valley. The Marlstone Rock is a very productive aquifer while the silts and clays are impermeable but highly frost-susceptible. This combination would have produced massive linear ground ice features (open system pingos) along the faults in each cold stage and a string of deep elongated thaw lakes at the beginning of each warm one. The lower base-level provided by the thaw lakes would have drained the Milton Formation at Weedon along the line of the faults through the former high ground to the north of Hunsbury Hill to the Bozeat Gap, so initiating in the Early Pleistocene the present course of the Nene through Northampton. Deep open water allowed the land-slipping of the very steep lake sides which would have been followed by infilling with

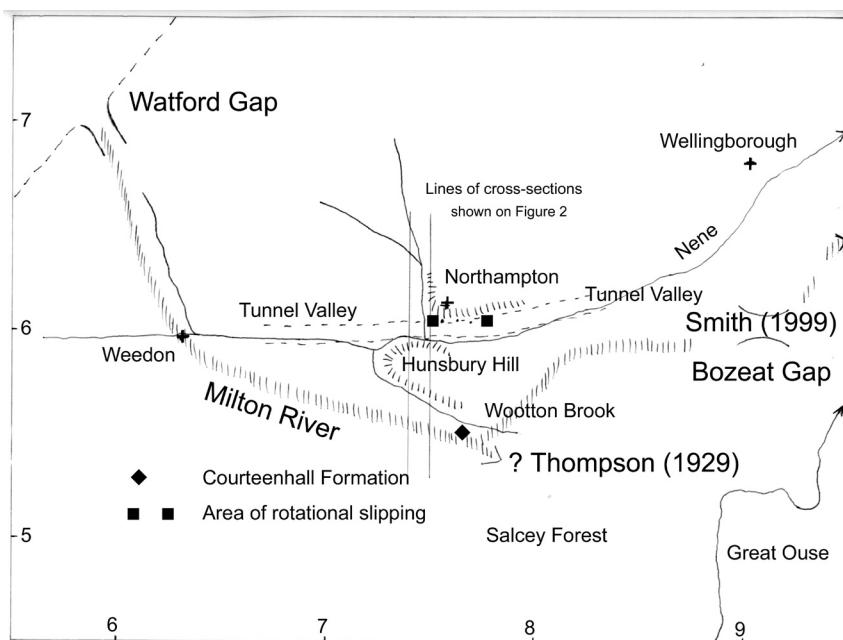


Figure 1. The Milton River and the Northampton Tunnel Valley

clays derived from the Middle and Lower Lias. It is very unlikely that clastic material moved far along the valley due to the lakes until the advent of ice in the late Middle Pleistocene.

The base of the tunnel valley is 30 to 40 m lower than the surface of the late Tertiary landscape as defined by the Milton Formation, causing structural instability on the north side of the narrow part of the Nene valley through Northampton from Bridge Street (SP754600) to the west end of Midsummer Meadow (SP763601). The ground under Derngate and the General Hospital has suffered large-scale rotational slipping (Thompson, 1896) with blocks of Lias clays overstepping the floodplain gravels in the vicinity of St John's multi-story car park and just to the south of the Cripps Medical Centre in the grounds of the hospital.

The over-deepening of the valley floor in the early Quaternary may account for the lack of clearly defined terraces in the late Quaternary in the wide valley between Northampton and Wellingborough (Castleden, 1976; Smith, 1999) when compared with the classic post-Anglian suites seen between Wellingborough

course due to the lowering of base level to the west of Hunsbury Hill. As a till immediately overlies the Cromerian deposits the diversion of the Milton River to form the Nene from Weedon to Wellingborough must have been completed by the time of the first glaciation of this area (Figure 2).

The occasional lenses of till and gravels in the tunnel valley fill would have been deposited as glacial activity in the area brought the cyclical pattern of deep permafrost and thaw to a close. The Bozeat Gap was filled with drift during the Anglian glaciation and ceased to be a focus of drainage for the area from that time (Smith, 1999) (Table 1).

The formation of Harper's Brook from the Brigstock River

The Milton Formation at Brigstock, to the north, overlies the complex pattern of minor faults in the Jurassic strata associated with the Stanion-Aldwinckle Trough, which generally parallel the lines of drainage (Hackney, 1989). The lack of a powerful aquifer produced a much less dramatic modification of the drainage pattern, but an irregular course has been cut a short distance to the southwest of the line of the Brigstock River through the Milton Formation into the underlying rocks to establish the narrow valley of the present day Harper's Brook (Figure 3). The extensive till sheets have assisted in the preservation of the Milton Formation in this area.

Relationship of the developments in the Northampton area to the surrounding areas

Due to the isolation of the Northampton area from late Tertiary through to late Middle Pleistocene times it is difficult to fit the pattern of drainage development in Northamptonshire to the models for the surrounding areas. This difficulty will be explored in a forthcoming paper. Here, however, it is necessary to assess any evidence in Northamptonshire for the Letchworth River, which was postulated by Smith and Rose (1997) to have crossed this area to account for Triassic material and weathered flint (but little Carboniferous chert) immediately upstream of the Hitchin Gap. They realised that the Jurassic Escarpment, once it was formed by the excavation of the valley of the proto-Soar, would have precluded fluvial transport of such material from a source in the West Midlands across Northamptonshire to Letchworth, so they proposed that an early Letchworth River crossed the area to the north of Northampton prior to the formation of the Jurassic Escarpment and the beheading of the Milton River, and that the gravels were later re-worked to form a terrace at Letchworth contemporary with the Westmill Lower Gravel and the Lower St Osyth Gravel immediately before the Anglian glaciation. However, the Milton Formation shows evidence for the transport of only Triassic sand, not pebbles, suggesting that the proto-Soar beheaded the Milton River in the late Tertiary

before the change in environmental conditions that initiated the movement of clasts in the region. If a Letchworth River had existed at such a time in Northamptonshire it is very unlikely that it was able to move pebbles while immediately adjacent rivers moved only sand. This supports the conclusion of Boreham and Langford (2006) that the most probable source of the clasts in the gravels at Letchworth was the Lower Till that affected the Northampton area in early Anglian or immediately pre-Anglian times (Figure 3).

Timing	Event	Evidence
Tertiary	Milton and Brigstock Rivers	Mapping and characteristics of

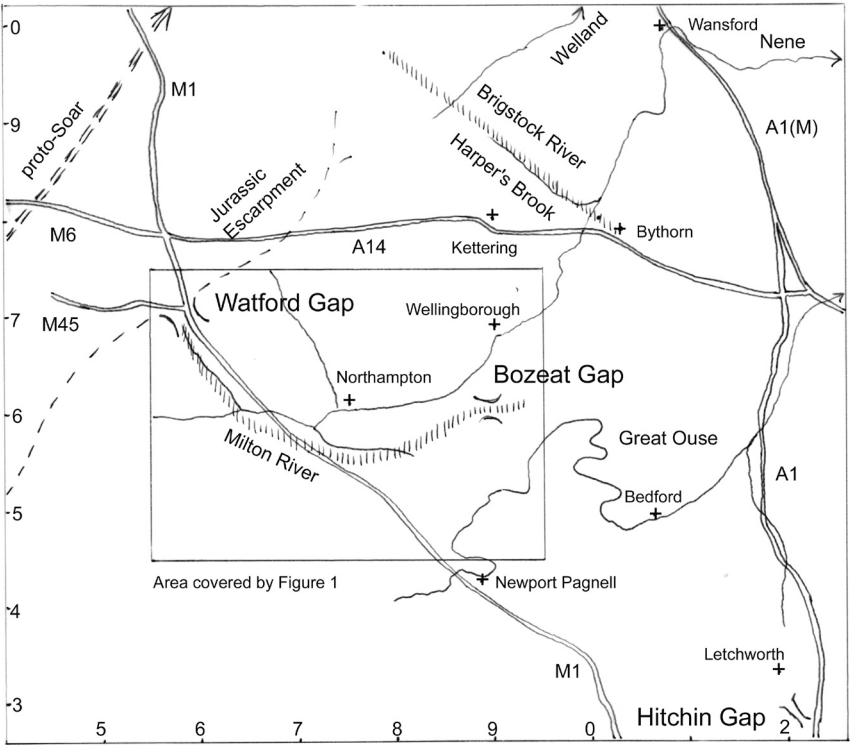


Figure 3. The location of the main bodies of the Milton formation relative to Letchworth and the Hitchin Gap.

	deposit the Milton Formation	the Milton Formation deposits Belshaw <i>et al.</i> (2004, 2005) Smith (1999)
Late Pliocene	Capture of headwaters by proto-Soar	Belshaw <i>et al.</i> (2004, 2005)
Early Pleistocene	Periglacial activity forms 'tunnel valley' through Northampton, diverting Milton River	Morphology of 'tunnel valley' and sedimentology of infill, Manning (1989)
Cromerian	Reworking of Milton Formation into Courteenhall Formation in the Woodstock Brook	Fossil evidence for timing – Smith <i>et al.</i> (2000)
First Ice Sheets (Anglian?)	Burial of Milton Formation and Bozeat Gap	Tills overlying Milton and Courteenhall Formations

Table 1. Outline of events affecting the Northampton area from the Tertiary to the Middle Pleistocene.

Conclusions

Disruption of the course of the Milton River was effected by deep periglacial activity in the long succession of brief but intense cold periods of the Early and early Middle Pleistocene that produced cambering and valley-bulging in the Jurassic rocks of the region. This was particularly effective along the line of the Northampton Fault where the Marlstone Rock is a productive aquifer and Lias clays are highly frost-susceptible. Extensive ground ice would have disaggregated the Lias clays, leaving a string of deep thaw lakes, which would have restricted the movement of clastic material along the valley.

Thaw water draining eastwards through the Bozeat Gap removed suspended silt, lowering the surface of the Nene valley floor to about 20 m below the surface of the Milton Formation. The adjustment of drainage to this new base level created the obsequent Wootton Brook. Reworking of the Milton Formation during the Cromerian into the valley of the Wootton Brook produced the Courteenhall Formation.

The tills overlying the Courteenhall Formation indicate that this new drainage pattern was well established by the arrival of the first ice sheets in the area. There is no evidence in Northamptonshire for the proposed Letchworth River.

Acknowledgements

As with Belshaw *et al.* (2005) this synthesis depends on the work of students

and staff of Nene College/Northampton University College through the 1980s into the 1990s and the encouragement of external examiners. The constructive comments of the two reviewers are gratefully acknowledged.

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ERRATUM

Hoare, P.G., Larkin, N.R. and Connell, E.R. (2006)

The first appearance of Norwegian indicator erratics in the glacial succession of northeast Norfolk, eastern England, UK. *Quaternary Newsletter*, 108, 6–13

Unfortunately, the wrong image was reproduced as Figure 1 in the paper detailed above. The correct picture is shown on the front cover. It is a rhomb porphyry erratic found by Harmer (1910, 111) in the ‘North Sea Drift’ at Catton brickyard (TG 233130), near Norwich, in 1909 (Norwich Castle Museum Accession Number NWHCM : 1909.36). The specimen measures ~210 x 210 x 80 mm. It is held, together with the greater part of the Norwich Castle Museum’s glacial erratic archive, in temporary accommodation at the Norfolk Rural Life Museum, Gressenhall.

The photograph that was mistakenly reproduced as Figure 1 in Hoare *et al.* (2006) has been published elsewhere (Hoare and Connell, 2005, figure 1). It is of a striated rhomb porphyry clast found in the Happisburgh Till Member at Happisburgh (TG 387307) on 1 August 2004 (Norwich Castle Museum Accession Number NWHCM : 2005.500). One particularly prominent rhombic phenocryst has an apparent *a*-axis length of 14 mm.

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COMMENT

A REPLY TO HOARE *ET AL.* 2006 - “THE FIRST APPEARANCE OF NORWEGIAN INDICATOR ERRATICS IN THE GLACIAL SUCCESSION OF NORTHEAST NORFOLK, EASTERN ENGLAND, UK”

J.R. Lee, B.S.P. Moorlock, J. Rose, R.J.O. Hamblin, S.M. Pawley, and
A.M. Jarrow

Following the recent publication by Hoare *et al.* in *Quaternary Newsletter* 108 we are responding to some of the issues that they have raised, despite the fact that these have already been debated, following a similar letter to the *Bulletin of the Geological Society of Norfolk* (Hoare and Connell, 2005a,b; Lee *et al.*, 2005). Our primary reason for replying is because, as in our earlier response, we feel that our own work and that of others has been either mis-understood, or mis-quoted.

1. Citing of previous literature

On p.8, Hoare *et al.* (2006) state that Buckland (1823) “...was the first to suggest that erratics from Norwegian bedrock sources were to be found in this deposit [the Happisburgh Till]...”. In fact, although Buckland (1823) recognised the presence of Norwegian erratics in eastern England, at no point within the text did Buckland state that he found Norwegian erratic clasts within the deposit now known as Happisburgh Till – basal till member of the Happisburgh Formation (previously First Cromer Till or Happisburgh Diamicton of the North Sea Drift). We pointed out this error in our previous response. Continued citing of Buckland is erroneous and scientifically misleading.

2. Our research rationale

Hoare *et al.* (2006, p.8) accuse us of “...rejecting the claims of others...” regarding the historical reporting of *in situ* finds of Norwegian indicator erratics such as rhomb porphyry and larvikite within the tills of northeast Norfolk. However, as stated earlier in Lee *et al.* (2005) following a similar accusation by Hoare and Connell (2005a), our rejection of many of these claims was based upon our own field experiences, a thorough and detailed evaluation of the literature, and a desire to follow correct scientific practices.

Like many others before us, we initially accepted without question that Norwegian erratics are to be found in the tills of northeastern Norfolk, and that these tills were deposited by Scandinavian ice. However, contrary to Gibbard and Ehlers (1991, p.18) who stated that "...[rhomb porphyry and larvikite]...are found at all exposures of the North Sea Drift Cromer Tills...", our own field observations failed to yield any *in situ* finds of such erratics within the tills of northeast Norfolk. Upon evaluation of the literature, we identified that many papers were review-style papers merely reporting the findings of others, whilst many of those that actually reported finds, neither identified specific geographic sites or stratigraphic levels where *in situ* Norwegian erratics had been discovered. In addition, where several papers reported the same find, there were frequent inconsistencies regarding the stratigraphic position of the erratic. For example, Hoare and Connell (2005b, p.53) cite Harmer (1904) who reported a rhomb porphyry from the 'North Sea Drift' from a brickyard at Hellesdon, Norwich, yet the same rhomb porphyry clast was reported to have come from a stratigraphically higher unit, the 'chalky boulder clay' (now known as the Lowestoft Till), by both Kendall (1904) and Phemister (1926).

As a consequence of these ambiguities, a short letter was published in *Quaternary Newsletter* (Moorlock *et al.*, 2001), not with any intention to deny the presence of these erratics in northern East Anglia, as Hoare *et al.* (2006, p.8) suggest, but rather to encourage anyone who had positively identified these erratics within the tills of northeast Norfolk to make their discovery known. Unfortunately, the letter did not elicit a single positive reply, but we did receive several negative responses. So for reasons of good scientific practice, we set-out to test whether the widely accepted concept that these deposits were Scandinavian was valid by examining the lithology and provenance of the Happisburgh Formation tills (Lee *et al.*, 2005).

3. Identification of erratic lithologies

As Hoare *et al.* (2006) correctly point-out, the identification of erratic lithologies can be problematic due to the issue of clast size, and the size of mineral grains within the clast. For rhomb porphyries, individual phenocrysts may be >42mm in length as Hoare *et al.* suggest. However, our own experience based on fieldwork examining these rocks both in their derived UK context and at outcrop in southern Norway, indicates that this represents the maximum end of the size range and that phenocrysts are typically much smaller than this as recently published photographs suggest (Hoare and Connell, 2005a, Fig.1; Hoare *et al.*, 2006, Fig. 3; Erratum this issue, cover photo)

Hoare and Connell (2005a) and Hoare *et al.* (2006) make the suggestion that clasts of rhomb porphyry will not be found in the size range that we have studied, but only in larger sizes that we have not quantified. We consider this

suggestion to be invalid as clasts can be broken-up into progressively smaller fractions by a variety of geological processes, and this is especially likely in northeast Norfolk where clasts will have been through a complex multi-phase transportation history. In support of this, we have identified a variety of different types of porphyry from Scotland, and individual types frequently occur both within our quantitative counts and as larger cobbles and boulders (Lee *et al.*, 2002, 2004).

Our quantitative clasts counts were undertaken on the 4-8mm and 8-16mm size fractions, whilst individual clasts of ≥ 16 mm diameter that were collected as part of the sampling process, together with *in situ* erratics collected from field exposures, were also examined and identified (Lee, 2003; Lee *et al.*, 2002, 2005).

4. Our research findings

Within Lee *et al.* (2002), and reported in subsequent papers (Lee, 2005; Lee *et al.*, 2004), our purpose was not to deny the existence of Norwegian indicators within the Happisburgh Till as Hoare *et al.* (2006, p.8) incorrectly claim, rather to demonstrate unequivocally that the Happisburgh and Corton tills of the Happisburgh Formation were deposited by British rather than Scandinavian ice. In total, we counted 4429 clasts between 4mm and 16mm (Lee *et al.*, 2002), and over 500 erratics collected within the sampling process and from field exposures and found no Norwegian indicator erratics.

Using the clast data in combination with derived palynomorphs, we were however able to trace the flow of the British Ice Sheet over successive geological strata from central Scotland to northern East Anglia via the east coast of England (Lee *et al.*, 2002). Critical to this interpretation was the presence of several key lithologies, including Carboniferous coal and limestone, and Magnesian Limestone, that are unique to the UK and could not have been derived from Scandinavia.

Since the publication of Lee *et al.* (2002), four *in situ* Norwegian erratics have been reported and verified from the Happisburgh Formation – namely single clasts of larvikite and Drammensgranit (Lee *et al.*, 2005), and two clasts of rhomb porphyry (Hoare and Connell, 2005a,b). These erratics do not invalidate our interpretation of these deposits being British in origin as Hoare & Connell (2005a) agree, rather they suggest deposition by an earlier Scandinavian glaciation of the North Sea, and their subsequent reworking by British ice. These new discoveries do demonstrate the presence of the Scandinavian sourced material, but they do not disprove the extreme rarity

of such material.

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REPORTS

THE QUATERNARY OF SOMERSET JOINT INQUA/QRA ANNUAL FIELD MEETING 2nd – 7th April 2006

Introduction

Sunday 2nd April

The field meeting commenced in the comfortable surroundings of the Bath Arms Hotel in Cheddar on Sunday evening with a short introduction to the Pleistocene and Holocene of the area by **Dr Chris Hunt** (QUB) and **Prof. Simon Haslett** (Bath Spa). The areas covered by the trip include the Somerset levels, the Mendip Hills, the Bristol District and the Avon Valley. There is unique evidence of Quaternary environmental change including evidence of ancient glaciation, sea level variation and cold-stage extra glacial environments but the varying underlying geology and topography gives rise to a complex Quaternary record. Attention was drawn to the cave deposits from the Early Middle Pleistocene of the Mendip and the Kenn Lowlands where glacial deposits underlie interglacial deposits. Important themes for the area include;

1. Evidence of early glaciation with its limits and timing
2. Evidence for high Pleistocene sea levels
3. The terrace stratigraphy
4. Cold stage sedimentation and palaeobiology

The Holocene record includes extensive marine silts and clays and peats of the Somerset levels, fragmentary tufa deposits associated with the Mendip, soils and alluvium in small river valleys and coastal deposits. Quaternary research here has a long history of over 200 years beginning with Smith (1815) who identified the alluvial origin of the Avon levels. More recently a complex history of sea level changes has been recorded on the coasts of Avon and Somerset, the great antiquity of the glaciation (possibly Oxygen Isotope Stage 15), has emerged and the high quality records of cold stage non-glacial environments have been recognised.

Monday 3rd April

We were blessed with cloudless blue skies, spring lambs and flowery hedgerows, which made our first foray into the Somerset countryside an extremely pleasant one. Our first port of call was the raised beach at Swallow Cliff (Figure 1), **Chris Hunt** (QUB) described the development of this 2.6m deep deposit which caps a wave cut platform of Carboniferous rock. This feature is of possible Ipswichian date the exact age remains ambiguous, sea level at the time of deposition is thought to have been five metres higher than those of today. Our second stop of the day was at a deposit of ‘enigmatic’ gravels, which consist of a series of deposits dominated by limestone cobbles, 2m deep that cling to the side of Bleadon Hill. **Chris Hunt** led the discussion, which focused on the depositional regime, theories include a Mesozoic/Pleistocene sea beach, a pro-glacial lacustrine beach or glaciofluvial gravel. **Hugh Prudden** (Somerset Geology Group) suggested it is possibly a Jurassic beach deposit and **Simon Haslett** discussed the likelihood of this deposit being related to an ice-dammed lake. Whilst the depositional regime which produced this enigma remains ambiguous, it provided much interesting discussion.

The afternoon session began with **Andy Currant** (Natural History



Figure 1. The raised beach at Swallow Cliff.

returning to his undergraduate days, involving an impromptu excavation with ice-lolly sticks (!) and the Pleistocene sequence at Sand Cliff. This 'Reindeer bed' is likely to have accumulated during an episode of lower sea levels at the beginning of the Devensian glaciation. Andy drew parallels between the Sand Cliff assemblage and the Banwell Bone Cave MAZ, deposition at Brean occurring from MIS 5a – MIS 4. This Pleistocene theme continued with **Chris Hunt's** molluscan and palynological environmental reconstruction of beds 8b to 13.

The afternoon session was concluded by **Martin Bell** (Reading) and **Keith Crabtree**. Keith entertained us with the tale of how the site was originally identified by his finding of a pair of gold bracelets of Bronze Age date and the enthusiasm of a young researcher by the name of Martin Bell. Martin then presented the results of over two decades of study at the Brean Down Multi-period site, evidence of human activity at the site dates from the Bronze Age to the Romano-British Period and is related to repeated episodes of stabilisation followed by site abandonment as a result of Aeolian deposition. The earliest evidence of salt extraction in Europe was also recorded in a middle Bronze Age context at Brean Down.

The first day drew to a close and we headed back through the spring sunshine to Cheddar where we nursed our sunburn over beers and the Wigan vs. Blackburn match, which to **David Simm's** (Bath Spa) disappointment, ended in a draw after Wigan took the lead.

Tuesday 4th April

The first stop was the Wellow Brook Valley where **Paul Davies** (Bath Spa) demonstrated the presence of tufa deposits forming *in situ* beneath the surface of the fields. These deposits are formed where water becomes supersaturated with calcium carbonate before precipitation in the soil horizons. The deposits here arise from spring lines emerging from the Mendips and are thought to be continuous across the valley, varying in depth up to 5 m. Tufa formation is thought to have declined at around 4500BP due to human impact but is demonstrable in this and other sub-Mendip locations. There was some discussion as to possible dating methods for the deposits and the dome shaped layers of the formations stratigraphy. **Emma Tetlow** (Birmingham) noted that well preserved beetle fauna could be found in tufa deposits. Molluscan analysis shows that the older tufas formed under wooded conditions at around 8500BP but some later tufas indicate more open landscapes. A complete Holocene environmental signal was present. Archaeological finds associated here include Mesolithic flint work and a small ball of tufa deposited in a pit, suggesting ritual. You could say that archaeologists always claim ritual when puzzled! A second small exposure of tufa which included a large charcoal fragment was then visited. This was

located in the bank of a small river close to Priddy.

At Wookey Station an exposure of Mendip fan gravels was seen in the yard of an industrial premises. Apart from patches of planted daffodils, there was a clear sequence of about 2 metres of sandy, cobbly gravel. Many of the long axes of the clasts could be seen to be vertical. These are interpreted as alluvial fan deposits and contain molluscs typical of cold stages e.g. *Pupilla muscorum*. There is also a notable absence of terrestrial plant pollen. Clasts mainly consist of Carboniferous limestone with some Old Red Sandstone and three layers have been recorded here.

After a lunch stop at Wells, including a brief visit to the cathedral, some Spelt bread and a kitchen shop there was time for some coring at Yarberry Farm in the Lox-Yeo valley. **Simon Haslett** explained that this location is under investigation by **Huw Williams**, a PhD student, but that he was unable to attend due to illness. The site has revealed over 10 metres of peat, thought to be a continuous Holocene sequence. The site is situated within a rock-silled basin and is unusual in this area for the thickness and continuity of the peat. At other sites such as Decoy Pool farm, a more typical tripartite sequence is present consisting of lower and upper silty clays separated by the peat layer. At Brean farm, Nyland Hill, the peat layer is divided into several units. Here major effort by female QRA members extracted some 5.5m of *Sphagnum* peat complete with a Chrysomellid beetle.

Wednesday 5th April

The first stop was at Shapwick Heath and the Peat Moor Visitor centre, lead by **Richard Brunning** (Somerset County Council). At Shapwick, the presentation centred on the *in situ* preservation of the Neolithic Sweet Track, and wetland management at the site. Further discussion centred on construction and possible ritual use of the Sweet Track in juxtaposition with other later prehistoric trackways in the Somerset Levels, which appear to have been used for transit and communication purposes. We then spent some time amongst the Iron Age roundhouses and reconstructed trackways at the Peat Moors Visitor Centre.

The morning was concluded in the Brue Valley at the Glastonbury Lake Village (GLV) and lead by **Tony Brown** (Exeter). The evolution of the valley and village was discussed in some detail, beginning with the contentious chronological phasing of the GLV and problems of dating at the site. The village was constructed on alder/willow fen and is intrinsically linked to the later Holocene evolution of the Brue Valley. New evidence suggests that the village is most likely to be related to a tidal channel through the Panborough Gap, created by positive sea-level trends which remained open when sea-levels regressed and provided a link between the interior as far as Glastonbury and the coast. Abandonment of the GLV is perhaps related to hydrological changes

which made the palaeochannel impassable.

Lunch was spent at Glastonbury before heading to Nyland Hill. **Simon Haslett** presented the area at Decoy Pool Farm on the northwestern flank of Nyland Hill as the 'typesite' of the tripartite sequence in the Axe Valley. This sequence consists of a lower marine silty-clay, a middle peat unit and an upper silty clay. This sequence extends almost 18 km to the modern coastline. Simon Haslett and **Paul Davies** (Bath Spa) had extracted 11 m of deposit at the Decoy Pool Farm and to further demonstrate this tripartite sequence, Simon suggested a bit of coring. **Paul Rae**, **Chris Spencer** (UWE) and **Emma Tetlow** obliged (Figure 2). The sequence itself produced no controversy; coring techniques however, produced some of the hottest debates of the day.

Thursday 6th April

Another glorious sunny morning and we set off bright and early to our first site in the Kenn lowlands. We made our way across farm land, over Kennpier



Figure 2. Coring at Decoy Pool Farm.

where exposures were previously visible, to the floodplain, which **Chris Hunt** informed us is underlain by a tripartite sequence of interglacial marginal-marine sediments (OIS 15), glaciofluvial sands and gravels, and diamicton. As there were no sections augering was called for (again) to provide a snap-shot of the underlying sediments. Initially, we auger through alluvium before recovering, what should have been coversands, although most of the group agreed that silty sand with major gravel clasts did not constitute that interpretation, indicating some local variation. The interglacial sediments must have been very limited in extent and unfortunately, we only recovered glacial sediments much to **Chris Hunt's** disappointment. Previous work by Gilbertson and others has shown that the sediments in this area of Somerset provide an interesting insight in to previous glacial incursions. We were directed to Court Hill, a suggested melt-water channel, which was a possible source for the glaciofluvial sediments as it contained sediments with similar erratic components. In the past this site at Yew Tree Farm Kennpier has not been fully investigated but it is hoped that in future a trench may be cut to provide better access, and to understand fully the sequence. As **Chris Hunt** concluded 'this site needs re-visiting and obviously, there is more to be done'. To conclude the story, we moved on to Court Hill, located next to the busy M5 motorway. **Chris Hunt** and **Gary Rushworth** (Bradford) had cleaned up a small section next to the footpath that afforded us a view of the gravels overlain by a silty sand. Work at this site by Gilbertson in the 1970s had shown that gravel contained a number of erratics and bedforms were clearly directed towards the north. This led to the interpretation of Court Hill as an infill of glaciofluvial gravels, aggraded as ice down-wasted and meltwaters escaped along the Court Hill channel.

We moved on to the Gordano Valley to take up the story of Late Quaternary environmental change. **Tom Hill**, **Chris Spencer** and **Wendy Woodland** (UWE) introduced us to the history of the valley. The site is characterised by a major barrier feature that separates the valley floor into two distinct areas, which record a terrestrial and marine sequence. They began by unveiling the first of three type cores taken from the valley floor. This initial core was taken through the barrier itself, and there has been much discussion about the origin of the feature (Figure 3). **Tom Hill** proposed three possible interpretations, but the one favoured by the group as well as Tom was a periglacial origin. **Pete Coxon** (TCD) was quick to confirm the idea that late glacial (Devensian) slope processes resulting in the deposition of a coalescing fan across the valley floor was the most appropriate conclusion. **Ann Bridle** (UWE) took up the story at this point to tell us a little bit about her PhD, which is concentrating on the basal sediments underlying the barrier feature and will extend the story of the Gordano Valley. A short jaunt up the valley and we are shown a second type core taken through the terrestrial sequence. Whilst a number of the palaeoenvironmental enthusiasts including **Emma Tetlow** (Birmingham)



Figure 3. The QRA group looking at one of Tom Hill's cores in the Gordano Valley.

examined the peat sequences for plant macros and beetle remains, the remainder of the group were concerned with the coversands and diamicton recovered at the base of the core. **Hannah Brown** (UWE) also gave us a short introduction to her PhD project which is looking at the geotechnical properties of the coversands aggraded in this area but which should add something further to the Late Quaternary story. Finally, we moved down to the marine side of the barrier where Tom unveiled his final type core and was able to bring together all the evidence to show the development of the Gordano Valley, clearly illustrated through a series of time-slice diagrams neatly presented on a number of posters.

After a brief stop for a late lunch at the roadside café, we headed up to Bristol and Shirehampton to look at Avon terrace (T2) gravels. **Martin Bates** (Lampeter) introduced us to the site, a trench excavated in the playing grounds of a local school which has provided access to the river gravels. In general, there is very limited access to this terrace due to urban development and information must be gathered where it can be found. Martin explained that a number of Palaeolithic finds have been associated with this terrace, giving a tentative date for aggradation. However, recent optical dating (OSL) has thrown up a number of inconsistencies and at present work is still on-going in terms of developing a robust chronology for this terrace. The section itself provided a fine example of cryoturbated fluvial gravels with drop structures or 'trogen boden' as **Pete Coxon** informed us, clear evidence of permafrost. So far, very few archaeological finds have come out of the trench. Flints were easy to find and whilst most showed evidence of periglacial activity, **Rick Shakesby** (Swansea) found an excellent example of a worked flint.

Friday 7th April

Chris Hunt provided a fascinating itinerary for the final day involving visits to four locations interspersed with an excellent lunch stop in one of the local hostels in Somerton. The first site, Cutley Farm, provided an example of interglacial marine shelly sand deposits known locally as Burtle Beds. These formations of mostly marine interglacial sediments occur in a number of locations across the Somerset and Avon Levels. Chris described a sequence of complex deposits, which indicate a minimum of two marine transgressions dated tentatively to Oxygen Isotope Stage 5e and Stage 7.

The next location, Combe, provided an example of a diverse series of Quaternary sites in the Langford Gap on the southern boundary of the Holocene deposits which form the Somerset Levels. The site comprises a wedge of post Oxygen Isotope Stage 5 cold-stage fluvial gravels and sands overlain by mainly Triassic-derived head deposits. The sediments indicate

flashy seasonal rivers with sand interlocated with sub-rounded to mostly sub-angular head-like material. Chris indicated that the sand deposits may have been formed from material recycled from the Burtle Beds located on the levels.

The final site before lunch, Low Ham Valley, provided evidence of a marine incursion into the Somerset Levels subsequent to the Ipswichian transgression (OIS 5e). The site is located in a palaeo-valley containing a complex of sands, silts and peats. Evidence from Ostracods, molluscs, plant macrofossils, diatoms, dinoflagellate cysts and pollen indicates a back estuarine environment consistent with temperate climatic conditions. Infinite radiocarbon dates and amino acid ratios consistent with late Oxygen Isotope 5 or early stage 3 indicates a high sea stand subsequent to the Ipswichian interglacial (stage 5e) i.e. probably early Devensian age.

After lunch we visited the last site of this year's field meeting at Hurcott Farm, the location of an unusual deposit of heavily cemented Pleistocene terrace gravels. The remainder of this deposit forms a 20m² area containing an abundant freshwater and terrestrial molluscan fauna. 80 pollen grains have also been identified indicating a small interglacial assemblage. The evidence indicates a minimum Oxygen Isotope Stage 7 age correlated with the Burtle Beds visited earlier in the day.

Pete Coxon expressed our thanks to **Chris Hunt** and **Simon Haslett** for organising the field meeting, and to everyone who contributed during the week on this very interesting and informative visit to some of the Quaternary sites of northern Somerset.

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QUATERNARY RESEARCH FUND

TEPHROCHRONOLOGY INVESTIGATIONS OF THE LONG CORE SEQUENCE AT LES ECHETS, FRANCE

Background and rationale

Les Echets (45°54'N; 4°56'E) is one of the few terrestrial sequences available in Europe that provides a continuous and high-resolution record of environmental variability during the last interglacial/glacial cycle. During the late 1970s, sediment cores from this infilled lake revealed a continuous sedimentary sequence extending back to ca. 140,000 years BP. Pollen analyses led to the reconstruction of vegetation development during this period which demonstrated the occurrence of several alternating warm and cold climatic phases (Beaulieu and Reille, 1984, 1989). As part of a new high resolution multi-proxy investigation of rapid climatic events spanning this period, new sediment cores from the centre and margin of the basin were obtained during autumn 2001 (funded by Stockholm University, Lund University and Columbia University). The location of this site, in an intermediate position between the North Atlantic and Mediterranean region, fills an important gap in determining the spatial variability and impact of these rapid and abrupt climate fluctuations that occurred on centennial and millennial time scales.

Central to this new project is chronological control, particularly the use of tephrochronology, to enable the direct comparison of this record to other high resolution chronologies and, as such, to provide an insight into the environmental impact of these rapid climatic events in Europe and the North Atlantic region. The tephra component of this project is an extension of preliminary tephrochronology investigations initiated at Stockholm University and funding from the Quaternary Research Association has enabled geochemical analysis to be undertaken. The density separation technique (Turney, 1998) has been employed to extract and identify tephra horizons within both the marginal (19 m in length) and central cores (30 m in length) from Les Echets spanning oxygen isotope stage 2 and 3.

Results and significance

A thin (3 mm thick) visible tephra horizon has been identified within the marginal core from Les Echets, but no trace of this tephra has been identified within the central core. Shards within this horizon are brown in colour and basanitic in composition. The tephra is thought to be between 30-40 ka BP in age and is thought to originate from the Massif Central. As yet, however, the specific volcanic source of this tephra has not been identified and it is thought

that this may represent a previously undiscovered tephra horizon. Although, at present, this tephra has limited application as a time synchronous marker horizon, this horizon will add significantly to the volcanic history of the Massif Central and also provides key information on the sedimentary processes and possible hiatuses in the Les Echets basin at the time of deposition.

A second tephra has also been identified in cryptotephra form (identifiable only through the employment of extraction techniques) within the central core (preliminary age estimate of ca. 40-45 ka BP). Only a handful of shards have as yet been extracted and their appearance suggest that they are of rhyolitic composition, but such low shard concentrations limit the possibilities of obtaining reliable geochemical results.

Investigations are still ongoing to trace some of the more well-known tephra horizons that are widely distributed within other palaeoclimate archives spanning oxygen isotope stage 2 and 3 e.g. the Fugloyarbanki tephra (23 ¹⁴C ka BP). This work will be undertaken under the auspices of the recently ESF funded RESOLuTION project (Rapid climatic and environmental shifts during Oxygen Isotope Stages (OIS) 2 and 3 – linking high-resolution terrestrial, ice core and marine archives) led by Prof. Barbara Wohlfarth. Further work will also focus on the tephra record spanning oxygen isotope stages 4 and 5.

Acknowledgements

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GEOPHYSICAL INVESTIGATIONS OF THE INTERNAL STRUCTURE OF OPEN SYSTEM PINGOS IN ADVENTDALEN, SVALBARD

Background and Rationale

Pingos are unequivocal indicators of the presence of permafrost because they develop only in ground that is perennially frozen (Mackay, 1979). Relict pingos of Pleistocene age are therefore proof of the past existence of permafrost. To accurately interpret relict forms, modern analogue data on the internal structure (ground ice geometry and physical characteristics) of active pingos in the current permafrost zone are required (Pissart, 1988). Studies of this type are rare due to the lack of suitable exposures and the difficulties associated with the transportation and deployment of drilling equipment. Here we present results from ground penetrating radar (GPR) investigations of the internal structure of open-system pingos on Svalbard. The research was designed to provide reference data for the interpretation of relict landforms in Wales.

Methods

GPR surveys of open system pingos were undertaken at Riverbed and Innerhytte pingos in Adventdalen, Svalbard between 14th-21st April 2004. This period was chosen as the use of sledges and snowmobiles facilitated equipment transport, and because there was no unfrozen active-layer to interfere with EM wave penetration. Because Innerhytte and Riverbed pingos are located above the upper altitudinal limit of fine-grained Holocene marine deposits in Adventdalen (which would significantly limit the penetration depth of EM waves) and are developed in frozen Jurassic shales, these pingos were chosen as the most suitable for GPR survey. This short report presents the results of GPR survey at Riverbed pingo, where interpretation of the GPR data could be constrained by earlier descriptions of ground ice exposed by fluvial erosion on one flank of the landform (Yoshikawa, 1993). Further details of the GPR surveys are available in Ross *et al.* (2005). A Pulse Ekko 100 system with a 100 Mhz antennae was used for the survey. Processing involved: (a) dewow, (b) gain function, and (c) band pass frequency. Based on a CMP survey, the velocity of the electromagnetic waves was 0.14 m/ns.

Results

THE GPR data are characterised by gentle to steeply dipping reflections that lie roughly sub-parallel to the pingo flanks (e.g. 45-60 m Figure 1). These dipping reflections are thought to represent alternations between thin units of ground-ice and frozen mineral material, probably partially disaggregated shale. Although strong continuous reflectors can be generated by the dielectric contrast

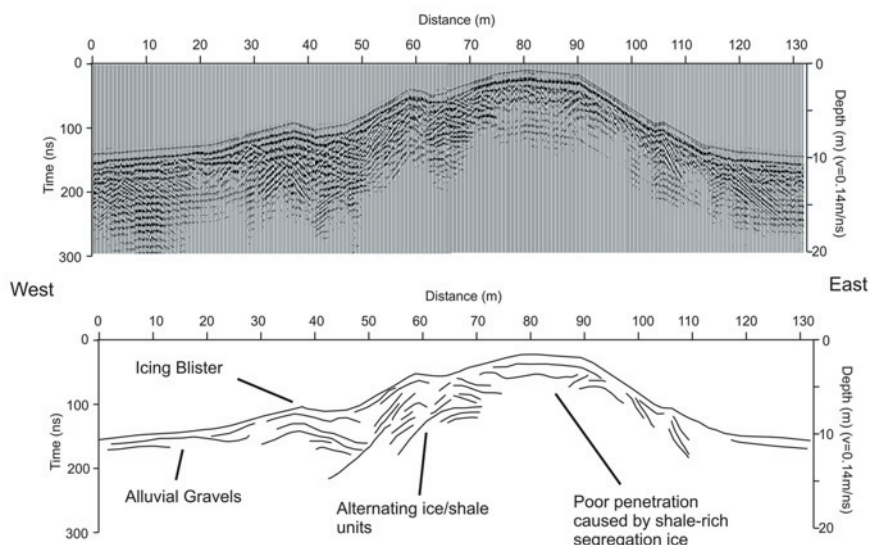


Figure 1. Ground penetrating radar profile, Riverbed pingo.

between zones of clear ice and ice with high air bubble content (Moorman and Michel, 2000), the evidence for alternating units of ice and shale observed by Yoshikawa (1993) at this site supports the former interpretation.

The GPR surveys at Riverbed pingo were unable to image the geometry of a massive ice-core. Because massive ice has homogenous dielectric properties and is highly resistive, EM waves propagate rapidly (0.16 mns^{-1}) through ground-ice without producing internal reflections (Moorman and Michel, 2000). However, below the upper few metres of the GPR profiles, no reflections that might be interpreted as the base of a massive ice body were observed. Such reflections would be expected from a contact between ground-ice and bedrock, or between ground-ice and a sub-pingo water lens because of the contrasting dielectric properties of these materials. The absence of a basal reflection is partly a function of problems with signal attenuation, but is also probably the result of the significant depth at which ground-ice formation and heave occurs (Mackay and Stager, 1966). The presence of segregation ice, causing intra-permafrost scattering of the GPR signal (Arcone *et al.*, 1998), has also resulted in signal attenuation. Scattering of the GPR signal is apparent in the central zone of the profile (70-90 m) where the data is characterised by complex chaotic reflections with little or no lateral continuation, and shallow signal penetration.

Significance

This project has provided further evidence that the upper few metres of some pingos are composed of alternating units of sediment and ice (Mackay and Stager, 1966; Tarnocai and Netterville, 1976; Yoshikawa, 1993). The observation of alternating units of mineral material and ice has important implications for rampart generation during pingo decay. These alternating ice units may represent segregation ice rather than injection ice, and during pingo decay may generate episodic gravity-driven mass movement events on the pingo sides. Accumulation of such mass movement deposits has been suggested as a major mechanism of rampart formation (Mackay, 1988). Little observational evidence is available on the mechanisms of rampart formation, and future work should be directed at monitoring and modelling these processes.

The study has demonstrated that the conceptual model that assumes pingos contain a simple plano-convex clear ice core is not necessarily the most appropriate. Many studies of the internal structure of pingos have emphasised the presence of segregated ice, even in medium-grained sands (Mackay and Stager, 1966; Mackay, 1973, 1979; Tarnocai and Netterville, 1976). It is therefore difficult to utilise the presence or absence of a particular ground-ice type (injection ice or segregation ice) to distinguish between pingos, lithalsas and other related ground-ice mounds. A more realistic approach is to view ground-ice mounds as a continuum of landforms varying in scale, relief and composition of their cores.

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NEW RESEARCHERS AWARD SCHEME

GEOCHEMICAL ANALYSIS OF TEPHRA SAMPLES FROM LATE HOLOCENE SMALL HOLLOW AND MOR HUMUS DEPOSITS IN KILLARNEY NATIONAL PARK, CO. KERRY, SOUTHWEST IRELAND

Background and rationale

The purpose of the geochemical analysis of tephra layers from small hollow and mor humus deposits in Killarney National Park, southwest Ireland, is to provide a precise chronological framework for subsequent analysis of sub-fossil insect remains from these deposits.

The overall project aim is to examine sub-fossil insect remains from such deposits in selected extant woodlands to answer questions regarding woodland structure, degree of canopy openness and prevailing ground conditions during the Late Holocene. These results will be compared with the vegetational history of the selected woodlands derived from other proxies. Precise chronology for this project is crucial to assess the rate of change and response time of vegetation.

Methodology

Three tephra layers from Derrycunihy Wood, Killarney were subject to geochemical analysis in April 2005. Tephra was extracted from the peat using the Acid Digestion method (Persson, 1971; Dugmore, 1989) and taken to Edinburgh for final mounting, polishing and carbon-coating. Samples were then analysed using a CAMECA SX100 microprobe in the NERC Microprobe laboratory, Department of Geosciences, University of Edinburgh.

Results

Results are detailed in Table 1 below. The tephra SH1 at 20-21cm has been identified as Hekla 1104 by comparison of the geochemistry with that of numerous other known Irish sites where Hekla 1104 has been confirmed e.g. Hall and Pilcher (2002).

SH2 at 51-52cm produced a small number of valid results but will need to be revisited. The sample proved to be contaminated with a waxy precipitate, a by-product of acid digestion, which obscured the tephra during analysis. The results have proved interesting as the geochemistry is similar to a tephra identified in blanket bog at Portmagee, Valentia Island, albeit stratigraphically

Table 1. Geochemical Analysis of Three Tephra Layers from Derrycunihy Wood, Co. Kerry, Southwest Ireland

	Oxide										
Data Point	SiO ₂	TiO ₂	Al ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Total
Small Hollow											
20-21cm											
SH1/1	72.84	0.19	13.43	2.26	0.12	0.05	1.77	5.41	2.59	0.00	99.37
SH1/2	71.77	0.20	14.00	3.39	0.16	0.12	1.83	5.07	2.83	0.01	99.30
SH1/3	71.76	0.20	13.88	3.33	0.09	0.09	1.72	5.33	2.85	0.05	99.29
SH1/4	71.71	0.18	14.25	3.24	0.14	0.11	1.71	5.13	2.80	0.02	99.21
SH1/5	71.70	0.23	13.69	3.40	0.12	0.12	1.77	5.64	2.40	0.00	99.18
SH1/6	71.61	0.18	14.40	2.98	0.11	0.12	2.01	5.21	2.57	0.00	99.08
SH1/7	71.58	0.22	13.97	3.31	0.03	0.12	1.89	4.99	2.86	0.00	98.97
SH1/8	71.54	0.18	13.83	2.79	0.11	0.10	1.80	5.38	2.93	0.00	98.93
SH1/9	71.15	0.23	13.95	3.08	0.08	0.12	1.94	5.34	2.77	0.05	98.69
SH1/10	71.02	0.19	13.98	3.33	0.09	0.10	1.96	5.36	2.80	0.11	98.66
SH1/11	70.93	0.18	14.52	2.82	0.12	0.13	1.92	5.38	2.77	0.06	98.65
SH1/12	70.86	0.21	13.73	3.12	0.06	0.10	2.06	5.10	2.48	0.05	98.09
SH1/13	70.86	0.19	13.55	3.08	0.08	0.13	1.83	5.28	2.63	0.02	98.49
SH1/14	70.79	0.19	13.65	3.17	0.12	0.13	1.90	5.17	2.75	0.07	97.93
SH1/15	70.73	0.20	13.74	3.11	0.09	0.11	1.88	5.19	2.68	0.00	97.75
SH1/16	70.26	0.19	14.21	3.05	0.14	0.12	1.86	5.14	2.70	0.04	97.71
SH1/17	69.60	0.20	13.95	3.04	0.06	0.13	1.89	5.15	2.55	0.00	96.56
SH1/18	70.31	0.18	14.01	3.22	0.13	0.11	1.99	5.36	2.77	0.00	97.72
SH1/19	69.98	0.20	13.91	3.08	0.11	0.13	2.08	5.15	2.84	0.09	97.32
SH1/20	69.60	0.16	13.81	3.13	0.15	0.06	1.85	4.96	2.69	0.05	97.15
Small Hollow											
51-52cm											
SH2/2	65.43	0.17	18.28	1.38	0.04	0.06	0.54	7.85	5.98	0.05	99.78
SH2/3	62.19	0.45	17.17	3.63	0.26	0.34	0.79	8.14	5.48	0.06	98.49
SH2/4	60.57	0.37	16.96	3.41	0.35	0.40	0.65	6.76	5.50	0.06	95.02
SH2/5	58.52	0.39	15.68	3.41	0.34	0.29	0.77	6.90	5.26	0.15	91.71
Mor Humus											
16-17cm											
MH1/1	62.66	0.92	15.47	7.82	0.16	1.22	4.43	4.58	1.79	0.39	99.42
MH1/2	62.12	0.89	15.42	7.62	0.16	1.17	4.20	4.75	1.84	0.41	98.57
MH1/3	61.98	0.88	15.55	7.76	0.24	1.26	4.41	4.43	1.79	0.29	98.59
MH1/4	61.48	0.57	19.14	4.64	0.15	0.70	5.90	5.78	1.07	0.20	99.63
MH1/6	60.99	0.91	15.08	8.33	0.28	1.31	4.74	4.57	1.75	0.35	98.30
MH1/9	60.69	0.87	14.96	7.32	0.20	1.17	4.27	4.13	1.59	0.28	95.47

much later than that found in Derrycunihy (Hall and Pilcher, 2002). Subsequently, work at An Loch Mór, Inis Oírr, off the west coast of Ireland, has identified no less than four tephra layers with this geochemistry and it has been tentatively identified as originating from Jan Mayen Island, in the Greenland Sea (Chambers *et al.*, 2004). Through additional dating and identification of known tephtras, these four layers are thought to occur at various dates between AD40 and 1400. The stratigraphic location of SH2 and slower accumulation rates observed in small hollows would indicate that it is probably at the older end of this scale but further clarification will be required using AMS radiocarbon dating.

The final tephra, MH1 at 16-17cm in the mor humus block, would appear to be Hekla 1510. This has been confirmed by comparison of the geochemistry results with other known Hekla 1510 findspots (e.g. Sluggan Bog, Antrim) and assessment of the accumulation rate of the mor humus.

Significance

The significance of the results are manifold:

The two tephra horizons in the small hollow will provide precise chronological markers against which the results from the sub-fossil insect remains and comparisons with results from previous pollen analyses can be assessed (Mitchell, 1988). They will also help to clarify the sedimentation rate of deposits in the small hollow, which were previously based on extrapolation of radiocarbon dates only.

The dating of a tephra from the mor humus deposit has helped clarify the length of time it has been accumulating as it was previously thought that this deposit formed as a result of disturbance in the 18th century (Mitchell, 1990). It would appear that at Derrycunihy it began forming much earlier, possibly as a result of late medieval disturbance of the forest canopy.

The potentially significant finding of a third location for a Jan Mayen tephra in the west of Ireland highlights the potential for such sites to add to the overall North Atlantic tephra record.

Finally, tephrochronology has rarely been attempted from small hollows or mor humus and, in conjunction with analysis of sub-fossil insect remains from these deposits, represents an advance in the development of both fields of study.

Acknowledgements

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EARTHQUAKES AND ASSOCIATED LAND/SEA-LEVEL CHANGES IN EASTERN HOKKAIDO, NORTHERN JAPAN

Background and rationale

Characterising patterns of earth motion (uplift and subsidence) associated with great earthquakes is an important first step for assessing seismic hazard. Research in the Pacific Northwest has used palaeoecological and lithostratigraphical evidence derived from estuarine sediments to reconstruct rapid sea-level changes and associated land motions linked to major plate-boundary earthquakes (Atwater, 1987; Nelson *et al.*, 1995; Clague, 1997). Microfossils, and other lithostratigraphical and geochronological techniques, can be used to identify periods of rapid sea-level change associated with tectonic processes (e.g. Long and Shennan, 1994; Atwater and Hemphill-Haley, 1997; Cisternas *et al.*, 2005; Hamilton *et al.*, 2005; Hawkes *et al.*, 2005; Kelsey *et al.*, 2005). Such research has been instrumental in demonstrating the hazard posed by plate-boundary earthquakes.

Our research builds upon previous work undertaken on active tectonic coastlines by using quantitative techniques (transfer functions) applied to microfossil data to reconstruct land-level changes in Eastern Hokkaido. This type of palaeoseismic work has only just begun in Japan (Sawai *et al.*, 2004a; Sawai *et al.*, 2004b) yet is essential to improve our understanding of seismic hazard awareness here and elsewhere in the Pacific. Intertidal sediments from this area provide evidence for repeated emergence events over the mid to late Holocene, which have recently been attributed to land movements associated with interplate earthquakes at the Kuril subduction zone (Figure 1).

Results and discussion

A QRA Research Award enabled us to conduct fieldwork in Eastern Hokkaido. We collected surface salt marsh samples and stratigraphic data from four sites. The QRA support enabled leverage of match funding from several other sources including the Japanese Geological Survey. The novelty of our research centres on the application of quantitative estimates of land-level changes derived from statistical modelling to directly constrain and test a recently developed elastic dislocation model for Eastern Hokkaido (Savage, 1983; Sawai *et al.*, 2004b).

The elastic model suggests that sites along the coast will record different patterns of land movement that will vary as a function of distance from the Kuril trench. The broad uplift/subsidence trends predicted by the elastic model may be recorded in tidal marsh stratigraphies. The purpose of our recent fieldtrip was to visit various sites around the coast, at critical locations in relation to the model, and collect fossil material. The first half of the fieldtrip

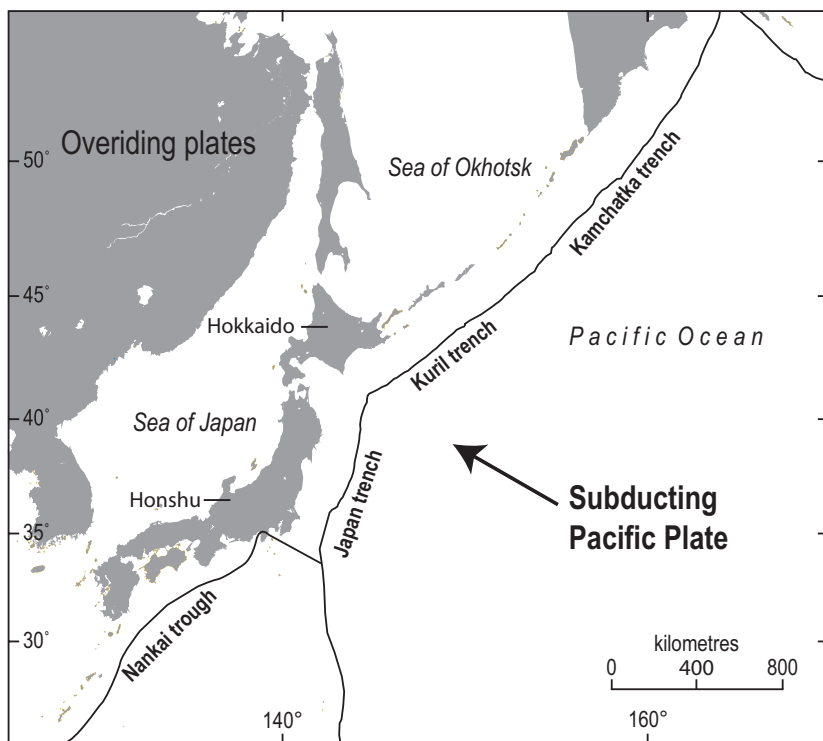


Figure 1. Plate tectonic setting around the Japanese Islands. The Pacific Plate sinks below the overriding continental plate(s) along the subduction zone, which comprises the Kamchatka, Kuril and Japan trenches.

was concentrated on sites on Eastern Hokkaido, nearest the Kuril trench. A long tide-gauge record spanning 100 years is available in this area, which can be used to validate the reconstructions given by transfer functions. This is a critical first step to assess the extent to which a high-resolution fossil core may reveal decadal changes in sea-level as shown in a tidal gauge record. We then studied salt marshes at various sites along the coastline, at strategic locations associated with land-level changes predicted by the model. Our first objective was to develop a comprehensive understanding of the contemporary marsh and its microfossil distribution. This programme directed the collection of sample cores. We focused particularly on looking for possible sites along the northern coast of Hokkaido to constrain the land-level changes suggested by the model, and to assess the contribution of non-seismic changes in relative sea-level. Although full biostratigraphical analysis has yet to be fully undertaken, the preliminary investigations suggest foraminifera should provide a valuable tool to quantitatively reconstruct sea-level and therefore tectonic deformation.

Significance

The QRA New Researchers Award (to KT) was instrumental in enabling us to collect important field data that will underpin subsequent stages of our research, in particular detailed laboratory studies on microfossil distributions and other physical characteristics of the sediments collected. The visit enabled us to better understand the range of depositional environments in Eastern Hokkaido and therefore target our sampling collection to maximise the potential resolution of our reconstructions. Lastly, the fieldwork facilitated a close co-operation between the Universities of Durham and Penn and colleagues at the Japanese Geological Survey, which we hope will significantly assist us in the subsequent stages of our research.

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We wish to thank the Quaternary Research Fund (to BH) and the New Researchers Award (to KT) for supporting research in this region. We also thank the British Sedimentological Research Group, the Royal Society, the Durham Geographers Graduate Association and the Geological Survey of Japan for their contribution towards the costs of KT's fieldwork in May/June 2005.

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RECORDING THE POSTGLACIAL SEDIMENT STRATIGRAPHY OF THE VALLEY SIDE AT BELDERG BEG, CO. MAYO, IRELAND

Background and rationale

Previous investigations have established the presence of Neolithic and Bronze Age field system remains under blanket peat on a gently sloping hill at Belderg Beg. Although the site has been partially excavated (Caulfield, 1978; 1983), little palaeoenvironmental research has been undertaken in the area and the landscape development in terms of blanket bog initiation and expansion with respect to the history of site occupation and abandonment was unclear. This project aimed to ascertain the date of peat initiation on the slope, its rate of spread, and whether or not blanket bog growth was retarded inside the field boundaries, perhaps as a deliberate management strategy of the Neolithic agriculturalists. Furthermore, the nature of the sub-peat sediments at various points on the slope might indicate the causal factors involved in peat initiation.

A three-dimensional record of sediment stratigraphy was constructed. Two transects were laid out, one along the slope (including areas within and downslope of a Neolithic field boundary) and the other roughly across the slope. Boreholes were taken at regular intervals along each transect with a narrow gauge Eijelkamp corer, and the sediment stratigraphy was described in detail. Basal peat samples for AMS radiocarbon dating were taken from six of the cores in order to establish the rate of peat spread on the hillslope (Figure 1).

Results and significance

Radiocarbon assays were calibrated using OxCal v. 3.9 (Bronk Ramsey, 2003) and atmospheric data from Stuiver *et al.* (1998). By correlation with previous studies (unpublished data) the radiocarbon and sediment stratigraphical analyses have shown that peat initiation did not commence on the Belderg Beg hillslope until farming was underway. Moreover, peat was observed to have grown directly on bedrock or patchy till in some locations and over a thin soil and/or colluvium in others. The inference drawn is that a thin soil profile developed over the slope in the Early Holocene, but whilst the Neolithic field system was in use, much was lost by severe erosion. The cause of this soil erosion is at present uncertain. Whilst agricultural activity could have been one factor, a severe climatic event is another. Recent investigations at Achill Island, 45km to the south-west of Belderg Beg, have uncovered evidence for a severe erosional event, probably caused by storminess, at c. 5200-5100 cal. BP (Caseldine *et al.*, 2005). At Belderg Beg, peat began to accumulate in topographically suitable

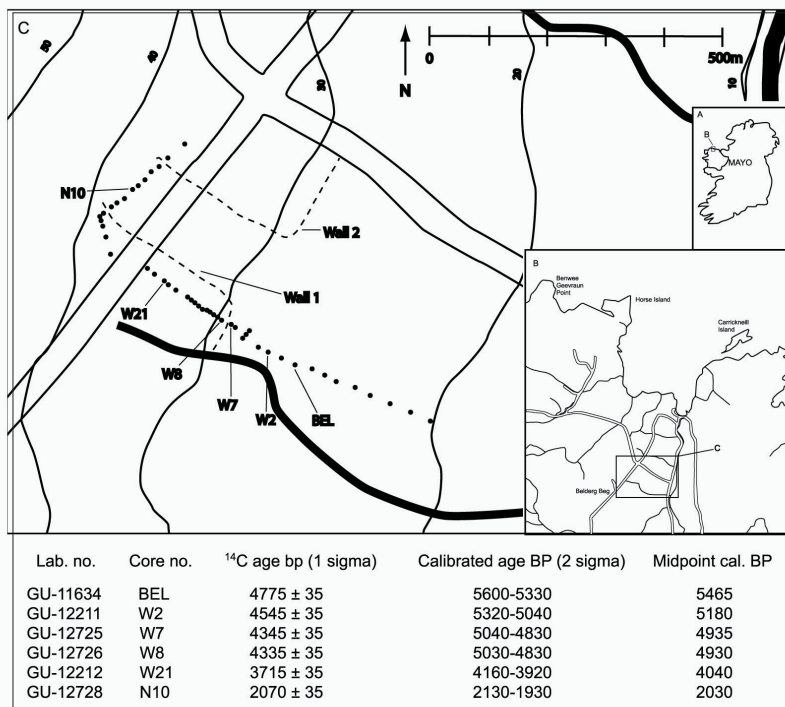


Figure 1. Plan of the Belderg Beg area showing archaeological features mentioned in the text and coring transects.

locations at c. 5465 cal. BP and spread via paludification. The blanket peat spread was apparently not the cause of abandonment of the Neolithic fields; cessation of agriculture occurred at c. 5375 cal. BP, some five centuries before they were covered by blanket peat.

Acknowledgements

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QRA-RLAHA

LUMINESCENCE DATING AWARD

OPTICAL DATING OF FLUVIAL DEPOSITS FROM THE RIVER EXE, DEVON, UK

Background and Rationale

The aims of this study were to investigate the chronology and palaeoenvironments of the lower terrace deposits and floodplain of the River Exe. The sequence of terrace deposits (BGS 1-3) (Edwards and Scrivener, 1996) is thought to represent a succession from the Late Pleistocene to the Holocene. There is, however, very little data on the ages of the river terrace material. Not only is the material primarily inorganic but there are also very few exposures. The deposits consist of clast supported gravels overlain by varying thicknesses of fine silts and sands, ranging from a few centimetres over Terraces 2 and 3 to several metres over parts of the floodplain. Flints have been recovered including a small unabraded microlith recovered in April 2003 at Washfield. Similar microliths regarded as Mesolithic have also been found further downstream in the NetherExe Basin (Silvester *et al.*, 1987). Large gravel bars or islands in braided reaches and at confluences appear to have been preferentially selected for human activity and the subsequent survival of such sites is dependent on the later floodplain geomorphology. In particular, periodic avulsion around such core locations has allowed preservation.

Methodology

OSL samples were collected from two sites i) at Washfield just north of Tiverton, and ii) on the floodplain at Brampford Speke (Figure 1). Samples were collected from the base of the silts, except in the case of sample X2178b. At Washfield, two samples were collected from a bank section; one from a palaeochannel base from where the unabraded microlith had been recovered, the other from the base of overlying alluvial silts. Practical difficulties with access onto agricultural land precluded collection of samples from the silts above Terraces 2 and 3 so a bulk sample of the gravel matrix from Terrace 3 was collected. Results are shown in Table 1.

Brampford Speke, just north of Exeter, is in an area of geomorphologically complex floodplain, part of which is designated as a geomorphological SSSI (Hooke, 1977; Gregory, 1997). There is a sequence of abandoned channels and ridges (Figure 2) in the area of the SSSI. Samples were collected from

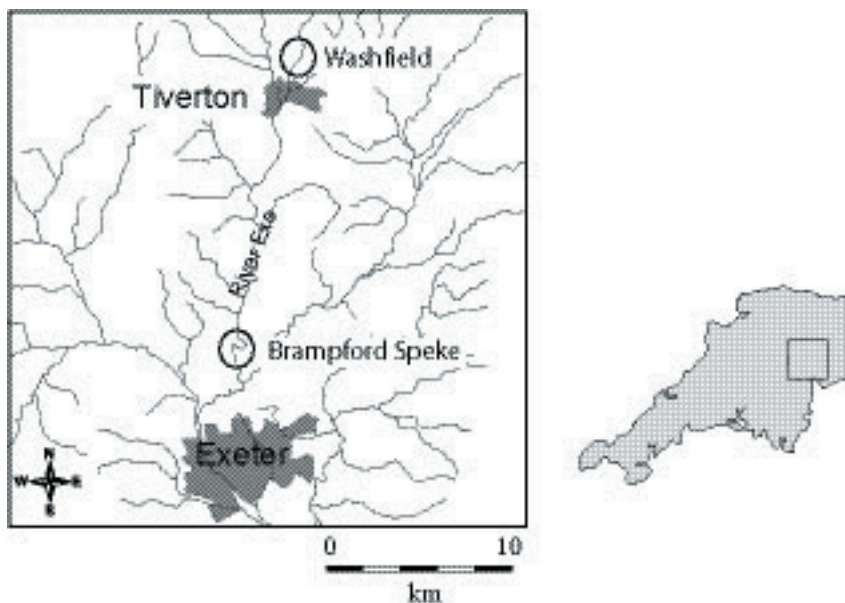


Figure 1. Two sites where OSL samples were collected; i) at Washfield just north of Tiverton, and ii) on the floodplain at Brampford Speke.

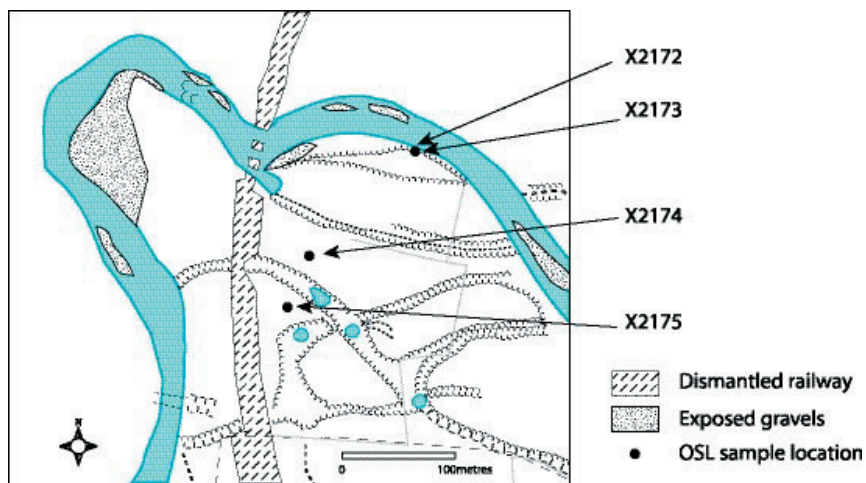


Figure 1. Brampford Speke, just north of Exeter, an area of geomorphologically complex floodplain.

each of three ridges in order to establish their relative ages. Results are shown in Table 2.

Results and Significance

Site description	Washfield Base of overbank silts	Washfield Base of palaeochannel	Washfield Terrace 3 gravel matrix
Laboratory code	X2176	X2177	X2178b
AGE (ka)	1.16	2.16	22.84
error	0.07	0.13	2.07
% error	6.16	6.23	9.06

Table 1. Washfield. OSL results

The dates from this award have been used together with geomorphological mapping and other data from the catchment to investigate periods of sediment aggradation and patterns of channel avulsion. Samples X2174 and X2175 at Brampford Speke (Table 2) are of a similar age, suggesting that both are overbank deposits from the palaeochannel that separates them, and that the palaeochannel has resulted from avulsion rather than migration of the main channel. The date from Terrace 3 (Table 1) at Washfield is obviously much older than the floodplain samples, providing a constraint on the ages of the Exe terraces. These results are incorporated into my PhD thesis and further papers are currently in preparation.

Site	Brampford Speke bank	Brampford Speke bank	Brampford Speke base of silts on ridge	Brampford Speke base of silts on ridge
Laboratory code	X2172	X2173	X2174	X2175
AGE (ka)	[0.48]	[0.62]	0.66	0.68
error	0.09	0.05	0.11	
% error	17.72	19.86	7.00	15.90

Table 2. Brampford Speke. OSL results

I am grateful to the QRA and RLHA for the award of OSL dates. Thanks

are due to Jean-Luc Schwenninger and David Peat from RLAHA for sample collection and training in sample processing; English Nature for permission to sample at Brampford Speke, landowners in the Brampford Speke and Washfield areas for access, to colleagues from the Department of Geography, University of Exeter, for assistance in digging pits, and to my supervisor Prof. Tony Brown.

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REVIEWS

**SOLWAY WEST (SPECIAL SHEET) ¹ : SUPERFICIAL
DEPOSITS AND SIMPLIFIED BEDROCK EDITION
(SCOTLAND)**

**LEADHILLS (SHEET 15E) ² : SOLID AND DRIFT EDITION
(SCOTLAND)**

**ABERFOYLE (SHEET 38E) ³, TOMATIN (SHEET 74W) ⁴,
BEN WYVIS (SHEET 93W) ⁵ AND EVANTON (SHEET (93E))⁶
: BEDROCK AND SUPERFICIAL DEPOSITS EDITIONS
(SCOTLAND)**

**DOUNREAY (1:25,000 GEOLOGY SERIES) ⁷ : SUPERFICIAL
DEPOSITS EDITION (SCOTLAND)**

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Apart from a specially commissioned 1:25,000 sheet, this review outlines the latest BGS 1:50,000 maps covering different parts of Scotland, showing what are now termed Superficial Deposits, when referring to the Quaternary, rather than the historic usage of Drift for these editions. Given the size of the original one-inch-to-the-mile (1:63,360) maps, most Scottish sheets are published as two east and west 1:50,000 editions, covering roughly 19 km east-west by 29 km north-south. Folded editions of these maps are now produced with a scenic colour photograph on the laminated front cover and an index map of Scotland and area covered by the sheet on the back.

Solway West is a special sheet with simplified pre-Quaternary bedrock geology covering a much larger 25 km by 40 km area than usual around Dumfries and Lockerbie extending southwards across the Solway Firth to beyond Sillloth on the Cumbrian coast. However, it does not extend as far as the 1998 Kirkbean (6W) sheet which it in part replaces, and so, along with the planned Solway East sheet, these maps will not quite cover all of the England and Wales sheets for Longtown (11), Sillloth (16) and Carlisle (17) and do away with the need to publish separate editions. Compared to this slightly earlier sheet, the glacial tills and gravels along with many other deposits are subdivided into over thirty units and many more geomorphological features (including glacial meltwater channels) added, thanks to a detailed partial resurvey aided by aerial photography. In addition, the intertidal offshore sediments have been incorporated, even if it is unclear if the boundary of the tidal river and creek deposits represents the low water mark. This is stated to be around 4.0 m below Ordnance Datum, as at around 9.2 m this estuary has a relatively dynamic tidal range. Also, unlike most other offshore BGS maps at this scale, there are no offshore bathymetric contours. In addition, the margins of this map contain a series of ten schematic cross-sections that clearly show the generalised relationships amongst the different superficial deposits and the bedrock, even if they show an idealised situation by wandering indirectly between stated grid references. Further, the perspective view is no better than a standard satellite image and as a result has a varying scale. On folded editions, this is compounded by this image being split by the principal fold: this could have been avoided if it had swapped places with the less significant simplified bedrock geology 1:250,000 insert map.

About 10 km north of Solway the newly revised Leadhills (15E) sheet provides a traverse through the Southern Uplands and clearly shows the intermittent superficial Drift deposits in relation to the underlying Solid bedrock. They consist of scattered peat, alluvium in the main valleys, and river terrace, glaciofluvial, till and hummocky glacial deposits. While the undivided tills have a similar tone of blue to some of the Ordovician greywackes they rest upon, this can be clearly distinguished. Furthermore, occasional glacial meltwater channels are shown, though other scattered small scale geomorphological features on the glacial map of Britain are not shown (QN107, 53-56). The accompanying sheet explanation adds little beyond just over a page of text and a few relevant comments in the applied geology section. For once, there would have been space to add a few diagrams or maps beyond the two informative cross-sections on the margins of the map showing the generalise relationship of the superficial deposits. Also, the area's understandably limited late Devensian chronology is only given in radiocarbon time with no explanation that these events really occurred up to a few millennia earlier than stated.

On the other side of the Midland Valley of Scotland, just north of Glasgow, the Aberfoyle (38E) sheet straddles the Highland Boundary Fault with Devonian and Carboniferous sediments filling the southeastern half of the sheet and much more mountainous and ancient Dalradian bedrock to the northwest of this fault. While the northeastern portion of the map shows a quite varied selection of scattered superficial deposits including till, the area within the Midland Valley is far more significant. During the end of the last ice age, this ice marginal landscape was partly submerged beneath the sea due to isostatic loading, and raised marine deposits are found up to nearly 40 m above mean sea level (Ordnance Datum). In addition, there is quite a complex series of lacustrine, hummocky glacial and glaciofluvial ice contact and sheet deposits around the Lake of Menteith and many other small areas of interest. It can only be hoped that, if a sheet explanation for this map is published, it will include similar diagrams and generalised sections to those found on the margins of the adjacent Glasgow (30E) Drift edition published in 1994, as this sheet has none.

The uplands of the Tomatin (74W) sheet, just south of Inverness, on the northwestern flanks of the Grampian Highlands, are blanketed in peat with patches of weathered regolith and occasional till. Towards the valleys there are accumulations of head, scree and other periglacial debris (even if such deposits are assumed to be Flandrian). Spreads of till with to a lesser extent hummocky glacial deposits are found covering slightly lower ground and extending along the sides of main valleys, which contain alluvium, river terrace, lacustrine and various glaciofluvial deposits. In addition, a comprehensive series of geomorphological features are marked. Even if there appear to be relatively few examples of glacial striae, crag and tail and roche moutonnée (these symbols along with those for the bedrock geology are rather small, to accommodate a lot of detail on this combined edition), the eskers, glacial

meltwater channels and their margins are readily apparent. A schematic section shows the superficial deposits on the southeastern margin of the map, which includes a short portion of the river Spey that drains the Grampian Mountains including the Cairngorms.

To the north of Inverness the Evanton (93E) and Ben Wyvis (93W) sheets stretch inland from between the Cromarty and Dornoch Firths. Both these maps were revised without resurvey from archive data, though it is unclear on what basis this was done beyond, I assume, using aerial photography. Compared to the historic 1912 Alness one-inch (1:63,360) sheet they replace, the superficial deposits have quite clearly been reinterpreted and river terraces are no longer subdivided. Since the last edition, a number of hydroelectric dams, including Loch Glascarnoch, have been built, and unlike some offshore coastal areas no information is provided for this now submerged landscape, leaving the adjacent areas out of their natural context. Unlike the original, the Ordnance Survey base map omits spot heights from the principal lochs, making their contours rather unfathomable. Also, the intertidal area on the Evanton sheet is too faint to perceive the extent of sandbanks and mudflats. Though these clearly drawn maps are welcome, they are no substitute for a complete resurvey along the lines of the nearby Fortrose (84W) sheet, which pioneered what it is now possible to delineate (*QN* 89, 42-44). Furthermore, there is a danger in a few years' time that policy makers will assume the mapping of Britain is complete, rather than requiring constant revision to provide the best interpretation possible within the available resources at any given time in the future.

Finally, a 1:25,000 special sheet covering the area around Dounreay on the northern coast of Scotland has been produced with funding from the United Kingdom Atomic Energy Authority. The 10 by 8 km sheet incorporates the offshore sea-bed sediments and bathymetry below Ordnance Datum. Particular attention is paid to geomorphological information and the location site investigation points, which are neatly shown without cluttering the map. In addition, the combined thickness of the superficial deposits and artificially modified ground, based on observations from 520 data points, is clearly contoured. Apart from dividing the bedrock into sedimentary and crystalline, this is ignored as there is a separate bedrock edition. But, judging from the 2003 Reay (115E) 1:50,000 sheet for this area, a combined edition would have been feasible, as the underlying bedrock is not that complex and helps put the superficial deposits into context. However, apart from a few areas mainly covered by hatching marking artificially modified ground, the underlying base map can be clearly read. Furthermore, this special sheet has a fine cross-section drawn to scale through the superficial deposits, which are also shown as a series of four typical sequences.

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UNDERGRADUATE DISSERTATION PRIZE (2005)

THE SEDIMENTOLOGY OF THE WEST RUNTON FRESHWATER BED (CROMERIAN *SENSU STRICTO* TYPE SITE)

The West Runton part of the Cromer Forest Bed (CFB) is widely regarded to be the type-site for the Cromerian stage and as such has attracted a great deal of scientific attention (e.g. Allen and Keen, 2000; Preece and Parfitt, 2000; Rink *et al.*, 1996). This investigation presents the most comprehensive sedimentological examination of the West Runton Freshwater Bed (WRFB) to date and was undertaken in order to establish the characteristics of the site's depositional environments. The eighty metre length of the exposed face of the WRFB was 'cleaned' to expose the underlying lithofacies and the section described according to lithology; texture; Munsell colour; and sedimentological structures. Sediment samples were retained for laboratory analysis to determine magnetic susceptibility; calcium carbonate; organic and mineral content; and for particle size analysis. The cleaned section was examined and divided into five sub-sections of approximately 10-20m in length each. These were further subdivided into eight sedimentological units, each with distinctive characteristics. Every unit varies in the degree to which it is present throughout each of the five sections and there is great variation in the positioning of these units within the sections. Brief descriptions of the 8 sedimentological units are given below, with an account of how each unit has been interpreted. Note that the units are numbered in ascending numerical order, but represent a transition from the top of each section to the base. i.e. Unit 1 caps the section, whilst Unit 8 underlies it:

Unit 8 is composed of a dark yellowish brown (10YR) cemented coarse sand matrix, supporting sub-angular- angular pebbles and cobbles, containing approximately 90-97 % sand in the < 2 mm fraction. Unit 8 has been identified as the How Hill member of the Wroxham Crag.

A very dark grey (2.5Y 3/1) calcareous clay containing c. 60% shell fragments and several complete bivalve shells, Unit 7 exhibits the clay nodules which have been interpreted as rip-up clasts. The unit appears to exhibit the remnants of lenticular bedding in places, indicating the availability of both mud and sand, and that periods of at least moderate current activity (sand deposition) alternated with periods of quiescence (mud deposition) (UBC, n.d.). The lenses of sand are probably vestiges of ripples formed during periods of slightly higher stream energy flow.

Unit 6 represents calcareous bands of yellowish brown (10YR) coarse to fine sands approximately 2-10 cm thick, and small lenses of dark yellowish brown coarse and fine sands containing shelly deposits or intraclasts (rip-up clasts). The sediments are lenticular bedded in places.

Units 5a and 5b are calcareous yellowish brown coarse sands (Unit 5a), interbedded with calcareous pale brown fine sands (Unit 5b) containing clay rip-up clasts. The overall picture is best described as a bed of sands which runs laterally across the WRFB, with coarse sand deposits at the southeast and northwest, and a unit of fine sands deposited in the centre. The interbedding of coarse and fine sands at this point is interpreted as being the result of a fluvial environment where energy flow alternates between moderate current activity and periods of quiescence. Units 5a and 5b are thus representative of small scale spatial and/or temporal variations in the flow regime and they are consequently understood to represent the transition from a fluvial to a lacustrine sedimentary regime.

Unit 4 is a highly consolidated, calcareous, dark brown silty-clay matrix, with fine horizontal bands of coarse sands. These sediments were most likely deposited within a standing body of water, or where a relatively low energy stream was flowing into a standing body of water. This may have been in the form of a lake, or may have been found as a smaller body, such as may be associated with the formation of oxbow lakes. The sedimentation of this unit may also be the result of a backswamp pond deposit.

Understood to be fluvially derived, Unit 3 is a calcareous, yellowish brown coarse sands interbedded with olive/olive brown coarse sands. The nature of the deposit suggests a period of reworking of the coarse sands found in the surrounding area. The interbedding of different lithologies may indicate the reworking of sediments located further upstream, or a change to a new source material. This unit is thought to be the result of a storm event of sufficient magnitude to cause entrainment of larger particles further upstream. Following this event, the river would have returned to its low energy flow regime.

Unit 2, a very dark greyish brown (2.5Y), highly consolidated, calcareous, silty clay. Low MS values towards the southeast of the WRFB indicate poor soil forming capability, concurrent with backswamp deposits which produce the gleyed and minerogenic sediments associated with waterlogging and the inwashing of suspended sediment.

Unit 1 caps the WRFB and is a 10-40 cm thick, dark yellowish brown (10YR), non-calcareous clay, with very fine (<1 mm thickness) dark reddish brown clay iron infusions arranged in a complex stratigraphy that is not reflected in any of the underlying units. The fine silts (85-95 %) and clays (< 2 %) that make up this unit are likely to have been deposited in a very low energy environment, possibly in standing and/or very shallow (< 1m) water.

Results and conclusions

The transition from Unit 8 to Unit 1 indicates a decline in energy that is consistent with a gradual evolution from a fluvial system to a lacustrine environment. The study concluded that the WRFB represents a lacustrine environment with relatively short-lived, periodic influxes of fluvially-derived, coarse material indicated by pebbles, gravels and coarse sands, separated by longer periods of quiescence during which fine material and organic detritus accumulated in relatively still water.

Deformation structures evident in the fluvially-deposited gravels that comprise the lower units of the WRFB were probably created post deposition, and given the proximity of these structures to the 'elephant' site it was suggested that the formative cause may have been trampling by large mammals. Micromorphological investigation of these structures to ascertain whether this was indeed the case were fraught with technical difficulties, with the result that there remains insufficient evidence to substantiate the above claim. Thus it is equally likely that the deformation structures were created by differential gravitational loading associated with density disparities between adjacent units of fine and coarse material.

The fine sediment which comprises the bulk of the WRFB was deposited in an intense, short-lived period of sedimentation within a shallow lacustrine environment such as an oxbow lake or a backswamp pond on a floodplain. These conclusions support previous studies of the WRFB that focus on palynological (West, 1980), isotopic (Davies *et al.*, 2000) and molluscan evidence (Stuart, 2000).

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