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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 Jpeg format. Quaternary Research Fund and New Research Workers Award Scheme reports should limit themselves to describing the results and significance of the actual research funded by QRA grants. The suggested format for these reports is as follows: (1) background and rationale (including a summary of how the grant facilitated the research), (2) results, (3) significance, (4) acknowledgments (if applicable). The reports should not (1) detail the aims and objectives of affiliated and larger projects (e.g. PhD topics), (2) outline future research and (3) cite lengthy reference lists. No more than one figure per report is necessary. Recipients of awards who have written reports are encouraged to submit full-length articles on related or larger research projects.

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COVER PHOTOGRAPH
Sands and gravels containing an ice-wedge psedomorph overlying laminated silts at Barmston, East Yorkshire (photo by Mark D. Bateman)

OBITUARY

JEAN-PIERRE LAUTRIDOU
1938-2010

In the summer of 2009 I took a colleague to a cliff outcrop south of the Palaeolithic site of La Cotte de St Brelade in Jersey. We looked at the succession there, comprising a *prima facie* top down sequence of head, a band of loess, a cobble beach, more head and a gravelly raised beach, resting on the granite bedrock. We pondered the succession and its possible interpretations. Some 37 years earlier in the summer of 1972 I took Jean-Pierre Lautridou to the same spot and we pondered in a way little different from that of the more recent visit. The problems of deciding whether one or two interglacials were represented or even whether head + raised beach had been involved in a landslip were in our minds back then in 1972 and were problems that Jean-Pierre was already addressing and would continue to address as one of his many Quaternary interests for the rest of his life. These two visits bracket much of the career of Jean-Pierre though his pre-1972 background had already launched him on a course of consistent application of his considerable abilities to the Quaternary of Normandy which subject and region acted as the foundation of most of his work. He ended up as a major player in most aspects of our understanding of the Quaternary of Normandy.

Jean-Pierre came to Caen in the late 1960 to study for his *Licence ès Lettres* (±BSc.). Following this he focused on physical geography with particular interest in geomorphology and covered many basic topics in geography, notably work on superficial deposits in a number of French localities and also built up expertise in geomorphological mapping techniques. For his *Thèse du troisième*

Cycle (±Master's degree) he chose the area of Saint-Romain-de-Colbosc in the Pays de Caux to the east of the Seine — only kilometres from his birthplace near Le Havre — and thus set himself, with its emphasis on loess, on the road which would ultimately lead to one of his informal and affectionate titles *Monsieur Loess*. He submitted his thesis in 1965 and its quality immediately led to his appointment as an *Attaché de Recherche* (±Research assistant) in the newly constituted *Centre de Géomorphologie du CNRS, Caen*. One of the features of this research centre was to be an experimental focus on the behaviour of rocks and soils under cold conditions; thus the *Laboratoire de Cryoclastie* was born, an establishment which, under Jean-Pierre's direction, was to become internationally known.

With the setting-up of the 'Cold Laboratory' the two major strands of Jean-Pierre's career were in place. First, stemming from his earlier and continuing interest in loess, he immersed himself in mastering all aspects of the deposits: facies, palaeopedology, chronostratigraphy, . . . and the setting of it all within no less a context than that of Northwest Europe as a whole. The second strand arose from the work of the 'Cold Laboratory' where the practical studies of periglacial and associated freeze-thaw effects meshed in neatly with the loess interest to create a comprehensive and rounded approach to deciphering the cold climate deposits of Normandy and wider afield. These researches were seriously under way during the late 1960s and continued through the following decades.

Jean-Pierre published an important interim paper on the loess in the 2nd *Bulletin du Centre de Géomorphologie* in 1968 with his complete work set out in his *Thèse d'Etat Majeur* (Habilitation thesis) in 1984 (published 1985) which covered the intended wide spectrum of loess matters. Notably he produced a thickness map of the loess across Normandy, a palaeogeographical map of loess origins (essentially from the winnowing of estuary and cold period, exposed Channel sea floor and the creation of a chronostratigraphy based on a subdivision of the loess, recognising no less than 7 paleosols.

Running in parallel with the loess studies in Normandy, Jean-Pierre was busily extending his research base by joining, under the auspices of PICG (Quaternary Glaciations of the Northern Hemisphere), with colleagues in Belgium (R. Paepe), the north of France to the east of the Pays de Caux (J. Somme) and Brittany to the west (J.-L. Monnier). In these collaborations can be seen one of his more important character traits, that of his innate desire and ability not only to enthuse others but to collaborate with them. He was also at this time becoming known and respected beyond Normandy and he became Secretary of the INQUA Commission (1982-1986). One of his last duties as Secretary was to organise the Loess Symposium at Caen in 1986. A number of you reading this will have attended both the Symposium and the Field Trips and some will recall the planned day visit to Jersey en route by ferry from the Cotentin to St Malo. I was responsible for the day in Jersey and what a nightmare it turned out to be, with rain beginning on arrival and worsening to a full gale by evening and no ferries sailing. Accommodation was found somehow for everyone but there was the additional problem I had in that I had guaranteed the local immigration authorities that two members of the party from Eastern Europe would not stay longer than 24 hours! And believe it or not there was the additional hazard that it could not be guaranteed that French immigration would let them re-enter France. However, all worked out more or less in the end and those on that day trip to the island that I have spoken to since have never forgotten it. But it should also be recalled that Jean-Pierre had overseen, not just the visit to Jersey, but had also provided the resources of the *Centre de Géomorphologie* to do research on the island sites to be examined, and co-ordinated the publication of the site descriptions in both French and English.

Returning to the late 1970s and early 1980s Jean-Pierre's cold climate interests spilled over into a much wider coverage of deposits in Normandy to embrace the river terraces and associated deposits of the Seine, the raised beaches of the Normandy coastline and their linked heads and loesses, various aspects of Holocene sea-level rise, even the Tertiary plateau deposits of *Haute Normandie* (Upper Normandy) and a significant input into the archaeology of the province. Almost without exception his involvement in these many researches was carried out within teams, either formal or informal, confirming his natural ability to work with others.

The work of the *Laboratoire de Cryoclastie* had strong implications for the understanding of present day high latitude and mountain processes but were applied intensively to the deposits of the Pleistocene cold climate cycles around the coasts of Normandy and particularly those of the Cotentin where he was to have many insights into the problems of interpreting the coastal cliff deposits. Not least among these were the creation of the term *plateau fondamentale* for the extensive shore and offshore platform occurring around the Channel Islands and adjacent coasts of Normandy and the replacement of the old term *Normannien*, applied until then to all the low level raised beaches and associated deposits, with a modern nomenclature. The *Laboratoire* welcomed researchers from many countries who spent time there joining in the research work or just inspecting results. A considerable number of publications of results have been widely quoted in the literature, not all with Jean-Pierre's name on them, but all with either his name or his support behind them.

His knowledge and work on freeze-thaw and the formation of heads and other slope deposits such as *grèzes litées* led to the presidencies of the *Commission du Périglaciaire de l'Union Géographique Internationale* (1988-1996) and to that of the *Groupe de Travail périglaciaire de l'Association Internationale du Pergélisol* (1988-1993).

The QRA visit of 1982 to Normandy will be a fond memory for many during which Jean-Pierre and his team of fellow researchers and assistants amazed us with the ladders and labels put up to access the beautifully cleaned down site, notably but not only that of Saint-Pierre-lès-Elbeuf. Those of us who were there were also trying to follow the fortunes of the Falklands War! Many of the results presented during this excursion were based on collaborative work with others within the framework of the *Groupe Seine* (1979-1993) which also included, as mentioned earlier, the Tertiary deposits of the adjacent plateau, such as La Londe, which was included on the excursion.

Throughout the period 1980 to his final field activities in 2007/8, Jean-Pierre immersed himself in an ever widening field of Normandy research. He was a fully active member of the *Groupe l'Homme et la Mer* steered by his colleague G. Fosse in the mid 1980s. This initiative began in a serious way the study of the interactions in Normandy between humans and the environment and this was to characterise a major part of both the geomorphological and archaeological collaborative inputs from then on—which continues healthily today. Major sites in the Cotentin, which were to provide the groundwork for significant advances in the understanding and dating of deposits, were investigated with a modern approach and modern techniques. Jean-Pierre's inputs did not end with geomorphology, soils and freeze-thaw but included a significant element of archaeological expertise.

Particular mention should be made of the close-knit team that grew up around Jean-Pierre at the Centre de Géomorphologie at Caen which included among others Martine Clet, Jean-Claude Ozouf and Jean-Pierre Coutard. The collaborative work that resulted epitomizes the ability of Jean-Pierre to inspire and build a team of workers around him.

The full flowering of the multidisciplinary studies was to be realised in the setting-up of the project *Les Premiers Hommes en Normandie* in 2000, steered by his long time close friend and colleague, Dominique Cliquet. This project is still running and already has a number of significant publications to its name. But preceding this was the development of the *Groupe Manche* which was a more informal arrangement with the friendship between Phil Gibbard of Cambridge's Centre of Quaternary Research acting as the main stimulus for a cross-Channel collaboration of areas of common interest. This began gradually but steadily attracted other colleagues eventually leading to a dedicated volume published in Journal of Quaternary Science in 2003 (Vol.18, pages 195-371).

I shall finish this all too brief summary of Jean-Pierre's career as I began with a personal reminiscence. From my first meeting in 1972, he sent me copies of his publications and those of his colleagues at Caen thus enabling me to keep up a good understanding of what was happening in Normandy at a time when I was in other full-time employment. And, when all is said and done, my home area of the Channel Islands is an integral part of Normandy for all researches until the vagaries of history in 1204 A.D.,when King John lost his mainland Normandy possessions, and after. Whenever I visited the *Centre de Géomorphologie* I was always met personally and made to feel at home and able to discuss the issues of the moment in a positive and challenging manner. Our condolences go out to his widow Line, his children and his grandchildren.

Acknowledgements

In writing this article I have taken much basic information from the obituary written by Jean-Pierre's close friend and colleagues, Jean-Pierre Coutard and Dominique Cliquet for the journal *Quaternaire*. I thank also the latter for further help in compiling this tribute. Discussion with Phil Gibbard was helpful and encouraging. The photograph shown is of Jean-Pierre Lautridou on site at Evreux in 2002 (Photo taken by Dominique Cliquet).

John Renouf
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LETTER TO THE EDITOR

Dear Sir,

It would appear from the articles of Straw and of White *et al.* in Quaternary Newsletter No, 123, February 2011 that there is increasing support for the hypothesis of an advance of a Saale-equivalent ice sheet into the Midlands and East Anglia. This begs the question of what was happening to the west of the Pennines. While not wanting to enter into any controversy relating to the 'Wolstonian type area' of the West Midlands, I would like to draw researchers' attention to previous work at the southern end of the Derbyshire White Peak area. During the geological survey of the Ashbourne area (Chisholm *et al.* 1988), at least three distinct glacial episodes were recognised that, at the time, were correlated with the Anglian, Wolstonian and Devensian of other regions. The distribution of glacial deposits from these events was shown in Figure 25 (p.93) of the memoir although the descriptions for ice limits given in the key were erroneously transposed. For the second of these events, Figure 25 also showed a clear distinction between glacial deposits of northern derivation (Area 2) from a late advance from the east by ice that deposited Cretaceous flints, believed to be mostly reworked, noted throughout this area in surface soils, sections and in the Rodsley BGS borehole (south of Ashbourne) in till to a depth of *c*.10 m (Area 3). Given Professor Straw's interpretations of the area only tens of kilometres to the east, could it not be that this late advance of eastern ice correlates with his Saale-equivalent deposits?

Sincerely

Tim Charsley

tcharsley@hotmail.com

Chisholm, J.I., Charsley, T.J. and Aitkenhead, N. (1988). *Geology of the Country around Ashbourne and Cheadle*. Memoir of Geological Sheet 124 (England and Wales), HMSO, London.

ARTICLE

THE POCKLINGTON ALLUVIAL FANS OF YORKSHIRE AND THEIR RELATIONSHIP WITH LATE DEVENSIAN SHORELINES OF PROGLACIAL LAKE HUMBER

Bill Fairburn

Received 21st September 2010 Reviewed and accepted 18th January 2011

Abstract

Landform mapping has shown that the geomorphology of the landscape in the region of Pocklington, between the eastern edge of the Vale of York and the Triassic / Jurassic escarpment of the Wolds, evolved in the Late Devensian by the depositional and erosional control exercised by receding shorelines of pro-glacial Lake Humber on prograding alluvial fans. Terminations of these alluvial fans, which originated by the degradation of frost-shattered Chalk formation was principally at elevations near 33 m and 20 m, with minor terminations at 25 m. The 33 m elevation is thought to be a shoreline equivalent to the 33 m surface of the York Moraine and the 100 Foot Strandline mapped on the western side of the Vale of York, south of Tadcaster.

Introduction

It has generally been accepted that during advance of Late Devensian ice in the Vale of York a substantial pro-glacial lake became impounded in the Vale of York due to a barrier of North Sea ice, and later till, blocking the Humber mouth (Gaunt, 1981). Lewis (1894) referred to this pro-glacial lake as Lake Humber. Two main stages of this lake have been recognised. Edwards (1937) identified strandline deposits around the 100 foot (30.5 m) contour, extending along the Permian escarpment from Tadcaster towards Doncaster. These deposits, also recognised by Bateman *et al*. (2008) near Ferrybridge, were referred to by Gaunt (1974) as the Older Littoral Sand and Gravel that originated during a high-level stage of Lake Humber at *c*. 33 m above OD. A second lower stage of Lake Humber recognised by Edwards (1937), at the base of the Permian escarpment, forms the plain of the Vale of York. This surface, considered by Gaunt (1974) to have been deposited between 10 to 14 m above OD during a low-level phase of Lake Humber, has been referred to informally in this text as the 10 metre surface.

Whilst low-level Lake Humber is clearly defined on the older Selby 1:50 000 sheet (British Geological Survey, 1973) by the eastern edge of the 10 m surface (underlain by the 25 Foot Drifts of Edwards, 1937) evidence for an eastern high-level Lake Humber is scarce. An inferred eastern edge of high-level Lake Humber, traced onto a glacial map of Britain (Clark *et al.*, 2004), is based on elevation only. Deposits thought to be equivalent to the Older Littoral Sand and Gravel of Edwards (1937), that form a southwesterly sloping surface, up to 4.0 km wide, underlain by chalk and flint gravel were mapped by the British Geological Survey (1973) near Pocklington. More recent mapping, however, has reinterpreted these deposits as glaciofluvial fans (British Geological Survey, 2008). The only gravel deposits, on the eastern side of the Vale of York, whose description shows any resemblance to the 100 Foot Strandline deposits of Edwards (1937) occur at Everthorpe [SE 907 320], and Mill Hill [SE 942 278] near Elloughton to the northwest of the Humber Gap. At both these locations gravels composed mainly of chalk and flint, outcropping between 30-35 m above OD, have been equated with the 100ft strandline by Edwards (1937) and de Boer *et al.* (1958). Additional descriptions of these deposits have been made by Dakyns *et al.* (1886), Lamplugh (1887) and Gaunt *et al.* (1992).

A differing view on the Late Devensian evolution of the Vale of York has however been presented by Fairburn (2009) based on geomorphological mapping of the York Moraine. This mapping, which was initiated after a series of traverses over the moraine near York, had identified the moraine as having a step-like or tiered profile: each step appearing to be a laterally horizontal terrace eroded into the rising surface of the moraine. Extension of the mapping to a large area of the moraine later revealed that the main terraces were not localised features but had regional significance. Because of this, it was concluded that the terraces were shoreline features produced by erosional stands of Lake Humber. The most prominent strandlines occur at *c.* 20 m, *c.* 25 m and *c.* 33 m above OD with a higher strandline at *c.* 40 m above OD near Bilborough (Fairburn, 2009).

The most important conclusion to be drawn from the geomorphology of the York Moraine was that if the terracing represented shorelines of Lake Humber, then at the time this occurred, the Vale of York glacier must have retreated well to the north of York (Fairburn, 2009).

Objectives and study area

This study is the second published segment of an on-going program of geomorphological mapping, currently in progress, being conducted in the central part of the Vale of York and along the western edge of the Wolds. The primary objective of the recent work was to re-examine, by landform mapping, the geometry of the Older Littoral Sand and Gravel described by Gaunt (1981) in the region of Pocklington and to confirm, if possible, whether these sediments are equivalent to the 100 Foot Strandline deposits of Edwards (1937). Secondary objectives would be to determine the significance of any landforms recorded in the area.

As however the mapping methods used in this study and in the earlier work by Fairburn (2009), differ from more traditional lithological mapping, a long-term objective of this work could be to present an alternate view on the Late Devensian evolution of the Vale of York. It is therefore not intended, at this stage, to resolve any contradictions made by the mapping with earlier work by Ford *et al*. (2008) or Murton *et al*. (2009). It is hoped, however, that this work will eventually lead to a better understanding of isostacy and geochronology in the Vale of York.

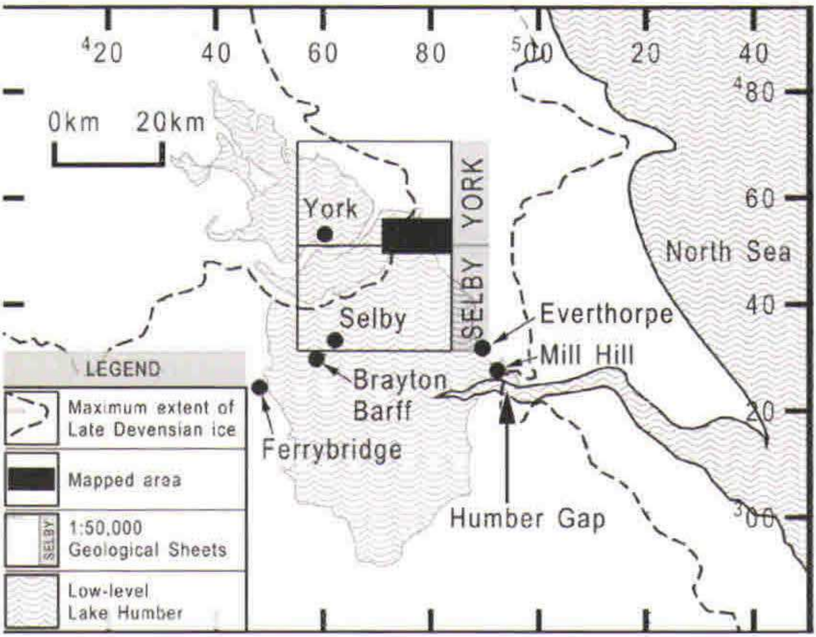

Figure 1. Location plan showing relationship of the mapped area to the maximum extent of Late Devensian ice (after Ford *et al*., 2008).

The selected study area (Figure 1), of just over 100 km^2, lies within the Selby and York 1:50 000 sheets (British Geological Survey, 1973; 1983) and extends from part of the eastern bank of the River Derwent, south of Stamford Bridge, towards the eroded edge of the Triassic-Jurassic escarpment of the Wolds. The area was specifically chosen to cover much of the Older Littoral Sand and Gravel mapped on the older Selby 1:50 000 sheet (British Geological Survey, 1973) around Pocklington [SE 802 489]. Geologically, the area includes the northern extremity of the Escrick Moraine and the eastern edge of the 10 metre surface west of Barmby Moor [SE 779 491] and Fang Foss [SE 765 532], which are continuous with part of the eastern edge of earlier mapping by Fairburn (2009).

Landform mapping

Recognition of landforms has long-been a part of geological mapping with significant features, such as floodplains bordering major rivers, being usually delineated in the field at the topographic boundary between the alluvial flats and the rising land surface. Such boundaries are both erosional and depositional. Whist such landforms have been identified flanking the River Derwent at Stamford Bridge many other landforms have been recognised in the Pocklington region. The most significant of these is based on the re-interpretation of the Older Littoral Sand and Gravel deposits of Gaunt (1981), which form the low-angle slope between Pocklington and Barmby Moor. These are now considered to be alluvial fans discharging from steep-sided valleys cut into the Triassic/Jurassic escarpment by drainage channels such as Pocklington Beck, Millington Beck and Bishop Wilton Beck (Figure 2). This change of interpretation has subsequently resulted in the recognition of two ages of alluvial fans (older high-level and younger low-level fans) separated by lateral erosional contacts. Whilst these features provide two of the major landforms in the region and an answer to the primary objective of the project, many other significant landforms were also noted during the mapping. In summary these include any level or gently inclined planar land surface, which has distinct topographic boundaries resulting from erosional or depositional processes, that can be plotted in the field on the 1:25 000 Ordnance Survey base map. The most important of these are:

1. Marginal erosion boundaries along the edge (or edges) of major depositional surfaces, such as the plain of the Vale of York.
2. Form lines recorded at the point of inflection of erosional terraces with the rising surface of a hillside.
3. Form lines marking a change of slope forming a visible break on the side of a hill.
4. Deposition edges produced by sediment terminations, or a marked down-slope gradient variation resulting from lithological changes, such as sediment fining.
5. Boundaries of erosion surfaces, particularly those in crestal or near crestal locations on hill tops or ridge lines.

However only those features that were robust enough to have regional continuity were used to delineate the major landforms shown on Figure 2.

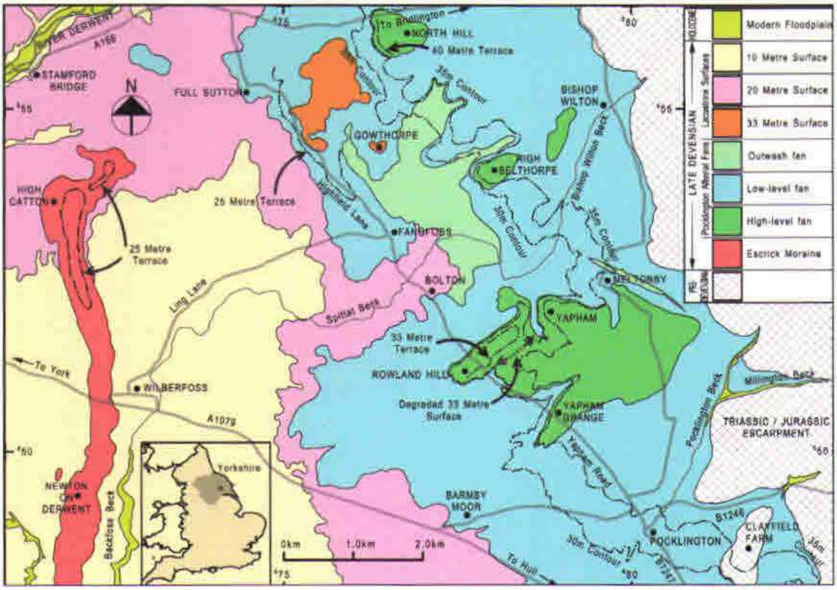

Figure 2. Landforms in the region of Pocklington resulting from the interaction of prograding alluvial fans with the receding shoreline of Lake Humber.

Landforms

The landforms shown on Figure 2, apart from the Pocklington alluvial fans, vary from major features such as extensive depositional surfaces down to minor features such as terracing. Implicit in this statement is that while the designated surfaces can be clearly mapped as continuous features, the terraces may be more localised. In some cases, however, a set of apparently minor erosional features, at a similar elevation, may define an extensive erosional event with regional implications. As in the description of the York Moraine (Fairburn, 2009), the terraces are laterally horizontal; may vary in width from a few metres to several tens of metres and are generally gently inclined into the rising hillside.

The 40 metre terrace is the least well defined landform and is only indicated by localised terracing near the 40 m contour at North Hill [SE 764 560] and above Yapham Grange [SE 791 505], and by an erosional area underlain by Triassic marl near Clayfield Farm [SE 816 485].

The 33 metre surface, the most conspicuous shoreline of Lake Humber on the York Moraine and on the western side of the Vale of York is perhaps only represented in the Pocklington region by isolated erosional features. These include the erosional surfaces, at between 30 m and 35 m, over inliers of Triassic marl southwest of North Hill [SE 757 554] and at Gowthorpe [SE 764 545], as well as erosional terraces close to the 35 m contour near Yapham [SE 789 521] and above the 30 m contour at Rowland Hill [SE 776 512]. The Yapham Cricket field [SE 784 516] also probably lies on this surface. Other erosional features that could mark a *c*. 33 m shoreline are the distal terminations of the high-level alluvial fans. These occur near 35 m at North Hill and southwest of Yapham Grange and between 30 and 35 m at High Belthorpe [SE 780 541] and Rowland Hill.

The 25 metre terrace that forms a conspicuous feature on the Escrick Moraine, in the vicinity of High Catton, is not a prominent feature elsewhere in the region, suggesting that this terrace could have been mantled or eroded by later fluvial sediments. The terrace is, however, present adjacent to Highfield Lane (Figure 2) between Fangfoss [SE 765 532] and Full Sutton [SE 745 554] over shallow subcropping Triassic marl, and possibly bounding a small planar surface at the edge of the high-level fan east of Bolton [SE 781 532]. It also marks the termination of the low-level alluvial fan southwest of High Belthorpe [SE 776 538] where it grades into an outwash fan of clayey sediment.

The 20 metre surface, which mainly lies between the 15 m and 20 m contours, is represented near Stamford Bridge by the extensive early floodplain of the River Derwent, where it breaks through into the Vale of York between the York Moraine and the northern termination of the Escrick Moraine. The surface here is continuous with earlier mapping by Fairburn (2009) west of Stamford Bridge. Elsewhere the surface appears to form a littoral deposit, standing above the Vale of York, stretching from west of Barmby Moor towards Full Sutton.

To the north of Spittel Beck [SE 760 519], and towards the Escrick Moraine, the western and southern edge of the 20 metre surface forms a distinct topographic feature as it rises about a metre above the lacustrine sediments of the Vale of York. Its eastern edge is also a distinct mappable feature, as it passes into the rising terminal margin of the low-level alluvial fans.

South of Spittal Beck, where the surface has been equated with the Bielby Sand Member of the Breighton Sand Formation on the Selby 1:50 000 sheet (British Geological Survey 2008), the western edge of the surface is often marked by extensive sand deposits, forming dunes and bars running parallel to a possible paleo-shoreline that has provided an environment for rabbit warrens. It's eastern edge, which may also be marked by sand ridges, particularly on a line southwest of Bolton [SE 771 523] towards the A1079, the boundary is more frequently only indicated by a barely perceptible change of slope or by mounds of wind-blown sand developed on the low-level alluvial fans. Southeast of Barmby Moor [SE 782 484] the boundary is partly obscured by earthworks along the A1079.

The 10 metre surface is the expanse of bedded clay and sand that forms the flat plain of the Vale of York, which adjacent to the Escrick Moraine, lies between 10 -15 m. Formerly known as the 25 Foot Drifts (British Geological Survey, 1973) these sediments, in the mapped area (Figure 2), have been renamed as the Thorganby Clay Member of the Hemingbrough Glaciolacustrine Formation and the Bielby Sand Member of the Breighton Formation (British Geological Survey, 2008). This surface has a distinct erosional or depositional edge against the Escrick Moraine and the 20 metre surface and rises above modern alluvium in the Derwent River valley. During the recent mapping (2009) a contact was not recognised between the Thorganby Clay Member and the younger Bielby Sand Member, although coarse to medium-grained yellow sands, attributable to the Bielby Sand Member, are widely distributed on the 20 metre surface and have been noted within cultivated ground on the 10 m surface (e.g. westerly of Barmby Moor [SE 756 482]).

Pocklington Gravel Formation

The Pocklington alluvial fans, shown on Figure 2, formerly mapped as the Older Littoral Sand and Gravel (British Geological Survey 1973) have been renamed the Pocklington Gravel Formation by Ford *et al.* (2008). During the recent mapping (2009), two sets of fans were recognised: older high-level fans which terminate down-slope close to the 30 m or 35 m contour, and younger, low-level coalescing fans originating from valleys in the Wolds, that terminate at or just below the 20 m contour. Straw (1963) has described similar 'low-level fans' emanating from valleys eroded into the scarp of the Wolds in north Lincolnshire, and these have been given an inferred age by Bateman *et al.* (2000), of between 14 and 18 ka.

The gravels forming the alluvial fans are dominantly composed of sub-rounded chalk pebbles, with many fragments retaining original tetragonal fracture shapes, more angular nodules of flint and lesser amounts of sand.

Typically, the high-level fans are represented by the erosional remnants of older planar sloping surfaces that were dissected by younger drainage channels, that deposited the low-level fans. Invariably, these residuals have proximal (i.e. closer to the Wolds) and lateral erosional contacts with the low-level fans but have distal depositional terminals near the 30 m or 35 m contours. The largest of these remnants extends from a ridge, at an elevation of about 55 m southeast of Meltonby [SE 802 521], down to terminal points between Rowland Hill and Yapham Grange on a decline of about 10 m/km. This slope, to the southwest, has been modified northeast of Rowland Hill by strandlines and erosion surfaces which are included in this text as part of the 33 metre surface. Other remnants of the high-level fans occur at High Belthorpe, North Hill and at a small ridge [SE 790 546] southeast of Bishop Wilton. In places, such as southwest of Yapham Grange [SE 784 500], the terminal slope of the high-level fan may extend further as a less-prominent low-profile ridge.

Although the present-day geometry of the high-level fans appears to have the form of low-angle sheets of colluvium on ridges with post-depositional erosional edges, underlain by near-surface Triassic marl, it is highly likely that these features originated as alluvial fans following older glacial events, as they are now detached from their depositional source.

The low-level fans occupy most of the mapped area from the edge of the Triassic/ Jurassic escarpment down towards the 20 metre surface. Generally the fans particularly between Bishop Wilton Beck and Millington Beck form a coalescing surface that slopes southwesterly (or more rarely southerly) from about 30 m/km down to less than 5 m/km. At some locations, for example along the Fangfoss – Full Sutton road, at Gowthorpe, and on a spur [SE 773 544] between Gowthorpe and High Belthorpe, discrete fans are separated by drainage areas forming clayey outwash fans. Mostly the fans terminate at or below the 20 m contour on the 20 metre surface, except in the region of Gowthorpe where terminations are closer to 25 m. The lithology of the low-level fans is comparable to the high-level fans, while sections through the deposit, which can generally only be seen in temporary excavations (see Ford *et al.* 2008, Plate 3), do show they have a clast supported fabric with crude cross bedding.

Features described as outwash fans are essentially drainage areas that take the form of a gently sloping plain composed of clayey alluvium mainly devoid of clastic sediment. These surfaces appear to have originated by a cessation of sediment supply to the discrete low-level fans mainly in the region southeast of Gowthorpe and southwest of High Belthorpe, at or near the 25 m contour. The lower edge of the outwash fan, despite appearing to grade almost imperceptibly into the 20 metre surface near Fangfoss and Bolton, has had a contact drawn arbitrarily against the 20 metre surface at the 20 m contour.

Isostacy

Gaunt (1974) has stated that low-level Lake Humber had a prolonged stay at 10 to 14 m above OD between York and Doncaster, during which time the 25 Foot Drifts were deposited. The northerly rise in the surface of these deposits, and for the older high-level sand and gravel (100 Foot Strandline deposits), has been attributed by Gaunt (1981) to existing isostatic depression.

In the mapped area around Pocklington the sediments underlying the plain of the Vale of York have a constant depositional boundary of about 15 m above OD against the Escrick Moraine and an erosional boundary at a similar elevation against older lacustrine sediments. Similarly both the proximal and distal edges of the 20 metre surface remain at a fairly constant elevation except where it is overlain by younger fluvial sediments: older terracing is not extensive enough to provide further evidence of elevation change. It can therefore be concluded, that within the confines of the mapped area, the lacustrine surfaces do not provide any evidence for isostatic change and if any change has occurred, it must have preceded the impounding of Lake Humber.

Discussion

As already discussed, Fairburn (2009) considered that terraces on the York Moraine, because of their regional extent, must have originated as shorelines produced by erosional stands of Lake Humber. Support for this assertion is provided by the fact that there is no likelihood that the terracing could be the result of differential erosion of a stratified sequence. It is therefore plausible that terracing in the region of Pocklington, at similar elevations, could also be lacustrine in origin. Such a conclusion is supported by additional evidence of the high-level fans having erosional terminations between 30 – 35 metres above OD, or close to what has been accepted as high-level Lake Humber. The added implication is that the high-level fans must have been in existence prior to the build-up of Lake Humber and consequently originating from an older glacial event.

The Pocklington alluvial fans, that extend westwards from incised valleys in the Wolds, must have originated by degradation of frost-shattered Chalk formation that had been locked in place by permafrost (French, 2007; see also Hitchens, 2009). The retained tetragonal shapes of some of the chalk clasts, within the alluvial fans, has resulted from the platy brecciation of Chalk bedrock that can occur at depths of up to 5-10m under periglacial conditions (French, 2007, Figure 13.2). Degradation of the permafrost by fluvial erosion would have been caused under ameliorating weather by meltwater from local snow accumulations (Price *et al.*, 2008 from Waltham *et al.*, 1997; Bateman *et al.*, 2000).

Conclusions

Geomorphological mapping along the eastern side of the Vale of York, near Pocklington, has revealed that all the strandlines described by Fairburn (2009) from the York Moraine, can be recognised in the region by their imprint on post-glacial depositional events. These events include lacustrine deposits, littoral shorelines and prograding alluvial fans.

Mappable shorelines, which are ubiquitous to the area, include the lacustrine edge of low-level Lake Humber, which is referred to in this text as the plain of the Vale of York or the 10 metre surface, and the 20 metre surface, which forms both a littoral zone and part of the older floodplain of the River Derwent. Less significant is the 25 metre strandline, which forms a terrace on the Escrick Moraine and a localised termination for some of the alluvial fans. The most widely recognised strandline (or erosional surface) of Lake Humber is the 33 metre surface (100 Foot Strandline of Edwards 1937) and this is recorded in the area, not as a continuous strandline, but by localised erosional surfaces such as:

1. Planar surfaces eroded on Triassic marls at *c.* 30 m above OD

2. Strandlines and planar surfaces eroded on the high-level alluvial fans at *c.* 33 m above OD; and

3. Depositional terminations of the high-level fans imposed by a shoreline at a stand of Lake Humber between 30-35 m above OD.

The alluvial fans, which result from degradation of permafrost shattered Chalk formation in the Wolds, occur at two distinct levels as a consequence of a partial drainage of Lake Humber to a base-level of 20 m above OD from 30-35 m above OD.

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REPORTS

QRA ANNUAL DISCUSSION MEETING: PALAEOHYDROLOGY: LEARNING LESSONS FROM THE PAST

4-6th January 2011

The QRA Annual Discussion Meeting 2011 was hosted by the University of Liverpool under the title '*Palaeohydrology: learning lessons from the past*'. This theme brought together researchers from across Quaternary science disciplines, and from universities and research institutions around the world. Material was presented from a range of environments; from temperate fluvial systems, lacustrine settings, peatlands, deserts and glaciated regions.

This year's meeting was organised by Fabienne Marret-Davies, Richard Chiverrell, Neil Macdonald, Barbara Mauz and Andy Plater and was held in the Victoria Museum, University of Liverpool. The three day programme comprised five oral presentation sessions, poster sessions, an open debate and conference dinner. Sessions were centred on five main themes: Quaternary changes in hydrological systems; Palaeohydrology of the last G-IG cycle; Holocene palaeohydrology; Human-induced changes in palaeohydrology; and Future changes in water regimes. Each session provoked lively discussion on the use of long-term palaeohydrological records in our understanding of past, present and future hydrological dynamics.

Neil Macdonald (University of Liverpool) provided a very fitting start to proceedings with his review of historical records of flooding in the UK. This provided a thought provoking introduction to the ways in which long-term records, over historical timescales and beyond, can be used to better understand contemporary fluvial system response to environmental change. **Richard Chiverrell** (University of Liverpool) echoed these sentiments with a review of flood records preserved within lacustrine environments. The discussion continued with **Graeme Swindles** (University of Leeds) presenting a multiproxy insight into palaeohdrological fluctuations at Malham Tarn Moss, in the Yorkshire Dales. This project emphasised the merits of combining multiple analyses, at a variety of spatial scales to better understand the palaeohydrological archive within peatland environments. The identification of the Glen Garry tephra layer here provided a robust geochronological marker, allowing the Malham Tarn record to be correlated with other peat-based records. The diversity of the conference was continued by **Roger Belshaw**, presenting a Middle to Late

Pleistocene sedimentary record of the Upper Thames Basin. This focused on the use of sedimentary architecture to infer process conditions at the time of deposition. This was used to suggest a spatially and temporally complex record of terrace formation under both periglacial and full glacial conditions.

The use of sedimentological records in resolving long-term river history was emphasised by **Varyl Thorndycraft** (Royal Holloway) through the comparison of the River Till and the River Erme. This combined floodplain stratigraphy and hydraulic modelling approaches to assess the impacts of land-use and mining activity on sediment supply over the last 800 years. These findings have important implications for our understanding of river systems elsewhere that have been influenced by Holocene land-use changes. Similarly, the complexities of Lateglacial fluvial activity were illustrated by **Lynda Yorke** (Aberystwyth University), through the investigation of postglacial fluvial sequences of the River Tyne Valley, Northumberland. Extensive field mapping, combined with NEXTMap DSM data has allowed important new interpretations of the links between river development, glaciation, climate and sea level during the Lateglacial. The importance of this critical period in Quaternary environmental history was further emphasised by **Jim Innes** (Durham University), presenting the postglacial evolution of the Swale-Ure Washlands, North Yorkshire, and **David Passmore** (Newcastle University), investigating the Lateglacial record of the River Till. The studies highlight the significance of postglacial records in providing a valuable long-term context for Holocene fluvial activity and human settlement.

After dinner, the delegates reconvened for the conference open debate, entitled '*Flood risks: your answers questioned?*'. The debate was well attended by members from academic, policy and public spheres. The panel was chaired by **Professor Peter Batey** (University of Liverpool), **Andrew Miller** (MP for Ellesemere Port and Neston), **Toby Willison** (Environment Agency), **Christine Darbyshire** (Liverpool City Council), **Professor Mike Ellis** (British Geological Society) and **Professor Kevin Horsburgh** (National Oceanography Centre). The panel of experts posed questions to the audience, generating lively discussion on the theme of flood management strategies. Amongst the key issues to be raised during the debate were: the importance of multi-disciplinary communication; and the necessity for a greater accessibility of research findings to policy makers. The debate sparked highly insightful discussion on the ways in which academic research could be more effectively transferred to the public and policy realms.

The second day of talks commenced with The Geological Society keynote presentation by **Phil Gibbard** (University of Cambridge) which reviewed and challenged the broad-scale models of geomorphological processes in European river systems and the origin of river terraces. Discussion focused on the significance of cold climate conditions in driving geomorphological activity, which contrast markedly with interglacial and 'climatic transitional' phases. This presentation provided important context for the variety of talks to follow. A high resolution study of Danish lakes, presented by **Wing Wai Sung** (Loughborough University), presented important findings from the Mesolithic-Neolithic transition, which separated climatic and cultural forcing factors. The importance of biological proxies in reconstructing palaeohydrological conditions was further emphasised by **Jens Holtvoeth** (University of Liverpool). This study focused on the organic-geochemical investigation of Lake Ohrid to assess the impacts of the 8.2ka event on the Balkan Peninsula through the use of lipid biomarkers. These studies demonstrated the advantages of palaeohydrological records in recording changes at a variety of temporal scales. Further discussion by **Harry Langford** provided a review of the long-term impacts of Middle-Late Pleistocene ice advances on the East Anglian region, whilst **Wim Hoek** (Universiteit Utrecht) provided a decadal-resolution LOI record of the River Rhine over the last 7ka, establishing the nature of extreme flood events. These sentiments were echoed by **Rebecca Briant** (Birkbek College) who highlighted the importance of understanding long-term fluvial records through linking sedimentology, geochronology and modelling approaches. This session was concluded by an exciting new dataset, presented by **Claire Mellett** (University of Liverpool). High resolution mapping and seismic surveys of the English Channel provided important context for the submarine record of this region, which has been previously poorly understood when compared to the terrestrial archive.

The following session was opened by a keynote presentation by **Jamie Woodward** (The University of Manchester). This provided an illuminating review of Quaternary palaeohydrological records from glaciated regions of the Mediterranean and demonstrated how these records may prove significant for our understanding of palaeohydrological systems across the world. This theme was continued by a presentation by **Abi Stone** (Oxford University). This study demonstrated a highly novel approach to developing a palaeo moisture proxy during the late Holocene in the Kalahari Desert Sand using groundwater recharge through sand dunes. A wider Mediterranean perspective was also provided by **Neil Roberts** (University of Plymouth) through the use of dryland lake records to quantify late Holocene hydro-climatic variability. This reaffirmed the notion of palaeohydrological records proving significant at a range of timescales from historical to geological. The session was concluded by a further talk from Jamie Woodward on collaborative research in the Sudanese Nile, establishing a detailed Holocene flood record. This study used OSL, ^{14}C and isotopic indicators to provide an insightful record of Holocene river behaviour and its implications for human settlement.

The final session of the day was kicked off with a keynote presentation by **Dan Charman** (University of Exeter) which provided a detailed insight into the use of peatland archives as high resolution indicators of seasonal water balance and precipitation. The quantification and calibration of peatland hydrological records should be more widely applied to allow these archives to be effectively tied to wider palaeoenvironmental proxies. For example, a promising new approach to organic geochemistry in peat-based reconstructions was presented by **Erin McClymont** (Newcastle University). This novel study used biomarkers and plant sterols to establish late Holocene hydrological variations in peatlands across Western Europe.

The merit of palaeoecological indicators from hydrological records was further illustrated by an insightful study presented by **Lynda Howard** (Loughborough University). The use of fossil macroinvertebrates from palaeochannel deposits were shown to provide an effective indicator of source environments within the fluvial realm. The day's presentations were concluded by a thought provoking talk by **Jim Rose** (Royal Holloway) which emphasised the necessity to more thoroughly understand the processes operating within Quaternary fluvial systems. This understanding can be used to reach more reliable palaeoenvironmental reconstructions. This sparked lively discussion amongst all delegates, and provided an excellent ending to a day of very enjoyable presentations.

The conference poster sessions provided delegates with a highly diverse and well-presented selection of posters on a range of topics including: palaeochannel fill architecture in Holland (**Willem Toonen** *et al.*); Palaeo-lake drainage in Canada (**Vicky Brown** *et al.*); River response to Pleistocene Mediterranean glaciations (**Kathryn Adamson** *et al.*); Palaeohydrological transitions in the Mer Bleue Bog, Canada (**Suzanne Elliot** *et al.*); ENSO analogues of tropical Pacific climate response to Termination 1 (**Erin McClymont** *et al.*); Hydrology, climate and social change in Ireland (**Stuart Black** *et al.*), and Palaeoecological and hydrological status of Keighley Moor (**Antony Blundell** *et al.*).

The conference dinner this year was held at the Hard Day's Night Hotel, themed around the 'Fab Four'. Delegates enjoyed a three course meal in the bar and restaurant of the Grade II listed building, whilst soaking up The Beatles atmosphere!

The final day of the conference began with the Wiley Lecture, presented by keynote speaker **Guillaume St Onge** (Institut des sciences de la mer de Rimouski (ISMER) and GEOTEP). This talk presented a highly insightful study into the Lake Agassiz-Ojibway outburst flood at c.8,500 cal BP. This dynamic talk discussed the use of sedimentological data alongside submarine sonar imagery to derive a reconstruction of deglacial flooding events in Eastern Canada. This project provided a very fitting example of the interplay between local-scale palaeohydrological dynamics and their impacts on regional, or even hemispheric Quaternary environmental change. The strongly multifaceted nature of this project perfectly epitomised to the talks seen in the previous sessions, all of which comprised strongly multi-proxy and collaborative approaches. The theme of megaflooding was continued by **Paul Carling** (University of Southampton), presenting a highly insightful talk on the sedimentology of megaflood deposits using examples from the Altai Mountains, Siberia. This discussion provided an informative review of the key characteristics of megaflood deposits, whilst suggesting a move towards a general model for styles of megaflood sedimentology that can be applied to both present and geological records. The necessity for palaeohydrological research to remain grounded within fundamental contextual framework was emphasised by a thought provoking discussion by **Ian Candy** (Royal Holloway) on the coupling of OSL and U-series geochronologies in the Mediterranean. Through combining multiple dating techniques, together with a sound understanding of the environmental context, it is possible to more securely constrain the nature and timing of palaeohydrological response to Quaternary environmental change. This provided a resounding message for all delegates, before a brief interlude and the Awards Ceremony.

This year, three QRA prizes were awarded to four distinguished members of the Quaternary community. Honorary membership was awarded to **Ann Wintle** (Aberystwyth University) for her pioneering contribution to, and enthusiasm for, the field of luminescence dating. Honorary membership was also awarded to **Valerie Hall** (Queens University, Belfast), for her exceptional dedication and contribution to palaeoecology and Quaternary tephrachronology. The Lewis Penny Medal, awarded for outstanding contribution to the Quaternary stratigraphy of the British Isles, was awarded to **Paul Butler** (Bangor University) for his pioneering role in the development of molluscan sclerochronology.

This year, the inaugural James Croll Medal, the highest honour of the QRA, was awarded to **Geoffrey Boulton** (University of Edinburgh). The Medal is a tribute to the life and work of James Croll and is awarded to a member of the QRA whose work in the field of Quaternary Science has attained significant international impact. Professor Boulton's groundbreaking work provided the first direct evidence for the deformation of subglacial sediment. His continued work has constantly developed and defined our understanding of subglacial sediment deformation and endeavours to expand our understanding of the broader scale links between ice sheets and the climate system.

The awards were followed by a highly dynamic presentation by Geoffrey Boulton on the theory of tunnel valley formation in the subglacial environment. The theory suggested that their formation reflects large-scale shifts in subglacial drainage patterns, and highlights ways in which these insights can be tested. The talk drew together many of the themes inherent to the overall conference ideology, and put forward challenging and stimulating material for all. The final talk of the conference, by **Trevor Faulkner** (University of Birmingham) presented a model for the deglaciation of Central Scandinavia. This model discussed the interactions between sea level, ice sheet dynamics, and ice dammed lakes to derive a detailed reconstruction of ice retreat and meltwater dynamics. These final presentations, alongside those delivered throughout the conference, highlighted the complexity of palaeohydrological systems, and emphasised our increasing ability to understand their dynamics over such a wide range of environmental contexts and timescales.

Long-term palaeohydrological change, short-term catastrophic events and human-induced changes in hydrological systems have all formed important themes and research stimuli for the duration of the conference. Discussion has also led the way in highlighting the significant value of Quaternary palaeohydrological records in informing our understanding of present and future hydrological systems. This demonstrates a promising start to encouraging greater discourse between the Quaternary science community, the public and policy makers. I'm sure I will be joined by all in attendance in offering my further thanks to all conference organisers and delegates for providing such an insightful and enjoyable start to 2011.

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GLACIAL LANDSYSTEMS WORKING GROUP MEETING 11: ANGLESEY

October 29th-31st 2010

This was the 11th meeting of the Glacial Landsystems Working Group but the first as a formal working group of the Quaternary Research Association. As the evening of the 29th October approached, 39 people from far and wide were making their way to The Outdoor Alternative, Holy Island, with the intention of a 20.30 hrs introductory talk in the common room, but as traffic and winding Welsh roads took their toll the night crept on. Once the group had collected we were treated to a brief overview of the weekend to come, including possibilities of bedrock control on subglacial bedforms and some new theories for stratified diamicts within drumlins. All in all it promised to

Figure 1. Attendees at the GLWG Anglesey meeting.

be a weekend of lively discussion. With that in mind the group proceeded to the local ale house for some much needed sustenance.

Saturday 30th October

Firmly prepared with waterproofs, just in case, the group headed out in convoy to the first field site at Cemlyn Bay. Before moving into the field, the group was treated to a look at a NEXTMap digital elevation model of Anglesey showing distribution of landform assemblages and underlying bedrock geology, inspiring conversation about possible bedrock control on the development of elongate subglacial bedforms and the 'footprint' of the Irish Sea Ice Stream.

Moving on to Cemlyn Bay itself, the group was presented with a cliff section through a drumlin that displayed distinct stratification including brown and grey diamicts and relatively well sorted sands exhibiting internal sedimentary structures. It was suggested that the sands may have been emplaced by mechanism of hydrofracturing; that water under intense pressure had been forced along the contact between units effectively splitting them apart and then depositing sands as pressure decreased in a manner that was dubbed 'split, squirt and seal'. While the hydrofracture theory came under much discussion there was a moment of silence as it was suggested that the sequence may not in fact represent tills but may have formed in a subaqueous environment thereby eliminating any need to explain the stratification within the drumlin itself. Whether the internal structure of drumlins need be explained by the drumlin formation process or whether it can be attributed to deposition prior to glacial overriding was to become a much debated feature of the weekend.

After a brief but pleasant stroll, the group reached Hen Borth, a drumlin truncated parallel to its long axis by wave action. The basal unit rests on bedrock and is described as a transitional sheared 'bedrock-diamict' unit. In the northern part of the section, sheets of bedrock can be seen to have sheared up into the overlying diamict. This conforms to ice flow direction established from striae in the local bedrock, which suggests ice flow was from the North East. This sequence provided more evidence for the previously discussed hydrofracture theory, with most agreeing that there was at least evidence of water transport along unit boundaries before the formation of water escape structures into the overlying diamicts.

After a slightly nervous drive through torrential rain, the skies cleared over the next field site at Penrhos. This drumlin section shows an internal structure consisting of crude bedding with stacked sheets of diamict interbedded with fine sand. The discussion here broadened to encapsulate the wider region, debating single and multiple event theories and the concept of a large scale surge type advance of ice south down the Irish Sea followed by a period of stagnation and eventual swift retreat. This provided an argument for the apparent lack of sediment deposited and evidence of a prominent retreat phase over Anglesey more generally.

The last stop of the day was unusual for the group in that it involved 'hard rock geology' rather than the Quaternary sediments most were used to. At the Rhoscolyn anticline the structural similarities and differences between sediments and hard rock were discussed, specifically in the context of deformation. The placement of S-type flanking folds in compressional or shear related environments was discussed with a view to establishing pressure direction and core features. Links were made to analogous glaciotectonic features that are often observed in diamicts.

A retreat was then made to the safety of the lodge to gather thoughts and prepare for the dark and winding route to the pub. During the course of the night it became obvious how stimulating the day had been as discussions and theories were all abound, ranging from ideas for a unifying theory of drumlinisation to how much importance should be ascribed to colour changes in the sedimentary sequence.

Sunday 31st October

During a bright morning, despite all forecasts for the area, a slightly relieved group made their way, although somewhat indirectly, to Lleiniog. At this site there were red-brown sands overlying a red-brown till and red-brown sands and gravels. The group were assured that several feet beneath us lay a blue-grey diamict and, as nobody seemed inclined to dig, this was generally accepted. The issue of Welsh ice versus Irish ice influence was discussed; the bulk of material within the section having being sourced from northern Britain and the Irish Sea Basin but with a small continuous influence of Welsh material taken to mean a confluence of the two ice streams somewhere to the North-east of the site.

While at this site, a structure previously identified as glaci-tectonic in origin was discussed in detail. However, as debate continued, overwhelming support for a syn-sedimentary process came to the fore, though exactly which process was still under question. The group fell predominantly into two camps; either a buried ice block with subsequent melting, slumping and water escape (the argument against being a lack of evidence for the processes necessary for ice block emplacement of the size required), or a density driven slump scenario eliminating the need for an ice block (the argument against being lack of evidence or space for movement in the underlying material). This debate remains unresolved and will, I am sure, feature in future communiqué.

After this site, those of the group eager to avoid being trapped in north Wales for the witching hour began the long drive home. In summary, the field sites inspired not only interesting discussion but also a basis for further research in the area. Overall, an excellent meeting and the organisers, Amanda Williams and Emrys Phillips, are thanked for all their hard work. The GLWG is going strong and plans are already in the making for next year's event.

For further details on GLWG and to join the mailing list for notification of future events, please visit:

http://www.dur.ac.uk/geography/qec/research_groups/glwg/

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IGCP PROJECT 588 1ST ANNUAL INTERNATIONAL MEETING, HONG KONG

30th November – 5th December 2010

IGCP Project 588 (*Preparing for Coastal Change: a Detailed Process-Response Framework for Coastal Change at Different Timescales*) is the successor of the highly successful Project 495 (*Quaternary land–ocean interactions: driving mechanisms and coastal responses*, 2004-2009), which was led by Antony Long (Durham University). It is the latest in a long series of IGCP projects related to Quaternary sea-level changes that dates back to 1974 and IGCP Project 61. The new project has four co-leaders: **Adam Switzer** (Earth Observatory of Singapore), **Craig Sloss** (Queensland University of Technology, Australia), **Ben Horton** (University of Pennsylvania, USA), and **Yongqiang Zong** (Hong Kong University). This inaugural meeting of the project was jointly organised with INQUA Project 1001 (*Quaternary Coastal Change and Records of Extreme Marine Inundation on Coastal Environments*), which together with the Singapore-based Stephen Hui Trust and UNESCO provided funding for many early career scientists, PhD students and scientists from developing nations to participate in the meeting.

The conference was hosted by Hong Kong University between 30 November and 5 December 2010. It encompassed 2.5 days of oral presentations and 1.5 days of field excursions. At the ice-breaker party on the eve of the meeting delegates were welcomed by the Pro-Vice Chancellor of Hong Kong University **John Malpas**, a geologist, and enjoyed local snacks and free-flowing beer. The meeting was truly international in scope, with 76 papers presented by scientists from 24 different countries, the majority coming from Southeast Asian countries, especially mainland China. The UK was represented by **Barbara Mauz** (University of Liverpool), **Michael Tooley** (St Andrews and Kingston Universities), **David Smith** (Oxford University), **Julian Orford** (Queen's University), and **Roland Gehrels** (University of Plymouth).

Four of the UK delegates were invited as keynote speakers. They delivered presentations on the history of sea-level research (Tooley), the impact of early Holocene rapid sea-level rise (Smith), coastal change in the Bangal Sundarban deltaic islands (Orford), and methods of sea-level reconstruction (Gehrels). Other keynote talks were given by **Yoko Ota** (National Taiwan University), **Yuki Sawai** (National Institute of Advanced Industrial Science and Technology, Japan), **Craig Sloss** (on behalf of co-author **Colin Murray-Wallace**, University of Wollongong, Australia), **Colin Woodroffe** (University of Wollongong, Australia), and **Bijan Saha** (Jadavpur University, India).

Michael Tooley provided an engaging personal perspective on the legacy of past sea-level researchers. He singled out the contributions of Sir Harry Godwin, Professor Rhodes Fairbridge, Dr Saskia Jelgersma, Dr Jørgen Troels-Smith and Professor Nils-Axel Mörner. The message to the audience was that these people were all exceptional field scientists (Nils-Axel Mörner is still active). Their papers form the foundation blocks of palaeosea-level research and are still deserving of citation, although many ideas may have been superseded by new ones. **David Smith** discussed the large sea-level rise during the early Holocene, when sea level rose globally by about 60 m in less than 5000 years, and highlighted its impacts on coastal societies and coastal landscapes. He provided insights on the various sources that may have contributed to the rise and on the feedback mechanisms between sea-level rise, inundation of continental shelves and climate change. **Julian Orford** fittingly addressed the problems facing the coastal communities in the deltas of the Gulf of Bengal in the light of future sea-level rise. Local knowledge about sedimentation processes and community support are key to successful adaptation in this region where 50-60 million people are confronted with the possibility of forced migration due to land loss. **Roland Gehrels** discussed methods of sea-level reconstruction from salt-marsh sediments, which have provided an important new dataset of sea-level data for the last half millennium. He highlighted the rapid early 20th century rise as a key feature of many proxy records and demonstrated that instrumental and proxy records were in agreement about the timing of this rise (i.e. the 1920s). He dedicated his talk to Orson van de Plassche, a former leader of IGCP Project 274, who passed away in 2009.

The inspired keynote address by **Colin Woodroffe** was of great significance to the project, as he spoke about the possible contributions that Quaternary coastal scientists can make to help address societal issues of coastal change and sea-level rise. He proposed that "if the present is the key to the past, then the past, seen from the context of the present, can be a guide to the future". This statement refers to the lessons that can be learnt from studying Quaternary sea-level changes and coastal processes: that patterns of sea-level change are regionally variable, that simple models such as the Bruun Rule should be replaced, and that GIA models and behavioural models of coastal change should be tested and validated with empirical data. Colin reminded the audience that IGCP Project 588 was not the first one that had the word *future* in the title. In fact, previous sea-level projects 200 (*Late Quaternary sea-level changes: measurement, correlation and future applications*, 1983-1987), 367 (*Late Quaternary coastal records of rapid change: application to present and future conditions*, 1994-1998), and 437 (*Coastal environmental change during sea-level highstands: a global synthesis with implications for management of future coastal changes*, 1999-2003) all had similar aspirations. Colin concluded that our knowledge of coastal change on annual ("PhD time") and millennial timescales is substantial, but that our knowledge on decadal to centennial time scales, which is so important for future planning, must be significantly improved.

Figure 1. Conference participants photographed on the Hong Kong University campus.

Yongqiang Zong and **Adam Switzer** lead the fieldtrip days. One afternoon was spent in the Mai Po marshes of the Pearl River Delta, where natural mangroves formed a wetland of international importance, although parts had been converted to shrimp and fish farms (*Gei Wei*). The city of Shenzhen loomed on the horizon on the other side of the border in mainland China. This is the fastest growing city in the world. About 30 years ago it was only a small fishing village, but now, mind-blowingly, Shenzhen is a mega-city bigger than London. The wetlands have somehow survived despite the impacts of pollution and increased sedimentation rates. We also spend half a day on the beach in Big Wave Bay where we discussed the impacts of a recent typhoon and the response by government agencies. There was controversial evidence of a mid Holocene sea-level highstand, which had been heavily debated in the literature, and also a Bronze Age rock carving.

The organisers must be congratulated with a successful inauguration of IGCP Project 588, in particular **Yongqiang Zong**, who was a superb and dedicated host. For more information on the project please visit the website www.coastal-change.org or contact the project co-leader **Adam Switzer** (aswitzer@ntu.edu.sg). At the business meeting it was proposed that future annual project meetings will be held in Thailand (2011), Singapore (2012), Germany (2013) and Alaska (2014).

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QUATERNARY RESEARCH FUND

CONSTRAINING THE RETREAT AND THINNING OF OUTLET GLACIERS OF THE SE GREENLAND ICE SHEET

Background and rationale

Elucidating the past behaviour of the Greenland Ice Sheet (GrIS) is essential to set current changes at the margin in context and provide data to constrain and validate numerical models predicting the future response of the ice sheet. The Holocene history of the South-East (SE) Sector in particular is only broadly known with little information on the detailed retreat of the marine-terminating outlet glaciers (Briner *et al*., 2010; Roberts *et al*., 2008) which are the dominant control on the volume of mass lost from the ice sheet (Alley *et al*., 2005; Velicogna, 2009). A grant from the Quaternary Research Fund facilitated fieldwork to Kangerdlugssuaq and Sermilik Fjords, SE Greenland in summer 2010 to address the current lack of information on glacier retreat rates beyond the last 30-50 years (Figure 1).

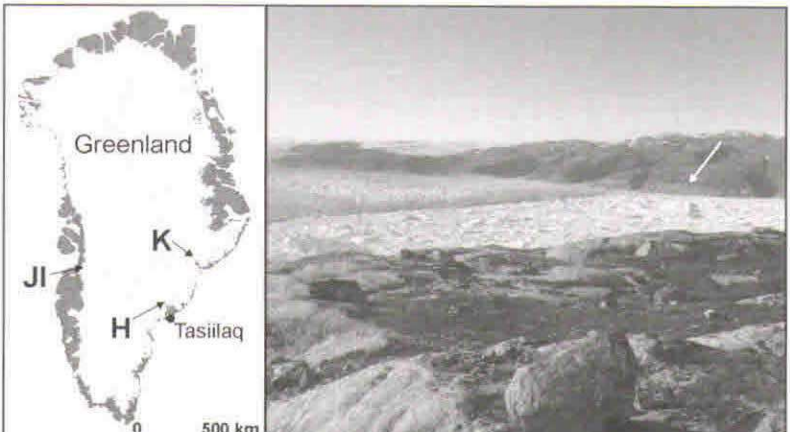

Figure 1: (a) Location map of SE Greenland. K = Kangerdlugssuaq Glacier, H= Helheim Glacier (Sermilik Fjord) the two largest marine-terminating outlet glaciers of the SE Greenland Ice Sheet. (b) Vegetation trimlines (shown by arrow) mark a previous vertical extent of Helheim Glacier.

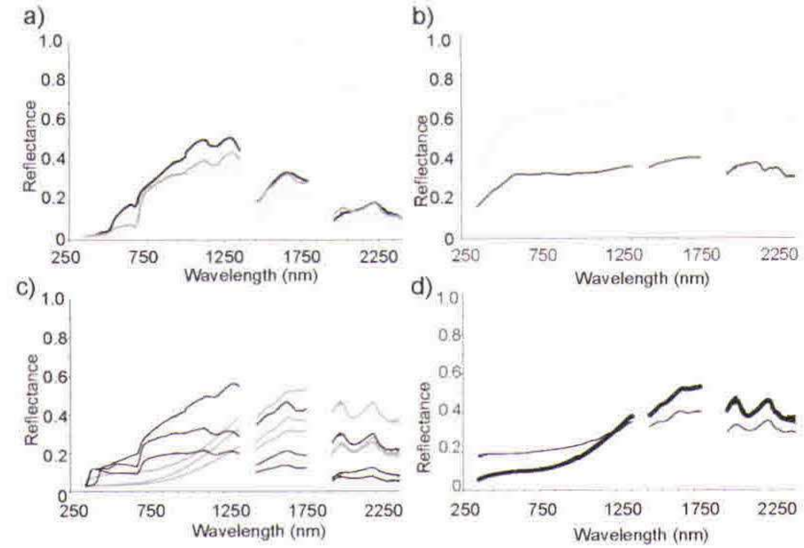

Figure 2. Field spectral measurements from surfaces characterising the deglaciated zone of Kangerdlugssuaq Fjord, SE Greenland. Key surface types exhibit distinct spectral responses: (a) Tundra vegetation; (b) pale and dark streamlined gneiss; (c) fructicose (dark lines) and black crustose lichen (grey lines); (d) Black crustose lichen (*Pseudephebe miniscula*) measured in the field (thick lines) and laboratory (thin line). Close correspondence of laboratory and field measurements suggests field measurements are reliable; slight differences likely reflect suboptimal lighting conditions in the field.

Preliminary results and significance

Vegetation trimlines are clearly visible in aerial photos and satellite imagery across the GrIS margin (Figure 1) and provide critical information on former extent (lateral and vertical) of the outlet glaciers during the Little Ice Age (1150-1850). Mapping trimlines for the whole ice sheet margin would provide an estimate of GrIS volume at this time (Csatho *et al.*, 2005). Distinct spectral differences between bare and lichen colonised rock surfaces allowed rapid mapping of trimlines from multispectral satellite imagery at Jakobshaven Isbrae, West Greenland (e.g. Csatho *et al.*, 2005; Knight *et al.*, 1987). To assess whether a similar approach can be applied across the ice sheet margin in different settings and rock types, spectral measurements of a variety of surfaces characterising the deglaciated margin of SE Greenland (including bare and lichen colonised rock and tundra vegetation) were collected. Measurements were made in Kangerdlugssuaq Fjord using an ASD FieldSpec3 on loan from the NERC Field Spectroscopy Facility. These data will be a critical quality assessment of classification mapping of the deglaciated fjords in SE Greenland to identify vegetation trimlines. Unfortunately poor weather conditions prevented sampling of the full range of surfaces found within the deglaciated zone and so further field work is planned for July 2011. Initial results show that this approach to mapping trimlines has potential in SE Greenland (Figure 2) and by extension supports use of the approach to locations without field data.

The timing of retreat following the last glacial maximum is only broadly constrained in SE Greenland (Roberts *et al.*, 2008; Bennike and Björk, 2002). To address this shortfall, rock sampling for terrestrial *in situ* cosmogenic nuclide (^{10}Be) exposure dating was undertaken in both Sermilik and Kangerdlugssuaq Fjords. In Sermilik Fjord sites increase the spatial coverage of samples collected in July 2009. Initial results from that previous work in collaboration with the University of Exeter (C.J. Fogwill and E. Rainsley) show rapid retreat of ice from the full length of the 80 km fjord at the start of the Holocene (Hughes *et al.*, 2010).

Samples from Kangerdlugssauq Fjord will be used to test whether such rapid and substantial early Holocene retreat was replicated at Kangerdlugssuaq Glacier ~300 km to the north. Rock preparation and isotopic analysis will be conducted during Spring-Summer 2011 and we expect exposure ages to be returned autumn-winter 2011.

Acknowledgements

An award from the QRA Quaternary Research Fund contributed to the costs of fieldwork in Greenland in summer 2010 by funding a return airfare for ALCH. Further fieldwork costs were met by an award from the Geological Society of London (WG Fearnsides Fund) and the Leverhulme Trust (GLIMPSE Project). The ASD FieldSpec3 was loaned from the NERC Field Spectroscopy Facility.

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A PRELIMINARY INVESTIGATION OF THE SARSTOON-TEMASH *SPHAGNUM* PEATLAND, SOUTHERN BELIZE

Introduction

Tropical lowland peatlands differ from high latitude, *Sphagnum*-dominated bogs, in that tropical peat formation typically occurs in forested swamps with little moss or sedge ground cover (Rieley *et al.*, 1997). Although *Sphagnum* is widely-distributed throughout the tropics where it has been shown to exhibit high species diversity (Shaw *et al.* 2003), it is not known to form the thick mats characteristic of high latitude peatlands in lowland tropical regions (Shaw *et al.* 2003; Ellison 2004). However, in 2003, a *Sphagnum*-shrub peatland was identified within the evergreen broad-leaf swamp forests of Sarstoon-Temash National Park (STNP), southern Belize (15°56' N, 88°58'W) (Meerman *et al.*, 2003), estimated to occupy 1840 ha of low-lying terrain at 5 m above sea level (asl) (Figure 1). Atypical of tropical lowland peatlands, the surface of the STNP peatland is dominated by thick *Sphagnum* mats interspersed with abundant sedges. Rapid floristic surveys indicate the *Sphagnum* co-occurs with cool-adapted taxa also characteristic of high elevations and poor soils in Belize, such as *Purdiaea belizensis* (Clethraceae) and *Cyrilla racemiflora* (Cyrillaceae).

The aim of this project is to determine the vegetation history of this potentially unique ecosystem. This pilot study will address broad research questions concerning peatland origin and succession, and climate-vegetation interactions through analysis of peat cores.

Fieldwork

Fieldwork was conducted in January 2010. Due to recent oil exploration in STNP, transects for seismic testing were cut through the park, thereby easing access through what is normally a near-impenetrable swamp forest. This allowed our crew to trek further into the peatland than the previous excursion for the initial floristic survey (conducted in 2003). However, despite the cleared trail, we could only rearch an outer lobe of the peatland, located west of the peatland centre.

The western lobe of the peatland (Figure 1) is dominated by an open-canopy *Cyrilla*-Cyperaceae-*Sphagnum* vegetation community and surrounded by evergreen swamp forest. A core site was chosen on an unvegetated, peaty depression where *Drosera* sp. and *Urticularia* sp. were locally abundant, and *Sphagnum* and Cyperaceae dominated the surrounding groundcover. Nearly 6 m of sedgy peat was recovered from the western lobe of the STNP peatland using a square-rod modified Livingstone corer.

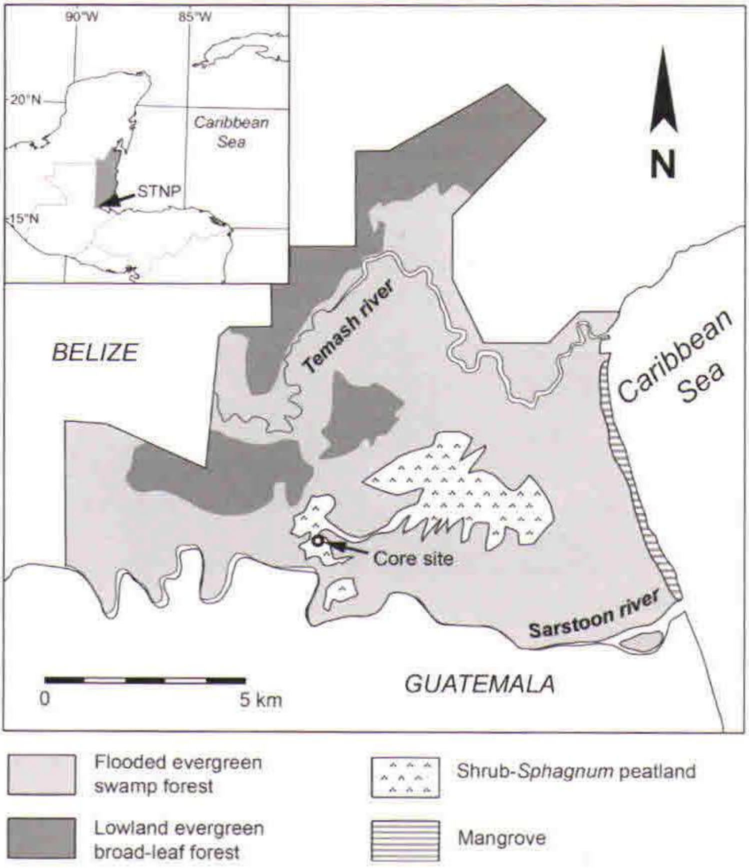

Figure 1. Location of the core site within the western lobe of the STNP shrub-*Sphagnum* peatland, southern Belize. The ecosystem boundaries were drawn from Landsat 5 imagery (1996) which estimated the peatland to cover 1100 ha. However, recent ground-truthing and reevaluation of remote sensing data have demonstrated the full extent of the peatland covers 1840 ha. Also, a subsequent expedition across the park has confirmed the peatland centre characterized by an open vegetation community, dominated by Cyperaceae and *Sphagnum*. (Ecosystem map modified from Meerman *et al*., 2003).

Preliminary Results and Projected Outcomes

Although the dominance of *Sphagnum* marks the STNP peatland as a potentially unique ecosystem in central America, the STNP peatland shares floristic similarities with a coastal peatland in Boca del Toro, Panamá (Phillips *et al.*, 1997). Despite lacking thick *Sphagnum* mats, the most recently assembled vegetation type in the Boca del Toro peatland is characterized by *Cyrilla racemiflora* and Cyperaceae, which developed after 4,000 yrs of successional change. Fossil pollen is abundant and well-preserved throughout the STNP core, and we hypothesize the STNP peatland has experienced a similar development of vegetation, and where the *Cyrilla*-Cyperaceae-*Sphagnum* assemblage in the STNP peatland might represent a late successional or climax community.

High abundance of vegetation tolerant of acidic and nutrient-poor conditions suggests the peatland is not hydrologically-linked to the sediment-rich and alkaline Sarstoon and Temash rivers, both of which originate in the karst hills of Guatemala and flow through the park (Figure 1), implying the peatland is ombrotrophic (rain-fed). Ombrotrophic peatlands are suitable for estimating past precipitation through humic acid analysis (Charman *et al.*, 2002), and clear stratigraphic changes identified in the core demonstrate episodes of past wetting (less humified) and drying (more humified) of the peatland surface.

A comparison of inferred precipitation change with the fossil pollen record will provide insight into precipitation-vegetation dynamics in the STNP peatland and the stability of this ecosystem under varying precipitation regimes. Furthermore, past precipitation inferred from humic acid analysis could also provide an approximate basal date for the peat cores through comparison with well-dated, regional palaeoclimate records in central America (e.g., Leyden *et al.*, 1994; Mueller *et al.*, 2009). Based on comparison with accumulation rates from Boca del Toro, as well as similar accumulation rates in tropical lowland peatlands of SE Asia, we estimate the 6 m record from STNP might span the past ~ 3,000 yrs. Full results of fossil pollen and humic acid analyses are expected in 2011.

Acknowledgements

Many thanks to the QRA Quaternary Research Fund for providing the funding for this fieldwork. This research is conducted in collaboration with Jan Meerman (Belize Tropical Forest Studies) and Iain Cameron (The University of Edinburgh). Many thanks to the Sartoon-Temash Institute for Indigenous Management (SATIIM) for logistical support, in particular Mr. Doyle Forman (Park Manager), Enrique Matrin (Park Ranger), Thomas Ishim (Park Ranger), and Anasario Cal (Park Ranger & Captain), and the Belize Defence Force (Pts. M. Usher & G. Santoya). Further infrastructure support and guidance was provided by Darwin Initiative project no. 17022 'Conservation of the Lowland

Savannahs in Belize' and the School of Geography, University of Nottingham. Thanks also to Sam Bridgewater for suggesting the site as a potential study. Additional project funding was provided by the British Ecological Society.

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OPTICALLY STIMULATED LUMINESCENCE DATING OF LOESSIC SILTS IN NORTHWEST ENGLAND

Introduction

It has been known for some considerable time that extensive but discontinuous deposits of loessic silt exist on the Carboniferous Limestone of northwest England and form the parent materials for some of the soils (Pigott and Pigott, 1963; Bullock, 1971; Furness and King, 1972; Catt, 1977; Vincent and Lee, 1981). Until recently no direct age determinations had been obtained for the silts; it was previously assumed that they were of deglacial/Lateglacial age (~18-12 ka BP) and were primary air-fall loesses derived by deflation of regional glacial and glacifluvial sediments.

In order to determine the age of the silts we sampled at three locations. The optically stimulated luminesence (OSL) dates obtained indicated that the silts were of Holocene rather than deglacial/Lateglacial age (Wilson *et al.*, 2008). These unexpected results led us to undertake a programme of more extensive and intensive sampling with a view to establishing a detailed regional depositional chronology for the silts and determining their mode of accumulation.

Sites and Methods

We have now obtained OSL ages on 29 silt samples from 6 general locations. Three locations are close to Morecambe Bay, two are in the vicinity of Malham and one is east of Shap. Samples were obtained from pits excavated in shallow (<5 m deep) karstic depressions at elevations ranging from 100 to 370 m OD. Pits were excavated to bedrock and samples collected by inserting light-tight plastic tubes horizontally into the walls of the pits at depths of between 20 and 110 cm.

Samples were prepared and measured in the Oxford Luminescence Dating laboratories following single aliquot regenerative protocols. Details of the methods followed are given in Wilson *et al.* (2008), Telfer *et al.* (2009) and Vincent *et al.* (2011). Dating of further samples from additional pits is in progress (Figure 1).

Results

Our results confirm that much of the silt is of Holocene age, but at some sites there is also silt that pre-dates the Last Glacial Maximum (LGM; ~22 ka BP) and silt of deglacial/Lateglacial age.

Figure 1. Loessic silts at Dowkabottom being sampled for OSL dating.

From a pit at Dowkabottom we obtained two OSL ages of ~27±2 ka BP and from Warton Crag and New Close ages of ~19.2 ka BP and ~17±2 ka BP respectively. The Dowkabottom dates constrain the onset of the last ice advance across this area and also indicate that the karstic depressions that characterise much of the landscape pre-date this event. The Warton Crag and New Close dates indicate that the ice had retreated from these sites thus allowing for silt accumulation. Although these ages are broadly consistent with existing estimates for the last ice sheet, they offer the tightest constraints yet available for advance and retreat of the ice sheet in northwest England. Further details of these ages and their significance are given in Telfer *et al*. (2009).

Nineteen of our OSL ages indicate the samples to be of Holocene age, thus confirming the results of our initial dating (Wilson *et al*., 2008). These samples are unlikely to represent primary air-fall loesses because Holocene environments in northwest England are considered to have been inimical to loess formation. We have therefore suggested that the silts result from the colluviation of loess and are best regarded as loess-derived colluvium.

Nine of our Holocene dates are coincident with the hypothesized climatic deterioration at 8.5-8.0 ka BP in the North Atlantic region. We have assessed the likely impacts of both climate change and Mesolithic activities at this time and conclude that the reworking (colluviation) of loess was most likely the result of the former rather than the latter. Further details of this aspect of our work are given in Vincent *et al.* (2010, 2011).

Acknowledgements

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NEW RESEARCHERS AWARD SCHEME

THE RESPONSE OF MEDITERRANEAN RIVER BASINS TO PLEISTOCENE GLACIATION

Background and Rationale

This research aims to establish the impacts of ice caps and valley glaciers upon Pleistocene Mediterranean fluvial system dynamics. Focus is placed upon fluvial networks draining the formerly glaciated Orjen Massif (1,894 m a.s.l) in western Montenegro (Figure 1). During the Pleistocene the Balkan region contained some of the largest ice masses of the Mediterranean basin (Hughes and Woodward, 2009). The water and sediment fluxes from glaciated catchments influenced landscape processes over extended periods and for considerable distances downstream (Clark, 1987). Meltwater routes emanating from the Orjen massif present a variety of depositional settings including: coastal and upland alluvial fans; polje fills and fluvial terrace sequences, which are broadly representative of glaciated terrains across the Mediterranean and elsewhere.

This project is examining multiple components of the fluvial environment to test current ideas of geomorphic response to Pleistocene glacial dynamics. The first phase of fieldwork was undertaken in May 2010 with the assistance of the QRA New Researchers Award Scheme. Analysis centred on five sites on the eastern sector of the former ice mass, investigating a range of depositional environments both within and outside the MIS 12 ice margin, reconstructed by Hughes *et al*. (2010). This analysis forms the basis of the PhD project to which additional sites from the west of the Orjen massif will be incorporated.

Methodology

Geomorphological and sedimentological appraisals were undertaken at five field locations. Key exposures were identified for sedimentological analysis. Particle size distribution and carbonate ($CaCO_3$) concentration of each sample was determined in the laboratory. Soil profiles on each land surface were also described and sampled in accordance with the Harden Soil Index (Harden, 1982; Birkeland, 1999) and used to develop a relative landsurface chronology. Secondary carbonate accumulations were described in the field and sampled for micromorphological analysis and uranium-series dating.

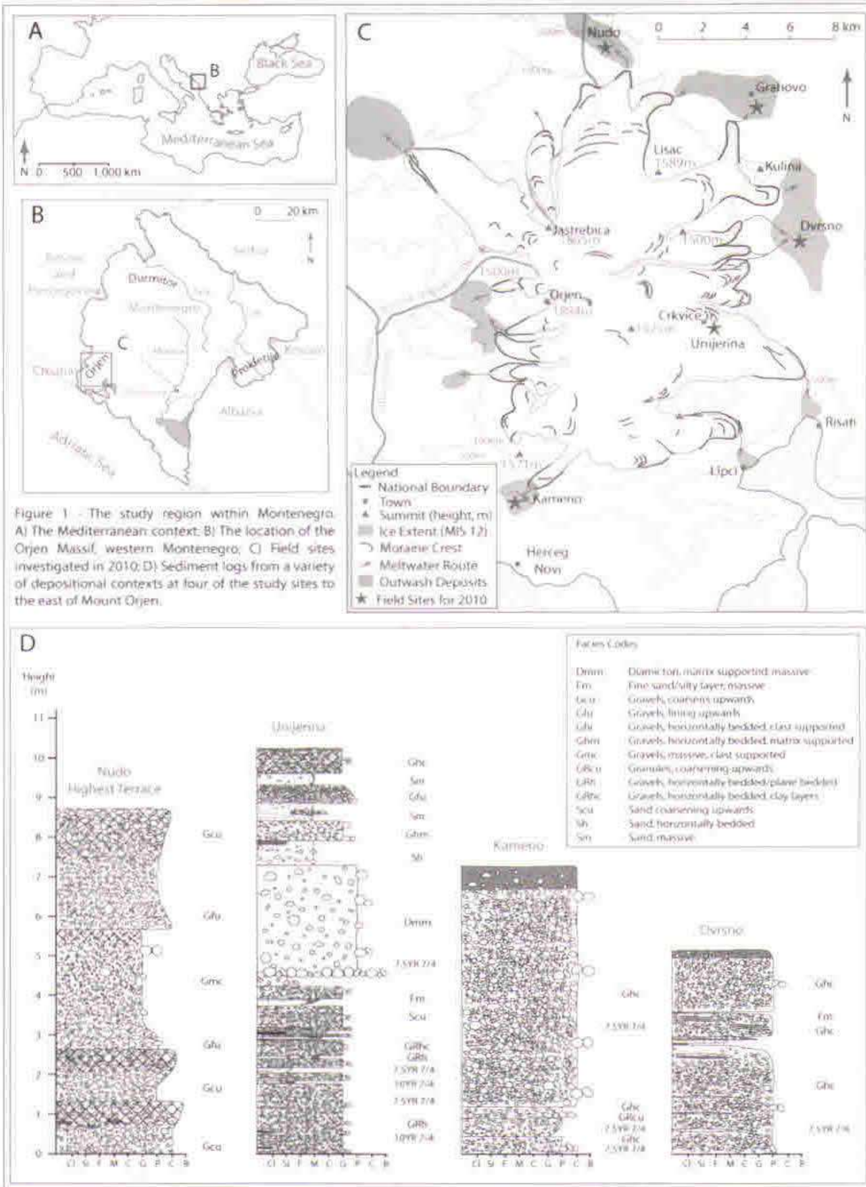

Figure 1 - The study region within Montenegro. A) The Mediterranean context; B) The location of the Orjen Massif, western Montenegro; C) Field sites investigated in 2010; D) Sediment logs from a variety of depositional contexts at four of the study sites to the east of Mount Orjen.

Figure 1. The study region of Montenegro highlighting field sites investigated in May 2010

Preliminary Results and Conclusions

Initial analysis reveals considerable variation in the nature of alluvial response to glaciation across the study region (Figure 1). The polje fills at Dvrsno and Grahovo present extensive deposits of sands and gravels, with only limited sedimentological variation with distance from the ice margin. In contrast, the proglacial fan at Kameno contains a highly complex record of outwash dynamics, containing one of the most detailed sedimentary expressions of the study region. The exposure at Unijerina, downvalley of an MIS 6 moraine, also presents a highly dynamic depositional environment; oscillating between glacial and fluvial deposits. Within the Nudo valley, five terrace surfaces have been identified and mapped, each associated with a body of coarse-grained alluvium with a distinct sedimentological signature.

Particle size distributions and carbonate concentrations of the fine sediment matrix (specifically the <63 μm fraction) are highly variable through time and space. This is thought to reflect the contrasting sediment sources and depositional processes operating between and within Pleistocene cold stages, as well as localised preservation factors. Profile development indices from the Harden Soil Index reveal that the soil profiles of Kameno, Dvrsno and to a lesser extent Grahovo, are the most mature of the study region. Using this relative age technique, the soils of Unijerina and Nudo appear to have developed much later. The U-series dating of calcites, which is currently in progress at the NERC laboratory, is required to further constrain the chronology of these sites, allowing the alluvial record to be integrated into the glacial chronology of Hughes *et al.* (2010). This initial investigation does however suggest that different components of the Orjen landsystem have responded in highly contrasting ways to Pleistocene glacial activity within the headwaters.

Acknowledgements

The author would like to acknowledge the kind assistance of the QRA through their contribution to fieldwork costs via the New Researchers Award. Thanks also to Prof. Jamie Woodward and Dr Phil Hughes for their support and guidance, both during field work and laboratory analysis. Special thanks go to Tim Lane for his unrelenting help and support in the field.

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MINERAL IDENTIFICATION OF CHINESE LOESS SAMPLES USING SCANNING ELECTRONIC MICROSCOPY

Background

The aim of this research is to identify mineral types within Chinese loess and their associated chemical compositions in order to better understand past depositional settings. X-ray diffraction (XRD) has been used for mineral identification. However, there are a few drawbacks to this approach: 1) although it is possible to identify mineral types by using built-in XRD analyzing software, it still largely depends on personal knowledge of mineralogy and experience of mineral identification using XRD; 2) XRD analysis can have difficulties in identifying a number of sub-species of mineral groups, e.g. feldspar, which can complicate further work if quantitative mineral analysis if required (Elton and Smith, 1999). Therefore, Scanning Electronic Microscope (SEM) has been used to refine the mineral identification. With the aid of QRA's New Research Worker's Award, fourteen powdered loess samples from a variety of localities within the Chinese loess plateau were carefully selected for polished thin section treatment at the Geosciences Department, University of Birmingham, and subsequently detailed mineralogical analysis on single particles was done using a Philips XL30 SEM with an Energy Dispersive X-ray Analyser (EDXA), at the Department of Earth Sciences, University of Liverpool. Secondary and backscatter images were obtained by SEM and the chemical composition of specific grains was acquired using EDXA.

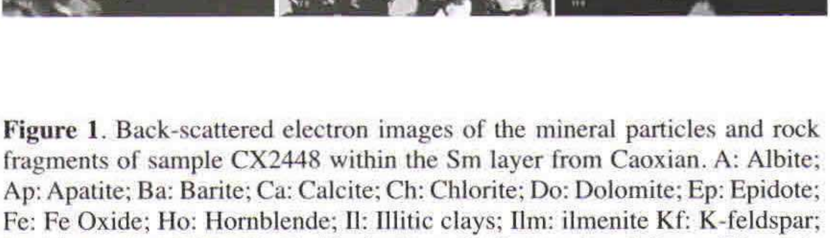

Figure 1. Back-scattered electron images of the mineral particles and rock fragments of sample CX2448 within the Sm layer from Caoxian. A: Albite; Ap: Apatite; Ba: Barite; Ca: Calcite; Ch: Chlorite; Do: Dolomite; Ep: Epidote; Fe: Fe Oxide; Ho: Hornblende; Il: Illitic clays; Ilm: ilmenite Kf: K-feldspar; M: Muscovite; NCP: Na-Ca Plagioclase; Q: Quartz; Sp: Sphene (Titanite); Zr: Zircon

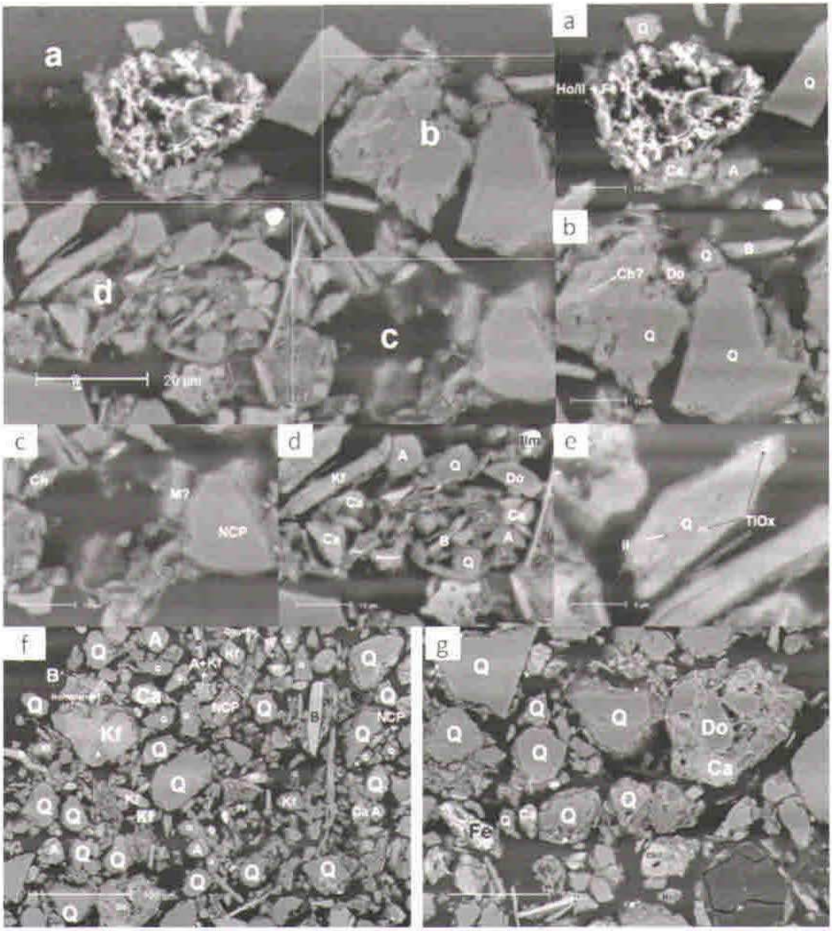

Figure 2. Back-scattered electron images of the mineral particles and rock fragments of sample CX3892 within the S1S1 layer from Caoxian. For key see Figure 1.

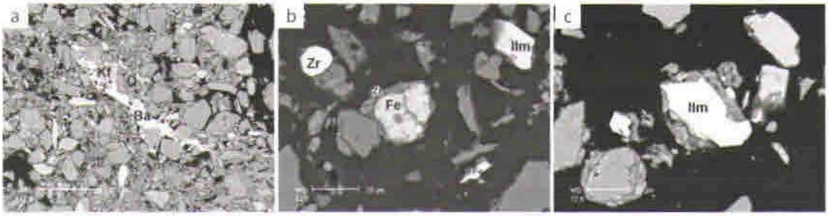

Figure 3. Back-scattered electron images of the mineral particles and rock fragments of sample CX4192 within the S1S2 layer from Caoxian. For key see Figure 1.

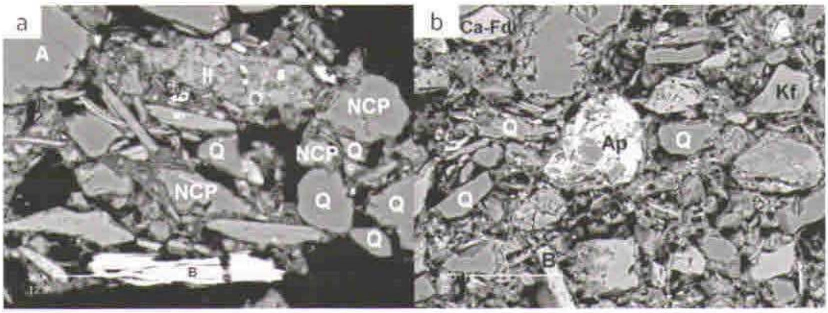

Figure 4. Back-scattered electron images of the mineral particles and rock fragments of sample B299 within the L5 layer from Luochuan. For key see Figure 1.

Results

Figures 1 to 4 show the back-scattered electron images of selected mineral particles and rock fragments from different samples. The samples in question mainly contain quartz, feldspars, biotite, carbonates and phyllosilicates (illite, muscovite, chlorite, etc.). Quartz mainly appears as single particles although some intergrowth with feldspars or clay minerals (e.g. chlorite and illite) can also be found (Figure 1a). Feldspars are divided into three groups based on EDXA: K-feldspar, albite and Na-Ca plagioclase (NCP). Feldspars normally occur as single grains, but intergrowth of albite and K-feldspar is still easily found in some samples (Figure 2f). In addition, NCP appears to be present in single grains rather than rock fragments (Figures 2f and 3a). Biotite is more easily found in single particles rather than rock fragments, with a bright needle-like appearance under back-scattered electron images (Figure 1b). Carbonates exist as fine-grained calcite particles (Figure 2d and 4a), fine-grained dolomite particles (Figure 2b) or coarse grains with a mixture of calcite and dolomite

(Figure 2g). The very fine-grained phyllosilicates mainly contain illitic clays and muscovite. Both large aggregates of illitic clays (Figure 2e) and mixtures of quartz-illitic clays (Figure 4a) are found in samples. Chlorite occurs either in the mixture with quartz (Figure 2b) or as a single grain (Figure 2c). Iron and titanium oxides can also be found in most samples observed. They have a wide range of formations: single-grained iron oxides (Figure 4a), single grained ilmenite (Figures 2d, 3b and 3c), intergrowth of iron oxides and clays (Figures 2a, 2f, and 2g), intergrowth of rectangular iron oxides – sphene – quartz – K-feldspar within the rock fragment (Figure 1c) and mixture of quartz and very fine single-grained titanium oxides. In addition, the SEM observation also shows the occurrence of single zircon particles (Figure 3b) and large aggregates of apatite and quartz (Figure 4b).

Significance

Compared with XRD analysis, more detailed mineral compositions of loess samples have been obtained with SEM and EDXA. This has assisted the calibration of quantitative XRD analysis on loess-palaeosol sequences. With direct access to these micromorphological images, it has been possible to better understand the relationship between environmental changes and the characteristics of different minerals. This has helped to establish the quantitative relationship between historical environmental changes and minerals within loess-palaeosol sequences.

Acknowledgement

The author would like to take this opportunity to thank QRA for its financial support. The thin sectioning was undertaken with QRA's New Research Worker's Award. Acknowledgements should also be given to Ms Carmel Pinnington, from Department of Geosciences, University of Liverpool, for her technical support and advice on SEM analysis.

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A MULTI-PROXY STUDY OF LATE HOLOCENE ENVIRONMENTAL CHANGE IN THE PROKLETIJE MOUNTAINS, MONTENEGRO: PRELIMINARY RESULTS

Background and rationale

Evidence of Little Ice Age (LIA) climatic cooling between AD 1650 - 1850 (as defined by Matthews and Briffa, 2005) has been recognised across the Mediterranean region in fluvial, sedimentary and glacial records (e.g. Sousa and García-Murillo, 2003; Marquer *et al*., 2008; Hughes, 2009). The validity of palynological records for use in palaeoclimatic studies in the region has been shown using longer-term records (Guiot *et al*., 1989; Bennett *et al*., 1991; Tzedakis *et al*., 1997; Goñi *et al*., 2002). However, long Quaternary records in the eastern Mediterranean have used relatively coarse sampling intervals that overlook/simplify the LIA.

Lake Plav (904 m a.s.l.) is a moraine dammed lake in the Prokletije Mountains, Montenegro. Pollen source areas include the lake edge, farmed floodplain, and lower hill slopes composed of pastureland and *Fagus* (beech) forests. *Pinus*-dominated semi-open woodland with *Abies* and *Picea*, and alpine meadow occur at higher altitudes in the catchment. The QRA New Researchers award contributed to field work expenses related to the collection of Core A, which was manually extracted to a depth of 8.30 m using a 50 mm diameter gauge auger. Work to date the cores using Cs-137 and Pb-210 has been carried out in collaboration with Dr Jackie Pates at The University of Lancaster.

Results

Initial dating results suggest an accumulation rate of around 5 mm per year in the upper 300 mm. Pollen samples were prepared using a HCl and HF digestion following Moore *et al*. (1991). A preliminary Lake Plav pollen profile is reported here (Fig. 1), but more sandy layers were not polleniferous.

LPCA I/II are dominated by *Alnus*, currently growing at river edge and valley bottom areas. Trees and shrubs dominate the pollen profile until the onset of LPCA III, when dwarf shrubs and herbs increase in frequency, including open-ground indicators and potentially anthropogenic weeds eg. *Rumex*, *Chenopodium*, which suggest ground disturbance. LPCA IV opens with a sharp, but temporary, fall in arboreal pollen, as *Pinus* and *Fagus* frequencies fall, implying recent clearance in the upper catchment, or a change in the dominant pollen source areas. These frequencies recover as *Fraxinus* and *Alnus* increase to high values. In LPCA IV open and weed indicators again return, and tree pollen numbers fall, suggesting a recent change. However, this variation could

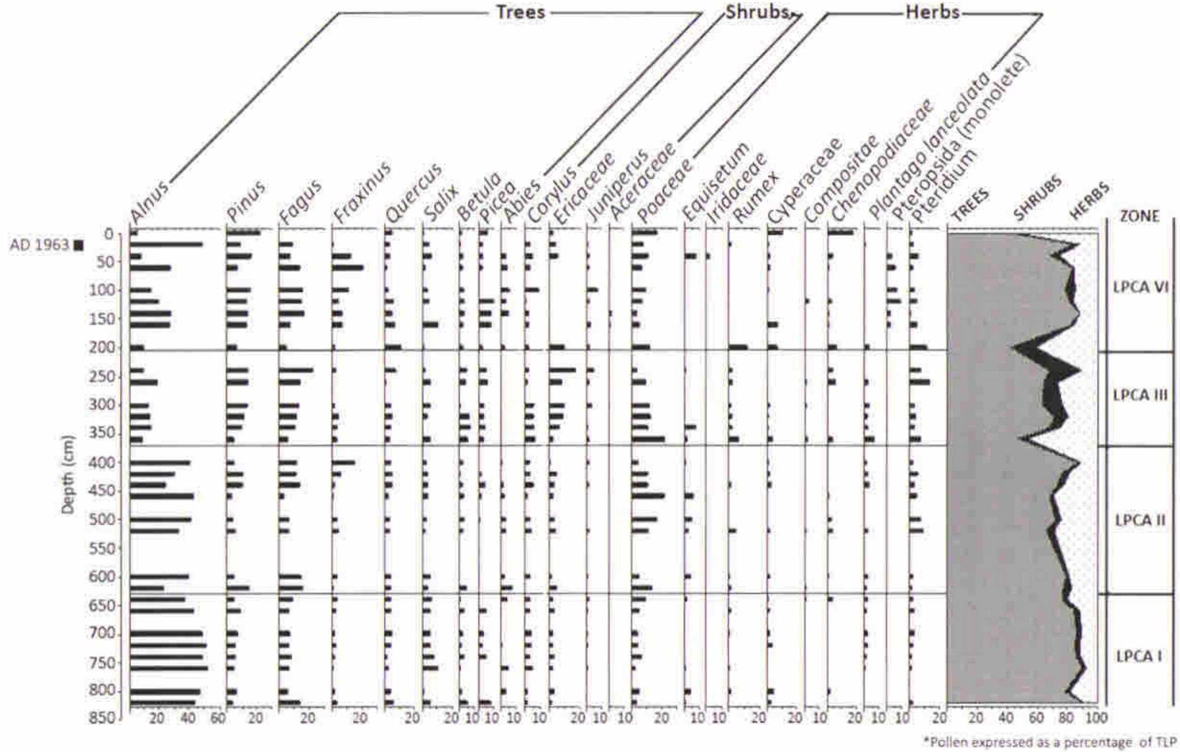

Figure 1. Condensed pollen sequence from Core A, Lake Plav, Prokletije Mountains, Montenegro (Altitude 904 m a.s.l.).

result from site being more permanently terrestrialised, as Cyperaceae (sedges) is indicative of the local flora. The changing vegetation can be explained in terms of land use, climate and pollen source areas.

Significance

Environmental responses to LIA climate change have yet to be studied in the Prokletije Mountains and have been overlooked in the eastern Mediterranean. This research aims to provide insight into how systems change and adapt during short abrupt climatic shifts. Therefore, providing a base for further research into how future climate oscillations may affect the environment.

Acknowledgements

This work has been funded by QRA New Research Workers Award, University of Manchester and Zochonis Travel Award. The author thanks Dr Jeffrey Blackford, Dr Phillip Hughes, Prof. Jamie Woodward, Dr Jackie Pates at The University of Lancaster, Skender Šarkinović, Robert Aleksić at UNDP, and Manchester laboratory staff.

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RECONSTRUCTING BASIN EVOLUTION AND PALAEOCEANOGRAPHIC CHANGE DURING THE LATE PLEISTOCENE - EARLY HOLOCENE TRANSITION AT EFFINGHAM INLET, BRITISH COLUMBIA, CANADA

Background and rationale

The coastal inlets of British Columbia are a particularly sensitive recording area for the study of Holocene palaeoceanographic, tectonic and climatic change in the northeastern Pacific region. Thick sequences of marine sediment often accumulate under dysoxic to anoxic conditions and are therefore undisturbed by bioturbation (Chang *et al.*, 2003; Dallimore and Jmieff, 2010). The result is an informative record, which documents environmental change over millennial to annual and even sub-annual scales (Anderson, 1996; Dean and Kemp, 2004). The sediments are often annually laminated, with each couplet consisting of a terrigenous winter lamina and a diatomaceous lamina which records seasonal deposition of diatom species throughout spring, summer and autumn (Chang, 2004).

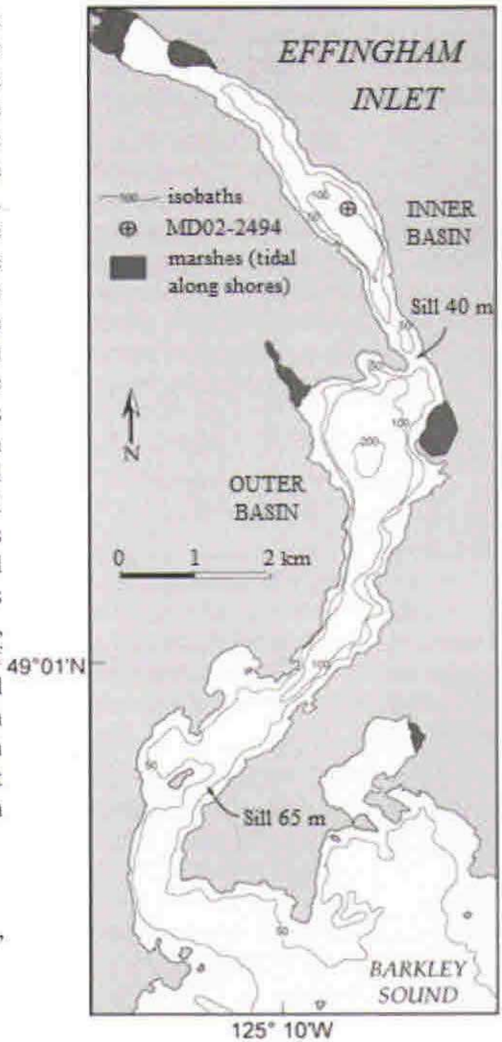

Figure 1. Sample area, Effingham Inlet, BC.

The 40 m Calypso core on which this research was based was collected in Effingham Inlet, SW Vancouver Island, as part of the IMAGES VIII MD126 MONA ('Margins of North America') research cruise. Effingham Inlet is a 17 km long fjord open to the Pacific Ocean through Barkley Sound, but sheltered to some extent by the presence of two sills (Figure 1). The primary aim of the research was to identify changes in environmental conditions, particularly changes in oceanographic conditions and RSL change, during selected intervals of the late-glacial and Holocene. The 'New Researcher Worker's Award' enabled the author to conduct a six week visit in November 2005 to Vancouver Island, where the core is stored. The purpose of this visit was to examine each of the component sections, devise a sampling strategy and complete sample retrieval.

Results

In order to assess long-term environmental change during the late Pleistocene – early Holocene transition, 180 plug samples were taken at *ca*. 10 year resolution from sections of the core dated between 12,216 – 9,383 ^{14}C yr BP. Based on the diatom record, and supported by mineralogical and geochemical evidence, nine stages were identified in the post-glacial evolution of the basin (Logan, 2009).

Initially a glacial embayment, the Effingham basin supported a brackish diatom assemblage characteristic of a shallow neritic environment after rapid ice retreat (*ca*. 12,200 – 12,000 ^{14}C yr BP). Following a rise in relative sea level, upwelling, and an increase in temperature, a period of high primary productivity dominated by the diatom *Skeletonema costatum* ensued until *ca*. 11,500 ^{14}C yr BP. A gradual transition then occurred as relative sea-level fell and the basin became increasingly isolated during cooler, wetter, downwelling conditions (*ca*. 11,500 – 11,000 ^{14}C yr BP). Marine conditions persisted until the subaerial exposure of the sill established a lacustrine phase (*ca*. 11,000 – 10,500 ^{14}C yr BP). This exposure of the sill is significant in that it allows a relative sea-level lowstand of 46 m to be identified at *ca*. 11,000 ^{14}C yr BP.

Marine inundation and deepening of the lake basin to form the anoxic marine environment of the present took place in three stages. These are marked by relative sea-level rise in what became a shallow littoral environment (*ca*. 10,500 – 10,100 ^{14}C yr BP). However, the diatom response was limited by the effects of the Younger Dryas in suppressing temperature and upwelling. The third stage, at the end of the Younger Dryas (*ca*. 10,100 – 10,000 ^{14}C yr BP), was a turbulent environment associated with rapid salinity change.

An open marine environment was established at *ca*. 10,000 ^{14}C yr BP, coincident with the strengthening of the North Pacific High and an increase in temperature, upwelling and seasonality (Walker and Pellatt, 2003; Logan, 2009). The final phase in the evolution of the basin was associated with the highest primary productivity and marine diatom species diversity, with evidence of offshore incursions. Bottom water renewal took place in response to stratification, and a flood event is conjectured as a possible cause for such rapid freshwater dilution (*ca*. 9900 ^{14}C yr BP).

Significance

The study has provided a much clearer understanding of the post-glacial evolution of Effingham Inlet and the wider west coast of Vancouver Island, an area for which limited information on deglacial history was previously available. In particular, the research has identified nine stages of basin evolution with well-dated stratigraphic boundaries and, through the identification of a lacustrine phase, has provided a new relative sea-level lowstand. Temperature and nutrient limitation of diatom productivity between 11,000 – 10,000 ^{14}C yr BP has been linked to the Younger Dryas and may represent further evidence of atmospheric teleconnection with what was previously thought to be an exclusively North Atlantic phenomenon (Walker and Pellatt, 2003).

Acknowledgements

Thanks to Luc Beaufort, Tom Pedersen and the scientific party involved in the MD 126 Mona IMAGES VIII research cruise, to all the members of the research group for their contributions and support, to my supervisor Helen Roe and to the Quaternary Research Association. Being able to examine and sample the core directly, as well as liaising with colleagues in Canada added tremendous value to the research approach.

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PALAEOECOLOGICAL EVIDENCE OF MID-HOLOCENE CLIMATE CHANGE IN SOUTH-CENTRAL SWEDEN

Background and rationale

The objective of the fieldwork was to collect samples in order to determine variability in atmospheric moisture availability throughout the mid-Holocene in south-central Sweden. It is hypothesized that shifts in atmospheric moisture followed a cyclical pattern as a result of orbital and ocean-driven forcing overlain by a local and regional climate signal. The QRA NRWA was used to help fund a field-expedition to south-central Sweden, carried out during the summer of 2009.

Methods and Study Area

Ombrotrophic peat bogs are an excellent archive of atmospheric moisture records (Barber and Langdon, 2007) and two raised peat bogs were cored to address the hypothesis outlined above. Additionally, the surfaces of a further eight sites were sampled in order to construct a testate amoebae transfer function for water table depth.

Figure 1. Coring location on Kortlandamossen with concentric bog islands in the background

Kortlandamossen [Lat: 59.8473°, Long: 12.2867°, altitude 112 m a.s.l.] (Figure 1) is a pristine concentric raised peat bog which is dominated by a healthy acid peat bog community of *Sphagnum* spp., *Calluna vulgaris*, *Erica tetralix*, *Vaccinium oxycoccus*, *Rhynchospora alba* and *Eriophorum vaginatum*. In contrast, Gällseredsmossen [Lat: 57.1751°, Long: 12.5975°, altitude: 99 m a.s.l.] has been heavily managed with a road passing through it. The bog surface is drier and dominated by *Sphagnum* spp., *Trichophorum cespitosum*, *Eriophorum vaginatum*, *Rhynchospora alba*, *Vaccinium oxycoccus*, *Rubus chamaemorus*, *Erica tetralix* and *Calluna vulgaris*.

All peat cores were extracted using an 11 cm diameter Russian corer, packed in air-tight carbon-stable plastic bags and transferred to a monitored cold store. On all sites, 15 surface samples were collected along moisture gradients, ranging from high hummocks to pools. At each sampling plot, two 5 cm x 5 cm samples of fresh peat were taken and water table depth measuring equipment was installed (Belyea, 1999). Measurements of depth to water table, pH, conductivity and temperature were taken and the surrounding vegetation and nanotope were recorded. The peat cores and surface samples were analysed for plant macrofossil and testate amoebae remains using standard methodologies (Barber *et al*., 1994; Charman 2000).

Preliminary Results

Initial results highlight clear changes in bog surface wetness (BSW) throughout the cores and significant responses in the testate amoebae assemblages to changes in water table depth. Variation in pH, conductivity and temperature, however, did not show a significant impact on the amoebae community. A series of wet shifts in the peat profiles from Kortlandamossen and Gällseredsmossen were identified. The preliminary evidence points to a synchronous wetting of both sites at *circa* 6200, 4800 and 4200 cal. yr. BP (within the error margins of the radiocarbon dating framework), but further analyses are needed to constrain these changes temporally. More detailed time-series analysis work is also needed to identify cyclicity in BSW changes.

Conclusion

The preliminary results show a lot of promise for the extracted cores to yield a wealth of palaeo-ecological and palaeo-climatic information, with a clear correlation in wet shifts at key events on both sites as reflected in the plant and amoebae assemblages.

Acknowledgements

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REVIEW

NORFOLK'S EARTH HERITAGE - VALUING OUR GEODIVERSITY

Tim Holt-Wilson

2010: Norfolk Geodiversity Partnership, 74pp
ISBN 978 1 84754 216 8

Many Local Geodiversity Partnerships are producing guides to their areas of interest in order to raise public awareness of their local geodiversity resource. Norfolk has followed this trend by producing a 74 page guide to this unique and complex Quaternary area. The test is admirably written by Tim Holt-Wilson and fully illustrated throughout. It is good also to see the forward written by someone from the Local Biodiversity Partnership showing an appreciation of geodiversity not always acknowledged and appreciated by our colleagues in that area.

The Introduction starts with the official planning definition of Geodiversity:

"The natural range (diversity) of geological features (rocks, minerals, fossils, structures), geomorphological features (landforms and processes), soil and water features that compose and shape the physical landscape"

Office of Deputy Prime Minister (2006).

However there are other definitions by Prosser (2002) and Gray (2004) which perhaps are better known and more acceptable. I would include landscape as part of geodiversity as it is the stage for biodiversity and sets the scene. Indeed on occasions the author's understanding and application of Geodiversity is ambiguous as the Norfolk vision is for geodiversity to contribute "to the landscape, biodiversity, economy and culture of Norfolk" but landscape should be part of geodiversity. However that notwithstanding, the chapters of the A4 publication highlight the importance of 'Valuing our Geodiversity' locally. As applied to Norfolk - its coast, Palaeolithic and Neolithic sites, Quaternary depositional and periglacial features, landforms and structures(e.g. Blackney Esker), the Chalk, fossils, the Broads, the earliest lowland glaciation evidence, the evidence for the course of the ancestral Thames, early Pliocene and Pleistocene stratigraphic sites, meres and interglacial vertebrates: a truly rich Quaternary heritage. I feel we owe a debt of gratitude to Norfolk Geodiversity Partnership (NGP) for trying to raise public awareness of these areas.

A detailed discussion of the economic, cultural, topographical and agricultural importance and how to safeguard and make sustainable the resource follows.

Firstly the solid geology of Norfolk (Chapter 2.2) is straightforward - no igneous, metamorphic or Palaeozoic rocks - just good Late Mesozoic to recent sedimentary rocks and present day sediments and processes, illustrated both visually and graphically, attest to the importance of the Quaternary. Good photographic evidence is used in Chapter 2 to discuss the difference rock types. A footnote discusses the ongoing debate about the base of the Pleistocene using the International Union of Geological Science's 2009 definition of 2.58 million years; which shows a good Quaternary understanding by the author. After a summary of Norfolk's geology, geomorphology, water, soil and cultural resources, all admirably illustrated and explained, the 3rd chapter looks at conserving Norfolk's geodiversity through Geoconservation. It is a shame that use was not made of the 2008 definition by Burek and Prosser:

"Action taken with the intent of conserving and enhancing geological and geomorphological features, processes, sites and specimens" (Burek and Prosser, 2008).

In Norfolk, 39 out of 162 Sites of Special Scientific Interest (SSSI) (23%) are designated for their geodiversity as opposed to their biodiversity and most of these are for their Quaternary interest. Of the 45 Norfolk sites mentioned in the Geological Conservation Review (GCR) volumes, 35 are of Quaternary importance. SSSIs are designated solely for their outstanding research / scientific interest and are protected by law under the Wildlife and Countryside Act 1981. Regionally Important Geological/geomorphological Sites (RIGS) are designated using much wider criteria and are non-statutory but are protected under Planning Policy Statements and Guidance (PPS/PPG). The statutory context for Geoconservation is discussed focussing on water, soil, coastal processes, archaeology and landscape. In this context then, PPS 5, 7 and 9 as well as PPG 20 gives this non-statutory protection. For Geodiversity I would argue that PPS 9 entitled "Planning Policy Statement 9: Biodiversity and Geological Conservation "(2005) is the most important for Local Site conservation.

The threats mentioned in Chapter 3.2 to Norfolk's geodiversity are identified as burial, vandalism, building works, soil and water contamination and most importantly lack of public understanding of its value. Geoconservation Principles and priorities are highlighted in section 3.3 with special mention being made of relict and active landforms as well as [Quaternary] stratigraphy and fossil sites.

The last Chapter (4) addresses the importance of working in partnership with others. No one can achieve geoconservation alone. The Norfolk Geodiversity Partnership developed in 2007, is in an enviable position to forward the Quaternary geoconservation agenda through its Local Geodiversity Action Plan (LGAP) membership. This includes Museums, landowners, quarrying companies, government agencies, as well as educational institutions at all levels. The Norfolk GAP covers 5 work areas (as do most other LGAPs):

1 Understanding our geodiversity resources

2 Embedding geodiversity in plans and policies

3 Protecting and enhancing our geodiversity resources

4 Promoting geodiversity awareness and understanding

5 Managing the Norfolk GAP

At the back of the document are 6 useful appendices including a Glossary, local site list, stratigraphic column, information sources and details of types of geoconservation sites. These will help the general public understand further the issues and aims of the LGAP. This whole publication certainly seeks to do this and will hopefully achieve its overall objective.

The document concludes with an invitation to support this Geodiversity Plan. Norfolk is a key and classic area for Quaternary research and the QRA membership should answer this call to help safeguard Norfolk's geodiversity for tomorrow's generations. Sustainable development through understanding and partnership is the key to successful Geoconservation.

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ABSTRACTS

QRA AND RGS-IBG UNDERGRADUATE DISSERTATION PRIZE WINNER 2010

A STUDY OF THE POTENTIAL OF THE LONG LIVED MOLLUSC *ARCTICA ISLANDICA* AS A PROXY FOR THE OCEANIC ^{13}C SUESS EFFECT OFF THE WEST COAST OF SCOTLAND

Elizabeth Daniel (BSc)
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The sequestration of anthropogenic CO_2 into the oceans is spatially variable with multiple uncertainties. Relative depletion of ^{13}C in anthropogenic CO_2 can be used as a tracer, with a known negative trend in $\delta^{13}C$ of ocean water DIC (^{13}C ocean Suess effect). A lack of historical $\delta^{13}C_{DIC}$ measurements highlights the need for palaeoclimate proxies such as the long lived, annually resolved bivalve mollusc *Arctica islandica* which forms an aragonite shell potentially recording the ambient $\delta^{13}C_{DIC}$. Diver collected specimens of *Arctica islandica* from shallow coastal waters off the west coast of Scotland were dated using acetate peels to calculate calendar ages. High resolution samples drilled from the outer valve of the 5 specimens used were analysed using IRMS to gain $\delta^{13}C$ values for known, dated growth increments. Crossdating of the particular specimens proved problematic, possibly as a consequence of the dynamic shallow environment specimens were obtained from or due to the small sample size. Preliminary results contrasting dating from the umbo region to the outer valve for the same number of growth increments seem promising, if in need of further research. *A. islandica* seems to exhibit ontogenetic $\delta^{13}C$ trends throughout the initial 20 years of growth, possibly linked to the animal's sexual maturation. Mature regions of *A. islandica* may offer greater possibility of acting as a proxy for $\delta^{13}C_{DIC}$, although decadal influence such as the NAO through dynamic pathways of primary production and water mass changes on $\delta^{13}C_{DIC}$ may prevent a clear signal from the ^{13}C Suess effect.

QRA AND RGS-IBG UNDERGRADUATE DISSERTATION PRIZE WINNER 2010

A PALAEOENVIRONMENTAL AND CLIMATIC RECONSTRUCTION OF LATE DEVENSIAN AND HOLOCENE CHANGE IN NORTHERN SKYE: A MULTIPROXY APPROACH

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A new core from Loch Mealt in the north of the Isle of Skye (6°10' W, 57°36' N) is examined for changes in environmental conditions since the end of the Devensian glaciation. A compiled understanding of such local palaeoenvironmental histories may be achieved by studying multiple proxies over time and inferring their climatic implications so that similar studies can be used to piece together regional and global climatic trends. The deglacial history in northern Skye is unclear due to disputes over the occurrence of readvances and standstills of the ice and the matter is complicated by a lack of direct evidence for the timing of deglaciation. Furthermore, Northwest Scotland is an important study area because of its proximity to the northern limit of the North Atlantic thermohaline circulation, the activity of which may have helped cause the Loch Lomond Stadial in Scotland and the equivalent Younger Dryas period across Northwest Europe. Therefore, the Hebridean islands mark a key location in understanding past global climatic changes and this palaeoenvironmental approach is one of the best ways to reconstruct the nature and timing of the Late Devensian and Holocene period.

The site at Loch Mealt has not been previously studied over this time-frame and a multi-proxy approach is used, combining lithology, magnetic susceptibility, loss-on-ignition, tephrochronology and palynology. Two potential tephra layers are identified at 100-99 cm and 25-20 cm which are tentatively correlated with local and regional studies and may represent the Hekla-4 and Glen Garry tephras. An age-depth model is then constructed which places the start of the Windermere Stadial at 13,100 years BP and a sudden deterioration into the Loch Lomond Stadial at 11,900 years BP. The Loch Lomond Stadial – Holocene boundary is found to be progressive between 11,350-9,450 years BP. The Holocene is punctuated by an unusual short event at ca 4,350-4,100 years BP and a significant vegetative change towards modern conditions after 2,200 years BP. The multi-proxy approach was found to be valuable in reconstructing past conditions at the site and creating a defensible age-depth model; however it requires strengthening using further results and additional dating techniques.

GLACIAL ISOSTATIC ADJUSTMENT AND RELATIVE SEA LEVEL CHANGE OVER THE LAST EARTHQUAKE CYCLE IN UPPER COOK INLET, ALASKA, USA

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Using observations of land surface deformation, sea level change and geophysical modelling, this thesis considers the interactions of ice mass fluctuations and tectonic deformation over the last great earthquake cycle in south central Alaska.

Reconstructions of relative sea level change over the last 900 years, based upon extensive lithological, biostratigraphical and chronological investigations of salt marsh sequences in upper Cook Inlet, Alaska, record changes in marine influence and the direction of sea level that do not fit the expected interseismic model of land level movements. Dating of the sequences suggests the changes in RSL occurred sometime through c. AD 1600 – 1900, during the middle and late phases of Little Ice Age ice mass balance changes. The chronological methods used comprise a multi-method approach: ^{210}Pb, ^{137}Cs, stable lead ($^{206}Pb/^{207}Pb$) ratios, pollutants associated with the history of regional gold mining and development, tephrochronology and AMS ^{14}C wiggle match dating. The research highlights some of the limitations of applying some of these dating methodologies to recent, high latitude, salt marshes.

GIA modelling identifies part of the GPS measured present day uplift in upper Cook Inlet as attributable to post Little Ice Age (AD 1200 – 1900) glacial isostatic adjustment, with a spatial signal over tens of kilometres. A set of viable Earth models, constrained by GPS data and the pattern of post-seismic displacement quantifies the relative displacement and deformation of the ocean geoid at a series of locations in south central Alaska over the past 1000 years. Modelling results show the asthenosphere viscosity and thickness to be the main rheological controls on relative displacement during the last earthquake deformation cycle.

Integration of the geological data and geophysical model results show RSL in upper Cook Inlet during the last earthquake deformation cycle is a combination of tectonic land-level changes, 'local' processes, glacial isostatic adjustment and deformation of the ocean geoid. To fully quantify the relative contribution of each mechanism requires improvements in the methods of RSL reconstruction, dating of recent salt marsh sediments and GIA modelling.

AN EXAMINATION OF THE SEASONAL PROCESSES CURRENTLY OPERATING WITHIN EARTH HUMMOCKS IN NORWEGIAN MOUNTAINS

Sally Hayward (Phd)
University of Reading

This research examines the seasonal processes operating within earth hummocks in two mountainous areas of Norway, Okstindan in the north and Jotunheimen in the south. A combination of direct evidence, obtained through dataloggers and primary field observations, and the indirect evidence from morphological analysis and the identification of environmental controls offer insights into the activity within these widespread but poorly understood periglacial landforms. At Okstindan, moisture, heave and temperature sensors recorded activity within an earth hummock between August 1988 and May 1989, and at Krossbu in Jotunheimen a detailed record of temperatures was obtained from another hummock between August 1990 and July 1991.

The direct and indirect evidence for four geomorphological processes is presented and analysed. Results suggest that differential frost heave is the dominant process currently operating, with flow of material during the thaw, mass-movement and erosion also playing a variable role in the formation of the earth hummocks. Differential heave, to a maximum of 41.67 mm (on the right north side) is recorded at Okstindan, with corresponding temperature and moisture changes marking possible cryodesiccation and phase changes. Failure of the logger during the thaw prevents the recording of any settlement and so it is not possible to conclude about the degree of net growth. The increased density of temperature sensors at the Jotunheimen site reinforce this identification of differential thermal regimes within earth hummocks and the surrounding troughs, indicating an asymmetrical freezing of the hummock, with the right (west side) remaining frozen for a considerable period.

An analysis of the external, internal form and micromorphology identifies key diagnostic features and demonstrates the variation to be found within earth hummocks. Common attributes include cryoturbative features, asymmetry, buried organic layers and a clearly defined base. Environmental controls identified are altitude, vegetation, regolith, topographical position, snow cover and water supply, and alongside the morphological features, these controls offer indirect evidence of the four processes identified. This research contributes towards a greater understanding of the complex nature of earth hummocks in the mountainous areas of Norway, with the potential for further post-thesis analysis of the data and revisiting of the field areas, as well as other localities in order to fully utilise recent technological advances and assess the current degree of activity, possibly within the context of global climate change.

QUATERNARY RESEARCH ASSOCIATION

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

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

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

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

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