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COVER PHOTOGRAPH.

A photograph of the mountains of Connemara from the Hill of Doon.

NEW OSL DATES AND POLLEN RECORDS FROM THE BEMBRIDGE RAISED BEACH SEQUENCE, ISLE OF WIGHT (UK)

Francis Wenban-Smith, Jean-Luc Schwenninger and Robert Scaife

Introduction

The Bembridge raised beach has been well-known since the 19th century (Codrington, 1870) as part of a major Pleistocene exposure at the eastern tip of the Isle of Wight (Figure 1), visible in the cliff section that stretches clockwise around Foreland for about 2.5 km from the Lifeboat Station to Bembridge School (SZ 643 865). The investigations reported here were carried out in advance of coastal defence works in front of the Warner Bembridge Coast Hotel (SZ 658 876; Figure 2). The works involved banking flint pebbles against the cliff, leading to unavailability for subsequent study of the affected parts, which included a key pollen-bearing unit of the raised beach sequence. When fieldwork took place, the site consisted of a low cliff c. 4 m high, with level turf behind it leading back c. 50 m to the hotel building. Recently collapsed sediment was banked against the cliff base, against which lay a narrow strip of shingle beach at the top of the high water mark, above a sloping sandy beach in the intertidal zone.

Geological and archaeological background

The Bembridge raised beach deposits were last studied in the 1980s (Preece *et al.*, 1990). They occur in the central part of the Bembridge School–Lifeboat Station cliff section, between Howgate and Foreland. The raised beach sequence consists of three conformably overlying sediment units, dipping and overlapping to the northeast. The lowermost deposit comprises a major body of sand and rounded beach pebbles, lying on an erosional base at c. 4 m OD, cut into Bembridge Marls. This sand/pebble deposit thickens to the southwest, butting against a cliff cut into the Bembridge Marls, with its upper surface reaching a maximum height of almost 18 m OD. Pebbles within the deposit are mostly sub-rounded and grade smaller to the northeast as the deposit thins, at the same time becoming increasingly sand-rich. The deposit is well-bedded, with bedding planes dipping 8°–13° in a generally ENE direction. Overlying the thinning northeast part of this lowermost sand/pebble deposit is a unit of sand interbedded with clay-silt laminations, which thicken and become more

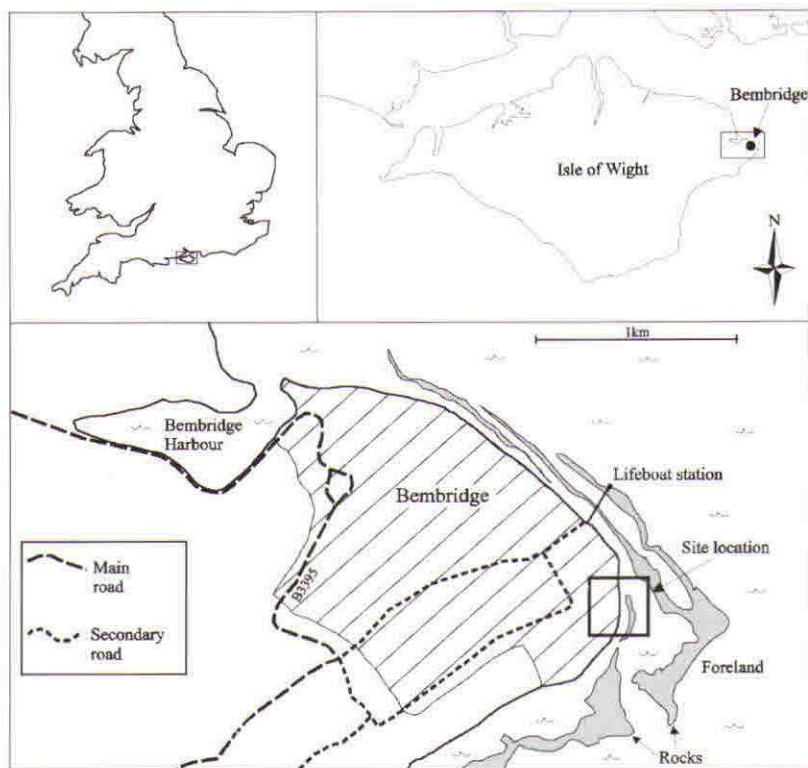


Figure 1. Site location.

closely spaced towards the base of the unit, culminating in a basal clay-silt bed 10cm thick. This bed is barren of any biological remains. Finally, overlying the clay-silt laminated sand unit, there occurs a brown humic silt, which has produced a rich pollen sequence at Foreland (Figure 2).

The basal sand/pebble bed has been interpreted by Preece *et al.* (*ibid.*) as a cusate foreland storm beach associated with a pre-Holocene high sea-level stand. Many features of the unit correspond with those observable in analogous situations in the present day, such as at the Ayre raised beach on the Isle of Man and the Dungeness Foreland in Kent. The overlying units are interpreted as belonging to the same high sea-level event, representing estuarine and salt marsh conditions abutting the main shingle beach. The sequence was attributed, primarily on the basis of its pollen content, to the peak high sea-level of the last (Ipswichian) interglacial, correlated with Marine Isotope Stage 5e *c.* 125,000 years BP. TL-dating of a sand lens within the shingle beach unit by Southgate (Appendix B in Preece *et al.* 1990) produced dates of 104.3 ± 14.1 and 115.1 ± 10.4 ka BP, broadly supporting an MIS 5 attribution.

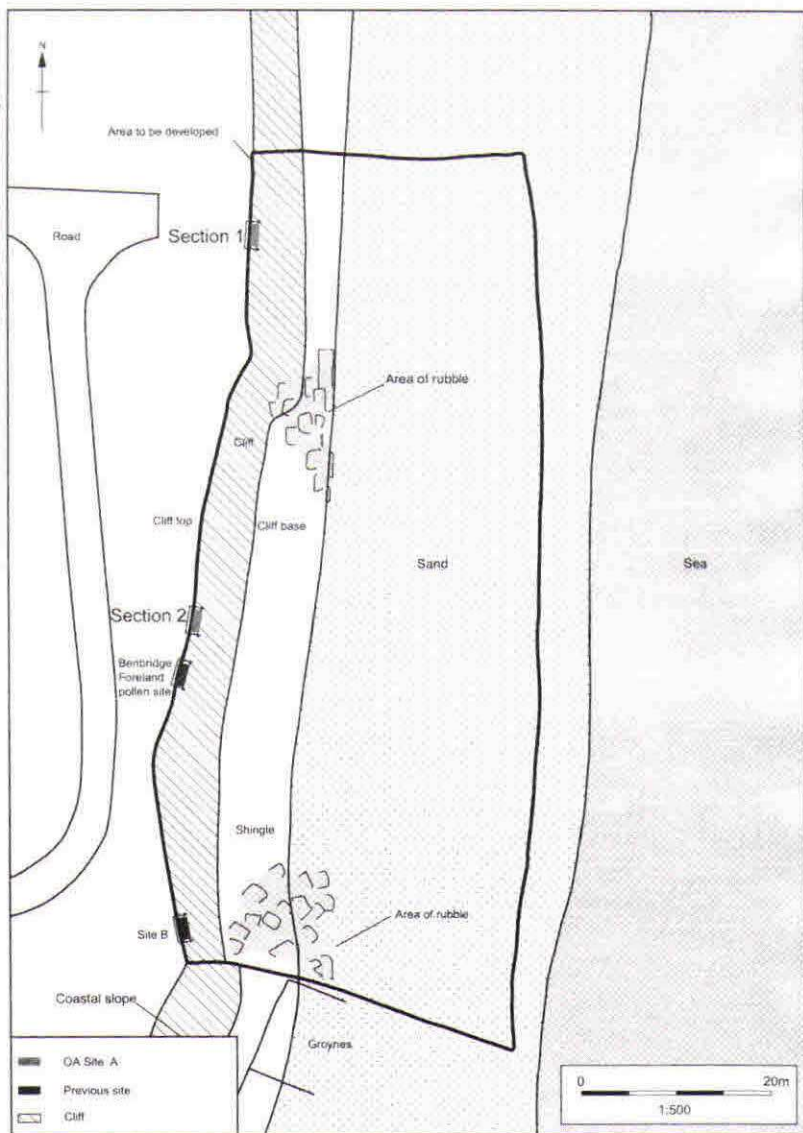


Figure 2. Locations of Sections 1 and 2.

At the southwestern end of the raised beach sequence, where it approaches the palaeo-cliff cut into the Bembridge Marls, the surface of the shingle beach dips slightly, forming a hollow against the base of the palaeo-cliffline. This hollow is filled with a brickearth deposit that reaches a thickness of 10m up against the palaeo-cliff, although thins rapidly to the northeast. The basal junction of the brickearth is marked by a 1m-thick deposit of clayey solifluction gravel. TL-dating near the top of the brickearth yielded a date of c. 24 ka BP, close to the Last Glacial Maximum (Parks and Rendell, 1992). The northwest end of the raised beach sequence is overlain by clayey gravel, the base of which slopes shallowly down to the northeast, truncating the uppermost raised beach sediments, and ultimately removing them altogether in the vicinity of Foreland. This clayey gravel is interpreted (Preece *et al.*, 1990) as Devensian colluviation/solifluction following the high sea-level event associated with the raised beach deposits. TL-dating of a thin bed of brickearth overlying this gravel at the Foreland pollen site [at the northeast end of the raised beach sequence] produced a date of c. 18 ka BP, at the peak of the LGM (Parks and Rendell, 1992).

The Bembridge Foreland region has produced many Palaeolithic artefact finds, although few are reliably provenanced (Wessex Archaeology, 1993). A small ovate handaxe in fresh condition and some waste flakes have been recovered from the thick brickearth deposit overlying the southwest end of the raised beach sequence at Howgate (Codrington, 1870; Poole, 1939). These are most likely derived from earlier deposits, since handaxes were not produced in the Late Devensian, when the brickearth was laid down. Several handaxes, including one pointed specimen, have been found in the grounds of Bembridge School in colluvial/solifluction deposits of uncertain age, but overlying the Steyne Wood Clay. These deposits may also be the source of the Howgate handaxe, although all [or some] of these artefacts could be derived from earlier sediments, and may be as old as the Steyne Wood Clay, which is thought to be pre-Anglian (cf. Holyoak and Preece, 1983; Preece *et al.*, 1990). Two more handaxes are known from Bembridge, one from a drainage trench along a main road of uncertain location (Morey, 1924), and another from a flowerbed within the grounds of the Bembridge Warner Hotel (Wessex Archaeology, 1993), both of uncertain geological context. Finally, approximately a dozen handaxes of various shapes and sizes have been found on the beach between Culver Cliff and the Lifeboat Station. These most likely originate from the overhanging cliff deposits, which probably include unrecorded Pleistocene beds, as well as those discussed above. Evidence of Palaeolithic activity might be expected to be commonplace in the vicinity of Culver Cliff, where the exposure of Chalk bedrock would have provided abundant flint raw material for tool manufacture. Handaxes found on the beach here could also, however, have been derived from one of the many other deposits in the vicinity that are known to be rich in handaxes, for instance Solent River gravel terraces submerged under the

Solent, or the gravels capping the cliff at Priory Bay 3km northwest of Foreland along the coastline (cf. Loader, 2001; Wenban-Smith, 2001).

Research background

We now have a good international framework of global climatic change through the Pleistocene resulting primarily from the study of ocean-floor sediments and ice-sheets, expressed as a record of marine $O^{18}:O^{16}$ isotope change (Shackleton and Opdyke, 1973, 1976; Imbrie *et al.*, 1984; NGICP, 2004). In the UK, correlation of the relatively fragmentary terrestrial record with this MIS framework has been achieved through fundamental assumptions over the attribution of a few key sediment bodies, such as equation of the glacial tills that cover much of East Anglia with MIS 12 (although see Lee *et al.*, 2004), and painstaking application of lithostratigraphy, biostratigraphy and absolute chronometric dating where possible.

For the last (Ipswichian) interglacial, a number of sites have produced both a distinctive set of faunal remains and independent dating that associates them with the warm peak of MIS 5e at c. 125,000 BP (Gascoyne *et al.*, 1981; Stringer *et al.*, 1986; Currant, 1989). A far greater number of sites have been attributed to the last interglacial on palynological grounds (Stuart, 1982; Jones and Keen, 1993, Figure 8.1). However, the last interglacial palynological sequence is a composite from numerous separate locations, particularly Bobbitshole and Ilford for its earlier part, and Wing for its later part. Unfortunately Ilford is one of the sites argued, e.g. by Currant (1989) on mammalian biostratigraphic grounds, to belong to an earlier MIS stage, and attribution of Wing to the Ipswichian is based on the premise that there are no other post-Hoxnian (and pre-Holocene) interglacials (Hall, 1980: 156). However, the MIS framework clearly shows temperate excursions that are likely of interglacial status in MIS 9 and 7, and it remains uncertain whether pollen sequences through these episodes can be distinguished from that through MIS 5e. Thus some sediments regarded as Ipswichian MIS 5e on palynological grounds may relate to a different MIS episode, and independent dating is desirable to confirm their MIS 5e attribution. Although the pollen-bearing unit from the Bembridge raised beach includes the rise in *Carpinus* that is regarded as characteristic of the latter part of the Ipswichian interglacial, it remains for this attribution to be independently confirmed by absolute chronometric methods.

Secondly, the colluvial/solifluction gravel that overlies the raised beach sequence has been attributed to post-Ipswichian climatic deterioration, but has not yet been independently dated — although it is known to be capped by a deposit dated to the LGM. There is some uncertainty over the timing and recognition of post-MIS 5e climatic events in the UK terrestrial record, particularly over: (a) recognition of deposits attributable to MIS 5c or 5a, and (b) the timing of the onset of significant climatic deterioration associated with

the last (Devensian) glaciation. Most (e.g. Jones and Keen, 1993) regard the onset of the last glaciation as corresponding with MIS 5d, at c. 115,000 BP, and sub-stages MIS 5c and 5a as being represented by unforested interstadial environments. However, the pollen evidence from Grande Pile in northeast France (Woillard, 1978) indicates that sub-stages 5a and 5c were interglacial episodes locally climatically indistinct from 5e. This suggests that some deposits attributed to MIS 5e, but lacking independent chronometric dating, may date from 5c or 5a, and that climatic deterioration associated with the onset of the Devensian glaciation could date to MIS 5b or 4. Dating the sequence at Bembridge could clarify this issue. The raised beach deposits are directly overlain by a substantial body of colluvial/solifluction deposits associated with significant climatic deterioration. Dating both the raised beach sediments and the overlying cold climate sediments can help identify the timing of the onset of post-Ipswichian climatic deterioration in Britain.

Optically stimulated luminescence (OSL) dating has undergone substantial improvement in recent years, with development of single-aliquot regenerative (SAR) dose measurement protocol (Murray and Wintle, 2000). Murray and Funder (2003) have shown that OSL dating using the SAR protocol can reliably distinguish MIS 5e from other MIS 5 sub-stages, and OSL dates at several late Middle and Late Pleistocene sites have recently been produced that are corroborated by other means. For instance Burchell's Temperate Bed at Northfleet, attributable to MIS 7 on the basis of geological and biostratigraphic considerations (cf. Wenban-Smith 1995), has been OSL dated to c. 190 ka BP (Wenban-Smith and Rhodes, unpublished research); and deposits at Harnham dated to an MIS 8 interstadial by amino acid racemisation have been OSL dated to c. 255 ka BP (Bates *et al.* in prep.). This confirms the suitability of OSL dating for the Bembridge sequence, which is (a) rich in sand-dominant sedimentary units and (b) can be expected to date in the range MIS 8 to MIS 4, where the SAR protocol has proven reliable.

Aims

The aims of the fieldwork were:

- To record the sequence of deposits affected by the beach recharge works, relate individual units to those previously recorded, and ascertain whether any pollen-bearing sediments were still present.
- To date different units within the raised beach sequence by OSL, and relate them to the MIS framework.
- To expand the previously recorded pollen sequence.
- To ascertain the relationship between the sequence of deposits and local sea-level history by sampling for testate amoebae.

Methods

Vertical sections of the cliff face were cleaned with hand tools at two locations (Figure 2, Sections 1 and 2). Each section was drawn, photographed and surveyed. Sedimentary units were recorded, and numbered in descending order from the top of the sequence, following standard archaeological practice. A vertical series of samples through the pollen-rich fine-grained humic silts was taken at both sections for pollen/diatom analysis, and a duplicate series taken for testate amoebae. Samples for OSL dating were taken from suitable sand-rich deposits at Sections 1 and 2, supplemented by *in situ* dosimetry readings.

Stratigraphy

A similar sequence of deposits was recorded at both Section 1 (Figure 3) and Section 2 (Figure 4). Eight groups (I to VIII) of deposits were recognised (Table 1). Groups II, III and IV can be confidently correlated with the three lithological units previously identified as defining the raised beach sequence. The surface of the Group IV organic silt was distorted and truncated by the lowermost unit of the overlying Group V sand/gravel deposits, which also filled intrusive pockets. The Group V deposits can be interpreted as reflecting mobilisation of sediments from higher ground under periglacial conditions associated with significant climatic deterioration. The Group VI gravel deposits also represent solifluction and have also been heavily cryoturbated in places subsequent to their movement. The Group VII deposits (Silt/fine sand) are equivalent to the loessic deposits previously studied by Parks and Rendell (1992) and TL-dated to 17–18k BP.

OSL dating

Eight OSL samples were taken, three (OSL 1–3) from the sequence at Section 1, and five (OSL 4–8) from the sequence at Section 2. In order to calculate the palaeodose, sand-sized quartz grains (180–255µm) were measured using the single-aliquot regenerative dose measurement procedure. Gamma dose rates were measured *in-situ* (Table 2). The beta dose rate was derived from the concentrations of U, Th and K determined by instrumental neutron activation analysis. No on site radioactivity measurements were available for OSL 8 and the dose rate is based on the INAA results. The cosmic-ray contribution to the dose rate was derived from data published by Prescott and Hutton (1994), taking into account overburden height, altitude and geographical position. Dosimetry readings from the sampling locations were mostly low, indicating high potential for achieving successful dating results.

The OSL dating results (Table 2) generally correspond with stratigraphic order and support correlation of the raised beach sequence with the high sea-level event of MIS 5e. Two of the five dates for the raised beach sediments are centred in the range 120,000 to 130,000 BP, which is also within the margin

Section 1

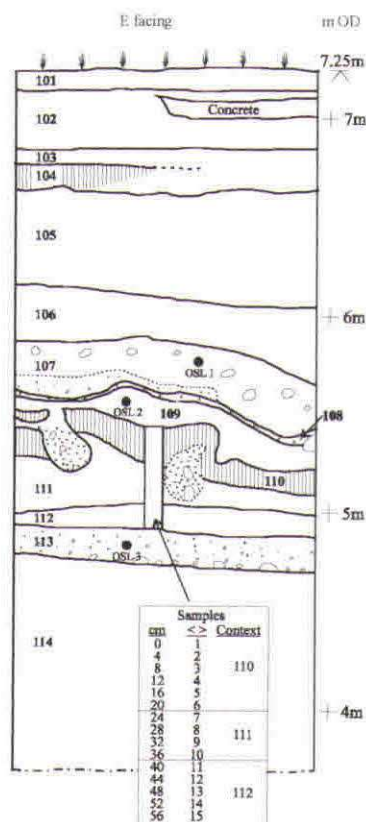


Figure 3. Section 1.

of error for a third. The other two dates, both from Section 2, are much older. These latter dates must therefore be wrong, since there is no doubt that the raised beach represents a high sea-level stand, and the stand preceding MIS 5e is, at c. 200,000 BP, far older than any of the results. One possible source of error is the model of water content history, which assumes that the present measured moisture content of the sediment has remained constant since its

VIII. TURF/TOPSOIL

101 Turf

- 102 Greyish brown friable moderately well compacted sandy clay-silt with angular to rounded flint pebbles

VII. SILT/FINE SAND

- 103 Pale greyish brown moderately well compacted slightly sandy clay-silt with angular to sub-angular fine to medium flint pebbles
- 104 Yellowish brown (10YR 5/8) moderately well compacted slightly sandy clay-silt with angular to moderately rounded fine to coarse flint pebbles

VI. CRYOTURBATED GRAVEL

- 105 Well compacted, almost elast supported, fine to v. coarse flint gravel in brownish yellow (10YR 6/6) fine-medium sand matrix, gravels poorly sorted, clasts gen. angular to sub-angular, occ. rounded
- 106 Gravels similar to above but much paler almost white (pale brown 10YR 8/2-3), in v. silty fine sand matrix, gravels gen. slightly coarser than in context 105

V. GRAVEL-RICH SANDS

- 107 Brownish yellow lightly cemented medium to very coarse sand with mod. common v. coarse rounded flint pebbles and frequent v. fine angular flint pebbles
- 108 Light brownish grey (2.5YR 6/2) moderately compacted sandy clay-silt
- 109 Yellowish brown (10YR 5/8) mod. soft fine-medium sand with occ. rounded very coarse flint pebbles, basal junction v. contorted and filling pockets cut into through units 110 and 111

IV. BROWN ORGANIC CLAY-SILT

- 110 Light brownish grey (2.5YR 6/2) stiff clay coarsening downwards to s. sandy clay-silt, occ. reddish yellow mottling towards base, top 1 cm reddish yellow stained and upper part light olive brown (2.5YR 5/4)

III. CLAY-SILT/FINE SAND

- 111 Mottled brownish yellow (10YR 6/8) and light brownish grey (2.5Y 6/2) soft to moderately compacted sandy clay-silt
- 112 Light brownish grey (2.5YR 6/2) soft to moderately compacted very fine sandy silt with occasional brownish yellow (10YR 6/8) mottling

II. SAND AND BEACH PEBBLES

- 113 Light olive brown (2.5YR 5/4-6) moderately soft silty fine to medium sand with intermittent layer of coarse to very coarse rounded flint pebbles at base

I. BEMBRIDGE MARL

- 114 Grey to light olive grey (5Y 6/1-2) moderately to well compacted clay with brownish yellow and reddish yellow mottling, top 1 cm stained brownish yellow

Section 2

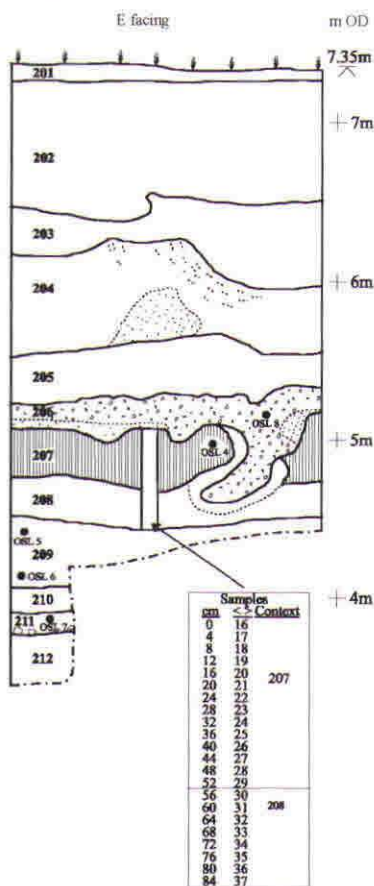


Figure 4. Section 2.

deposition. If better means can be found of modeling moisture content history, or at least assessing its constancy, then perhaps more reliable OSL dates can be obtained.

The dates from the colluvial/solifluction sediments (Group V) that overlie the raised beach sediments were between c. 82 ka and 115 ka BP, corresponding with the period MIS 5d to 5b. The youngest of these (OSL 2) had an unreliably high dose-rate (cf. Table 2), so greater credence can reasonably be attached to the other two Group V dates, which also match stratigraphic order. The

VIII. TURF/TOPSOIL

- 201 Turf
- 202 Modern made ground with CBM, freq. sub-angular flint gravel in compacted sandy clay-silt matrix

VII. SILT/FINE SAND

- 203 Brownish yellow (10YR 6/6) moderately compacted friable clay-silt with fine sand, strong brown (7.5YR 5/8) mottling; moderately frequent very fine to medium sub-angular flint pebbles

VI. CRYOTURBATED GRAVEL

- 204 Brownish yellow (10YR 6/6) sandy clay-silt with poorly sorted fine to very coarse densely packed angular to sub-angular (occasionally rounded) flint gravel

V. GRAVEL-RICH SANDS

- 205 Light grey (10YR 7/1) moderately well compacted fine to medium sand with frequent sub-angular to moderately rounded fine to coarse flint gravel
- 206 Reddish yellow (7.5YR 6/8) soft to moderately soft medium to coarse sand with moderately common rounded medium to coarse flint pebbles; bottom 2-5cm light yellowish brown (2.5YR 6/4) in places; basal junction v. contorted and filling pockets cut into/through units 207 and 208

IV. BROWN ORGANIC CLAY-SILT

- 207 Dark brown (7.5YR 3/2) moderately soft humic silt

III. CLAY-SILT/FINE SAND

- 208 Dark grey (7.5YR/N4) moderately soft clay-silt with some very fine sand
- 209 Olive grey (5Y 4/2) moderately soft silty fine to medium sand in upper part; olive (5Y 4/4) soft silty fine to medium sand in lower part
- 210 Light olive grey (5Y 6/2) moderately soft very slightly sandy clay-silt

II. SAND AND BEACH PEBBLES

- 211 Olive grey (5Y 4-5/2) soft very slightly silty medium to very coarse sand with some angular very fine flint gravel; basal layer of intermittent well rounded medium to very coarse flint pebbles

I. BEMERIDGE MARL

- 212 Grey (2.5Y/N5) soft to moderately compacted clay with top 2cm stained reddish yellow (7.5YR 6-7/8)

Sediment group	Section 1 units	Section 2 units	Deposition	Period	MIS	Date BP
VIII. Turf/topsoil	101 102	201 202	Recent soil development and turf growth	Holocene	1	Present
VII. Silt/fine sand	103 104	203	Colluvial/aeolian	Late Devensian	2	15,000– 25,000
VI. Cryoturbated gravel	105 106	204	Solifluction	Devensian	2–5d	15,000– 110,000
V. Gravel-rich sands	107 108	205	Colluvial/solifluction	Early Devensian	5b–5d	85,000– 110,000?
	109	206	Colluvial/solifluction	Early Devensian	5d	110,000– 115,000
IV. Brown organic clay-silt	110	207	Salt marsh in lower part, becoming freshwater in upper part	Ipswichian	5e	120,000– 125,000
III. Clay-silt/fine sand	111 112	208 209 210	Anoxic stagnant swamp, possibly sealed behind off-shore bar			
II. Sand and beach pebbles	113	211	Tail end of raised storm beach			
I. Bembridge Marls	114	212	-			
				Tertiary	-	-

Table 1. Stratigraphy: correlation, deposition and MIS/Stadial attribution.

Group	Section	Context	OSL sample	Moisture (%)	Palaeodose (Gy)	Dose rate (mGy/a)	Age (ka BP)
V	1	107	1	6.0	80.4 ± 4.3	0.78 ± 0.03	102.5 ± 7.2
		109	2	10	188.8 ± 24.2	2.31 ± 0.10	81.7 ± 11.2
	2	206	8	16	127.3 ± 3.4	1.10 ± 0.07	115.7 ± 8.3
IV	2	207	4	28	228.3 ± 11.3	1.77 ± 0.10	129.1 ± 8.1
III	2	209	5	15	232.6 ± 2.9	1.65 ± 0.07	141.3 ± 14.4
			6	17	209.1 ± 9.1	1.33 ± 0.05	156.8 ± 9.2
II	1	113	3	18	217.0 ± 16.0	1.78 ± 0.07	121.9 ± 10.4
	2	211	7	17	222.1 ± 4.7	1.22 ± 0.04	182.6 ± 8.3

Table 2. OSL measurements and dating.

older date of 115.7 ± 8.3 ka BP comes from the unit that directly overlies and truncates the organic silt, suggesting a possible correlation with MIS 5d. The other date of 102.5 ± 7.2 ka BP comes from the next unit up in the sequence, suggesting possible correlation with MIS 5b.

Pollen analysis

Pollen grains were only present in the brown organic clay-silt — contexts 110 (Section 1) and 207 (Section 2). Preservation was better and the sequence deeper in context 207, so analysis was carried out of the full sequence of samples through this context (samples 16–29), and into the top part of context 208 (sample 30). Pollen analysis of the deposit had already been carried out (Preece *et al.*, 1990) at a nearby location (cf. Figure 2), and the focus of this analysis was on complementing or enhancing the previous analysis, specifically:

- To correlate the surviving part of the organic silt with that previously studied.
- To look for pollen evidence stratigraphically higher or lower than that previously studied, to expand knowledge of palaeo-climate and environment at the site.
- To provide a fuller record of diversity and vertical variation in the part of the sequence represented.

Preservation

Pollen grains were abundant and well-preserved in context 207, with absolute frequencies between c. 100,000 and 450,000 grains/ml. Small numbers (c. 7,000 grains/ml) were present at the interface of contexts 207 and 208. Fine-grained sediments of underlying context 208 were devoid of pollen and spores and appeared to have been deposited in highly anoxic conditions.

Pollen zonation

In general, the pollen spectra are similar throughout the sequence (Figure 5). However, small changes in *Chenopodiaceae* (goosefoots, oraches and glassworts) and *Acer* (field maple) between 28cm and 32cm can be used to divide the pollen diagram into two local assemblage zones: BEMB 1 (32–54cm) and BEMB 2 (0–28cm).

BEMB 1

Trees and shrubs are dominant with *Quercus* (oak) and *Corylus avellana* (hazel) most common. *Acer* has higher values in this zone and *Alnus* (alder) appears at 44cm. Herbs are dominated by *Poaceae* (20–30%) and *Chenopodiaceae* (12%). There is a moderately diverse range of herbs with occasional halophytes including *Armeria* 'A' and 'B' line, *Plantago maritima* type and *Aster* type. There are few freshwater marsh and aquatic taxa with only small numbers of *Cyperaceae*, *Myriophyllum* and *Typha angustifolia* type.

13



Rob Scoife 2004

BEMB 2

This zone has been delimited by reductions of *Acer* (to <1%) and *Chenopodiaceae* (to 10%). There are also slightly higher values of *Corylus avellana* type (to 30% at 0cm), *Carpinus betulus* (hornbeam) and *Fraxinus excelsior* (ash). In all other aspects, the pollen assemblages are similar to those described for BEMB 1.

Depositional environment

Through unit 208, below the pollen-bearing sediments, the sediments are humic and dark, and it was clear during sample preparation that the deposit was laid down in highly anoxic/reducing conditions. This may have been a stagnant backwater or swamp behind a beach barrier or off-shore bar, which subsequently became inundated (cf. Preece *et al.*, 1990).

The lower half of the pollen-bearing sequence (BEMB 1) has almost certainly been laid down under salt marsh or estuarine conditions. There are substantial numbers of *Chenopodiaceae* and other typical salt marsh taxa, including *Plumbaginaceae* (*Armeria* types), which are typically significantly under-represented in pollen spectra. The levels of salt marsh indicators decrease in the upper half of the profile (BEMB 2), suggesting that the salt marsh may have become a more freshwater habitat. Although there are only small numbers of aquatic taxa at this horizon, this is not unusual for such a situation, and the presence of *Nymphaea* (white water lily) is sufficient to indicate an aquatic environment. The transition from salt marsh to freshwater conditions is most likely due to local landscape evolution, since sea-level is unlikely to have decreased within the early temperate interglacial stage represented by the pollen sequence.

Terrestrial vegetation

Trees and shrubs are dominant throughout the profile with minor variations in frequency for particular species, indicating fully temperate conditions with closed forest inland from the salt marsh itself. Oak and hazel are the most significant contributors to the pollen spectra, but this is probably not a true reflection of their prevalence due to the relative abundance of their pollen. Maple, ash and holly all produce small quantities of pollen, so, despite their relatively small contribution to the pollen spectra, would probably also have been important constituents of the local woodland. Hornbeam was also present almost throughout the sequence, although in low quantities. Small quantities of alder, birch and pine are also present, but these are not regarded as major contributors to the local forest environment as these taxa are often greatly over-represented in pollen assemblages due to the vast quantities of pollen grains produced and the large distances they travel.

Correlation with the Bembridge Foreland Pollen Site sequence

The pollen sequence studied here was only a few metres away from the previous Bembridge Foreland Pollen Site (Preece *et al.*, 1990). In the previous study the pollen-bearing deposit was 1 m thick, and present between 1.45 m and 2.45 m from the ground-surface. In the present study the same unit was 50 cm thick and was present between 2.25 m and 2.75 m from the ground-surface. The pollen spectra in the present study are almost identical to those in the lower assemblage zone of the previous study, which comprised the bottom 25 cm of the sequence. It appears, therefore, that the present profile represents a thicker manifestation of the basal unit previously described (*ibid.*), and as such provides a higher degree of resolution, allowing identification of new features such as the variation in halophyte presence noted above.

The fuller profile previously described was unequivocally attributed to substages I Ib (Early Temperate) and III (Late Temperate) of the Ipswichian interglacial. The sequence in the present study corresponds with the basal part of the early study, and can therefore, in conjunction with the OSL dating results, be attributed to the Ipswichian Early Temperate substage I Ib. The paucity of birch and pine in the spectra preclude the possibility of an earlier substage.

Testate amoebae

The various fine-grained sediment units associated with the raised beach sequence were assessed for testate amoebae by Prof. Dan Charman (University of Plymouth, Department of Geographical Sciences). None was found, despite the pollen evidence for a transition from salt marsh towards a more freshwater environment. Testate amoebae are more susceptible to decay than pollen and many of the pollen grains showed signs of degradation. Therefore it seems that the absence of testate amoebae must be due to lack of preservation.

Lithic artefacts

A single lithic artefact was found in the Group VI cryoturbated gravels (unit 204) overlying the raised beach deposits in section 2. It is slightly patinated with a faint, mottled blue/white patina and heavily abraded. It appears to be a thinning flake from handaxe manufacture, and is almost certainly derived from a much older deposit than that in which it was found.

Conclusions

The sequence of deposits seen was similar, although not identical, to that previously recorded. The new investigations can be combined with the earlier work to produce a more up-to-date synthesis (Table 1). Key results of the new investigations are:

- Confirmation that the Bembridge Raised Beach sediments date to the Ipswichian high sea-level event MIS 5e.
- Attribution of the immediately overlying solifluction deposits to MIS 5d–5b.

Confirmation of the MIS 5e attribution of the raised beach sequence establishes that the Bembridge pollen sequence be relied upon as representing the Ipswichian. Dating of the post-raised beach solifluction deposits to MIS 5d demonstrates that MIS 5e was closely followed in Britain by a significant deterioration in climatic conditions. The MIS 5d unit is covered by another similar deposit dated to MIS 5b and these deposits are in turn buried by a substantial body of solifluction gravels that have not been dated, but are sealed by a Late Devensian loessic unit previously dated to 17–18k BP. This body of colluvial/solifluction and loessic sediments overlying the raised beach sequence seems most likely to represent deposition throughout the Devensian.

In principle, this sequence does not rule out post-MIS 5e and pre-Holocene oscillations of interglacial status, which are not represented at Bembridge or in any other UK sequences. However, until any deposits fill this gap, it seems reasonable to accept that the Devensian glaciation in Britain can be regarded as starting in MIS 5d. This in turn suggests that subsequent undated warmer interludes, such as the Chelford, Wretton and Brimpton interstadials, may indeed be associated with MIS 5c or 5a, as suggested by Bryant *et al.* (1983), rather than post-MIS 5 interstadials. Indeed, the recent identification of 25 separate warm [Dansgaard-Oeschger] events in the northern hemisphere in the period following MIS 5e (NGICP, 2004), dramatically raises the difficulty of correlation of specific short-lived interstadials in this period.

Finally, the differences between the exposures investigated in the present study and those previously studied highlight the impact of coastal erosion over the intervening 20 years. The thickness of the pollen-rich sediment unit, which is of limited lateral extent, was substantially less than previously seen. It is uncertain to what extent this unit continues inland. Although there may be substantial remnants, possibly with evidence from new phases of the sequence, there is also clearly a risk that ongoing coastal erosion will further diminish, and possibly destroy altogether, this valuable part of the Bembridge Raised Beach sequence. While the protective designation as SSSI can control human impact, it does not halt natural erosional processes. This is a particular problem for coastal exposures, where wider coastal management policy is moving from recognition of the futility of attempting to halt erosion, towards letting erosion take place with minimum intervention. Vulnerable sediment units will thus be exposed to an increased erosional threat, and inactivity on the part of the geological curatorial community will potentially lead to loss of valuable parts of the geological sedimentary archive. In this case, it is proposed to secure and preserve a pair of witness monoliths through the present exposure of the

fine-grained sediments including the pollen-rich unit. Applying this approach on a wider scale would require substantial resources and consideration of the long-term storage implications. Nonetheless, it seems that a survey of sites threatened by ongoing coastal erosion would be a useful exercise, complemented by consideration for each of possible steps to mitigate the threat of destruction, which could include any, or a combination, of:

- Preservation of witness archives
- Study with up-to-date methods where not already carried out
- Local protection from erosion

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NEW MICROFAUNAL DATA FROM THE RAINCLIFF FORMATION (SPEETON SHELL BED), NORTH YORKSHIRE

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Introduction

The Speeton Shell Bed is an enigmatic deposit situated in the cliffs of southern Filey Bay, resting on and overlain by angular gravels of predominantly white chalk. The lower gravel is underlain by the Speeton Clay Formation and the upper gravel is overlain by till, sands and other gravels. According to Thomas (1999), because the Speeton Clay Formation is a subdivision of the Early Cretaceous, the Quaternary deposit must now be known as the Raincliff Formation. Initially regarded as Hoxnian in age, both palynology and amino-acid dating suggest it is younger (*ibid.* 1999, 97). A full description of the Raincliff Formation, its 'high' and 'low' level occurrences, stratigraphical situation and age is given by Gaunt (2001). During the Autumn Field Meeting of the Ostracod Group of The Micropalaeontological Society, held at Scarborough, an opportunity was taken during a visit to Speeton on the 18th September 2004 to sample the Raincliff Formation (Speeton Shell Bed) (Grid ref. TA 147 758) at its 'high' level occurrence. From a sample collected by DJH, two washings were made of approx 300g each through a 75 micron sieve. Both faunas were practically the same, so joint lists of Ostracoda and Foraminifera are given below. The microfaunal list, especially the Ostracoda, is considered to be of interest and we record it here.

Microfauna - Ostracoda

17 ostracod species were identified, as follows in order of abundance:

Leptocythere castanea (Sars, 1866)

Leptocythere psammophila (Guillaume, 1976)

Leptocythere lacertosa (Hirschmann, 1912)

Hemicythere villosa (Sars, 1866)

Palmoconcha laevata (Norman, 1865)

Cythere lutea O.F. (Müller, 1785)

Hemicytherura clathrata (Sars, 1866)

Cytheropteron latissimum (Norman, 1865)

Cytheropteron depressum (Brady & Norman, 1889)

Cyprideis torosa (Jones, 1850)

Sarsicytheridea bradii (Norman, 1865)
Hirschmannia viridis (O.F. Müller, 1785)
Robertsonites tuberculatus (Sars, 1866)
Elofsonella concinna (Jones, 1857)
Cuneocythere semipunctata (Brady, 1868)
Semicytherura undata (Sars, 1866)
Semicytherura sp.

Leptocythere castanea was by far the commonest species (often preserved as whole carapaces and with juveniles, and therefore *in situ*), followed in terms of decreasing abundance by *L. psammophila*, *L. lacertosa* and *H. villosa*. Almost all the rest were each represented by a few valves only. All except *H. clathrata* (and possibly the *Semicytherura* sp.) can be found living off the coast of NE England today. Although not dateable *per se*, the fauna represents a fully temperate interglacial deposit. The environment is that of an outer estuarine tidal flat, and the occurrence of *H. villosa* may reflect the presence of intertidal algae.

Microfauna – Foraminifera

To complete the record, associated foraminifera from the same sample are also listed. An almost identical fauna of 6 species was given by Austin and Evans (1999). The species in order of abundance are:

Elphidium williamsoni Haynes, 1973
Elphidium excavatum (Terquem, 1875)
Elphidium gerthi (van Voorthuysen, 1957)
Ammonia batavus (Hofker, 1951)
Haynesina germanica (Ehrenberg, 1840)
Cibicides lobatulus (Walker & Jacob, 1798)

In terms of abundance, by far the commonest species are *E. williamsoni* and *E. excavatum*. The fauna is typical of an estuarine subtidal environment.

Discussion

The Raincliff Formation (Speeton Shell Bed) was first mentioned in the literature some 130 years ago (Gaunt 2001, 90) but its precise age and stratigraphical and environmental significance remain unclear, not least because age-diagnostic fossils have not been found. It is clearly an interglacial deposit, and clearly

older than the overlying till, however, attempts to reach an 'older than' age are inconclusive because of difficulties of correlation with the till sequences of Holderness and other adjacent areas. Amino acid ratio results have generated two ages (reviewed by Gaunt 2001, 92) of MIS 7 ("Saalian Complex") and MIS 5e (Ipswichian), while the palynology (West, 1969) supports the latter (younger) age.

Catt and Penny (1966) and Catt (1991) had earlier proposed a correlation between the Speeton Shell Bed and the Kirmington Formation of north Lincolnshire. The foraminifera from the Speeton Shell Bed have nothing in common with those found in the interglacial Kirmington deposits. The latter, although also estuarine, are totally dominated by the "southern" warm temperate species *Aubignyna perlucida* (Heron-Allen and Earland, 1913) (from Reid's original sample (1885) of estuarine "warp" in The Natural History Museum, London, collections), which today is not found in England outside the furthest southwest. The presence and abundance of *A. perlucida* at Kirmington is intriguing in its own right. *A. perlucida* is without question a "warm water" taxon and presumably migrated from southernmost England via a direct marine connection from the south, since it is very unlikely to have reached Kirmington via a northern route. The occurrence of *A. perlucida* therefore raises questions about the age of the Kirmington interglacial deposit in relation to the opening of the Straits of Dover and contemporary marine connections.

Our Raincliff Formation assemblage indicates water temperatures similar to those of the adjacent modern coastal waters, i.e. full interglacial conditions, but cooler than the water temperature indicated by the Kirmington assemblage. It therefore seems unlikely that the Speeton and Kirmington deposits represent different phases of the same interglacial event.

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REPORTS

THE QUATERNARY OF CENTRAL WESTERN IRELAND

IRISH QUATERNARY ASSOCIATION (IQUA) AND QRA FIELD MEETING, 6TH – 10TH APRIL, 2005

Introduction

A contingent of around 60 Quaternary scientists from Britain and Ireland took part in the joint QRA and IQUA field trip to central western Ireland which took place between the 6th and 10th April, 2005. During the four days of field excursions, evidence was presented from a suite of sites containing Quaternary as well some Late Tertiary stratigraphic sequences. Each day of the field trip focused upon one of four very distinctive landscapes, the Burren, located in County Clare, the lowlands of east County Galway, the region of Connemara and up into the mountains of County Mayo. These landscapes encompassed the karstic topography of the Burren and lowlands around Lough Corrib, the Atlantic coastline of southwest Connemara and finally, the heavily glaciated topography of northern Connemara and Mayo. Although the discussion of Late Quaternary glacial sequences provided a common thread between all four days of the trip, a wide diversity of sites were visited and a range of archaeological, geomorphological and geological evidence was presented.

Day 1: Landscapes of the Gort lowlands and the Burren

Having met up the previous night at the Imperial Hotel in Galway City Centre, the group promptly set off the following morning for the landscapes of the Burren and Gort lowlands situated to the south in County Clare. The Burren, together with the neighbouring Gort lowlands comprise an expanse of thinly vegetated Carboniferous limestone. However, until the recent geological past the limestone of the Burren was shielded from weathering by a protective (Namurian) shale cap. The corollary of this is that the region now forms a distinctive plateau rising to over 300m that stands proud of the adjacent Gort lowlands. **Michael Simms**, who led most of the first day, gave his expert account of the erosion of the various rock types and outlined the fascinating enigma of the rates of differential erosion or 'tortoise and hare race' (Simms, 2004).

Tides and journey times decreed that the sites were to be visited in reverse order. The first site was at Murrough on the north-west Burren coast. After a walk through an impressive dune field (the site of a caravan park) Michael familiarized the party with a drumlinoid ridge which has been neatly exposed

in cross-section through coastal erosion. At Murrough, horizontally bedded limestone is overlain by brecciated rock that in turn gives way to a heterogeneous diamict unit. Croot and Simms (1996) had described the sequence found at this locality although their interpretation of the facies associations were not universally held by all members of the party. From Murrough, the group then walked southward, following the course of the Caher River up through the Khyber Pass. Here till units were seen to be cut into by gravel and boulder-filled channels, probably subglacial in origin. *Dryas octopetala* was all over the surrounding slopes, but unfortunately not yet in flower. This locality is in fact unusual since surface water is an atypical feature on the limestone of the Burren. At more than one point, the Caher has truncated the till deposits that align the Khyber Valley, revealing laterally extensive free face exposures. However, the steep gradient acted as an effective drain on the groups energy so the next stop was in a traditional pub in Lisdoonvarna for soup, sandwiches and liquid refreshment.

Immediately after lunch the party visited Poulsallagh Bay, located on the south-western edge of the Burren. Owing to the plethora of karstic, glacial and coastal features present, the group spent much of the afternoon at the site although unfortunately, on more than one occasion Michael Simms was to be interrupted by fierce squalls and windswept sea water! In between the storms however, Michael Simms delivered a fascinating discussion on a range of features present in this karstic landscape including an intriguing quartz pebble cave (*Pol na Grianloch*) situated on the north side of the bay. However, arguably of greatest interest, was a site to the south of the Bay where two recently obtained U-Th dates are likely to prove significant in elucidating the Devensian glacial history of this area. Here, a rock fissure contains two separate diamict associations and the presence of flowstones adjacent to these distinct units has enabled ages to be obtained for the emplacement of the till. These dates suggest that two discrete ice advance episodes have occurred in this region during Oxygen Isotope Stages 4 and 2 and support recent suggestions that a substantial expansion of the BIIS took place around 40kyr ago (e.g. Bowen *et al.*, 2002).

On the return leg of the journey back to Galway City, the group stopped at Lough Bunny, a shallow, 2km long lake basin just to the south-west of Gort. Michael O'Connell's palynological work on a sediment core extracted from an adjacent lake has enabled the reconstruction of the local vegetation history since the Late-glacial. Michael's absence meant **Fraser Mitchell** was called upon to deputize and his jocular dialogue was much appreciated at a time when the inclement weather was causing minds to drift towards Guinness back at the Imperial Hotel.

Day 2. Galway Bay and the Galway lowlands.

The focus of the second day was the Irish lowlands and the area around Lough Corrib, which lies to the north of Galway City. However, before moving inland, **Marshall McCabe** began the days proceedings with a detailed presentation of the Derryloney drumlin, Barna, that is situated a short way along the coast to the west of Galway City. Much like the drumlin seen at Murrough on the previous day, coastal erosion has revealed the drumlin in extensive cross section, enabling four major lithofacies associations to be highlighted. The nature and relationship between the facies implies deposition in a shallow water environment. Whether this shallow water environment is indeed marine remains a moot point and one debated by the group.

From the Derryloney drumlin, the group traveled north to Pollnahallia to the site of a disused sand quarry, located just to the east of Lough Corrib. The area is characterized by karstic depressions, often capped by a veil of lodgement till. Prior to quarrying in the late 1980's, the gorge in which the site at Pollnahillia is located contained a thick (20m) fill of pure, silica rich sand which in turn, was overlain by till. However, during borehole investigations associated with the extraction of the sand, it was discovered that a thick (>10m) sequence of organic rich silts and clays containing lignite existed beneath the sand unit. In 1986, **Pete Coxon** extensively analyzed the palynology of this lignite unit and he reflected upon his findings to the assembled party. The biostratigraphical composition suggests a Late Pliocene age for these deposits and moreover, has delivered a fascinating glimpse into Ireland's Late Tertiary environment. Furthermore, the fact that these Tertiary sediments exist at the ground surface and have remained, despite Quaternary ice activity across the region, suggests that not all the geomorphological features of the region have a Quaternary origin.

Having had lunch in the Angler's Rest at Headford, the group moved on to Lough Mask, the second largest of the Great Western Lakes. Again, **Michael Simms** was called upon to explain the karstic features of this lacustrine environment. The group was introduced to a range of features from the unique phenomenon of 'boulders in socket' (that can be traced to the time of ice withdrawal from the region) through to the peculiar 'eggbox pitted' surface that characterizes the contemporary shore line of the lake. A short walk around the lake to visit a spectacular and well-developed set of röhrenkarren nearly resulted in a premature end to the 2005 field trip when a mix up in land access permission resulted in the entire party being locked behind a gate by two angry farmers. Only Michael Simms looked enthused at the prospect of remaining on the shores of Lough Mask for the rest of his days. Thankfully the situation was diffused and we were soon on the bus back to Galway.

The evening saw the AGM of the QRA held in the Imperial Hotel and while a full report of this will be minuted in the Circular it is worth noting the award of the Lewis Penny medal, which by coincidence, went to Colm O'Cofaigh, now at Durham but a former student of TCD.



Barna drumlin, (Galway Bay).

Day 3. Connemara

Day three saw the group depart from Galway City for the small town of Clifden in Connemara. *En route*, the party traveled along a narrow road (*Bóthar na Scrathóg*) and to the disused Gowlan East Quarries. Both quarries reveal *in situ* granite tors and adjacent deposits of weathered granite and soliflucted debris. Of greatest interest however, were the exposures of palaeosols, found in lenses within this weathered debris. Although spore counts are low, the palynological work carried out by Pete Coxon on the palaeosols is revealing in that the lower unit has its origins in the Late Tertiary. Arguably of even greater interest is the presence of a second palaeosol unit separating two glacial units. Low pollen counts have so far prevented a relative age being obtained for this unit yet visually, it appears very similar to Middle Pleistocene palaeosols found from elsewhere (e.g. Kemp, 1985). This site may thus be the first evidence in Ireland for Middle Pleistocene glacial activity.

Having had an excellently prepared lunch in Ryan's Pub in Roundstone, we moved on a short distance along the coast to our next field site. **Alan Lees** discussed the sedimentary system of Dogs Bay and introduced us to the unusual marine carbonate sediments found along this stretch of coastline. Unique to this particular location were the foraminiferal sands which, owing to (*inter alia*) sediment transport and bay morphology, account for up to 60% of the beach material in this Bay. Having inspected the beach sands, the group moved on towards Bunowen Castle.

We had been fortunate enough to have had a running commentary throughout

the day on the regions historic past by the esteemed local archaeologist **Michael Gibbons**. At Bunowen, Michael delivered an in depth account of the history of this castle along with the nature of pre-modern land ownership and societal interactions stretching back to the Medieval period. After a short (but exhausting) climb up the nearby Hill of Doon (special permission had been granted by the local landowner), the assembled party was rewarded with a spectacular panoramic view of the Connemara landscape to end the day on a high.



Day 4. Connemara and on to Killary and the Galway/Mayo mountains

The final day of the trip began with sunshine, meaning that the gloves, hats (and in one instance) boots were off. We were fortunate enough to have **Michael Gibbons** with us again and he accompanied us along the Sky Road to our first site where he delivered a fantastic discussion on the Megalithic tomb at Fahy whilst also alerting us to various other relicts of Connemara's prehistoric past. From here, the group moved northwards, on up into the mountains of northern Connemara. **Geoff Thomas** and **Richard Chiverrell** were gearing up to discuss the ice marginal depositional environments of western Connemara and for some members of the party, this next field site couldn't come soon enough. (This may have been related to the caliber of the speakers although it might also have had something to do with the combination of the winding mountain roads and the Guinness from the previous night).

In the Kylemore Valley of northwestern Connemara, extensive aggregate quarrying at Tullywee has provided a number of exposures in the large drift terraces which flank the valley. The depositional sequences seen at Tullywee appear, in part, to be of subaquatic origin, with the associated water body occupying a height at least 60-65m above Irish OD. The deposits include a spectacular array of eskers feeding a large ice-marginal fan system and delta surfaces. The proximity of the deposits to the coastal margin allied with

'evidence' from elsewhere around the Irish coastline prompts the question of whether these deposits are indicative of a glacio-lacustrine or marine setting. Unsurprisingly, unequivocal evidence for either is lacking and the search for glaciomarine muds containing foraminiferal assemblages is ongoing.

After lunch at the Leenaun Hotel, it was left to Geoff Thomas and Richard Chiverrell to begin the afternoon's proceedings. At Leenaun on the eastern side of Killary Harbour, a large incised delta terrace (with surface altitude of 70-75m) can be seen flanking both sides of the Valley and the group was introduced to these and associated features. As with the deposits found in the Kylemore Valley, the contentious debate surrounding the notion of high Late Devensian sea levels was raised with the suggestion that the deposits at Leenaun may have a marine origin. From Leenaun, the group passed northwards up into Mayo and along the south side of Clew Bay. Clew Bay is host to a swarm of submerged and semi submerged drumlins and at Thornhill, **Jane Hart** presented evidence from one such feature in what was the concluding discussion of the trip. Jane's presentation included detailed descriptions of stratified and deformed sediments within the drumlin's core and allowed the group (still 40 strong at the last site!) to get close to the internal workings of drumlin sedimentation.

The drive back to Clifden allowed the group to see the magnificent valley of Doo Lough between the Mweelrea Mountains and the Sheefry Hills with their extensive recessional moraines and delta kame surfaces of Late Midlandian deglaciation. The circuit for the day was completed with a view across Killary Harbour to the delta tops of Leenaun.

The joint QRA and IQUA field trip investigating the landscape of central western Ireland was an undoubted success, thanks in no small part to the individual leaders who presented their research at the many field sites visited on the trip. Particular thanks, however, are due to Pete Coxon whose organisation, local knowledge and enthusiasm were integral to the success of the trip. The trip emphasized that this region is rife with evidence that can be used to distill information about Ireland's Quaternary and Tertiary past. In particular, the location of the region on the periphery of the former BIIS means it is likely to hold critical clues into the nature and behaviour of this ice sheet during the Late Quaternary. Indeed, whilst a corpus of work already exists from across the region, the trip underlined the need for further work to be carried out and the numerous avenues which exist for future study in central western Ireland.

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QRA ANNUAL DISCUSSION MEETING: 'THE PALAEOOLITHIC OCCUPATION OF EUROPE'

The British Museum, 5-6th January 2005

The first day of the meeting focused on the earliest occupation of Europe and the Lower Palaeolithic. The meeting opened with **Chris Stringer** (NHM) providing an overview of the current state of knowledge of human evolution in Europe, the controversies still surrounding the origin of the European populations and the precise timing and extent of the earliest occupation. He also raised the intriguing questions of a possible link between fossils at Tighenif in Algeria, Atapuerca in Spain and Ceprano in Italy during the late Lower Pleistocene. The level of variability of Middle Pleistocene fossils potentially indicates that two distinct groups were present in Europe during marine isotope stage (MIS) 11. The issues of the timing and nature of the first human occupation of Europe and the patterning of human spread across the continent were central themes of the meeting and were picked up by several subsequent speakers. **David Lordkipanidze** (Georgian State Museum) also set the scene of the appearance of humans in Europe by describing the hominin fossils and the environmental circumstances of the Plio-Pleistocene occupation of the Caucasus, with small brained hominins showing affinities to African early *Homo*, living in a diverse lacustrine and riparian habitat surrounded by forest-steppe.

The dating of human presence in Britain was debated in the presentations of **Richard Preece** (Cambridge) and **Simon Parfitt** (NHM), and **Jim Rose** (RHUL). Pre-Anglian Middle Pleistocene occupation of Britain was accepted by all, with Rose placing the earliest evidence from Pakefield in Suffolk of lithics in association with a *Mimomys* fauna in late MIS 19 based on the lithostatigraphy of the Bytham river terraces and its positioning relative to the Happisburgh till, which Rose assigned to MIS 16. However, Preece and Parfitt contested that the Happisburgh till is younger than MIS 16 as it overlies sediments containing *Arvicola*, leaving insufficient time for the complex faunal turnover seen between the Brunhes-Matuyama boundary and these deposits. **David Bridgland** (Durham) presented a summary of the nature of the British river terrace sequences, demonstrating that glacial cycles may produce several terraces, contrary to Rose's argument concerning the Happisburgh till, and therefore highlighting the need to use other dating methods in conjunction with lithostratigraphy to provide accurate dates. Bridgland suggested that in Britain the Palaeolithic archaeological record may provide a means of dating terraces, with the earliest assemblages in the late Cromerian, twisted ovate handaxes in MIS 11, the appearance of Levallois in early MIS 8-7, the absence of artefacts in MIS 6-5, and finally the Mousterian with bout coupé handaxes during the

last glacial. This proposal was supported by the evidence presented by **Rebecca Briant** (KCUL) *et al.* concerning the terraces of the Solent River. Problems of resolving dating differences between techniques such as biostratigraphy and lithostratigraphy, and of correlating regional sequences between Britain and continental Europe were also discussed by **Thijs van Kolfschoten** (Leiden). He provided a continental perspective of Lower and Middle Pleistocene biostratigraphy, indicating that the clustering of sites around 1 million years ago in southern Europe and 0.5 million years ago in northwest Europe may be the result of biostratigraphical dating practices rather than a reflection of the actual presence of humans in Europe over time.

The afternoon session on the Lower Palaeolithic in Europe concentrated on sites and regions in Britain, highlighting environmental adaptations and behaviours associated with occupation. **David Keen** (Birmingham) *et al.* addressed the colonisation of the West Midlands and the possibility that much of the archaeological record in this region recovered from post-Anglian river terraces is actually reworked from the pre-Anglian Bytham river. David put forward a model of the Bytham river as a major corridor for the early colonisation of Britain. The prospect of more complex behaviour in the British Lower Palaeolithic than previously thought was also raised by finds of andesite tools in the West Midlands. There are no andesite outcrops in the region and therefore its presence could indicate the transport of raw material over more than a hundred kilometres unless the headwaters of the Bytham river are found to have extended as far as North Wales to create a natural source of andesite in the river deposits. Alternatively, hominins transported andesite from its sources in North Wales or Cumbria, indicating that human presence extended further north and west than the West Midlands.

Hoxnian environmental adaptations and behaviours were addressed in several presentations. **Richard Preece** presented findings from Beeches Pit in Suffolk, which showed multiple phases of Acheulean occupation in a closed deciduous forest habitat, with signs of the presence of fire, and possibly of controlled fire use in hearths indicated by localised reddened patches and burnt flints and bones reflecting temperatures of 600-800°C, far hotter than natural forest fires. **Francis Wenban-Smith** (Southampton) discussed the findings of a Clactonian elephant (*Palaeoloxodon antiquus*) butchery site at Ebbsfleet in Kent from a woodland environment. Both Preece and Wenban-Smith addressed the implications of the presence of both Acheulean and Clactonian sites in Britain during MIS 11. The habitats of preference of Hoxnian humans were re-evaluated in the presentation by **Nick Ashton** (BM) *et al.*, with the conclusion that lacustrine locations were not occupied and sites previously thought to be lacustrine were utilised during fluvial periods, creating a picture of a strong preference for riparian habitats in MIS 11, perhaps because rivers formed access corridors, as suggested by Keen *et al.* for the pre-Anglian landscape, and that lithic raw

materials and other resources were available along rivers. The visibility of human presence in situations of low raw material availability was also raised with respect to the West Midlands and Hoxnian lacustrine locations, as high levels of curation in situations of poor resources would leave little trace in the archaeological record.

These themes of dating, behaviour, and environmental adaptation were brought together in **Wil Roebroeks'** (Leiden) presentation of the John Wiley lecture, in which he called for the greater use of biogeographical models to explain the spatiotemporal patterns of the Palaeolithic occupation of Europe. Roebroeks urged greater consideration of the types of range limits that many have affected the hominin range over time, such as abiotic factors of temperature, daylight length and biotic factors of competition within the carnivore guild, faunal turnover and hominin behavioural changes. He suggests that the spread to the north and increase in hominin presence in the Middle Pleistocene may be related to the development of co-operative hunting based on knowledge of animal behaviour, and also that the stability of the range in the Middle Pleistocene reflects the behavioural stasis seen in the archaeological record.

The chronological theme was picked up on the second day of the meeting in several presentations about advances in dating techniques. **Tom Higham** (Oxford) *et al.* discussed improvements in the AMS radiocarbon dating technique applied to bone in Middle and Upper Palaeolithic sites in Britain. Pre-treatments of bone samples to extract Type 1 bone collagen, tripeptides and purified amino acids, and means of validating the results were described. The ORAU ultrafiltration technique presented provides a means of improving the quality of the collagen extracted from bone, and has resulted in the revision of dates from Middle Devensian British Palaeolithic sites, as the more effective removal of contaminants produces older dates. **S. P. E. Brockley** (RHUL) *et al.* put forwards tephrochronology as a means of improving the chronology of the Late Glacial, and correlating between the ice core records and European terrestrial environmental proxies, to resolve the timing of abrupt warming events in the Late Glacial and human recolonisation of Northern Europe. **Ian Candy** (RHUL) and **Danielle Schreve** (RHUL) took up the theme of correlating relative chronologies beyond the timescale of radiocarbon dating by putting forward new high precision U-series dates, using the MC-ICP-MS technique which can date samples of 0.2-0.3g, as a means of absolutely dating Middle Pleistocene deposits, which they showed to be capable of dating substages within MIS 7. The virtues of amino acid racemization dating were supported by **Kirsty Penkman** (York) *et al.*, when applied to sites from MIS 9 or younger to date calcite *Bithynia* opercula, which are commonly found in freshwater deposits, and can be used to identify marine isotope substages of the Middle Pleistocene.

Michael Richards (Max Planck Institute) also discussed developments in

scientific techniques, by the analysis of hominin diet through biomolecular evidence from carbon and nitrogen in bone protein, which can be applied to bones younger than 100,000 years. These techniques were shown to reveal dietary differences between Neanderthals and modern humans in the European Palaeolithic, with Neanderthals as specialist carnivores and modern humans eating a more generalised and diverse diet, including birds and fish. This presentation sparked a debate concerning the level of carnivory that could be maintained by hominins, given that humans require a dietary source of vitamin C which cannot be obtained from meat consumption.

Advances in geomorphological studies of the English Channel and evidence for a catastrophic flooding event during the formation of the Straits of Dover were presented by **Sanjeev Gupta** (ICUL) *et al.*. They suggest a catastrophic drainage of a pro-glacial lake in the southern North Sea were features of the English Channel detected to the south of the Isle of Wight, which show a massive river system within a box shaped canyon with bedrock streamlined islands, longitudinal erosional grooves, inner gorges and erosionally terraced smoothed valley margins. These features were compared to the Channeled Scabland in the USA, known to have been created by catastrophic drainage of a pro-glacial lake and even to images of outflow channels on Mars! The timing of this event and its implications for hominin colonisation of Britain during the Middle and Late Pleistocene were strongly debated. The topic of drowned palaeolandscapes surrounding the British Isles was taken up by **Ken Thomson** (Birmingham) *et al.* in relation to the effects of sea level rise in the Late Pleistocene and early Holocene through the use of high resolution 3D seismic datasets. These datasets provide extremely detailed terrain models which could be used to investigate the submerged Late Glacial landscape that would have provided a resource rich region and the means of colonising the British Isles.

Archaeological site formation and hominin behaviour were addressed in a number of presentations on the second day of the meeting. **Danielle Schreve** discussed the problems associated with detecting exploitation of mammoths, as cutmarks are usually absent due to the depth of muscle tissue on such large animals; therefore fragmentation and skeletal part representation may resolve this difficulty. Schreve also proposed the use of damage on bones to ascertain their depositional and transport history, whereas **Russell Coope** (RHUL) put forward the use of insect faunas as a means of determining whether species lived where their remains have been recovered, by looking for the presence of dung beetles. Intriguingly this method was used to demonstrate that at Orvelte in the Netherlands and Salsgitter-Lebenstedt in Germany assemblages of mammoth bones and artefacts seemingly *in situ* are associated with very few dung beetles; thus neither the mammoths nor humans were likely to have lived at these locations and some transport must have occurred. **Barbara Speleers**

took a larger scale approach to the problem of the formation and preservation of the archaeological record, by considering environmental change during MIS 6 and 5, the landscapes present in North-western Europe during these periods, and the chances of subsequent site preservation through the erosion of the last glacial. She argued that the sites recovered are not representative of Pleistocene hominin behaviour, as the record has been strongly biased by landscape processes of erosion and sedimentation. **Mark White** (Durham) *et al.* also discussed the problems of using the archaeological record to determine the level of hominin presence in a region by considering the impact of varying lithic raw material availability during MIS 8-7 in Britain, suggesting that lithic sources were most plentiful in the late glacial and early interglacial, and hence that the decline in site numbers during MIS 7 reflects increasing curation of lithics rather than a decreasing population.

I would like to thank the organisers **Simon Lewis** and Nick Ashton for their hard work in organising such an interesting and thought provoking meeting.

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FIRST QUATERNARY VERTEBRATE RESEARCH GROUP (QUAVER) MEETING REPORT

The first Quaternary Vertebrate Research Group (QUAVER) meeting (a QRA research group meeting) was held at Liverpool John Moores University on 21st -22nd March 2005. The meeting was opened with a welcome address from the Dean of the Science Faculty, Professor Peter Wheeler. In his speech, he announced that LJMU had launched a Research Centre in Evolutionary Anthropology and Palaeoecology. The talks at the meeting were designed to present the breadth and scope of current work in Quaternary palaeontology and to stimulate discussion between practitioners in the field.

The presentations covered a range of topics from scientific techniques that can be applied to archaeological problems to studies dealing with specific taxonomic groups. **Silvia Gonzalez** spoke on the use of stable carbon isotopes for the reconstruction of diets and palaeoenvironments of geoarchaeological Quaternary megafauna from Mexico. **Rhiannon Stevens** spoke on the applicability of stable isotopes of nitrogen and carbon for the understanding of changes in mammal diets. A new initiative called the 'National Ice Age Network' for the monitoring of archaeological material coming out of active quarry sites was outlined by **Danielle Schreve**, while **Kate Scott** talked about gravel Devensian sites in the Upper Thames Valley. Excavation reports of new or previously little-known sites were presented on the sites of Dog Hole Cave, Haverbrack by **Dave Wilkinson**, while **Sue Stallibrass** described a new Welsh cave in Denbighshire. **Tom Lord** and **Terry O'Connor** spoke on the new perspectives on two Yorkshire cave sites, namely Victoria Cave and Kinsey Cave.

Several talks dealt with studies on specific taxa. **Barnaby Crocker** spoken on his proposed study on European woolly rhinoceros phylogeny, while **Sarah Elton** discussed ecological aspects of hominin species from Koobi Fora site, Kenya. QUAVER organiser **Hannah O'Regan** spoke on her new study focusing on palaeodietary adaptations of macaque monkeys at Eurasian fossil sites as a proxy for hominin dietary evolution. Several papers dealt with broader patterns of change in the fossil record. **Tony Stuart** spoke on the use of ¹⁴C techniques to examine the staggered extinction pattern of the large mammal fauna of Europe and Asia. **Stella Blockley** spoke on continuity and change in human behavioural response to climatic changes. **Sally Reynolds** outlined her study of body size changes in the African Plio-Pleistocene, with specific reference to the Sterkfontein site whilst **Alan Turner** described the Paleobiology Database project that is being compiled to investigate Plio-Pleistocene faunal movement out of Africa.

The talks were followed by a 'show and tell' of interesting and unusual specimens. In the final session of the day a short discussion was held to consider how

QUAVER will develop in future. It was agreed that the group will create an open access database of sites and museums, to facilitate finding Quaternary vertebrate material. The School of Biological and Earth Sciences at LJMU hosted a wine and nibbles reception after the conference, and the conference dinner was held at an Italian restaurant close to the hotels and a good real ale pub. The second day of the conference featured an excursion led by Tom Lord to Kinsey Cave, a site containing late Glacial – Roman archaeology and Victoria Cave, known for its Ipswichian to Roman bone assemblages, and some possibly Anglian sediments which require further investigation. Both caves are Scheduled Ancient Monuments near Settle in the Yorkshire Dales.

The 2006 meeting of QUAVER will be hosted by Kate Scott at Oxford and further information on the group can be found at: <http://cwis.livjm.ac.uk/bie/quaver/welcome.htm>

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MULTIPROXY STUDY OF THE EEMIAN LACUSTRINE DEPOSIT AT TURBUTA (ROMANIA)

Background and rationale

Well-dated continental climate records of the Last Interglacial from mid-latitude European regions are scarce. Situated well beyond the limits of the Scandinavian ice sheet, Romania may have acted as an important refuge for the temperate flora and fauna that spread out over Europe since the penultimate glaciation. Knowledge of its Eemian flora and fauna is therefore of importance for understanding the present biogeography of Europe.

A complex interglacial sequence of lacustrine sediments has been found near the village of Turbuta in NW Romania (Figure 1). A preliminary investigation showed that mollusc, plant macrofossil and pollen analyses reflect climatic and environmental changes (Onac *et al.*, 2001). Only the uppermost part (1.5 m) of a total of 3 m was earlier sampled and analysed. The QRA Award provided funds to core, sample and analyse the sediment sequence. Here we report some preliminary results after investigating a 5.3 m sediment core of this Eemian lacustrine deposit from Romania.

Methods

A range of sedimentological, palynological, and mineral magnetic investigations was carried out on the recovered core. Five samples of snail shells were collected for U/Th dating, only two of which are being dated so far. Laboratory testing of samples included clast lithological and particle size analyses, X-ray diffraction (XRD) and X-ray fluorescence.

Preliminary results and work in progress

A 5.3 m sequence was obtained from the left bank of the Mare Valley, close to the location first sampled by Onac *et al.* (2001) (Figure 1). Below the sandy clay, located between 1.0 and 1.5 m in depth, another peat layer of 15 cm in thickness was found (1.5 to 1.65 m). Further down, between 1.65 and 2.05 m, the grayish clay sediments are laminated but also include fragments of angular boulders of various rocks. The last peat horizon was intercepted between 2.05 and 2.45 m in depth, below which only light or dark brown clay was encountered.

Preliminary results demonstrate a good correspondence between the proxy datasets. Furthermore, the two U/Th dates (130.2 ± 3.4 and 126.6 ± 2.7 kyr, respectively) obtained on aragonite from molluscan shells from right above the

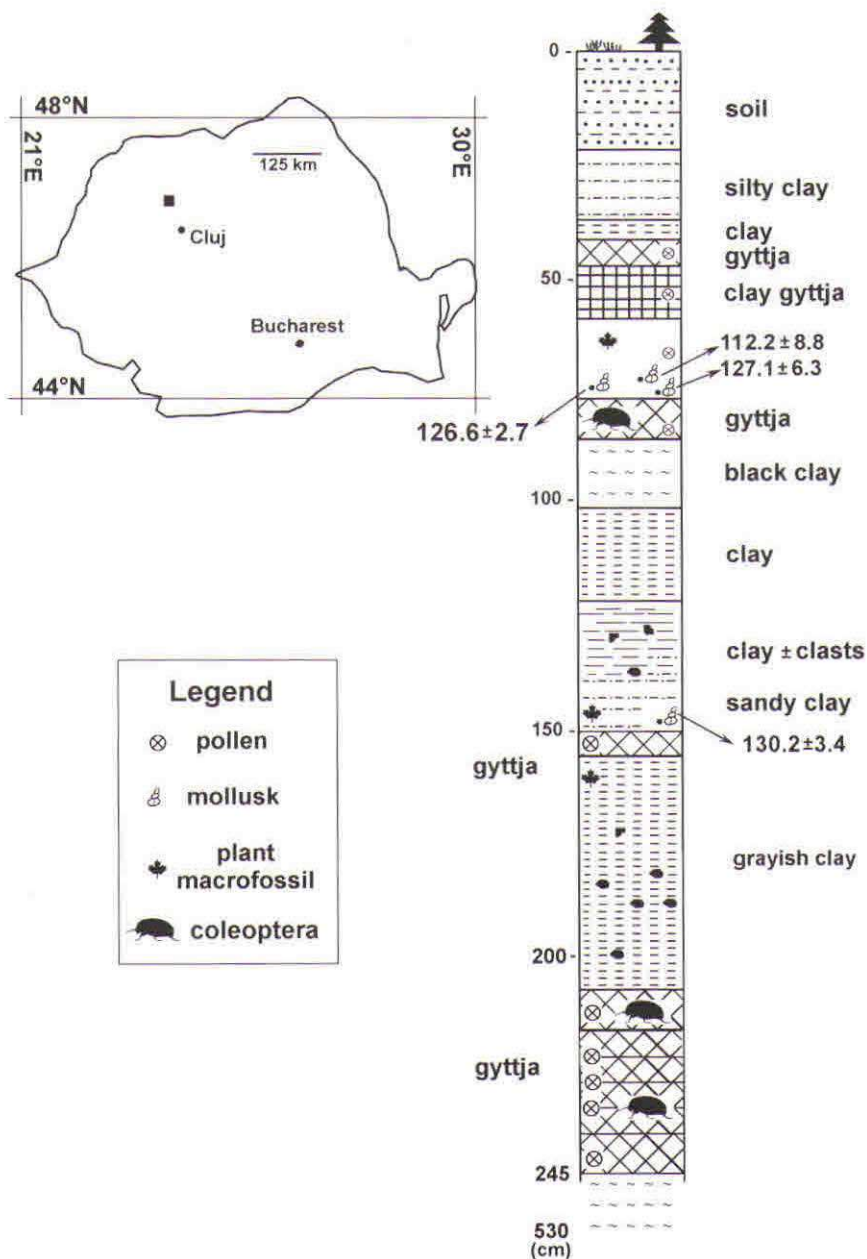


Figure 1. A complex interglacial sequence of lacustrine sediments found near the village of Turbuta in NW Romania.

upper and the middle peat layers validate the Eemian age of the investigated sequence at Turbuta. Several dramatic changes in the hydrology were highlighted above, between, and below the peat horizons based limnological variables, grain size distribution, chemical composition, and mineral magnetic investigations. A plant macrofossil assemblage and coleopteran remains, along with new pollen diagrams, have provided an additional independent body of supporting evidence concerning the climate and environmental changes over the isotope stages 5e to 5c.

The pollen diagram and plant macrofossil assemblage from the lowermost peat layer, combined with the new U/Th ages obtained on samples from above this unit, will thus allow us to begin to address outstanding issues concerning Eemian climate and vegetation variability in NW Romania.

Acknowledgements

The author thanks the QRA for the financial contribution toward the fieldwork costs of drilling the site and performing 2 additional U/Th TIMS datings. Thanks to Radu Breban and Bogdan Valentin for field assistance.

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LATE PLEISTOCENE VEGETATIONAL AND ENVIRONMENTAL CHANGES ON LESVOS ISLAND, GREECE

Background and rationale

The discovery of dramatic millennial-scale air temperature fluctuations coeval with iceberg discharges and sea surface temperature variations in the North Atlantic throughout the last 110 kyr (e.g. Dansgaard *et al.*, 1993; Bond *et al.*, 1993) has raised important questions on the geographical extent of these climatic oscillations and their downstream impact on terrestrial ecosystems. To address this matter, continuous, high resolution and well-dated terrestrial sequences are required. High-frequency oscillations in pollen values during the Pleniglacial have been known from sequences in Italy (e.g. Follieri *et al.*, 1998; Allen *et al.*, 1999) and western Greece (Tzedakis *et al.*, 2002, 2004), but it is only recently that a close temporal link with North Atlantic variability has been demonstrated by examining marine and terrestrial proxies within the same deep-sea sequences off Portugal. These sequences have provided not only some of the most detailed marine oxygen isotope records available for this interval (e.g. Shackleton and Hall, 2000), but also the first unequivocal evidence of the immediate response of vegetation to millennial-scale variability in terms of contractions and expansions of tree populations (Sanchez-Goni *et al.*, 2000; Roucoux *et al.*, 2001). However, it remains uncertain as to how far east this variability has extended and whether any modulations occurred with respect to its character during individual events.

Given its position between the climatic regions of southern Europe and the Near-East, Greece represents a critical area for the establishment of the dominant mode and character of variability and its origin. Existing records spanning the Pleniglacial have until now only been available from the mainland and there was a complete lack of sequences from any island in the Mediterranean. In an attempt to address this lack of information, a lake basin, Megali Limni, was identified on the island of Lesvos in the northeast Aegean Sea (Figure 1). The site is located in the southwestern part of the island at 323 m above sea level. The lake, which was probably formed by a landslide dam at its southern end, was artificially drained in 1925. The work summarised here is taken from the detailed study of the lake basin by Margari (2004).

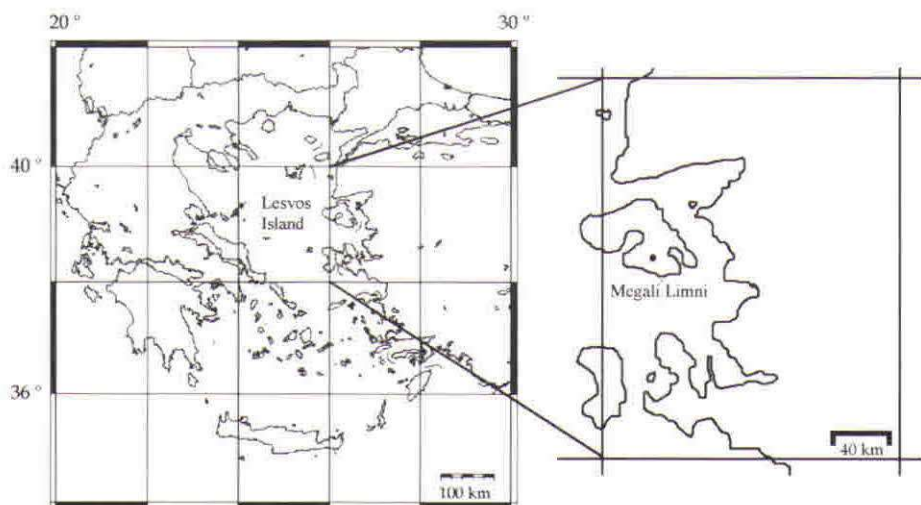


Figure 1. Map showing the position of Lesvos Island and the Megali Limni basin.

Results and significance

In total, four cores have been obtained from the Megali Limni basin. Standard sediment description techniques, as well as a number of supporting studies (magnetic susceptibility, loss-on-ignition and particle-size analysis) have been applied on the sediments. In addition detailed pollen analysis was undertaken from two of the four cores and a 36 m composite record was obtained.

The chronological framework of the composite pollen sequence, which is yet to be finalised, is based on tephrochronology (the tephra units have been assigned to five discrete volcanic eruptions), 19 Accelerator Mass Spectrometry dates (18 funded by NERC [Allocation Number 1001.1002] and 1 by the Quaternary Research Association New Researcher's Award Scheme) and 5 conventional radiocarbon bulk dates.

The preliminary age model suggests that the sequence spans the interval broadly equivalent to the Middle Pleniglacial (Marine Isotope Stage [MIS] 3) and parts of the late Early Pleniglacial (late MIS 4) and the early Late Pleniglacial (early MIS 2). During the Early Pleniglacial, steppe vegetation, composed of *Liguliflorae*, *Artemisia* and *Chenopodiaceae*, dominated the landscape, suggesting particularly cold and arid conditions. This was followed during the Middle Pleniglacial by a series of high-frequency vegetational changes, mainly between *Pinus* (and to a lesser extent *Quercus* and *Juniperus*) and

non-arboreal taxa. The warmest phase of the entire record occurred in the course of the early Middle Pleniglacial and is characterised by the significant expansion of *Juniperus*, *Olea* and *Carpinus*. During the short portion of the Late Pleniglacial which is presented in the record, vegetation was dominated by *Artemisia*, Chenopodiaceae and Gramineae.

The vegetational and environmental changes recorded on Lesvos Island suggest the occurrence of a series of climatic oscillations, primarily in precipitation and to a lesser extent temperature during the Pleniglacial. At one end of the spectrum, during interstadials, precipitation increased leading to the expansion of arboreal populations, while at the other end, during stadials, increased aridity led to the contraction of arboreal populations. During interstadials, tree cover was never complete, while during stadials the record suggests that small populations of trees managed to survive in favourable localities in the area (Margari, 2004).

The high-resolution (mean sampling interval of c. 160 yr) record from Megali Limni is the first from any island of the eastern Mediterranean Sea that spans most of the Pleniglacial and contributes to the understanding of the nature of vegetational and environmental changes at a millennial-scale. The pattern and amplitude of the observed changes suggest a response to the North Atlantic millennial variability. Moreover, the detailed information added regarding the character of individual events could provide valuable insights into the nature of this variability.

Acknowledgements

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VATNAJÖKULL OUTLET GLACIER RESPONSE TO LITTLE ICE AGE CLIMATE CHANGE – COLLECTION OF RADIO-ECHO SOUNDING DATA FOR THE CONSTRUCTION OF A COUPLED MASS BALANCE-ICE FLOW MODEL

Introduction

The Little Ice Age (LIA) was a period of global glacier expansion c. 14th-early-20th C (Grove, 2001). Opinions differ as to when the maximum extension of Icelandic glaciers occurred, with possibilities ranging from the late 18th to late 19th C. This variation may be explained by differing glacier responses, selective preservation of evidence or unreliable dating techniques (Thórarinnsson, 1943; Bradwell, 2001; Kirkbride and Dugmore, 2001). It is crucial to determine which of these factors is responsible and then to delimit the extent to which Icelandic glacier fluctuations may be decoupled from climate change. We will constructively add to this debate by reassessing LIA fluctuations from a suite of Vatnajökull outlet valley glaciers, Europe's largest ice-cap located in southeast Iceland.

The project aims are:

- (1) to reconstruct the LIA chronology of Skálafellsjökull and Heinabergsjökull using geomorphology, tephrochronology and a new lichenometric dating method (Bradwell, 2001; 2004);
- (2) to elucidate ice dynamics and glacier response to climate change using established 3D models (Hubbard, 1999), which have not been previously applied to LIA research;
- (3) to determine the wider implications of the Vatnajökull record for both Icelandic glacial history and our understanding of North Atlantic oceanic-atmospheric interactions (Broecker, 2000).

Methodology

Between 11 June and 3 July 2004, ice radar surveys of the outlet glaciers Skálafellsjökull, Heinabergsjökull (both medium-sized outlets) and Lambatungnajökull (another small outlet with a well-constrained LIA chronology) were conducted by Krista McKinzey and Dr. Alun Hubbard (University of Edinburgh). Whilst traversing the glaciers on foot and by skis, we used a 5/100 MHz radio echo-sounding Tx/Rx to collect continuous ice thickness and bed topography data across the survey area. Approximately 150 km cumulative distance was covered during the field season. A GPS base station was set-up daily to allow <1 m horizontal and vertical data precision

when surveying the ice surface using a Magellan roving differential GPS along the ice radar traverses.

Collectively, field data collected during summer 2004, in conjunction with temperature/precipitation records (1823-2002 - Iceland Meteorological Office), will provide the basis for a coupled 3D climate-glacier model². The model works by using reconstructed LIA glacier limits to dynamically calibrate the relationship between the ice-cap's equilibrium line altitude and meteorological data over the past few hundred years. We can then examine different LIA climatic scenarios and compare glacier response for a suite of glacier sizes and sensitivities.

Additionally, Krista McKinzey and Dr. Rannveig Ólafsdóttir (University of Iceland) spent the last week of fieldwork (4-9 July 2004) travelling throughout SE Iceland to interview the local community to learn in detail historical information passed down through the generations, subsequent to an extensive questionnaire disseminated during spring 2004.

Results

Most of the length and width of Skálafellsjökull and Lambatungnajökull were traversed despite extreme crevassing of the former and bad weather at the latter. Unfortunately, the extent of Heinabergsjökull remained inaccessible, although Dr. Hubbard managed to ski across the head of this glacier above the main ice fall. Ice depth ranged from at 40 m to at least 350 m at the different glaciers, which is an excellent return for temperate and heavily crevassed ice. The entire eastern margin of Vatnajökull (except for Hoffellsjökull) has not previously been RES due to the hazardous ice surface topography, remote valleys and generally inclement weather. Thus, the data we have retrieved will not only be of value to research about LIA fluctuations of the SE outlet glaciers, but also to other groups, such as at the University of Iceland, who have spent many years collecting ice thickness measurements to create a bed DEM for the greater extent of Vatnajökull. A more complete understanding of the dynamics of Vatnajökull may potentially be realised.

Interviews were a great success, and sometimes lasted for several hours. In particular, we were lucky enough to speak to the Björnsson brothers from Kverkfjöll. These gentlemen are self-taught naturalists and highly respected within the scientific community both throughout Iceland and abroad. They provided detailed knowledge regarding the recent and LIA fluctuations of the outlet glaciers. Overall, this anecdotal evidence, as a supplement to the documentary record, provides an alternative constraint on outlet glacier margins during the LIA and will prove most valuable during the glacier modelling experiments.

Conclusions

Fieldwork was successfully conducted during summer 2004, particularly due to an enthusiastic and hard-working team, brilliant weather, supportive Icelandic colleagues and helpful financial assistance (the support from the QRA assisted payment of subsistence and transportation costs). The mass balance – glacier flow model is in progress and should be completed during summer 2005. Furthermore, the interviews have been translated and a paper is in preparation. Outcomes will be exciting, as complimentary mapping and dating methods integrated for the first time with high resolution glacier modelling will further elucidate LIA glacier-climate interactions in the North Atlantic. We also hope that our work will form the basis of further collaboration between the UoE and the UoI glaciology groups.

Acknowledgements

We gratefully acknowledge the Quaternary Research Association, Mackay Fund, Royal Geographical Society, Institute of Geography (UoE) and Leverhulme Trust for financial assistance towards fieldwork in 2004. We also thank Dr. Bryn Hubbard, the Glacier Jeeps team of Vatnajökull, the University of Iceland, Guðný Svarvārsdóttir and the Höfn Library staff, Nina Sigurjonsdóttir and Flatey Farm, Skalafell Farm, and the people of SE Iceland for their continual support and interest in this research. KM also thanks her supervisors, Dr. Andy Dugmore, Professor David Sugden and Dr. Alun Hubbard for guidance and encouragement.

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Various maps from the Geodaetisk Institut ('90) and aerial photos from Landmaelingar Íslands (1946 and 1989).

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REVIEW

GEOLOGY OF THE BUILTH WELLS DISTRICT : SHEET EXPLANATION (196) 34PP ¹

**D.I. Schofield, J. R. Davies, R.A. Waters, P.R. Wilby, M. Williams and
D. Wilson**

GEOLOGY OF THE HAY ON WYE DISTRICT : SHEET EXPLANATION (197) 29PP ² P.R. Wilby

GEOLOGY OF THE BEACONSFIELD DISTRICT : SHEET EXPLANATION (255) 34PP ³

A.N. Morigi, M.A. Woods, H.J. Reeves, N.J.P. Smith and R.J. Marks

GEOLOGY OF THE SIDMOUTH DISTRICT : SHEET EXPLANATION (326 / 340) 30PP ⁴ R.A. Edwards and R.W.Gallois

**WHITEHAVEN (SHEET 28) ⁵, HAY-ON-WYE (SHEET 197)
⁶: BEDROCK AND SUPERFICIAL DEPOSITS EDITIONS
(ENGLAND AND WALES).**

**APPLEBY (SHEET 30) ⁷, BUILTH WELLS (SHEET 196) ⁸,
BEACONSFIELD (SHEET 255) ⁹ AND RINGWOOD (SHEET
314) ¹⁰ AND SIDMOUTH (SHEET 326 / 340) ¹¹ : SOLID AND
DRIFT EDITIONS (ENGLAND AND WALES).**

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Sheet explanations £9 each and £18 with accompanying map, 1:50,000 sheets £11 each; 25 % discount for academic institutions when ordered from : **Sales Desk, British Geological Survey, Keyworth, Nottingham NG12 5GG Tel : 0115 - 936 3241 Fax : 0115 - 936 3488** (prices exclude post and packing - in the UK a minimum of £2.50 and 10% of the original value of the goods up to maximum of £7.50).

This selection of recently published BGS 1:50,000 maps and Sheet Explanations follow on from my last review (*Quaternary Newsletter* No. 105, 71-74). Since then, the first maps with a changed nomenclature have started to appear, so we now have Bedrock and Superficial Deposits rather than Solid and Drift, which is literally antediluvian. It is hoped this change will make it easier for non-specialist users to understand what they are dealing with when they wish to consult a geological map. Each standard England and Wales sheet covers roughly 29 km east-west by 19 km north-south. In the meantime, a vastly improved Superficial Deposits map of Aberdeen (sheet 77) has now been published to replace the old Drift edition and complement the outstanding Cainozoic geology and landscape evolution of north-east Scotland special memoir (*QN* 103, 47-51).

The Whitehaven sheet on the Cumbrian coast is underlain by a complex series of Ordovician rocks flanking the central fells overlain in turn by Carboniferous and Permian-Triassic sediments shown in more detail on the separate Bedrock edition. The past history of increasingly opencast coal mining has left parts of the sheet riddled with a complex series of clear hatching to show five different types of artificially modified ground and underlying deposit or rock type. In addition, 20 different Quaternary units are shown: even if the map is mainly covered in Till and less extensive glacial sands and gravels, there are also limited river terraces, coastal deposits, landslips and the usual spreads of alluvium, peat and heath. The four schematic sections showing how these different units relate to each other are particularly well drawn with good height control, while glacial meltwater channels are shown on the face of the map. Unlike the adjacent Gosforth sheet (37) this map does not state the tidal range relative to Ordnance datum (*QN* 90, 53-55) or cover the offshore area apart from on two 1:250,000 insert maps.

The Appleby sheet to the east of Whitehaven covering the northeastern Lake District up to the edge of the Pennines has a similar underlying bedrock geology, apart from no coal measures. Though the Solid bedrock geology is simplified, the pattern of faulting in the fells is intensely complicated and distracting, while the underlying Carboniferous Yoredale Group which pokes through the monotonous blanket of Till is unfortunately only a slightly darker shade of blue. Furthermore, glacial meltwater channels are not directly shown, but added to a 1:150,000 insert map showing other features such as drumlins and glacial striae, along with the western limit of Shap granite erratics. However

to compensate there is a 1:100,000 insert map clearly showing the main Quaternary geological domains.

Moving on to Mid-Wales progress is being made in closing the last major gap in coverage with the publication of two more adjacent sheets. The first, Builth Wells, covers an upland area mainly in Powys on the southeastern fringe of the Cambrian mountains drained by the River Irton below, to the south, the Old Red Sandstone escarpment of Mynydd Eppynt before at Llanfair-ym-Muallt (Builth Wells) joining the southwards flowing River Wye on the eastern margin of the sheet. Like the adjacent Hay-on-Wye sheet the underlying bedrock geology could be simplified, as there is a separate Solid edition: while this would have made this map less cluttered, the Drift geology can be easily read, as it displays a relatively straightforward combination of glacial, fluvial and solifluction deposits. The margins of the sheet also has a schematic cross section for the superficial deposits with grid references for key examples of these features and a slightly enlarged map of showing the detailed surface morphology for part of the first terrace of the River Wye. The accompanying Sheet Explanation, sold at a discount with the map in a clear plastic wallet, provides a general introduction which recognises the role of isostatic uplift during the Quaternary. This also provides further references along with a section on applied geology, which includes water resources and geological hazards such as flooding and slope instability.

To the east the neighbouring Hay-on-Wye sheet includes part of Herefordshire round the small town of Kington in England. Until recently this would have been classified as a provisional map with a soft rather than laminated external cover, as it has been compiled from aerial photographs and other sources with limited field reconnaissance. Thus the bedrock geology is rather simplified and the only truly complex area is also covered by a Solid geology insert at the same scale. Without the normal sheet size there is no additional Quaternary marginalia beyond the key, even if glacial meltwater channels are shown on the face of the map. The accompanying explanation goes into more detail than its neighbour, with numerous grid references, more extensive references and also in the introduction a satellite image of the district.

Over on the western margins of Greater London, the Beaconsfield sheet is centred on southern Buckinghamshire (including High Wycombe) along with smaller portions of Berkshire (including Maidenhead alongside the Thames) and Hertfordshire around Rickmansworth on the River Colne. Parts of this map have been completely resurveyed and so the Chalk has the new standard subdivisions, while the superficial deposits have undergone an even more extensive revision. As it happens this sheet contains most of the terrace type locations in the Thames Valley and the gravels have been divided with tentative marine oxygen isotope stages into numerous pre- and post-Anglian diversionary units when the river was diverted to its present more southerly course. Thus

there is an insert showing the palaeogeography of the River Thames across and just to the south of this most significant sheet. The accompanying account in the explanation is very well written and goes into some detail with tables, further references and good use of bold highlighting. The applied geology section also deals at some length with water resources and engineering ground conditions, including the Jubilee River flood alleviation scheme - which is not marked on the base map.

Following on from my recent review (*QN* 105, 74), the Ringwood sheet, on the borders of Hampshire and Dorset with Wiltshire to the north, has now been published and as promised provides a complete revision, including the underlying lower Cenozoic and Chalk. As usual areas of worked ground are indicated by varying types of hatching and the numerous river terraces - mainly associated with the River Avon, which drains into the English Channel - are clearly shown. In addition, to the west there is extensive peat in the valley of the river Allen and various spreads of solifluction deposits including the enigmatic clay-with-flints confined to mainly south-facing slopes on the chalk downs.

Finally, the Sidmouth sheet covers the channel coast, from Lyme Regis in Dorset almost to Budleigh Salterton in Devon. The western margin of this map includes the River Otter up to beyond Honiton and shows a complex series of scattered and often fragmentary river terraces resting on the Sherwood sandstone. Further east the River Axe flowing southwards from around Axminster to Seaton has a wider alluvial plain with a few patches of undifferentiated terrace gravels. The map comes into its own in showing how the solifluction deposits have been remapped to mantle most of the lower slopes below the clay-with-flints capping the extensive Cretaceous outliers. In addition, significant areas covered by major landslips are clearly shown along with the solid bedrock geological boundaries below such floundered strata. Furthermore, as this sheet extends some way into Lyme Bay it includes the offshore bathymetry at five metre intervals and seabed sediments resting on the faulted bedrock: a narrow and varying inshore strip is quite rightly uncoloured, as it is very hard to survey this zone properly and the exact details are unknown. In the explanation, given the problematic age of the clay-with-flints, along with the rest of the superficial deposits these are outlined at some length under Cainozoic in the geological description. Unlike the other accounts the symbols for these superficial deposits are inserted into the clearly written text which also has an extensive section on geotechnical considerations in the applied geology, as slope stability and coastal erosion are highly significant factors.

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1:625,000 GLACIAL MAP OF BRITAIN, NORTH AND SOUTH SHEETS, 1ST EDITION

**C.D. Clark, D.J.A. Evans, A. Khatwa, T. Bradwell, C. J. Jordan,
S. H. Marsh, W.A. Mitchell and M.D. Bateman. 2004**

**Map and GIS database of glacial landforms and feature related to the
last British Ice Sheet. Boreas, volume 33 (4), 359-375**

£10 per map or £16 for north and south sheets, inclusive of postage and packing, cheques payable to "University of Sheffield" and available from **Chris Clark, Department of Geography, University of Sheffield, Sheffield, S10 2TN United Kingdom** Further details at [Http://www.shef.ac.uk/geography/staff/clark_chris/britice/index.html](http://www.shef.ac.uk/geography/staff/clark_chris/britice/index.html)

This pair of innovative maps and associated GIS database (which can be downloaded for free from the above web site along with pdf files of the maps, accompanying paper in Boreas and extensive reference list) has come about via an academic collaboration with the British Geological Survey (BGS) which provided financial support for this project. They clearly summarise all the available features on the more detailed GIS database that provides evidence for the extent and flow geometry of the last major ice sheet to cover Great Britain during the Devensian. While these maps show features formed at various times during the height of this glaciation, those associated with the Loch Lomond readvance are ignored apart from showing its main West Highland limit, as this limited ice sheet reformed after the preceding Windermere interstadial at the end of the Devensian. They are based on the modern coastline with the ten kilometre Ordnance Survey National Grid and also have a useful 30 km overlap between the two sheets, even if they have not been designed with mounting in mind, by moving the marginalia on the southern sheet slightly downwards. In addition, the northern sheet has a fine insert map with a digital colour terrain image of Britain at 1:3,000,000 with a 50 km grid, which also shows related glacial features including offshore shelf-edge fans and moraines that are now underwater since sea levels rose at the end of the last ice age.

The maps firstly show evidence that constrains the extent of the Devensian ice sheet and so include glacial moraines, trimlines above which mountain summits are covered in frost shattered detritus, the limit of glacial deposits (drift limits) and unglaciated areas. Given the limited evidence and uncertainty of post-glacial erosion the exact extent of ice-free areas in places such as Yorkshire and southern Britain to the east of Wales, this boundary is hard to tell without either a clear line or a darker tone to indicate the former extent of exposed tundra. Secondly, the maps indicate flow geometry within and at the margins

of this former ice sheet by including the central axes of eskers, meltwater channels, tunnel valleys and the long axis direction of drumlins, along with erratic dispersal patterns. The latter are cleverly shown by marking source areas in solid light green with neat arrows to show their direction of travel - assuming, as the authors make clear, that this was straightforward, without the complication of multiple phases and varying flow directions. The limit at which erratics are found away from a particular source area is marked by lines of green dots, while dashes indicate significant lithological boundaries such as the Highland Boundary Fault which can generate their own distinct erratic trains in the areas beyond their source outcrops. However, ice flow directions indicated by glacial striae on bedrock were excluded as they can be unreliable indicators of regional ice flow and the compilers would have been swamped by the sheer volume of data. Similarly, areas of streamlined bedrock, roches moutonnées and crag-and-tails were excluded because of limited information on their distribution, which is evident by their inconsistent treatment on published BGS maps.

Furthermore, these maps show glaciolacustrine deposits and the extent of ice-dammed lakes, including lower stand levels in Lake Pickering and Lake Humber. While the addition by the authors of the approximate positions of ice marginal dams which impounded some of these lakes is welcome, it undermines their insistence on only using peer-reviewed or BGS sources for these maps and any future editions. For example, Lake Fenland south of the Wash looks highly suspect, as its level takes no account of the inevitable glacial downloading to the north, which would have limited its southward extent, and yet any isostatic correction could be difficult to publish. A simple flexural loading calculation to supplement much more complex models (Lambeck 1995) might be dismissed as trivial by a geophysical journal, while being beyond the scope of refereeing for more qualitative Quaternary publications. There may be other gaps in this presentation that could also be profitably filled by commissioning otherwise hard to publish work.

The accompanying paper explains that these maps have drawn on over 2,000 publications with more than 20,000 individual and sometimes conflicting features, which in some cases were modified by working with a shaded Digital Elevation Model (DEM) to yield, for example, more realistic moraines which fit the topography. A lot of this material is drawn from the archives of more than a century of BGS mapping, which given the time span is quite varied in quality and interpretation. This compilation concentrated on using the 1:50,000 series, though in Scotland large scale 1:10,560 maps were drawn upon where this data seemed to be unusually sparse. Thus it would have helped if the otherwise excellent references made this clear by stating the scale of each map in this incredibly extensive list. In addition, the scientific literature was thoroughly examined for suitable figures, even if in many cases, including contemporary

work, this was hindered by the lack of National Grid co-ordinates: great efforts were made to try to locate given features by matching the positions of roads and rivers. In spite of all this work, these maps can be used to identify under-researched areas such as Orkney or Mid Wales, even if the lack of most Isle of Man data is an omission. As the authors also make clear, the kilometre National Grid used on Ordnance Survey and BGS maps is out of copyright (in any case, it was never enforced for grid references), so there is no excuse for referees and journal editors allowing authors to publish work that does not use such reference systems (Geoscientist, July 2001, p.15) as this hinders the critical examination and use of their data.

Though they are remarkable maps, their greatest weakness is not placing as much offshore information as possible on the main sheets in addition to the adjacent Irish and continental coastlines, even if they were partly covered by inserts and marginalia. Unlike on land where it would add clutter, it would help if the extent of offshore tills were also shown, as it is easy to get hemmed in by the modern coastline while forgetting that mid-ocean eustatic sea levels were at least 120 m lower at the glacial maximum. Thus, while compared to the map of France at the height of the last glacial maximum (Petit-Maire *et al.*, 1999), these maps are a great step forward in the coverage of formerly ice covered areas, future editions would benefit from drawing on the underlying concept behind the French map. Such maps could attempt to reconstruct the wider geography at this time, including the periglacial rivers that flowed over England and the exposed continental shelf - though it would still have to include the surge of ice down what is now the east coast of England around 21,450 years ago (18,000 radiocarbon years as shown on the map of France), after the main glacial maximum at around 26,000 years ago (22,000 radiocarbon years). However, as most raised beaches were clearly formed after the glacial maximum, it would be better to exclude them rather than risk adding significant confusion. Given the uncertainty in dating these events, the authors have been wise in managing to ignore the whole issue by concentrating on the physical evidence for the last (Devensian) ice sheet. Far from being critical, I hope these final comments will suggest how future editions may build on and expand on this trail blazing work.

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ABSTRACTS

GEOCHEMICAL EVIDENCE FOR WEATHERING IN NORTHWESTERN EUROPEAN LOESS SUB-MILLENNIAL SCALE DURING THE LAST ICE AGE

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This study seeks to determine the extent to which chemostratigraphy can supplement other stratigraphic tools in determining the effects of climate change in loess-palaeosol sequences. Geochemical change has been used to illuminate the effects of glacial/interglacial climate change in Chinese loess-palaeosol sequences; less work has been done to examine the effects of stadial/interstadial climate change and little work has been carried out in Europe on either aspect.

Two loess-palaeosol sites were selected in northwestern Europe that were known to provide good records of the last ice age. This study has produced detailed descriptions of variation in concentrations of the major, minor and rare-earth elements. These are compared with variation in the standard sedimentological parameters (grain size, organic carbon content and carbonate content) and in enviromagnetic characteristics, which are accepted as palaeoclimate proxies. The existing polymineral-based luminescence chronology at each site has been enhanced using a quartz-based approach, which broadly confirms the accuracy of previous ages and generates estimates of increased precision.

That chronology facilitates comparison of these analyses with evidence for palaeoclimatic change in the wider record, including GRIP ice-core data. Grain size is shown to be a strong proxy for variation in mean wind strength and in accumulation rates which can be correlated in detail with GRIP.

The study has established that geochemical heterogeneity now apparent at the sites has been imposed by weathering. Carbonate weathering is a reliable indication of major pedogenic episodes but its detailed interpretation is tempered by carbonate mobility. Silicate weathering occurs at lower intensity than carbonate weathering but is a permanent record since silicates are not subject to reprecipitation under these conditions. The study concludes that chemostratigraphy is a climatological proxy, detecting periods of significant amelioration. It is not a replacement for conventional proxies, it complements them and provides additional evidence upon which climatic reconstructions can be made.

GEOMORPHIC RESPONSE OF UPLAND SLOPE AND FLUVIAL SYSTEMS TO HOLOCENE ENVIRONMENTAL CHANGE ON THE BRANDON MOUNTAIN MASSIF, DINGLE PENINSULA, SOUTH WEST IRELAND

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Over the last two decades attention has focused on Holocene landform development in many upland regions, where researchers have sought to elucidate the dynamics, timing and palaeoenvironmental significance of geomorphic activity. To date these investigations have suggested that Holocene landform development has not been uniform. Instead, landscape evolution has fluctuated between periods of accelerated geomorphic activity and periods of relative quiescence. Three distinct viewpoints have emerged explaining these phenomena: climatic change, anthropogenic activity and the extreme event hypothesis.

Four mountainous sites across the Brandon Mountain Massif, Co. Kerry, southwest Ireland, were studied to investigate the geomorphic response of upland slope and fluvial systems to Holocene environmental change. In order to address the research issues, a multi-proxy approach was taken which combined the fields of geomorphology, palynology and sedimentology. A robust chronology was established by employing radiocarbon dating. The aims of the research were successfully accomplished and produced detailed geomorphological maps, sediment sections and high-resolution pollen profiles in association with a reliable chronology.

The results suggest that variations in vegetation composition have occurred during the mid to late Holocene throughout the Mount Brandon Massif. Evidence for human habitation and agricultural activity throughout the upland areas of the Dingle Peninsula began in the late Neolithic *ca.* 2450 B.C. During the Bronze Age *ca.* 2000 B.C., the interior of the Mount Brandon Massif was opened, used and in places occupied by humans. Archaeological evidence indicates limited or reduced occupation of the interior through the Iron Age *ca.* 700 B.C. However, the palynological and archaeological evidence, dating to the Early Christian period *ca.* 400 A.D. saw the establishment and spread of permanent settlement throughout the interior of the Mount Brandon Massif.

Radiocarbon dates from Mount Brandon show that phases of enhanced geomorphic activity fall into three distinct groups, the first after 2450 -1400 cal. yr B.C. The second group dates from after 800 cal. yr B.C. to cal yr A.D.

700, and the third after cal. yr A.D. 1000 to cal. yr A.D. 1850. Data from the Mount Brandon Massif indicates that phases of upland geomorphic activity and valley floor alluviation cannot be attributed to one specific cause. The evidence suggests enhanced geomorphic activity is probably a function of both human activity and climate forcing, including extreme events. A likely scenario may have involved initial slope destabilisation due to disturbance and removal of vegetation by human activity, followed by slope failure and sediment mobilisation during intense rainstorms associated with climatic change.

Results from Mount Brandon compare well with recent research undertaken 30 km to the south in the Macgillicuddy's Reeks. The similarities between the timing of the geomorphic activity from the Macgillicuddy's Reeks and Mount Brandon are notable and both areas display a significant increase in geomorphic activity during the Bronze Age, a time of increasing anthropogenic activity. All three phases also coincide with additional episodes of late Holocene upland geomorphic activity and valley-floor alluviation from the British Isles.

Undergraduate Dissertation Prize Winner

A 150 YEAR PALAEO LIMNOLOGICAL INVESTIGATION OF A REMOTE, TROPICAL, ALPINE LAKE

Palaeolimnological techniques were adopted in this study to place rapid glacial retreat in the Rwenzori Mountain National Park (RMNP) into a palaeocontext. Lake Bujuku is a tropical, alpine lake situated within the afro-alpine zone at c. 3960 masl. A 40.5 cm core (Buju3) was collected on the 22nd June and high-resolution diatom analyses were conducted. An annual ^{210}Pb derived rate of sedimentation was estimated at 2.9 mm yr^{-1} and bottom sediments date back to 1864 ± 20 years.

Prevalent taxa in the littoral assemblages of Lake Bujuku include *A. minutissima*, *F. pinnata* and *Tabellaria flocculosa*, with the latter preferring high humic acid content associated with the neighbouring bog region. Diatom flora for Buju3 is less diverse being dominated throughout by small, tychoplanktonic species of *Fragilaria* and the absence of dominant littoral taxa most likely results from taphonomic processes. Multivariate analysis (PCA) results suggest that axis 2 is significant in explaining floral changes, with *F. pinnata* and *F. construens* more dominantly driving assemblages. The absence of significant ecological changes over the period of reconstruction is arguably associated with the ecological characteristics of the lake (i.e. polymictic, high UVR incidence and lack of perennial ice cover). However, % DW and % LOI profiles do suggest a gradual increase in organic content through the profile, with the former decreasing by 30 % and the latter increasing to 25 %.

The littoral species assemblage and the increasing organic content of Buju3 have suggested gradual changes in the lake-catchment dynamics of the region, over the period of reconstruction. However, in conclusion, Lake Bujuku's ecology is not being affected at the same rate or scale as the glaciers in the RMNP and is therefore not as sensitive as other lakes (particularly in the high/mid latitudes) in documenting recent warming in the region.

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NOTES

WELTON-LE-WOLD QUARRY, LINCOLNSHIRE (TF 282881)

Excavated wholly in Quaternary sediments lying NE of Welton village, the quarry ceased to be worked in the mid-1970s because of increasing thickness of overburden, and near exhaustion of the commercially-valuable flint gravels and sands.

Backfilling took place as working proceeded and only two sections survive. Through meriting their SSSI and RIGS status, they provide only limited insight into the circumstances and environments of deposition of the main body of sediments.

The quarry was visited intermittently by myself over the period 1954-1973. In 1969 and 1970 a few Palaeolithic artefacts and some vestigial mammalian fossils were recovered from the northern part of the site. The sedimentary context of these finds was described in 1976 (Alabaster and Straw, 1976: Straw, 1976) and the artefacts and fossils were subsequently placed with the City and County Museum, Lincoln (now known as *The Collection* [Lincolnshire County Council], Danes Terrace, Lincoln, LN2 1LP).

43 photographs of sections taken over the 20-year period have recently been given to The Collection, with detailed explanatory notes, on the understanding that they will be available for consultation by interested researchers. The materials have the Accession Number LCNCCP384 – LCNCC:P427, and they illustrate and describe the lithology and stratigraphy of, and structures within, deposits comprising the Welton Gravels which accumulated under Subarctic and Arctic fluvial and mass-wasting regimes, the overlying Welton and Calcethorpe Tills, and the considerably younger Marsh Till.

References

- Alabaster, C. and Straw, A. (1976). The Pleistocene context of faunal remains and artefacts discovered at Welton-le-Wold, Lincolnshire. *Proceedings of the Yorkshire Geological Society*, 41, 75-94.
- Straw, A. (1976). Sediments, fossils and geomorphology: a Lincolnshire situation. In: Davidson, D.A. and Shacklev, M.L. (eds) *Geoarchaeology*, Duckworth, London, 317-326.

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ERRATUM

Payne, R. & Blackford, J.J. Microwave digestion and the geochemical stability of tephra. (2005) QN 106, 24-33.

Addendum:

On page 25 microwave digestion methodology should read 'heating to 170°C'.
On page 26 microprobe operating conditions should read 'beam rastered over 5x5µm grid' for Edinburgh probe and '1µm beam' for Bergen probe.

Some columns of data were missing in Table 1 so that table is re-produced here.

QUATERNARY RESEARCH ASSOCIATION

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

The main meetings of the Association are the Annual Field Meeting, usually lasting 3–4 days, in April, and a 1 or 2 day Discussion Meeting at the beginning of January. Additionally, there are Short Field Meetings in May and/or September, while Short Study Courses on techniques used in Quaternary work are also occasionally held. The publications of the Association are the *Quaternary Newsletter* issued with the Association's *Circular* in February, June and October; the *Journal of Quaternary Science* published in association with Wiley, incorporating *Quaternary Proceedings*, with eight issues per year, the Field Guide Series and the Technical Guide Series.

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

President: *Professor J.J. Lowe*, Department of Geography, Royal Holloway, University of London, Egham TW20 OEX
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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**.

QRA home page on the world wide web at: <http://www.qra.org.uk>



October 2005 No. 107

Contents

Page

1 ARTICLES

- 1 New OSL dates and pollen records from the Bembridge raised beach sequence, Isle of Wight (UK) *Francis Wenban-Smith, Jean-Luc Schwenninger and Robert Scaife*
20 New microfaunal data from the Raincliff formation (Speeton Shell Bed), North Yorkshire *John E. Whittaker, David J. Horne and Alan Lord*

24 REPORTS

- 24 Irish Quaternary Association (IQUA) and QRA Field Meeting - The Quaternary of Central Western Ireland
31 QRA Annual discussion meeting: 'The Palaeolithic Occupation of Europe'
36 QUAVR: Quaternary Vertebrate Research Group

38 Quaternary Research Fund

- 38 Multiproxy study of the Eemian lacustrine deposit at Turbuta (Romania)

41 New Research Workers Award Scheme

- 41 Late Pleistocene vegetational and environmental changes on Lesbos Island, Greece
45 Vatnajökull outlet glacier response to Little Ice Age climate change – collection of radio-echo sounding data for the construction of a coupled mass balance-ice flow model

49 REVIEWS

- 49 Geology of the Buih Wells district, Hay on Wye district, the Beaconsfield district and Sidmouth district British Geological Survey 2004 and 2005
53 1:625,000 Glacial Map of Britain, north and south sheets, 1st Edition *C.D. Clark, D.J.A. Evans, A. Khatwa, T. Bradwell, C. J. Jordan, S. H. Marsh, W.A. Mitchell and M.D. Bateman*

57 ABSTRACTS

- 57 Geochemical evidence for weathering in northwestern European loess on a sub-millennial scale during the last Ice Age, *Terry Hill*
58 Geomorphic response of upland slope and fluvial systems to Holocene environmental change on the Brandon Mountain Massif, Dingle Peninsula, South West Ireland, *Phillip Allen*

60 Undergraduate Dissertation Prize Winner

- 60 A 150 year palaeolimnological investigation of a remote, tropical, alpine lake, *Virginia Panizzo*

61 NOTES

- 61 Welton-le-Wold Quarry, Lincolnshire

62 ERRATUM

- 62 Payne, R. & Blackford, J.J. Microwave digestion and the geochemical stability of tephra, *Richard Payne and Jeff Blackford*

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