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Quaternary Newsletter

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QUATERNARY NEWSLETTER

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Instructions to authors

Quaternary Newsletter is issued in February, June and October. Articles, reviews, notices of forthcoming meetings, news of personal and joint research projects etc. are invited and should be sent to the Editor. Closing dates for submission of copy (news, notices, reports etc.) for the relevant issues are 5th January, 1st May and 1st September. These dates will be strictly adhered to in order to expedite publication. **Articles must be submitted at least 6 weeks before these dates in order to be reviewed and revised in time for the next issue of QN, otherwise they may appear in a subsequent issue.**

Suggested word limits are as follows: obituaries (2000 words); articles (3000 words); reports on meetings (2000 words); reports on QRA grants (800 words); reviews (1000 words); letters to the Editor (500 words); abstracts (500 words). Authors submitting work as Word documents that include figures must send separate copies of the figures in .eps, .tif or .jpg format (minimum resolution of 300 dpi is required for accurate reproduction). Quaternary Research Fund and New Researchers Award Scheme reports should limit themselves to describing the results and significance of the actual research funded by QRA grants. The suggested format for these reports is as follows: (1) background and rationale (including a summary of how the grant facilitated the research), (2) results, (3) significance, (4) acknowledgments (if applicable). The reports should not (1) detail the aims and objectives of affiliated and larger projects (e.g. PhD topics), (2) outline future research and (3) cite lengthy reference lists. No more than one figure per report is necessary. Recipients of awards who have written reports are encouraged to submit full-length articles on related or larger research projects

NB: Updated guidelines on the formatting of contributions are now available via the QRA webpage and from the editor.

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COVER PHOTOGRAPH

View of the submerged forest between Borth and Ynyslas, Cardigan Bay, west Wales *(Image P. Dark)*.

EDITORIAL

I haven't written an editorial since October 2020 and thought it was time to tell you the plans we are making for the future of *QN*. The print (and more recently online) version of the newsletter has been produced in largely the same format since 1970, with 156 issues in that time (including this one). We truly acknowledge the historical importance of *QN* but also want it to remain relevant in today's increasingly electronic and online world. We want *QN* to continue to be a place to publish new ideas, to discuss ongoing debates, to report advances made as a result of QRA funding, to describe events and meetings held under the QRA banner and many other things. However we realise that with the most recent three issues restricted to within the Members Area of the QRA website there are many members who do not routinely read it, and its visibility to the wider national and international Quaternary community is very low.

The QRA executive have therefore decided that in the short-term, all QRA members for whom we have their email address, will receive the new copy of *QN* directly to their inbox each time that it is published. This will hopefully significantly increase readership by QRA members. In the longer-term (over the next couple of years) we plan to move to a new fully open access, online version of *QN* which will be accessible to all, QRA members or not, and will allow viewing of individual articles or the whole issue from a new QRA website.

We hope that these changes will improve *QN*'s visibility both within and beyond the QRA membership, and will encourage more of you to submit articles for publication in the knowledge that *QN* has a significant reach both in the UK and internationally. I am very excited about these future developments as I think they provide a clear future for *QN* in the changing landscape of how we receive and consume news and articles within science. So for now *QN* will look the same but will hopefully be more easily accessible to those who might have forgotten their QRA members area login details. I will update you via a future Editorial about when *QN* will become a true open access publication available to all online.

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OBITUARY

HILARY DAVIES (NÉE WATERS)

10TH OCTOBER 1947 – 31ST DECEMBER 2021

Hilary Davies was a Quaternary Scientist who contributed significantly to our understanding of the mineralogy of the tills and aeolian deposits of southern Britain. Hilary grew-up in Hull and completed a degree in Natural Sciences at the University of Cambridge, and it was at Cambridge that she met and married her husband, Alun Davies, then a Demonstrator in the department of Agriculture. Upon graduating she worked with Bob Perrin in the Department of Applied Biology, sharing a room with Christopher Jeanes. Hilary left Cambridge to be with her husband who was appointed lecturer in the University of Liverpool School of Veterinary Science and it was at her home on the Wirral that she spent the rest of her life.

Hilary was an expert heavy mineralogist and, along with Bob Perrin and co-workers from Cambridge and elsewhere, she provided detailed descriptions of the size distribution and mineralogy of soils and soil parent material in midland, eastern and southern Britain. This work has stood the test of time and findings have made significant contributions to the description and understanding of Quaternary deposits in the region. Also at Cambridge she was very generous with her time and assistance. For instance Phil Gibbard records that she taught him to do grain-size analysis whilst he was carrying out his PhD research and stresses that she was ‘a very careful, systematic lab worker’.

At Liverpool, Hilary was employed by the Open University to teach Geology, and it was here that her wide knowledge of and enthusiasm for the subject had its greatest expression. She was an excellent teacher and after her OU work ceased she ran voluntary classes and always had a large number of recruits. Over this period Hilary also acted as a skilled indexer for a number of publishers. At the same time she was involved with the Liverpool Geological Society taking the role of Treasurer and being elected President. Over this period she organised a number of field meetings, especially in the Yorkshire Dales, and her colleague and friend Eileen Stonebridge recalls how, following a field trip she helped with levelling the elevation of river terrace deposits formed along the River Swale, which Eileen was studying at the time. Also whilst at Liverpool Hilary set up a business partnership with fellow Quaternary scientist Cynthia Burek, called *Earth Science Information*. This operated until the mid-1990s helping small businesses find and interpret geological data. Hilary was an active member of the local church, and the Chester and North Wales Cambridge Alumni (and acted for a time as treasurer for both). Despite leading a very busy life, Hilary always had time for people.

Hilary was a long-standing member of the Quaternary Research Association and carried out the role of Treasurer from 1980 to 1984. She contributed to, and was a regular attendee at field meetings where many members first met her and established friendships (the left-hand figure shown above was taken on the 1982 Annual Meeting in the Netherlands (with Jürgen Ehlers in the background)). In addition to her interests in matters Quaternary, she also acted as an independent researcher on the coastal research around the Irish Sea. This was transnational project designed to assess the application of the European Spatial Development Perspective and the Integrated Coastal Zone Management project upon the effectiveness of European coastal strategy and future management of the Irish Sea region.

She had a great love for the Yorkshire Dales which she visited not long before her final illness. Hilary Davies died of pneumonia after a long illness following a stroke and will be greatly missed by her husband Alun, and her friends in the community, to which she contributed so much.

Publications

Kidd, S., Massey, D. and Davies, H., (2003). The ESDP and integrated coastal zone management: implications for the integrated management of the Irish Sea. The Town Planning Review, pp.97-120.

Lewis, S.G., Rose, J. and Davies, H., (1999). Pre-Anglian fluvial and Anglian glaciogenic sediments, Knettishall, Suffolk, England. Proceedings of the Geologists' Association, 110(1), pp.17-32.

Perrin, R.S.M., Davies, H. and Fysh, M.D., (1973). Lithology of the Chalky Boulder Clay, Nature Physical Sciences, 245, 101-104.

Perrin, R.S.M., Davies, H. and Fysh, M.D., (1974). Distribution of late Pleistocene aeolian deposits in eastern and southern England, Nature, 248, 320-324.

Perrin, R.S.M., Rose, J. and Davies, H. (1979). The distribution, variation and origins of pre-Devensian tills in eastern England. Philosophical Transactions of the Royal Society of London, 8287, 535-570.

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ARTICLES

THE SUBMERGED FOREST BETWEEN BORTH AND YNYSLAS, CARDIGAN BAY, WEST WALES: OBSERVATIONS RELATING TO THE STRUCTURE OF A PREHISTORIC PINE WOOD

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Abstract

In his recent article (QN 155) Martyn Waller noted the potential of large tree remains ('megafossils') to provide evidence for the character of prehistoric woodland. Here I discuss the tree remains from the coastal submerged forest at Borth, west Wales – probably the most extensive example in Britain – which has recently been spectacularly exposed by winter storms. The results of a quick opportunistic survey designed to quantify the spacing of trees are presented, in the context of previous research at the site.

Introduction

In his recent article (*QN* 155), Martyn Waller noted the potential of large tree remains ('megafossils') preserved by waterlogging to provide evidence for the nature of prehistoric woodland, and specifically the debate over the extent to which these woods were closed, or had a more open canopy due to grazing by large herbivores - the 'Vera hypothesis' (Vera 2000). Waller cited evidence from the East Anglian Fens, Lincolnshire coast (Clapham 1999) and Severn Estuary Levels (Timpany 2005, Bell 2007) for closed canopy woodland, noting the need for further megafossil data from large coastal exposures. The submerged forest between Borth and Ynyslas, on the west coast of Wales, has been spectacularly well exposed on several occasions in recent years, with hundreds of stumps and numerous fallen trunks appearing as storms have swept away their usual covering of sand. During a visit in April this year (2022), unusually extensive areas of peat were seen, presenting a particularly clear impression of the distribution of trees in the original prehistoric woodland. This article reports the results of an impromptu rapid survey to record the spacing of the trees as an insight into the structure of a lowland Neolithic pine wood.

The site

The submerged forest at Borth stretches for some 4 km along the foreshore between the southern end of Borth village northwards to Ynyslas (Figure 1). The beach is separated from the large expanse of Borth Bog/Cors Fochno by a substantial sand and gravel spit deposited as a result of long-shore drift – currently the subject of an investigation by the CHERISH (Climate, Heritage and Environments of Reefs, Islands, and Headlands) project. The main distribution of tree stumps lies midway between mean low and high water. For much of the time it is covered by sand, but winter storms usually remove at least some of this covering, after which it generally returns over the calmer months.

Figure 1: Location of the submerged forest between Borth and Ynyslas. Inland is the large expanse of Borth Bog/Cors Fochno, the canalized course of the Afon Leri running near its western margin.
Source: Google, Imagery ©2022 TerraMetrics, Map data ©2022. Scale: box width = 10 km.

The first scientific study of the forest was by F. N. Campbell James (published by Godwin and Newton 1938), primarily involving pollen analysis, followed by radiocarbon-dating of samples of birch (*Betula*) (6026±135 BP, Q-380) and bulk peat (5898±135 BP, Q-382) from the base of the peat layer at Ynyslas (Godwin and Willis 1961). More detailed consideration of the trees themselves began with Alan Heyworth (1985) who mapped the overall distribution of peat and associated tree remains and undertook ring counts and radiocarbon dating on selected stumps, as well as pollen analysis of the associated peat. Most of the stumps were of pine (*Pinus sylvestris*), radiocarbon-dated to between *c*. 5200 and 4800 BP, with occasional remains of birch and alder (*Alnus glutinosa*), but Heyworth marked the exact positions of relatively few (35) of the trees, so that the general character of the woodland in terms of the density and spacing of the trees is not apparent. In addition to the main area of pine, there were the remains of several large oaks (*Quercus*) at the southern end of the beach, where the peat abuts rocks, dating to *c*. 4000 BP. Heyworth also recorded the remains of alder and hazel (*Corylus avellana*) in this area, along with the presence of 'hoof-prints' (Heyworth 1985, Figure 6.1). He concluded that the main area of forest developed across an alluvial clay surface, on which there had been a succession from salt marsh and fen to pine woodland. This woodland appeared to have been killed subsequently by a rising water table due to sea-level rise, triggering peat formation and burial of the stumps.

Exposures of the submerged forest seem to have become more extensive from around 2010, when the Royal Commission on the Ancient and Historical Monuments of Wales undertook a rapid hand-held GPS survey (RCAHMW 2011) to plot the distribution of 630 stumps which at that time were exposed in three distinct areas. Subsequently, spectacular exposures of large numbers of stumps and fallen trunks have been reported in the local and national media on several occasions, along with the discovery in 2012 by Martin Bates of human and animal footprints, including those of cattle and sheep/goats, from the southern end of the beach (https://www.bbc.co.uk/news/uk-wales-mid-wales-17353470, last accessed 21.04.22). Like the oaks from that area, these appear to be later in date than the main area of pine woodland. Other evidence for the local prehistoric fauna has come from the almost complete skeleton of an auroch found on the foreshore in the 1960s, followed more recently by the discovery of a large pair of red deer antlers.

My own visits to Borth and Ynyslas over recent years have involved photographic recording of the tree stumps and trunks as they have been exposed and eroded by the tides. While numerous stumps are now visible quite frequently, they are often surrounded by sand, obscuring the stratigraphic relationship between individual and groups of stumps. In April this year, however, the severe storms of the previous few months had exposed extensive areas of peat so that the relative positions of many trees could be seen without intervening spreads of sand. From this the clear impression was of a woodland of closely spaced trees (Figure 2), often with roots inter-mingled with those of their nearest neighbours (Figure 3). Given the rarity of such clear exposures of the main areas of submerged forest, and unpredictability over when, and even if, such a good opportunity would arise again, I decided to take make a quick record of the spacing between as many trees as practical in the time available.

Figure 2: General view of the submerged forest between Borth and Ynyslas, looking north. Scale 1 m.

Method

Recording took place on the 4th and 5th of April 2022. At this time many hundreds of stumps were exposed mid-way between the low and high tide points stretching for over 1 km between the village of Borth and Ynyslas. Most stumps appeared to be of pine on the basis of the morphology of the exposed roots and trunk base, and in some cases the presence of bark (Figure 4), but there were also, towards the southern part of the distribution, a few large stumps thought to be of oak. Occasional remains of birch (identifiable from the characteristic bark), and probably alder, were also present among the pines. Many of the stumps were associated with expanses of peat free of sand, especially towards the northern part of the distribution. There were also extensive exposures of peat higher up the beach, closer to the high tide mark, but these had few trees and are assumed to be of later date on the basis of Heyworth's study. Further towards the low tide mark the shore remained covered in sand.

To stand the best chance of trees being contemporary, only stumps visible within the same continuously visible peat surface were recorded. The peat exposures were patchy and separated by sand. Patches for recording were chosen by starting

Figure 3: Pair of pine stumps with overlapping root systems from the submerged forest between Borth and Ynyslas.

at the southern end of the main distribution of trunks (NGR SN 6066 9030) and walking northwards in a straight line. Where a patch of peat was encountered with two or more trunks, the distance between the centre of each trunk and its nearest neighbour was recorded. Initially stumps of any size were included and the diameter of the remains of the trunk recorded (the first 12 trunks encountered had diameters in the range 16-42 cm), but this was problematical because many of the stumps were eroded so that the original diameter was unclear. Given constraints on time, it was decided instead to record all stumps that appeared originally to have been at least 10 cm in diameter. In practice, the vast majority of stumps encountered were at least this size, perhaps reflecting differential erosion and decay of smaller remains. A total of 106 spacings were recorded from 23 areas of peat, the number of trees in each peat exposure ranging from 2 to 15.

Figure 4: A pair of fallen pine stumps from the submerged forest between Borth and Ynyslas. Note intact bark on lower portion of nearest tree.

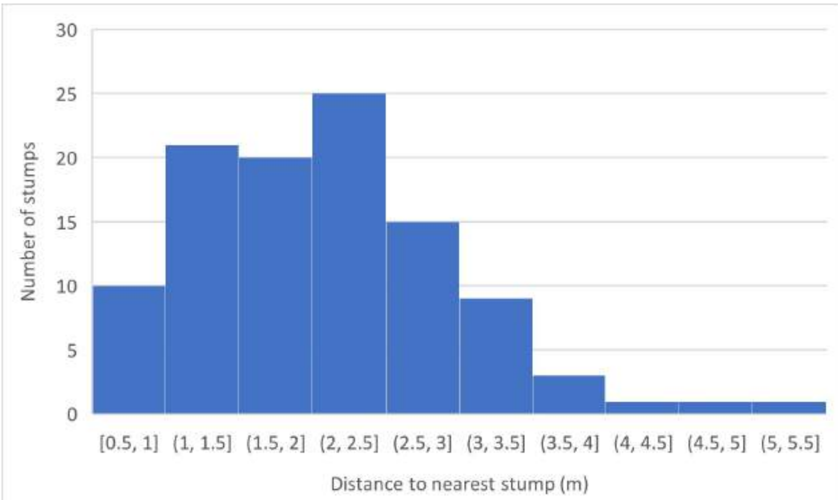

Figure 5: Histogram of inter-stump distances for trees on continuous peat exposures between Borth and Ynyslas. '0.5, 1' refers to distances >0.5≤1 m, '1, 1.5' to >1≤1.5 m etc.

Results

A histogram of the distribution of recorded inter-stump spacings is shown in Figure 5. Inter-stump-distances were in the range 0.7-5.5 m, 2-2.5 m being the modal grouping. Almost half (48%) of the stumps were within 2 m of another stump, and almost 10% within 1 m, suggesting that, if the trees were indeed contemporary, they formed dense stands. Several trunks were also visible (Figure 4), most having fallen perpendicular to the shore with their roots at the seaward end, as expected due to the prevailing westerly winds. The longest trunk was 7.7 m in length, unbranched, with a diameter of 16 cm at its widest point. As with the stumps, most of the fallen trunks were clearly of pine.

Discussion

This quick opportunistic survey of inter-stump spacings suggests that the Neolithic pine woodland between Borth and Ynyslas had a dense structure, probably with a closed canopy and sparse ground vegetation. Given more time, it would obviously be desirable to undertake a more detailed survey of the distribution of stumps where they appear on continuous peat exposures, including measurements of stump diameter, so that the spacing and overall density of trees of different size/ age classes could be seen in more detail.

The RCAHMW (2011) GPS survey (positional accuracy $\pm$7 m) of the forest, while also lacking details of stump size, can be used to provide a rough estimate of the density of trees, with the proviso that even within the three individual areas mapped (A-C) they would not all have been situated on the same continuous peat exposure. The central of the three areas (B) was most extensive and had the greatest number of stumps. Using the mapped distribution, a 50 x 50 m square (= 0.25 ha) imposed over the area of greatest density can be seen to contain approximately 70 stumps, equivalent to a density of around 280 trees/ha. While they cannot all be assumed to have been growing at the same time, Heyworth's observations on the relative ages of pines in this area suggest that most probably were (Heyworth 1985, 134).

Today, native pine woodland is confined to Scotland, especially the Highlands, where there have been several studies characterizing the structure of these woods using a variety of methods to determine the density of trees (e.g. Summers *et al.* 1999, Edwards and Mason 2006). That producing data most easily compared to the Borth situation is the study by Edwards and Mason (2006), which provides data on pine stem density for trees (defined as >7cm d.b.h, diameter at breast height = 1.3 m), smaller saplings and seedlings. At Borth almost all of the stumps visible today are >7cm in diameter (at ankle or shin height). Tree stem density for pine stands from Glenmore was 372/ha and for Glen Garry 167/ha. Tree stem density estimates of 158/ha and 103/ha from the Black Wood of Rannoch and Glen Affric respectively included a small number of specimens of birch and rowan (*Sorbus*) that grew alongside the pines. The Borth estimate lies towards the upper end of this range, suggesting that the Neolithic woodland there may have had a more closed character than typically found in native pine woodland today. The structure of surviving native pine woodland in Scotland is heavily influenced by its management history, in many areas having an open park-like character reflecting grazing by deer and livestock (Summers *et al.* 1999). Scotland also has areas of native pine woodland on drier parts of bogs, which might be more analogous to the prehistoric woodland at Borth (although in these, again, the trees tend to be widely spaced), but these have received little attention (Legg *et al.* 2003) and are not included in the National Vegetation Classification for woodland (Rodwell 1991).

On the basis of pollen evidence, the 'typical' mid-Holocene woodland of lowland parts of Wales would be expected to be dominated by oak and hazel, with alder on soils prone to waterlogging, pine generally having been out-competed by these broadleaved trees earlier in the Holocene (as, for example, at the inland raised mire complex of Tregaron Bog/Cors Caron, 30 km south-east of Borth (Hibbert and Switsur 1976)). The predominance of pine at Borth probably reflects its ability to survive in the specific hydrological setting that prevailed by the mouth of the River Dovey/Afon Dyfi at around 5000 BP. It is, nevertheless, probably the most extensive example available of a mid-Holocene submerged forest in which megaherbivores including aurochs and red deer were likely to have been present. Clearly the populations of these animals were not sufficiently great to create the sort of park-like landscape proposed by Vera, as appears also to have been the case for the Neolithic submerged forests from Merseyside and the Lincolnshire coast investigated by Alan Clapham (1999). There only small exposures were generally available, with few trees at the Lincolnshire sites, but at Hightown on Merseyside 298 stumps and trunks were recorded, most of which were birch, but also including willow/poplar (Salicaceae), oak and alder. Clapham estimated a very high density, of 1511 stems/ha (which included stumps with diameters as small as 5 cm), for Hightown. This he attributed to the large number of young trees, most of which were in the 5-10 cm diameter size class.

Conclusion

While of necessity basic in nature, and relating to the character of a very specific type of lowland woodland, the data from the Neolithic pine woodland at Borth can be added to the short list of mid-Holocene woodland types for which we have sufficient *in situ* tree remains to provide an indication of the original woodland structure. This woodland appears to have been closed in character, despite the probability that it was inhabited, or at least visited, by megaherbivores including aurochs and red deer.

References

Bell, M. (2007). *Prehistoric Coastal Communities: the Mesolithic in Western Britain*. CBA Research Report 149, CBA, York.

Clapham, A.J. (1999). *The Characterisation of Two Mid-Holocene Submerged Forests*. Unpublished PhD thesis, Liverpool John Moores University.

Edwards, C. and Mason, W.L. (2006). Stand structure and dynamics of four native Scots pine (*Pinus sylvestris* L.) woodlands in northern Scotland. *Forestry* 79, 261-277.

Godwin, H. and Newton, L. (1938). The submerged forest at Borth and Ynyslas, Cardiganshire. Data for the study of post-glacial history. No. 1. *New Phytologist* 37, 333-344.

Godwin, H. and Willis, E.H. (1961). Cambridge University Natural Radiocarbon Measurements III. *Radiocarbon* 3, 60-76.

Heyworth, A. (1985). *Submerged Forests: a Dendrochronological and Palynological Investigation*. Unpublished PhD thesis, University of Wales.

Hibbert, F.A. and Switsur, V.R. (1976). Radiocarbon dating of Flandrian pollen zones in Wales and northern England. *New Phytologist* 77, 793-807.

Legg, C., McHaffie, H., Amphlett, A. and Worrell, R. (2003). The status of wooded bogs at Abernethy, Strathspey. In Caledonian Partnership, *Restoring Natura Forest Habitats*. Highland Birchwoods, Munlochy, 14-18.

Rodwell, J.S. (ed.) (1991). *British Plant Communities Volume 1. Woodlands and Scrub*. Cambridge University Press, Cambridge.

RCAHMW (2011). *Borth Submerged Forest. Non intrusive survey*, https://coflein.gov.uk/media/158/416/dsc_bsf01.pdf, last accessed 22.4.22

Summers, R.W., Mavor, R.A., MacLennan, A.M. and Rebecca, G.W. (1999). The structure of ancient native pinewoods and other woodlands in the Highlands of Scotland. *Forest Ecology and Management* 119, 231-245.

Timpany, S. (2005). *A Multi-proxy Palaeoecological Investigation of Submerged Forests and Intertidal Peats, Severn Estuary, UK*. Unpublished PhD thesis, University of Reading.

Vera, F.W.M. (2000). *Grazing Ecology and Forest History*. CABI International, Wallingford.

Waller, M. (2022). Megafossils: evidence for the nature of Holocene lowland woodland in England and Wales. *Quaternary Newsletter* 155, 17-31.

DRIVERS OF LONG-TERM AQUATIC PLANT CHANGE IN UPLAND LAKES AND STREAMS IN THE UK: A DNA APPROACH

Background and Rationale

The analysis of DNA preserved in soils and sediments is increasingly being used as a tool in environmental research, particularly palaeolimnology (Capo *et al*., 2021). The primary aim of this element of the PhD is to examine the scientific potential of plant sedDNA in lake sediments for reconstructing the past aquatic plant assemblages in a low-alkalinity upland lake, the Round Loch of Glenhead. A secondary aim will determine whether littoral or deep-water cores provide the best archive for plant sedDNA. Validation of sedDNA results will be done through comparison with three-decades of historic biomonitoring archives of aquatic plant abundances and distribution records from the UK Upland Waters Monitoring Network (Battarbee *et al*., 2014). Robust sediment core chronologies are essential to the interpretation of any sedDNA results.

Methods and Results

Deep-water (RLGHE2) and littoral (RLGHE3) cores were collected on 14th Sept 2020 using an HTH Renberg gravity corer, from 12.1m and 3.5m water depths respectively. Cores were kept refrigerated in the dark until extrusion at 0.25cm increments in a clean room where no previous DNA work had been performed. Two replicates for each level were sampled and frozen immediately. DNA extractions were performed on selected levels using QIAGEN PowerSoil Pro kits. DNA concentrations were measured using a Qubit fluorometer and DNA purity using a Nanodrop spectrophotometer. Sediment sub-samples were analysed for wet density, percentage dry weight and loss on ignition. Selected levels were dried and sent to the UCL Environmental Radiometric Facility for radiometric dating using ^{210}Pb, and isotope spikes of ^{137}Cs and ^{241}Am, to establish core chronologies. PCR analyses of the DNA samples are ongoing, using the trnL barcode developed for characterising plant species from degraded sediment and archaeological samples (Taberlet *et al*., 2007). Amplicon libraries will be sequenced on an Illumina MiSeq machine.

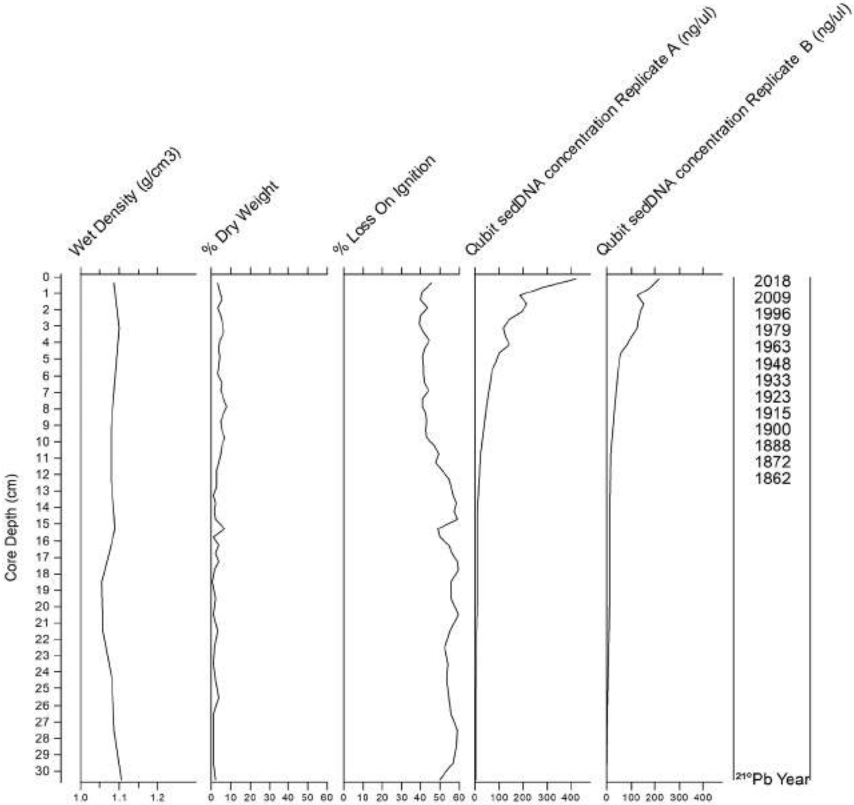

Figure 1. Deep-water core RLGHE2. Sediment sample wet densities, dry weights, loss on ignition, DNA concentrations and chronology.

Loss on ignition and percent dry weight in both cores (Figures 1 and 2) indicate organic sediments and values are consistent with historic cores from the same site (Jones *et al*., 1989). Values changed little down the profile in the deep core whereas the shallow core was slightly more minerogenic in the bottom 5cm. The dating report (Yang, 2021) indicated that both cores have undisturbed chronologies (Tables 1 and 2), with the maximum measurable age of the deep core 1862 ±30 at 12.25cm depth and that of the shallow core 1825 ±35 at 21.5cm depth. The sediment accumulation rate was higher in the shallow-water core than the deep-water core but both fall within the range of rates that Allot *et al*. (1992) observed in a multi-core study of the site. Sediment DNA concentrations were higher in the deep-water core than the shallow-water core and declined with depth in both replicates from both cores. Even at the bottom of the cores however, DNA concentrations are sufficient for PCR analyses. Both replicates in the shallow core show a slight decline in concentrations at the surface.

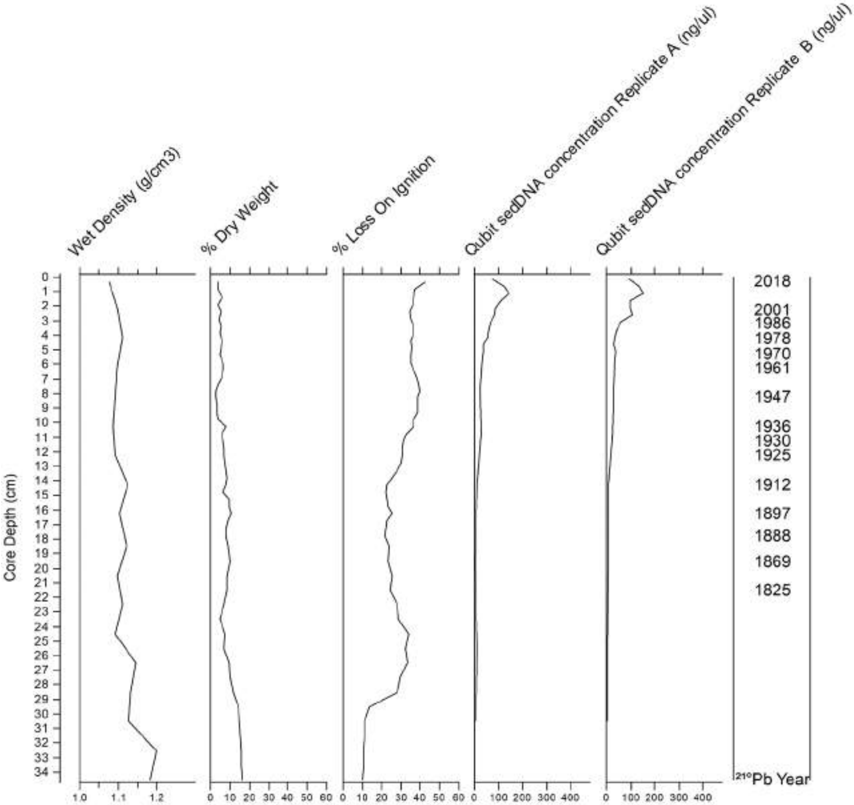

Figure 2. Shallow-water core RLGHE3. Sediment sample wet densities, dry weights, loss on ignition, DNA concentrations and chronology.

Significance

Establishing that both cores represent undisturbed continuous records of the time period of interest in this project provides confidence that stratigraphical interpretations of the DNA analyses will be robust. If sedDNA from sediment cores matches known aquatic plant species occurrences, then down-core results from the most representative coring location can be used to establish pre-acidification ecological baselines and address whether aquatic plants are returning to pre-industrial assemblages or are responding to nutrient deposition and changes in climate. If the sedDNA technique is sufficiently accurate and sensitive, then core surface sediment or annual sediment trap samples may provide statutory bodies with an innovative and more cost-effective methodology for characterising and monitoring aquatic plants than current traditional surveys.

Table 1 ^{210}Pb chronology of deep-water core RLGHE2

Depth	Dry mass	Chronology			Sedimentation Rate		
		Date	Age				
cm	g cm^{-2}	AD	yr	±	g cm^{-2} yr^{-1}	cm yr^{-1}	± %
0	0	2020	0				
0.25	0.0093	2018	2	2	0.0057	0.121	9.5
1.25	0.0585	2009	11	2	0.0046	0.092	12.6
2.25	0.1094	1996	24	2	0.0032	0.059	9.3
3.25	0.1661	1979	41	3	0.0036	0.064	12.6
4.25	0.2208	1963	57	3	0.0033	0.06	16.6
5.25	0.274	1948	72	4	0.0038	0.073	15.7
6.25	0.3253	1933	87	6	0.0034	0.061	23.4
7.25	0.3837	1923	97	7	0.0127	0.215	82.4
8.25	0.4436	1915	105	8	0.0044	0.074	31.5
9.25	0.5034	1900	120	12	0.0034	0.064	50.4
10.25	0.5492	1888	132	16	0.0046	0.101	70.6
11.25	0.5949	1878	142	20	0.004	0.087	98.1
12.25	0.6407	1862	158	30	0.0021	0.043	106.5

Table 2 ^{210}Pb chronology of shallow water core RLGHE3

Depth	**Dry mass**	**Chronology**			**Sedimentation Rate**		
		Date	**Age**				
cm	**g cm^{-2}**	**AD**	**yr**	**±**	**g cm^{-2} yr^{-1}**	**cm yr^{-1}**	**± %**
0	0	2020	0				
0.25	0.0091	2018	2	2	0.0061	0.152	23.4
2.25	0.0898	2001	19	6	0.0035	0.077	39.9
3.13	0.1387	1986	34	6	0.0049	0.087	63.9
4.25	0.2033	1978	42	6	0.0082	0.132	11.6
5.25	0.2705	1970	50	6	0.0083	0.122	12.1
6.25	0.3397	1961	59	6	0.0066	0.109	12.3
7.25	0.3917	1953	67	7	0.0068	0.134	9.5
8.25	0.4412	1947	73	7	0.0089	0.172	13.1
9.25	0.495	1941	79	8	0.0119	0.221	14.8
10.25	0.5488	1936	84	8	0.0086	0.125	18.4
11.25	0.6335	1930	90	9	0.0258	0.305	41.8
12.25	0.7182	1925	95	9	0.0127	0.149	29.2
14.25	0.8876	1912	108	11	0.0123	0.134	35.9
15.25	0.993	1904	116	12	0.0136	0.129	41
16.25	1.0983	1897	123	13	0.0176	0.163	49.2
17.75	1.2628	1888	132	15	0.0193	0.182	76.5
19.5	1.4427	1869	151	18	0.0051	0.053	53.9
21.5	1.6256	1825	195	35	0.0029	0.034	61.1

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References

Allott, T.E.H., Harriman, R., Battarbee, R.W. (1992). Reversibility of lake acidification at the Round Loch of Glenhead, Galloway, Scotland. *Environmental Pollution* 77, 219-225.

Battarbee, R.W., Shilland, E.M., Kernan, M., Monteith, D.T., Curtis, C.J. (2014). Recovery of acidified surface waters from acidification in the United Kingdom after twenty years of chemical and biological monitoring (1988-2008). *Ecol. Indic*. 37, Part B, 267-273.

Capo, E., Giguet-Covex, C., Rouillard, A., Nota, K., Heintzman, P.D., Vuillemin, A., Ariztegui, D., Arnaud, F., Belle, S., Bertilsson, S., Bigler, C., Bindler, R., Brown, A.G., Clarke, C.L., Crump, S.E., Debroas, D., Englund, G., Ficetola, G.F., Garner, R.E., Gauthier, J., Gregory-Eaves, I., Heinecke, L., Herzschuh, U., Ibrahim, A., Kisand, V., Kjær, K.H., Lammers, Y., Littlefair, J., Messager, E., Monchamp, M.-E., Olajos, F., Orsi, W., Pedersen, M.W., Rijal, D.P., Rydberg, J., Spanbauer, T., Stoof-Leichsenring, K.R., Taberlet, P., Talas, L., Thomas, C., Walsh, D.A., Wang, Y., Willerslev, E., van Woerkom, A., Zimmermann, H.H., Coolen, M.J.L., Epp, L.S., Domaizon, I., G. Alsos, I., Parducci, L. (2021). Lake Sedimentary DNA Research on Past Terrestrial and Aquatic Biodiversity: Overview and Recommendations. *Quaternary* 4, 6.

Jones, V.J., Stevenson, A.C., Battarbee, R.W. (1989). Acidification of Lakes in Galloway, South West Scotland: A Diatom and Pollen Study of the Post-Glacial History of the Round Loch of Glenhead. *The Journal of Ecology* 77, 1.

Taberlet, P., Coissac, E., Pompanon, F., Gielly, L., Miquel, C., Valentini, A., Vermat, T., Corthier, G., Brochmann, C., Willerslev, E. (2007). Power and limitations of the chloroplast trnL (UAA) intron for plant DNA barcoding. *Nucleic Acids Res* 35, e14-e14.

Yang, H. (2021). *Report on the Radiometric Dating of Sediment Cores RLGHE2 and RLGHE3 from Round Loch of Glenhead, Scotland*, Environmental Change Research Centre, Geography Dept, UCL, London.

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UNDERSTANDING LATE PLEISTOCENE-HOLOCENE TERRACE DEVELOPMENT IN THE NORTHEAST HIMALAYAN FRONTAL THRUST ZONE, INDIA

Background and Rationale

To understand the relationship between climate change, surface processes and tectonic movement, an increasing number of studies have paid attention to the fluvial processes leading to morphological and sedimentological change with the chronology of river terrace formation and the degree of tectonic deformation (Starkel, 2003; Srivastava et al., 2008; Prizomwala et al., 2016). The main aim of this research is to establish an understanding of the late Pleistocene-Holocene terrace development in the Northeast Himalayan Frontal Thrust Zone (HFT). This gives information about landscape evolution and how denudational processes respond to ongoing processes. In this context, fieldwork was carried out to look for exposed outcrops to document the lithostratigraphic framework, sedimentological character of the deposits and collection of samples for optical dating techniques.

Methods

Lithofacies analysis is a field-based observation used to identify and describe different lithofacies and the vertical-lateral stacking of sedimentary units. Based on the characteristics of lithofacies, lithologs were prepared to reconstruct the depositional environment and palaeohydrological conditions which when aided with chronology would help in evaluating the relative role of climate and tectonic forcing in the evolution of the landform studied (Miall, 1996). The luminescence dating of the sand horizon provides a temporal constraint on aggradational and incisional phases. OSL dating of the terrace samples were analyzed at the OSL Laboratory, Institute of Seismological Research (Gujarat, India).

Results

Samples collected from the sand layer of various levels of the terraces, yield the depositional age of sediment (Table 1). Along the Solongi river section, T_1 terrace yields an age of 1.5 ± 0.2 ka while, T_2 and T_3 give ages of 4.8 ± 0.7 ka and 26 ± 2 ka respectively. Similarly, the Burai river terrace sequence yields ages of 7.9 ± 0.6 ka for T_1 terrace and 18 ± 1.4 ka for the paleobank. The optical dating of the samples collected from the Tabang river sequence is underway.

Significance

This work provides much needed information to better understand the intricacies in geomorphic evolution of the frontal segment in the tectonically and climatically active northeast Himalayan region and how denudational processes respond to

Table 1: OSL data of samples collected from terrace sequences.

ISR sample ID	**Sample Name**	**U (ppm)**	**Th (ppm)**	**K (%)**	**Cosmic ray (μG/a)**	**D_e (Gy)**	**Dose rate (Gy/ka)**	**Age (ka)**
ISR-469	IT_3	2.9±0.15	9.3±0.47	1.57±0.03	195.4±6.3	66.7±3	2.5±0.2	26 ± 2
ISR-471	IT_2 B	2.5±0.13	9.8±0.5	1.79±0.04	164.2±37.5	12.7±1.5	2.6±0.2	4.8 ± 0.7
ISR-472	IT_1	2.8±0.14	10.3±0.52	1.94±0.04	160±42	4.1±0.5	2.8±0.2	1.5 ± 0.2
ISR-480	DG-CF 2	3.4±0.2	10.9±0.5	1.9±0.04	196.2±4	23.6±0.5	3±0.2	7.9 ± 0.6
ISR-481	DG-PB	3.5± 0.18	11.7±0.6	2.0±0.04	196.2±4	56.6±1.1	3.1±0.2	18 ± 1.4

the tectonic uplifts versus intense monsoonal erosional processes. The clear data from the Solengi and Burai river sections provide first-hand evidence of various aggradational and incisional cycles in response to different causal mechanisms like climate and tectonics.

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References

Miall, A. D. (1996). The Geology of Fluvial Deposits. Sedimentary Facies, Basin Analysis, and Petroleum Geology. 582. *Berlin, Heidelberg, New York.*

Prizomwala, S.P., Das, A., Chauhan, G., Solanki, T., Basavaiah, N., Bhatt, N., Thakkar, M.G. and Rastogi, B.K. (2016). Late Pleistocene-Holocene uplift driven terrace formation and climate-tectonic interplay from a seismically active intraplate setting: An example from Kachchh, western India. *Journal of Asian Earth Science,* 124, 55-67.

Srivastava, P. and Misra, D.K. (2008). Morpho-sedimentary records of active tectonics at the Kameng river exit, NE Himalaya. *Geomorphology*, 96, 187–198.

Starkel, L. (2003). Climatically controlled terraces in uplifting mountain areas. *Quaternary Science Reviews*, 22, 2189-2198.

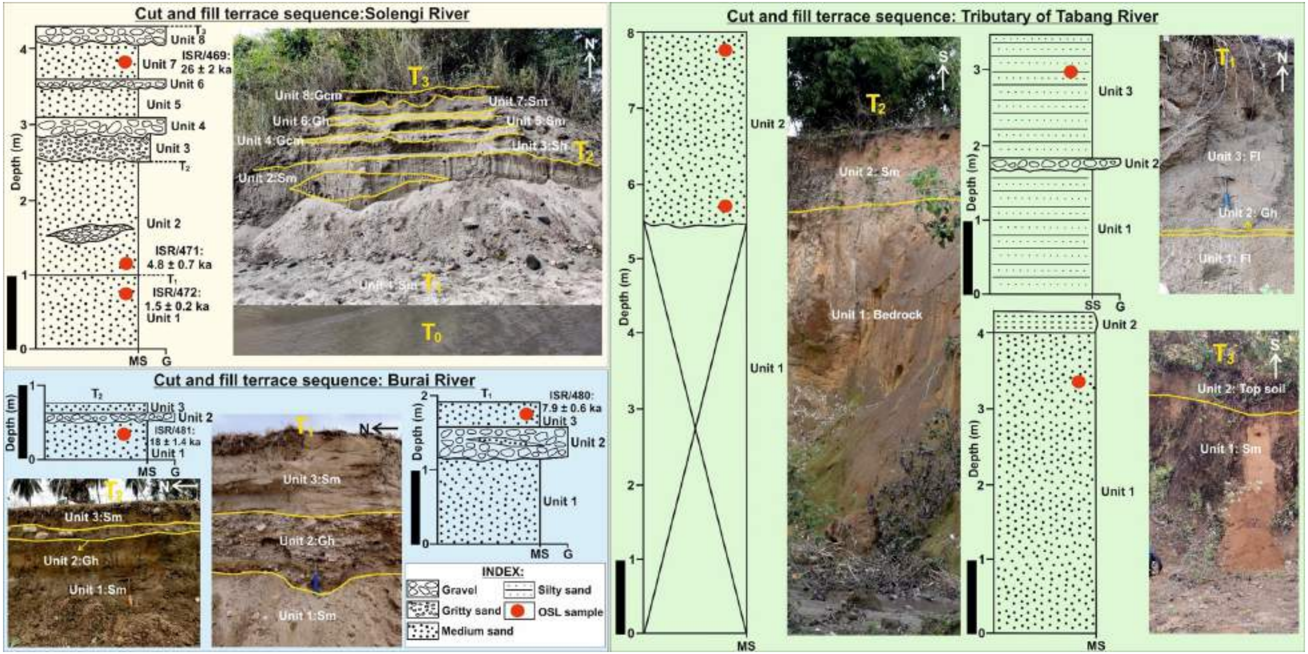

Figure 1 Litholog and field photograph of representative terrace sequence with the lithofacies identified in the central segment of the study area.

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VARIABLE MIGRATORY BEHAVIOUR IN LATE PLEISTOCENE REINDEER AND BISON FROM ARCTIC SIBERIA

Background and Rationale

The Arctic is, and has likely always been, a rather hostile environment to humans and animals alike. Plant growth is suspended for many months during the annual Polar Night and mean daily temperatures (°C) are negative for most of the year. Subsistence strategies of contemporary people living in or near the Arctic are largely influenced by seasonal availability of various prey species, and monitoring changes in the migratory behaviour of said species is vital to survival (Parlee *et al.*, 2005). While the mammoth-steppe ecosystem, which used to cover large parts of the Arctic during the Pleistocene, contained a higher herbivorous biodiversity and biomass than the current ecosystem (Zimov *et al.*, 2012), Upper Palaeolithic hunters still had to monitor annual changes in prey availability. As part of a study looking into human-animal interactions at the ~32,000-years-old site of Yana (Northern Yakutia, Russia)(Pitulko *et al.*, 2004), strontium isotope ($^{87}Sr/^{86}Sr$) analyses revealed that there was inter- and intra-specific variation in the migratory behaviour of reindeer and bison; all three analysed bison show substantially different $^{87}Sr/^{86}Sr$ patterns throughout their teeth, while three of the four analysed reindeer exhibit roughly similar intra-tooth patterns (Fig. 1 and Table 1).

To understand why some animals at Yana migrated, when others didn't, oxygen ($\delta^{18}O$) and carbon isotope ($\delta^{13}C$) were analysed from intra-tooth carbonate samples. This is because $\delta^{18}O$ values are affected by air temperature and precipitation (Pederzani & Britton, 2019), while $\delta^{13}C$ values in the Arctic usually differ between plant types (e.g., herbs vs graminoids)(Schwartz-Narbonne *et al.*, 2019, but see Metcalfe, 2021), plant parts (e.g., stems vs leaves), and environmental conditions (e.g., open vs canopy vegetation, and mean annual precipitation)(Kohn, 2010; Metcalfe, 2021). The analysis of these carbonate samples was made possible by the Quaternary Research Association's New Research Workers Award.

Results

In total, 79 tooth carbonate samples were taken and analysed from the lower second (M2) and third molars (M3) of four reindeer and two bison and from the lower third molar of one bison (Fig. 1 and Table 1). The $\delta^{18}O$ and $\delta^{13}C$ analyses, of which the full datasets are still to be published elsewhere, produced intriguing results. Two individuals (B02 and B03) exhibit similar $\delta^{18}O$ and $\delta^{13}C$ values (Fig. 1 and Table 1), though with different intra-tooth patterns, while the third individual (B05) yielded substantially lower $\delta^{18}O$ values and higher $\delta^{13}C$ values.

Interestingly, all four reindeer individuals yielded a somewhat sinusoidal intra-tooth $\delta^{18}O$ pattern, which was contrasted by an opposing pattern in the $\delta^{13}C$ value. However, while R01 and R06 had similar maximum and minimum $\delta^{18}O$ values, R04 and R06 yielded somewhat lower minimum $\delta^{18}O$ values. Finally, all four reindeer had slightly different $\delta^{13}C$ ranges, with R01 having the highest values, followed by R06, R02, and R04, respectively.

Significance

The obtained results help explain intra-specific difference to some extent. One bison (B05) exhibited substantially lower $\delta^{18}O$ values and higher $\delta^{13}C$ values than were found in the other two individuals. This might indicate it lived in a generally colder and more open environment. The other two bison individuals (B02 and B03) exhibited similar $\delta^{18}O$ and $\delta^{13}C$ values, albeit with different intra-tooth patterns, but substantially different $^{87}Sr/^{86}Sr$ values. These animals might thus have experienced similar environments, but either behaved differently, or inhabited different home regions.

The similarity in $^{87}Sr/^{86}Sr$ values in three out of four analysed reindeer (R01, R02, and R06) might indicate that these animals were part of the same herd, while differences in the $\delta^{18}O$ and $\delta^{13}C$ values between these animals seems to demonstrate that inter-annual changes in environmental temperature or vegetation did not necessarily affect their migratory behaviour. The higher $^{87}Sr/^{86}Sr$ values found in R04, in combination with its generally lower $\delta^{13}C$ values, might indicate that this individual belonged to a different herd that lived in a more canopied and/ or wetter environment, albeit with similar temperatures as demonstrated by its similar $\delta^{18}O$ values.

Attempts at reconstructing past air temperatures for Yana using the $\delta^{18}O$ data following the methods outlined by Pryor *et al.* (2014) have so far proven problematic, as the preliminary temperature estimates are substantially lower than those obtained from pollen-based reconstructions (Pavlova and Pitulko 2020). At the time of writing, we do not have a clear explanation for this discrepancy. Unfortunately, to the best of our knowledge, there is no prior $\delta^{18}O$ and $\delta^{13}C$ data from modern or fossil reindeer and/ or bison from Northern Yakutia against which we can compare our data. Comparing the Yana data against modern reindeer/caribou or bison $\delta^{18}O$ data from different Arctic regions (Britton, 2010; Glassburn, 2015) is problematic as well, as there is a spatial effect on the relationship between air temperatures and the $\delta^{18}O$ values of precipitation (and therefore on the $\delta^{18}O$ values found in tooth enamel). These relations are not well understood for the regions from which modern data has been collected, hampering comparisons.

The $\delta^{13}C$ values, on the other hand, can be compared directly between the Yana and the modern animals, with the caveat that baseline $\delta^{13}C$ values have become more negative by about 1.5‰ compared to thirty-thousand years ago due to modern

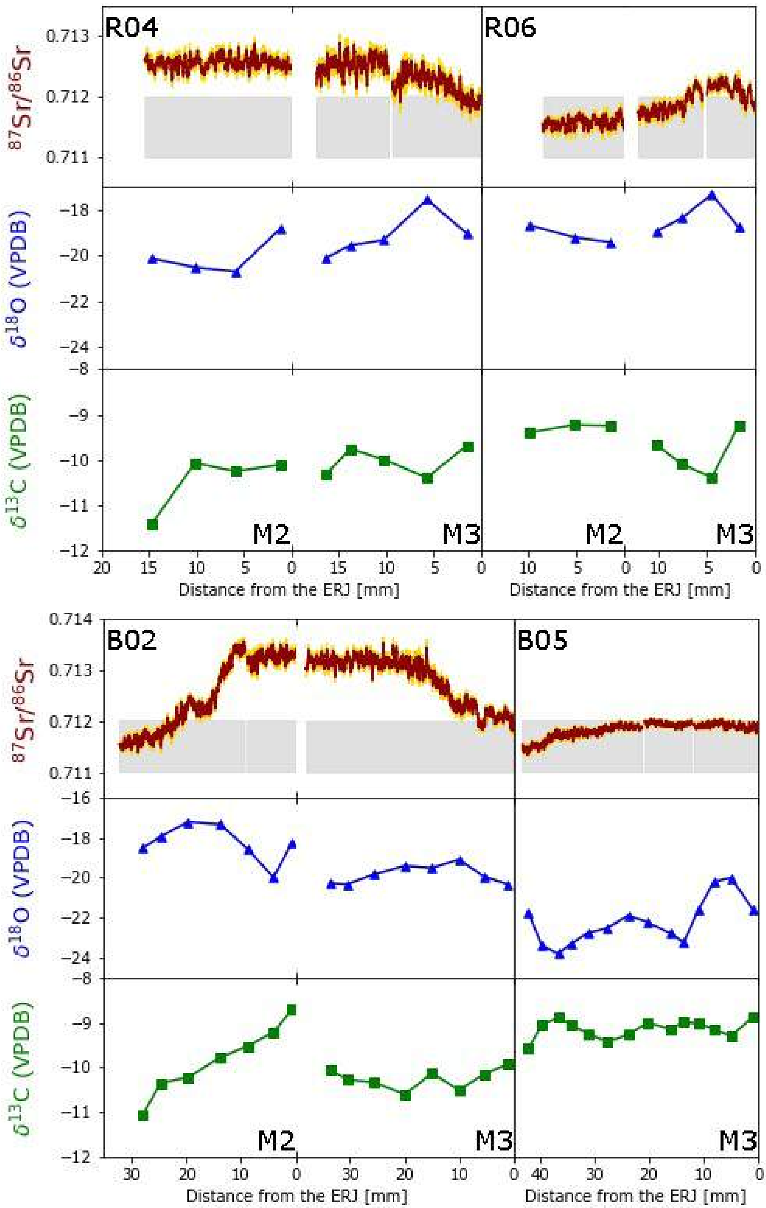

Figure 1: Isotope data from the lower molars (M2 and M3) of two reindeer (R04 and R06) and two bison (B02 and B05) from Yana. Red line indicates running 10-point mean, yellow boundaries the running 10-point standard error and the shaded grey area indicates local bioavailable $^{87}Sr/^{86}Sr$ value.

CO_2 emissions (Hare *et al.*, 2018). This reveals that the $\delta^{13}C$ values of modern bison from interior Alaska (Glassburn, 2015) are more negative (-15.2 to -14.3‰ uncorrected) than those of the Yana bison (-11.06 to -8.71‰), indicating that the Yana bison occupied a more open and possibly dryer environment than is currently found in interior Alaska, which is predominantly boreal. The $\delta^{13}C$ values of the Yana reindeer (-11.29 to -8.47‰) are similar to $\delta^{13}C$ values obtained from teeth of modern caribou from Western Alaska (-13.1 to -9.3‰ uncorrected) and north-eastern Canada (-13.0 to -9.8‰ uncorrected)(Britton, 2010). The environment of Yana may thus have been comparable to the open tundra environments currently found in these regions.

There is a multitude of possible explanations for the different $^{87}Sr/^{86}Sr$ values and patterns between the bison and reindeer individuals that cannot be observed in $\delta^{18}O$ and $\delta^{13}C$ values. These consist of intrinsic factors such as inter-herd differences in migratory behaviour and a possible lack of strong site fidelity in bison as a species, as well as extrinsic factors such as inter-annual changes in predator pressure, landscape destruction by natural catastrophes (e.g., fires and flooding), and disease. Regardless of the exact reason(s) for the differences observed in the $^{87}Sr/^{86}Sr$ values, the obtained data demonstrate that people in the past, as people do now (Parlee *et al.*, 2005), had to monitor more than just changes in the weather and local vegetation to ensure they would be able to find sufficient prey.

Table 1. Summary of intra-tooth isotope data of reindeer and bison specimens from the Yana site. Oxygen and carbon isotope values are normalised against VPDB. n samples refers to total number of intra-tooth carbonate samples and analysed for $\delta^{18}O$ and $\delta^{13}C$ per individual, while the $^{87}Sr/^{86}Sr$ isotope data was collected via laser ablation multi-collector inductively coupled plasma mass spectrometry.

Sample	Teeth	*n* samples	$^{87}Sr/^{86}Sr$ min	$^{87}Sr/^{86}Sr$ max	$^{87}Sr/^{86}Sr$ mean	$\delta^{18}O$ min	$\delta^{18}O$ max	$\delta^{18}O$ mean	$\delta^{13}C$ min	$\delta^{13}C$ max	$\delta^{13}C$ mean
REINDEER											
R01	M2+M3	10	0.71138	0.71208	0.71175	-19.62	-17.53	-18.91	-9.78	-8.47	-9.11
R02	M2+M3	10	0.71163	0.71211	0.71185	-22.93	-18.27	-21.03	-10.95	-9.19	-9.83
R04	M2+M3	9	0.71173	0.71289	0.71244	-20.80	-17.63	-19.71	-11.29	-9.79	-10.26
R06	M2+M3	7	0.71138	0.71234	0.71179	-19.42	-17.31	-18.67	-10.39	-9.23	-9.61
BISON											
B02	M2+M3	15	0.71139	0.71356	0.71265	-20.32	-17.20	-19.10	-11.06	-8.71	-10.06
B03	M2+M3	14	0.71038	0.71118	0.71075	-20.80	-17.47	-18.81	-10.57	-9.63	-10.25
B05	M3	14	0.71134	0.71204	0.71183	-23.81	-20.00	-22.22	-9.57	-8.88	-9.14

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References

Britton, K.H. (2010). Multi-isotope analysis and the reconstruction of prey species palaeomigrations and palaeoecology. Unpublished PhD Thesis: Durham University

Glassburn, C.L. (2015). A Reconstruction of Steppe Bison Mobility in the Yukan-Tanana Uplands and Implications for Prehistoric Human Behaviour. Unpublished MA Thesis: University of Alaska Fairbanks

Hare, V.J., Loftus, E., Jeffrey, A. and Ramsey, C.B. (2018). Atmospheric CO_2 effect on stable carbon isotope composition of terrestrial fossil archives. *Nature Communications,* 9(1), 252.

Kohn, M.J. (2010). Carbon isotope compositions of terrestrial C3 plants as indicators of (paleo)ecology and (paleo)climate). *PNAS*, 107(46), 19691–19695.

Metcalfe, J.Z. (2021). C_3 plant isotopic variability in a boreal mixed woodland: implications for bison and other herbivores. *PeerJ,* 9, e12167.

Parlee, B., Manseau, M. and Łutsël K'é Dene First Nation (2005). Using Traditional Knowledge to Adapt to Ecological Change: Denésǫłıné Monitoring of Caribou Movements. *Arctic Institute of North America,* 58(1), 26–37.

Pederzani, S. and Britton, K. (2019). Oxygen isotopes in bioarchaeology: Principles and applications, challenges and opportunities. *Earth-Science Reviews,* 188, 77–107.

Pitulko, V., Nikolskiy, P., Girya, E.Y., Basilyan, A.E., Tumskoy, V.E., Koulakov, S.A., Astakhov, S.N., Pavlova, E. and Anisimov, M.A. (2004). The Yana RHS Site: Humans in the Arctic Before the Last Glacial Maximum. *Science,* 303(5654), 52–56.

Pryor, A.J.E., Stevens, R.E., O'Connell, T. and Lister, J.R. (2014). Quantification and propagation of errors when converting vertebrate biomineral oxygen isotope data to temperature for palaeoclimate reconstruction. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 412, 99–107.

Schwartz-Narbonne, R., Longstaffe, F.J., Kardynal, K.J., Druckenmiller, P., Hobson, K.A., Jass, C.N., Metcalfe, J.Z. and Zazula, G. (2019). Reframing the mammoth steppe: Insights from analysis of isotopic niches. *Quaternary Science Reviews,* 215, 1–21.

Zimov, S.A., Zimov, N.S., Tikhonov, A.N. and Chapin, F.S. (2012). Mammoth steppe: a high-productivity phenomenon. *Quaternary Science Reviews,* 57, 26–45.

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QUATERNARY ENGINEERING GEOLOGY FOR OFFSHORE RENEWABLES AND CAREERS EVENT

A half-day, online event held on 14th October 2021

On the afternoon of the 14th October 2021, 95 participants convened online for an afternoon of presentations, questions, discussions and a careers event focused on Quaternary geoscience in supporting the delivery of offshore renewables.

The growth in offshore renewables has re-ignited a requirement for the development of high-quality ground models to support the engineering design and performance of offshore structures. Quaternary geoscience, geoarchaeology and geomorphology play a critical role in understanding the mechanical and thermal properties and behaviour of the ground. Their properties and behaviour influence factors including the thermal capacity and protection of buried cables, seabed scour, wind turbine generator and substation foundation design. Geoarchaeology provides an important resource in the present-day marine environment that contributes to understanding landscape and human interaction.

This online event was the first in a new initiative that aims to promote collaboration between industry and academia to better understand and communicate the role of Quaternary engineering geology in the offshore renewables sector. Eight presentations delved into examples of current research in Quaternary geoscience and its application to offshore renewables.

Mike Clare (National Oceanography Centre and British Sedimentological Research Group) argued that an integrated approach is essential for delivering good science that contributes directly to optimal engineering design. Mike identified opportunities for combining established survey and investigation techniques, together with new tools for high-resolution seafloor mapping for example, to identify geohazards, mitigate them and optimise design. Characterising and understanding vertical and lateral variability in Quaternary sediments was seen to be a key contribution that Quaternary scientists can bring to a successful integrated approach.

Baseline geoscience data and information forms a core part of any integrated approach to characterising the ground in offshore environments. Dayton Dove (British Geological Survey) presented examples of existing, and up-and-coming, offshore datasets ranging from 1:250 000 to 1:10 000 scale that are essential for any offshore desk study and that are readily available from the BGS's Offshore GeoIndex. New 1:10 000 scale datasets are being produced for areas including offshore East Anglia and the Bristol Channel.

With investment from developers, offshore bathymetric surveys and geotechncial investigations can generate vast amounts of high quality, high-resolution data, and information. The ability to interpret that factual data using a robust scientific approach is key to unravelling the geological history of a site and its influence on geotechncial property and behaviour variation. Andy Emery (Gavin & Doherty Geosolutions and the University of Leeds), demonstrated how this works in practice using shallow seismic, vibrocores and cone penetration tests (CPT) at Dogger Bank in the Southern North Sea. Not only did this reveal the glacial and de-glaciation history of the site, it allowed potential geohazards to be identified and mitigated.

The direct benefit of combining scientific interpretation to geotechncial property and behaviour relationships was demonstrated by Kirstin Johnson (British Geological Survey). At Dogger Bank, apparently anomalous trends in the relationship between pre-consolidation stress and undrained shear strength had been identified from the results of ground investigations using seismic surveys, wireline borehole logging and CPT. A closer interpretation of the geotechncial data was made possible by relating the data to the stratigraphy and its palaeoenvironmental interpretation. Patterns of probable periglacial weathering, resulting in desiccation and consolidation, were interpreted to explain the apparent anomalous trends in pre-consolidation stress and undrained shear strength.

Following an online break for home-made refreshments, the more recent parts of marine Quaternary geomorphology were explored. Hendrick Jan Reizebos (Deltares) gave examples of how numerical modelling can be used to hindcast and forecast the dynamic evolution of the seafloor, including the migration of sand waves and development of scour over timescales up to 30 years. The direct application of this approach is to model the depth of burial of cables and identify areas of over- or under-burial, plan inter-array and export cable routes within a windfarm and its onshore connection and to estimate the required depth of dredging needed for cable burial.

The uniqueness of peat was the topic of two talks, the first of which from Leah Arlott (RWE Renewables), asked ‘What’s everyone’s problem peat’? After some online debate it was concluded that there were many people who, in fact, did like peat not least because it can contain a treasure trove of palaeoenvironmental and geoarchaeological information. Nevertheless, peat can cause problems in the ground. Leah emphasised the challenges including the ability to confidently interpret peat from seismic data, generating refusal during CPT and vibrocore investigations, its potential to cause settlement under load and its relatively high thermal resistivity. Integrated teams including geoscientists, geophysicists and geotechncial engineers are essential to identify and mitigate the presence of peat.

Stephen Eaton (University of Leeds and Jacobs) demonstrated a methodology for mapping and calculating the carbon stocks in the southern North Sea. The area covered by Holocene peat in the present-day southern North Sea was calculated to be more than 400km^2. Two methods were used to characterise peat-bearing sediments; one based on sedimentology and a second based on the laboratory measurement of carbon content from sediment samples. The first method resulted in an estimated 11.72 million tonnes of organic carbon, compared with 9 million tonnes using laboratory measured values with a minimum cut-off organic carbon content of 25%.

In closing the presentations, the role of peat and other post-glacial sediments in reconstructing past landscapes and human's interaction with it, was discussed by Claire Mellett (Wessex Archaeology). Planning policy remains one of the key drivers for any marine geoarchaeological investigation. But, along with often widely spaced intrusive investigations, responsive planning means that discoveries are often made by chance. What are the opportunities for ensuring that investigation could be more systematic? Integrated teams are needed to make sure that there is a unified geotechnical and geo-archaeological ground model that combines the results of all ground investigations.

The careers event was an open, panel-led discussion on careers in Quaternary science focused on its application to engineering. Although many participants had an academic background with post-graduate qualifications, this was not considered to be essential. Perhaps coincidentally, many of those with postgraduate qualifications had obtained them either part-time or after working in industry. Skills, including sedimentology, transferred from the offshore oil and gas industry were discussed as some participants had moved from that industry into civil engineering. Opportunities in the planning and execution of ground investigation were identified. Opportunities for helping to promote inclusivity, accessibility and diversity were discussed and it's hoped that using the Quaternary Engineering Research Group ArcGIS StoryMap can be used as a place to promote it.

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2022 QRA ANNUAL DISCUSSION MEETING QUATERNARY GLACIATIONS: PROCESSES, ENVIRONMENTS AND RECONSTRUCTIONS

The University of Sheffield 5th – 7th January 2022

The 2022 Quaternary Research Association Annual Discussion Meeting (ADM) was held from 5th to 7th January by the Department of Geography at the University of Sheffield. The ADM was hosted and organised by **Jeremy Ely, Ann Rowan, Chris Clark, Mark Bateman, Stephen Livingstone, Jenny Doole, Rosie Archer, Remy Veness, Christiaan Diemont** and **Charlotte Curry**. The 2022 ADM was planned to be a hybrid in-person and online event, but unfortunately had to be moved online for the second year running.

- The theme for this year's meeting was 'Quaternary Glaciations: Processes, environments and reconstructions', and was split into five themes of:
- The depositional and erosional imprint of ice on the landscape
- Reconstructing ice sheets
- Modelling ice masses and sea level change
- Glacial environments
- Using the Quaternary record to decipher glacial processes

There were a total of 24 talks and 24 posters, presented by participants from institutions across the UK, Europe, Canada and the USA. As a result, the online format provided an excellent opportunity for international networking and participation. Overall, the 2022 QRA ADM proved to be a great success, with over 200 registrations.

The first day started with a welcome to the conference, followed by the first session, 'the depositional and erosional imprint of ice on the landscape'. **Anna Hughes** (University of Manchester) gave a keynote address about new, high resolution datasets that showcase the glacial landform record, and how this can be used to provide insights to the last Eurasian ice sheet. **Benjamin Boyes** (University of Brighton) then presented a reconstruction of the deglaciation of the Fennoscandian ice sheet from the Last Glacial Maximum (LGM) at the Kola Peninsula, using glacial landforms and previously published geochronology. This was followed by **Michelle Gauthier** (Manitoba Geological Survey), who shared some insights into the erosion and depositional signatures of glacial terrain zones**.** Next, **Christiaan Diemont** (University of Sheffield) shared a new landform mapping approach that is being applied to the southern and eastern sectors of the last Fennoscandian ice sheet, to reconstruct ice marginal retreat dynamics. To conclude the session, **Chris Clark** (University of Sheffield) talked us through the BRITICE-CHRONO project's reconstruction of the last British-Irish ice sheet.

After a short coffee break, we started the first of two poster sessions. The participants of the session were split into two breakout groups each containing six poster presenters. The session started with each presenter giving a brief overview of their poster, followed by five minutes of questions per presenter. The poster sessions were commenced by **Connie Harpur** (Durham University) and **Sam Roberson** (British Geological Survey). Connie looked at reconstructing the LGM ice dynamics around the North Pennine Escarpment, and Sam presented a new Quaternary geological map of the United Kingdom. Next, **Christopher Darvill** (University of Manchester) discussed the stability of the Cordilleran ice sheet in western Canada over the last deglaciation, and **Frances Butcher** (University of Sheffield) presented a method for mapping of subglacial bedforms and ice flow directions for the Fennoscandian Ice Sheet. **Remy Veness** (University of Sheffield) then discussed using model-data comparison routines to learn about drumlin formation, which was followed by a new map of subglacial meltwater routes of the Scandinavian Ice Sheet, presented by **Nico Dewald** (University of Sheffield). **Clare Boston** (University of Portsmouth) then took us to Tanzania, showcasing late Quaternary patterns of ice advance and recession from Mt. Kilimanjaro. Following on, **April Howden** (Liverpool John Moores University) reviewed geochronological data at the south-eastern margin of the last Laurentide ice sheet, focusing on proglacial lakes. **María-Paz Lira** (Durham University) then presented a reconstruction of the last glacial cycle of the Skyring Ice Lobe in southern Patagonia, and **Gywneth Rivers** (Sheffield Hallam University) illustrated the results of high resolution crevasse-squeeze ridge study in the northwest territories, Canada. The penultimate poster investigated the infill of Quaternary tunnel valleys in the central North Sea, with **James Kirkham** (British Antarctic Survey/Scott Polar Research Institute) illustrating that the sequence reflects receding ice sheet sedimentation. To conclude**, Cristina-Ioana Balaban** (Durham University) mapped and interpreted the glacial landforms of Scărișoara Plateau, in the Southern Carpathians, Romania.

The day was brought to a close with the Wiley Lecture, given by **James Scourse** (University of Exeter). James spoke about the advancement of BRITICE-CHRONO, and discussed ideas for future work following on from the project. Problems remain relating to the western margin of the ice sheet, as well as accurately capturing marine processes in ice sheet models. His work offers new hypotheses for numerical simulations and field tests, whilst highlighting the additional applications of the BRITICE-CHRONO project.

Day two commenced with a session on 'reconstructing ice sheets'. **Chris Stokes** (Durham University) started the session with a reconstruction of the evolution of the Laurentide and Innuitian ice sheets from 115 ka to 10 ka. Next, **Matthew**

Carney (Manchester Metropolitan University) illustrated the retreat dynamics of the last Irish Ice Sheet using proglacial lake sediments. **Benjamin Stoker** (Charles University) then outlined the deglaciation of the Mackenzie Mountains following the LGM. Subsequently, **Tancrede Leger** (University of Edinburgh) presented a multi-glacial cycle cosmogenic nuclide chronology of Patagonian Ice Sheet expansions in the north-eastern sector, with 60 new geochronological dates. To conclude the session, **Adrian Palmer** (Royal Holloway University of London) showcased varve and radiocarbon-based age estimates for the deglaciation of the British and Irish Ice Sheet in South Wales.

The second poster session started following a short coffee break. First, **Jane Leathard** (University of Sheffield) presented a novel approach that may be used to determine pre-depositional environments, using natural luminescence signals in feldspar grains. **Julian Murton** (University of Sussex) then reported the results of reconnaissance observations of the stratigraphy, sedimentology and geochronology of permafrost deposits at the stratotype section of the Ulakham Sular Formation in eastern Siberia. Next, **Brian Whalley** (University of Sheffield) displayed an information mapping approach to mountain systems, and **Luke Parker** (Archaeological Research Services) utilised a landform element approach to showcase post-glacial human occupations of the Killerby landscape. **Rosie Archer** (University of Sheffield) then presented two updated model-data comparison tools for lineation and geochronological evidence comparisons for the last Eurasian Ice Sheet, and **Violet Patterson** (University of Leeds) used a coupled climate-ice model to model the Penultimate Glacial Maximum, and compared this to the LGM. **Yucheng Lin** (Durham University) then quantified the impact on sediment loading on relative sea-level change across the Great Barrier Reef during the last deglaciation, and **Amy McGuire** (University of Leeds) provided the first chronological constraints on the timing and rates of relative sea level change in the southern North Sea, using offshore sedimentary cores. After that, **Alvaro Castilla-Beltrána** (Universidad de La Laguna) looked to characterise local vegetation and erosion regimes since the LGM in the Canary Islands, and **Sharman Jones** (University of Aberystwyth) presented high resolution mapping of the Greenland Ice Sheet. Finally, **Sarah Walton** (Sheffield Hallam University) presented mapping of southeast Iceland since the Little Ice Age, and **Olivia Verplanck** (Keele University) looked at finding context to Herefordshire's Ice Age Ponds using geomorphology and near surface geophysics.

After lunch the third oral session began, entitled 'modelling ice masses and sea level change'. It kicked off with a keynote address by **Lauren Gregoire** (University of Leeds) who explained the importance of palaeo-ice sheet modelling and their different applications. Then, **Oliver Pollard** (University of Leeds) presented a history matching approach combined with the ICESHEET model to reduce the plausible input parameter space on the Penultimate Eurasian Ice Sheet. **Niall Gandy** (Sheffield Hallam University) explored which parameters contribute the highest uncertainty when modelling the LGM in North America. A keynote talk by **Louise Best** (University of Gloucestershire) showed relative sea level during the LGM using geochronological and isolation basin data for the Isle of Skye. **Graham Rush** (University of Leeds) brought the session to a close with an initial analysis of sediment cores used to constrain sea-level change during the Last Interglacial.

The Annual General Meeting was held in the afternoon of day two. Three Honorary Life Memberships of the QRA were awarded to **David Horne** (Queen Mary University of London), **Kevin Edwards** (University of Aberdeen), and **Pete Coxon** (Trinity College Dublin). The Undergraduate Dissertation Prize was awarded to **Sylvie Hodgson Smith** (University of Cambridge) for her dissertation titled ‘Reconstructing the global climate effects of the volcanic eruption of Mt. Samalas, 1257 AD’, as well as three highly commended dissertations by **Tom Garrod** (University of Sheffield), **Catherine Dorey** (University of Nottingham) and **Jack Crouch** (Royal Holloway, University of London). The award for outstanding paper in JQS by an ECR 2021 went to **Francesca Pasquetti** (Università di Pisa) for the paper ‘Chronology of the Mediterranean sea□level highstand during the Last Interglacial: a critical review of the U/Th□dated deposits.’ Special commendations went to **Marina Morlock** (University of Bern), **Alejandro Cisneros de Leon** (Universität Heidelberg), and **Rachel Bynoe** (University of Southampton). **Tim Lawson** and **Tim Atkinson** (University College London) won the Quaternary Research Award 2021 for their project ‘Speleothem dating and the onset of ice-sheet glaciation in NW Scotland’. The Lewis Penny Medal 2022 was awarded to **Ben Chandler** (Durham University) and the Croll Medal 2022 was awarded to **Paula Reimer** (Queen’s University Belfast).

The final day began with a session on ‘glacial environments’. **Aleksandra Osika** (University of Silesia) first presented Holocene glacier fluctuations in Hornsund, Svalbard, which was followed by **Benedict Reinardy** (Stockholm University) who outlined sedimentation processes along the Antarctic continental rise. Next, **Anna March** (Queen Mary University of London) presented evidence for a possible abrupt climate change signal from lacustrine faunal and geochemical data from Mark Tey, Essex. The session was then concluded with an environmental reconstruction of the early Weichselian southern North Sea by **Irene Waajen** (Utrecht University).

After the break, the final session ‘using the Quaternary record to decipher glacial processes’ began with **Jane Hart** (University of Southampton) quantifying subglacial soft bed sedimentary processes. Next, **Martin Kirkbride** (University of Dundee) outlined positive mass balance responses and the formation of moraine complexes at debris-covered glaciers, which was followed by **Maximilian Van Wky de Vries** (University of Minnesota) who presented evidence of accelerated 21st century melt of the Patagonian Icefields from proglacial river discharge. The session and this year's meeting was concluded by **Geoffrey Boulton** (University of Edinburgh), who presented on the evolution of mega-scale glacial lineations beneath an Antarctic ice stream.

The organising committee would like to thank the QRA for the opportunity to host the ADM at The University of Sheffield, and for all of the presenters and spectators for their discussion and contributions throughout. Although the ongoing COVID-19 health guidance has hindered us gathering together again, we look forward to the day that we are safely able to do so again.

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QRA ENGINEERING GROUP FIELD MEETING, WEST CUMBRIA

17th – 20th March 2022

The West Cumbrian coastal region lies between the Irish Sea and the foothills of the Cumbrian Mountains and is home to complex and variable Quaternary geomorphology and sediments. This field meeting was the first QRA trip to the area since 1994 and the first field meeting for the QRA's Engineering Group. A considerable amount of work has been undertaken in the area in the intervening years and more work is currently ongoing associated with the Sellafield and LLW Repository nuclear sites, and the Network Rail Cumbria Coast route. The trip was an excellent opportunity to foster collaborations and bring together a wealth of knowledge from people with wide-ranging academic and industry backgrounds.

The trip leaders were **Jon Merritt** and **Emrys Phillips** (British Geological Survey), **Paul Fish** and **Chris Coleman** (Jacobs), **Nick Smith** (National Nuclear Laboratory), with contributions from **Sinead Birks** (Imperial College), **Dave Evans** (Durham University) and **Keith Nicholls** (Network Rail).

Thursday 17th March

After some long journeys to reach West Cumbria, we gathered on Thursday evening at Santon Bridge Village Hall. **Jon Merritt** set the scene for the next three days with his informative talk 'Characterisation of Quaternary deposits in West Cumbria'. West Cumbria was affected by three main ice sources, the Irish Sea Ice Stream (ISIS), Scottish ice, and local Lake District ice from Cumbrian mountains centred on Ennerdale, Eskdale and Wasdale. Understanding ice dynamics and behaviour of these glaciers is an ongoing challenge. We were taken through the findings of work from the Nirex investigations during the 1990s, and subsequent published and unpublished work. The group were fortunate to see photographs of cliff sections and river exposures that are no longer visible but still important to consider when interpreting the past environment of West Cumbria. Following the talk, we got to know each other over refreshments before heading out in the field the next day.

Friday 18th March

Jon Merritt led the first full day starting with a walk along the cliff top at St Bees to find the famous kettle hole infill sequence, with a return along the beach to inspect the coastal sections in the moraine. From the cliff top we inspected the St Bees – Whitehaven meltwater channel that is now blocked by the St Bees moraine and the coastline south towards Drigg. Further along the cliffs we investigated exposed kettle hole infills comprising a primary stratified sand and clay overlain by a diamicton and peat, but it appears the basin with both Lateglacial and Holocene peats has been lost to cliff instability and erosion.

On our return walk along St Bees beach the group inspected the St Bees Sand and Gravel member (figure 1), a chaotic boulder rich outwash that is exposed at the southern part of the moraine. The size and abundance of clasts indicates a high energy rapid depositional event such as a jökulhlaup; this event occurred during the Scottish Readvance (~19,000 ka BP). Overriding the outwash is a laminated diamicton within which previous work found a shell fragment dated at ~39 ka BP, predating the Last Glacial Maximum (LGM). Some argued the unit was a subglacial till including material incorporated from the Irish Sea, while others preferring a lacustrine origin with subsequent pro-glacial deformation by Irish Sea ice. The group then studied the spectacular recumbent fold and stacked thrust-block sequence exposed in the cliff that was formed by Irish sea ice moving obliquely to the coast. Interpretation of the deformation structures was aided by **Emrys Phillips'** excellent annotated drone imagery. Further along the moraine, fine grained sands with ripple structures highlighted by coal fragments were inspected, highlighting the significant variation in deformation structures present. **Paul Fish** discussed problems in the interpretation of borehole data recovered through sequences such as the St Bees moraine if a suitable ground model had not first been considered and **Chris Coleman** discussed the importance of correct interpretations for development of hydrogeological modelling.

Figure 1. St Bees Sand and Gravel Member on St Bees beach (*Photo credit: James Lawrence*).

Our final stop at St Bees was to see the Lowca till close to St Bees Head. This is an over-consolidated subglacial till deposited by the ISIS. **Dave Evans** described how the subangular to subrounded clasts are typical of a subglacial till and discussed the transition from bedrock glacitectonite, comprising angular blocks of St Bees sandstone plucked from the bedrock, to till. Engineering geologists present discussed problems in consistent interpretation of 'engineering rockhead' in sequences comprising weathered bedrock, glacitectonite and bedrock-rich till.

Mid-afternoon we travelled south of St Bees to Nethertown beach. Here we saw large sandstone boulders in the cliffs within a sandy matrix, which is believed to be from a further jökulhlaup event. Overlying the jökulhlaup deposit is a thin layer of till from an ice margin advance. Close to the car park a 'raised beach' deposit was observed. These features are common on the West Cumbrian coast but do not necessarily indicate higher sea-levels since they are within the current range of tides and storm surges.

We returned to Santon Bridge Village Hall on Friday evening to hear a series of excellent talks by **Dave Evans**, **Keith Nicholls**, and **Sinead Birks**. The talks covered the myths and reality of tills, engineering glacial sediments to protect railway lines, and recent research on the glacial geomorphology and geology in West Cumbria. The themes of these talks were reiterated during the rest of the field meeting.

Saturday 19th March

In the morning we gathered adjacent to Muncaster Castle near Ravenglass and set off on a scenic walk towards Ravenglass estuary. Descending Muncaster Fell we walked through a deep bedrock cut meltwater channel which was part of a larger meltwater spillway network, the meltwater would have flowed parallel to ISIS at the coast. Some suggested it was a subglacial channel under cold-based ice from Eskdale. Further along the walk debris flow deposits formed after ice had retreated were inspected. The deposit was dominated by local granite bedrock suggesting a locally-sourced mass movement rather than the action of glacier ice. Close to the Ravenglass estuary **Jon Merritt** showed us a moraine ridge which is associated with ISIS when at times it flowed in land from the Irish Sea. At the Ravenglass estuary **Keith Nicholls** discussed recent coastal protection works for the railway line and **Paul Fish** described the Lateglacial to Holocene sea-level history of the area revealed by work in the Ravenglass area. He described how knowledge of past sea-level was used to inform understanding of future millennial-scale change at the coast, which is needed to support environmental safety cases for the nuclear sites.

After lunch on the sand dunes at Drigg we continued along the beach to inspect the Barn Scar cliff sections. **Chris Coleman** explained current research on the Drigg beach cliffs and the Quaternary sequence beneath the Low Level Waste Repository

(LLWR). The cliff sections suggest a shallow proglacial lake dammed by ISIS was present at the current LLWR site. Data from the LLWR suggests the lake drained and refilled at least three times. This work has allowed the development of a 3D geological and hydrogeological model for the site, which is a critical component of the environmental safety case. Alternative interpretations of the sediments was offered by **Nick Smith** and **Jon Merritt** who suggested a fining-up sequence with multiple tills and outwash gravels. **Dave Evans** prompted further debate by questioning the description of the clast-poor units as diamictons given the rarity of gravel. **Chris Coleman** discussed a solution using geotechnical testing and interpretation of stress history as a diagnostic tool for subglacial deposition. The group agreed that geotechnical testing can provide useful data and encouraged greater collaboration in this area.

Figure 2. Looking at core from the LLWR at Santon Bridge Village Hall (*Photo credit: Sinead Birks*).

The final part of the afternoon was spent discussing and examining core extracted from the LLWR at Santon Bridge Village Hall (figure 2). A range of Quaternary sediments were on display, including till, outwash, and laminated lacustrine deposits. **Chris Coleman** and colleagues presented their work on these cores, including logs, 3D geological models and results of microfossil studies that suggest basal lacustrine deposits are of middle Devensian age. **John Shevelan** from the LLWR described the importance of this work to the site's ongoing environmental safety case.

Sunday 20th March

The trip concluded at Seascale where **Sinead Birks** explained the findings of her current work on the cliff sections. Following her evening presentation she discussed how the depositional environment changes from outwash plain to proglacial lake. The palaeo-channels (Figure 3) contain very coarse material suggesting they were proximal to the ice margin. Within the channels rip clasts were seen which are indictive of an erosive current.

Figure 3. Members of the group viewing cliff sections at Seascale (*Photo credit: James Lawrence*).

Figure 4. Group photograph at Seascale (*Photo credit: Simon Price*).

At the final section members returned to the debate on whether the deposits exposed were subglacial till or lacustrine. While the deposit was clast poor, shearing structures were visible suggesting a subglacial origin. **Dave Roberts** and **Emrys Phillips** discussed how the 'shears' could be interpreted as hydro-fractures originating from dewatering due to sediment consolidation. Sinead's research is ongoing at these sections.

The meeting concluded with thanks from Paul Fish to trip leaders, attendees and industry supporters, and a call from QRA Vice President Dave Roberts for greater collaboration between Quaternary geoscientists in research and industry.

Acknowledgements

Thanks are due to the QRA, the Engineering Group and to the organisers for hosting an excellent and very informative trip.

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QUATERNARY RESEARCH ASSOCIATION

The Quaternary Research Association is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. The majority of members reside in Great Britain, but membership also extends to most European countries, North America, Africa, Asia and Australasia. Membership (currently *c.* 1,200) is open to all interested in the objectives of the Association. The annual subscription is £20 with reduced rates (£10) for students and unwaged members and an Institutional rate of £35.

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

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

President: ***Professor Simon Lewis***, School of Geography, Queen Mary University of London, London E1 4NS (email: president@qra.org.uk)

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

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