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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

**S'Illot island, Alcudia, Mallorca, looking north (see Boreham and Boreham article inside this issue) (photo credit Steve Boreham).**

# SPOTLIGHT ON A SITE

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## QRA50: TOP 50(80) QUATERNARY SITES – SPOTLIGHT ON A SITE:

I hope all members are looking forward to a productive summer during this INQUA Congress year. As we start to look west toward Ireland for the conference, and with a Quaternary Research Fund report in this issue of *QN* on Caldey off the coast of Pembrokeshire, this time we will have a look at Abermawr within the QRA TOP 50(80) sites collection.



**Figure 1.** The northern exposure in Abermawr Bay (photo credit: Brian John).

Here is a summary of the entry from Silva and Phillip (2015, p4):

- The exposures at both ends of Abermawr bay provide the most comprehensive Quaternary deposits in West Wales.
- Ipswichian raised beach material is found on a remnant of a rock platform.
- Deposits above this contain angular bedrock fragments and far-travelled erratics and represents a periglacial sequence.
- Above this a clay-rich Irish Sea till unit is found containing striated clasts and carbonised wood and sea shell fragments, showing that the glacier ice dredged the sea-floor deposits. There are also flow-tills.
- The till is capped by glaciofluvial materials, and this unit contains fossil ice-wedges and involutions.

### References (and key sources for the site)

Rijsdijk, K., McCarroll, D. (2001). Abermawr, in *The Quaternary of West Wales Field Guide*, QRA, 32-38.

John, B.S. (1970). Pembrokeshire, in Lewis, C.A. (Ed) *The Glaciations of Wales and Adjoining Regions*, 229-265.

# ARTICLES

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## LATE PLEISTOCENE COASTAL GEOLOGY OF THE S'ILLOT REGION, ALCUDIA, MALLORCA: A CLASSIC LOCATION FOR QUATERNARY FIELDWORK TEACHING

Steve Boreham and Julie Boreham

### Abstract

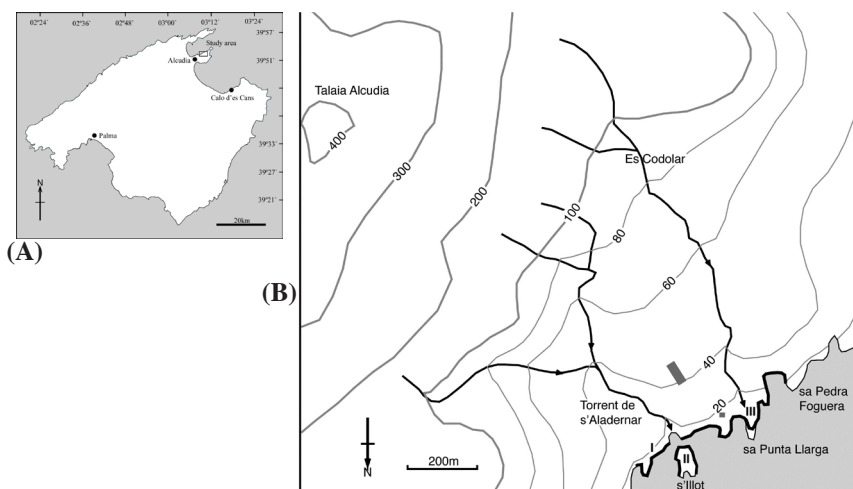
This paper describes the lithology and stratigraphy of Pleistocene deposits exposed in coastal cliff sections near the small island of s'Illot, located on the Alcudia peninsula on the southern side of Pollença Bay in northern Mallorca. The palaeosols and aeolianites from the sequence are described. These deposits potentially span some 100k years in the Late Pleistocene and record changing palaeoenvironments, distinct lithologies and well-defined stratigraphic relationships that make this location ideal for teaching Quaternary studies. Overall, this sequence records a last interglacial raised beach environment, covered by fluvial fan sediments, interbedded with palaeosols and aeolianites, recording alterations in moisture availability through MIS5, MIS4 and MIS3, with possible fluvial incision during MIS2 or the Holocene.

### Introduction

SB has run field excursions to examine the Pleistocene deposits exposed in cliff sections at s'Illot, Alcudia for more than a decade (Figure 1). These geological sections contain an interesting variety of deposits (aeolianites, fluvial gravels and red/yellow palaeosols), which can be attributed to different palaeoenvironments throughout the Late Pleistocene including the Last Interglacial (MIS5e) and MIS5d-a, 4 and 3 of the Last Glacial Period. The exposures are easily accessible, relatively safe and in many respects present an ideal teaching resource.

The classic work of Butzer and Cuerda (1962) provides reconstructions of Pleistocene palaeoenvironments that include a number of climatic cycles. Each cycle comprised a warm transgressive marine phase that laid down raised beach deposits, followed by a cooler continental phase where colluvial palaeosols and sand dunes deposits (aeolianites) were deposited. Rose *et al.* (1978) built on the earlier works of Cuerda, refining the model of Mallorcan Quaternary chronostratigraphy, and Ginés *et al.* (2012) produced a recent synthesis of Mallorcan Quaternary studies.

In 2009 Fornós *et al.* described some of the cliff sections on the Alcudia peninsula and provided OSL dates for key aeolianite sequences. However, the generalized coastal sections provided by Fornós *et al.* (2009) do not match well with more detailed descriptions of deposits around s'Illot. This is largely due to the limited resolution possible when reporting on a long stretch of cliff section, and problems



**Figure 1.** (A) Map of Mallorca showing the location of the Study Area on the Alcudia peninsula. The location of Calo d'es Cans (Rose *et al.*, 1999) is also shown. (B) Map of the study area showing elevation, drainage and the location of the Pleistocene cliff sections (I, II, III) described in the text. Note the orientation of this map with North at the bottom to aid reader to relate sections to the view of the cliffs.

caused when three-dimensional sediment architecture is projected onto a two-dimensional plane.

This paper describes the stratigraphy and three-dimensional architecture of Pleistocene deposits exposed in cliff sections between s'Illot and the sa Pedra Foguera peninsula (Figure 1), and incorporates the OSL (optically stimulated luminescence) dating of Fornós *et al.* (2009) to create a palaeoenvironmental history for the area.

## Methods

Geological sections were described by the authors along a c.750m section of coast over multiple visits to the s'Illot cliffs between 2005 and 2018 (Figures 1 and 2). Individual sites were located with handheld GPS, and cliff heights measured using tape measures and a telescopic ranging staff. Samples of aeolianite and palaeosol were taken for laser particle size analysis and elemental analysis by ICP-OES in the Geography Science Laboratories, University of Cambridge. A thin section of the aeolianite was manufactured by JAB (Earthslides).

## Geological setting

The Alcudia peninsula southeast of s'Illot is underlain by Jurassic and Cretaceous limestones, which rise from the coast to form the peak of Talaia Alcudia (c. 446 m a.s.l.) (Figure 1). The northwest facing slopes are drained by seasonal streams or 'torrents', which rise from springs at c. 150 masl. The low coastal cliffs are largely comprised of Pleistocene deposits including medium-coarse partly bioclastic sands, interpreted as aeolianites, and matrix-supported gravels, interpreted as fluvial fan gravels. The aeolianites often form inclined dunes, sometimes interbedded with talus, palaeosols and fluvial gravels, ramped against fossil cliff-lines cut into the bedrock by high Pleistocene sea levels (Butzer and Cuerda 1962). Fluvial gravels often form fans where torrents exit confined valleys and empty on to the coastal plain (cf. Rose *et al.*, 1999). Fornós *et al.* (2009) identified two such gravel fans, the s'Illot Fan Formation and the sa Punta Llarga Fan Formation in this study area. In stratigraphic order the main Pleistocene sedimentary units identified in this study are:

- 4) Upper Gravel – matrix-supported sand and gravel occupying a channel-form
- 3) Middle Gravel – matrix-supported sand and gravel occupying channel-forms
- 2) Aeolianite – carbonate cemented medium-coarse partly bioclastic sands, sometimes incorporating palaeosols and gravel beds.
- 1) Lower Gravel – horizontally bedded matrix-supported gravels with palaeosols and an often clast-supported basal cobble bed.

## Description of geological sections

The coastal cliffs exposing Pleistocene deposits have been divided into three separate sections;

- I – to the northeast of the Torrent de s'Aladernar (Figure 2A,B, 3(I))
- II – s'Illot (Figure 2C, 3(II))
- III – to the southwest through sa Punta Llarga towards sa Pedra Foguera (Figure 2D, 3(III))

Section I (Figure 2A,B, 3(I)) starts to the northeast in a rocky cove where the Pleistocene deposits are ramped up against a buried cliff line cut in to Jurassic limestone. Logs A-C show steeply inclined angular clast-supported talus from the cliff grading into the Lower Gravel, which is overlain by aeolianite. Within the Lower Gravel are two prominent red palaeosol beds comprising pea grit (a term for ~10mm clasts) and coarser gravel in a matrix of red silt. The very basal part of the palaeosol at logs B and C also contains often clast-supported cobbles within a sand matrix.

The aeolianite has inclined beds of angular talus both within it and above it. The basal part of the section between logs C-H is partly obscured by fallen blocks. It appears that the Lower Gravel here is mostly horizontally bedded, although this could be a function of the alignment of the section and the apparent dip of the



(A)



(B)



(C)



(D)

**Figure 2.** (A) Photograph of Section I Log B (c.7m high) showing aeolianite with interbedded talus and red palaeosols, (B) Photograph of Section I Log G showing the yellow palaeosol (c.20cm thick) within the lower gravel unit, (C) Photograph of S'Illot island looking north (Section II Logs L-Q) showing aeolianite capped by middle gravel, (D) Photograph of Section III Log T (c.5m high) showing aeolianite overlying the lower gravel and red palaeosols.

beds. Angular talus beneath aeolianite was encountered in logs D-F, and this can also be seen at log E in a section normal to the fossil cliff, where a bed of talus within the aeolianite is evident. At log H it appears that the red upper palaeosol has bifurcated, and above this are at least two thin yellow palaeosols. The aeolianite is progressively cut out by the Middle Gravel of the s'Illot Fan Formation, which fills a channel-form at Log J, where it is partly obscured and possibly slumped. At log K a second channel-form filled by Upper Gravel (gravel, sand and silt) cuts out the Middle Gravel, and the entire sequence is cut through by the incised channel of the Torrent de s'Aladernar. The red upper palaeosols at log J progressively thin to the southwest and are absent at log K. The very basal part of the palaeosol at log J also contains mostly clast-supported cobbles within a sand matrix.

Section II (Figure 2C, 3(II)) shows the Pleistocene stratigraphy of s'Illot as viewed from the northern seaward side of the island (logs L-Q). The basal

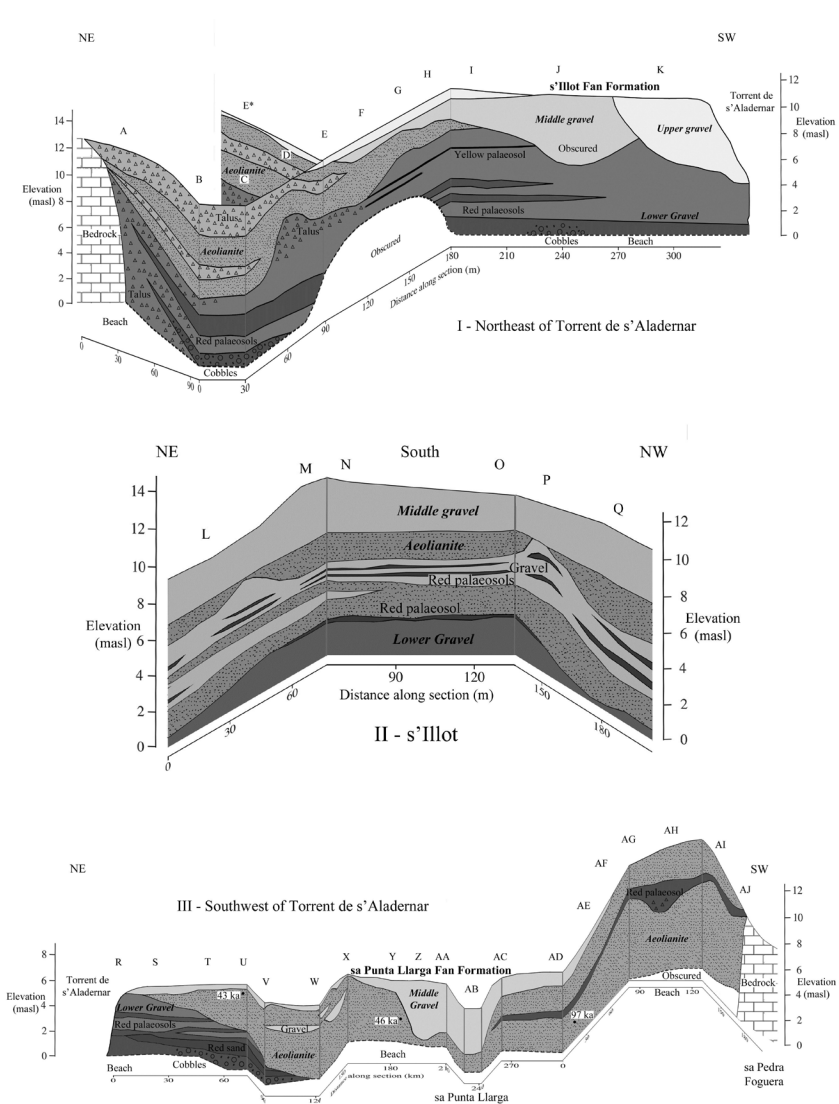
horizontally bedded matrix-supported Lower Gravel contains a red palaeosol towards the top. The overlying aeolianite contains intercalated horizontally bedded clast-supported gravel and two thin red palaeosols comprising pea grit in a matrix of red silt. The aeolianite is overlain by the horizontally bedded clast-supported Middle Gravel, which caps s'Illot island.

Section III (see Figure 2D, 3(III)) starts at the incised channel of the Torrent des'Aladernar. Horizontally bedded clast-supported Lower Gravels containing a lower red sand unit and red palaeosols comprising pea grit in a matrix of red silt are present at logs R-V. The very basal part of the palaeosol at logs T-V also contains cobbles within a sand matrix. The palaeosols are progressively cut-out by the overlying aeolianite, which at log U has been OSL dated to  $43 \pm 5$  ka BP and interpreted as of MIS 3-to-MIS4 age (Fornós *et al.*, 2009). Several shallow channels filled with matrix-supported gravel are present within the aeolianite (logs V-X). At log Y the aeolianite has been OSL dated to  $46 \pm 5$  ka BP and again interpreted as Middle Weichselian (MIS 3/4) (Fornós *et al.*, 2009). Between logs Y and AD the aeolianite is incised by a large channel-form filled by matrix-supported Middle Gravel of the sa Punta Llarga Fan Formation, which forms the promontory of sa Punta Llarga. The Middle Gravel here also contains some pockets of red sand and a little angular clast-supported talus. To the southwest, aeolianite is exposed in a rocky cove and is ramped-up against a buried cliff line cut in to Jurassic limestone (logs AD-AJ). A red palaeosol comprising pea grit in a matrix of red silt is present within the aeolianite. At log AH the palaeosol is represented by a small channel containing red-stained angular clast-supported talus. At log AD the aeolianite beneath the palaeosol has been OSL dated to  $97 \pm 2$  ka BP and interpreted as of MIS 5b age (Fornós *et al.*, 2009).

### **Palaeosol investigations**

Red palaeosols (terra rossa soils), sometimes called red rendzinas or chromic luvisols, are usually formed through the weathering of limestone bedrock in Mediterranean climates with cool wet winters and hot dry summers, and are rich in ferric iron oxide (haematite). Yellow (cinnamon) palaeosols (ferric luvisols), are formed through weathering of limestone in more arid conditions, and are rich in hydrated ferric iron hydroxide (limonite) and calcium carbonate (Boero and Schwertmann, 1989). Both are 'zonal soils' (Allen, 2001) whose distribution reflects climate rather than topographic position or other local factors.

Samples of the red and yellow palaeosols at log H (section I Figure 2B, 3(I)) were investigated using laser particle size analysis. Both beds showed a fine-skewed distribution with a modest amount (<10%) of fine-medium (250-500µm) sand. The yellow palaeosol samples showed a clear peak in the 4-8µm (fine-medium silt) fraction, whilst the red palaeosol samples were finer grade with a peak in the



**Figure 3.** Geological section (I) of the cliffs northeast of Torrent de s'Aladernar s'Illot, Alcudia peninsula, Mallorca and (II) of s'Illot, Alcudia peninsula, Mallorca and (III) of the cliffs southwest of Torrent de s'Aladernar, s'Illot, Alcudia peninsula, Mallorca.

range 2-4 $\mu$ m (very fine silt) (Figure 4). Neither bed had appreciable amounts of sub-micron clay.

Samples from the red and yellow palaeosols were subjected to elemental analysis by ICP-OES. The two palaeosols were comparable across a wide range of elements, but the red palaeosol showed elevated iron (c.3%), aluminium (c.2%), magnesium (c.1%) and potassium (c.1%), whilst the yellow palaeosol contained elevated calcium (>20%) levels. This is entirely compatible with their interpretation as red chromic and yellow ferric luvisols.

### **Aeolianite investigations**

A thin section of an aeolianite sample taken from log H was manufactured by JAB (Earthslides). Figure 5 shows a photomicrograph of the thin section in plain light. A large proportion of the sand-sized clasts are composed of reworked Mesozoic limestone, with some biogenic material and a few quartz grains (Calvet *et al.*, 1980). Laser particle size analysis of the aeolianite suggests that most of the clasts are 300-800 $\mu$ m (medium sand), with a tail of silt in the 10-100 $\mu$ m range (Figure 4). This is confirmed by the micromorphology, which shows 2-5 mm thick laminations of medium-coarse sand interbedded with lightly cemented bands of finer sand and a little silt. These have been interpreted as a type of pin-stripe lamination formed by migrating wind ripples (Fryberger and Schenk, 1988) that are often overprinted by coarser-scale rhythmic banding (2-5 cm). Fornós *et al.* (2012) suggested that the degree of cementation is related to seasonal changes in Mediterranean humid and dry periods. The aeolianites also show cross-bedding formed by large climbing dunes (Clemmensen *et al.*, 1997, Clemmensen *et al.*, 2001). The aeolianite at log H appears to represent sand ramp or cliff front dunes (Fornós *et al.*, 2012).

### **Timing of formation**

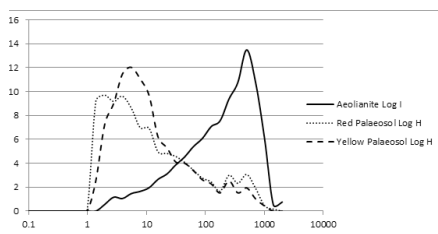
The Lower Gravel unit represents the oldest deposits encountered in this study. It occurs stratigraphically below the oldest aeolianite (see Section III) dated to  $97\pm12$  ka (see Table 1). The basal cobbles within the Lower Gravel seen in Sections I and III appear to represent raised beach deposits c.1.5m asl and most likely relate to the marine transgression in the latter part of MIS 5e (122-117 ka); the Y2 marine cycle [Eutyrrhenian] of Butzer (1975). Raised beach deposits from the earlier part of the last interglacial MIS 5e (128-138 ka), the Y1 marine cycle of Butzer (1975), generally occur at a greater elevation (>9 m.a.s.l.) and are not seen in this study (Vicens *et al.*, 2012, Fornós *et al.*, 2012). For the most part the Lower Gravels appear to be fluvial in origin, but incorporate talus from the buried cliff line and several palaeosols representing an increasingly continental phase within MIS 5d/c (117-100 ka).

There is clearly an erosional phase that occurred after the deposition of the Lower Gravels, but before the deposition of the First Aeolianite at  $97\pm12$  ka MIS 5b/c).

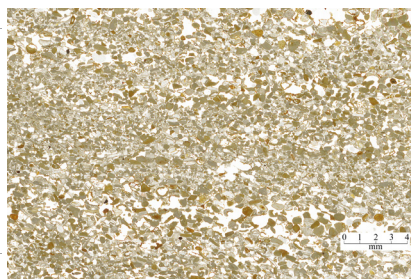
**Table 1.** Chronostratigraphy proposed for the s'Illot Pleistocene deposits

Approx Age (ka)	Marine Isotope Stage	British Terrestrial Climatostratigraphic Stages	European Terrestrial Climatostratigraphic Stages	Section I	Section II	Section III	Environment
11.7	1	Flandrian	Holocene	Upper Gravel	Middle Gravel	Middle Gravel	<incision> River deposits <incision>
	2	Late Devensian	Late Weichselian				
26	3	Middle Devensian	Middle Weichselian	Middle Gravel	Aeolianite	Aeolianite	River deposits <incision> Dunes
43-46	4	Early Devensian	Early Weichselian	Talus	Palaeosols	Palaeosols	Land surface
50	5a			Aeolianite	Aeolianite	Aeolianite	Dune
72	5b			Talus	Lower Gravel	Lower Gravel	<incision> River deposits
97	5c			Lower Gravel	Lower Gravel	Lower Gravel	River deposits
110	5d	Ipswichian	Eemian	Talus	Palaeosols	Palaeosols	Land surface
117	5e			Cobbles	Cobbles	Cobbles	Raised beach

This is most likely due to fluvial incision driven by lowered sea levels. Raised beach deposits from the MIS 5a marine transgression (~ 80 ka) (the Y3 marine cycle [Neotyrrenian] proposed by Butzer 1975) are not seen in the sections. MIS 5a may be represented by the palaeosol within the aeolianite (sections II and III). MIS 4 is represented by renewed aeolianite formation terminating soon after the start of MIS 3 (43-46 ka). The Middle Gravel is everywhere incised into the aeolianite and must be younger than ~40 ka. The Upper Gravel incised into the Middle Gravel must be younger still and may also date from MIS 3 or MIS2 as is the case at Calo d'es Cans further east along the coast (Rose *et al.*, 1999). It seems plausible that the incised channel-form occupied by the Torrent de s'Aladernar and Holocene fluvial deposits may have been cut in MIS2, or the Holocene, when vegetation cover inhibited the sediment supply to the local streams.



**Figure 4.** Laser Particle Size Distribution Plots for the Aeolianite, Red Palaeosol and Yellow Palaeosol.



**Figure 5.** Photomicrograph of a thin section of aeolianite in plain light from log H from Geological Section I.

## Conclusions

Taken together, the sequence from s'Illot represents a fragmented record potentially spanning some 100k years in the Late Pleistocene. The changing palaeoenvironments recorded in the deposits (raised beach, talus, fluvial fan, sand dunes and land surface) are striking, and the distinct lithologies and well-defined stratigraphic relationships make this location ideal for teaching and student projects. Investigations into the nature of the palaeosols and aeolianite conformed with previously published descriptions and interpretations. The s'Illot Fan Formation is clearly the product of Pleistocene fluvial activity from the Torrent de s'Aladernar, but the sa Punta Llarga Fan Formation originates from an un-named torrent that exits onto the coastal plain through a narrow gorge just to the west of the s'Illot cafe. Presumably several of these seasonal streams and the nearby Torrent de ses Fontanelles once joined to form a fluvial system in Pollença Bay at times of low sea level.

## Acknowledgements

The authors would like to thank Tim Bayliss-Smith and Jim Rose for valuable discussions.

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# LEWIS PENNY AWARD

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## LEWIS PENNY MEDAL ACCEPTANCE: STYLES OF FORMER GLACIATION IN BRITAIN

Claire Boston

### Introduction

I am deeply honoured to have been awarded the Lewis Penny Medal from the QRA. The QRA has formed an integral part of my academic career through the field meetings, ADMs, and wide range of colleagues that I have met along the way. I also thoroughly enjoyed serving on the Executive Committee for three years as Meetings Officer. To be awarded the Lewis Penny Medal is the highlight of my career so far, and I must acknowledge the collaborators and friends who have inspired, contributed to, and made possible my research, which I briefly describe below. My interest in Quaternary glaciation was sparked during my BSc in Geography undertaken at Durham University. I continued at Durham to complete an MSc (by research) on the tills of east Yorkshire, which, rather appropriately, is an area well known to Lewis Penny. This research laid the foundations for PhD study and a subsequent academic career in which I have been fortunate to work (and teach) in a number of areas in Britain and further afield.

### Ice sheet dynamics in eastern England

The North Sea lobe of the Late Devensian British-Irish Ice Sheet has been the subject of extensive research over the last 15 years (e.g. Boston *et al.*, 2010; Evans and Thomson, 2010; Davies *et al.*, 2012; Roberts *et al.*, 2013, 2018; Bateman *et al.*, 2015, 2018; Busfield *et al.*, 2015; Cotterill *et al.*, 2017; Dove *et al.*, 2017; Evans *et al.*, 2017, 2018). Understanding ice flow pathways, ice sheet dynamics and the chronology of glacial events has been of particular interest. At the time of my MSc in 2006, the complexity of glacial sediments, traditionally divided into the Basement, Skipsea and Withernsea tills in east Yorkshire, was well known, but models for their deposition were wide ranging (e.g. Catt and Penny, 1966; Boulton *et al.*, 1977; Madgett and Catt, 1978; Eyles *et al.*, 1994; Evans *et al.*, 1995). The research was supervised by David Evans and Colm O' Cofaigh and used till geochemistry to shed further light on the mode of till emplacement and the glaciological implications for the North Sea lobe. Although geochemical analysis of tills has been used extensively in Canada and Scandinavia, it had (and still has) rarely been used to investigate glacial sediments in the British Isles (e.g. Scheib *et al.*, 2011; Dempster *et al.*, 2013). The research (Boston *et al.*, 2010) focused on till units at seven sites from Filey in North Yorkshire to Morston in north Norfolk, all

correlated to the Skipsea and Withernsea tills. The major finding of the research was that the geochemical signatures were laterally discontinuous, and within thick sediment sequences were repeated vertically, thus failing to clearly differentiate between the traditional divisions. We interpreted this to imply firstly, that as the North Sea lobe advanced southwards, incorporation of local material (bedrock and pre-existing sediments) into the subglacial traction layer progressively changed the composition of the till. Secondly, thicker sequences of till were emplaced through tectonic folding and stacking of the sediment pile, interrupting a progressive increase in far-travelled material upwards as predicted by Boulton (1996), and causing vertical repetition of the geochemical signatures.

### **Plateau icefield glaciation in the Monadhliath, Scotland**

In 2008 I started a PhD at Queen Mary University of London, supervised by Sven Lukas and Simon Carr. Incidentally, I first met Sven and heard about the PhD position at the 2008 QRA ADM at the RGS. Whilst still working on former glaciation in Britain, the PhD saw a move away from lowland glaciation towards mountain ice masses and a shift towards geomorphology. The research focussed on elucidating the extent, timing and dynamics of former glaciation in the Monadhliath in the central Scottish Highlands. Despite previous/contemporaneous research around the periphery of the Monadhliath massif (Barrow *et al.*, 1913; Hinxman and Anderson, 1915; Charlesworth, 1955; Young, 1977, 1978; Auton, 1998; Phillips and Auton, 2000; Trelea Newton and Golledge, 2012; Gheorghui *et al.*, 2012) and to the west near Glen Roy (Benn and Evans, 2008), a large proportion of the glacial geomorphological evidence in the Monadhliath had not been investigated. Thus, the first year was spent establishing the extent and nature of evidence for former glaciation in the region. It quickly became apparent that there was a wealth of moraines and meltwater channels in the majority of major valleys that radiated from the central plateau (Boston, 2012), which became the focus of the PhD. A morphostratigraphic approach (cf. Lukas, 2006) was used to identify a relative chronology for glacial events and provide a framework for future targeted dating campaigns; an approach which has been effective elsewhere in Scotland (e.g. Lukas and Bradwell, 2010; Finlayson *et al.*, 2011).

The outcome of the research was the reconstruction of a hitherto unknown 280 km<sup>2</sup> Younger Dryas plateau icefield (Boston *et al.*, 2013, 2015), which added a substantial new ice mass to the record of Younger Dryas glaciation in Britain (Bickerdike *et al.*, 2018). The icefield had an equilibrium line altitude (ELA) of approximately  $714 \pm 25$  m and palaeoprecipitation estimates indicate that climate was slightly more arid than present day, corroborating with other findings in central and eastern Scotland (e.g. Finlayson, 2006; Benn and Ballantyne, 2005; Chandler *et al.*, 2019). Our calculations estimated that from west to east across the icefield, precipitation reduced by approximately 500 mm a<sup>-1</sup> over a distance of around 50 km, supporting other palaeoglaciological

evidence across Scotland for a strong precipitation gradient during the Younger Dryas (recently summarised in Chandler *et al.*, 2019).

The research also found evidence for a large pre-Younger Dryas icefield that must have existed at a time following Late Devensian ice sheet recession and prior to the Younger Dryas (Boston *et al.*, 2015; Boston and Lukas, 2017). This pre-Younger Dryas icefield is likely to have interacted with receding ice sheet lobes in the major valleys, such as the Spey, forming ice-dammed lakes (Phillips and Auton, 2000; Boston *et al.*, 2013). Evidence for this Lateglacial configuration of interacting local and regional ice masses is becoming increasingly apparent in this central area of Scotland (e.g. Everest and Kubik, 2006; Chandler, 2018; Chandler *et al.*, 2019) and will be the topic of forthcoming publications.

Most recently I have used the geomorphological record in the Monadhliath to examine topographic controls on plateau icefield recession (Boston and Lukas, 2019). The research utilises the distribution of moraines (cf. Lukas and Benn, 2006) to examine the influence of topography on the style of plateau icefield outlet glacier recession. Our analysis indicates that the spacing of moraines (i.e. zones of moraine formation/preservation) was heavily controlled by valley morphology. The style of recession indicated by the moraines is therefore individual to each valley, although some broad patterns related to valley shape are apparent, suggesting a complex relationship between moraine formation and climate.

## **Recent and future work**

My interest in plateau icefield response to climate change has led me to work on modern plateau icefields and other small ice masses from the Little Ice Age onwards. I am currently working on Hardangerjokulen and Svartisen icefields in Norway (Reinardy *et al.* 2019; Weber *et al.*, under review), Killimanjaro (Pepin *et al.*, 2017) and small ice masses in Northeast Greenland (Carrivick *et al.*, 2019). I am particularly interested in the role that topography plays in moderating the response of ice masses to changes in climate. I have also continued working on British Quaternary stratigraphy, in particular, using ground penetrating radar to examine the sedimentary architecture of the Brampton Kame Belt (Lovell *et al.*, 2019 QN147; under review). I look forward to continuing this complimentary work on Quaternary and modern glacial environments into the future, working with existing and new collaborators, and continuing as an active member of the QRA.

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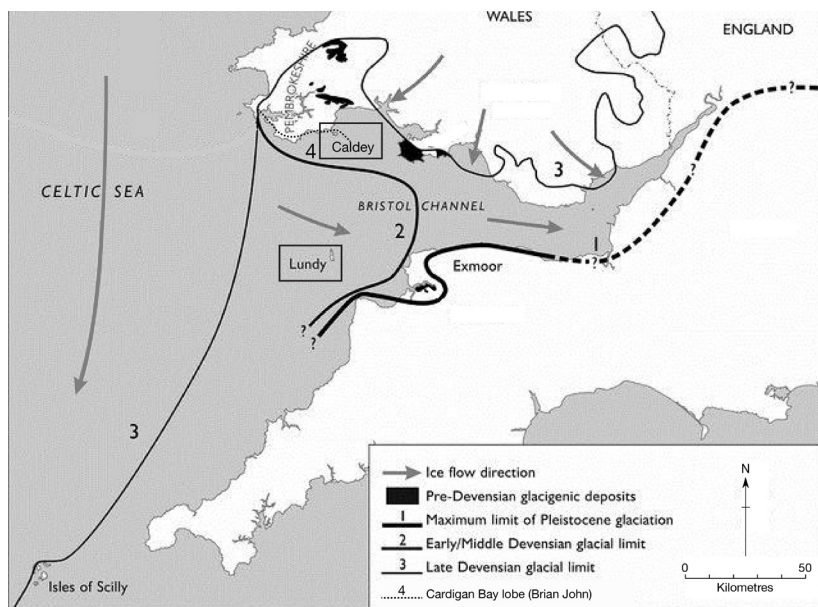
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## CALDEY ('KALD EY' IN OLD NORSE) WAS LITERALLY A 'COLD ISLAND', BUT WAS IT UNDER DEVENSIAN ICE?

### Background

The idea of an Irish Sea Ice Stream (ISIS), the largest drainage conduit of the last British-Irish Ice Sheet, is now well established. Whilst there is a strong consensus about its maximum southerly limit (Scourse and Furze, 2001; Hiemstra *et al.*, 2006; McCarroll *et al.*, 2010), it is still unclear how exactly this ice stream interacted with the Welsh ice cap in the Welsh sector (cf. Patton *et al.*, 2013; Glasser *et al.*, 2018). The accepted view has been that most of the Bristol Channel, including large parts of southern Pembrokeshire, has been ice-free possibly throughout the Devensian, but very likely during the Late Devensian (cf. Clark *et al.*, 2012). There are, however, also suggestions that during the Early and Middle Devensian there may have been eastward incursions of 'Irish Sea ice' into the Bristol Channel (Gibbard *et al.*, 2017; see Figure 1).



**Figure 1.** Suggested possible Devensian ice limits in the Bristol Channel area. Caldey and Lundy Island indicated (Modified from Gibbard *et al.*, 2017; Copyright © 2017, with permission from John Wiley and Sons, Ltd.)

Brian John ([brian-mountainman.blogspot.com](http://brian-mountainman.blogspot.com)) has repeatedly made the point that the currently accepted Devensian ice limits and ice sheet configuration in south west Britain appear mechanically implausible. His view is that acceptance of the ISIS occupying the Irish Sea and reaching all the way down to the Isles of Scilly would make it rather unlikely that the ice did not at the same time reach the coasts of Devon and Cornwall, as it is thought to have done in the Anglian (see Figure 1).

To test whether Irish Sea ice did indeed push into the Bristol Channel in Devensian times, there are two obvious onshore locations to investigate: Lundy Island and Caldey Island. Recently, Carr *et al.* (2017) argued – based on a field study and a reassessment of existing cosmogenic exposure dates – that Lundy Island, off the Devon coast (Figure 1), was ice-free during the Devensian (MIS 4-2), implying that Welsh ice did not cross the Bristol Channel this far south, and/or that the ISIS did not encroach this far east in the southern part of the Bristol Channel. Carr *et al.* (2017) proposed that Lundy experienced mainly periglacial and cool temperate conditions during the Late Quaternary and Holocene and that landscape development was dominated by surface lowering through subaerial granite weathering. This view contradicts that of Rolfe *et al.* (2012) who interpreted cosmogenic exposure dates and Lundy's geomorphology as representing a Middle Devensian (MIS 3) glaciation of the island.

Caldey Island, almost due north from Lundy Island, just off Tenby on the Pembrokeshire coast (Figure 1), is the subject of the present study. There are no cosmogenic exposure dates available for Caldey, and much of the geomorphology is masked by vegetation unlike that of Lundy. The island is in the middle of what is thought to have been an ice-free enclave separating Irish Sea and Welsh ice during the LGM (see Clark *et al.* (2012) and Figure 1), although recent suggestions by Brian John offer a different perspective. In fact, our study was a direct response to his call for 'bright, young researchers' to revisit, describe and interpret exposed diamictons which he suspects are fresh (i.e. Devensian) tills.

## Results and Discussion

Although we made observations across the island, this report focuses on the best exposure of Quaternary sediments that we could find and access, at Bullum's Bay on the east coast (SS 1492 9647; Lat/Long 51.6366, -4.675877). The exposure of diamicton sits in a 3-4 m wide bedrock gully eroded near High Water Mark (HWM) in steeply dipping strata of the local Carboniferous Limestone bedrock (Figure 2).

The exposure shows 2.5 m of reddish yellow diamicton (7.5 YR 7/8) containing abundant clasts overlain by a silt-rich deposit at least c. 0.5 m thick. This possibly loessic unit may actually be 1-2 m thick but dense vegetation obscures the top of the section. The diamicton shows variable clast content, with some parts very gravel-rich making it almost a clast-supported gravelly



**Figure 2.** The section at Bullum's Bay.

diamicton (Dcm). Towards the top of the diamicton, there are sub-horizontal concentrations of coarser cobbles and pebbles that give it a stratified character (Dms). Lower down, the diamicton is massive (Dmm), albeit with local swirling arrangements of clasts that suggest some form of 'flow' deformation. The bottom of the exposure is rather disturbed, preventing detailed observations of the sediment. An earlier report described the diamicton overlying a cemented raised beach and a head-like deposit ([brian-mountainman.blogspot.com/2018/09/scilly-and-south-pembrokeshire-two-of.html](http://brian-mountainman.blogspot.com/2018/09/scilly-and-south-pembrokeshire-two-of.html)), but these units were not exposed in 2016.

X-ray diffraction analysis of the diamicton matrix shows that it has two coalescing modes, one in the sand-silt and the other in the silt-clay range. In fact, the clay proportion is substantial at c. 25%. Given that last interglacial sea-level would have inundated the site, it is conceivable that some of this clay may have been derived from a marine environment and somehow introduced into the diamicton. An alternative and arguably simpler explanation is that the clay fraction represents a weathering residue of the underlying Carboniferous Limestone. It is even possible that the gully itself is a solution feature. It is not uncommon for an impure limestone to leave an insoluble residue of (red) clay minerals and chert fragments after weathering in a wet climate (Carroll and Hathaway, 1953; Yamasaki *et al.*, 2013). There are good examples of these weathering residues on the Carboniferous Limestone of nearby Gower (Shakesby and Hiemstra, 2015).

The provenance of the diamicton clasts was also studied (Table 1). The only rock type in our sample (N = 159) that could be directly derived from the underlying limestone bedrock within Bullum's Bay is the chert (3%), which may be a weathering residue from the Carboniferous Limestone. It is clear from the conspicuous lack of limestone in the large sample that 97% of the clast fraction in the diamicton could not have been derived directly from the

underlying bedrock. The large majority of clasts (94%) are sandstone, and the clasts differentiated as 'sandstone', 'quartzitic sandstone' and 'quartz' could all be from a similar source. The sandstone is mostly fine- to medium-grained. Of the quartzitic sandstone, approximately 65% is brown, and 35% white. Of the brown sandstones, an estimated 10% may be Old Red Sandstone (ORS), which could be derived from outcrops immediately to the south of Bullum's Bay and all along the southern coastline of Caldey Island. The geological boundary between pre-Carboniferous rocks (mostly Devonian Sandstones) and Carboniferous Limestones runs WNW-SSE across the island. The white sandstones, like the quartz clasts, are likely to have been derived from the Twrch Sandstone of the Marros Group or sandstone from the Coal Measures, the nearest outcrop found just north of the island, along the axis of the WNW-SSE trending Pembroke syncline. An additional possibility is that some of the clasts were transported from regional outcrops of ORS conglomerates, as suggested by Sid Howells on Brian John's blog (18/10/2011). All sandstones are thus 'exotic' as regards the Carboniferous Limestone setting, although not necessarily very far-travelled.

Whilst the only unidentified (5-mm) clast could be an ore mineral, arguably the most interesting rocks in the sample from a provenance perspective are the igneous rocks noted in Table 1. Three of the four clasts are rather small and rock type identification was not straightforward. Nevertheless, the elongated feldspar crystals, some of which seem to be aligned - at least in the largest pebble - suggest that it is either a welded tuff or a microgranite. Moreover, similarities between all four igneous pebbles make it feasible that they all come from the same source area with north or west Pembrokeshire, Snowdonia or the Builth/Llandrindod area as the most likely possibilities. It is interesting to note in this context that we observed that, in dry stone walls across the island, c. 95% of the rocks are limestone, with most of the

**Table 1.** Clast lithology at Bullum's Bay.

LITHOLOGY	a-axis >1cm		a-axis <1cm		TOTAL	
	Number	%	Number	%	Number	%
Sandstone	23	68	74	59	97	<b>61</b>
Quartzitic sandstone	6	18	32	26	38	<b>24</b>
Quartz	2	6	12	10	14	<b>9</b>
Chert	2	6	3	2	5	<b>3</b>
Tuff or Microgranite	1	3	3	2	4	<b>2</b>
Uncertain	0	0	1	1	1	<b>1</b>
<b>TOTAL</b>	<b>34</b>	<b>100</b>	<b>125</b>	<b>100</b>	<b>159</b>	<b>100</b>

remaining 5% identified as micaceous (white) sandstones. Pebbles on Tenby beach to the north of the island as well as on the beach in Bullum's Bay showed an assemblage of limestone, diverse sandstones and mudstones, and c. 5% chert (notably in Tenby). In both dry stone walls and on the beaches, local bedrock types dominate, albeit in different proportions. We did not find any igneous rock types, such as the rare clasts in the Bullum's Bay diamicton. Limestone was quarried from the north of the island for use in the building and was probably the source of many of the wall clasts. Nevertheless, any suitably sized clasts adjacent to the walls would doubtless have been used, as is indicated by the small numbers of sandstone, so that the absence of far-travelled erratics is thought still to be a reliable indicator of absence from the surrounding sediment.

Clast form was also analysed and provides another possible line of evidence of transport and deposition. Of the 159 clasts extracted from a sediment sample, we assessed the roundness characteristics (Powers (1953) and Table 2) and the shape using axial ratios ( $C_{40}$  index, Table 2). The modal roundness class for the dominant rock types - sandstone and quartzitic sandstone (85% of all pebbles) - is in the SA-SR range, with the distribution slightly skewed towards SA. Of the other rock types, the proportion of angular clasts in the quartz pebbles is roughly twice that of the (quartzitic) sandstones. However, assuming that the quartz is probably from the same source, the additional skew towards more angular clasts is probably a function of rock hardness rather than of differences in transport distance or mode.

The numbers of clasts in the other lithology categories are generally low and any inferences based on clast form are therefore unlikely to be statistically significant. The chert pebbles and uncertain ore mineral clast are the most angular types observed, but probably this is simply a result of the relative hardness of these rocks. The igneous pebbles are all either subangular or subrounded, which is consistent with a relatively long transport distance, with glacier ice as the possible medium. No striations were found on the igneous clasts. Only c. 2% of the clasts (all white sandstones) shows indistinct scratches that might represent striations.

The shape characteristics of the clasts were calculated using the  $C_{40}$  index (cf. Benn and Ballantyne (1994), Table 2). This is a measure of 'flatness' (axial ratio  $c/a$ ), with a low  $C_{40}$  index theoretically implying a high degree of transport modification, particularly if combined with a high %SR+R+WR index. Assessing the ranges in co-variance of these indices for the sample of clasts as a whole and individual rock types (the low numbers of some rock types again prevent meaningful inferences), it can be concluded that the clasts in general (including the suspected erratics) show a degree of modification that is not uncommon in subglacially transported materials.

**Table 2.**Clast form at Bullum's Bay.

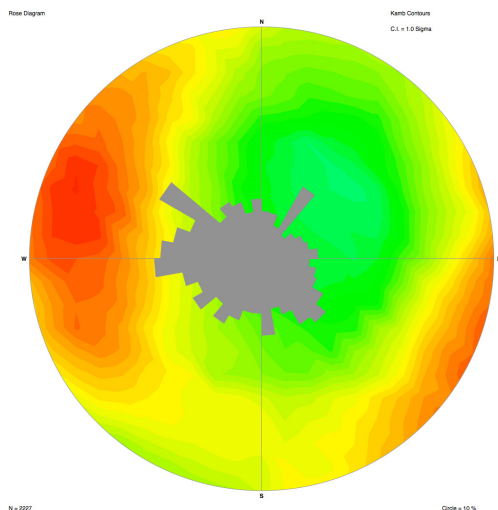
LITHOLOGY	Roundness								Shape
	VA	A	SA	SR	R	WR	%SR+R+W R		
Sandstone	2 (2%)	15 (15%)	38 (39%)	32 (33%)	10 (10%)	0 (0%)	42%	C <sub>40</sub> 32%	
Quartzitic sandstone	1 (3%)	7 (18%)	15 (39%)	12 (32%)	3 (8%)	0 (0%)	40%	37%	
Quartz	1 (7%)	4 (28%)	6 (43%)	2 (14%)	1 (7%)	0 (0%)	21%	14%	
Chert	1 (20%)	2 (40%)	2 (40%)	0 (0%)	0 (0%)	0 (0%)	0%	20%	
Tuff or Microgranite	0 (0%)	0 (0%)	2 (50%)	2 (50%)	0 (0%)	0 (0%)	50%	25%	
Uncertain	0 (0%)	1 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0%	100%	
TOTAL	5 (3%)	29 (18%)	63 (40%)	48 (30%)	14 (9%)	0 (0%)	38%	31%	

VA = very angular; A = angular; SA = subangular; SR = subrounded; R = rounded; WR = well rounded

From the covariance analysis, it is not possible to establish whether clasts have experienced additional modification during (subsequent) slope transport. Debris flow, for example, another candidate for the emplacement of the diamicton at Bullum's Bay after subglacial deposition, is a relatively low-energy process and clasts would thus tend to retain any characteristics developed in an earlier transporting episode. To some extent, the same applies to the involvement of marine or coastal processes. Cox *et al.* (2018) found that the degree of modification of clasts in the marine environment is dependent on their size, with smaller clasts generally showing less rounding. Also, the degree of rounding of coastal boulders (significantly higher in calibre than the clasts in this study) is reported to be higher near the high water mark compared to higher elevations (Cox *et al.*, 2018). Having said that, the percentage of rounded boulders that these authors reported is close to the percentage (9% of total) we found for the small clasts in our sample, which makes it possible that the assemblage of clasts (and the diamicton) represents pre-existing and recycled sediments. Alternatively, instead of direct glacial deposition during the Late Devensian, the diamicton in the narrow gully might have been emplaced mainly by slope processes after the material had been delivered around the island's coasts in periods when sea-level was higher than today. In this scenario, the possible glacial signature of the clasts and their 'exotic' provenance could be explained if glacial deposition occurred during the Anglian rather than Devensian.

Particle fabric analysis was used to derive information on the direction of sediment flow immediately prior to deposition. Ice flow and mass flow directions are known to be reflected in preferred orientations of long axes of grains and clasts (Evans *et al.*, 2007). From the exposure at Bullum's Bay, we took an undisturbed and oriented monolith sample for micro-CT scanning and subsequent semi-automated grain fabric analysis. We selected particles with a b-axis >500 microns and a/b ratios >1.25, leading to a dataset of well over 2000 grains.

Eigenvalue analysis and the plotted data (lower hemisphere stereonet; Figure 3) show a girdle distribution with one smoothed primary mode, which is known to be common for both mass flow deposits and glacial tills. Although the first Eigenvalue is not particularly strong ( $S_1 = 0.41$ ,  $S_2 = 0.34$ ,  $S_3 = 0.25$ ) when compared to clast fabric values (see, e.g., Evans *et al.*, 2007), the range of values is not uncommon for large datasets in the silt-sand fraction of both glacial tills and mass flow deposits. There is a clearly discernible WNW mode ( $V_1 = 283.7^\circ/17.4^\circ$ ), which suggests a 'flow' of sediment towards the ESE. This direction matches the alignment of joints and of the gully in the Carboniferous Limestone, which could suggest that sediment flowed downslope under gravity into spaces and depressions in the jointed bedrock surface. Alternatively, it could be argued that Irish Sea ice overrode Caldey to deposit a Bullum's Bay till (brian-mountainman.blogspot.com/2018/08/south-pembrokeshire-devensian-till). In this scenario, an approximately W-E-flowing 'Carmarthen Bay Lobe' is envisaged impinging on the present-day south Pembrokeshire coastline (Brian John, pers. comm.). The grain fabric signature found in this study would not be incompatible with this



**Figure 3.** Lower hemisphere contoured stereoplot and rose diagram: grain fabric, Bullum's Bay (n=2227).

scenario. For either depositional origin, the setting of the diamicton in Bullum's Bay resting in a narrow bedrock cleft (see Figure 2) would be expected to exert a strong control on the fabric of the diamicton.

### Assessment

From the evidence, two possible likely alternative scenarios accounting for the Bullum's Bay diamicton are now considered.

#### (1) In situ Devensian till

This was the scenario we set out to test. Several features certainly favour this origin: (i) 'foreign' igneous erratics; (ii) dominance of sandstone clasts mostly probably from outcrops on the west of the island lying slightly south of Bullum' Bay, which would tally with an ENE flow direction of ice as envisaged by Brian John; (iii) clast form characteristics; and (iv) probable loessic sediment overlying the diamicton without obvious hiatus, consistent with a Devensian origin. There are, however, several drawbacks to this scenario: (i) the very low content of any material that does not have a likely relatively local provenance; (ii) no observed far-travelled erratics or glacial diamicton in parts of the island we could access, and also very few such erratics on the beaches; (iii) flow structures atypical of till; and (4) no convincing striations. (The grain fabric evidence is equivocal, neither supporting nor ruling out a till origin.)

#### (2) Redistribution of pre-existing sediment including any residual Anglian glacial sediment during Devensian periglacial conditions

An in situ Anglian till origin is not feasible because raised Ipswichian sea level - probably at least c. +5 m OD (Dutton and Lambeck, 2012) - would have removed any existing sediment from the lower part of the gully where the diamicton lies. An origin by redistribution of regolith and soil as well as any Anglian glacial material by mass flow under Devensian periglacial conditions is, however, plausible. The igneous pebbles could have been derived from two possible transport directions and by two possible sequences of events. (In either case, mass flow would have moved sediment downslope from higher ground in the south of the island to the gully.) One alternative is that they could have been deposited on the island during the Anglian glaciation when many argue that ice from the Irish Sea Basin moved eastwards and southwards across this region. Mass flow processes would then have carried these clasts into the gully. The other alternative is that there is a possible source to the south of Bullum's Bay of the igneous pebbles in conglomerates of the West Angle Formation of the upper ORS, which is said to be 'rich' in such clasts as well as those of some other lithologies (Howells, 2007). In this case, sediment containing clasts derived from mainland sources would have been transported to the island by glacial action, and during the Devensian any remnant glacial material would have been carried north(east)wards downslope to Bullum's Bay by mass flow processes together with any locally eroded material including the igneous erratics. The flow structures, lack of striations, clay-rich texture and grain fabric evidence tally with an origin by periglacial slope processes. Clast rounding could be the result of one or a combination of long-term weathering, residual glacial modification or limited modification acquired during mass flow transport. The clast form characteristics of the igneous clasts would favour a glacial rather than fluvial (i.e. ORS conglomerate) origin, although reconstructing transport history from just four clasts must be treated with caution. Lack of angular clasts from the underlying limestone either in the diamicton or forming the main constituent of a discrete single-lithology periglacial diamicton might appear problematic given the frost susceptibility of this rock type. However, the lack of steep surrounding slopes with exposed bedrock that could act as the source of such material is the probable explanation. (Transport to Bullum's Bay of the igneous erratics by northward-moving longshore drift during raised Ipswichian sea level is conceivable but their incorporation into the exposed diamicton seems unlikely given the lack of contained marine shells.)

On balance, therefore, we prefer the second scenario to explain the Bullum's Bay diamicton as it provides a better explanation of the evidence. Like previous investigations at this site and across the island, however, ours was limited by time and other logistical constraints. The enigmatic deposits at this critical location for unravelling the glacial history of the Bristol Channel region warrant further, more comprehensive analysis in the future - perhaps by even 'brighter' and 'younger' researchers!.

## Acknowledgements

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# THE FUNDAMENTAL KNOWLEDGE GAP IN COASTAL TERRESTRIAL PALAEOCLIMATE RECORDS FOR GREENLAND

## Background and Rationale

The Arctic is predicted to experience some of the greatest climate and environmental changes in response to anthropogenic forcing. Such changes will have far reaching consequences globally, thus, understanding how the climate is capable of developing in the Arctic is highly important. To date, such knowledge is obtained largely from deep ice cores drilled from the interior of the ice sheet, whereas understanding of the response of lowland coastal areas is largely lacking. In this pilot project, we aimed to assess the suitability of sedimentary archives found in coastal caves on the low-lying Wegener Halvø peninsula (71.65156 N, 22.73001 W) of East Greenland for reconstructing records of past climate and environmental change.

## Aims

Our goals were highly ambitious, but if successful offered the potential for high gain. We aimed to: (1) explore, document and photograph caves in East Greenland; (2) collect sedimentary and mineral samples from the caves; (3) construct records of climate and environmental change from the sediment and speleothem archives; (4) interpret the records with respect to e.g., changes in sea ice; climate stability and abrupt events; synchronicity with the nearby RENland ice CAP (RENCAP) ice core and marine records; and teleconnections with distant regions; (5) undertake public outreach throughout the duration of the project to better inform people about the issues of climate change, Quaternary and cave-based science and (6) engage local Inuit communities on the work of climate scientists in Greenland.

## Approach and Results

The fieldwork took place in August 2018, and was supported by funding from the QRA specifically for the research permits. In order to reduce the carbon footprint of the expedition, return travel between Iceland and Greenland was achieved by sailing with the Top to Top Global Climate expedition (Figure 1). Unfortunately, due to a low pressure system that sat over East Greenland for the majority of the summer of 2018, it was not possible to fully achieve the goal of sailing all the way to the peninsula because the route never cleared of sea ice. Hopeful, the expedition waited five days in Ittoqqortoormiit to see how the sea ice would develop and undertook outreach with the local community where possible. In the end the final leg was achieved by helicopter. Three days were spent undertaking long and arduous hikes (Figure 2) around the peninsula targeting locations where geologists (who had previously worked in the area) claimed there to be caves. Despite determined attempts to access the sites, the 'caves' mostly turned out to be rock shelters

devoid of sedimentary deposits. Such is the nature of real, first-time exploration, it is not every time that major discoveries are made. In summary, palaeoclimate reconstructions from caves on the Wegener Halvø peninsula will not be possible.



**Figure 1.** Navigation between Iceland and Greenland (Photo credit: Robbie Shone).



**Figure 2.** Chris Blakeley hikes towards a potential cave entrance on the Wegener Halvø peninsula. Photo Robbie Shone (Photo credit: Robbie Shone).

### **Acknowledgments**

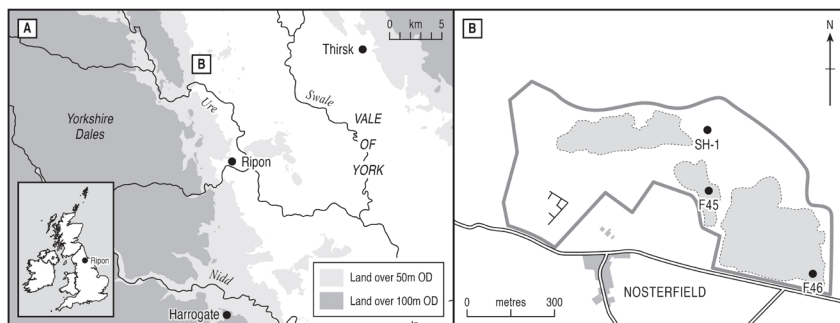
I would like to thank the Top to Top Global Climate Expedition for supporting our travel, Chris Blakeley and Robbie Shone for assistance in the field, and Clive Johnson for logistical support.

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# POLLEN ANALYSIS OF A PEAT PROFILE FROM SHAFT F46, NOSTERFIELD QUARRY, NORTH YORKSHIRE

## Introduction and background

Nosterfield village lies in the valley of the River Ure in North Yorkshire, to the west of the Vale of York (Figure 1). The area has been the site of extensive gravel extraction from a deglacial meltwater outwash fan that lies at the entrance to Wensleydale, upon which lies a Neolithic triple henge monument and its associated rich multi-period archaeological landscape at Thornborough (Harding, 2000), to the south of Nosterfield village. Exposure of the gravel fan surface before aggregate extraction by Tarmac Ltd. in Nosterfield Quarry revealed a number of narrow vertical shafts, probably gypsum solution hollows. These were filled with organic deposits, providing a sedimentary record with which to investigate the environmental history of the outwash fan and the environmental context of the Thornborough archaeological complex. Long and Tipping (1998) examined the lithostratigraphy of three of these shafts (F44, F45 and F46) and radiocarbon dated the top and base of their organic sediments (Tipping, 2000), showing that they contained a palaeoenvironmental record from Lateglacial to late Holocene times. The shafts were destroyed by quarrying, but their sampled sediment profiles were archived. A geo-archaeological research project (Bridgland *et al.*, 2011) was funded by English Heritage under the Aggregates Levy Sustainability Fund to study the landscape evolution of the lower valleys of the rivers Swale and Ure, and the opportunity was taken to examine the sediments in the archived Nosterfield F45 profile, as well as a new core SH1, using a range of palaeoenvironmental techniques.



**Figure 1.** Location of Nosterfield Quarry and profile F46. The Thornborough henges lie 500 m south of Nosterfield village.

Pollen analysis of F45 and SH1 provided information regarding vegetation change in the area to the north of the Thornborough henges during the Neolithic and Bronze Age (Bridgland *et al.*, 2011), the henges themselves being dated to the later Neolithic (Harding, 2000). Throughout the Neolithic the area seems to have been well wooded, with substantial frequencies of *Alnus*, *Quercus*, *Betula*, *Pinus* and *Corylus*. In both profiles there is evidence of forest disturbance and farming during the Neolithic and Bronze Age, with cereal-type pollen and clearance indicator weeds like *Plantago lanceolata*. In both cases, however, indications of human activity were low-scale, and the area appears to have remained largely wooded during the period of the construction and use of the henges, perhaps contrary to expectations of land use near such a major archaeological site complex. It was decided to analyse profile F46, which is closer to the Thornborough henges than F45 and SH1, to see if the pollen signal of human activity and farming increased in strength nearer the monuments, or whether the evidence for very limited woodland clearance remained the case, which would have major implications for our understanding of the place and function of these monuments in the landscape. The top of F46's organic sediment was dated to  $3930 \pm 40$  BP (Beta-143454; 2565-2294 cal BC) by Tipping (2000).

## Results

Pollen at 22 levels from F46 was analysed by Kristie Lo, who completed a pollen diagram at 2 cm sampling intervals through the Neolithic age sediments. The diagram is dominated by pollen of *Alnus* and *Corylus*-type, with low frequencies of other woodland trees, and has substantial Poaceae values. These taxa comprise about 90% of total land pollen throughout. Evidence of woodland disturbance and human farming activity is low, with only two episodes of disturbance recorded. The first, near the base of the diagram, is very slight and has no impact on tree pollen frequencies. It has moderately elevated microcharcoal values and the appearance of pollen grains of weeds including *P. lanceolata* and *Potentilla*-type. The second phase, which occurs nearer the top of the diagram and must be late Neolithic in age, has very low frequencies of cereal-type pollen, a small peak of microcharcoal and increased indicators of disturbance, including *P. lanceolata*, *Silene*-type, *Rumex*, *Chenopodiaceae* and *Pteridium*. This disturbance has only a small and temporary impact on tree pollen frequencies.

The F46 data are very similar to those from the previous analyses at F45 and SH1, and the closer proximity of the profile to the Thornborough henges has not resulted in evidence of a more open and farmed landscape adjacent to the archaeological sites. Poaceae frequencies are slightly higher in the new diagram and might suggest a little more grassland and open ground than did the earlier studies. Tree cover is confirmed as being high throughout the period, although *Quercus* seems to have been less common nearer the henges than further away at

F45, with alder and hazel more abundant. Overall the new work has confirmed both the number of disturbance and human activity phases and their very low intensity during the later Neolithic when the three henges were constructed and occupied. It confirms the location and use of these monuments within a largely wooded landscape, and suggests that large human populations and intensive land use were not associated with the function of these major cultural sites. Future research will include more radiocarbon dating of the profile to relate it more precisely to the archaeological record.

## **Acknowledgements**

We are grateful to the Quaternary Research Fund for supporting the laboratory preparation of the pollen samples from F46, and to Collingwood College, Durham University for providing an internship for Kristie Lo. We are also very grateful to Richard Tipping for access to sediment profiles F45 and F46.

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# NEW RESEARCH WORKERS AWARD

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## BEDROCK MEGA-GROOVES IN ASSYNT, SCOTLAND. FROM LANDFORM TO LANDSCAPE

### Background and rationale

Bedrock mega-grooves occur as straight and parallel features in previously glaciated terrain. They are thought to form subglacially and are important for understanding processes at the ice-bedrock interface (Newton *et al.*, 2018). Two sites have been described in Assynt, NW Scotland: one at Elphin where groove formation has been interpreted as independent of any structural control (Bradwell, 2005; Bradwell, 2010), and one north-east of Ullapool where lateral plucking has been proposed to explain groove formation (Krabbendam and Bradwell, 2011) under ice streaming conditions (Bradwell *et al.*, 2008). The fieldwork recently carried out at these locations aimed to advance understanding of bedrock mega-groove formation by bringing new empirical evidence and reappraising some of the existing interpretations.

### Results

The signal of glacial abrasion and plucking, and that of meltwater erosion were assessed based on characteristic aspects described elsewhere (Dahl, 1965; Benn and Evans 2014), recorded in the field and mapped in ArcGIS. The dip and strike of the joint systems which facilitated plucking were measured and recorded systematically. The substrate along eastern margin of the Ullapool site was assessed through field survey along river cuttings. The continuity of streamlined forms cross-cut by structural lines (i.e. faults) was assessed from various angles in the field following preliminary observations on aerial imagery. The data was gathered mainly from the ridges, as the bedrock is rarely visible in the grooves.

The signal of glacial and meltwater erosion varies widely over small distances. Multiple polished and striated surfaces occur on the Cambrian quartzite at Elphin with striae less than 2-mm deep oriented 090/270. On the Moine schist at Ullapool glacial abrasion rounded off the highly foliated rocks along formerly plucked edges, but no striae were found. The signal of glacial plucking is ubiquitous in both areas, plucked blocks measure on average 20x15x30 cm and dislocation occurred along pre-existing geological fractures. The top of the intervening ridges at Elphin are flat and their altitude matches up across the mapped area (Figure 1).

Subdued mounds of glacial deposits are widespread along the eastern margin of the Ullapool site, and tend to become more elongated from east to west. At three locations the ridges and grooves continue over cross-cutting trenches which formed along geological faults.



**Figure 1.** Mega-grooves at Elphin, Scotland on Cambrian quartzite, looking east. Note the flat top of ridges. The ice-flow direction was towards the reader.

## Significance

Systematic mapping of landforms and geological features shows that plucking has been the most efficient process of bedrock erosion, and was controlled by the pre-existing joint systems. The landscape topography shows that the Elphin grooves were eroded into a pre-existing land surface (Figure 1). The Ullapool landscape is likely one of aerial scouring, whereby the passage of ice revealed and emphasised a stepped terrain, which may be an intrinsic geological characteristic. Significantly, preliminary observations of the grooves/ridges in conjunction with geological faults point to a possible older age for the former, but this requires further investigations. The widespread signal of glacial and meltwater erosion is indicative of warm-based ice. Further insights into groove formation will hopefully be gained through gathering similar data from a wider areas and interpreting it in close connection to the geological history.

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# EXPLORING THE DIETARY ECOLOGY OF EXTANT MIXED-FEEDING ANTELOPES TO INVESTIGATE PALAEOVEGETATION IN EASTERN AFRICA (3.5-1.6 MA)

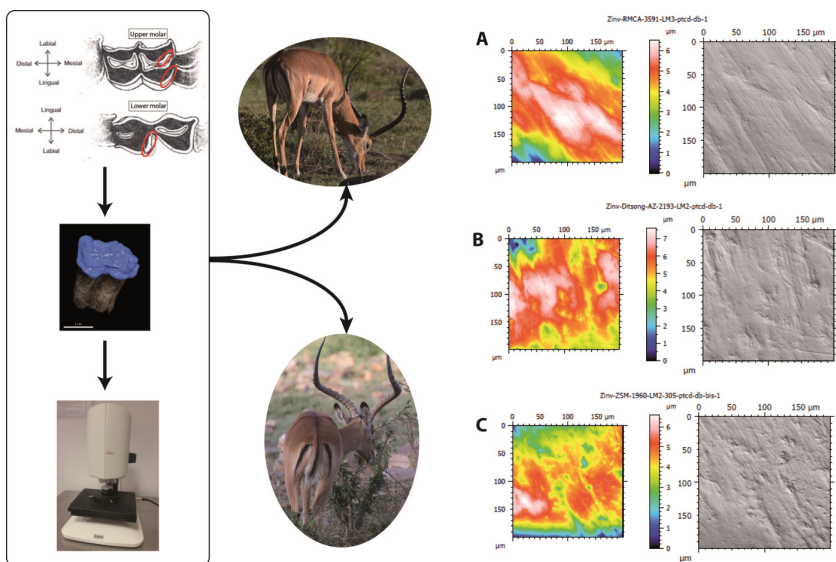
## Background and rationale

The Omo-Turkana basin (Kenya/ Ethiopia) is a key region for African hominin sites, and provides a detailed record of vertebrate evolutionary patterns (Behrensmeyer, 2006; Bobe, 2011; Bobe and Eck, 2001). The impala (genus *Aepyceros*), is particularly well-represented in the fossil record, and has been suggested in previous studies to be an excellent proxy for paleo-environmental studies due to its high dietary adaptability (Greenacre and Vrba, 1984). Modern impalas are mixed-feeding antelopes, feeding on both browse and graze according to the available vegetation (Wronski, 2002). Similarly, fossil impalas are likely to have adapted their diets to the prevailing vegetation conditions, and might therefore reflect potential changes in paleo-vegetation in the past. Their diet is studied through stable isotope and dental use-wear analyses.

To understand how dietary patterns might reflect specific landscapes in the past, it is essential to assess the dietary variability of these antelopes today across Africa, as well as within population, by studying dietary patterns on modern samples of known provenance. The funds provided by the Quaternary Research Association allowed accessing the 3D Optical Surface Metrology System Leica DCM8 housed at the Institut de Paléoprimatologie, Paléontologie Humaine: Evolution et Paléoenvironnements (PALEVOPRIM, Université de Poitiers, France), as well as the ToothFrax and SFrax software packages, to scan and analyse 187 dental casts of modern specimens acquired from zoological collections for dental microwear textural analysis (DMTA - Figure 1).

## Preliminary results

The main variables used in DMTA are complexity (Asfc – area scale fractal complexity) and anisotropy (epLsar - exact proportion length-scale anisotropy of relief). Complexity is a measure of the roughness at a given scale, with high complexity values found for surfaces dominated by pits of various sizes or pits and scratches overlaying one another. Anisotropy measures the orientation concentration of surface roughness; surfaces with parallel scratches tend to have high anisotropy values. According to previous studies (Calandra and Merceron, 2016; J.R. Scott, 2012; R.S. Scott *et al.*, 2006), browsing behaviours (i.e. brittle and/ or hard food items) tend to yield intermediate to high complexity values associated with low to intermediate anisotropy. Herbivores grazing on tough and abrasive monocots tend to display high anisotropy as well as low complexity.

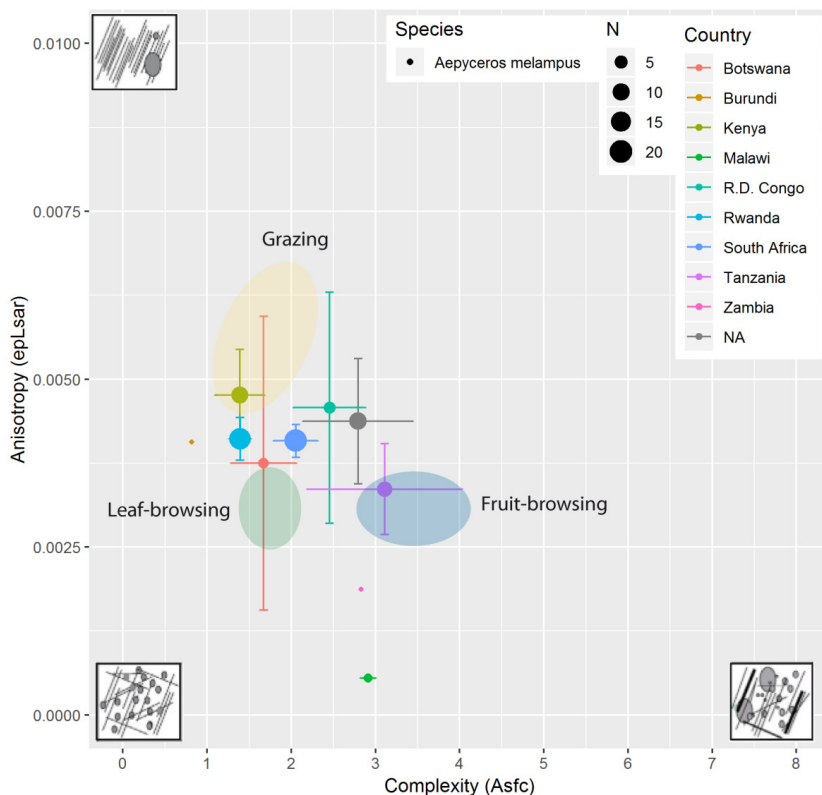


**Figure 1.** Dental Microwear Textural Analysis (DMTA), from data collection to scanned surfaces. A, B and C: photo-simulations for *Aepyceros melampus* modern specimen. These specimens illustrate the dietary adaptability of modern impalas, with A) suggesting a preference for grazing, B) mixed-feeding practices, C) a preference for browsing (based on combined DMTA parameters). (A) specimen RMCA 3591, Royal Museum for Central Africa, Tervuren, Belgium; B) specimen AZ 2191, Ditsong Museums, Pretoria, South Africa; C) specimen 1960-305, Zoologische Staatssammlung München, Germany).

Preliminary analyses highlight a high dietary variability across Africa for impala specimens (Figure 2). A wide range of values are found for both variables, with for example samples from Kenya and Rwanda displaying values comparable to those of grazing species, while samples from Tanzania are more similar to fruit-browsing species. This likely reflects differences in local environments and vegetation cover in these localities, with impalas adapting their diet to differing habitats in each region.

## Significance

As preliminary results indicate differing dietary preferences among impalas across Africa, future work will investigate climate and vegetation conditions at smaller scales (i.e. localities) in each of these studied countries, to better understand the relationship between microwear patterns and the environmental conditions experienced by these animals. This will help create a modern baseline for vegetation cover and associated dental dietary information for this species, with



**Figure 2.** Distribution (mean and standard error of mean) of *Aepyceros melampus* samples per country, depending on the complexity and anisotropy of the dental facets. The coloured areas reflect typical values for the main dietary categories, based on values from reference specialist species (Grazers: *Alcelaphus buselaphus* and *Equus burchelli*; Leaf-browser: *Giraffa camelopardalis*; Fruit-browser: *Cephalophus sylvicultor* – data from *A. buselaphus*, *G. camelopardalis* and *C. sylvicultor* provided by G. Merceron).

which to compare data acquired from fossil specimens. This approach should help understand the type of landscapes fossil impalas might have lived in, between 3.5 and 1.6 million years ago, in the Turkana Depression.

### Acknowledgements

I would like to thank the QRA for funding this part of my research through the New Research Worker's Award, as well as the British Institute in Eastern Africa,

the Association for Environmental Archaeology and the Prehistoric Society for providing the funds necessary to collect data on modern specimens (in Pretoria, Tervuren and Munich, respectively). I also wish to thank G. Merceron, C. Blondel and J.-R. Boisserie (PALEVOPRIM, UMR 7262 CNRS INEE) for supervision and advice during my visits for microwear analysis at the University of Poitiers. I wish to thank as well A. van Heteren (Zoologische Staatssammlung München, Germany), E. Gilissen (Royal Museum for Central Africa, Tervuren, Belgium), and H. Fourie (Ditsong Museums, Pretoria, South Africa) for their assistance during data collection. Finally, I would like to thank my supervisors, S. Reynolds, R. Hill and P. Hopley for their advice and expertise.

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# SEARCHING THE GEOLOGICAL SIGNATURE OF SUBDUCTION ZONE EARTHQUAKES IN THE PACIFIC COAST OF MEXICO

## Background and Rationale

The Rivera plate subduction zone lies ~400km along the central Pacific coast of Mexico. Interplate ruptures between Rivera plate and the overriding North American plate have produced three of the largest earthquakes recorded by instruments: 1932 (Moment Magnitude = Mw 8.2), 1995 (Mw 8.0) and 2003 (Mw 7.8). Historical evidence suggests the presence of more great earthquakes (Mw > 8.0) along this coast (Castillo-Aja and Ramírez-Herrera, 2017). However, the scatter palaeoseismic studies that rely on tsunami reconstructions (Ramírez-Herrera *et al.*, 2016; Bógalo *et al.*, 2017; Ramírez-Herrera *et al.*, 2014; Castillo-Aja *et al.*, 2019) cannot prove the occurrence of Holocene megathrust earthquakes. This project aims to contribute to our understanding of the long-term seismicity of the Rivera plate.

The QRA New Researchers Award Scheme funding facilitated fieldwork carried out during the first two weeks of December 2018, along the coast adjacent to the southern limit of the Rivera plate. The aim of this fieldwork was to map the sub-surface lithology of the estuary of the Marabasco River in order to find the geological signature of Holocene earthquakes. I followed the criteria common to coastal palaeoseismology, which relies upon methods of Quaternary relative land/sea-level change reconstructions (Nelson *et al.*, 1996; Shennan *et al.*, 2016). In this context, I seek to investigate the stratigraphy of the estuary in order to characterise former environments and identify abrupt relative sea-level changes, which may be indicative of either coastal subsidence or coastal uplift due to coseismic crustal deformation.

## Results

Three different sites were chosen for coring across the delta of the Marabasco river. Despite some restriction faced in the field, eleven sites were core logged in a site next to a 1.5 km of a creek (19.157° N, 104.567° W; 19.162° N, -104.557° W), and two outcrops were found in a man-made drainage channel (Figure 1). The uneven distribution of the cored sites reflects the exploratory nature of this analysis. It is important to associate the observations to a regional event in order to prove that they correspond to an earthquake. For example, some of the cores host contacts of mud overlying highly organic layers across the whole area. A future correlation of such contacts between different sites, based on radiocarbon ages, will test the hypothesis that abrupt stratigraphic changes in the cores are genetically correlated to a regional seismic event. This evidence would help to rule out alternative hypotheses related to other

local processes. Nevertheless, these sedimentary sequences will be further analysed and characterized in terms of particles size, the content and type of organic material, and the assemblages of microfossils (diatoms and pollen).



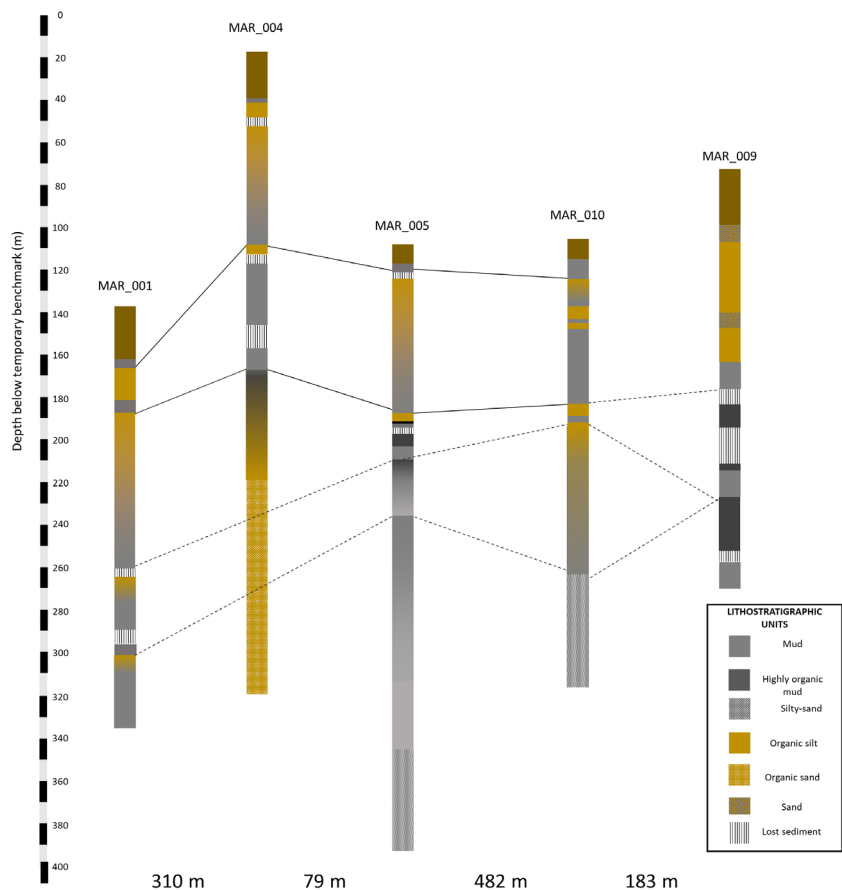
**Figure 1.** (A) Example of the stratigraphic successions found in the site of interest. (B) Outcrop found in a man-made drainage channel. Both images show black layers that potentially might be indicative of a buried soil caused by coseismic subsidence.

## Significance

These analysis will provide evidence of earthquake reconstructions at centennial scales. The findings of this first phase of sample collection will be useful to correlate the evidence of cores logged during the next field trip obtained from areas adjacent to the previous sites. Additionally, the microfossils better preserved in the cores will be useful to design the collection of modern samples across intertidal zones in order to reconstruct a transfer function and provide quantitative estimates of relative land-level changes.

## Acknowledgments.

I acknowledge my field assistants Adrián Ciprés (UAM), Andrea Mancera (UNAM) and Emilio Saavedra (UNAM). Moreover, I also want to thank to MSc Ana Patricia Méndez Linares and Dr. José Ramón Hernández Santana, from the National Autonomous University of Mexico, for providing me the facilities to translate the coring equipment from Mexico City to Colima. Additionally I would like to thank



**Figure 2.** Stratigraphy of five cores located along the creek. The numbers in the bottom indicate the distance between each core.

to those Associations and Institutions that fund partially this fieldwork season: The Estuarine and Coastal Sciences Association (The Charles Boyden Fund for Small Grants), Hatfield College (MCR Research Award), Department of Geography and Santander Universities Scholars (Latin America Mobility Grant).

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## CREATING PALEOENVIRONMENTAL CHRONOLOGIES IN SEMI-ARID ISLANDS: A CASE FROM CAPE VERDE

### Background and Rationale

Studying the palaeoecology of semi-arid regions is challenging due to poor preservation of fossil evidence, as well as the paucity of deposited sediments (Brunelle *et al.*, 2018). To provide a historical perspective of ecosystem degradation processes in Cape Verde, we have analyzed stratified sediments in volcanic calderas using palaeoecological methods. While the sediment are clearly stratified and show sequences of environmental change in the middle and late Holocene, erosion processes and the scarce presence of macrofossils or charcoal are major limitations for building strong chronologies. Here we discuss the intrinsic challenges for radiocarbon dating of these sediments from volcanic calderas on two islands. We report two radiocarbon assays of humic acid extractions, which do not significantly differ from standard bulk sediment dating. As a way forward, we propose the creation of combined chronologies integrating various dating techniques and biostratigraphic markers.

### Results and discussion

After being awarded the 14 Chrono Award of the QRA, we submitted two bulk sediment samples to the Belfast CHRONO centre in order complete our age-depth model from the Cova de Paúl site (COVA, 130cm) in Santo Antão Island, and to provide a basal date (185cm) from Calderinha site (MNTG-C2) in São Nicolau Island. We agreed with Prof. Reimer to explore how dating humic acid extractions would compare to standard bulk sediment dates we had previously obtained in the COVA record middle section, as this method enables dating the organic matter proceeding from plants, rather than other sources of carbon such as carbonates (Pessada *et al.*, 2001) (see results Table 1).

The COVA middle section (180-110 cm) is characterized by the occurrence of erosion processes, which have produced C14 age inversions. However, due to the identification of biostratigraphic markers (*e.g.* *Zea mays* pollen) we interpret that this section represents the first anthropic phase of the record estimated ~450-350 yr BP (Figure 1). The calibrated humic acid date for COVA (UBA-38472) was 1528-1394 cal. yr BP. This date suggests that erosion processes brought re-deposited materials in this section of the core (see Grimm *et al.*, 2009), reinforcing our previous interpretation. The second calibrated date was from Calderinha (UBA-38473), dating from 5934-5749 cal. yr BP, the oldest obtained in the archipelago so far.

**Table 1.** Humic acid radiocarbon dating results.

UBANo	Sample Site and depth	Radiocarbon Age	Calibrated (95.4%)
UBA-38472	COVA (130cm)	1561 ± 26	1528-1394 cal. yr BP
UBA-38473	MNT-G C2 (185cm)	5120 ± 33	5934-5749 cal. yr. BP

### Significance

Thanks to this QRA grant, we have dated humic acid extraction in Cape Verde sedimentary archives. The result of the COVA 130cm Humic Acid C14 dating reported age falls within the cluster of older-than-expected bulk sediment dates from the anthropogenic section of the Cova de Paul sequence (Figure 1). It suggests that this alternative dating technique was not useful for to ascertain the age in which the material was deposited. In addition, we obtained the oldest date so far in Cape Verde for the basal section of the Calderinha record.

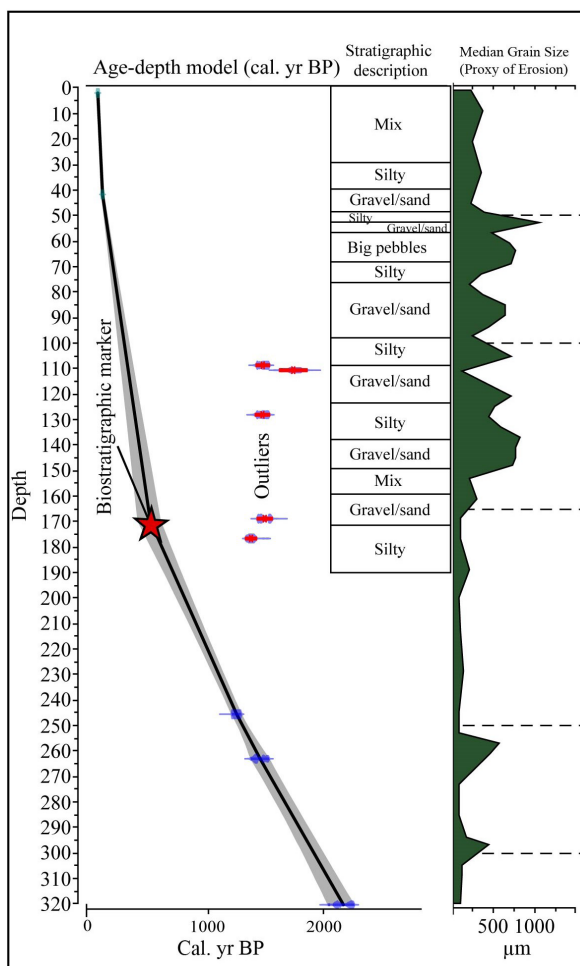
Based on these findings, we will avoid dating material within sections of the coarse deposits that indicate erosion in other semi-arid island records, and concentrate our radiocarbon assays in charcoal peaks and sections that show stable, organic-rich sediments. We also aim to combine diverse dating methods including optically stimulated luminescence.

### Acknowledgements

We would like to thank the Quaternary Research Association for the QRA-14 Chrono Award (2018), and the kind assistance and suggestions of Prof. Reimer and Mr Stephen Hoper.

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**Figure 1.** Age-depth model Cova de Paul site, including stratigraphic descriptions and erosion indicators.

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# OUTREACH AWARD

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## THE SECRETS OF IRELAND'S PEATLANDS: BOG BODIES, VOLCANOES AND CLIMATE CHANGE

11<sup>th</sup> September 2018, Ulster Museum, Belfast

Ireland boasts some of the best examples of peatlands in NW Europe, many of which have formed the focus of palaeoenvironmental and archaeological studies. With the aid of a QRA Outreach Award, a team from Queen's University Belfast hosted an outreach evening in the Ulster Museum on the 11th September 2018 to raise awareness of the insights that Irish peatlands can provide into long-term environmental change, and to highlight ongoing initiatives aimed at restoring the region's peatlands. The event was attended by over 200 members of the public as well as representatives from groups involved in peatland management and conservation from across Ireland.

The evening opened with a lively exhibitor session in the atrium of the museum, where representatives from 15 NGOs and volunteer groups ran displays featuring a range of management and conservation activities (Figure 1). These included an impressive array of props and visual aids, including samples of typical *Sphagnum* species from Irish peatlands (Figure 2), peat cores, and large pieces of wood extracted from a Fermanagh bog. Posters covering a range of research projects were also displayed.

After a formal welcome by **Marie Cowan**, Director of the Northern Ireland Geological Survey (GSNI), a series of peatland-themed talks followed. **Graeme Swindles** (Leeds University) explained how Irish peat records have shed new light into patterns of climate change and volcanic eruptions over the past few thousand years and are providing important context for understanding current climate trends. **Gill Plunkett** (Queen's University Belfast) described some of the many well-preserved bog bodies recovered from Irish bogs, and the fascinating insights which they provide into past cultures. **Maurice Eakin** (National Parks and Wildlife Service) and **Trish Fox** (Ulster Wildlife) both focused on the challenges of peatland conservation and management, providing stimulating overviews of restoration projects across Ireland and the need to develop this work more widely.

Thanks are expressed to everyone who supported this successful event, including the QRA, the *British Ecological Society*, and GSNI who provided financial support, the event hosts, *National Museums of Northern Ireland*, and representatives from the many agencies, groups and project participants who exhibited, including *Birdwatch Ireland*, *CEdar*, *Community Wetlands Forum*, *Forest Service of Northern*



**Figure 1.** Public outreach event on peatlands, Ulster Museum, Belfast-exhibitor displays in the atrium area. (Photo credit: Tim Patterson)



**Figure 2.** Sphagnum moss samples on display. (Photo credit: Tim Patterson)

*Ireland, Girley Bog Meitheal, GSNI, Irish Peatlands Conservation Council, Keep Northern Ireland Beautiful, Marble Arch Geopark, Mourne Heritage Trust, National Parks and Wildlife Service, Northern Ireland Environment Agency, Northern Ireland Water, RPS Group, RSPB, The Conservation Volunteers, The Living Bog Project and Ulster Wildlife. In the words of one member of the public who attended “this was a really fun event - I never knew that peat could be so interesting!”*

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# REPORTS

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## **EGU TRAINING SCHOOL FOR ECR. GLACIERS, MORAINES AND CLIMATE: CHALLENGES OF IDENTIFYING, DATING AND EXTRACTING PALAEOCLIMATIC DATA FROM FORMER GLACIER FLUCTUATIONS**

**13-16<sup>th</sup> August 2018, Inchnadamph, Scotland**

Reconstructions of former ice extents provide valuable information to improve our understanding of past atmospheric circulation and climate changes. However, existing paleoglaciological approaches often lack the cross-fertilization of ideas that lifts the impact of inter-disciplinary research beyond the sum of its parts. Our EGU-supported training school encouraged early career researchers to integrate multiple lines of glaciological evidence in their studies to strengthen their findings and embrace a more holistic research approach. Our group of international experts covered geomorphological, sedimentological, limnological and geochronological approaches and highlighted their synergies at the forefront of currently relevant paleoglaciological research topics. Nineteen participants from 12 nationalities attended during the summer holiday season, demonstrating the timeliness and appeal of this initiative (Figure 1). Set in the intimate informal setting of the small Inchnadamph Hotel in the Northwest Highlands of Scotland, this initiative allowed participants to discuss, question and meet in a safe environment – building future collaborations.

### **Training School objectives**

Glaciers are highly sensitive to climate change, as demonstrated by their rapid retreat in response to on-going warming. Beyond instrumental observations, different types of geological evidence document the past response of glaciers to climate change. Key examples include moraine ridges, providing snapshots of past glacier extent, or glacial lake sediments, recording continuous changes in glacier activity (Figure 2). When dated, such evidence provides us with critical information on the amplitude and pattern of climate variability over thousands of years. This long-term perspective contextualizes on-going warming and helps us understand Earth's climate system. Consequently, glacial features and landforms rank as first-class climate change archives. However, a lack of cross-fertilization between the different disciplines involved in paleoglacial studies (e.g. geomorphology, limnology and geochronology) restricts this research potential. Against this background, we organized our EGU-supported training school on “Glaciers, moraines and climate: Challenges of identifying, dating and extracting palaeoclimatic data from former glacier fluctuations” to accomplish the following aims:



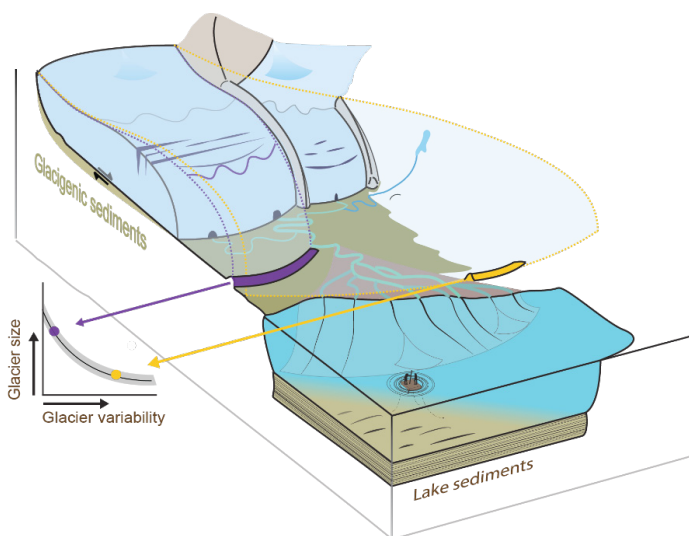
**Figure 1.** Organizers and participants in the field

1. Introduce and train (theory and practice) young geoscientists to the multitude of tools available across the different relevant fields (e.g. geomorphology, sedimentology, limnology and geochronology), while raising awareness about their synergies and challenges
2. Encourage the participants to broaden their horizons and develop an inter-disciplinary mindset beyond their own specialized fields.
3. Favor inter-disciplinary networking and collaboration among the next generation of geoscientists.

### **Training School proceedings**

In order to achieve the above goals, we organized the Training School around:

1. **Field excursion:** field-based learning approaches are essential to link theory and observations in Earth Science, while creating a connection between subject and researcher. The Inchnadamph area, where we hosted our Training School, offers many textbook field sites that contain a wide array of glacial landforms that have been the subject of fierce debate and re-interpretation(s) (Figure 3). The background of these advancing insights represents tangible examples of the risks of specialized approaches, as well as the value of inter-disciplinary collaboration. Key examples include the integration of geomorphological and sedimentological evidence, as well as dated moraines and lake sediments.
2. **Lectures:** six theoretical lectures were given in a safe environment and informal atmosphere by international specialists from the fields of geochronology (Dr.



**Figure 2.** Simplified schematic used to highlight different lines of paleoglaciological evidence and their synergies.

Susan Ivy-Ochs and Dr. Natacha Gribenski), limnology (Prof. Jostein Bakke and Dr. Willem van der Bilt) and geomorphology/sedimentology (Dr. Clare Boston and Dr. Sven Lukas). We divided the lectures into three hour-long blocks with time-outs in between to allow participants to absorb, discuss and reflect upon content. Each lecture provided an overview of the current state of the art, listed key methodological challenges and highlighted synergies. At the end of this seminar, there were many opportunities for participants to ask questions linked to their own research, and to share their knowledge and experiences with the others

3. **Break-out sessions:** we divided participants into three groups with the objective for each group to identify key take-home points from the different Training School activities and discussions. These small discussion fora enabled young geoscientists from various specialized field to confront, explain and adapt their views through interaction with researchers from different disciplinary background.

## Key outcomes

1. **Instilling excitement for inter-disciplinary approaches:** we actively encouraged students to step outside their comfort zone in the intimate and non-threatening setting of Inchnadamph hotel and approach their research from new scientific angles. Halfway through the Training School, this approach started to pay off as participants were asking ever-broader questions, while reaching out for input from different archives/disciplines. We believe that participants no longer feel



**Figure 3.** Some of our visited field sites in the Inchnadamp area and respective key references for discussion.

threatened or insecure about inter-disciplinary research strategies, and that they will bring this newfound excitement for reaching out and broadening horizons to vitalize and invigorate their research.

2. ***Facilitating long-term collaboration:*** not only topical discussions, but also social downtime in the intimate setting of the Inchnadamp Hotel, allowed participants to network and establish collaborations. The organizers stimulated participants to use various digital tools (e.g. Twitter) to stay updated and in touch with one another. We also provided participants with a concrete opportunity to meet up again soon in real life, by hosting an eponymous session during the INQUA 2019 conference in Dublin.
3. ***Stimulating a follow-up:*** Both organizers as well as participants express their desire to reprise a similarly themed Training School to stimulate inter-disciplinarity amongst early career paleo glaciologists. We made sure to schedule a two-hour interactive evaluation on the final day to allow participants to suggest improvements for the future. Often-expressed desires included the integration of a modelling component, as well as a longer duration to allow for more in-depth discussion.

Participants and organizers alike greatly appreciated the financial support from the European Geosciences Union (EGU) and co-sponsorship from the QRA to help organize this Training School.

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## 23<sup>RD</sup> ANNUAL QRA POSTGRADUATE SYMPOSIUM

22rd – 24th August 2018,

School of Geographical and Earth Sciences, University of Glasgow

2018's QRA Postgraduate Symposium was held at the University of Glasgow (Figure 1). It was hosted by the School of Geographical and Earth Sciences and the Scottish Universities Environmental Research Centre (SUERC). Early Career researchers in the Biomarkers for Environmental and Climate Science (BECS) research group formed the organisation committee; made up of **Charlotte Slaymark** (PhD student), **Anca Amariei** (MRes student), **Mike Zwick** (PhD student) and **Scott Kirby** (MRes student). Their research focusses on various aspects of biomarker and microfossil proxy development and application for reconstructing late Quaternary climate. The conference was a great success thanks to the valuable support by staff in the department; **Prof. Jaime Toney**, **Dr Derek Fabel**, **Dr Hannah Mathers**, **Dr John Faithfull** and **Katrina Gardner**.

Eighteen students from fourteen universities attended the symposium, providing brilliant oral and poster presentations on exciting topics ranging from palaeoclimate/ecological reconstructions, glacial systems, landscape evolution and archaeology. Their research took us to diverse environments and locations including Patagonia, Australia, Yucatan, Canada, Shetland and Greenland.

### Day 1: PGR presentations and keynote speakers.

The conference started with the welcome lecture by **Dr John Faithful** who is a petrologist, mineralogist, geologist and curator at the Hunterian Museum. We enjoyed his entertaining presentation on the historical developments on early isotope research and some of its colourful characters involved in it. Isotopes were discovered by Freddirck Soddy at the University of Glasgow in 1913 and the term 'isotopes' was suggested by his wife whilst at dinner on the campus.

The afternoon continued with excellent contributions by PGR students **Monika Mendelova**, **Mike Zwick**, **Coleen Murty**, **Aiden Starr**, **Allan Cochrane**, **Rachel Devine** and **Luis Rees-Hughes**. Their talks focussed on various aspects of glacial systems, palaeoclimate reconstructions, landscape evolution and archaeology. We heard about Patagonia de-glaciation at the end of MIS 5, the development of long-chain diols as paleothermometers, the proxy potential of moss specific biomarkers and inferences of climate from subarctic ice-rafted debris over the last one million years. Presentations also covered chironomid temperature reconstructions for the Late Glacial in Northern Scotland, the trials and revelations of differences between varve counting methodologies for a Swedish Varve sequence and the development of ground-penetrating radar data to inform 3D modelling.



**Figure 1.** Conference location in the historical Main Building (University of Glasgow).

The final and keynote talk of the day was provided by **Prof. Jaime Toney** who is the head of BECS (Biomarkers for Environmental and Climate Science) Laboratory. She uses organic geochemistry as a tool to understand how the earth system responds to past, present and future change. She gave us an introduction to her background in Quaternary Science, working in palynology and Holocene climate changes whilst studying and working in the USA. Her talk included some of her PhD work on the development and application of alkenones in lacustrine systems for use as a quantitative proxy for temperature, as well as North Atlantic Ocean Oscillation reconstructions during the Holocene and an overview of the array of research sites around the world being investigated by her group using organic geochemistry.

The first day ended well by an evening get together in the 78 bar, situated in Glasgow's West End. A decent selection of beverages was enjoyed over conversations of the day's research topics. It was a great opportunity for old friends to meet up, new ones to get to know each other and for all to discuss life as a PhD student.

## **Day 2: PGR presentations, CV workshop and SUERC visit**

In the morning of the second day we heard presentations by **Luke Andrews**, **Emily Wiesendanger**, **Adam Bermingham**, **Caitlin Nagle** and **Luke Dale**. Their research topics belong within palaeoecology, landscape evolution and archaeology. They presented their research on; carbon cycling in peatlands, Late Pleistocene reindeer migration and seasonality and the land-use strategies of the ancient Mayas and Holocene sea level changes in the Dysynni Valley. We finished the oral presentations on the topic of early Neanderthal social and behavioural complexity during the Purfleet Interglacial.

We then had a great CV writing workshop provided by **Katrina Gardner** and supported by **Dr Hannah Mathers**. Mrs. Gardner is a Careers Manager at University of Glasgow and offers consultations and workshops helping to develop strong job

applications. After she offered some general remarks, we discussed ways on how we can improve our CVs to communicate our strengths. **Dr Hannah Mathers**, a Quaternary glacial geomorphologist complemented the workshop by providing specific teaching and field skill CV tips.

The poster session followed, paired with a great lunch. **Sophie Williams, Kristy Holder, Joanna Tindall** and **Sophie Vineberg** presented in the session. During their poster presentations and in discussion, we learned about multiproxy approaches in Holocene carbon accumulation reconstructions, ostracod isotopes as tracers of climate change, cryptotephra in Greenland and recent change to salt marshes in Australia.

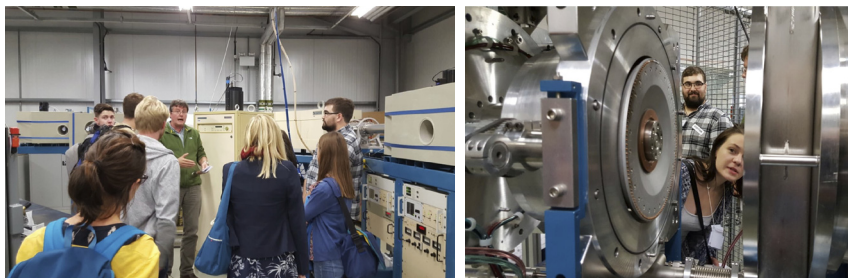
The afternoon was spent at the Scottish University Environmental Research Centre in East Kilbride, 20 minutes outside of Glasgow. We started the visit with a presentation on radiocarbon dating by the Head of NERC Radiocarbon Facility – **Dr Philippa Ascough**. We then toured the NERC chemistry laboratory with **Dr Pauline Gulliver** and enjoyed a lively tour of AMS 14C instruments from **Dr Derek Fabel** (Figure 2). Seeing ‘the journey’ of a radiocarbon sample helped many students understand the meticulous work that goes into producing the ages for their quaternary research.

After our return to the University we headed to the Italian restaurant Zizzi’s, to enjoy a 3 course conference dinner and to fuel us for an evening of Ceilidh dancing. The key aim for this evening was to have a much fun as possible without being self-conscious of not knowing the steps to the dances. The band had an excellent compare, which helped the many of us who knew little of the dances but ensured we learnt quickly.

During the evening, we also announced the winners of this year’s best oral and poster presentation, decided on the next QRA PG representative and next year’s hosts. **Aidan Starr** was voted the best oral presentation for his presentation: “1 Million Years of Ice-Rafted Debris Variability from the Agulhas Plateau, Subantarctic Zone”. The best poster was by **Sophie Williams**, entitled: “Digging in mud: How Australian salt marshes can resolve the mysteries of a faraway melting ice sheet.” Congratulations to their and everyone’s great contribution to this year’s QRA PG Symposium. **Luis Rees-Hughes** (University of Leeds) was elected for postgraduate representative on the QRA committee and next year’s symposium will be held at the University of York.

### **Day 3: Field visit to Quaternary sites in Loch Lomond south**

As tradition, the third day of the symposium hosted a field visit. We met on Gilmore Hill, a drumlin on which the University sits on. PhD student **Charlotte Slaymark** and supervisor **Dr Derek Fabel** planned a tour of Quaternary sites in the Loch Lomond south area with support from **Dr Hannah Mathers**. The stops throughout the day focussed on the morphological evidence and timing of ice



**Figure 2.** Dr Derek Fabel explaining technical aspects of AMS 14C dating at SUERC.

retreat during the Dimlington and Loch Lomond stadials.

The first stop was a short 20-minute drive to Bardowie Loch, one of Charlotte's research sites. It has been the focus of several undergraduate projects in the School of Chemistry and Geographical and Earth Sciences at the University. Great thanks to **Alistair Angus** from the Clyde Cruising club for access to the site. The club uses the loch for sailing and was very supportive of and interested in the research carried out. We heard from Derek on the path of ice retreat in the Dimlington stadal. This is evident by the drumlins orientated west east around Bardowie. Charlotte presented the stratigraphy of the loch's sediments and new chronological data for the site. Her research focuses on the development of biomarkers to reconstruct climate. We moved into the sailing clubhouse as the wind picked up and continued hearing from Charlotte on her pilot study using n-alkane biomarkers to reconstruct vegetation change in the Late Glacial.

We left the site after delicious homemade snacks from Hannah and headed North West for a short hike up to some exposed, striated bedrock outside the village of Strathblane. From here, we also viewed slope processes on the Campsie Fells and discussed Colin Ballantyne's work on slope failures during the Holocene which is attributed to tectonic activity rather than the rebound effects caused by ice unloading. To reach the third site we drove along the lake floor of glacial palaeo-Lake Blane. We travelled to Croftamie to discuss the work of Jim Rose, Alison MacLeod and others on the southernmost extent and the timing of the Younger Dryas ice extent in Scotland. Students engaged in discussions on the stratigraphy, varve chronology and radiocarbon dating utilised to constrain the stadal. Although the area was very overgrown this summer and sediments were not visible, merely being at the site impressed everyone due to its 'celebrity' status as the type-site for the Younger Dryas in Scotland.

We then drove north, up the eastern shores of Loch Lomond to reach Rowardennan. The striated bedrock and p-forms at the shoreline provided the perfect picnic stop for lunch. We took in the views of the Western Highlands and students explored



**Figure 3.** The group on Duncryne, with views North of Loch Lomond (top) and striated bedrock near Strathbane (bottom).

the area looking at evidence of the Younger Dryas glaciation there. We moved on to the last stop - a volcanic plug at Duncryne. Not strictly a Quaternary site, but it did provide a view point from which we can see the pathways that ice travelled during the late Quaternary. We hiked up the landform and were rewarded with panoramic views (Figure 3). Northwards we saw Loch Lomond and the Western Highland Boundary Fault. Eastwards we saw the Campsie Fells and drumlins orientated north south because of the Younger Dryas ice retreat. To the south, a Younger Dryas end-moraine was just visible in the distance. We returned to Gilmore Hill and said goodbye until next year.

We are very grateful to Van Walt for their generous sponsorship of the symposium, which enabled this field visit. Also, a special thanks to Derek Fabel for producing field maps and figures for presenting in the field. In addition, thanks to Derek and Hannah for sharing their enthusiasm and knowledge for Quaternary Research throughout the day. Much appreciation was voiced from students on the journey back to campus.

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# INTEGRATING DIVERSE KNOWLEDGE SYSTEMS FOR FIRE MANAGEMENT AND BIODIVERSITY CONSERVATION

4-7<sup>th</sup> September 2018, Royal Holloway, University of London

Over the last few years, the occurrence of highly devastating, catastrophic fires (e.g. Portugal in 2017 and California in late 2018) is increasingly getting the media's attention and raising debates about best mitigating strategies for severe wildfires, especially at the wildlife-urban interface (Moritz *et al.*, 2014). Understanding the role of fire in a warmer world (e.g. Fischer *et al.*, 2018) is therefore of paramount importance to tackle future challenges about fire impacts on ecosystems and societies.

Regional and global syntheses of biomass burning over millennia through the Global Charcoal Database (GCD; [paleofire.org](http://paleofire.org)) emphasized the complex interactions between fire, climate and people on decadal to millennial time scales (e.g. Daniau *et al.*, 2012, Marlon *et al.*, 2012, Vannière *et al.*, 2016a, Power *et al.*, 2018), and the need for an improved understanding of past fire dynamics in key geographic regions (e.g. Colombaroli *et al.*, 2014). With the growing need in the Quaternary Science community to make palaeodata interpretation more accessible to applied disciplines (Colombaroli *et al.*, 2017, Vannière *et al.*, 2016b), the Global Paleofire Working Group (GPWG2) is promoting new cross-cutting approaches that includes both the stakeholder's needs and the decision making process.

Between 4-7 September 2018, ca. 30 international participants gathered at Royal Holloway, University of London, to discuss integrative approaches to inform current Fire Policy and Biodiversity conservation. The workshop, titled: "*Diverse knowledge systems for fire policy and biodiversity conservation: integrating palaeoecology, traditional knowledge and stakeholders*", was coordinated by **D. Colombaroli**, **B. Vannière**, **A. Milner**, **J Mistry**, with the support of the GPWG2 and ECR/PAGES ECN leaders, **C. Adolf** and **D. Hawthorne**. Participants included modern ecologists and palaeoecologists, physical and cultural geographers, park managers and researchers working at the science-policy interface. Such diverse background and expertise from both the northern and southern hemispheres was conceived for promoting the knowledge transfer from palaeofire research to more applied science (Colombaroli *et al.*, 2017, Blarquez *et al.*, 2018).

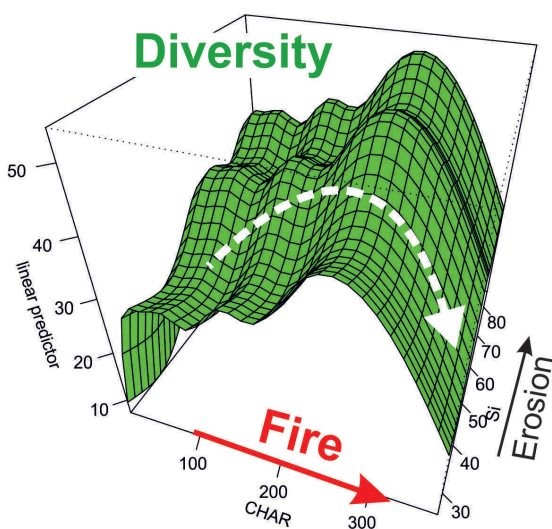
The meeting included keynote speakers and breakout/plenary sessions (details via this [hyperlink here](#)) to prioritize and discuss topical challenges for fire policy and ecosystem management. To achieve this goal, and to promote a more direct involvement of policy makers and stakeholders in the discussion, key priority challenges were selected in collaboration with the Department for Environment, Food and Rural Affairs (DEFRA) prior to

the workshop. During the four days of the workshop, participants discussed and provided evidence-based expertise on: the impact of changing climate and land use on fire regimes, the rates of ecosystem recovery after fires, the optimum fire regimes required to achieve management objectives, and the effects of certain land-management practices including prescribed burning.

**Day 1** of the workshop focused on the current “fire issue” in the context of the long-term fire variability observed during the Quaternary, and accounting for the role of traditional land-use practices in present ecological systems (e.g. Mistry and Berardi, 2016). Breakout-groups identified specific case studies on post-fire vegetation recovery, sustainable land use practices successfully implemented by local communities, and conditions that maximize biodiversity across ecosystems (e.g. Colombaroli *et al.*, 2013, Fig 1).

**Day 2** provided complementary examples on fire risk and ecological impacts, with a visit to Chobham Common, the largest National Nature Reserve in South East England (lead by George Rockell, Surrey Wildlife Trust see [hyperlink here](#)). Based on the feedback from the first two days of group discussions, **days 3 and 4** focused on using our collective knowledge to identify appropriate restoration goals for fire management and ecosystem conservation. Groups also identified key knowledge gaps and the critical role of traditional knowledge for sustainable landscape management. The discussion highlighted the need of balancing specific targets in areas that offers conservation challenges on both natural and cultural values (Whitlock *et al.*, 2018), and the identification of alternative management objectives that best meet landscape management goals, for instance by including local community knowledge into decision-making processes. In the final sessions of the workshop, participants began drafting a Policy Brief that included specific recommendations, highlighted key knowledge gaps and put forth ideas for integrating science and management in the future (to be released in late 2019). Additionally, several Early Career Researchers (lead by Carole Adolf and Donna Hawthorne) gathered to develop a systematic review (<https://www.roses-reporting.com>) to evaluate the effects of changing climate and land-use practices on local-to-global scale fire regimes.

This workshop offered a novel and alternative approach to foster collaboration among ecosystem practitioners, academic scholars and policy makers with themes that included “palaeoecology informed conservation” (i.e. long-term perspectives), “local community-owned conservation” (i.e. traditional practices and modern management perspectives), and the importance of “stakeholder-driven research”. This integrated framework provided capacity building and network development for researchers working at the interface between Palaeoecology, Ecosystem management, Biodiversity conservation and Fire ecology. The Palaeofire community will continue to provide user-friendly web-tools for data access (Paleofire.org, Vanniery *et al.*, 2016b) for all stakeholders (scientists, ecosystem managers, traditional and modern fire practitioners and policy-makers). Complementary



**Figure 1.** Top: a recent fire in Chobham common affected vegetation structure and composition, with consequences on soil nutrient cycling and erosion. Bottom: optimal conditions for biodiversity following fire, together with the long-term effects on soil erosion, as reconstructed from lake sediment records (modified by Colombaroli *et al.*, 2013).

initiatives led by the GPWG2 include the development of community tools for data analyses (Blarquez *et al.*, 2014), database standardization, and integration of other data-sharing platforms via web-services (e.g. NEOTOMA). Finally, the inclusion of other fire-related proxy (e.g fire-scarred tree rings data, biomass burning metrics from ice cores, soil charcoal, etc.) will help the community to design and develop new projects across the Quaternary Sciences.

## Aknowledgements

More information about interdisciplinary work in the field of Conservation Palaeobiology and engagement with external stakeholders is further available on our website and Twitter accounts (@paleofireWG, @diverse\_k). We would like to thank the GPWG community for promoting and inspiring this initiative, and Past Global Changes (PAGES), the QRA, and UMR-CNRS Chrono-environnement at Université Bourgogne Franche-Comté for funding.

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**9<sup>TH</sup> INTERNATIONAL SYMPOSIUM ON TESTATE AMOEBAE  
(ISTA9):  
RECENT ADVANCES AND FUTURE RESEARCH PRIORITIES**

**10-14<sup>th</sup> September 2018, Belfast**

Testate amoebae are an important group of protists that preserve well in sediments and are highly sensitive to environmental change. Research with the group is evolving rapidly, and there have been many recent advances, most notably in the applications of testate amoebae for reconstructing hydrological changes in peatlands and other wetland environments, in biomonitoring and bioindication, and in the sub-fields of phylogenetics and morphometric studies. These topics were amongst the themes under discussion at the '*9th International Symposium on Testate Amoebae*', which was held in Belfast between 10-14 September 2018 and attended by 56 delegates, including participants from as far afield as Brazil, China and New Zealand. We thank the **QRA for co-sponsoring the sessions on 'Palaeoecology and Palaeoclimatology' and 'Ecology and Bioindication' on 11-12<sup>th</sup> September**, which included 26 presentations (16 oral presentations and nine posters).

The opening '*Palaeoecology and Palaeoclimatology*' session focused on records from peatlands and fenland environments. **Anna Šímová** (Masaryk University, Czech Republic) and **Marissa Davies** (University of Toronto) both highlighted the importance of peatland testate amoebae for reconstructing late Holocene climate change, presenting work from Southern Poland and the Hudson Bay region respectively. **Andrey Tsyganov** (Moscow State University) showed how testate amoebae can be used to track floating *Sphagnum* mat development in the mixed forest zone of Russia, whilst **Graeme Swindles** (Leeds University) reviewed some of the benefits and challenges of collecting peatland testate amoeba records from Amazonia. Flash poster presentations by **Anatoly Bobrov** (Lomonosov Moscow State University) and **Liam Taylor** and **Graeme Swindles** (Leeds) extended the geographical focus to sub-arctic and arctic environments, the latter showing how testate amoebae can be used to track peatland responses to recent climate change and permafrost degradation.

Testate amoeba-derived transfer functions have played an important part in understanding Holocene climate change in many regions, and there have been advances both in modelling approaches and the development of training sets. **Matthew Amesbury** and **Tom Roland** (Exeter University) gave an overview of two new continental-scale peatland training sets from North America and Europe, highlighting some of the challenges of collating records and the advantages of the datasets to the community.

**Caroline Meyer** (UMS Patrimoine Naturel, Paris) delivered the opening keynote address in the *Ecology and Biodindication* session, showing how testate amoebae have great potential for tracking airborne contaminants in peatlands. Developing this theme, **Alex Whittle** (Exeter University) showed how peatland testate amoeba records from islands in the Southern Ocean can provide fascinating insights into changing patterns of salt-spray deposition and wind directions.

Several talks focused on fenland environments or peatlands which have undergone terrestrialisation or other forms of alteration. **Dominka Łuców** (Adam Mickiewicz University, Poland) showed how testate amoebae can be used to track deforestation caused by tornadoes and anthropogenic forest clearance in Poland, whilst **Yangmin Qin** (China University of Geosciences) discussed the response of peatland testate amoebae to fires. **Marius Lamentowicz** (Adam Mickiewicz University, Poland) gave an overview of the responses of the group to nutrient enrichment in fens, and **Richard Payne** (York University) discussed the interactions between bog testate amoebae and trees. **Isabelle Koenig** (University of Neuchâtel, Switzerland) completed this set of presentations with an overview of the applications of testate amoebae for peatland monitoring and restoration.

The emphasis on the second day moved to lakes. **Tim Patterson** (Carleton University, Ottawa) gave a QRA-sponsored keynote talk that reviewed developments in the study of lake Arcellinida (testate lobose amoebae), underlining how advances in coring technologies (e.g. freeze-coring) can aid in the acquisition of high resolution records that are essential for tracking the responses of Arcellenida to contaminants. Other members of the Carleton group developed this theme, **Nawaf Nasser** showing how lake testate amoebae are sensitive indicators of Arsenic contamination, and **Charlotte Coburn** and **Braden Gregory** discussing responses to winter de-icing salts. A poster by **Angel Wen**, also from Carleton, considered spatial and inter-annual controls on lacustrine testate amoeba communities in a lake in eastern Canada.

The remaining sessions of the conference focused on phylogenetics, taxonomy, the development of novel analytical approaches and interactions between testate amoebae and other microbial groups. A recurrent theme was the need for greater integration of approaches within the research community, particularly the need to use phylogenetic studies to refine taxonomy and systematics, and further emphasis on understanding the complex interactions between shell morphology, environment and evolutionary processes.

A fieldtrip on the final day of the meeting included a visit to a County Antrim peatland, providing the delegates with the opportunity to examine bog vegetation at close hand and view changes in peat humification driven by climate change.

All in all the meeting was a great success; the discussions were lively and productive and the social events, which included a conference dinner in Belfast City Hall (Figure 1) and a ceilidh, provided further opportunities for delegates to interact informally. Some delegates also participated in an outreach event on Irish Peatlands which was held one evening during the conference (see report in this issue p.52). This gave the peatland researchers the opportunity to meet agency representatives and volunteer groups involved in peatland management across Ireland as well as members of the public.

The next meeting of the biennial 'ISTA' series will be held at Brock University, St. Catharines, Ontario, Canada in 2020.



**Figure 1** ISTA9 delegates at Belfast City Hall, the venue for the conference dinner. Photo credit: Joe Fitzgerald.

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# 2019 QRA ANNUAL DISCUSSION MEETING ENVIRONMENTAL CHANGE: PACE, MAGNITUDE AND IMPACT

University of Chester, 3<sup>rd</sup>-5<sup>th</sup> January 2019

The 2019 QRA Annual Discussion Meeting was hosted by the Department of Geography and International Development, University Chester. The conference was organised by **Graham Wilson, Katharine Welsh, Amanda Williams** and **Dale Tromans** (University of Chester), and was attended by 66 delegates (including 15 PhD students) from the UK, Ireland, Singapore, South Korea, Austria, France and Canada. The ADM theme was '*Environmental Change: pace, magnitude and impact*' and coincided with the 50<sup>th</sup> Anniversary of the formal adoption of the name 'Quaternary Research Association'. This was marked in a specially invited talk by **Frank Oldfield** (University of Liverpool and former QRA president), who reflected on a 60+ year career in Quaternary science. Quantifying the pace, magnitude and associated impacts of environmental change are key overarching themes in Quaternary research. Investigating these central themes drives our understanding of system behaviour and interconnectivity, and fundamentally informs the effective management and stewardship of the natural environment. The ADM was an opportunity to disseminate some key advances in these areas amongst the diverse Quaternary science community. As such, the conference was organised into four thematic sessions:

- I. Terrestrial depositional sequences (chaired by **Katharine Welsh**, University of Chester)
- II. Marine and nearshore depositional sequences (chaired by **Will Fletcher**, University of Manchester)
- III. Geomorphic records (chaired by **Amanda Williams**, University of Chester)
- IV. Record integration and system simulation (chaired by **Mick Frogley**, University of Sussex)

Adopting such a framework facilitated the discussion of emerging challenges and provided a platform to encourage cross-disciplinary interaction and integration. Each thematic session was opened with a keynote address, and closed by specially-invited talks from early career researchers who have made a significant contribution to their respective fields. A total of 36 oral presentations were delivered, and 16 posters presented. Throughout the event, new and stimulating material was presented, providing the impetus for many thought-provoking discussions, debates and exchanges of ideas. This report focusses upon the oral presentations, but a range of excellent posters were also presented on which the authors must be congratulated.

**Christine Lane** (University of Cambridge) opened the *Terrestrial Depositional Sequences* session with a keynote address on 'Volcanic chronologies and tephra connections in East Africa.' This important work aims to improve the tephra record of East Africa by identifying visible and crypto tephra layers within mid to late Pleistocene lake deposits across the region. This will allow paleoclimate and archaeological archives to be placed within a regional tephrostratigraphic framework. **Lauren Davies** (University of Alberta, Canada) presented a case study from Cascade Lake, Alaska, demonstrating the challenges of achieving reliable age estimates of Holocene lake sediments in this region. A range of radiometric dating approaches were applied to the sequence and compared with isochrons determined from the cryptotephra record. The work highlighted the issue of old carbon contamination, which caused age offsets of up to 2800 years. **Graham Wilson** (University of Chester) presented a new Penultimate Glacial (MIS 6) diatom record from Lake Ioannina, NW Greece, which provided firm evidence that climate instability pervaded the entire penultimate glacial in southern Europe. **Joanne Egan** (Edge Hill University) rounded off the morning session. Her talk focussed on the utility of the Holocene diatom record of Moss Lake, Washington, to determine limnic responses to climate changes in the Pacific northwest region, particularly in relation to variations in ENSO, PDO and solar output.

**Mick Frogley** (University of Sussex) continued the lake sequence focus after lunch with a talk on the mid- to late Holocene lacustrine response to millennial scale climate forcing in the southern Peruvian Andes. He detailed a highly resolved 5000-year multi-proxy record which revealed periods of aridity coeval with lowered sea surface temperatures in the North Atlantic. He revealed that this pattern was in anti-phase with many other records across the southern South American tropics, suggesting a more dominant role for Pacific climate drivers in modulating the intensity of the South American summer monsoon. Such records are instrumental to better understand the climatic context for key events in societal evolution in the region, such as the first appearance of maize agriculture. **Will Fletcher** (University of Manchester) investigated the pollen and non-pollen palynomorph record of an alpine marsh in the High Atlas, Morocco, to determine the influence of snow melt on alpine ecology over the last 500 years. The record revealed recurrent multi-decadal to centennial wet shifts, thought to be driven at this site by changes in winter snowfall and subsequent snowmelt. The work highlights the potential of such records to determine the influence of High Atlas snowpack and glacier dynamics on wetland development, which in turn has important implications for enhancing the pastoral economy. **Matthew Jones** (University of Nottingham) reviewed work using Proxy System Modelling (PSM) of lake  $\delta^{18}\text{O}$  at varying scales. PSM skill was assessed by comparing empirical  $\delta^{18}\text{O}$  records with a 1000-year pseudoproxy time-series of lake carbonate calculated for every terrestrial grid square in the SPEEDY-IER isotope enabled GCM. The model replicated general patterns of spatial variability in the empirical data, with future work aiming to further improve PSM skill by using larger lake  $\delta^{18}\text{O}$  datasets

and comparing the impacts of varying hydrology, basin size and shape. **Meighan Boyd** (Royal Holloway, University of London) took us a little further back into the Quaternary and explored climate changes during the Last Glacial as recorded in multi-speleothem sequences from Gibraltar. The records span the interval 110-30 ka, and are underpinned by seventy U-Th dates. The highly-resolved (10-20 yr)  $\delta^{18}\text{O}$  and  $\delta^{13}\text{O}$  dataset provides an important new climate record, particularly of the tempo and magnitude of rapid climate variability in the Western Mediterranean during the last glacial. The final presentation of the day was an invited talk by **Gina Moseley** (University of Innsbruck, Austria). Gina provided a captivating talk on the potential of cryogenic cave calcite (CCC) deposits to track the demise of permafrost during the last glacial. She also demonstrated the power of citizen science (and persuasion), with the caving community promised rewards of beer and rope to search for CCCs in UK caves; they duly found examples at a number of UK sites! This promises to be truly transformative research, allowing a chronological basis for permafrost response to rapid climate change during the last glacial.

The AGM (including the medal ceremony), chaired by **Neil Glasser** (Aberystwyth University), was held on the afternoon of the 3<sup>rd</sup> January. The James Croll medal was awarded to **Ann Wintle** (Aberystwyth University), with **Clare Boston** (University of Portsmouth) receiving the Lewis Penny Medal and **Phil Gibbard** (University of Cambridge) an Honorary Membership (see QN 146, February 2019 for details). These deserving recipients were very warmly congratulated by the delegation. **Jack Wharton** (University College London) won the Undergraduate Dissertation Prize for his work on '*Reconstructing AMOC over the past 7,000 years: is the Industrial Era weakening an unprecedented event?*' (see QN 146, February 2019 for details). Additionally, excellent undergraduate dissertation research by **Tamara Brian** (University of Cambridge) and **Annabel Everard** (University of St Andrews) was recognised with a 'Highly Commended' award. The ADM was followed by a wine reception and a chance to view a range of poster presentations detailing new and exciting research.

On day 2 of the conference, **Maria Fernanda Sánchez Goñi** (EPHE, PSL University, France) opened the *Marine Depositional Sequences* session with the **Wiley Annual Lecture** 'Air-sea-ice interactions at orbital and millennial timescales: the puzzle of the Ice Ages'. Maria delivered a thought-provoking talk on unresolved puzzles in Quaternary climate change. She used the MIS 19 inception and the MIS 4/5 transition as examples to explore the link between changes in Earth's orbital parameters and climate. She then went on to review the character of different climate cycles, and the role played by internal feedbacks in explaining their pacing since the Middle Pleistocene Transition. Central to this discussion was the impressive data that has emerged from European marginal sequences, including a recent 1.4 Ma long sequence from IODP site U1385. **Mark Hardiman** (University of Portsmouth) provided a lesson in tenacity, with a pain-staking search for volcanic ash deposits in ODP 980. This work has now led to the first complete

tephrostratigraphic framework for MIS 11 and MIS 9 in the North Atlantic. The potential of this new record was discussed, particularly its use in differentiating between MIS 11 and MIS 9 deposits in the Northern European terrestrial record. **Mark Coughlan** (University College Dublin) demonstrated the importance of the Western Irish Sea Mud Belt (WISMB) sediment depocentre in understanding the palaeoenvironmental changes in the North Irish Sea, from the advance of the British-Irish Ice Sheet during the last glacial, through to contemporary evidence of anthropogenic disturbance from trawling and radionuclide contamination. A thick accumulation of Holocene material is also present in this depocentre, detailed multiproxy analysis of which is yielding a record of WISMB development. **Mark Bateman** (University of Sheffield) explored the Storegga tsunami depositional sequence from the Montrose basin, Scotland. The advantages of utilizing OSL to precisely date this event was exquisitely demonstrated, with detailed analysis of the deposits, including single-grain measurements, allowing a highly constrained age to be determined.

After coffee, the shift focussed to sea-level. **Graham Rush** (University of York) presented new records of early Holocene relative sea-level change from the Ythan Estuary (Scotland), and from the Falkland Islands. Graham's work is particularly concerned with the centuries preceding the '8.2 ka event', where he is using the sediment record to detect the source and relative importance of freshwater inputs. Next, **Timothy Shaw** (Nanyang Technological University, Singapore) presented a new 4,000-year relative sea level record from Chesapeake Bay (USA) based on fossil foraminiferal assemblages in a salt marsh peat. He found that modern rates of relative sea-level rise are unprecedented in the last 4,000 years. **Geoff Richards** (University of York) detailed a novel approach to extracting relative sea-level records from back-barrier peat sequences, based on the observation that tidal height governs groundwater levels in back-barrier marshes. New sea-level index points were presented from back-barrier sites in northwest and southwest Wales, and the potential of these records discussed. **Martina Conti** (University of York) detailed another novel approach to identifying past sea-level change. The utility and performance of biomarkers was demonstrated and assessed using a sediment sequence from the mid-late Pleistocene. Martina concluded that this approach holds great promise, not least because it allows an insight into the sensitivity of response of different primary producers to changing conditions. An invited talk by **Niamh Cahill** (Maynooth University, Ireland) rounded off the morning talks and the thematic session. Niamh provided an engaging overview of Bayesian statistical models, and their application in analysing former sea-level records. Niamh has been instrumental in developing and applying Bayesian statistical models to paleo sea-level datasets. She provided examples of the power of this approach, which allows the rates of sea-level change to be accurately constrained. Application to US Atlantic East coast palaeo records reveals that the rate of 20<sup>th</sup> century sea level rise exceeds those of at least the past 15 centuries.

**Phil Hughes** (University of Manchester) opened the *Geomorphic Records* thematic session with the keynote address 'Quaternary glaciations in the Mediterranean mountains: extent, timing and palaeoclimate significance'. Phil provided a detailed review of the extent and chronology of the Pleistocene mountain glaciers of the Mediterranean region, and identified the key controls on both the extent and timing of mountain glaciation in this region. His talk also highlighted the transformative impact that cosmogenic exposure dating has had in this field. **Ben Davenward** (Keele University) added to the glacial theme with a discussion on 'megaslumps' in the Canadian Northwest Territories, which are developing and expanding following exposure and melt-out of ground ice in response to rapid climate change. Ben presented some preliminary results of ongoing research, which aims to apply a range of techniques to determine the presence, extent and land systems context of ground ice within glacial environments. **Stephen Davison** (CGG Services (Robertson) Ltd.) explored much smaller-scale features, specifically the surprising discovery of euhedral quartz overgrowths in a glacial sequence from Anglesey, Wales. This discovery highlights the possibility that quartz cements can form at lower temperatures and pressures than previously thought. **Clare Boston** (University of Portsmouth) presented results of a large-scale survey of the sedimentary architecture and morphology of the Brampton kame belt. The work also sought to test the application of GPR in investigating complex glaciofluvial landform-sediment assemblages. Such an approach enables a more detailed understanding of individual landform evolution within the kame belt, and thus further insights into sub- and ice-marginal meltwater drainage pathways during the recession of the British-Irish ice sheet.

After the coffee break, **Becky Briant** (Birkbeck, University of London) reported on 35 years of research in the Sussex / Hampshire Coastal Corridor (SHCC). SHCC sediment deposits, such as the Pagham raised beach, have been used previously to constrain mean sea-level position during the Last Interglacial high stand. A detailed study of SHCC deposits by Becky and co-workers reveals that the Pagham raised beach and other deposits within the Solent seaway were likely emplaced at elevations well below mean sea-level. This work provides a cautionary tale of uncritically relating clastic sequences to sea-level position. **Trevor Faulkner** (University of Birmingham) considered the evolving eustatic and isostatic contexts of glacials and deglaciations, and how changing conditions are expected to have led to the formation of, now-submerged, caves beneath the Norwegian Sea. **Geoff Duller** (Aberystwyth University) presented some truly ground-breaking research into the novel application of luminescence dating of cobbles. The evaluation of this method is ongoing, but results indicate the potential to obtain more precise luminescence ages than is possible with sand-sized grains. **Rachel Smedley** (University of Liverpool) closed the session with an invited talk which critically reviewed the advantages and disadvantages of luminescence dating. In particular, Rachel focussed on the challenges of using single grains of both quartz and

k-feldspar for luminescence dating. She demonstrated how such challenges can be overcome, using examples from some of her recent work on glacial sediments from Patagonia and as part of the BRITICE-CHRONO project.

The Conference dinner was held later that day at Chester Cathedral, offering an evening of discussion, comradery and good food and drink (Figure 1). A celebratory evening was topped with a commemorative cake for the 50<sup>th</sup> Anniversary of the formal adoption of the name 'Quaternary Research Association' and with **John Lowe** (Royal Holloway, University of London) proving a memorable after-dinner speech. His speech covered an array of topics, from the importance of the 1977 INQUA congress to the QRA, through to the critical role of a society like the QRA in the current challenging academic climate. The evening was concluded with a toast to the QRA and some late-night discussions thereafter.



**Figure 1.** The 2019 QRA ADM conference dinner, Chester cathedral.

On the third and final day of the QRA ADM, dubbed 'Super Saturday', the thematic session *Record Integration and System Simulation* was opened with a keynote address from **John Dearing** (University of Southampton). In a compelling talk, John demonstrated the need to view modern environmental problems through the lens of complex social-ecological systems, and particularly the recognition of system resilience, system states, feedbacks and thresholds when considering human-environment interactions. The temporal extent of instrumental data is often insufficient for such a task, and the importance of a longer palaeoenvironmental perspective was highlighted, not least to determine the safe operating spaces for the use of lake-catchment systems. **Helen Roberts** (Aberystwyth University) detailed some impressive research into the application of luminescence dating of long lake sequences. The ability to accurately date lake sediment deposits beyond the radiocarbon limit is often challenging, and can severely limit the potential

of these archives. Working on long lacustrine sequences from eastern Africa, Helen demonstrated the application of luminescence dating to generate robust chronologies over the timescale of interest for understanding modern human evolution and dispersal. **Jonathan Dean** (University of Hull) provided some environmental context to the dispersal of anatomically modern humans (AMH) out of eastern Africa, courtesy of new lake sediment records from Chew Bahir (southern Ethiopia), which are thought to extent to c. 650 ka. Stable isotope analysis reveals changes in regional hydroclimate coeval with glacials and interglacials. Highly variable hydroclimate conditions continued to characterise the region between 116-66 ka, but the onset of a drier, but more stable climate (and thus of more habitable ecosystems) from 58-32 ka may help to account for the dispersal of some AMHs out of Africa.

After the coffee break, **Abi Stone** (University of Manchester) took us to the Wadi Dabsa basin, which contains one of the richest assemblages of Palaeolithic artefacts in southwest Saudi Arabia. To fully appreciate the environmental and chronological context of these artefacts, and thus of hominin activity in the area, Abi investigates the tufa carbonate deposits, which are widespread in the basin, indicating that the basin has experienced perennially wet intervals. Twelve tufa deposits were dated, and stable isotope analysis to determine source waters. This work is contributing to an improved understanding of the environments and landscapes occupied by Palaeolithic populations in the Saharo-Arabian belt. Moving on to more recent human activity, **Madeleine Moyle** (University of Liverpool) provided an impressive 12,000 year perspective of phosphorous and detrital erosion fluxes at Crose Mere, Shropshire. Intervals of elevated in-wash into the lake of particulate bound phosphorous coincided with episodes of increased human impact, as revealed in the pollen record. Linking 24 months of lake phosphorous monitoring with the sedimentary phosphorous record suggests that the EU threshold for poor nutrient status was exceeded c. 60 years ago, with declining nutrient status detected from c. 800 years ago. **Richard Chiverrell** (University of Liverpool) concluded the morning presentations with a talk presenting the first lake sediment-based palaeoflood reconstruction for the UK. In impressive detail, Richard provided an exemplar of the potential of lake sequences to record palaeoflood events. Meticulous analysis of a sequence from Bassenthwaite Lake, North West England, revealed that the cluster of devastating floods experienced from 2000 to present is without precedent in the 528-year Bassenthwaite lake palaeoflood record. Such palaeoflood records provide much-needed longer temporal perspectives on flood magnitude, with implications for risk evaluation and management.

The afternoon session was devoted to the recent subdivision of the Holocene, and to the debate surrounding the formal recognition of the 'Anthropocene' (Figure 2). **Mick Frogley** (University of Sussex) bravely agreed to chair the session and to attempt to keep a lid on the excitement. **Michael Walker** (Trinity Saint David, University of Wales, Lampeter, and Aberystwyth University) started the series of solicited

and extended talks by providing a detailed precis on the formal subdivision of the Holocene Series/Epoch, explaining the rationale of the subdivision, and detailing the nature of the GSSPs which delineate the Greenlandian, Northgrippian and the Meghalayan. **Mark Maslin** (University College London) immediately followed with a spirited talk entitled '*Goodbye Holocene. Welcome to the Anthropocene*' where he and colleague **Simon Lewis** (University College London and University of Leeds) argued for the formal recognition of the 'Anthropocene Epoch' to reflect the immense scale of human impacts on Earth. Mark distinguished five major stages in the development of human society, with each stage relying on increased energy, production, knowledge and environmental impacts, and evaluated each transition as a potential GSSP. Logically, he argued, the Pleistocene Epoch should be extended to meet the start of the Anthropocene Epoch, making the Holocene Epoch superfluous and hence downgrading it to a stage.

**Frank Oldfield** (University of Liverpool) presented the views of the Anthropocene



**Figure 2.** Question time! Views on the subdivision of the Holocene Epoch/Series and the recognition of an Anthropocene Epoch. Professor Michael Walker (left), Professor Mark Maslin (centre) and Professor Frank Oldfield (right).

Working Group of the Subcommittee on Quaternary Stratigraphy, on behalf of **Jan Zalasiewicz** (University of Leicester), who authored the slides used in Frank's talk. The range of stratigraphic proxies of recent human impact were reviewed, as was the progress in the search for candidate stratotype sections in preparation for a formal proposal for an Anthropocene Epoch/Series. After the initial presentations, a panel session featuring all three speakers was formed to allow delegates an opportunity to ask for opinions and views on the recent

subdivision of the Holocene, and the recognition of an Anthropocene Epoch. This prompted some lively discussion between members of the panel and individuals in the audience. We are particularly grateful to Michael, Mark, Frank and Jan for agreeing to provide extended presentations on these themes, and to Mick for doing a sterling job on managing the situation / session! In the wonderfully entitled talk 'A dinosaur reflects', **Frank Oldfield** (University of Liverpool) closed the conference by reflecting on his 60+ years in Quaternary science, and some of the many highlights of a long and very distinguished career. A truly special and moving talk, and a fitting end to what had been an enthralling and insightful three days of presentations.

The organising committee would like to thank the support of the QRA, and the valuable guidance and advice provided by **Becky Briant** and **Clare Boston** (current and former meetings officers, respectively), as well as Van Walt and Beta Analytic for sponsoring the event. A huge thank you to our keynote and invited speakers and all of those who attended the ADM, particularly so soon into the New Year (and in an INQUA year too)! We would like to extend our gratitude to all of the speakers and poster authors, and especially to those who, when approached by the organisers, kindly agreed to present their research at the conference. Graham, who is inept at all things social media, would especially like to thank **Abi Stone** for her fortuitous coverage of the conference via her Twitter account! We look forward to the next ADM meeting 'Quaternary Earth System processes, feedbacks and challenges for society' at the University of Leeds in 2020!

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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:

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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**.

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

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1 Abeermaur, Pembrokeshire

**3 OBITUARY**

3 Athur Massey ApSimon *Clive Gamble*

**2 ARTICLE**

2 Late Pleistocene coastal geology of the S'illot region, Alcudia, Mallorca: A classic location for Quaternary fieldwork teaching Steve Boreham, Julie Boreham

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13 *Acceptance of the Lewis Penny Medal Clare Boston*

**21 QUATERNARY RESEARCH FUND**

21 Caldey ('Kald ey' in Old Norse) was literally a 'cold island', but was it under Devensian ice? *John Hiemstra*

32 The fundamental knowledge gap in coastal terrestrial palaeoclimate records for Greenland. *Gina Mosely*

34 Pollen analysis of a peat profile from Shaft F46, Nosterfield Quarry, North Yorkshire. *James Innes*

**37 NEW RESEARCH WORKERS AWARD**

37 Bedrock mega-grooves in Assynt, Scotland - from landform to landscape. Mihaela Newton

40 Exploring the dietary ecology of extant mixed-feeding antelopes to investigate paleo-vegetation in eastern Africa (3.5-1.6 Ma) Lucile Cr    

44 Searching the geological signature of subduction zone earthquakes in the Pacific Coast of Mexico. J. Emmanuel Bustamente-Fernandez

**48 <sup>14</sup>CHRONO AWARD**

48 Creating palaeoenvironmental chronologies in semi-arid islands: A case from Cape Verde. Alvaro Castilla-Beltr    , Sandra Nogu    

**51 OUTREACH AWARD**

51 The secrets of Ireland's Peatlands: Bog bodies, volcanoes and climate change. Helen Roe

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53 Glaciers, moraines and climate: challenges of identifying, dating and extracting palaeoclimatic data from former glacier fluctuations. Inchnadamph, Scotland, 13th to 16th August 2018.

57 23rd QRA Postgraduate Symposium, University of Glasgow, 22nd- 24th August, 2018.

62 Global paleofire working group meeting on fire management and biodiversity conservation. 4-7th September 2018. .

68 9th International Symposium on Testate Amoebae (ISTA9): Recent advances and future research priorities. 11-12th September, 2018.

71 QRA Annual Discussion Meeting: Environmental Change: pace, magnitude and impact. University of Chester 3rd-5th January 2019