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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

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COVER PHOTOGRAPH

Participants at the 5th annual Sea Level and Coastal Change (SLaCC) meeting in September 2019 in South Devon listening to Prof Gerd Masselink describing the environment of Start Bay and the history of the nearby lost village of Hallsands.

EDITORIAL

Happy new academic year to you all. What a lot has happened since the last QN in February. I firstly want to introduce myself as the new editor of *QN*, but also to apologise for the fact that there was not an issue of *QN* as would normally be the case in June 2020. I, as many of you will relate to, suddenly found myself with hugely time-consuming caring responsibilities at the end of March which meant it was impossible for me to dedicate the time required to get my first *QN* issue as editor out on schedule. I could tell that others were in a similar situation from the lack of copy landing in my inbox from the end of March onwards. Fortunately the QRA executive understood mine and others situations and decided to cancel June's issue in mid-April when it became apparent that the lockdown was not going to end in a hurry.

So here we are in October 2020, six months on from the first lockdown and, for those of us employed to teach in Higher Education, facing significant challenges in teaching largely online at least for the start of this academic year, and for who knows how long into the future. But let's look on the bright side, and hope that by summer 2021 we will be able to resume all of our research activities that will provide interesting results for future editions of *QN*!

I first joined the QRA as an MSc student in around 2002. When each issue of *QN* landed in my letterbox I eagerly read it from cover to cover, keen to hear what the big names in Quaternary Science were researching and what meetings I should be attending. Reading *QN* has always made me feel part of an open and welcoming community of scholars of the Quaternary. I hope that during my editorship the Newletter will continue to be a source of information, inspiration and sense of community for all of us with an interest in the Quaternary. In these difficult times I find it comforting to know that the Quaternary 'world' is still turning and I hope that this and future issues of *QN* provide an interesting and motivating read.

Finally I want to thank all of those who have managed to find the time over the last few months in spite of the ongoing turmoil caused by the pandemic to put pen to paper and contribute articles and reports for this issue. We have a thought-provoking perspective piece triggered by the 'Spotlight on a site: Leet Hill' from the last issue, reports about dating interglacial high sea-level in the Fens, iceberg roll in east Greenland, and turbidite reoccurrence intervals in Sumatra, and a write up about the Oxford Geoheritage Virtual Conference (a true pioneer in the world of online meetings).

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RESPONSE LEWIS PENNY MEDAL

I would like to express my sincere gratitude to the QRA for awarding me the 2019 Lewis Penny Medal. It was particularly special to be presented with it whilst hosting the first QRA Annual Discussion Meeting to be held at the University of Leeds. A meeting I now appreciate even more as it was the last conference I, and many others, attended in person, prior to the Covid-19 restrictions which have since had such a huge impact on our lives and research.

My interest in Quaternary environments was founded in my first year as an undergraduate in the Department of Geography at Durham University, where my Physical Geography introductory lecturers included Prof Antony Long, whose enthusiasm for the subject you could not help being motivated by. With such a strong Quaternary research group at Durham, it was easy to engage with world-leading researchers throughout my degree and I greatly enjoyed field classes led by Prof David Roberts, Prof David Evans, Dr Jim Innes, Prof Ian Shennan, Dr Ian Evans and Prof David Bridgland. I specialised in Quaternary environments as soon as I could, and the second year 'Quaternary Studies' module was the first course I attended every session! It was past sea level which really grabbed my interest, and on the encouragement of Ian Shennan, I led a group of 9-undergraduate students on a trip to Alaska for 5 weeks to conduct our dissertation field work. This was the first time I had been outside Europe; and the landscape, the novel research and Ian's guidance left a real impression that encouraged me to pursue a PhD in the same topic.

Having come straight from undergraduate to PhD I didn't receive typical funding, instead working as a Research Assistant for Ian on a USGS funded-project researching palaeo earthquakes in the first year of my PhD, which in turn supported the rest of my project. At the age of 21 it was very daunting to be undertaking paid research whilst also starting my PhD, but looking back I realise how much I learnt from the experience. I was privileged to undertake a total of 5-field trips to Alaska whilst working on my PhD into glacial isosatic adjustment and relative sea-level (RSL) change during the Little Ice Age (Barlow *et al*., 2012), and further palaeo earthquake projects with Ian. Our work culminated in better understanding of the recurrence and spatial pattern of large (>M_w 8) earthquakes over the last 4000 years in south central Alaska (e.g., Shennan *et al*., 2014a; Shennan *et al*., 2008; Shennan *et al*., 2014b; Shennan *et al*., 2016), which has in turn fed into regional seismic and tsunami hazard assessments.

During the end of my PhD, I was fortunate to be employed as postdoctoral researcher on a project led by Prof's Roland Gehrels, Antony Long and Philip Woodworth on late Holocene sea-level change around the North Atlantic. This allowed me to develop my expertise in using salt marshes as late Holocene tide gauges, as we titled a paper in 2013 that outlined the state-of-the-science using microfossils to quantitatively reconstruct past sea level (Barlow *et al*., 2013). This project resulted in far better understanding of the spatial patterns of sea-level change across the North Atlantic (Long *et al*., 2014), the first 2000-year long continuous RSL record from the eastern Atlantic (Barlow *et al*., 2014), plus identified the importance of the NAO and oceanographic processes in driving regional changes in sea level (Gehrels *et al*., 2020; Saher *et al*., 2015). I was fortunate to travel a lot as part of this project, conducting field work in eastern USA, Scotland and southern England as well as attending numerous conferences, in particular QRA and PALSEA meetings, which greatly expanded my research network.

My skills in developing Holocene RSL reconstructions allowed me to move to a second postdoctoral position at Durham, this time as part of the large NERC iGlass Quaternary interglacials project, led by Prof Eelco Rohling. Having spent all of my career working on mid-late Holocene sediments this was a huge learning curve. Much to Dave Bridgland's amusement I had no idea what the Hoxnian was, and certainly couldn't tell you the duration of MIS 5e! However, I really enjoyed the challenge and expanding my knowledge into new time periods and questions. The primary outcome of this was revisiting the well-documented Nar Valley sequences, and applying approaches more commonly used in Holocene estuarine settings to reconstruct in-detail, the nature of MIS 11 and 9 sea-level change as recorded in the Nar Valley (Barlow *et al*., 2017). Collaborating with Prof Kirsty Penkman and Prof Rob Scaife really opened my eyes to the chronological challenges of reconstructing past sea level prior to the ^{14}C dating window.

Working on previous late Quaternary interglacials opened up questions about sea-level changes, driven by large-scale ice sheet fluctuations (Long *et al*., 2015), of far greater magnitude that those I had studied over the last 2000 years. In my final couple years at Durham (whilst working as a joint Postdoctoral Researcher for Antony on Holocene Greenland sea-level change, and a temporary lecturer), I had the pleasure, and often significant challenge of pulling together much of the Ice Sheets and Sea Level (aka QEC) research group to look at the proposed double-peaked sea-level highstand during MIS 5e. Alongside Prof Erin McClymont and 14 other Durham researchers we published a Nature Geoscience paper identifying a lack of evidence for a substantial sea-level fluctuation within the Last Interglacial (LIG) (Barlow *et al*., 2018). I became really motivated by questions around the rate and magnitude of sea-level change during the LIG, compounded by my growing involvement in PALSEA (Capron *et al*., 2019), and what can be learnt from previous interglacials to better understanding future Earth system responses to changing climate.

In 2016 I left Durham after 13 years and moved to Leeds as a University Academic Fellow, establishing the Leeds Quaternary group with Prof Graeme Swindles (now QUB). This exposed me to new areas of research, including the use of offshore industrial geophysical data to reconstruct submerged landscapes, through collaboration with Prof David Hodgson (Eaton *et al*., 2020; Emery *et al*., 2019a; Emery *et al*., 2019b). These new avenues, alongside my skills developed at Durham, and my collaborations with Dutch researchers Dr Kim Cohen, Dr Freek Busschers and Dr Marc Hijma, resulted in me being awarded a European Research Council Starting Grant in 2018. The RISeR project (2019-2023) seeks to better understand the hazard of long-term ice sheet melt by collecting LIG sediments preserved offshore in the North Sea, to reconstruct rates of past sea-level change. The ultimate goal is to provide high-end projections of sea-level rise beyond 2100 for northwest Europe, based upon the reconstructed magnitudes and rates of regional LIG sea level. This really is a culmination of my background in Holocene sea-level reconstruction (Brader *et al*., 2017; Hamilton *et al*., 2015; Long *et al*., 2016; Watcham *et al*., 2013), interests in chronological techniques, collaborations with modellers (Barlow *et al*., 2016) and a passion to use the past to better understand the future. However, more than that, I am fortunate to be leading a large Quaternary-facing research project at this point in my career due to the support, mentoring and guidance provided by so many QRA members since my postgraduate days. I first attended a QRA ADM in London as a PhD student and was blown away to see Prof's John Lowe and Mike Walker; the people who had written the book that was the bible of my undergraduate studies! It turned out they, just like many members of the QRA, are incredibly approachable and supportive of early career researchers like myself. I have valued so many discussions at QRA conferences and field meetings since, and now actively encourage my research students to be involved as well. There are so many people I wish to name who have had an impact on my career which resulted in me being awarded the Lewis Penny Medal, but the list would take the entire issue of QN. However, I particularly wish to thank Prof Ian Shennan, Prof Antony Long, Dr Sarah Woodroffe, Prof Roland Gehrels, Prof Mike Bentley and Prof David Hodgson for all their guidance and friendship. Finally, I must thank my parents, brother and husband for all their support and longstanding tolerance of my love of mud.

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PERSPECTIVE

THE LEET HILL SITE: A CORRECTION. A RESPONSE TO "SPOTLIGHT ON A SITE" – LEET HILL, NORFOLK, ENGLAND

The last issue of *Quaternary Newsletter* (QN No. 150) included an article on p.3-4, entitled 'Spotlight on a site', in which the Leet Hill locality in southern Norfolk is described. Whilst Leet Hill is undoubtedly an interesting and important site, providing a record of events at the onset of glaciation during the earliest part of the Anglian Stage (= MIS 12), we consider the summary of this controversial site, attributed to Silva and Philips (2015, p.55) – the source of which is unstated – both unsatisfactory and, at worst, misleading. Two controversies that are firstly ignored by Silva and Philips, and secondly mentioned without comment are, whether or not the "Bytham River", as first envisaged by J. Rose in 1987 and elaborated in numerous later publications, actually existed, as challenged by us and other workers (Gibbard *et al.* 2013; Belshaw *et al.* 2014). Note that in its lower course Rose's 'Bytham River' incorporated the well-established Ingham River of R.W. Hey (1973; 1976; Clarke and Auton 1984; Hey and Auton 1988). The second controversy relates to the suggestion put forward by J. Rose, J.R. Lee and others (Rose, Candy and Lee 2000; Lee *et al.* 2004), that the North Sea Drift Formation (including the Happisburgh Till, Leet Hill Sands and Gravels and Corton Sands) related not to the Anglian but to a much older glacial stage (MIS 16). We now rehearse briefly how these controversies relate to the Leet Hill site. The references given in the article simply do not give the range of views published on this site, or accurately.

The stratigraphy and lithologies of the site have been described by Rose *et al.* (1999), Rose, Candy *et al.* (2000), Lee, Rose *et al.* (2008) and Gibbard and van der Vegt (2012). The key features of the site are the Kirby Cane Sands and Gravels, the youngest Member of the Ingham Formation, originally described by Hey at its stratotype locality at Ingham, near Bury St Edmunds and representing a pre-Anglian river, the Ingham River, which, from its lithological content, originated in the English Midlands, then flowing eastwards, eventually to become a left-bank tributary of the proto-Thames, whose changing course is marked by the gravels of the Kesgrave Formation further south (Rose and Allen 1977). However the Kirby Cane Gravels contain, as well as typical lithological elements of the Ingham Formation, also erratic clasts and clay balls (till) derived from the North Sea Drift Formation, which includes the Cromer and Happisburgh Tills. Clearly the Ingham River persisted into the early Anglian, and glacial outwash at that time impinged on its course upstream.

Overlying the Kirby Cane Member is the Leet Hill Sand and Gravel Member, belonging to the North Sea Drift Formation, comprising a series of sand and gravel units representing a braided river transporting not only flint, chalk and quartz clasts but also a Scandinavian igneous and metamorphic erratic suite and a heavy-mineral assemblage indicating derivation from the North Sea region. This unit is, in turn, overlain by the Corton Member. Gibbard and van der Vegt (2012) have shown how the Corton Sands were deposited, as marginal, shallow-water sediments of the great freshwater lake in the southern North Sea during the Anglian, when Scottish and Scandinavian ice sheets coalesced to form a barrier to the north. Later in the Anglian the gradual rise of the level of this lake created an overspill that began the breaching of the Strait of Dover.

It is instructive to consider why Rose, Lee and others proposed that the North Sea Drift Formation was much older than the Anglian and equivalent to the Don Glaciation (= MIS 16) and the role that the Leet Hill section played in this conclusion.

1. Oxygen isotope curves from deep-sea sediments suggest major glaciation during MIS 16 – and indeed in eastern Europe this is the case (Turner 1996). The model derived by Hamblin *et al.* (2000, 2005; Lee *et al.* 2004), following their study of sediments within the area proposed that northern East Anglia had been glaciated on several separate occasions during the Middle Pleistocene, with an earlier glaciation than the Anglian.

2. Lee (2003), noted, as had earlier workers, that marine mollusc remains occurred at horizons within the Corton Sands, and similarly Candy (2002) had detected a rhizogenic calcrete within the Corton Sands at Leet Hill, which might just possibly relate to an interglacial horizon prior to deposition of the overlying Lowestoft Till.

3. More significantly, when erratics and till balls were found in the Kirby Cane Sands and Gravels at Leet Hill, Rose, together with his co-workers, claimed that not only were these sediments part of the "Bytham River", but also could be traced upstream as part of the Knettishall Terrace (Knettishall Gravel Member of the Ingham Formation, as defined by Rose *et al.* (1999). Significantly he believed that this aggradation ('Terrace' is an inappropriate name cf. below) was separated from the Anglian glaciation by two major periods of river incision and one major period of river aggradation. Consequently the evidence for glacial outwash in these deposits suggested a much older age than the Anglian for the North Sea Drift Formation (Lee *et al.* 2004).

The acid test for this proposition was immediately seen as the biostratigraphical evidence that would be provided by sampling of the organic deposits of the Cromer Forest Bed Formation, immediately below the Happisburgh Till at Happisburgh and Sidestrand, following the discovery of Lower Palaeolithic flint artefacts within the pre-glacial sediments at Happisburgh (Banham *et al.* 2001).

Of particular significance initially would be the microvertebrate fauna, and whether the water vole species present would be *Arvicola terrestris cantiana* or *Mimomys savini*, since the first appearance of *Arvicola* corresponds to MIS 13, when, according to evidence from right across Europe from Russia to the Netherlands, it completely replaced *Mimomys*, which had been present throughout the earlier part of the early Middle Pleistocene. When indeed *Arvicola t. cantiana* was found at Happisburgh and Sidestrand together with other stratigraphically significant mollusc and vertebrate taxa, this appeared to settle the matter and confirm an Anglian age for the Happisburgh Till, but nevertheless Rose (Rose 2009, Lee, Pawley *et al* 2008), refused to accept this conclusion, claiming that biostratigraphy was unreliable and suggested that there were 'regional differences in biological variations", implying that *Arvicola cantiana* might have evolved separately in Britain by MIS 17, even though other European records suggested it appeared in MIS13! This view was thoroughly rejected by Preece and Parfitt (2008, Preece *et al*. 2009), noting that *Arvicola cantiana* had also been found in the *Unio* Bed at Sidestrand, below the Happisburgh Till.

Considering other evidence relevant to this debate, the western limits of the Don ice sheet (MIS 16) have now been identified in the central North Sea Basin (Lamb 2016, Bendixen *et al*. 2017). No doubt there was also glaciation of much of upland Britain at that time, but certainly no ice sheet reached as far south as north Norfolk. The Corton Sands have been discussed in detail by Gibbard and van der Vegt (2012). The only autochthonous fossils are cold climate plant remains, preserved in clay layers (West and Wilson 1968), but these deposits also contain reworked Mesozoic foraminifera and marine nannofossils, derived from glacial excavation of the floor of the North Sea (e.g. Gibbard *et al*. 2008). It has long been known that similarly reworked shell fragments of marine molluscs may also occur and have been recorded quite frequently in the past, but erroneously used to suggest a temperate horizon within the Corton Sands (e.g. Slater1929).

We come finally to the matter of the evidence of glacial outwash material undoubtedly found in the Kirby Cane Gravels and Sands, this being the principal evidence on which Rose and colleagues have based their case for a pre-Anglian glaciation. We state from the outset that we have never accepted the existence of a "Bytham River", as proposed by Rose (1987) and rehearsed and elaborated in numerous later publications, as if there was no dissent. Nevertheless our views also have been made clear in print (Gibbard *et al*. 2009; 2013; 2018). Whilst we regard certain sections of the proposed "Bytham River" as an artifact and certainly not of pre-Anglian age, we certainly accept the pre-Anglian Ingham River of Hey (1973; 1976), which we can see here just lasting into the early Anglian, and which Rose incorporated as the lower reaches of his "Bytham River" (Rose 1987). The subdivision of the Ingham Formation into successive stratigraphical units, which should be called Members, and not Terraces, since that term refers strictly to top surfaces of aggradations (i.e. landforms), which are seldom identifiable in many gravel sections, has been controversial, even amongst those who accepted the notion of a "Bytham River".

Whereas Lewis (1993), recognized four terraces, Lee *et al*. (2004) described six and Westaway (2008) only three. The Kirby Cane Member was equated with the second youngest aggradation of the "Bytham River" by Rose *et al*. (2000) or the third youngest according to Lee *et al* 2004. Much of the basis for this subdivision was based on altitude and the calculation of gradients, and these subdivisions and calculations extended back to correspond with and link 'terraces' proposed for the upper part of the "Bytham River", but particularly with the north-south flowing course along the edge of the Fenland Basin between Shouldham, Norfolk and High Lodge and Warren Hill (Three Hills), Suffolk, where the proposed river turned east to join the already recognised Ingham River.

It is the sites at High Lodge and Warren Hill that precisely define the inferred stratigraphic succession of Rose's 'terraces' and indeed the position and interpreted age of the Kirby Cane Gravels and Sands. Both these sites have been misinterpreted. The gravels at Warren Hill contain high-angle bedding, which can be traced over a wide are and is characteristic of a glacial outwash delta – furthermore the gravels contain balls of diamicton, which can only be till, but have been overlooked or dismissed. The gravels contain a range of Palaeolithic artefacts, including handaxes, often very rolled, but which it has been attractive to date as pre-Anglian, but have been swept off nearby land surfaces. The deposits at Warren Hill simply cannot be interpreted as part of a pre-Anglian river aggradation (Gibbard *et al*. 2009). At High Lodge it has long been recognized that the organic silt deposits, which contain a distinctive Palaeolithic flint industry, have been sheared and displaced by ice (Turner 1973, Lewis 1992, Lee *et al*. 2004). They range in height from ca. 19 m to a maximum of ca. 27 m at the Partridge Pit, close to the summit of the hill. Therefore, this is a particularly unsuitable deposit to use as a key altitudinal horizon in trying to develop an altitudinally based 'terrace' system. Furthermore in almost all sections and boreholes these glacially sheared silt deposits overlie a distinctive chalky till (Lowestoft Formation), so, if they were actually part of a pre-Anglian river system, they must have simply been a raft of sediment transported by an ice-sheet, as Rose had previously suggested (1992) – again useless for altitudinal correlation. In fact, revision of the High Lodge stratigraphy and environment (West *et al*. 2014) strongly suggests that the organic silts were deposited in a typical Breckland sinkhole environment, and the plant macrofossil assemblages (Turner unpublished) would support this. In conclusion then, the idea that the Kirby Cane Gravels and Sands Member at Leet Hill can provide evidence for a pre-Anglian glaciation is simply not tenable but has been driven by a mistaken imperative to link a fictitious pre-Anglian river in the English Midlands and Fenland with the well-established Ingham River, leading to the importation of a spurious 'terrace' stratigraphy. The deposits at Leet Hill are all of Anglian age.

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DETERMINING THE AGE OF THE LATE MIDDLE PLEISTOCENE MARINE MARCH GRAVEL OF EASTERN ENGLAND

Background and rationale

The term March Gravel was introduced by Baden-Powell (1934) to represent a widespread fossiliferous sand and gravel that contains a mixture of marine, estuarine and fluvial fauna and crops out in the central and western Cambridgeshire Fens. The British Geological Survey (BGS) mapped the extent of the March Gravel (Figure 1) and considered it to represent a single marine incursion dating to the Ipswichian (Horton, 1989). Bridgland *et al*. (1991) and Boreham *et al.* (2010) correlated the March Gravel to Marine Oxygen Isotope Stage (MIS) 9, Maddy (1999) assigned the March Gravel to the March Formation, correlating it with MIS 7, and more recently Rose (2015) assigned the March Gravel to the March Gravel Member, correlating it with MIS 9–7. West *et al*. (1999) interpreted an Ipswichian (Eemian/MIS 5e) age for estuarine deposits at Somersham (Figure 1), and assigned a Devensian (MIS 5d to MIS 2) age to the overlying March Gravel containing reworked elements of the underlying estuarine deposits. At King's Dyke quarry (Figure 1) two separate deposits mapped as March Gravel (BGS, 1984) were dated by optically stimulated luminescence (OSL), one indicated a minimum MIS 7 age and the other a minimum Ipswichian age (Langford *et al*., 2004).

The March Gravel at Northam Pit, Eye Green (Figure 1) has been designated a geological Site of Special Scientific Interest (SSSI; 0°112'W; 52°369'N), and has been visited during two QRA field trips (Bridgland *et al.*, 1991; Langford, 2004). Keen *et al.* (1990) concluded that the age of the deposits at Northam Pit was indeterminate based on the evidence then available, and reliable dating of the deposits has still to be undertaken. During site clearance work in 1999 a stratified series of samples was collected in order to enhance the palaeoecological data reported by Keen *et al.* (1990). The foraminifera and ostracod assemblages from those samples confirms an estuarine depositional environment from 1.9 m OD to about 2.6 m OD (Figure 2), but indicates marine proximal conditions at 1.9 m OD and commencement of influx of fluvial ostracod specimens at 2.4 m OD, with the deposits above about 2.6 m OD considered to be reworked (J. Whittaker, unpublished data).

The uncertainty outlined above indicates a clear need for reliable age-estimate data to enable meaningful stratigraphical interpretation of deposits mapped as March Gravel.

Figure 1. Distribution of the March Gravel and the location of Northam Pit.

Approach

Two samples for luminescence dating were collected during the site clearance of 1999 but natural radiation *in situ* was not measured. In May 2019 measurements *in situ* were made using a sodium iodide gamma spectrometer at the location of one of these samples (Shfd19183), at about 2.5 m Ordnance Datum (OD), and at the location of a new sample (Shfd19175), at about 2.4 m OD (Figure 2). Full details of laboratory sample treatment will be published separately. Feldspar rather than quartz grains were subject to luminescence dating given the potential late Middle Pleistocene age of the March Gravel, because the signal saturates more slowly in feldspar than in quartz so older samples can be dated more reliably. A

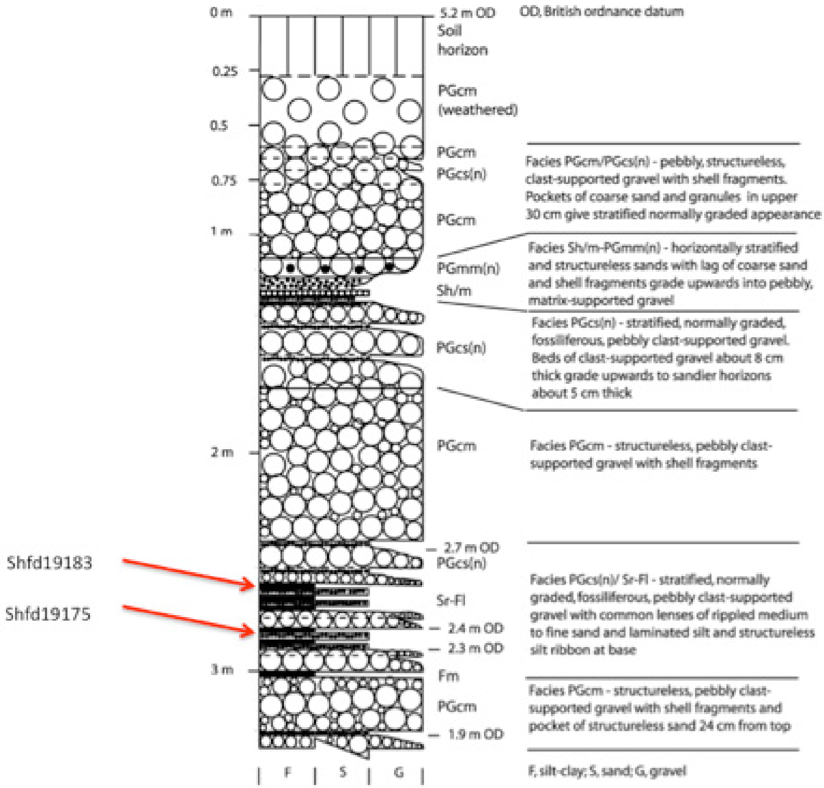

Figure 2. Sedimentary log of March Gravel exposed at Northam Pit, Eye Green (Cambridgeshire).

post-infrared (IR) IR_{225} protocol (pIRSL or $pIRSL_{225}$; Buylaert *et al.*, 2012) was used for measurement. In addition a vertical sequence of samples was collected from the approximately 70 cm depth of sediments exposed (1.9–2.6 m OD) for potential dating of foraminifera by amino acid racemization (AAR) using an intracrystalline protein decomposition (IcPD) protocol. The results of the IcPD analyses are not available for this report.

It should be noted that a strict sampling protocol, i.e., removing 50 cm of sediment from the face, could not be used for the collection of samples in 2019 because of the need to preserve the face intact as far as possible.

Results

Sample Shfd19183 yielded an age of 205 ± 14 ka, indicating that deposition of the estuarine sediments at Northam Pit correlated with MIS 7, probably late in that interglacial (spanning 243–191 ka according to the scheme of Lisiecki and Raymo (2005)). Sample Shfd19175 yielded an age of 3.28 ± 1.30 ka, which is far too young, indicating that the sediments have been compromised by the disturbance they experienced during previous investigations and site clearance activities.

Significance and future prospects

The invalid age for sample Shfd19175 implies that the samples for IcPD analyses on foraminifera may also be compromised. If, however, meaningful data are provided by the IcPD analyses then the age provided by sample Shfd19183 will prove to be a valuable tie point. The age-estimate data provided by sample Shfd19183 indicate that some deposits mapped as March Gravel may represent high eustatic sea level during the penultimate interglacial, e.g., Block Fen (Figure 1; West *et al.*, 1995), Manea (Figure 1) and Somersham (West *et al.*, 1999) as determined from AAR data by Meijer and Cleveringa (2009). Whether or not the March Gravel represents a single aggradation event, however, remains a matter of debate, not least because stratigraphical interpretation has relied heavily upon altitudinal grouping of sedimentary bodies. The uncertainty of this approach in the context of the March Gravel is exemplified by comparison with the Pleistocene deposits at Whittlesey. In the same altitudinal envelope occupied by the Northam Pit deposits, March Gravel comprises fluviatile deposits correlated with MIS ≥ 8 overlain by an estuarine influx dated to the Ipswichian (Langford *et al.*, 2004; Langford and co-workers, unpublished), and River Nene 1st Terrace deposits correlated with MIS ≥ 8 to MIS 5b–2 (Langford *et al.*, 2007, 2014a,b, 2017) include an estuarine–marine influx correlated with MIS 7(Langford and co-workers, unpublished). At another location at a slightly higher altitude within the Whittlesey sedimentary succession, March Gravel comprises fluviatile deposits correlated with MIS ≥ 8 to MIS 5d–2, but with influx of marine microfauna ≥ MIS 6 (Langford *et al.*, 2004). Similarly, deposits at Block Fen (West *et al.*, 1995) and Somersham (West *et al.*, 1999) record multiple estuarine–marine influxes at different altitudes, which are palynologically assigned to the Ipswichian Interglacial. The MIS 7 age for the estuarine deposits at Northam Pit, however, suggests that at these sites deposits from two interglacials may have been conflated into one, as previously implied by uncertainties in age-estimation data reported by West *et al.* (1999) and the MIS 7 ages reported by Meijer and Cleveringa (2009).

The MIS 7 age for the estuarine deposits at Northam Pit augments data from Easington (Durham; Davies *et al.*, 2009). Although the Easington raised beach is dated reliably to MIS 7 (Davies *et al.*, 2009), little is known about sea level in the North Sea and English Channel during this interglacial. There are, however, a few sites that record high sea level at the MIS 7–6 transition (Lefebvre, 1999; Bates *et al*., 2000; Hoare *et al*., 2009; Jones and Whittaker, 2010). A MIS 7 age for the Northam Pit deposits therefore is a valuable addition to this sparse dataset. In a wider context the data will be valuable for ongoing research into past records of high sea levels (Dutton *et al*., 2015), for the regional palaeosea-level archive and wider investigations around the North Sea region (Long *et al*., 2015).

As we enter a future facing the threat of higher sea levels it is important that we investigate Pleistocene interglacial sea-level deposits, particularly at higher latitudes (Dutton *et al*., 2015; Long *et al*., 2015), because they provide insight into parameters of variables such as glacio-isostasy, magnitude and rates, and how these vary spatially and temporally. In Britain, however, there are few reported onshore and offshore sequences that record transgressive–regressive system tracts, or parts thereof. The March Gravel deposit at Northam Pit appears to represent one of these few records.

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ICEBERG-KEEL SCOURING IN DIAMICTON: SCORESBY SUND, EAST GREENLAND

Background and Rationale

Icebergs are important as agents of deposition and seafloor reworking on glacier-influenced continental margins. When the keels of icebergs (and sea-ice pressure ridges) exceed water depth they plough through soft sediments producing scour marks (also known as 'ploughmarks' (Dowdeswell and Ottesen, 2013), furrows or 'gouges' (Palmer and Chan, 2012)). The scours can be kilometres long, hundreds of metres wide and sometimes tens of metres deep. Here, the term 'ice-keel scour' is used to describe scour by either icebergs or sea-ice pressure ridges (Linch and van der Meer, 2014). As well as excavating and pushing the sediment within the scour, the ice keel deforms the sediment a significant distance (up to several metres) below the base of the scour trough, a process known as 'sub-scour deformation' (e.g. Woodworth-Lynas and Guigné, 1990; Linch *et al.*, 2012; Palmer and Chan, 2012; Linch and van der Meer, 2014).

Previous work has shown that a distinctive suite of structures (dominated by planar shear, sediment mixing and porewater structures) characterises ice-keel scoured (i) clays, and (ii) pebbly sandy mud and fine-grained sands (Linch *et al.*, 2012; Linch and van der Meer, 2014). This suite of structures is unlike those associated with subglacial tills and mass-wasting deposits. However, ice-keel scoured diamicton (poorly sorted sediment comprising a variety of particle sizes) is reported from Late Quaternary sediments in a number of high-latitude fjords and continental shelves, including much of the 500,000 km^2 shelf around the coast of Greenland (Dowdeswell *et al.*, 1993, 1994a,b) and around Antarctica (Anderson, 1999), yet the structures it contains are poorly known. Since fast-flowing outlet glaciers and ice streams are the principal source of icebergs and ice-rafted debris (IRD) entering the marine environment (Ó Cofaigh *et al.*, 2001), being able to recognise iceberg rafted and scoured diamicton in the modern and ancient glacimarine sedimentary record could be indicative of the presence of fast-flowing outlet glaciers and/or ice streams draining large ice masses, which is crucial for reconstructing the geometry and dynamics of former ice sheets (Dowdeswell *et al.*, 1994a; Ó Cofaigh *et al.*, 2001). In turn, it may lead to the reinterpretation of diamicton currently considered to be, for example, subglacial (Dowdeswell *et al.*, 1994a; Eden and Eyles, 2001), which will hold implications for existing ice sheet and glacier reconstruction models. Finally, understanding scouring processes, particularly the style and intensity of sub-scour deformation, is a critical first step to inform the safe installation and protection of offshore structures (e.g. pipelines) in diamicton where iceberg-keel scouring presents a geohazard (e.g. Woodworth-Lynas *et al.*, 1996; Barker and Timco, 2002, 2003; Been *et al.*, 2008; Sancio *et al.*, 2011; Palmer and Chan, 2012).

Does a distinctive suite of structures characterise iceberg-keel scoured diamicton? To answer this, the aim of this research is to macroscopically and microscopically examine iceberg-keel scoured diamicton from Scoresby Sund, East Greenland. Seven gravity cores, previously retrieved in the early 1990s from Scoresby Sund (Dowdeswell *et al.*, 1993), were carefully chosen from zones of high-intensity iceberg scouring, intermediate-intensity iceberg scouring and low-intensity iceberg scouring as identified on acoustic records in Dowdeswell *et al.* (1993). Cores were described macroscopically by eye and with the use of x-radiographs, and 17 undisturbed samples of diamicton were taken for micromorphological (thin section) analyses. The reader is referred to Linch and Dowdeswell (2016) – upon which this report is based – for further information on the study area, methods, results and discussion.

Results

The diamictic sediment in this investigation is characterised by a number of deformation structures attributable to (direct/indirect) mechanical iceberg-keel scour processes (Fig. 1). These include microstructures indicating processes related to: (i) rotation/compression/slump (grain turbates, folds, sheath folds, realigned bedding, skelsepic plasmic fabric); (ii) planar shear (augen-shapes, normal faults, discrete shears, grain lineations, unistrial plasmic fabric); (iii) sediment mixing (intraclasts type III, multiple domains); (iv) porewater (water escape structures); (v) ice rafted debris (dropstones); and (vi) high magnitude unidirectional lateral stress (sub-horizontal microfabrics). Of these structures, the most dominant are dropstones and structures related to planar/brittle deformation, sediment mixing and porewater processes. In addition, a suite of complex overprinted microstructures, indicating at least two phases of sediment deformation in the diamicton, is identified. The presence of both ductile and brittle structures in iceberg-keel scoured diamicton indicates a complex polyphase deformation history (Menzies, 2000; Phillips *et al.*, 2007; Linch *et al.*, 2012; Linch and van der Meer, 2014).

Results also show that diamicton from high-intensity scoured (HIS) zones of the Scoresby Sund seafloor (indicating multiple, overprinted scour events) tends to show a wider variety of microstructures than diamicton from intermediate-intensity scouring (IIS) and low-intensity scouring (LIS) zones. In addition, in HIS zones microstructures are more frequently identified and distributed (i.e. throughout cores), more abundant (i.e. quantities) and generally better developed (i.e. strength) than in IIS and LIS zones. There are considerably fewer rotation, compression and slump structures noted in IIS and LIS zones. Similarly, there are considerably fewer well-developed planar shear structures, as well as less evidence of sediment mixing, in IIS and LIS zones. Water escape structures, bedding-parallel plasmic fabric and dropstones are also limited in IIS and LIS zones.

Finally, results indicate that grain size of diamicton partially affects the detectability, style and intensity of deformation structures in response to iceberg-keel scouring. For example, there are few folds and faults in diamicton in this investigation, whereas there is an abundance of discrete shears (which are the equivalent of faults where layers/bedding are absent). This is because well laminated sediment allows the development and identification of folds and faults (layers/bedding act as 'markers') whereas a sediment with a more 'massive' structure (like the diamicton in this investigation) will not, regardless of whether it has been subjected to processes of compression/slump and planar shear or not (Linch and van der Meer, 2014).

For full descriptions and interpretations of results see Linch and Dowdeswell (2016).

Significance

The suite of microstructures in iceberg-keel scoured diamicton

The suite of microstructures identified in iceberg-keel scoured diamicton in this investigation (Fig. 1) is distinctly different from the suites of microstructures related to subglacial tills and mass-wasting deposits. Here, iceberg-keel scoured diamicton is dominated by planar/brittle deformation, sediment mixing and porewater processes, and dropstones. This contrasts with subglacial tills and mass-wasting deposits that are instead dominated by (a wider variety of) rotational/ductile and planar/brittle structures, including a range of plasmic fabrics (Linch *et al.*, 2012). The suite of microstructures (in combination with macroscale context wherever possible) identified in diamicton in this investigation can now be used to identify iceberg rafted and scoured diamicton in both the modern and ancient glacimarine sedimentary record in outcrop and especially in cores. It may even lead to the re-interpretation of sediments that previously have been assigned a subglacial origin, providing new insights into ice-sheet and glacier reconstructions (Gilbert *et al.*, 1992; Dowdeswell *et al.*, 1993, 1994a,b; Eden and Eyles, 2001; Woodworth-Lynas and Guigné, 2003; Linch *et al.*, 2012). In addition, since fast-flowing outlet glaciers and ice streams are the principal source of icebergs and IRD entering the marine environment (Ó Cofaigh *et al.*, 2001), such facies (in the modern and ancient glacimarine sedimentary record) could be indicative of the presence and role of outlet glaciers and ice streams in draining large palaeo-ice masses, with implications for reconstructing the dynamics and extents of former ice sheets (Dowdeswell *et al.*,1994a; Ó Cofaigh *et al.*, 2001). For more details see Linch and Dowdeswell (2016).

High-, intermediate- and low-intensity iceberg-keel scouring in Scoresby Sund

Whereas discrepancies in the type, frequency/distribution, abundance and development of some structures may be partly explained by local variations

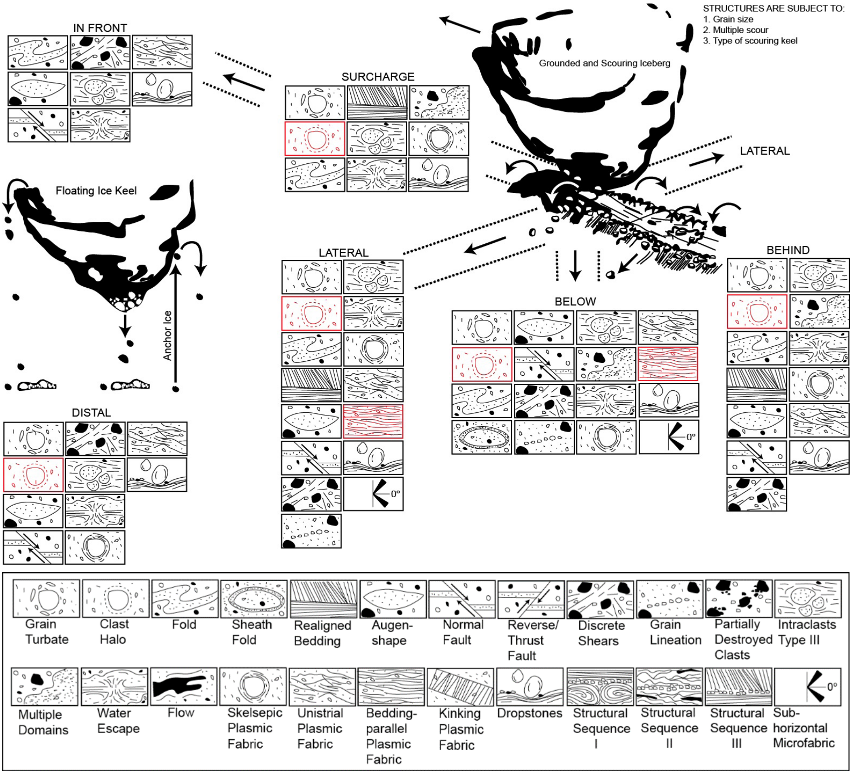

Figure. 1. Micromorphological deformation structures attributed to iceberg-keel scouring processes in diamicton, Scoresby Sund, East Greenland (from Linch and Dowdeswell, 2016). Structures in black are unambiguously attributed to iceberg-keel scouring, while structures in red are only potentially attributed to iceberg-keel scouring. Note that this figure is a conceptual model that attempts to link deformation structures identified in iceberg-keel scoured diamicton in this investigation to known mechanical processes operating in an iceberg-keel scouring environment - it is not depicting, nor a representation of, any one particular existing iceberg-keel scour – see Linch and Dowdeswell (2016) for more information. Note that all structures listed in the key have been identified in ice-keel scoured sediments either as part of this investigation and/or in Linch *et al.* (2012) and/or in Linch and van der Meer (2014).

in grain size, a more obvious reason why there are more, well-developed structures in HIS zones compared to IIS and LIS zones in Scoresby Sund is because HIS zones have been subjected (by definition) to higher intensities of iceberg-keel scouring. It follows that diamicton in HIS zones was subjected to more frequent, probably multiple/superimposed, scour events (i.e. stress) and thus generally higher strains than IIS and LIS zones. This supports Linch *et al.* (2012), who note higher strain deformation patterns in sediment scoured multiple times. However, strains were not so high in HIS zones in Scoresby Sund that diamicton was entirely reworked and/or homogenised, otherwise there would be very few remaining intact structures (Menzies, 2012). For more details see Linch and Dowdeswell (2016).

The influence of grain size on ice-keel scour deformation

It is known that grain size and sorting partly affect the detectability, style and intensity of deformation structures (Linch and van der Meer, 2014). This also appears true for diamicton examined in this investigation. However, iceberg-keel scoured diamicton examined in this investigation remains dominated by planar/brittle deformation, sediment mixing and porewater processes, and dropstones, which is consistent with observations made in iceberg-keel scoured clays from Glacial Lake Agassiz and ice-keel scoured pebbly sandy mud and fine-grained sands from Scarborough Bluffs, Ontario, Canada (Linch *et al.*, 2012; Linch and van der Meer, 2014). Therefore, a dominant suite of deformation structures develops in response to ice-keel scour processes independent of grain size. For more details see Linch and Dowdeswell (2016).

The value of micromorphology

The value of micromorphology as a means of examining sediment texture and structure in great detail is clear. It is particularly relevant in the detailed examination of sediment cores from marine environments, when outcrops do not exist. Here, micromorphology demonstrates that sediment previously described as ‘massive’, ‘structureless’ and ‘homogenous’ (Dowdeswell *et al.*, 1994a,b) is in fact far from massive, structureless and homogenous under the microscope. Therefore, ‘massive’ sediment at the macroscale is, in reality, ‘macroscopically massive’. Understanding this implies that the potential for sediments to contain extremely valuable textural and structural information at the microscale should not be overlooked. In addition, results from this investigation, which suggest deformation in HIS zones is generally more intense than in IIS and LIS zones, directly supports the initial classification of iceberg-keel scour intensity zones on acoustic records as proposed by Dowdeswell *et al.* (1993). This demonstrates how large- (acoustic) and small-scale (micromorphology) techniques are complementary to one another as a way to strengthen interpretations. It means that where broad-scale contextual information is lacking, micromorphology provides an invaluable tool for examining sediments. For more details see Linch and Dowdeswell (2016).

Offshore engineering in ice-keel scoured areas

Finally, information from this investigation, which allows better understanding of the style and intensity of sub-scour deformation, is likely to be relevant to inform the safe installation and protection of offshore structures (e.g. pipelines) where ice-keel scouring presents a geohazard (e.g. Palmer and Chan, 2012).

Acknowledgements

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REPORTS

FIFTH SEA-LEVEL AND COASTAL CHANGE MEETING – SLACC 2019

1st– 4th Sept. 2019. Devon and Cornwall, England

The Sea-Level and Coastal Change (SLaCC) meetings have run since 2015 after they won QRA Research Group status for the years 2015 to 2018. In 2019, due to the long-running success of the meetings, SLaCC enjoyed continued support from the QRA thanks to a Meeting Co-sponsorship Award. This year, the Fifth SLaCC meeting was held in Plymouth, England, where participants working in both the physical and social sciences, as well as the arts, attended a day of presentations and discussion sessions (Monday 2nd Sept.) before visiting a range of sea level and coastal research sites across southwest England (Tuesday 3rd – Wednesday 4th Sept.). The meeting, organised by SLaCC coordinators **Sarah Woodroffe** (Durham) and **Rob Barnett** (Exeter), with significant contributions from **Gerd Masselink** (Plymouth), **Roland Gehrels** (York), **Matt Telfer** (Plymouth), **Isabel Kelly** (Plymouth Coastal Observatory), **Les James** (Quaternary Research Association) and **Peter Ealey** (Quaternary Research Association), included an evening event open to the public on the theme of Sea Level and Coastal Change in Devon and Cornwall. Alongside the QRA, SLaCC2019 was generously supported by the International Union for Quaternary Research, Deltares (Netherlands), the Marine Institute (Plymouth), BLUEcoast (Plymouth) and the University of Exeter.

Figure 1. SLaCC participants on the beach at Torcross where a large seawall defends the properties behind from shoreline erosion.

The aims of the meeting aligned closely with principles long held by the QRA; attendance of early career researchers (ECRs) was encouraged and supported thanks to the grants from our multiple sponsors. SLaCC2019 welcomed over 30 participants to Plymouth, over half of which were ECRs. The meeting also established a comfortable and inclusive platform for contributions from all career stages and a diverse spread of subject areas.

Improving integration between researchers from different fields and disciplines in sea level and coastal research is an objective that is growing in value at SLaCC meetings. Past successes at integrating palaeo and modern studies in SLaCC2018 were built upon by further introducing the social sciences and arts into the programme in SLaCC2019.

SLaCC 2019 started with an evening ice-breaker at the University of Plymouth Marine Station that supports teaching and research across the full breadth of marine and environmental science and engineering. With a beautiful view on Plymouth marina, local flavours were enjoyed in a relaxed setting where participants founded new relationships and enriched existing ones.

The following day (Monday 2nd Sept.), the participants gathered at the Sherwell Centre and the posters were erected. The first presentation session started after a welcome note from **Rob Barnett** (Exeter) and **Gerd Masselink** (Plymouth) with a keynote contribution from **Iris Möller** (Cambridge) on the relative importance of frequency versus magnitude of events shaping the evolution of coastal landforms. Iris presented two true-to-scale experiments to demonstrate the relative importance of magnitude and frequency of events controlling the evolution of salt marsh landforms. This insight was informed by research on the biophysical linkages in salt marsh ecosystems that affects their responses to low magnitude shifting baselines (altered sediment supply, sea-level rise) or high magnitude-low frequency events (storms). The second presentation of the meeting was given by **Guillaume Goodwin** (Edinburgh), who talked on the roles of platform elevations, storms and spring tides in salt march evolution. His finding suggests that the deposition of coarse concentrated sediments during infrequent high deposition events is necessary for saltmarshes to withstand sea-level rise. **Helen Brooks** (Cambridge) continued the session by presenting a comparison of two methods for quantifying salt marsh and tidal flat shear strength using data from Tillingham marsh (eastern England) and Morecambe Bay (northwest England). Ultimately, this research will inform the implementation of nature-based coastal flood defences, such as managed realignment schemes. **Elizabeth Christie** (Cambridge) gave the last talk of this first session on the resilience of an embanked coastal freshwater wetland to extreme storms and sea-level rise.

After a short refreshments break and some poster presentations, the morning session continued with a presentation on conceptual improvements of predicting long-term coastal changes in embayed coastlines by the ECR guest speaker from the BLUEcoast project **Jack McCarroll** (Plymouth). This insight was developed using data from long-term monitored beaches in Cornwall, and Devon combined with 35-years of satellite observation and recently applied techniques for estimating long-term coastal change and responses to sea-level rise. **Ben Evans** (Cambridge) presented the erosional responses of salt marsh sediments to storm conditions followed by the keynote speaker **Anne-Marie Culhane** who introduced a creative topic to many of the group and presented her work with communities across disciplines concerning the climate and ecological emergencies. Another ECR guest speaker **Tara Quinn** (Exeter) concluded the presentations of the morning by using examples from South Africa, UK and France to emphasise how the relationship with place shapes the perception of environmental and social risk.

A delectable lunch was provided within the beautiful, skilfully converted conformist church during which conference attendees enjoyed a wide range of poster presentations. **Robert Barnett** (Exeter) presented the drivers of sea-level changes in eastern Canada and the importance of replicating their contributions in climate models. **Jesús Emmanuel Bustamante Fernández** (Durham) presented his findings on the late Holocene paleoseismology of the southern region of Rivera plate in Mexico. SLaCC's 2019 furthest travelled participant **Deron Maitland** (West Indies Mona, Jamaica) presented a flood risk maps projecting the 21st-century sea-level rise in Jamaica using SimCLIM. **Silvia Palotti Polizel** (UCL) presented the Holocene evolution of the Doce River delta in south-eastern Brazil. **Victoria Naylor** (Exeter) contributed a poster concerning the quantification of rocky coastline evolution using 36Cl exposure dating and structure-from-2 motion photogrammetry.

The afternoon presentations started with the third guest ECR speaker of the day**: Sophie Ward** (Bangor). Sophie presented the importance of ocean models in the simulation of the evolution of tidal dynamics in response to the change in sea levels and continental configurations. The validation of palaeo tidal models is still a challenge and new proxies for past shelf sea hydrodynamics are still needed to constrain numerical model output at regional scales. Sophie's presentation was followed by a talk on local and regional constraints of relative sea-level changes in Southern Isle of Skye since the Last Glacial Maximum by **Louise Best** (Gloucestershire). Following Louise, **Greg Rushby** (Sheffield) presented his findings on the need of revision of GIA models that include mid-Holocene sea level highstand for North Wales in the modelling of past and future relative sea-level changes around the British Isles.

After a second short refreshments break, the second-afternoon session started with a presentation from the former keynote speaker of SLaCC2018, **Helene Burningham** (UCL). Helen presented the contribution of climate variability and human intervention in the long-term historical variability in ecosystem structure and function at the recent decadal scale. Helen was followed by **Juliet Stefton** (Durham) who presented proxies for sea-level reconstruction in mangrove environments. **Daniel King** (Victoria University of Wellington, New Zealand) concluded the day by presenting sea-level reconstructions from New Zealand's subsiding coastlines. At this point, after a short summary note by the organisers, the participants were granted a few hours respite prior to a relaxed evening conference dinner by the marina at The Plymouth Stable.

Two days of field excursions followed the day of presentations, posters and discussion sessions. The excursions were informed by a comprehensive 30 page, full-colour field guide prepared by **Rob Barnett** and **Gerd Masselink** that contained a tour of 10 stops around southwest England. The guide presents an invaluable introduction to seminal and ongoing sea level and coastal research in the region. Excursion day 1 in Start Bay, South Devon (Tuesday 3rd Sept.) included informative visits to Lannacombe Beach (classic Quaternary coastal stratigraphy; sea-level history); Start Point (wave/tide conditions; long-term coastal evolution; role of Skerries Bank); Lost Village of Hallsands (dredging; role of NAO); North Hallsands (Holocene sea-level reconstruction; coastal water table); Beesands (coastal management; social justice); and finally Torcross (storm impacts; beach rotation; military history). The first day featured **Gerd Masselink** and **Roland Gehrels**.

The 1st excursion day was followed by a public engagement event organised at the Sherwell Centre, University of Plymouth. With the aim to foster discussion and collaboration across all disciplines and industries, the evening events included guest talks, a chaired panel discussion and a public Q&A session. With an incredible turnout from diverse communities (over 100), the thematic of coastal change, loss, social justice, artists/community involvement and shared decision making were explored.

The second excursion day (Wednesday 4th Sept.) was organised in the Godrevy Heritage Coast, North Cornwall. Guided by **Les James** and **Peter Ealey** from the Quaternary Research Association and **Isabel Kelly** from Plymouth Coastal Observatory. Four sites were explored: Godrevy Point (Late Quaternary exposures and St Ives Bay overview), Godrevy Cove and Godrevy Rocks (raised beaches, modern cliff erosion); Magow Rocks (extension of Pleistocene sequences, Holocene dune deposits); and finally Gwithian & Upton Towans Beach (beach sediment transport, dune progression).

The conference organisers are pleased to acknowledge a wide variety of support that ensured the success of this meeting. The QRA, University of Plymouth, University of Exeter, INQUA, Deltares and BLUEcoast are once again thanked for grant contributions. The hosts at the Sherwell Centre were exceptional and we hope to revisit them again soon. Thanks to: the keynote

speakers, **Iris Möller** (Cambridge) and **Anne-Marie Culhane** (Plymouth); the guest ECR speakers, **Jak McCarroll** (Plymouth), **Tara Quinn** (Exeter) and **Sophie Ward** (Bangor); the outstanding contributions from **Gerd Masselink** (Plymouth), **Roland Gehrels** (York), **Matt Telfer** (Plymouth), **Isabel Kelly (**Plymouth Coastal Observatory), **Les James** (Quaternary Research Association) and **Peter Ealey** (Quaternary Research Association); the official conference photographer **Salma Sabour** (Southampton); the meeting coordinators **Sarah Woodroffe** (Durham) and **Rob Barnett** (Exeter); and of course all the presenters and participants of SLaCC2019.

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THE OXFORD GEOHERITAGE VIRTUAL CONFERENCE: BRINGING OUR COMMUNITY TOGETHER DURING A GLOBAL PANDEMIC

As Coronavirus spread across the world in early 2020, one of the impacts was the necessary cancellation or postponement of conferences. For the geoheritage community this was most apparent in the moving of 10th International ProGEO Symposium to 2021. Recognising the often dispersed nature of workers within our field, and therefore the vital role meetings play, a small group of early career researchers came together to organise the Oxford Geoheritage Virtual Conference, 25-29th May 2020.

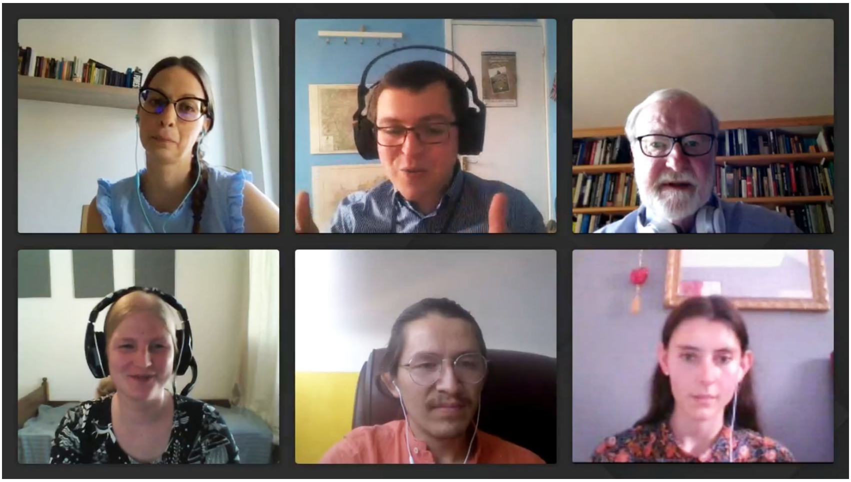

Figure 1. Speakers for OxGVC Session 3, clockwise from top left: Anna Masseroli, Jack Matthews (Chair), Prof. Murray Gray, Helena Tukiainen, Jose Gomez Romero, Abigail Brook-Petty.

Back in September of 2018, no one would have predicted how different daily life would be just 18 months later, and yet the foundations of one response to coronavirus were laid back then. The University of Minho, Portugal, was hosting an EGU training school on Geoheritage Management – a wonderful meeting that not only taught attendees a great deal, both in the lecture theatre and the field, but also fostered lasting connections between them. The stage was therefore set for late March that Dr Helena Tukiainen (University of Oulu, Finland), Dr Taha Younes Arrad (Chouaïb Doukkali University, Morocco), Dr Lucie Kubalikova

(Institute of Geonics of the Czech Academy of Sciences, Czech Republic), Dr Lubomir Strba (Technical University of Kosice, Slovakia), and myself had the existing connections to each other, to come together and organise the first major virtual conference on geoheritage.

Following our launch across social media on April 1st, we were nervous about how the idea would be received – hopefully not as an April Fool's prank! Our fears were allayed as it only took 2 days for the first 100 delegates to register, a number that would eventually increase to over 600 from 60 different countries. We are grateful to groups such as the Geological Association, the Quaternary Research Association, the English Geodiversity Forum, and ProGEO for all they did in supporting the event, and advertising the opportunities to be involved to their members.

We were also pleased to receive 86 abstract submissions. Even after taking the decision to extend the conference by an extra day, we were still only able to accommodate 60 of these, in both standard talk (15 minutes) and flash talk (5 minutes, 3 slides) formats. If you missed the conference, a number of talks have been uploaded to the OxGVC Youtube Channel. The OxGVC organisers are also indebted to our 3 keynote speakers:

Prof. José Brilha - Director of the Centre for Applied Research in Earth Sciences, University of Minho. *Geoethical principles in geoconservation*

Prof. Murray Gray - Honorary Professor of Geography, Queen Mary University of London. *Geodiversity: redundant term or evolving, multi-faceted, geoscience paradigm?*

Prof. Heather Viles - Professor of Biogeomorphology and Heritage Conservation, University of Oxford. *Integrating the conservation of geological, biological and cultural heritage: challenges and prospects*.

The meeting was run over the WebinarJam system, which had a number of benefits. Firstly both attendees and presenters were able to access the system through their web-browser, without downloading software. Also all the slides were uploaded in advance ready for presentation, meaning those with a poor internet connection did not have to use their limited bandwidth for data-hungry screen sharing. Presenters were able to give their talk using webcam and microphone alongside their slides, in real time, and then respond to questions attendees asked in the lecture room chat. It was great to see how the chat allowed attendees not only to engage with the speakers, but also with each other, exchanging papers, contacts, and ideas.

OxGVC benefitted from the fact that the Webinarjam online platform to run the conference had already been paid for to assist a research project, and therefore the conference itself could be provided to delegates for free. We therefore recognise financial support from the Higher Education Innovation Fund, through the Oxford Policy Engagement Network. The fact that OxGVC was free to attend, and accessible online anywhere in the world was no doubt an important factor in the high attendance in general, but also the relative high turnout from specific groups, such as undergraduate students, and those from developing countries. A questionnaire sent to attendees revealed that 52% had never previously attended an international geoheritage conference.

Further discussion around the topics raised in the conference sessions was facilitated through a conference facebook group, which also hosted informal drinks between attendees at the end of each day. There were also a number of unexpected outcomes from the meeting. We were very lucky to have Rachel Simpson attending the conference, a recent graduate of the University of Plymouth's degree in Illustration, who is always keen to apply her skills to anything geological. As well as the delight of illustrations inspired by talks being posted on social media throughout the week, attendees were treated to a montage of illustrated portraits of all the presenting authors at the end of the conference. It was a wonderful addition to the meeting and was greatly appreciated by presenters and attendees alike.

The other major unexpected outcome was a declaration from the meeting. Following a number of inspiring talks on the topic of geodiversity, we were contacted by Professors Brilha, Gray, and Zwoliński suggesting we use the conference to start

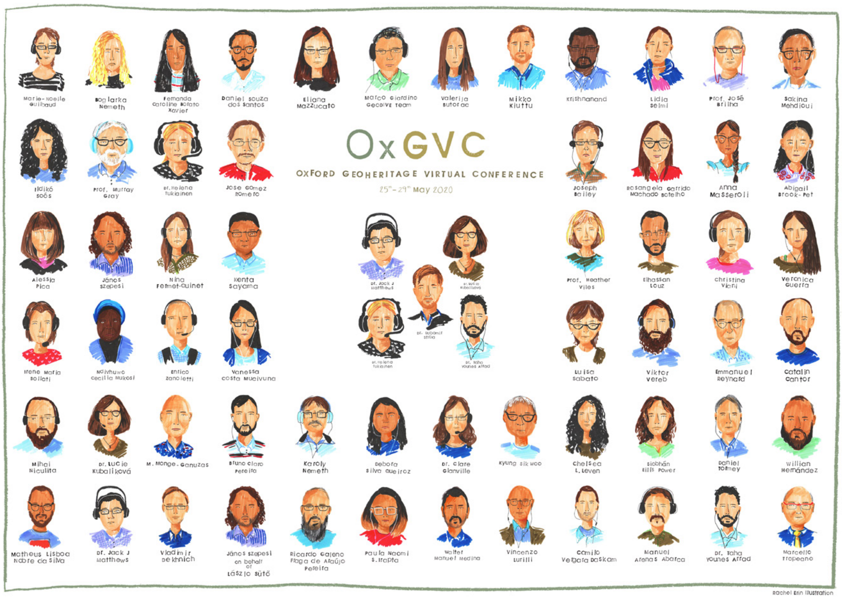

Figure 2. Illustrated portraits of OxGVC Presenting Authors by Rachel Simpson (hyperlink to https://www.rachelerinillustration.co.uk/)

a campaign to establish an International Geodiversity Day. Conference attendees have been signing a declaration, and the Professors and I have been contacting national and international organisations seeking their support – expect to hear more on this soon!

Face to face meetings will continue to play an important and necessary role in our discourse on geoheritage, but we have also shown that virtual meetings can be an effective way to convey knowledge and also engage groups who have previously been excluded. The OxGVC team and I hope to publish a more complete analysis of the conference organization and outcomes in a proposed article to *Geoheritage*, which we hope will support others looking to run virtual conferences. Thank you so much to all those who were a part of this meeting, and who knows, maybe we will have another one some time!

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GLOBAL PALEOFIRE WORKING GROUP 2 (GPWG2) FIRE POLICY BRIEF

2019 has been an exceptional year for highly devastating, catastrophic fires. The destructive Amazon rainforest and Australian fires have received worldwide media attention, raising debates about the causes and consequences of future wildfires in a warmer world.

Members of the PAGES Global Paleofire Working Group 2 (GPWG2), together with another 30 international colleagues, recently released a Policy Brief discussing how the integration of traditional ecological knowledge and long-term ecology could better support the evidence base for future decisions on fire policy and biodiversity conservation.

http://pastglobalchanges.org/download/docs/working_groups/paleofire/gpwg2-fire-policy-brief-2019.pdf

This Policy Brief results from a previous PAGES workshop hosted by the Geography Department at Royal Holloway University of London, UK, and supported by PAGES, the Quaternary Research Association (QRA), and CNRS/Université de Franche-Comté. The workshop attracted 30 international participants from 15 countries to discuss ongoing challenges on biodiversity conservation and fire policy at a global scale.

The Global Paleofire Working Group is a network of researchers promoting data collection and analyses of sedimentary charcoal records from around the world.

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^{14}C CHRONO AWARD

WHAT CONTROLS TURBIDITE RECURRENCE INTERVAL ON THE CENTRAL SUMATRAN MARGIN?

Earthquakes have claimed over thirty-five thousand deaths in the past decade. A sediment record of every earthquake is suggested to be deposited on the deep-sea floor. As a result, a better understanding of this record can be used to understand previous earthquakes and thus predict and plan future earthquake hazards. This project analyses deep sea sediment cores collected from the Sumatran convergent margin, in a region that recently experienced large magnitude earthquakes in 2004 & 2005. Each earthquake induced shaking on the continental shelf is suggested to trigger submarine mass movement on the continental slope, resulting in gravity-driven flows of sediment travelling into the deep sea known as turbidity currents. By calculating the sedimentation rates and temporal frequency of turbidity currents in these cores, we aim to better understand what controls the frequency of turbidites (turbidity current deposits), e.g. sedimentation rate or earthquake frequency.

Through visual core logging of six sediment cores, we have used sediment grainsize and colour to differentiate between background sedimentation and turbidite deposits. Accordingly, we have collected three radiocarbon dates, which have allowed us to constrain sedimentation rates in these cores. These were kindly funded by the Quaternary Research Association through the 14Chrono Award. Using this data, we conclude that sedimentation rate, earthquake frequency and turbidite frequency vary on a local scale. This results in localised turbidite sources and triggers, unique to each core location.

Our results suggest no one explicit influence controls turbidite frequency. Sedimentation rate varies locally, and our results indicate an inversely proportional relationship with turbidite frequency (figure 1). Earthquake rupture frequency shows a hesitant correlation with flow frequency, but suggests outside influences. Depositional setting appears to best regulate turbidite deposition, but only within defined settings, such as steep sided isolated basins.

In conclusion, our results advocate that turbidite recurrence on the Sumatran margin is controlled by numerous factors, but is best defined by depositional setting. These results can be applied to the ongoing study of turbidite paleoseismology in this region. This is the study of earthquakes as trigger mechanisms for turbidites. There is controversy whether turbidites are triggered by earthquakes in this region (Patton et al, 2013), or aren't always triggered by earthquakes in this region (Sumner et al, 2013). Our results do not disprove turbidite paleoseismology on the Sumatran margin, but highlight the need for investigation of depositional setting.

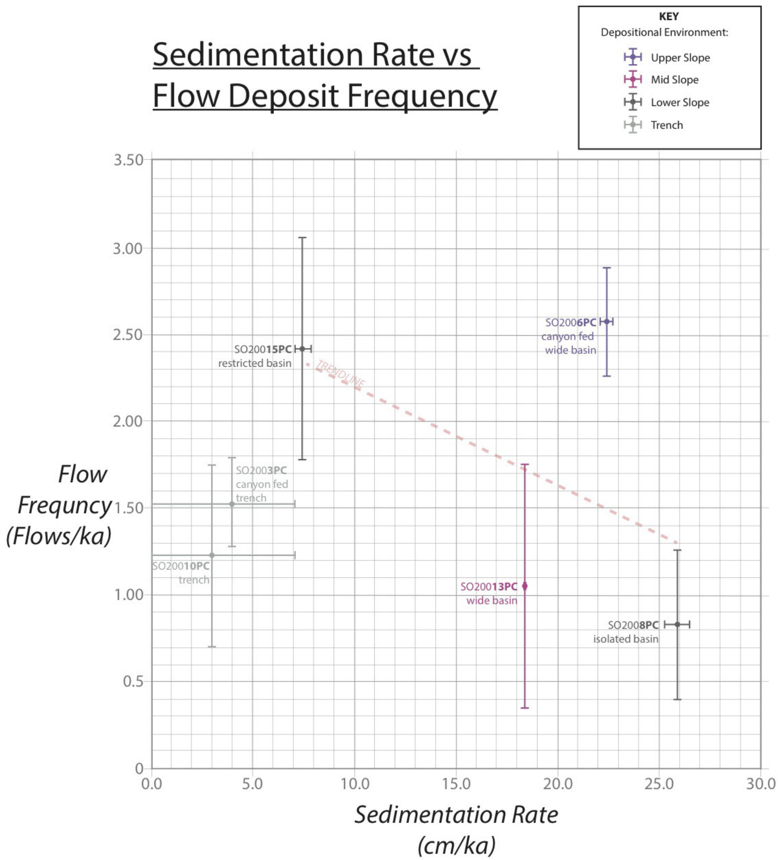

Figure 1. Sedimentation rate against temporal turbidity flow (earthquake) frequency for all studied cores.

With vigilant core locations, we therefore suggest that the trigger mechanism and recurrence of turbidites on the Sumatran margin can be better understood. This can help construct a turbidite record which can be used to extend earthquake histories beyond the human record. By recognising the frequency and patterns of past turbidites, the resultant statistics can be used to forecast earthquake hazards in the future.

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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 age on the world wide web can be found at: http://www.qra.org.uk

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