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Instructions to authors

Quaternary Newsletter is issued in February, June and October. Articles, reviews, meeting reports and reports on projects funded by QRA grants are invited and should be sent to the Editor. Closing dates for submission of copy 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 (not including captions or references) are as follows: articles (3000 words); obituaries (2000 words); reports on meetings (2000 words); reports on QRA grants (800 words); reviews (1000 words); letters to the Editor (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. Ph.D. 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

Mammalian teeth excavated from Loch Borralie Cave, near Durness, N. Scotland *(photo: Colin Coventry).* In this issue, Lawson and Kitchener present the oldest recorded radiocarbon date for lynx from a Scottish site.

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THE SIGNIFICANCE OF FAUNAL REMAINS INCLUDING LYNX, WOLF AND WILDCAT FROM LOCH BORRALIE CAVE, NEAR DURNESS, N. SCOTLAND

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The site

Faunal remains were uncovered in a narrow cave near Durness in northern Scotland in the 1990s during the removal of part of the sedimentary infill to aid exploration. Some of the identified species (lynx, wolf and wildcat) are of national significance. We present radiocarbon dates from lynx and wildcat; the lynx date is the oldest so far recorded from a Scottish site. Human remains were also recovered and dated to the Neolithic period, when burial of at least partial remains in caves was a fairly common phenomenon.

The site

The entrance to the cave (NGR 3864 6730) is situated at about 30 m O.D. on a low crag overlooking the SE side of Loch Borralie, 1.7 km WSW of the village of Durness (Fig. 1, inset). The cave is developed in the Croisaphuill Formation (Early Ordovician) near the top of the Durness Group of carbonate rocks. It developed as a phreatic tube which descends gently into the hillside at an average slope of 8°; some poorly-developed solution scalloping on the walls suggests water flow during formation was from the back of the cave towards the entrance.

The cave was discovered by a local resident, Mr Colin Coventry, in 1992. At that time only the first 5 m or so of the cave were accessible (F. Eadie, *pers. comm.*). Over a number of years of sporadic digging, Mr Coventry worked to open up the cave until his untimely death in 2019. Unfortunately, he did not keep detailed written records of this excavation but he did send the larger bones he uncovered to National

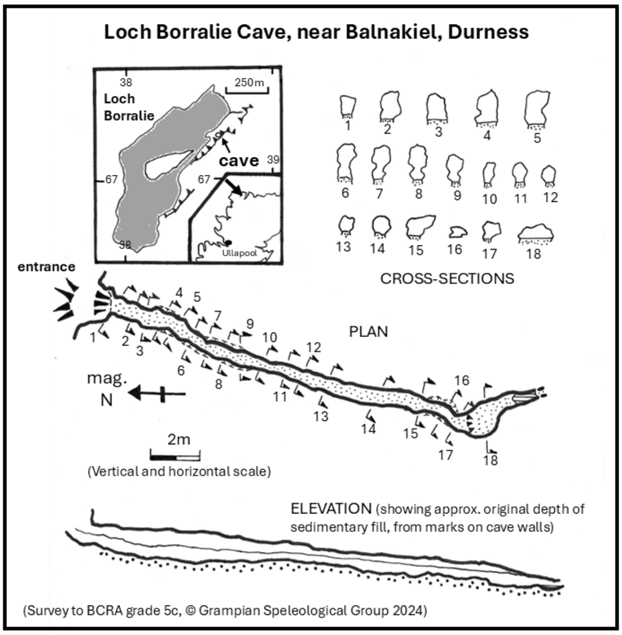

Figure 1. showing the cave plan, elevation and selected cross-sections. The inset shows the cave's situation on the east side of Loch Borralie, and location in northern Scotland.

Museums Scotland, where they have been curated. Some of these finds are of national importance, hence this attempt to bring them to a wider audience. Nowhere has the cave been excavated down to bedrock, and the sedimentary infill that remains still contains faunal material.

The cave comprises a narrow tube of broadly ovoid cross-section with a 'shelf' on either side approximately 1 m from the roof (Figs 1 and 2). Mr Coventry often referred to the cave as "Egg Timer Dig" or "The Lesser Northern Egg Timer" on account of this shape. Without further excavation down to bedrock, it is not clear whether the cave passage was formed originally by two phreatic tubes following a line of weakness in the limestone, subsequently breached by solution of the intervening rock, or the creation primarily of a classic 'keyhole-shaped' profile from an initial phreatic phase of formation followed by vadose entrenchment as water tables fell. What is clear is that deposits of a hardened but tufaceous flowstone cover most of these side ledges and have augmented the characteristic passage cross-section (Fig. 2). They are not found below the shelf and may therefore represent speleothem development down and onto clastic sediments in the bottom half of the passage, which were partly removed by Mr Coventry. Some 18 m inwards from the entrance a narrow zig-zag squeeze allows access to a small chamber. A sketch survey of the cave made by Mr Coventry indicates that the larger faunal remains were found in this chamber, but this is difficult to corroborate as smaller bone fragments are currently found throughout the existing sedimentary fill leading to the chamber. After wet weather a shallow pool forms towards the back of the cave, with the tube continuing beyond mostly blocked with sediment and currently impenetrable.

Figure 2. Photograph at approximately point 6 on the cave plan (Fig. 1), looking into the cave, illustrating the typical 'egg-timer' cross-section. On left side of the cave, a geological hammer (with a 25cm handle) indicates the scale.

The clastic sediments

During a visit to the cave in November 2023, a small exploration trench (approximately 15 cm deep x 10 cm wide x 30 cm long) was opened up against the NW wall some 3 m inside the entrance. Against the wall, small limestone blocks and cobbles created an open framework with voids, some containing smaller pebbles which exhibited a degree of rounding of corners. This coarser layer may extend beneath the main sediment in the cave, but the need to preserve the integrity of the deposits meant that this idea was not pursued at the time. The remaining deposits comprise a lower very dark grey-brown, clay-rich mud (Munsell colour 10YR 3/2) containing limestone breakdown, overlain by 10 cm of silty brown mud (Munsell colour 10YR 5/3) which contains some individual rounded and more angular limestone clasts up to 20 mm diameter. Small bones and bone fragments were found throughout the uppermost layer, but it was not possible to be sure whether the lowermost layer also contained faunal material without more extensive excavation. The clastic fill shows all the characteristics of having been introduced into the cave from the entrance by wash and creep processes, progressively moving sediment down the low-angled cave passage through time. Details of the lithostratigraphy require further investigation, which is being planned.

The faunal remains

Table 1 lists the animal bones excavated by Mr Coventry that were identifiable to species level.

Table 1. A list of the non-human mammalian finds excavated from the cave by Colin Coventry. ('MNI' = minimum number of individuals present.)

Latin name	Common name	No. of finds	MNI
Vulpes vulpes	Red fox	65	5
Meles meles	Badger	11	2
Canis lupus	Grey wolf	5	1
Felix silvestris	Wildcat	15	1
Lynx lynx	Eurasian lynx	40	2
Oryctolagus cuniculus	European rabbit	18	2
Ovis aries	Sheep	39	3
Sus domesticus	Pig	1	1

One canine tooth attributed to grey wolf might have come from domestic dog (*Canis familiaris*). Seven further bones could only be assigned to unidentifiable artiodactyls (i.e. either sheep or deer) as they were morphologically undiagnostic, as were two bones of a large mammal (a cranial fragment might be lynx), 27 bones from medium-sized mammals (some possibly small wolf/fox/wildcat), two microtine rodents (one of comparable size to water vole), and five bone fragments that defied any form of identification). There were also several bones that were clearly human (*Homo sapiens*), including a small mandible with very worn teeth, the upper part of a femur, and another part of a limb (fibula, radius or ulna?). Mr Coventry also excavated 11 mammal teeth from the cave, now also in the National Museums Scotland collection. One appears to be that of a grey wolf (*Canis lupus*), four are domestic dog (*Canis familiaris*), two of red fox (*Vulpes vulpes*) and two are the teeth of seals, one of which has been identified as grey seal (*Halichoerus grypus*). The November 2023 visit also recovered a large number of small bones and bone fragments that were washed out of the surface layers by roof drip. Two cockle shells (*Cardium edulis*) were found, although the cave is over 1 km from the coast. These finds await detailed investigation.

Four of the bones excavated by Mr Coventry were submitted to the Scottish Universities Environmental Research Centre AMS Facility for radiocarbon dating. The calculated dates are given in Table 2.

Calibrated age ranges are given at the 95.4% confidence level and rounded to the nearest 10 years. The date for the wildcat remains has not been corrected for any marine reservoir effect as its $\delta^{13}C$ value indicates that it had a relatively fish-enriched diet (Ascough et al. 2004), so the suggested age might be a few hundred years too old (K. Britton, pers. comm.).

Significance of the faunal remains

Loch Borralie Cave is significant for the number of skeletal remains from carnivorans. No other site in Scotland has yielded so many lynx bones (n=40) and few other sites in Scotland have produced wolf (n=4) and wildcat (n=15) bones. The radiocarbon date for the lynx femur is the only confirmed record of Mesolithic lynx in Scotland and collectively the bones represent at least two individuals, one of which is probably a male based on size. There is a possibility of confusion between wolf and domestic dog bones, which will require analysis of aDNA to confirm species' identification. Certainly, some of the canine teeth are too small to be wolf teeth and too large to be fox teeth, so that these are probably from domestic dogs.

Further radiocarbon dating is required in order to understand when different species' remains accumulated within the cave.

The presence of human remains within the cave is problematic, given the very constricted means of access to the small chamber where it is believed they were found. The radiocarbon dates obtained from two of them are of similar age to four dates on human bones excavated from Reindeer Cave on the Creag nan Uamh in Assynt (in Saville 2005), some 55 km to the SSW. This confirms the local presence of Neolithic humans, and the cultural use at that time of caves as sites for interment (Bonsall et al. 2012), at least for partial skeletal remains. Alternatively, in the case of this specific site, human remains might have been introduced into the cave by one of the larger predators. A detailed taphonomic study of these bones is required to test the latter suggestion.

Acknowledgements

The authors would like to acknowledge the work of Sheena Fraser who identified the faunal remains. Julian Walford and Simon Brooks, colleagues from the Grampian Speleological Group, helped Tim Lawson make a survey of the cave. Kevin Crowe kindly assisted in arranging a grant from the Durness Community Council to pay for the lynx radiocarbon date. Jessica Bownes obtained the other radiocarbon dates as part

Table 2. A list of AMS radiocarbon dates obtained from selected bones recovered from the site.

Species	Sample no.	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C/N ratio	^{14}C age (yrs BP)	Calibrated age (IntCal20)
Eurasian lynx	SUERC-44164	-21.1	5.9	3.2	7258 ± 24	8170-8010 cal. BP
Wildcat	SUERC-57754	-18.1	9.3	3.3	2917 ± 30	3160-2960 cal. BP
Human	SUERC-57755	-20.7	9.3	3.3	4743 ± 31	5590-5320 cal. BP
Human	SUERC-57756	-19.7	9.7	3.3	4875 ± 32	5710-5480 cal. BP

of her research project at SUERC. Kate Britton is thanked for her help calibrating the radiocarbon dates and helpful comments on their significance. Danielle Schreve is thanked for her helpful comments on the initial draft of this paper. Finally, we would like to highlight the efforts of the late Colin Coventry whose careful exploration of the cave over a number of years uncovered these important finds.

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STRATIGRAPHIC RECORDS OF COASTAL STORMS IN UK SALTMARSHES

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Abstract

Analysis of saltmarsh sediments allows a long-term record of storm events to be developed and patterns of change to be better understood. Storm surge saltmarsh deposits are identified through geochemical and particle size analyses of two saltmarshes from the east and west coasts of England. The deposits are dated using the radionuclides ^{137}Cs and ^{210}Pb and then compared with documented evidence of known storm events to consider the factors that influence their preservation. The presence of coarse-grained, mineral-rich sand units within the stratigraphy of both saltmarshes varies, but is correlated with known storm events. Not all documented storms are evident in the stratigraphies but where present they have contributed to maintaining saltmarsh elevation relative to sea level, demonstrating the importance of storm events for marsh resilience.

Introduction

Saltmarsh sediments provide records of past coastal storm events in the accumulation of stratified sequences (Croudace et al., 2012; Bunzel et al., 2021). Through analysis of this archive it is possible to detect patterns of change at a high resolution, thereby allowing a long-term record of storm events to be developed. Such sedimentary sequences have the potential to add significant value to knowledge of coastal storm events where historic records do not exist. However, the geomorphological impacts of coastal storms on saltmarshes are variable and not well understood. This research develops a greater understanding of the mesoscale (decadal- to century-scale) geomorphic impacts of recent storm events (from circa 1930) on saltmarshes, through elemental and radiochronological analysis of sediment boreholes from two different coastal settings in the UK. Comparison of the saltmarsh archives with documented records of storm events contributes to the analysis of factors that influence their preservation.

Study sites

Kilnsea Marsh is located on the neck of Spurn Point, a 5.5 km long ridge of sand and gravel at the mouth of the Humber Estuary which has been in place for at least 440 years (east coast of the UK; Figure 1a and 1b) (Bateman et al., 2020). It is a sheltered back-barrier silt-clay saltmarsh. Historically Spurn Point has been subjected to numerous storm-related breaches, which may in part govern its rate of development (de Boer, 1969; Crowther, 2010). Despite the rapid retreat of the Holderness coast and the macro-tidal conditions of the Humber Estuary (maximum range 7.2 m) (Cave et al., 2003), Spurn Point has maintained a relatively constant position owing to historic management and the presence of resistant, underlying glacial till (Crowther, 2010). Notable periods of anthropogenic change include during the mid 1800s, when artificial dunes approximately 50 metres wide and 3 km long were created at the neck of Spurn Point by trapping sediments behind wattle fences and planting marram grasses (Lee and Pethick, 2018). Prior to this, significant land reclamation in the Humber from the

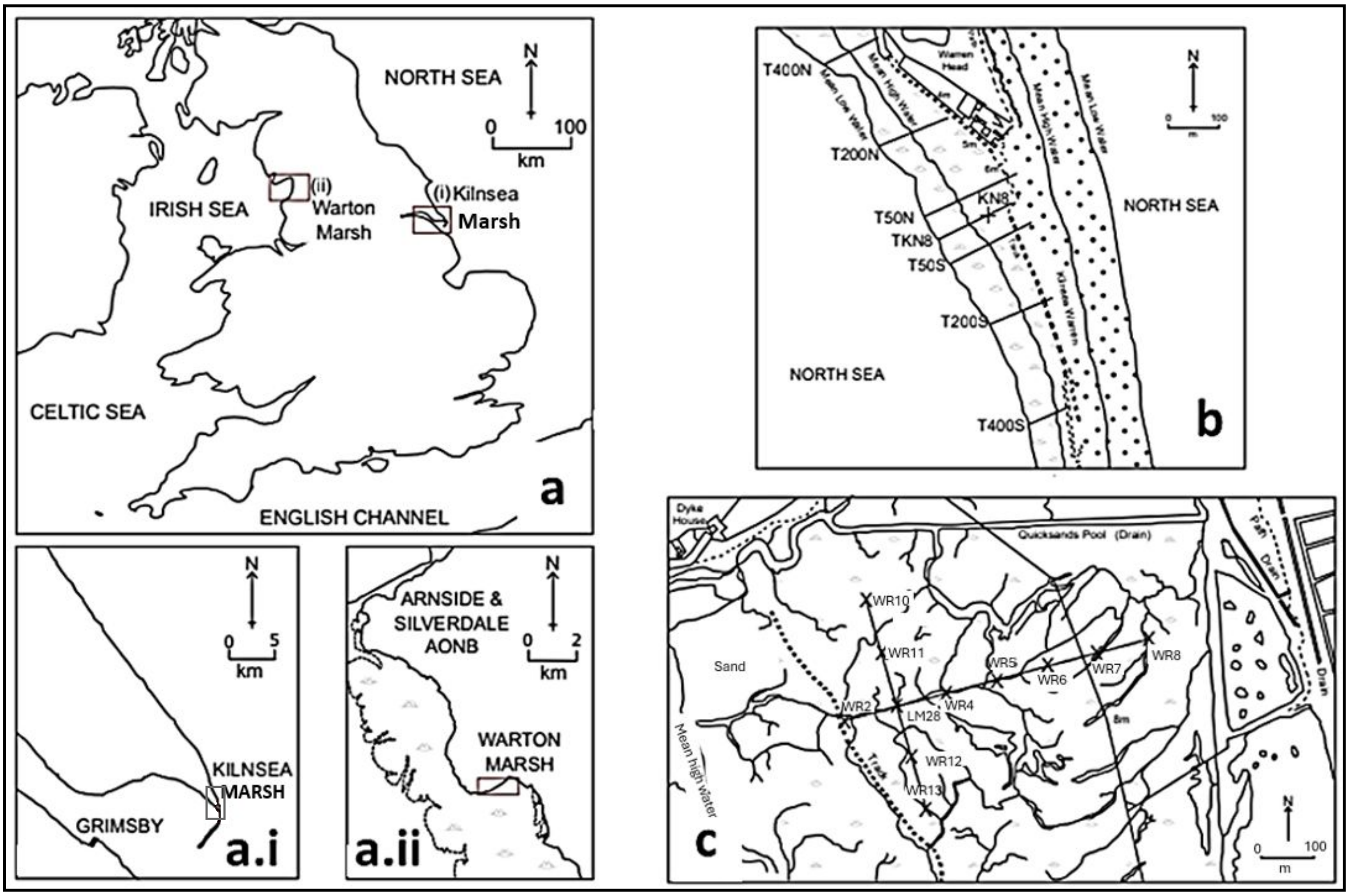

Figure 1. (1a) Map of the UK and insets showing the two study sites at Kilnsea Marsh, Spurn Point, Humber Estuary and Warton Marsh, Morecambe Bay; (1b) map of Kilnsea Marsh, showing the coring site at KN8 and borehole transects at 50 m, 200 m and 400 m north and south of KN8; (1c) map of Warton Marsh, showing the coring site at LM28 and borehole transects. WR8 is located in the high marsh and WR2 is close to the marsh cliff.

1600s is likely to have had an impact on the sediment dynamics of Spurn Point (Lee and Pethick, 2018). The saltmarshes of the Humber Estuary are largely ungrazed and rich in plant species characteristic of lower saltmarsh communities.

Warton Marsh in Morecambe Bay is an exposed marine embayment with notable sandflats (Figure 1a and 1c). Marsh cliff erosion occurs during storm events and this has increased in severity in recent years due to the increased incidence of extreme high water levels in the Irish Sea (Brown et al., 2010). The study site at Warton Marsh is characterised by cyclic saltmarsh development driven by river channel migration (Pringle, 1995; Mason et al., 2010). The saltmarshes of Morecambe Bay are heavily grazed.

Methodology: Fieldwork

The stratigraphy of the study sites was tested using a gouge auger and recorded using a modified Troels-Smith (1955) classification. Transects of cores were taken at regular intervals (Figure 1b, c) and the borehole locations and elevations recorded using a differential Global Positioning System (dGPS) with a precision of ± 0.1 mm (Woodroffe and Barlow, 2015). A representative sample borehole (KN8, Kilnsea Marsh and LM28, Warton Marsh) was extracted from each study site for laboratory analyses.

Laboratory analyses: Particle size analysis

Particle size analysis (PSA) was undertaken to identify changes in the sedimentary sequences. The cores were subsampled contiguously then pretreated with 30% H_2O_2 to remove organic matter and ultrasonic treatment was used to disaggregate flocs (Vaasma, 2008). The samples were analysed using a Coulter LS 230 laser granulometer. The Fraunhofer optical model was applied to produce curves of particle size (µm) against volume (%). These data were grouped using the Wentworth scale (Wentworth, 1922) and mean values of the replicate subsamples were calculated to determine the relative percentage volume of the sand, silt and clay fractions (Figure 3 and Figure 4).

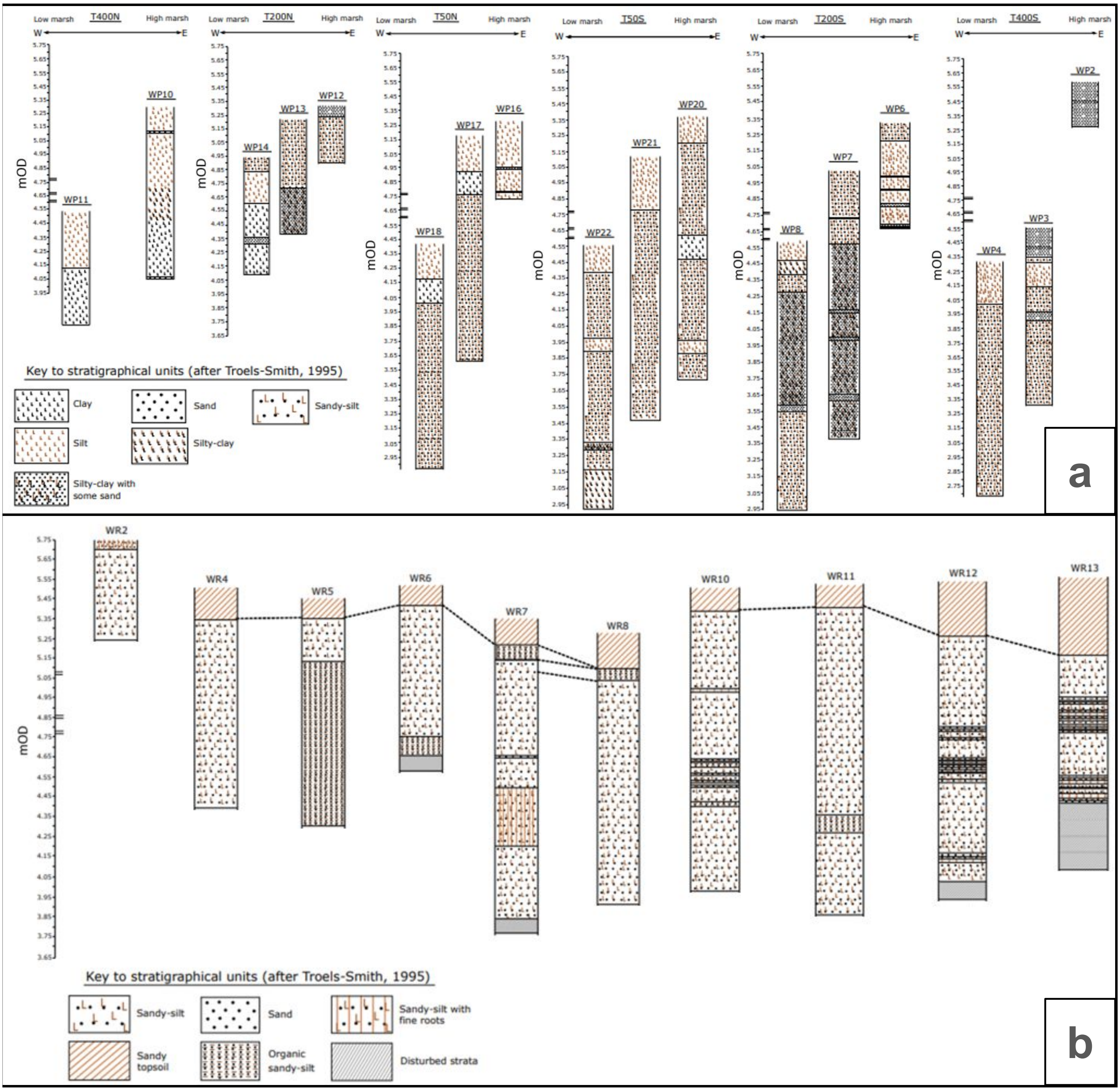

Figure 2. Stratigraphy of the saltmarsh at Kilnsea Marsh (a) and Warton Marsh (b) (after Troels-Smith, 1955). The position of sand layers in the KN8 core are highlighted on the altitude axes to facilitate comparison with the borehole stratigraphy.

Loss on Ignition

Loss on ignition (LOI) analysis was undertaken to identify any changes in the carbon content of the sediments which could be associated with changes in sediment deposition. LOI was undertaken at 550°C and 950°C following Heiri et al. (2001) to estimate organic matter and carbonate content respectively in the sediment. Subsamples of 1 cm^3 were oven-dried at 105°C for 12 hours and at 550°C for 3 hours, then at 950°C for 2 hours.

Geochemical analysis

To identify potential proxy elements indicative of a storm surge, the sediment cores were investigated using a Core Scanning X-ray fluorescence System (Itrax core scanner at NERC-BOSCORF, Southampton; Croudace et al., 2006; Rothwell and Croudace, 2015). This instrument acquired a radiographic image and a range of element variations at 200-400 μm resolution along the sediment core. Ba, Ca and Sr were used as indicators of marine flooding and evidence of storm and tsunami events (e.g. Szczucinski et al., 2012; Goslin and Clemmensen, 2017). Si and K were indicators of the abundance of medium-coarse grained sand often found in storm surge deposits and heavy trace minerals (e.g. zirconium) were measured due to their concentration during storms (Tsompanoglou et al., 2010). Elemental variations were normalised to Ti integrals to provide compensation for variations in physical and chemical (inter-element) properties. The relative abundance of each element (i.e. indicator/ Ti) was presented as natural log (ln) ratios for comparative purposes.

^{137}Cs and ^{241}Am radiochronology

^{137}Cs and ^{241}Am radionuclide dating were undertaken to evaluate the sediment accumulation rates and provide an estimated age for the identified storm deposit layers (Croudace et al., 2012; Andersen, 2017). Radionuclide determinations were made using well-established and validated methods at GAU-Radioanalytical Laboratories (National Oceanography Centre) (Croudace et al., 2012; Croudace et al., 2019). Caesium-137 and Am-241 were measured using low background, well-type HPGE gamma spectrometry systems (Mirion UK Ltd, Didcot, UK) at GAU-Radioanalytical. Weighed samples were typically counted in scintillation vials for 80,000 seconds and spectral analysis was carried out using Fitzpeaks software (JF Computing, Stanford in the Vale). In these coastal UK sediments, Cs-137 was used to identify chronological markers of key radionuclide events (e.g 1963 global 'bomb' pulse and Sellafield marine releases) consistently identified in UK western saltmarshes (Croudace et al., 2019). Marine locations in the Irish Sea Basin, relatively close to the Sellafield nuclear processing site, often present measurable ^{241}Am data that corroborate the ^{137}Cs interpretation. Comparison of the ^{137}Cs chronology with the published ^{137}Cs discharges from Sellafield (Tsompanoglou et al., 2010; Swindles et al., 2018; Croudace et al., 2019) enabled the creation of age-depth models which reflect the lag time between discharge, deposition and sediment transportation to the west coast (circa 1 year) and the east coast (circa 3 years).

Results: Stratigraphy

All of the boreholes at Kilnsea Marsh (Figure 2a) are dominated by silts and clays with the inclusion of some sand layers below circa 4.65 mOD. The lithostratigraphy of the sample borehole (KN8) primarily comprises olive to grey-brown silt. The borehole transects surrounding KN8, show variation in the frequency, thickness and altitude of sand layers across the marsh. At Warton Marsh the boreholes are dominated by sandy silts (Figure 2b). The transect from WR10 to WR13 shows the greatest lithostratigraphic variety, with multiple sand layers visible at circa 5-4 mOD. KN8 and LM28 were selected for laboratory analysis as the stratigraphies showed multiple visible sand layers and their positions in the marsh were considered likely to have been affected by past storms.

Loss on ignition and particle size analyses

Very fine to medium silt dominates the sequence at Kilnsea Marsh, with peaks in the medium to coarse-grained silt fraction which correspond with increased percentages of sand. The sand fraction is plotted with organic matter content (%) and the profiles of Zr, Ti, Ca and Si (Figure 3).

Medium, coarse and very coarse-grained sand peaks are evident in the profile at Warton Marsh, with a clear transition from silty clay to sandy silt at the core base. The sand fraction is plotted with organic matter content (%) and the profiles of Zr, Ti, Ca and Si (Figure 4).

Geochemical analysis

Kilnsea Marsh

There is co-variation in Zr, Ti, Ca and Si with the peaks in very fine to fine sand fractions, indicating potential storm derivation (Figure 3). There is also co-variation in the Ca and Si profiles where there is minor variability in sand (%) between 25-0cm.

Zirconium (Zr) is likely represented by dispersed mineral grains of zircon (Tsompanoglou et al., 2010) and there is some correlation between sand layers and peaks in Zr in the profile indicating offshore derivation. There are three key phases of coarse mineral sand deposition represented in the sediment record, which may be associated with high-energy storm events: 27-25.5 cm, 20-21 cm and 8-8.5 cm.

Warton Marsh

At Warton Marsh (Figure 4) there are peaks in Pb, Si, Ti, Zr, Sr and Cr at 64 cm. A spike in Ti at 42 cm coincides with increases in Zr, Ca, Si and Sr. Peaks in Zr and Ti occur at 38 cm and slight spikes in Zr, Ca, Sr and Cr occur at 24 cm. There are further mineral peaks at 10 cm. The dark black-brown, silty-clayey

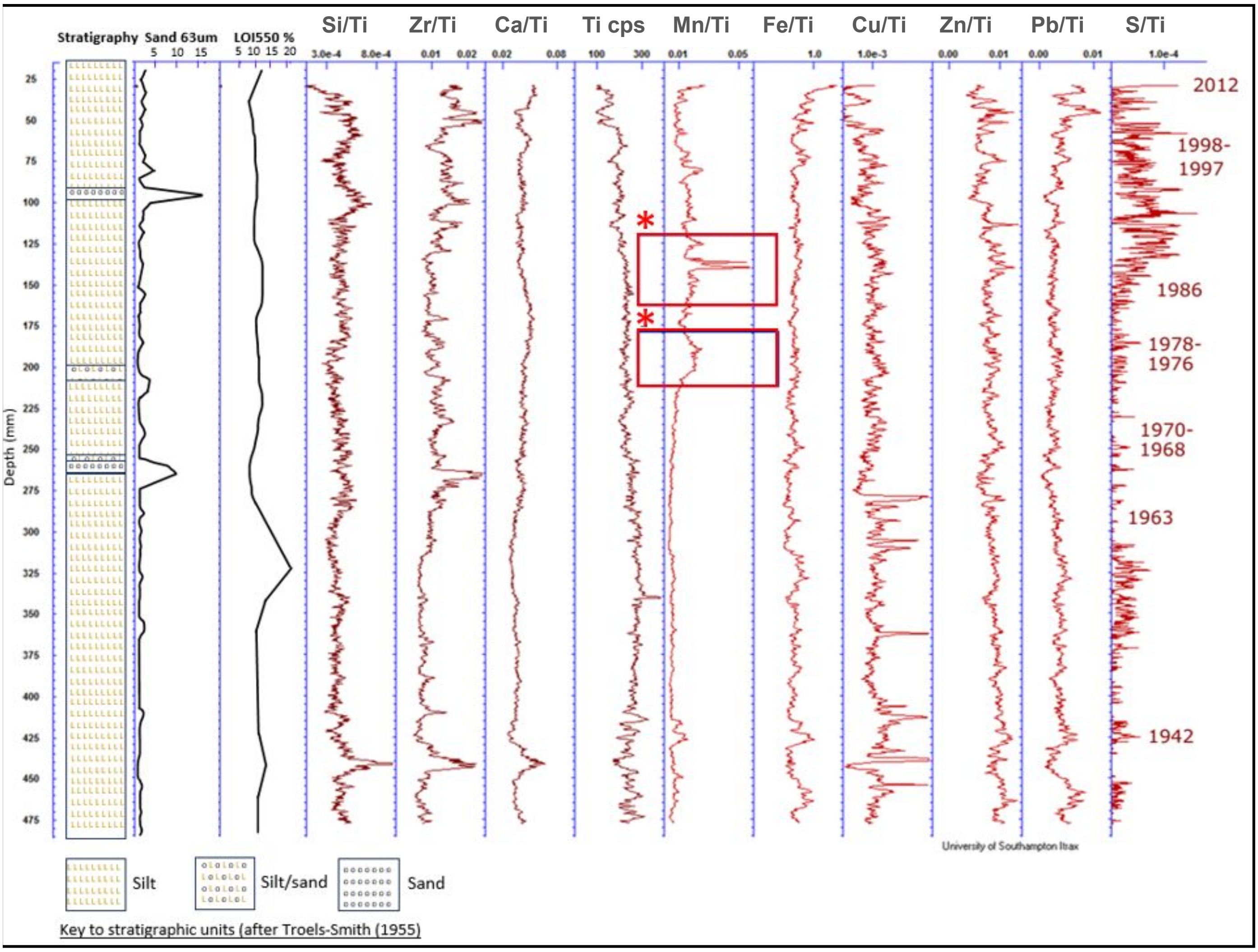

Figure 3. Stratigraphy (after Troels-Smith, 1955) of core KN8 from Kilnsea Marsh, Spurn Point plotted alongside the results of the PSA (sand 63 um), LOI550 and geochemical analyses. * = Redox zones where Mn oxyhydroxide is precipitated.

peat at 34-27.5 cm yields a substantial decrease in Si, Ti and Ca, due to reduced sand content. There are three key phases of heavy mineral sand deposition represented in the sediment record, which may be associated with high-energy storm events: 41-42 cm, 33-34 cm and 10-11 cm.

Chronology

The uppermost sediments in the analysed cores represent deposition up to approximately 2005–2006 based on the radionuclide-derived age-depth model; therefore, more recent storm events are not represented within the stratigraphic record analysed in this study.

Kilnsea Marsh

^{137}Cs dating indicates that the Kilnsea Marsh core has a sediment accumulation rate of ~1.30 cm a^{-1} (Figure 5). This is based on the broad ^{137}Cs spikes at 38.5 and 45 cm depth that are attributed to Sellafield discharge spikes (Gray et al., 1995). A 3-year lagtime is used for ^{137}Cs transport and deposition of Sellafield derived ^{137}Cs and is consistent with arrival times in southern North Sea marshes (Tsompanouglou et al., 2010; Swindles et al., 2018). The ^{137}Cs peak at 34.5 cm depth is attributed to Chernobyl fallout from 1986 and is again consistent with saltmarsh sediment cores from southern North Sea marshes (Tsompanoglou et al., 2010).

Warton Marsh

The presence of ^{137}Cs and ^{241}Am in the Warton Marsh profile are attributable to transported sediment contaminated/labelled by sorbed radionuclides from Sellafield nuclear plant releases (Gray et al., 1995; Figure 5). Similar patterns for ^{137}Cs and ^{241}Am are well-known from other intertidal Irish Sea sediments

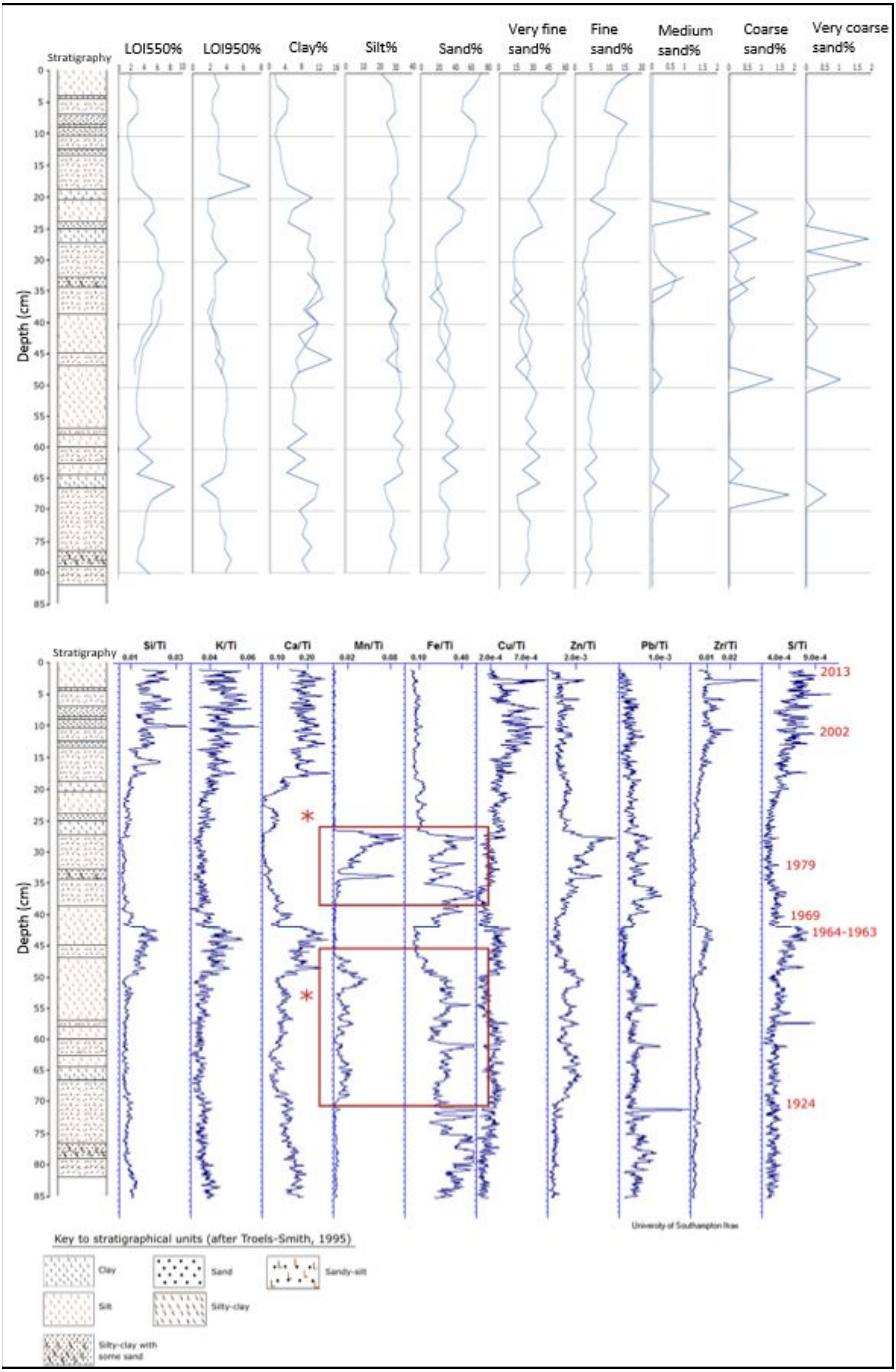

Figure 4. Stratigraphy (after Troels-Smith, 1955) of sediment core LM28 from Warton Marsh plotted alongside the results of the PSA, LOI550, LOI950 and geochemical analysis. * = Redox zones where Mn oxyhydroxides are precipitated.

(Kershaw et al., 1990; Croudace et al., 2019). A generalised 1-year lag time is used for ^{137}Cs transport to Warton Marsh (Croudace et al., 2019). The smaller contribution from the 1963 ^{137}Cs 'bomb peak' is generally obscured by the larger Sellafield signal (Croudace et al., 2019). Similarly, the contribution of ^{137}Cs fallout from the 1986 Chernobyl event is barely discernible at Warton but is known in saltmarsh sediments nearby (Croudace et al., 2019). It is notable that Sellafield releases had declined significantly by 1986, but they clearly remained in the sedimentary system. A sediment accumulation rate of 0.87 cm a^{-1} over the 90 cm length of the core is determined and indicates the base of the core to be ~1910.

Comparison with documented storm events

Data on historical storm events, derived from tide gauge stations, scientific reports, news reports and aerial photographs, were compared to the chronology, PSA, LOI and geochemical analyses to investigate which storms were recorded within the stratigraphy. Twelve potential storm events were identified at Kilnsea Marsh and eighteen at Warton Marsh (Table 1).

Kilnsea Marsh

The peaks in coarse-grained, mineral-rich sands in the stratigraphy correspond with documented storm events in 1969 and 1976-1978. Deposition during the periods circa 1985 (27.0-25.5 cm depth), circa 1991 (21.0-20.0 cm depth) and circa 2005 (8.5-8.0 cm depth) may be due to significant North Sea storm surges. Deposition from the east-tracking surge of 9 February 1997 may be recorded at 21-20 cm and the surge of 12 January 2005 may be recorded at 8.9 cm. The presence (or absence) of sediment transport pathways within Kilnsea Marsh, such as streams and creeks may account for the spatially non-uniform deposition of sediments observed at this site during individual inundation events (French and Spencer, 1993; French et al., 1995), including during high water depths and high wave energy conditions (Van Proosdij et al., 2006).

Warton Marsh

Documented storm events at Warton Marsh correspond with peaks in coarse-grained, mineral rich sediment deposition at 79.2 cm (19 February/30 December 1926), 78.4 cm (28 October 1927), 63.8 cm (February 1943), 33.7 cm (January 1976) and 27.3 cm depth (January 1983). These events damaged coastal protection structures and caused flooding in Morecambe and Heysham. A major surge on 1 February 1983 appears to be recorded in the heavy mineral sand peak at 27.3 cm. Heavy mineral sand peaks at 22.8 cm depth may represent the significant surge of 9 February 1988 that produced overmarsh tides at neighbouring Silverdale Marsh, to the north of Warton Marsh. Wave action removed and disaggregated turf blocks and the composite sediment was deposited upon the marsh. There are significant alterations at 41, 33 and 10 cm which may be attributable to documented Irish Sea storm surges. In circa 1969 (41.0 cm depth) the surge damaged coastal protection in Morecambe and eroded dunes along the Sefton coast (Brown et al., 2010). In circa 1977 (33.0 cm depth) Morecambe sea walls were breached and may be attributable to the east-tracking surge, which was recorded at Immingham on 13 November 1977. In circa 2002 (10.0 cm depth) a skew surge of 1.08 m at Heysham tide gauge and return period of 28 years were observed.

Discussion

Inferred storm layers identified in sediment cores based on chemical and mineralogical data show that the presence of coarse-grained sediment deposits alongside peaks in heavy metal concentration can be a consistent indicator of storm events, even in contrasting estuarine settings with different geology, orientation and bathymetry. At Kilnsea Marsh there are three key phases of coarse mineral sand deposition represented in the sediment record alongside some peaks in Si, Ti, Zr and Ca. At Warton Marsh there are multiple phases of coarse-grained, mineral rich sediment deposition. Comparison with the historic record of documented storm events shows that multiple events were potentially recorded in the stratigraphies of both study sites as depositional events. However, some storms have not been recorded. For example, following a storm in 1925 (~80 cm maximum surge), flooding was documented at Morecambe, Pilling, Knott End, Bolton-le-Sands and Cockerham Sands (Zong and Tooley, 2003). Whilst there are peaks in Zr, Ti, Ca, and a slight peak in Si at this depth, there are no corresponding coarse-grain peaks in the particle-size data. Another example is the southeast-tracking surge of 31 January to 1 February 1953, the most devastating storm to affect north-western Europe in the last century (Duiveman and Jensen, 2025). A substantial skew surge of 1.58 m was recorded at Immingham, 20 km west of Kilnsea Marsh, with a

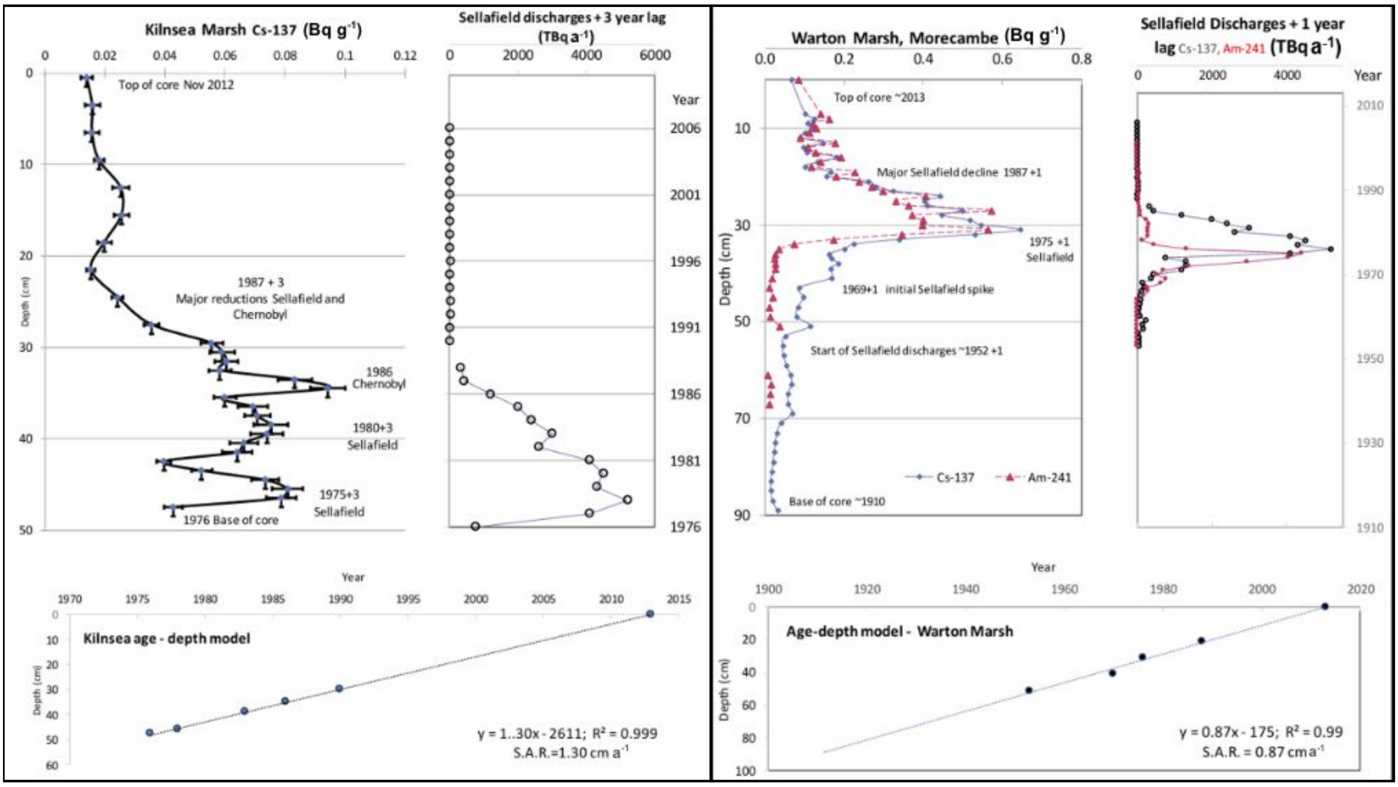

Figure 5. Cs-137 (Bq g^{-1}) in the saltmarsh sediment at Kilnsea Marsh and Warton Marsh against depth (cm). The inferred chronology for the saltmarsh sediment is presented based on correlations with Sellafield liquid discharges (TBq a^{-1}) and Chernobyl fallout event of 1986. The Sellafield liquid discharge data from Gray et al (1995) are modified using a +1 time lag in the age-depth model.

NOTE: The indicative lag time is +1 year and +3 years respectively for West coast and East coast saltmarshes

return period of 21 years. Coarse-grained, mineral-rich silty-sands in the marsh stratigraphy at Wrangle, north Norfolk were attributed to the 1953 surge (Tsompanoglou et al., 2010; Swindles et al., 2018). The Kilnsea Marsh stratigraphy does not, however, record such deposits and one possible explanation is that the marsh was insufficiently established to record such deposition.

While the data from this study show that major storm surge deposition can contribute to sustaining saltmarsh elevation relative to sea level, storms have likely had a range of impacts on the saltmarshes. Storms may be erosional in nature and as such eliminate previous deposits (Riddin and Adams, 2021). Some storm surges may not show as depositional events in higher areas of the saltmarsh if they do not coincide with high tide because the coarse grain sediments would be intercepted by the low marsh grasses (Rupprecht et al., 2017). Furthermore, it is highly plausible storms may have negligible sedimentological impacts if the bathymetry, meteorological and environmental conditions hinder surge wave propagation or are conducive to effective wave dissipation, preventing substantial erosion or deposition (Spencer et al., 2015; Rupprecht et al., 2017).

Saltmarsh orientation is a key determinant of exposure to waves, currents, and onshore winds. Kilnsea Marsh is relatively sheltered in the lee of Spurn Point, which acts as a partial barrier to wave energy and storm surge propagation. This choking/filtering effect likely reduced the frequency and magnitude of sediment delivery to the marsh surface during easterly storm events. Consequently, only storms associated with particularly high water levels, overwash, or breaching of Spurn Point may leave clearly identifiable sedimentary signatures within the marsh stratigraphy. On the other hand, Warton Marsh faces southeast towards the mouth of Morecambe Bay. It is therefore more exposed to onshore winds and wave run-up and at greater risk of erosion during storm events. For example, during the 5th December 2013 surge, Morecambe received the full force of the waves, whilst east-facing Grange-over-Sands was comparatively sheltered from westerly winds and waves (Morecambe Bay Partnership, 2013).

Nearshore bathymetry, such as river channels and

Table 1. Documented regional storm events and potential storm sediment characteristics. [1]Muir Wood et al. (2005); [2]Troels-Smith (1955); [3]Spencer et al (2015); [4]SurgeWatch (2016); [5]Dawson et al. (2007); [6]Richards (1978); [7]Spink (1988); [8]Crowther (2010); [9]Tsompanoglou et al. (2010); [10]Heaps and Jones (1979); [11]Spink (1978); [12]Steers et al. (1979); [13]Banks (1974); [14]Heaps (1969); [15]Heaps (1983); [16]Steers (1953); [17]Corkan (1950); [18]Brown et al. (2010); [19]Zong and Tooley (2003); [20]Pringle (1995); [21]Lancaster City Council (2008); [22]Posner (2004).

Documented Storms		**Kilnsea Marsh**							
Date	**Ref**	**Depth (cm)**	**Altitude (mOD)**	**Sediment**	**Coarse grains**	**Geochemistry**			
						Zi	**Ti**	**Ca**	**Si**
12/01/05	3,5,6	4.14	4.8	Fibrous silt		✓	✓	✓	✓
09/02/97	4	8.85	4.75	Fibrous silt	✓		✓	✓	✓
07/10/90	3,4	13.02	4.71	Fibrous silt	✓	✓		✓	✓
01/02/83	4	17.16	4.67	Fibrous silt	✓	✓	✓		✓
11/01/78	4,7,8,9,10	20.12	4.64	Fibrous sandy silt	✓	✓		✓	✓
15/11/77	11	20.71	4.63	Fibrous sandy silt	✓	✓		✓	✓
13/11/77	4	20.71	4.63	Fibrous sandy silt	✓	✓		✓	✓
31/01/76	9	21.31	4.63	Fibrous silt	✓	✓		✓	✓
03/01/76	4	21.31	4.63	Fibrous silt	✓	✓		✓	✓
29/09/69	3,4,7,12,13	25.45	4.59	Fibrous silt	✓	✓	✓	✓	✓
19/02/69	7,8,13	25.45	4.59	Fibrous sandy silt	✓	✓	✓	✓	✓
15/02/62	14,15	29.59	4.54	Fibrous silt			✓		✓
20/03/61	14	30.18	4.54	Fibrous silt				✓	✓
31/01/53	4,8,10,16	34.92	4.49	Fibrous silt					
08/01/49	17	37.29	4.47	Fibrous silt with charcoal			✓	✓	✓

Documented Storms		**Warton Marsh**							
Date	**Ref**	**Depth (cm)**	**Altitude (mOD)**	**Sediment**	**Coarse grains**	**Geochemistry**			
						Zi	**Ti**	**Ca**	**Si**
03/12/06	18	6.37	5.11	Sandy silt		✓	✓	✓	✓
01/02/02	4	10.03	5.07	Sand	✓	✓	✓	✓	✓
10/02/97	4	14.59	5.02	Sandy silt		✓	✓		
01/02/90	18	20.97	4.96	Silty clay					✓
09/02/88	20	22.79	4.94	Silty clay	✓	✓	✓	✓	✓
01/02/83	4,19	27.3	4.9	Silty clay	✓	✓	✓	✓	✓
Jan 83	21	27.3	4.9	Silty clay	✓	✓	✓	✓	✓
Nov 77	18,21,22	32.82	4.84	Black sand	✓	✓	✓		✓
Jan 77	21	33.74	4.83	Black sand	✓	✓	✓	✓	✓
Mar 68	18,21	41.03	4.76	Silty sand	✓	✓		✓	✓
Nov 60	21	48.23	4.69	Organic silty clay	✓	✓	✓	✓	✓
Aug 57	21	51.06	4.66	Silty clay, fine sand		✓	✓	✓	✓
Mar 45	21	62	4.55	Sandy silt	✓			✓	✓
Feb 43	21	63.82	4.53	Sandy silt	✓	✓	✓	✓	✓
Nov 38	21	68.25	4.49	Silty clay with grit		✓	✓	✓	✓
28/10/28	19	77.5	4.4	Silty clay with grit	✓		✓	✓	✓
Oct 27	19,21	78.41	4.39	Silty clay with grit	✓	✓	✓	✓	✓
19/02/26	19	79.17	4.38	Silty clay with grit	✓	✓	✓	✓	✓
1925	19	80.24	4.37	Silty clay with grit		✓	✓	✓	✓

sandbank proximity, can account for differential erosion or deposition during high-energy events, as was evident at Silverdale Marsh, Morecambe Bay (Pringle, 1995). Sandbank and tidal channel mobility in Morecambe Bay can yield distinct variability in saltmarsh geomorphological response to a storm with westerly storms and peak spring tides causing tidal channel and sandbank shifts, particularly in the inner Bay (Zong, 1993). Sandbanks may protect the marsh during storm events through increased bottom friction and concurrent wave energy reduction (Zong, 1993). The absence of laterally continuous stratigraphic correlation between sand units across the transects at both study sites highlights the spatial heterogeneity of storm deposition within saltmarsh systems. Storm-derived sedimentation is strongly influenced by local controls including creek proximity, vegetation density, marsh elevation, inundation depth, and sediment transport pathways (Tweel and Turner, 2012). Consequently, storm deposits may occur as discontinuous lenses rather than regionally extensive beds. This spatial variability suggests that caution is required when interpreting individual storm horizons from isolated cores and reinforces the importance of combining sedimentological, geochemical, and chronological proxies when identifying storm signatures.

Sandbanks within Morecambe Bay also function as a source of sediment availability and delivery to Warton Marsh (Montreuil and Bullard, 2012). At Spurn Point, eroded material from the Holderness Cliffs is an important sediment source that is transported south through longshore drift and stored in offshore sandbanks. It is predicted that sediment transport into Morecambe Bay will increase in response to sea-level rise and increased surges (Wyre Borough Council, 2013).

Conclusions

This study uses sedimentological, radiochronological, geochemical and historical evidence to investigate the impacts of storms on two saltmarshes located in eastern and western England. Radionuclide dating combined with stratigraphic and geochemical evidence identifies storm deposits dating between 1910 and 2013, with multiple events evident in the stratigraphy of both sites in the form of coarse grained, mineral rich horizons. Comparison with regional documented storm events allowed the timing and stratigraphic impacts of storm events to be analysed. Key events captured included the November 1977 storm surge which was evident at both study sites. However, not all storm events were captured in the sediment record, demonstrating that the effects of storms on saltmarshes can be variable. Analysis of deposits from two contrasting estuarine settings allowed the causes of this variability to be considered and illustrates the importance of using multiple proxies to help determine the levels of erosion, deposition, and the subsequent ecological consequences which can be traced back to storm events with any certainty.

The combined sedimentological and archival analyses of two saltmarsh sedimentary sequences in England highlight that uncertainty remains around the regional impacts (or non-impacts) on saltmarshes as major deposition events are shown to be inconsistent. The inconsistency raises important questions regarding the future sedimentological and geomorphological impacts of coastal storms on the saltmarsh environments which are susceptible to retreat given the predicted increases in regional relative sea level, storm frequency and coastal squeeze. More research is required to explore the uncertain sedimentological impacts of storms in the region. This could contribute to sustaining the vulnerable coastal saltmarsh environments and the important ecosystem services they provide.

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Quaternary Newsletter
Article

PUBLIC ENGAGEMENT WITH LIFE IN THE ICE AGE AT CRESWELL CRAGS

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Creswell Crags is a unique site on the Derbyshire/Nottinghamshire border, a Scheduled Ancient Monument and SSSI celebrated for its Ice Age cave art and over 50,000 years of human habitation, cared for by Creswell Heritage Trust. The purpose of the project, supported by QRA Mabel Tomlinson Outreach funding, was to promote better awareness and understanding of the Palaeolithic heritage of Creswell Crags and our Ice Age ancestors more generally, as well as to engage new audiences with this heritage.

Our team specifically wanted to explore the theme of migration, which was central to the lives of the people who came to Creswell Crags as well as a thought-provoking theme for the present day. The project centred around a public event over the weekend of the 25th and 26th October 2025 and a family trail that was available throughout October 2025.

'Signs, Spears and Smoke: Hunting in the Ice Age'

These free family sessions, led by the Education Team in Ice Age costume, explored how the skills of animal tracking, fire-lighting and hunting would have been learned and shared between families and tribes during the Ice Age. Each session started indoors looking at replica Palaeolithic objects, real animal furs and talking about the essentials for living in the Ice Age. Families then moved outside to find clues that helped them to track a series of Ice Age animals and learn how people who have followed their food sources across the continent. Everyone had a chance to try spear-throwing with an atlatl and watch a traditional fire-lighting demonstration. One hundred and fifteen people took part in these sessions over the weekend, which was fully booked, and it attracted families with wider age ranges to our usual cave tours, which are not accessible for under-fives.

Living History

In addition to the above bookable sessions, Experimental Archaeologist Chris Woodland was on site all weekend with fire-lighting demonstrations using tools and materials used in the Ice Age (Fig. 1). Chris also had a display of prehistoric tools and fish traps he had made. Ecologist Daisy Fretwell was there in costume to demonstrate bark tanning and talk about different ways of tanning and preserving skins for clothing during the Ice Age. Daisy had originally offered to demonstrate tanning using brains; however, our team had decided this might be too gory for our visitors. Surprisingly visitors' feedback on the day was that they would have been interested to see this demonstration!

Verbal feedback on the day to both the family sessions and living history demonstrations was very positive – people said how much they enjoyed it, learnt something new, were impressed by seeing how fire was made for example.

Frozen Footsteps: Wanderers of the Ice Age

Another element of the project was a family trail with a quiz which explored the other European sites that people who migrated to Creswell Crags during the Ice Age may have visited. A printed trail sheet was accompanied by trail boards placed around the outdoor spaces and cave entrances. Unfortunately this was less successful. Possibly due to the format, or possibly because people just weren't interested enough by the theme as it was presented. We will be reviewing the use of trails for interpretation going forward as a result.

What the team at Creswell Crags have learned from the project

- Just because we think something is interesting doesn't mean our audience will – e.g. the content / theme of the trail.
- The sessions were all fully booked and received positive reviews and had a good indoor / outdoor combination – we can repeat this again either as the same session or a variation.
- Intergeneration learning and 'edutainment' was a key benefit of the sessions.
- The pop-up fire demonstrations were a big success. Future programming of pop-up activities could work if built up adequately and could encourage repeat visits and increase engagement / dwell time.
- Attaching an 'expert-led' activity like fire demo / flint napping to a session led by the Learning Team worked well – it's something we would do again in the future, or the potential to train up the Learning Team to be able to deliver this themselves.

Although the project might not have resulted in the levels of participation we hoped for, the quality of engagement was high and those activities that worked well will be taken forward into future programming. Creswell Heritage Trust are extremely grateful to the QRA for making this possible.

Figure 1. Chris Woodland demonstrating fire lighting with visitors

QN Quaternary Newsletter
Article
QRA Quaternary Research Association

JQS@40: SOME OBSERVATIONS ON 40 YEARS OF THE JOURNAL OF QUATERNARY SCIENCE

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The first issue of Journal of Quaternary Science was published forty years ago in June 1986, and it has gone on to establish a place in the ranks of the leading international Quaternary journals. Neither its foundation nor subsequent success were inevitable; rather, they resulted from the foresight of its founding editors and QRA executive, and the efforts of their editorial successors. JQS has brought multiple benefits to the QRA, for example in helping to give the Association a prominent profile in the wider international community of Quaternary researchers. Its current Editorial Advisory Board members come from 17 countries, from Mexico to Kenya to Hungary to India. No less important was the decision to publish the journal via commercial publishers while retaining ownership of the title, rather than trying to publish it in-house. Initially this was with Longmans, but after their decision to cease journal publications, a contract was agreed with Wiley, and this publishing partnership has now endured for 35 years, to mutual benefit. The income from Wiley is, by some way, the QRA's largest source of funds and it has supported hundreds of grants for research, conference attendance, etc.

In this short note, I summarise some of the main trends in the journal over the last four decades and highlight a number of recent developments. A full account of the founding of JQS and developments up to 2013 can be found in the history of the QRA published on the 50th anniversary of its establishment (Catt, 2014).

One of the key decisions made early on was for JQS editors to be given a fixed, 5-year term of office. This has ensured editorial turnover and brought in "new blood" and novel perspectives. Altogether there have been ten different editors-in-chief, starting with John Lowe, and with the role currently shared by Mary Edwards and Achim Brauer. All apart from Achim have been based at universities in the UK. In addition, the editorial team has included at different times, book review editors, associate editors for the Americas (from 2003) and for Asia/Australasia (from 2008), with the latter two coming from outside the UK and adding to the journal's international coverage and readership. A full list of editors, past and present, is shown in table 1.

In its first year, JQS published 12 research articles across two journal issues. By volume 15 (2000) this had risen to 57 articles across eight issues (Figure 1). After 2008, the number of published papers rose again to current levels, typically to between 80 and 100 each year. In total the journal published 2,367 articles up to the end of volume 40 (2025). From 2003 on, papers included Rapid and/or Short Communications, which have remained a feature of the journal since then (Figure 1). From 1986 to 2009, JQS also published book reviews, up to 30 per annum. They were eventually discontinued in order to free up more page space for research articles in the journal, then entirely printed, a constraint that subsequently disappeared with the move to on-line publication.

One of the most significant and encouraging long-term trends in the journal's published papers has been the increase in female lead and/or corresponding authors. Establishing the gender of authors of published JQS articles is neither easy nor 100% accurate, but an attempt was made as part of the QRA EDI initiative in 2025 (Palmer et al., 2025). This analysis was done manually, based on traditional gender constructs for the first/given name. In around 12% of cases, it was

Table 1. Past and current JQS Editors

Editor	Role	Start date
John Lowe	Editor in Chief	1986
Phil Gibbard	Editor in Chief	1991
Mike Walker	Editor in Chief	1995
James Scourse	Editor in Chief	2000
Chris Caseldine	Editor in Chief	2005
Antony Long	Editor in Chief	2010
Geoff Duller	Editor in Chief	2015
Neil Roberts	Editor in Chief	2020
Mary Edwards	Co-Editor in Chief	2025
Achim Brauer	Co-Editor in Chief	2025
Phil Goddard	Book review editor	1986
Richard Bradshaw	Book review editor	1989
Jaap van der Meer	Book review editor	1995
Simon Lewis	Book review editor	2002 (to 2009)
Don Rodbell	Associate Editor for the Americas	2003
Jason Briner	Associate Editor for the Americas	2008
Joe Licciardi	Associate Editor for the Americas	2013
Nick Balascio	Associate Editor for the Americas	2018
Meredith Kelly	Associate Editor for the Americas	2023 (to 2024)
Chris Turney	Associate Editor for Asia and Australasia	2008
Rewi Newnham	Associate Editor for Asia and Australasia	2013
John Tibby	Associate Editor for Asia and Australasia	2024
Pete Coxon	Special Issues Editor	2004
Achim Brauer	Associate Editor for Europe	2021 (to 2024)
Sarah Woodroffe	Associate Editor	2025

not possible to obtain gender information easily and thus lead author gender was classed as "unknown". The analysis, summarized in Figure 2, shows an upward trend from 0% female lead authorship in the first two volumes of the journal (with the lead author gender of two articles "unknown") to around 40% today. Because of the additional papers where gender was "unknown", the true proportion of female authors is likely to be slightly higher than this figure. This gradual rise reflects the increasing contribution of female researchers to Quaternary Science over recent decades, especially for ECRs, where there is now broad gender parity. At an editorial level, progress with gender parity was slower, with the first female associate editor of JQS only being appointed in 2023, and the first female editor-in-chief appointed in 2025.

From 1998 onwards, JQS published thematic "Special Issues" on a wide variety of topics ranging from *Quaternary Climate Change and South America to BRITICE-CHRONO reconstructions of the Last British-Irish Ice Sheet*. Altogether a total of 33 guest-edited Special Issues were published up to the end of 2025. The two most recent are *Southern Hemisphere records of Late Quaternary climate change, people & dust: Papers in memory of Lynda Petherick,* and *Palaeo-perspectives on anthropogenic soil loss and landscape resilience*, the latter published jointly with *GeoArchaeology*, another Wiley journal. Both of these were published as Virtual Special Issues (VSIs), with individual articles published in regular journal issues, a format which is likely to continue into the future.

Of the many excellent papers published over the years in JQS, some have been especially influential and highly cited (table 2). Fourteen such articles are included in a 40th anniversary Virtual Special Issue, along with an editorial by the current editors (Edwards and Brauer, 2026). They cover a wide range of topics, with Quaternary stratigraphy being especially prominent, and with several past JQS editors among their authorship. Raw citation counts provide an imperfect representation of significance, notably because they privilege older papers that have accumulated more citations than more recently published ones. Some of the latter, not listed in Table 2, were included in the VSI for this reason. Citation counts also provide the input data for the journal's citation index, currently 2.2 (2024), a metric that is now used alongside others such as downloads and online views as a measure of reach and impact.

In 2020, it was decided to establish an annual award for an outstanding research article in JQS by an Early

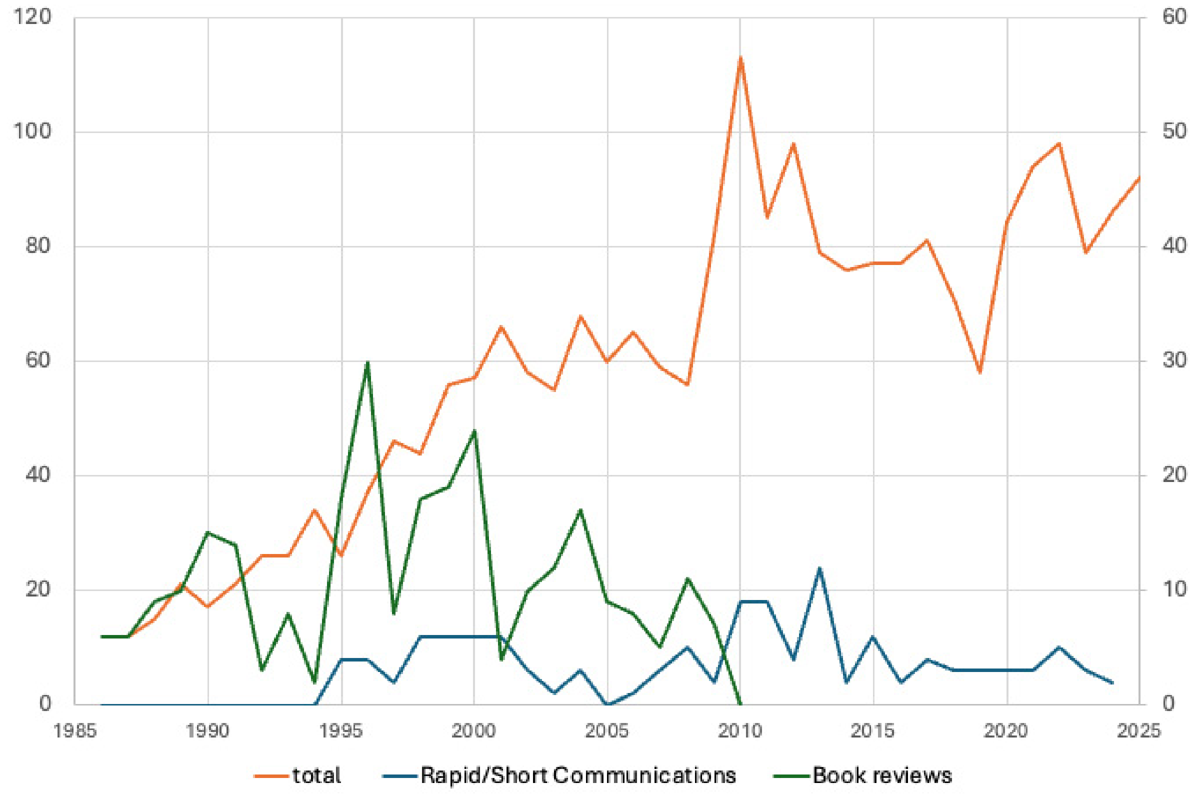

Figure 1. Number of articles and book reviews published in JQS annually, 1986-2025. Right hand axis scale for rapid communications and book reviews.

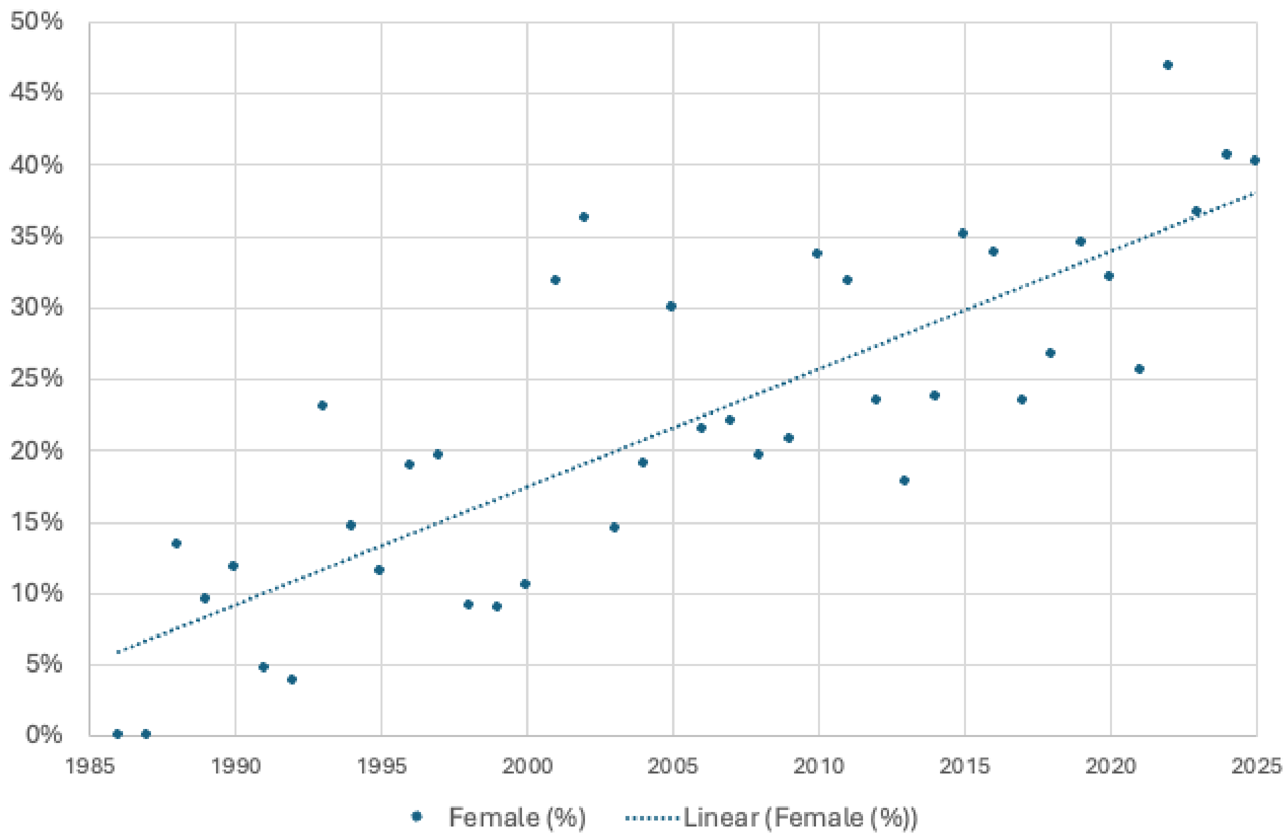

Figure 2. Proportion of JQS articles with a female first author, 1986-2025; the remainder include those of unknown gender (av. 12%).

Career Researcher (ECR), now named the Dorothea Bate award. 47% of the journal's papers in 2025 had an ECR as the first author. A short-list of papers is drawn up by the journal's editors, which are then ranked by two members of the QRA Executive Committee, with the winner announced at the January AGM. The first five winners are listed in Table 3, a list which is characterized by a wide range of topics, the international nature of ECR manuscript submissions and balanced gender representation.

Recent years have also seen a sustained increase in articles published with Gold Open Access (i.e., free to read); 56% of the total in 2025. While the journal currently remains hybrid in format, in time it may move towards full Open Access as other journals, such as Boreas, have done. Just as the past success of JQS was not pre-ordained, nor is its future success; rather, it will depend on its response to the changing publishing landscape, and to the continued active support of QRA members. For the moment, 40 years of JQS is a landmark worth celebrating.

Table 2. Most highly cited articles in JQS

Authors	Title	Year of Publication	Citations*
Johnsen, S.J., Dahl-Jensen, D., Gundestrup, N., Steffensen, J.P., Clausen, H.B., Miller, H., Masson-Delmotte, V., Sveinbjörnsdottir, A.E. and White, J.	Oxygen isotope and palaeotemperature records from six Greenland ice-core stations: Camp Century, Dye-3, GRIP, GISP2, Renland and NorthGRIP	2001	1,355
Walker, M.J., Berkelhammer, M., Björck, S., Cwynar, L.C., Fisher, D.A., Long, A.J., Lowe, J.J., Newnham, R.M., Rasmussen, S.O. and Weiss, H.	Formal subdivision of the Holocene Series/Epoch: a Discussion Paper by a Working Group of INTIMATE (Integration of ice-core, marine and terrestrial records) and the Subcommission on Quaternary Stratigraphy (International Commission on Stratigraphy)	2012	1,148
Björck, S., Walker, M.J., Cwynar, L.C., Johnsen, S., Knudsen, K.L., Lowe, J.J. and Wohlfarth, B.	An event stratigraphy for the Last Termination in the North Atlantic region based on the Greenland ice-core record: a proposal by the INTIMATE group	1998	1,014
Gibbard, P.L., Head, M.J., Walker, M.J. et al.	Formal ratification of the Quaternary System/Period and the Pleistocene Series/Epoch with a base at 2.58 Ma	2010	896
van Geel, B., Buurman, J. and Waterbolk, H.T.	Archaeological and palaeoecological indications of an abrupt climate change in the Netherlands, and evidence for climatological teleconnections around 2650 BP	1996	813
Kylander, M.E., Ampel, L., Wohlfarth, B. and Veres, D.	High-resolution X-ray fluorescence core scanning analysis of Les Echets (France) sedimentary sequence: new insights from chemical proxies	2011	668
Cook, E.R., Seager, R., Heim Jr, R.R., Vose, R.S., Herweijer, C. and Woodhouse, C.	Megadroughts in North America: placing IPCC projections of hydroclimatic change in a long-term palaeoclimate context	2010	618
Shennan, I. and Horton, B.	Holocene land- and sea-level changes in Great Britain	2002	614
Ivy-Ochs, S., Kerschner, H., Reuther, A., Preusser, F., Heine, K., Maisch, M., Kubik, P.W. and Schlüchter, C.	Chronology of the last glacial cycle in the European Alps	2008	554

*up to the end of 2025, via GoogleScholar

Table 3. Dorothea Bate award winners 2021-2025

Year	Winner	Affiliation	Title
2021	Francesca Pasquetti	University of Pisa	On the chronology of the Mediterranean sea-level highstand during the Last Interglacial: a critical review of the U/Th-dated deposits
2022	Neil Adams	University of Leicester / National History Museum, London	An Early Pleistocene hippopotamus from Westbury Cave, Somerset, England: support for a previously unrecognised temperate interval in the British Quaternary record
2023	Aditi K Dave	University of Mainz / University of Cluj	The patchwork loess of Central Asia: Implications for interpreting aeolian dynamics and past climate circulation in piedmont regions
2024	Sean Field	University of Notre Dame / University of Wyoming	Climate and Community in Central Mesa Verde
2025	Erin M. Keenan Early	The University of Texas at Austin	Proteomic analysis resulting in species-level identification of recently diverged North American arvicoline rodents

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Edwards, M. and Brauer, A. (2026) Journal of Quaternary Science 40th anniversary Special Issue, *Journal of Quaternary Science* 41(2), 197-198.

Palmer, A.P., Boyall, L., Fletcher, W.J. et al. (2025) Exploring gender equality trends within the QRA to establish our current baseline. *Quaternary Newsletter* 164, 12-18.

FLAG ARISES FROM THE COVID ASHES: FLAG 2025, TÜBINGEN

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The first face-to-face meeting of the Fluvial Archives Group (FLAG) since the hiatus caused by the Covid pandemic took place in Tübingen, Germany, 4–7 September 2025. Led primarily by Tobias Lauer, with a strong team of supporters, this followed the template that had become traditional for FLAG since it began its programme of Biennial meetings (which followed the end, in 2000, of its period as a QRA-funded working group). Thus, two days of oral presentations and posters were followed by two days of field excursions, all based in Tübingen.

The discussion meeting was in the Geo- and Environmental Center (GUZ) at Tübingen University, with refreshments in the foyer and visits to a nearby refectory for lunch. Day 1 began with the customary introduction and welcome to members, old and new, and was followed by four themed sessions throughout the day. These comprised 'fluvial geomorphology, tectonics and sedimentation/erosion' and 'Fluvial climate/palaeoenvironmental archives' in the morning, with 'Rivers and human impact/geoarchaeology' and 'Holocene and late Pleistocene fluvial processes' in the

Figure 1. FLAG participants outside the GUZ (top) and on the excursion (bottom).

afternoon. At the end of Day 1 there was an organized meal in a restaurant specializing in traditional local cuisine.

Day 2 dawned with rain coming in over the nearby Swabian Alb, making for an atmospheric backdrop to the conference proceedings. The 'Holocene and late Pleistocene fluvial processes' session continued from Day 1, with an extended coffee break to allow for a poster session taking up the rest of the morning. In the afternoon, there was time for a general session and then one focussed on dating and geochronology, which was followed by a field briefing and a discussion about the location of the 2027 FLAG conference. Our colleagues based in Britain will, no doubt, be delighted to hear that the next FLAG will be in Essex in September 2027, to be organized by DRB and EL – more details to follow!

We were also treated to a tour of the fantastic labs and told about the dating capacities in-house at the GUZ on the afternoon of Day 2. Thankfully the rain had eased off by the evening which allowed us to have a dry and relaxing voyage on the River Neckar in a pair of (professionally operated) punts. The good weather held up for the excursion too, which everyone was glad of. Across the four days, FLAG was delighted to hear the work of colleagues from a breadth of career stages, from Masters students to well-established professors, with people travelling from ten countries to be at the conference (Figure 1).

The first excursion day saw the party join a coach in the GUZ car park for a drive to a viewpoint at Heuchelberg, high on a slope covered in heavily laden vines. This provided a view over the Neckar valley to the higher Löwensteiner Berge uplands in the distance. Here was discussed the geological setting of the Neckar valley, the understanding of its terrace sequence and means of dating this: transitioning in recent times from biostratigraphy and interpretation of loess overburden with soils to an emphasis on numerical geochronology. This is of considerable significance given that the hominin fossil localities of Steinheim (see below) and Mauer (type locality of *Homo heidelbergensis*) fall within this sequence (Bibus and Wesler, 1995).

The main site of the morning was a nature conservation site at Frankenbach in the Heilbron Basin (see Littlewood et al., 2025). This was worked as a gravel pit from the early 19th until the late 20th Century, which involved removal of several metres of loessic overburden. After working ceased it has been managed to maintain the disturbed-ground, minor wetland and small-pond communities that had

Figure 2. Frankenbach disused quarry showing (a) the loess deposits capping the exposed sequence, (b) imbricated fluvial gravels of the 33 m Neckar terrace underlying the loess, and (c) example of the wetland habitat cultivated in the quarry.

developed following quarrying, the dumping of the unrequired overburden having provided much of the variable terrain supporting these habitats. The party was joined here by Wolf-Dieter Riexinger from the Heilbronn City Nature Conservation Authority, who is responsible for the management of the site on behalf of the local community. He explained that there is no specific geo-conservation legislation applied to the conservation of this site but its geodiversity value is clearly recognized, as is exemplified by the variety of explanation boards dotted around, revealing the nature of palaeoenvironments indicated by the faunal remains discovered during the excavation of the gravels here (see also Hansch et al., 2009; Rosendahl and Döppes, 2009). The deposits at Frankenbach have long been regarded as equivalent in age to those at Mauer, attributed to the latest Cromerian Complex). The group was able to view the loess exposure from a distance, typically maintained in a near vertical face and revealing the upper two of four recognized palaeosols. Close examination of the underlying gravel was also possible, the platy nature of much of its content revealing bedding and imbrication. Figure 2 shows a representative sample of the different sections of the quarry viewed by the group.

Following the site visit, a picnic lunch was enjoyed amongst flowers and wildlife in the nature reserve here, with local pretzels and wine from the vineyards at Heuchelberg.

A notable highlight was an afternoon visit to the Urmensch Museum at Steinheim an der Murr, which is dedicated to the discovery in 1933 of a largely intact human skull in terrace gravel of the local Neckar tributary: a specimen that has long been compared closely with the Swanscombe skull from the Lower Thames. Like the ‘Swanscombe skull’ the species represented here is debated; the museum claims it as the holotype for *Homo steinheimensis*, although it is referred to as *Homo heidelbergensis*/‘pre-Neanderthal’ in literature (van Asperen, 2013). DRB had visited this museum previously with a 1996 INQUA field-trip group and noticed some significant changes, not least a splendid life-size reconstruction by Paris-based sculptor Elizabeth Daynès (commissioned in March 2017) of the prehistoric woman; the real skull resides in Stuttgart, although there are two casts of it in this museum (Figure 3). Presentation of the accompanying mammalian fauna has also been enhanced, with reclassification of the mammoth from here to *Mammuthus trogontherii*, termed ‘steppe elephant’ in the German interpretative information. The assemblage also includes *Palaeoloxodon antiquus* (straight-tusked elephant or ‘forest elephant’) and *Bubalus murrensis* (water buffalo).

Figure 3. A cast of the proposed *Homo Steinheimensis* skull and sculpture of what the woman may have looked like. *Sculpture by Elizabeth Daynès.*

The museum displays reflected recent advances in numerical geochronology (particularly luminiscence and cosmogenic nuclide methodologies) to fluvial sequences – a running theme of the meeting. This saw the age of Steinheim, long attributed to MIS 11, regarded as more likely to date from MIS 9 (Van Asperen, 2013).

After a lengthy but thoroughly worthwhile museum visit, the party returned to the outskirts of Tübingen to look at the Ammer valley, a Neckar tributary that remains idyllically rural despite its proximity to the university town. The Holocene evolution of the Ammer has been studied in detail by K. Johann Holdt, who provided a description of his work on the sedimentary infill of the valley, which incorporates both peats and tufas, the latter yielding an impressive molluscan fauna that includes *Vertigo sp*. There was a lively discussion of the enigmatic juxtaposition of normally acidic peats with calcareous precipitates, DRB noting a comparable occurrence in North Yorkshire in the Snape Mires palaeolake basin (Bridgland et al., 2011). The Ammer and the Snape vicinity have in common, in addition to the peat/shell-marl juxtaposition, the local occurrence of gypsum karst, there being a recently collapsed gypsum doline feature in the Ammer that was examined at close quarters (Figure 4).

On the final day of the meeting, led by Alexander Beer, there was a repeat rendezvous with the coach and a drive to a different vantage point, this time high on the crest of the Swabian Alb cuesta for a view of deep dissection valleys that eat into the front of the escarpment, as well as outlying 'witness mountains' (Figure 5). The latter record the earlier north-westward extent of the escarpment, although some represent Miocene volcanic necks that were once within the cuesta and remain now as upstanding features thanks to their greater resistance to erosion in comparison with the more widespread geological sequence. It was explained that the progressive dissection of the scarp-edge hereabouts has coincided with the loss of catchment area by the Danube to the Rhine, the latter via the Neckar (Beer et al., 2025; Schaller et al., 2025). A FLAG first was the brewing of fresh coffee in the open air, the equipment having been trolleyed from the coach.

A dissected maar lake from the Miocene volcanism, the Randecker Maar, was the second locality, with a view across the former lake basin to the gorge through which it is now drained, as well as information boards depicting a reconstruction based on the Miocene fauna from the lake sediments and the modern wildlife and vegetation that characterize this protected location.

In addition to the ancient volcanism, the cuesta rocks have also been disrupted by two meteorite impacts, also attributed to the Miocene, which have given rise to craters (Eberle et al., 2017). The smaller of these was visited, being easier to appreciate from ground

Figure 4. The view over the Ammer Valley with the collapsed gypsum doline feature in the foreground, including highlighted internal fault structures.

Figure 5. The view from the Swabian Alb cuesta, with the 'witness mountains' in the distance (top) and deep dissection valleys. *Photographs courtesy of P. Cunha.*

level. A road closure forced the omission of the drive through the Eyb valley, although evidence for the substantial and rapid incision to be seen there was observed in high-level limestone pinnacles capping the tops of slopes above the forest. Lunch was in the form of a picnic at the Wentaler Felsenmeer, in a dry valley dotted with upstanding dolomite outcrops, seemingly 'tower karst' in miniature (Figure 6). There was much discussion about the origin of this unusual geomorphological phenomenon, most interpretations invoking a residual origin, with preferential preservation of more resistant dolomitized limestone. Oligocene gravel was once quarried from the highest plateaux of the Swabian Alb cuesta: the Ochsenberg gravels, thought to represent an early drainage system (the Ur Brenz) flowing to the Danube (Strasser et al., 2010). An old, vegetated quarry was visited and residual sections observed, although these were little more than scrapings and no bedded material could be seen; it was, however, possible to extract a few gravel clasts that were appropriately shaped for a fluvial source.

The final site was Rainau quarry, an operating gravel pit that extracts the Goldshöfer sands (Figure 7), another deposit associated with the former Ur Brenz drainage system flowing to the Danube (Zeese, 1975; Simon, 1996). These deposits, significantly younger than the Ochsenberg gravels, represent the final and best-preserved palaeovalley-fill left by that river. They are probably Lower Pleistocene, as evidence by faunal discoveries that include *Mammuthus meridionalis* and *Cervalces latifrons* (Adam, 1953), although there are potentially later terrace aggradations that date from shortly before drainage hereabouts switched to the Rhine (Strasser et al., 2010). An extensive section here, freshest at the end furthest from the access point, showed a well-bedded, very sand gravel/pebbly sand. Loessic topsoil had been stripped prior to quarrying and was being used for progressive agricultural restoration of the worked-out area.

The party was kept amused for some while studying the exposures and looking for interesting contents of the gravel (Figure 6). Iron and manganese straining was noted and the largest gravel clasts examined included

Figure 6. The impressive dolomite outcrops at Wentaler Felsenmeer – note the people on the left-hand side for scale! *Photograph courtesy of P. Cunha.*

Figure 7. Rainau quarry sections showing exposures of the Lower Pleistocene Goldshöfer sands. *Photographs courtesy of P. Cunha.*

ironstone (some of 'boxstone' type) and cherts, the latter potentially including celebrated multicoloured 'Keuper flint' (actually chalcedony) from the Triassic (Schüssler et al., 1999; Schüssler, 2015). Part of the outcrop, to the south of the Rainau quarry, is identified as the Goldshöfer Sands Nature Reserve (Goldshöfer Sande Naturschutzgebiet), located in the Aalen–Ellwangen–Abtsgmünd area, protecting the Quaternary deposits as well as the habitats and landscapes formed on them (State Institute for the Environment Baden-Württemberg, 2000).

After votes of thanks to the leaders of the meeting and field trip as the party left the final site, the journey back to Tubingen was rather impeded by late weekend traffic.

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NEW RADIOCARBON AGES TO CONSTRAIN LATE GLACIAL ENVIRONMENTAL CHANGE AT WHITRIG BOG, SE SCOTLAND

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Whitrig Bog in the Tweed valley is a small palaeolake basin, which started to infill after the local Last Glacial Maximum (LGM) and the retreat of the former Tweed Palaeo-ice stream. Previous research at Whitrig Bog focused on reconstructing the environmental change over the Late Glacial period. The site specifically records a thick Windermere Interstadial sediment sequence where pollen, macrofossil, sedimentology and chironomid-inferred temperature (C-IT) proxies (Mayle et al., 1997; Brooks et al., 1997; Brooks and Birks, 2000), reveal a site that is highly responsive to rapid environmental change during the Late Glacial. Based on this work, Walker and Lowe (2019) argue that the Whitrig Bog archive could represent a type-site for the Scottish Late Glacial period, although greater insight into this period of abrupt climate change would require a more robust chronological control on the sediments. This work forms part of a broader PhD studentship to constrain the timing of deglaciation and understand the timing of landscape response to rapid environmental change at specific locations in northern Britain. For Whitrig Bog, the aim was to generate an improved age model for the site by generating a revised tephrostratigraphy and radiocarbon chronology, using terrestrial plant macrofossils (TPM), combined with a varve chronology from the Dimlington Stadial age sediments. The work funded by the QRA specifically concentrated on generating robust radiocarbon dates from the sequence.

Figure 1 presents the lithological sequence recovered from Whitrig Bog in 2023, with the position of new ^{14}C dates, organic content, carbonate content, minerogenic content from this study against the C-IT change reported by Birks et al. (1997). The presence of carbonate-rich lake sediments in the Windermere Interstadial and marl in the early Holocene required the careful identification of terrestrial material for radiocarbon dating to avoid recognised issues with radiocarbon ages generated from bulk sediment samples.

Table 1 shows the results of four radiocarbon dates sent for analysis as part of the QRA 14Chrono award. UBA-55420 was unsuccessful in producing sufficient carbon for a radiocarbon determination. UBA-55419 and UBA-55421 produced results that demonstrate the viability of using above ground parts of terrestrial plant macrofossil material, as each of these dates are coherent with the other stratigraphic information (see Table 1 for details). UBA-58568 produced an anomalous result; stratigraphically the age is too young for a sample mid-Loch Lomond Stadial and highlights potential issues with downward intrusion of younger plant material into older sediments.

Combining these new radiocarbon dates with improved tephrostratigraphic resolution within a new Bayesian Age model has been possible for two ages (Table 1). This method shows the importance of using a combined approach for generating highly resolved chronologies of the Late Glacial and provides robust understanding of rapid environmental change during the WI in SE Scotland.

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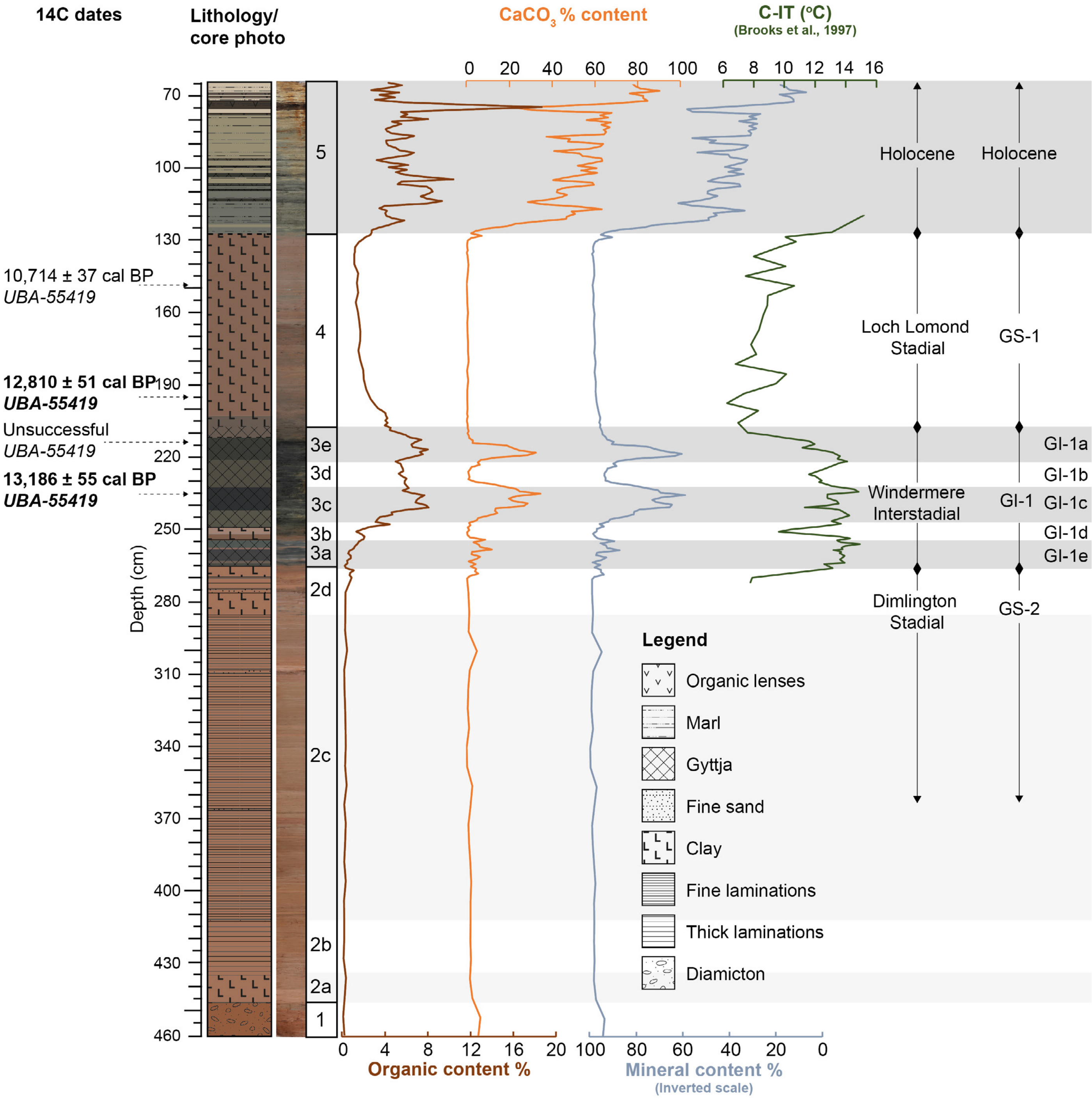

Figure 1. Lithostratigraphy of the WB23 sequence alongside sedimentary properties: organic content, calcium carbonate content and minerogenic content. Scaled Chironomid Inferred Temperature change from work on the Whitrig sequence by Birks et al., (1997). Radiocarbon dates obtained through the 14Chrono award are presented on the left, with the two in bold considered to be reliable and will be utilised in a Lateglacial age model in Beckett et al., (in prep).

Sample code	Sample ID	Material Type	Depth (cm)	^{14}C age	Age cal BP (mean)	Age cal BP (median)	Uncertainty 1σ (95.4)	Stratigraphic position	Accepted for age model (Y/N)
UBA-55419	WB23_191-194	12 x wood fragments, 8 x leaf fragments, 6 x *Ericaceae sp.* Seeds, 2 x *Betula* fruit, 1 x *Poaceae* seed	191 - 194	10,883 ± 55	12,810	12,803	51	Transitional sediments between the WI and LLS	Y
UBA-55420	WB23_214-216	1 x *Harimanella hypnoides* seeds, 9 x *Ericaceae sp.* seeds, 2 x *Betula nana* fruit, 1 x *Betula* fruit, ericaceous wood fragments, wood fragments, 3 x leaf fragments	214 - 216	Failed		Failed	Failed	Mid WI sediments, likely GI-1a to GI-1b positioning	N/A
UBA-55421	WB23_232-235	1 x *Alnus glutinosa* fruit, 8 x *Betula* fruit, 1 x *Betula nana* fruit, 6 x woody fragments, 15 x small leaf fragments cf. *Betula*	232 - 235	11,293 ± 56	13,191	13,186	55	Mid WI, positioning within likely GI-1c expression	Y
UBA-58568	WB23_149-152	4 x *Salix herbacea* budscales, 1 x *Salix sp.* fruit capsule, *Salix* leaf fragments, 4 x undiff. Budscales, seeds (terrestrial)	149 - 152	9473 ± 37	10,746	10,714	37	Mid-late LLS sediments, post Vedde Ash deposition, pre tentative Abernethy Tephra	N

Table 1: Details of the sample content for 4 radiocarbon dates obtained from Whitrig Bog. Each with indication of material identified, stratigraphic justification, and reliability for use in an age model. Calibrated ages have been undertaken using Oxcal v4.4.4 (Bronk Ramsey, 2009) and utilised the IntCal20 curve (Reimer et al., 2020)

Quaternary Newsletter
Report: Award

MICROTEXTURES OF QUARTZ GRAINS FROM AN ARID FLUVIAL ENVIRONMENT: THE LUNI RIVER FLOODOUT ZONE, SOUTHEASTERN THAR DESERT, INDIA

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Background and Rationale

Aeolian processes are commonly thought to dominate dryland landscapes but occasional flow in normally dry ephemeral or intermittent rivers also can create or modify geomorphic landforms. In many drylands, characterising fluvial-aeolian interactions is key to advancing palaeoenvironmental, geomorphological and sedimentological knowledge, including through use of modern analogues for interpretation of the rock record (e.g. Priddy and Clarke, 2020). In some drylands, alterations in the size, morphology and position of channels approaching a river terminus, technically known as a 'floodout', preserve a range of geomorphic landforms and sediments that can serve as "geoproxies" (Thomas, 2013; Tooth et al., 2022). Floodouts provide key locations to reconstruct past river changes and assess the relative influence of external drivers such as climate change, tectonic activity and human impacts (e.g. Tooth, 1999), but many remain to be fully investigated.

The Luni River floodout zone (LRFZ), located on the southeastern margin of the Indian Thar Desert (Fig. 1), represents a critical zone for investigating fluvial-aeolian interactions. The LRFZ is marked with various active, partially active and inactive fluvial landforms, including meanders, anabranching and distributary channels, and in many locations is bordered by aeolian dunefields. The region has undergone significant transformations due to weakening of the Indian Summer Monsoon (ISM) and associated aridification, particularly during the mid to late Holocene (Ponton et al., 2012), but has also been subject to tectonic activity and rising anthropogenic activities like canal-fed irrigation agriculture and mining. My PhD research project primarily focuses on deciphering the coupled geomorphological and sedimentological development of the LRFZ through reconstruction of the channel and palaeoenvironmental changes that have occurred over time. Luminescence (OSL) dating will provide geochronological evidence of channel evolution (e.g. depositional history, palaeohydrology and channel shifts) over the late Quaternary. The QRA's New Research Workers Grant funded scanning electron microscope (SEM)-based microtextural analyses of quartz grains, including from some of the key OSL sampling locations. The preliminary findings form the basis of this report. The microtextures on quartz grains, such as surface etching, abrasion patterns, and other mechanical features, will help to infer the prevailing environmental conditions (e.g. relative importance of aeolian and/or fluvial process activity) during sediment transport and deposition (Smith et al., 2018). Detailed findings will contribute new insights for regional palaeogeography and archaeology, potentially including development of the palaeo-Saraswati River (Alok and Pant, 2020) and fall of the Indus Valley Civilisation (Dutt et al., 2019).

Results

A JEOL JSM-IT 200 bench-top SEM at Aberystwyth University was used for the study. A secondary electron detector (SED) has a focused beam of electrons to create high-resolution detailed images of grain surfaces. Prior to SEM analysis, crucial steps involve cleaning (chemical treatment with HCl, H_2O_2 and distilled water), mounting on stubs (using a conductive black adhesive tape) and platinum/palladium coating. The cleaning procedure eliminates surface residues (e.g. carbonates and organic matter)

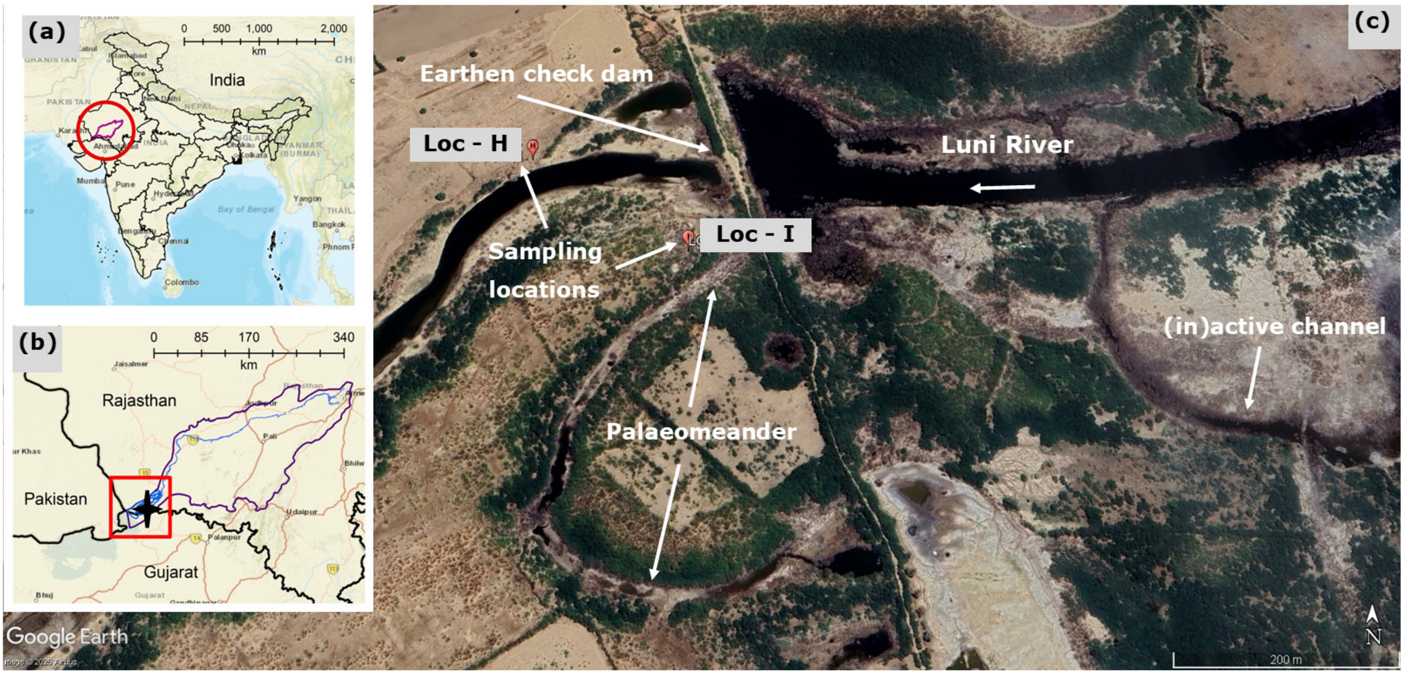

Figure 1. (a) The Luni River is situated along the eastern margin of the Thar Desert near the India-Pakistan border. (b) The river begins in the Aravalli Ranges near Ajmer and dissipates as a system of distributary channel approaching its floodout, which adjoins the endorheic salt flat of northeastern Rann of Kutch (or Kachchh) in northern Gujarat. (c) The location, geomorphic landforms (e.g. palaeomeander, inactive channel) and anthropogenic modifications (e.g. earthen check dam) adjoining the sampling locations H and I in the LRFZ.

while preserving the original microtextures. Figure 2 illustrates the preliminary results from some of the quartz grains collected from locations H and I (see Fig. 1c).

A complex suite of microtextures documents both mechanical and chemical processes in the dryland setting. Mechanical features including grooves, v-shaped pits, bulbous edges, elongated depressions, large conchoidal fractures, and abrasion features indicate high energy transportation and grain–grain collision under episodic fluvial flow. Straight steps further indicate brittle fracture under stress. Etch pits, solution channels and pits, and more general etch features are suggestive of post-depositional chemical alteration, likely linked to fluctuating wet and dry cycles and the prevailing saline conditions found across the LRFZ. Clay attachments and silica precipitates likely highlight periods of diagenetic overprinting during low energy conditions under fluctuating groundwater conditions and evaporation, which elevate dissolution and lead to re-precipitation of silica and other minerals. Therefore, the observed microtextural features provide a valuable insight into the prevailing transport conditions and depositional environments, indicating a complex interplay between aridity, evaporation, and sediment reworking.

Significance

Further microtextural analysis of quartz grains from a wide range of sampling locations in the LRFZ (24 samples total) will provide additional inferences regarding shifts in dominant transport and depositional processes, including the relative importance of fluvial versus aeolian-derived sediments during palaeochannel infilling. Combined with OSL dating, the approach will help to infer shifts in the relative importance of fluvial-aeolian activity in response to climatic fluctuations, particularly ISM weakening and aridification trends (Ponton et al., 2012) that have been observed elsewhere in the Thar during the mid to late Holocene. The findings will help provide a more nuanced understanding of the changing palaeoenvironmental conditions in the LRFZ.

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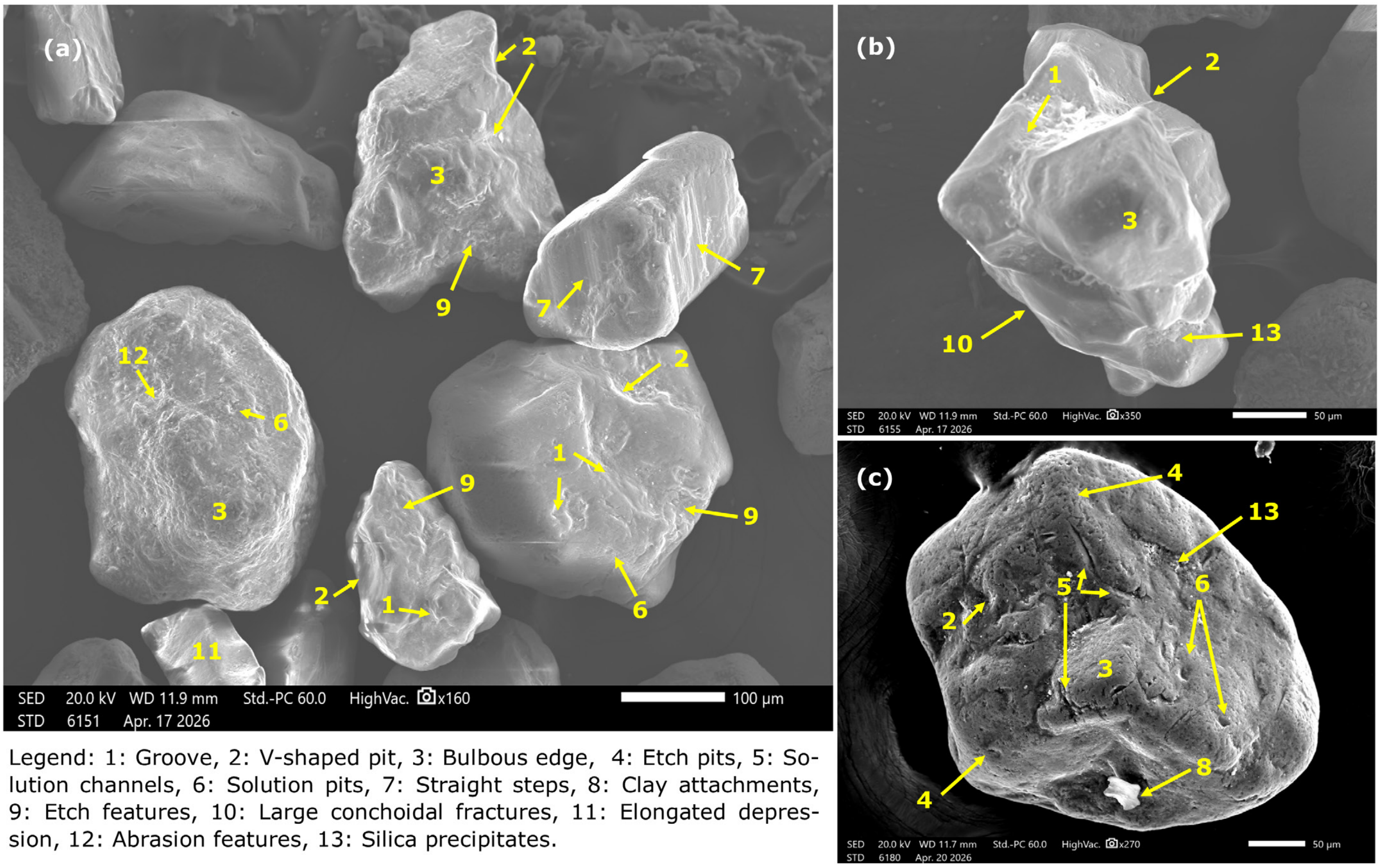

Figure 2. SEM micrographs showcasing various quartz grain microtextural characteristics from sediments collected at locations H and I (see Fig. 1c).

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