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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

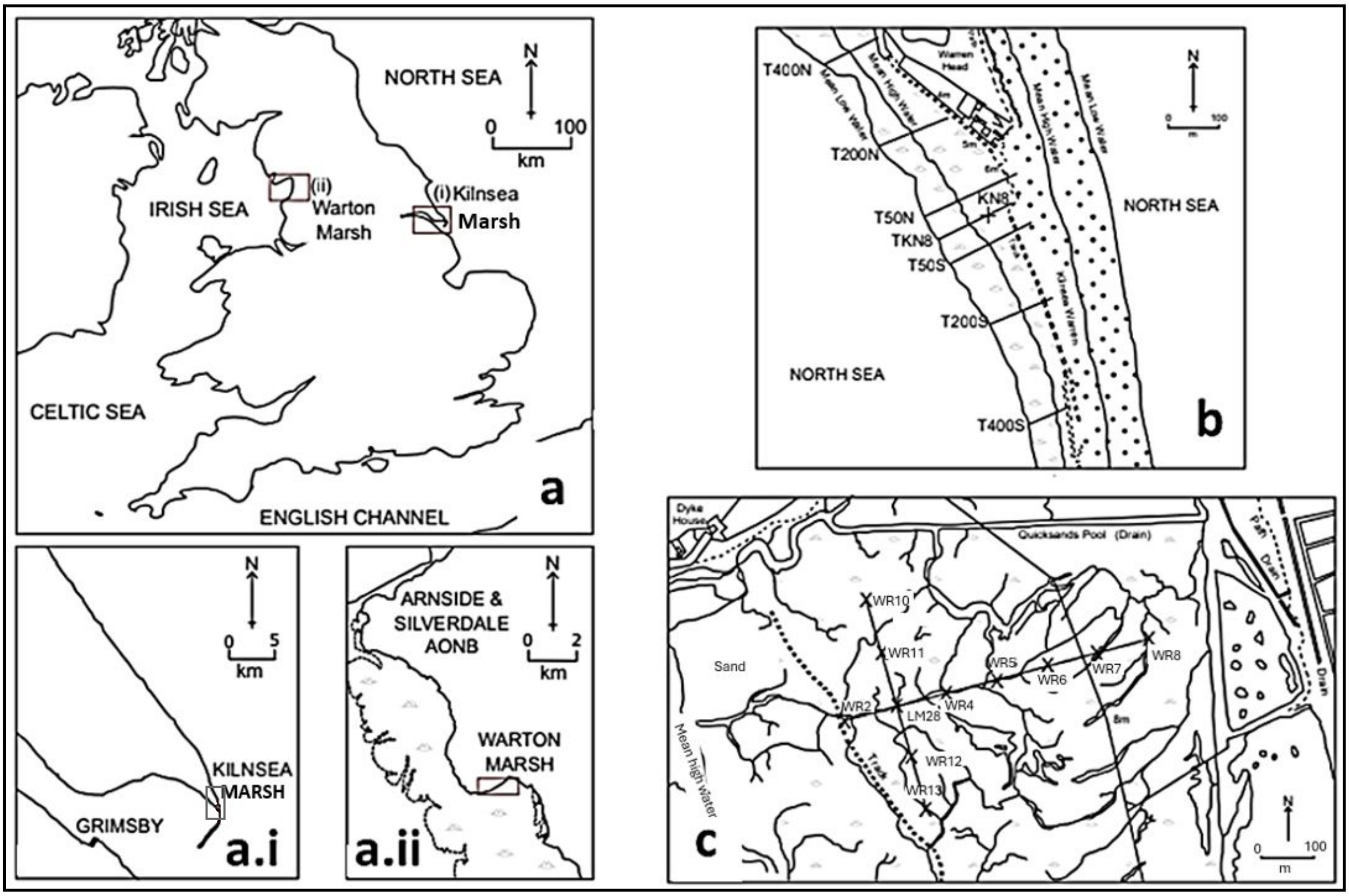

Figure 1. (1a) Map of the UK and insets showing the two study sites at Kilnsea Marsh, Spurn Point, Humber Estuary and Warton Marsh, Morecambe Bay; (1b) map of Kilnsea Marsh, showing the coring site at KN8 and borehole transects at 50 m, 200 m and 400 m north and south of KN8; (1c) map of Warton Marsh, 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).

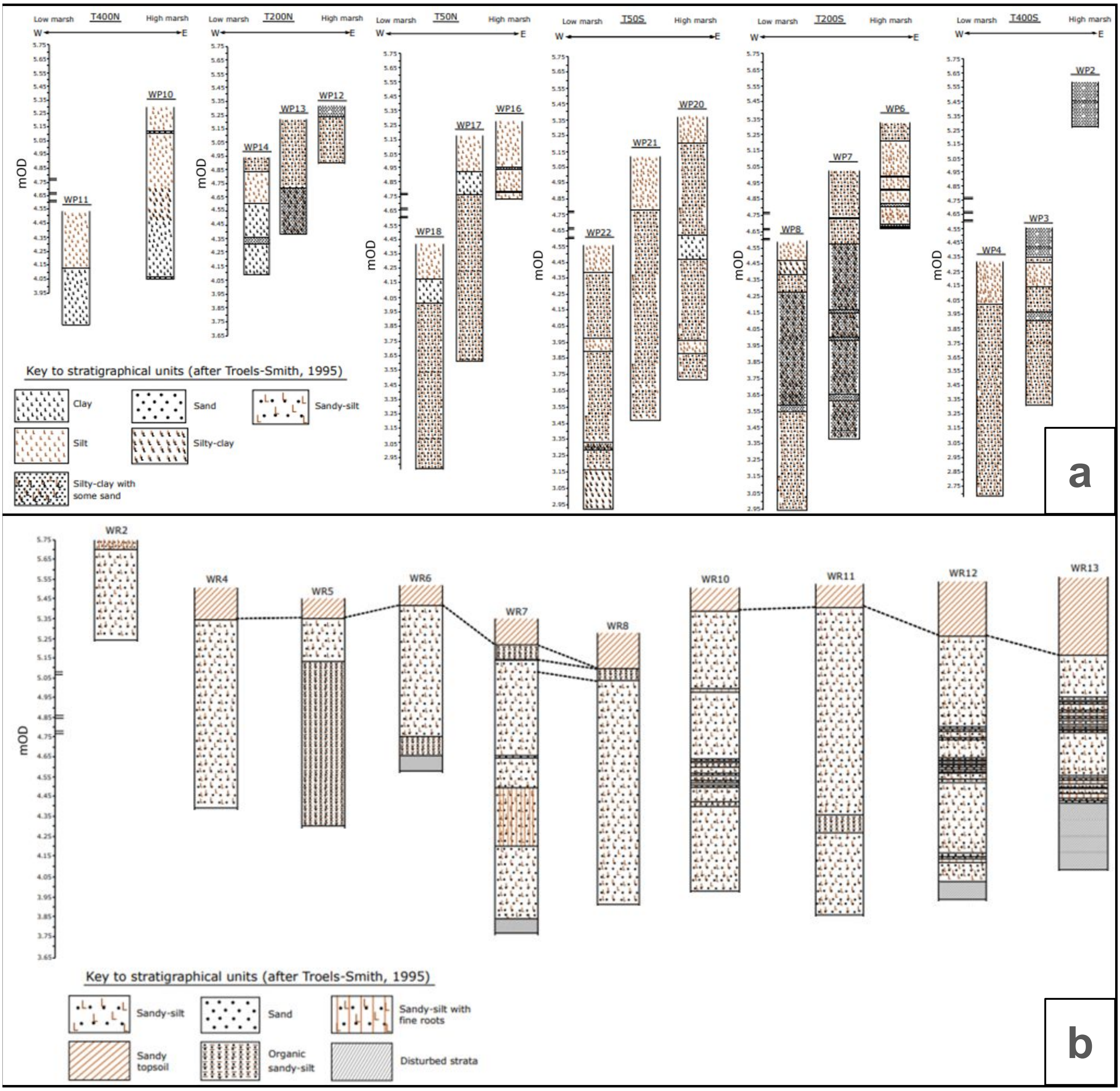

Figure 2. Stratigraphy of the saltmarsh at Kilnsea Marsh (a) and Warton Marsh (b) (after Troels-Smith, 1955). The position of sand layers in the KN8 core are highlighted on the altitude axes to facilitate comparison with the borehole stratigraphy.

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

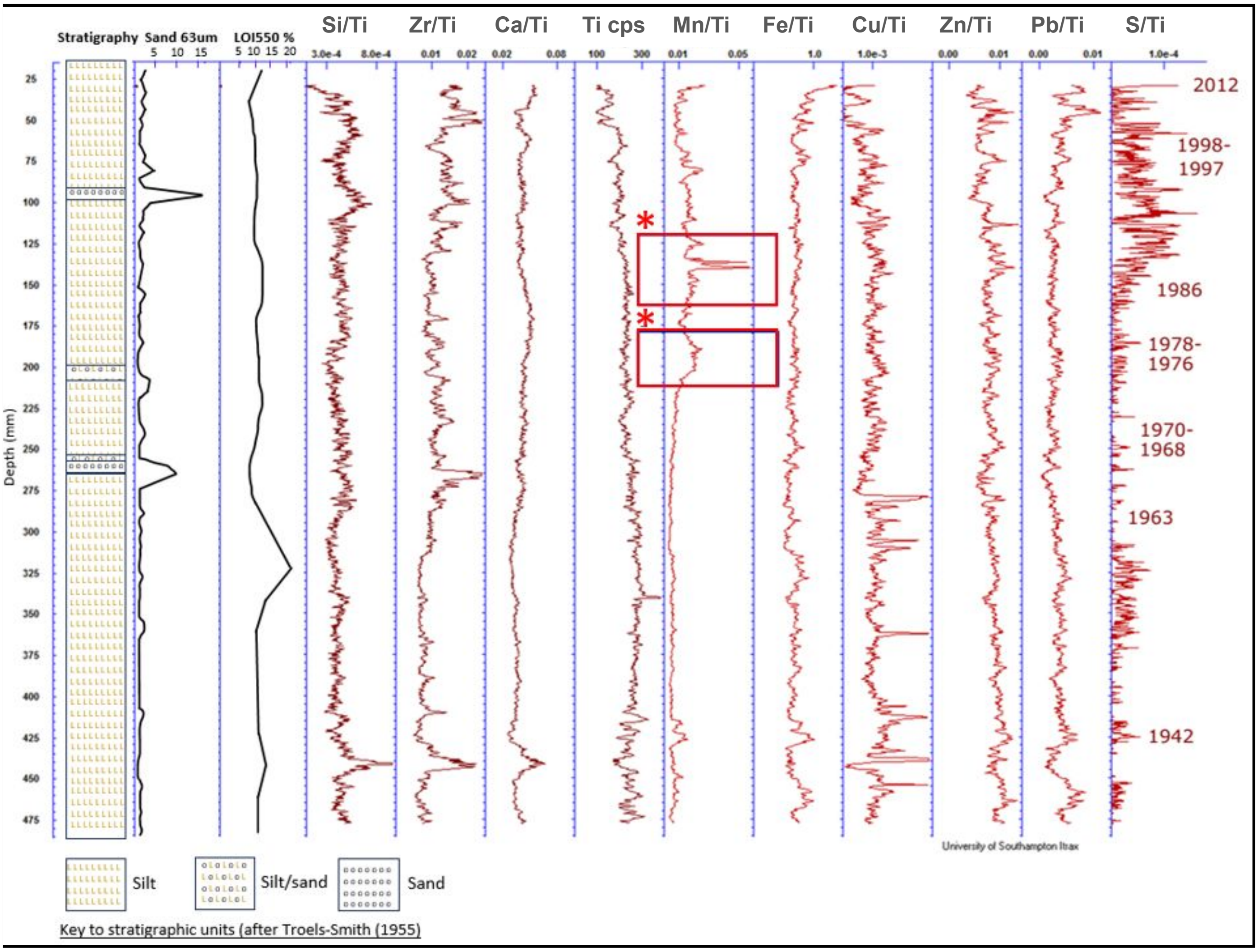

Figure 3. Stratigraphy (after Troels-Smith, 1955) of core KN8 from Kilnsea Marsh, Spurn Point plotted alongside the results of the PSA (sand 63 um), LOI550 and geochemical analyses. * = Redox zones where Mn oxyhydroxide is precipitated.

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

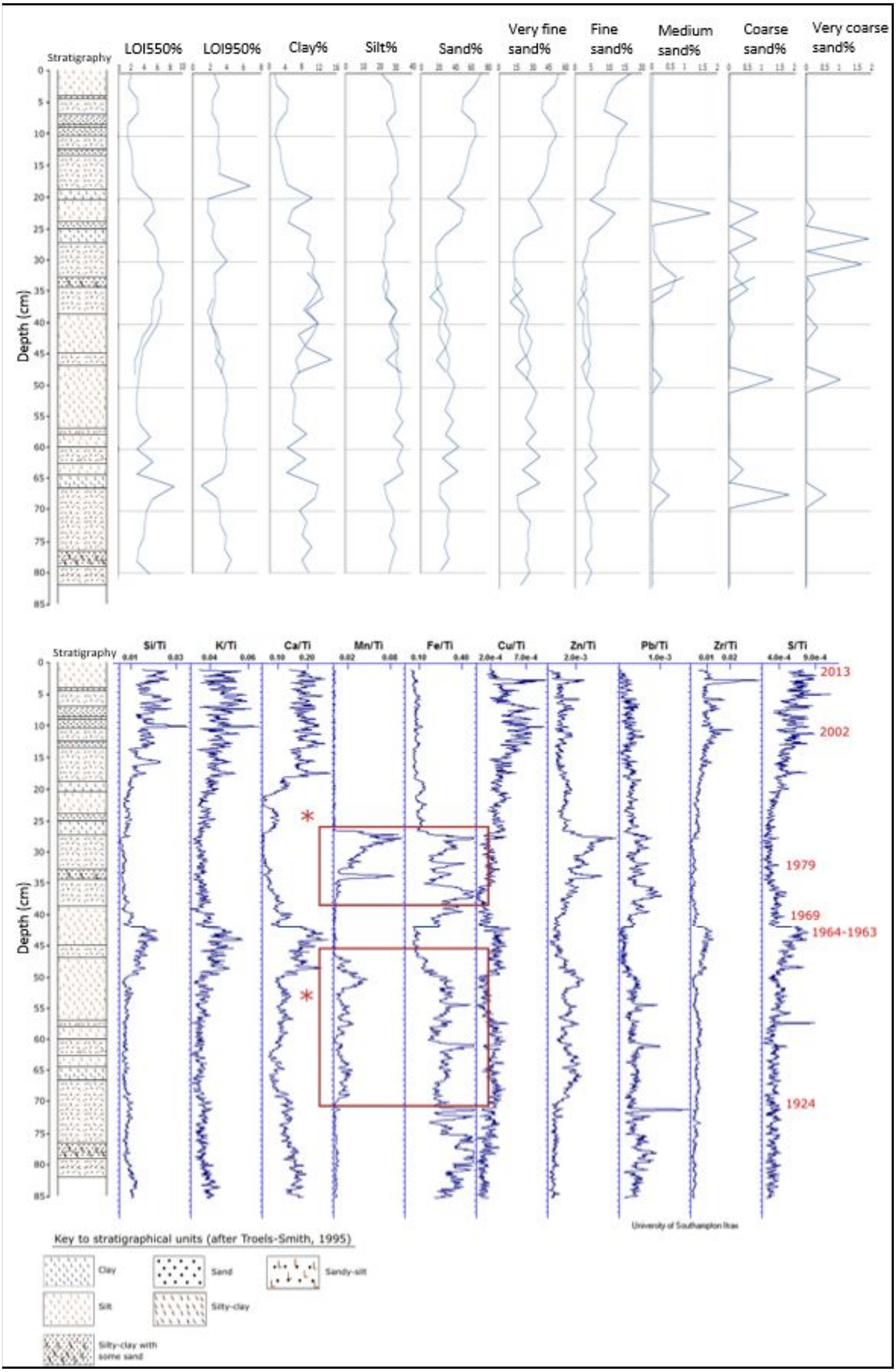

Figure 4. Stratigraphy (after Troels-Smith, 1955) of sediment core LM28 from Warton Marsh plotted alongside the results of the PSA, LOI550, LOI950 and geochemical analysis. * = Redox zones where Mn oxyhydroxides are precipitated.

(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

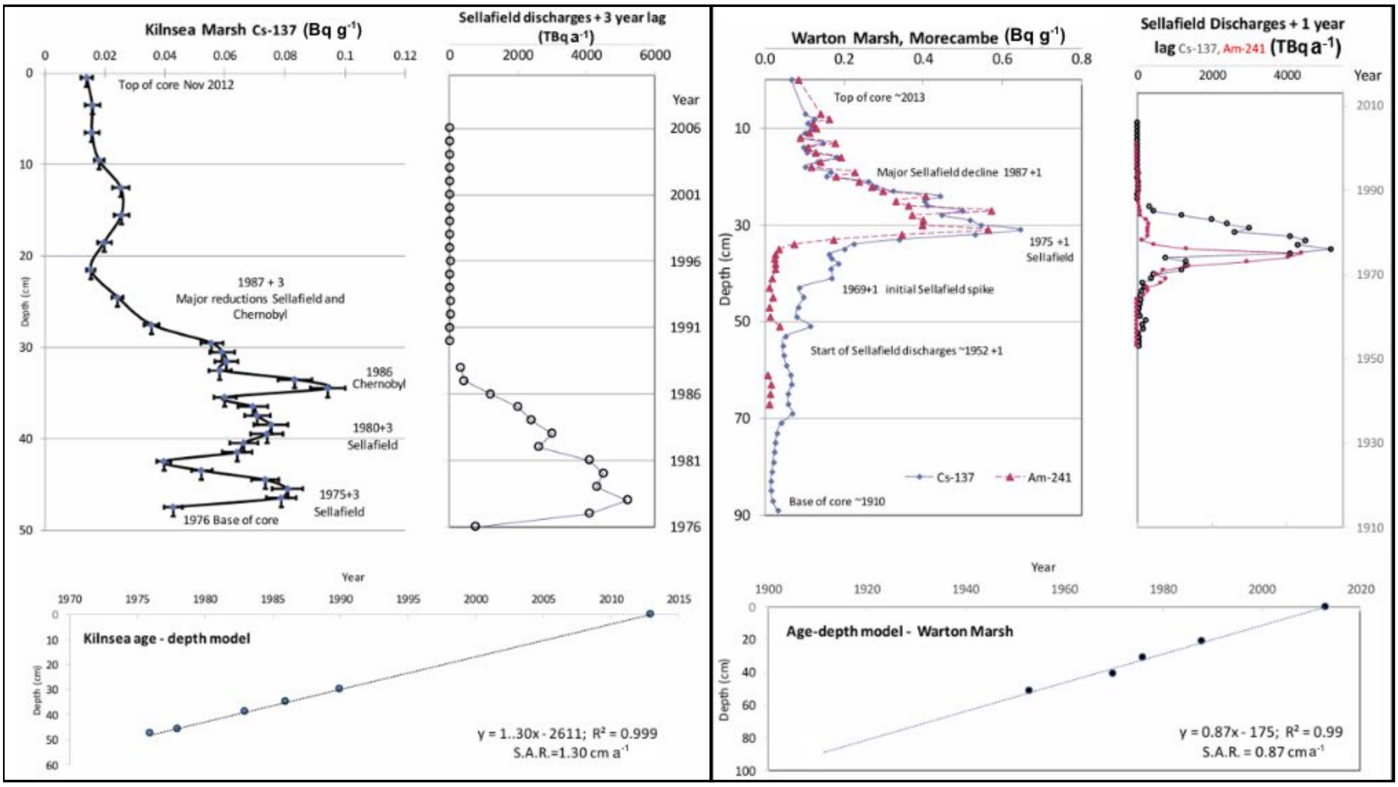

Figure 5. Cs-137 (Bq g^{-1}) in the saltmarsh sediment at Kilnsea Marsh and Warton Marsh against depth (cm). The inferred chronology for the saltmarsh sediment is presented based on correlations with Sellafield liquid discharges (TBq a^{-1}) and Chernobyl fallout event of 1986. The Sellafield liquid 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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