Touching The Tide Project Report

Dunwich Land-based Archaeological report

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Touching the Tide
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Dunwich Land based Archaeological Survey: 2014-15

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1.0 Introduction

The fate of the medieval town of Dunwich is well documented (Gardner, 1754; Parker, 1975; Comfort, 1994; Sear et al., 2011; Sear et al., 2012). The precise size of the original town is unknown, but was sufficiently important to have once perhaps have been the seat of the first Bishop of East Anglia, and to have received Royal Charters for a market and a mint (Gardner 1754; Bacon and Bacon 1979, Chant, 1986). In 1086 Dunwich was one of the ten largest towns in England (Comfort, 1994). The wealth of Dunwich was primarily based on sea trade, fishing and ship building; with substantial investment by different religious orders and at times the Crown. Until the middle of the 14th Century, Dunwich was a nationally important seaport. By 1225 it was approximately 1.6km (1 mile) from north to south, with an area similar to the City of London at the same time (Gardner 1754). The town of Dunwich contained up to 18 ecclesiastical buildings, a mint, a large guildhall and several large important houses (Comfort, 1994, Bacon 1979; Chant 1986). By 1242 Dunwich was the largest port in Suffolk with a population estimated to be 5000 at its height, with at least 800 taxable houses, and an area of c.800 acres (Comfort, 1994; Bailey 2007).

The town declined rapidly in the later 13th Century due to blocking of the harbour by extension of a sandy gravel spit during large storms in 1287, and 1328. Sear et al., (2008) suggest that this coincided with a phase of climate change during transition from the Medieval Warm period into the Little Ice Age. Storminess increased in both frequency and magnitude during this period and continued with phases in the later 17th Century and early 18th century, and again at the end o the 19th and start of the 20th centuries. The result of this storm activity was the collapse in shipping trade and income from the market, plus the physical loss of the town and its valuable infrastructure including

churches, Friaries and domestic homes. The loss of the market place and town hall ended the viability of Dunwich as a centre of trade in the late 17th century (Sear et al., 2011).
Whilst much is known about the decline of the town, comparatively little is know about its origins. Many speculate that it was a Roman settlement, and indeed artefacts dating from this period including tiles, have been found. The town was a Saxon settlement but the scale and precise extent of this is uncertain (Sear et al., 2012; Chant 1986). Thus this project represents an attempt to better understand the value of the existing sedimentary archives associated with the town with a view to providing evidence of its origins and history.

2.0 Project Aims

The main aims of the project were:

1. To establish a minimum date for the construction of the town based on dating of sediments at the base of road and defensive ditch deposits exposed in the cliff.

2. To establish an environmental history of the harbour and in particular to determine the sequence and timescales over which it changed from an open estuary to a freshwater marsh and where possible, to identify flood event deposits.

3.0 Site Overview

3.1 Cliff Exposures

The eroding cliffs at Dunwich provided an opportunity to access sections cut through the archaeological horizons within the western extent of the Pales Dyke. This work is vital since these remains are potentially at risk from destruction from cliff retreat (Sear et al., 2012). The land within the Pales Dyke is only 30m wide at the widest point and is likely to be lost within the next 50-100 years. However, it is this exposure in the cliff face that provides an opportunity to access the archaeology without the need for destructive trench digging.

3.2 Objectives

1. To obtain dateable material from the lowest horizon within the Pales dyke defensive ditch and roads. This material to be either organic (bone, plant material or charcoal) for radiocarbon dating or in the absence of dateable organic material, to collect sediment samples from below and within the lowest disturbed sediments for optical luminescence dating.
2. If pottery fragments are evident and accessible without disturbance, then a sample of these will also be recovered.

3. In ALL cases we are only interested in recovering a minimum 1 sample from the lowest (oldest) layers of the exposed roads and Pales Dyke exposures.
4. To obtain dates for each sample and report to Greyfriars Trust and Dunwich Museum.

3.3 Methods

A stipulation of the permission to undertake the Cliff Face sampling given by the Greyfriars and Dunwich Town Trust, was that minimal disturbance was made to the cliff face. This required a method to access and sample the lowest horizons of each site without full cleaning of the whole section. Access to the sediment layers exposed in the cliff were undertaken by climbing up stable vegetated talus (St James Street/Pales Dyke), or by abseiling (Scott's Lane) using a fixed top rope set >10m back from the cliff edge. The cliff edge was protected from the rope by using tarpaulin and wooden boards to distribute the load over the ground adjacent to the cliff edge. On arrival at the base of the section the surveyor identified the lowest of the sections above the undisturbed cliff sediment. In all cases we used naturally exposed sections, but where necessary we carefully cleaned a small section to reveal this lowest horizon.

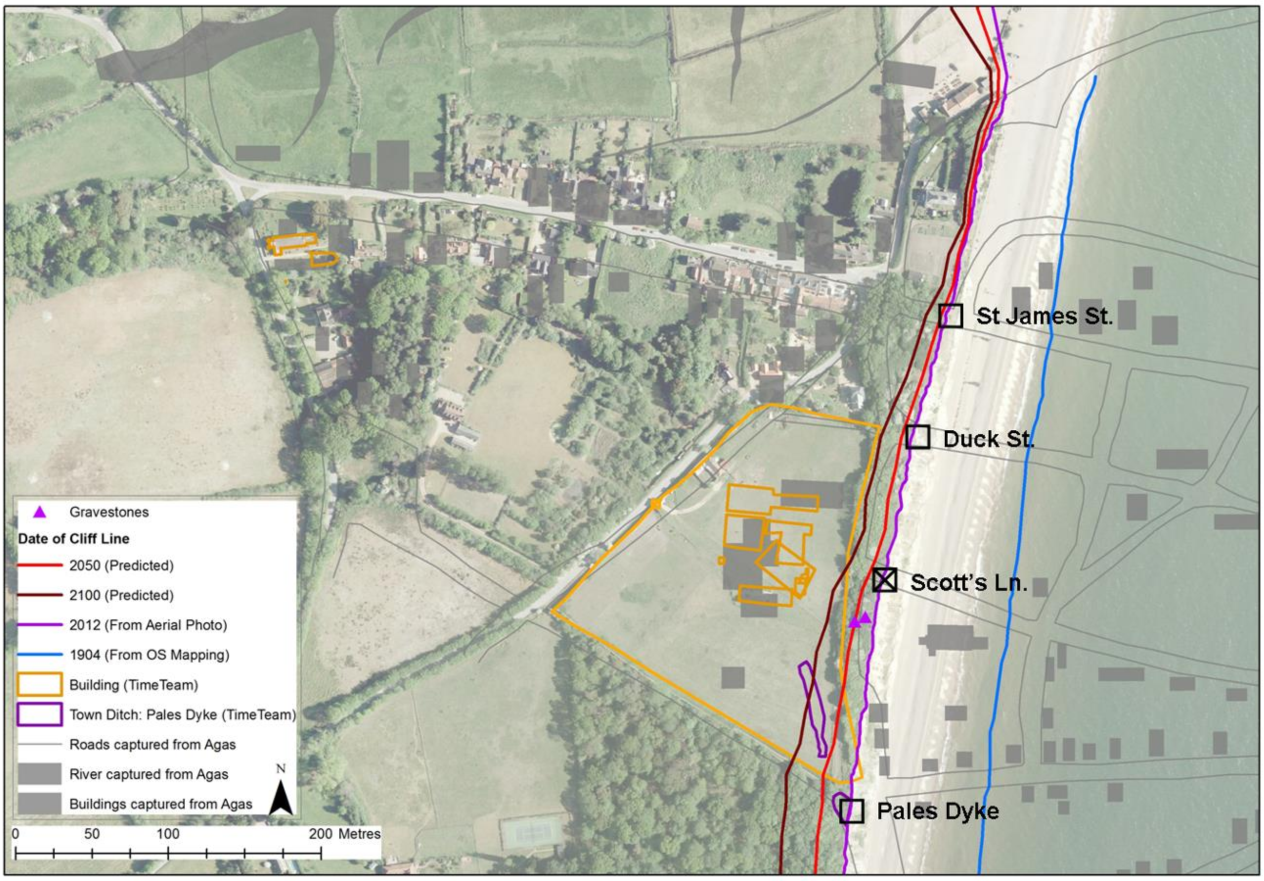


Figure 1: Cliff sites identified for sampling. Note the predicted position of the 2050 – 2100 coastline shows the imminent loss of these sites. Scott's Lane site was not sampled for safety reasons. Samples were taken from the base of St James Street, Duck Street and the Pales Dyke. Base map from Sear et al., (2012).

This minimized disturbance to the cliff face whilst ensuring access to any dateable material exposed at that point. For Radiocarbon and pottery dating we photographed and recovered the exposed fragments/soil, minimizing disturbance to the cliff face.
The sample sites were selected using the digital mapping developed by Sear et al., (2012), and locating the positions where major roads and the town defensive ditch – the Pales Dyke, intersected the 2012 Air photo cliff line (Figure 1).

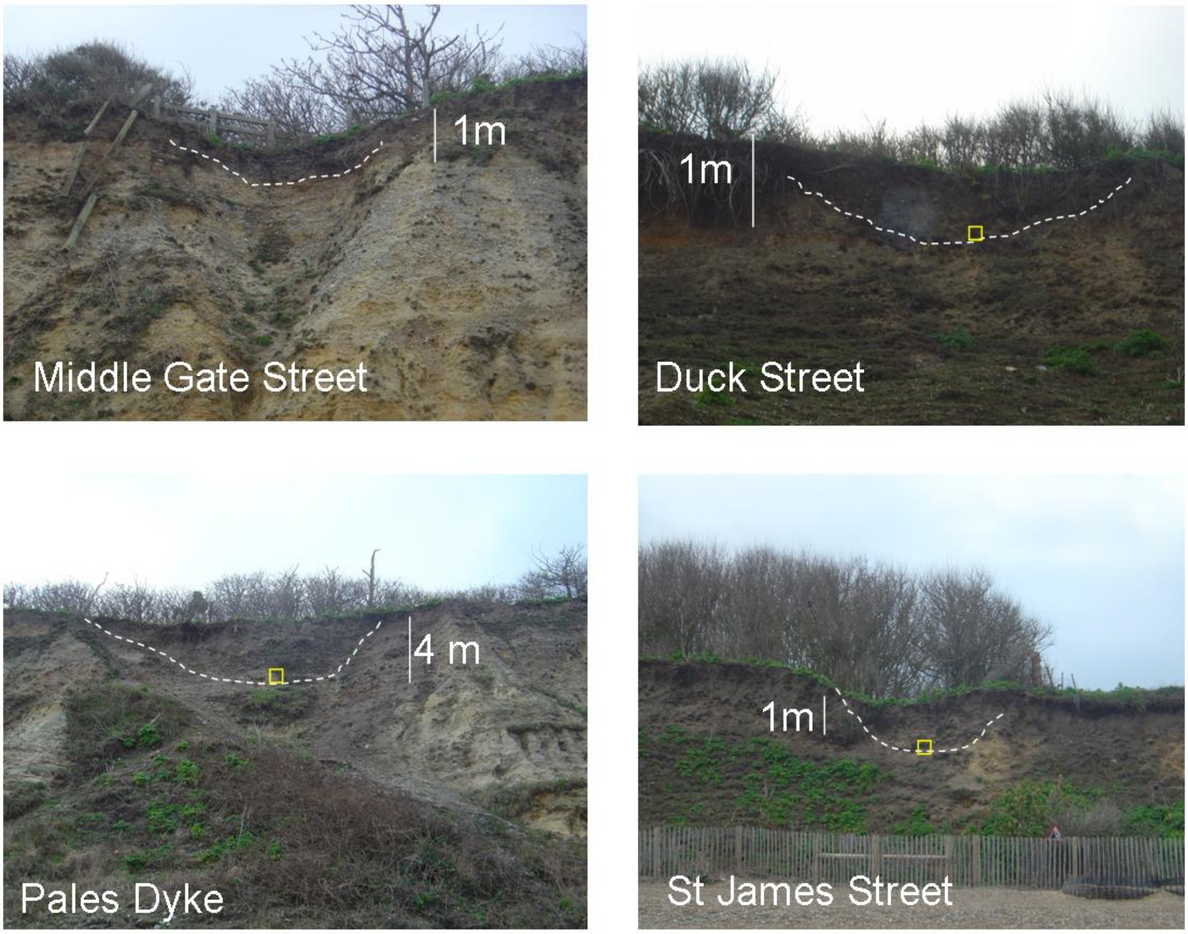


Figure 2: Cliff exposures identified as sampling sites. The lowest horizon above the natural geology of the cliff was sampled (Yellow square). Middle Gate Street was not sampled for safety reasons assessed on the day of survey.

3.4 Geochronology

Three dating methods were considered; 1) dating of any archaeological material found within the sections (e.g. pottery/bone); 2) AMS Radiocarbon dating of charcoal, organic rich sediments and / or plant/bone material; and 3) Optical luminescence dating, which works on the principal that exposure to sunlight 'zeroes' the natural radiation stored over time within the crystal lattice of quartz. Hence the amount of stored radiation (released as luminescence) is a function of time since last exposure to sunlight. It can be used on sediments that are from 300 to 100,000 years BP, and has a 5% accuracy (±50 years on a 1000 year old sample) (see http://crustal.usgs.gov/laboratories/luminescence_dating/what_is_tl.html).

There is the risk that the ditch and road fills were periodically cleaned out or deepened later in their lifetimes. Thus any age is likely to be a minimum date. The purpose of securing dates from a range of sites is to try and maximize the probability of securing a date which reflects the earliest date of construction for the town. In the event, 3 sections were sampled, and two were amenable for AMS bulk radiocarbon dating. One sample from St James Street, contained coal fragments and was therefore unable to be dated. It proved impossible to obtain samples for OSL, due to the presence of pebbles in the layers in or around the location of the dateable layers which prevented recovery of a suitable sample.

In the core samples taken in the floodplain (See section 5 below). Four samples were picked for AMS radiocarbon dating, located at 28cm, 64cm, 70cm and 84cm below ground surface in core Dun4. All samples were sent to Beta Analytical for dating. Table 1 reports the full dates.

Sample	**Material**	**Conventional Radiocarbon age**	**Calibrated Radiocarbon age**
Pales Dyke TTTDunwichS2 Beta – 397875	Organic sediment (bulk)	2270 ± 30 BP	Cal BC 375 (Cal BP 2325)
Pales Dyke DUN Bottom Ditch Beta - 420095	Organic sediment (bulk)	2360 +/- 30 BP	Cal BC 480 to 390 (Cal BP 2430 to 2340)
Duck Street TTTDunwichS3 Beta - 397876	Organic sediment (bulk)	1310 ± 30 BP	Cal AD 675 (Cal BP 1275)
Core DUN28 Beta - 417861	Organic material (bulk)	20 ± 20 BP	100.2 +/- 0.3 pMC
Core DUN64 Beta-407117	Organic material (bulk)	1620 +/- 30 BP	Cal AD 420 (Cal BP 1530)
Core DUN70 Beta - 417862	Organic material (bulk)	1110 ± 30 BP	Cal AD 885 to 995 (Cal BP 1065 to 955)
Core DUN84 Beta-407118	Plant material (Cannabis Seed)	980 +/- 30 BP	Cal AD 1025 (Cal BP 925)

Table 1: Radiocarbon dates for the cliff sections (TTTDunwichS2,S3, DUNBottom Ditch) and for the core samples (DUN64,DUN70,DUN84) collected from the floodplain. Dates are calibrated using Reimer PJ et al. (2013). IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. Radiocarbon 55(4):1869–1887.Note that for DUN28, pMC is percent Modern Carbon.

All dates reported are earlier than expected, dating from the middle Iron Age through to late Saxon-early medieval. One sample (DUN28) was contaminated and returned an age that was modern –due to contamination and/or presence of recent root material.

3.5 Age Depth Model

The sediment core was dated using a combination of data sources. The upper (more recent) sediments were dated using Spheroidal Carbonaceous particles after the method and regional curves from Rose and Appleby (2005). SCP's are the product of high temperature combustion typically found in furnaces or power stations. They are molten ash and since they travel in the atmosphere via wind, they can be found in sediments all over the UK. The necessary combustion temperatures were not attained in furnaces until c. A.D. 1850, and so SCP's are not found before this date. Similarly, SCP's are most abundant in 1970 (±5years) with the peak in fossil fuel power station outputs. Thereafter SCP deposition rates decline. SCP's were counted in 1cm intervals down the core until no more were detected. We continued for 3 cm further to check that this was the boundary. The data were then converted into dates using the eastern England regional age model of Rose and Appleby (2005).

Additional dates were determined using the Pine pollen rise, which for Dunwich are occurs around 1920 when the Forestry commission plantation was of pollen generation age, and a lower rise for the region of around A.D. 1750-1800. Radiocarbon dates from Table 1 were used to augment the earlier age records.

The dates were entered into the CLAM and OXCAL (Blaauw, 2010, Bronk Ramsey 2013) age modelling software and a series of age:depth curves with modelled uncertainties produced (Figure 3). We have used the DUN6 curve throughout as it does not contain the estimated date assigned to the 1740 flood and is therefore unbiased.

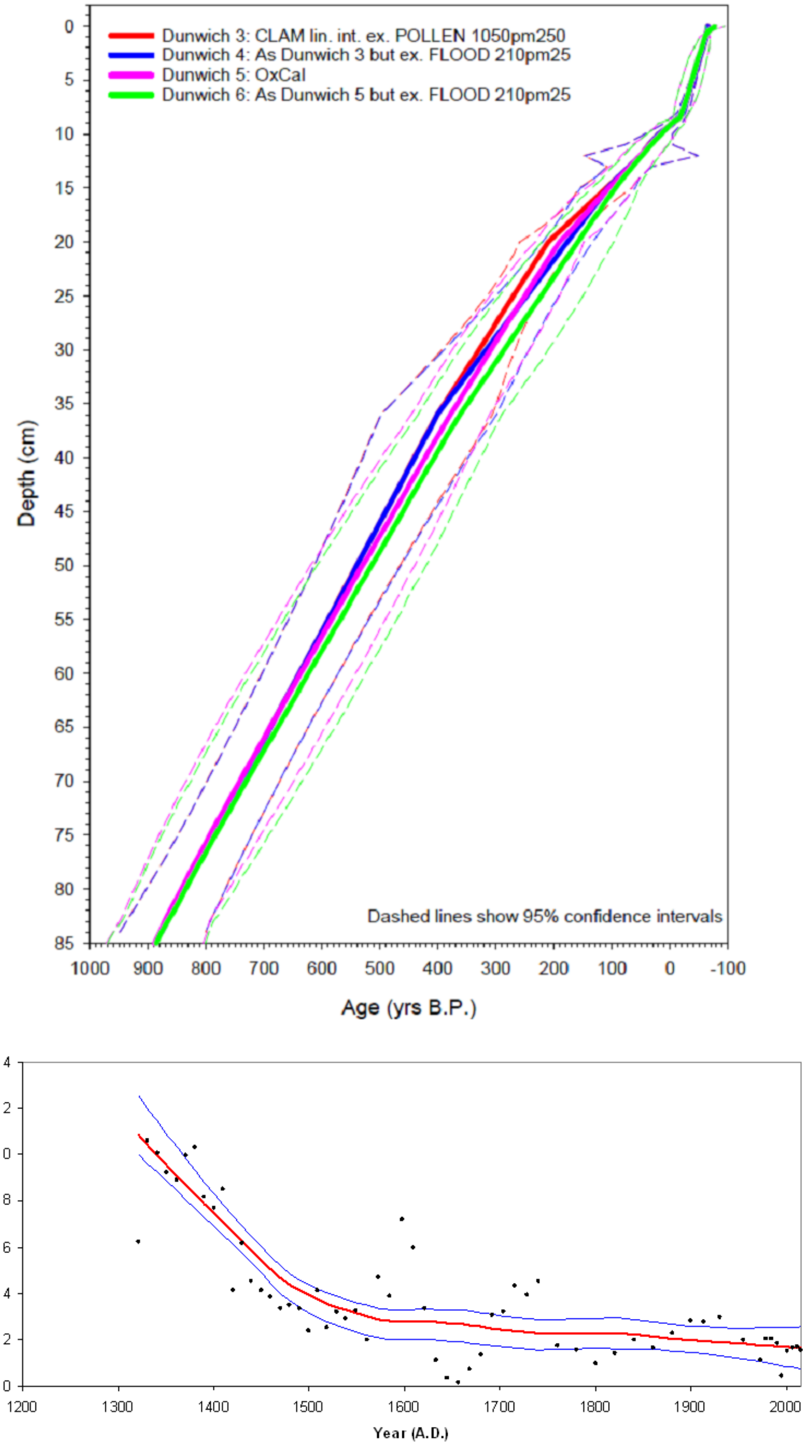


Figure 3: Age depth models for Dun-Core4 based on SCP, Pollen and Radiocarbon dates. Lower graph shows the reduction in clay content used as a proxy for increasing proximity of the coastline to the core site. Note the rapid change up to c. 1570.

4.0 Results

The site was visited on September 5th-7th 2014, and again in 2015. A visual survey was made of the cliff top and the location of sections identified and photographed. A GPS (Garmin eTrex 10, horizontal accuracy +/- 2m) survey of the cliff top was then used to find the centre point of each section and checked against a) the GIS mapping, b) the field evidence (relationship to walls, earthworks), and c) stratigraphic evidence in the cliff exposure. Two sites, Middle Gate and Scotts Lane (Fig 1), were considered too dangerous to sample at the time due to evidence of loose and recently eroded sediments that reflected locally active cliff erosion. The remaining sites – Pales Dyke, St James Street and Duck Street were accessed and sections identified for sampling.

At each site the position of the transition from undisturbed geology to disturbed soil and fill were identified visually, and a small 0.3m wide x 0.5m high section cleared for detailed stratigraphic recoding and sampling for dateable materials. The transition was readily identifiable in the form of yellow marine sand exposed in layers along the cliff (Duck Street, St James Street), and a continuous, orange stained layer of sand and marine pebbles (Pale Dyke). The underlying geology is undivided drift, mainly fine-grained buff to brown, locally shelly, micaceous sands, with local rounded flint gravels (BGS 191).

4.1 Pales Dyke

The town of Dunwich was enclosed to the west, south and most probably north by a defensive ditch called the Pales Dyke (Comfort 1994). A defensive ditch and palisade is said to have been present during the regional insurrection led by The earl of Leicester, that threatened Dunwich in 1173 AD. This puts the earliest date for the ditch in the 12th Century. West (1973) reports "the presence of three pieces of Romano-British pottery from the infilling of the ditch are indications of some sort of occupation during that period but allow nothing more", thus suggesting a possible earlier origin for the ditch.

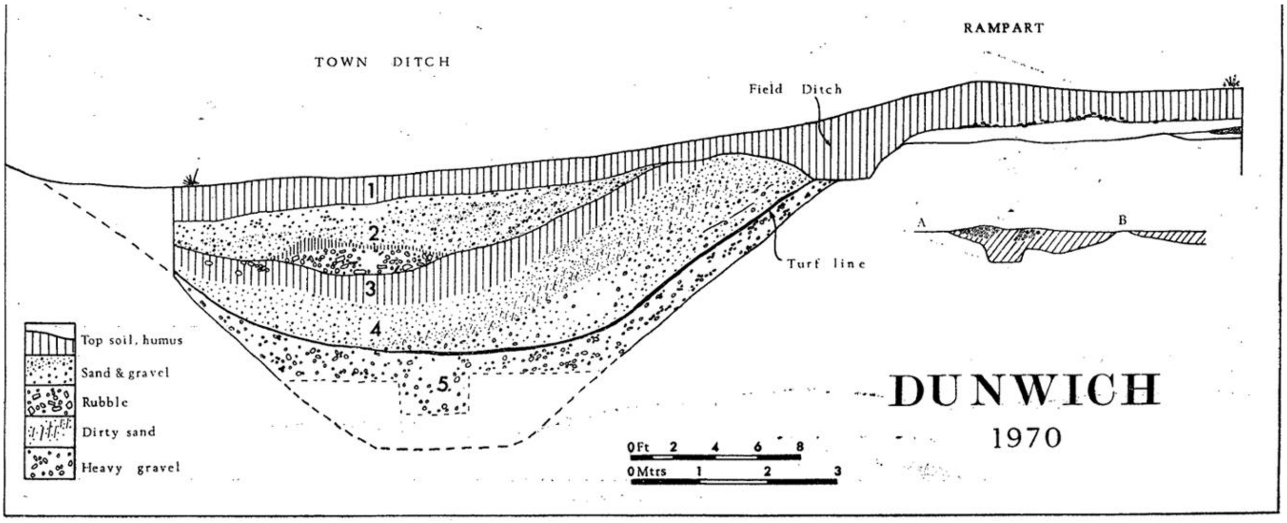
Excavations through the ditch and eastern (inner) rampart were conducted by West in 1970 (West 1973) and by the Time Team in 2011 (Wessex Archaeology 2012). Additional associated excavations of the Temple Mound in 1936 (Spencer 1936) showed that this structure post-dated the ditch and rampart. Similarly Norris (1939) and West (1973) demonstrate that the ditch predates the construction of Greyfriars Friary (c.1290 AD) which accords with documentary accounts (Parker 1976; Comfort 1994).

The West 1970 excavations were conducted at a location similar to that of the current cliff section survey. The section was outside the south and eastern perimeter of Greyfriars Friary. In contrast, the Time Team section was within the eastern perimeter of Greyfriars. Figure 3a shows the stratigraphy of West (1973) section, and Figure 3b the Stratigraphy of the Time Team section (Wessex Archaeology, 2012).

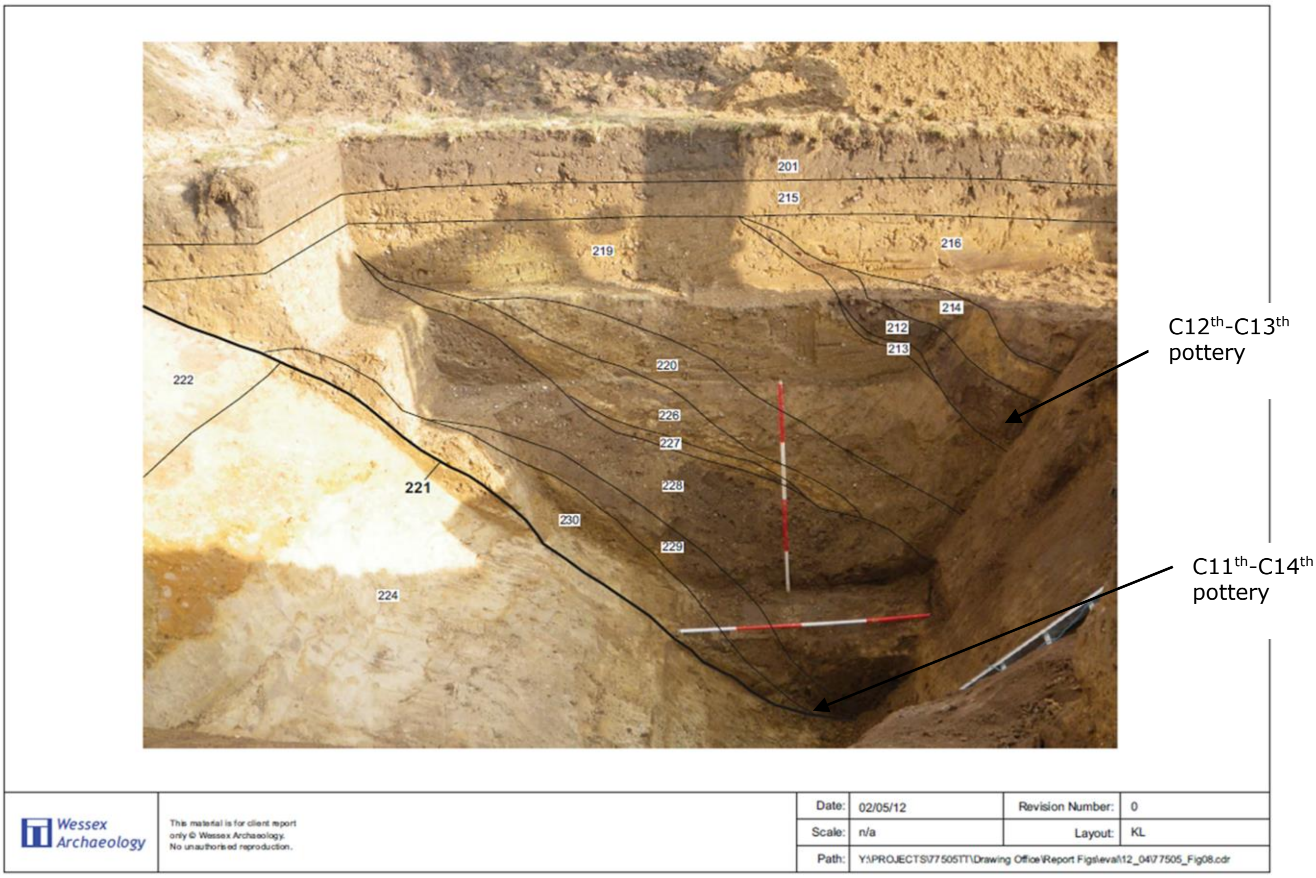
Spencer records the ditch as 10ft (3.05m) deep and 40ft(12.19m)wide. West (1973) records a ditch 15ft (4.57m) deep and 40ft (12.19m) wide, explaining that the lower turf layer in his trench (see boundary between 4 and 5 in Fig Xa) represented the bottom of Spencer's trench. Wessex Archaeology (2012) record broadly similar dimensions as West, at 10m (32ft) wide and 3.7m (12ft) deep.

Stratigraphy is different although broadly similar trends can be seen. The base of the ditch is cut into a Mid orange sand. 5% stone/gravel, surrounded–rounded, <1-2cm gravels (Wessex Archaeology, 2012). Above this is the start of the fill (229-228 in Fig 3b and layer 5 in Fig3a), a layer of Dark brown sandy silt loam. <1% stone, sub-rounded – rounded, <1-2cm, Fairly homogeneous; moderately compact; slightly humic. Wessex Archaeology suggest that this is water-worked inwash containing topsoil which accounts for the humic nature of the sediments. Above this layer are a series of complex infills, including materials associated with the lowering of the eastern rampart, rubble from 19th Century activity in Greyfriars, and humic topsoil. Detailed stratigraphy can be found in Wessex Archaeology (2012) and West (1973).

No dates were produced by the 1970 excavation of West. Time Team provided a tentative estimate based on one small pot sherd which was dated to the 11th - 12th Century, suggesting an early medieval or late Saxon origin.



a)



b)

Figure 4a Section through the Pales Dyke based on the excavations by West (1973). Note the 5ft depth of dark silts sand with gravels overlain by a turf layer. 3b Section through Pales Dyke within the Greyfriars eastern perimeter wall. Gravelly humic silty sand layers 229-228 likely correspond to the layer 5 in West's section. Figures reproduced from West (1973) and Wessex Archaeology (2012).

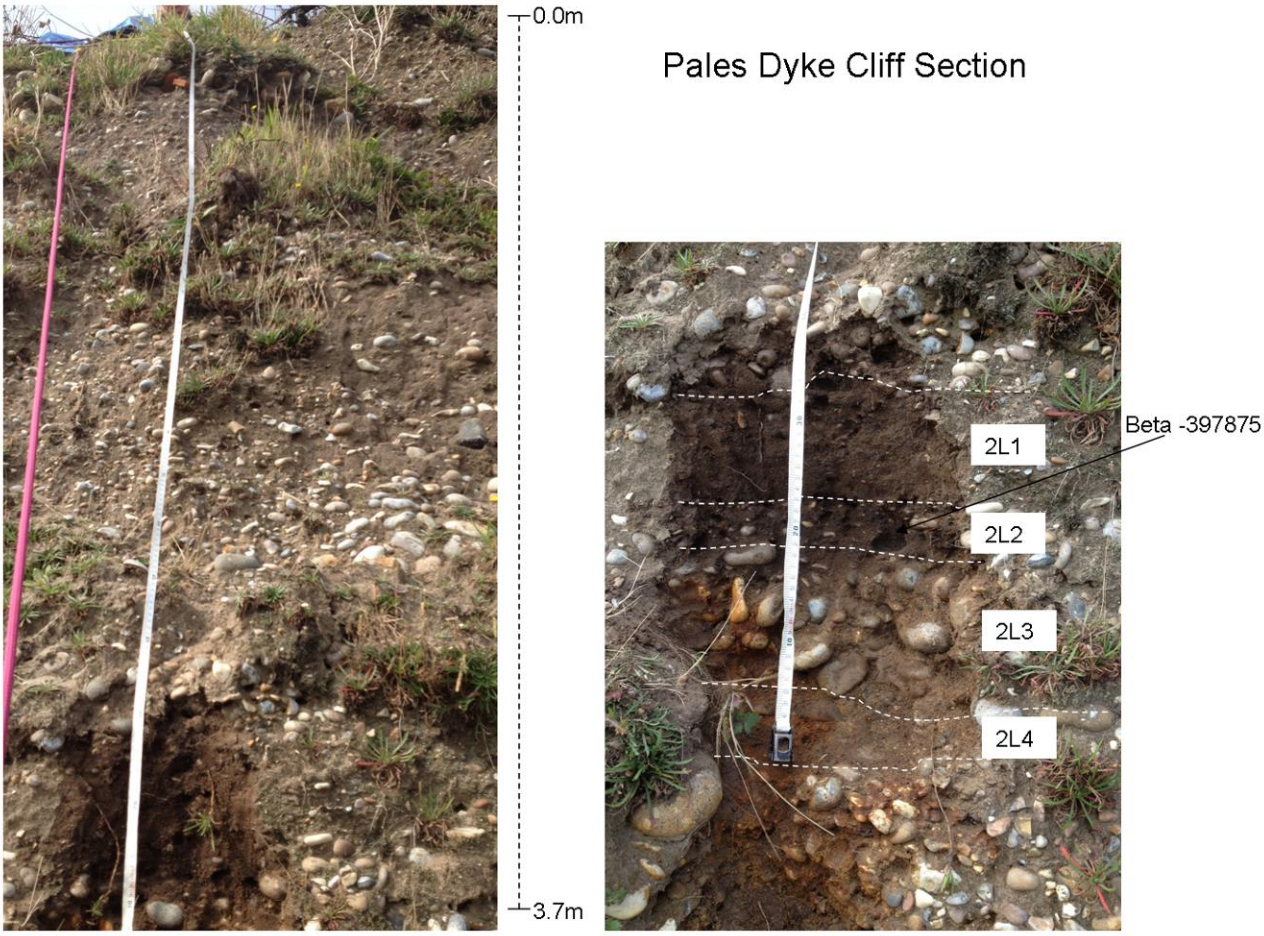


Figure 5: Section through the Pales Dyke bottom sediments. Left shows context for the bottom section. Right shows bottom section with stratigraphic markers and the location of the radiocarbon sample. Details of these are given in Appendix 1.0 2L3-2L4 is in-situ cliff material.

The 2015 cliff section across the Pales Dyke was located at TM47743 70702 (Figure 1) at an altitude of 27m (Full details in Appendix 1.0). The Bottom of the ditch was identified as a brown silty sand with small matrix supported gravels (<1cm diameter, <5%) with humic organic material. This layer is very similar to 229-228 in Wessex Archaeology and Section 5 in West (1973), although the latter appears to have higher gravel content. Below this layer are two layers of water-worked larger framework supported gravels, with an orange sand matrix. The lower of the two layers (2L4) is indurated and compacted, with iron staining, typical of layers of gravel outcropping in the cliff face. These are interpreted as in-situ geology associated with the undisturbed cliff material. Two samples of humic rich sediment were collected from 2L2 for Radiocarbon analysis. The presence of gravels made the collection of optical Luminescence samples impossible. No evidence of pottery or larger organic remains were evident in the section. Of interest is the exposure of what may be the 19th Century rubble deposit identified by West (1973) in his excavations (see top of left hand panel in Figure 3, and lens of rubble in Figure 4 between layers 2 and 3). Additional work to clean up a complete vertical section to fully contextualise the lower section was conducted in June 2015 (Appendix 1.0).

The two samples were returned to the Palaeoecology laboratory at the University of Southampton (PLUS), Department of Geography and Environment for preparation for Radiocarbon dating. Samples were prepared for radiocarbon analysis by careful sorting in a sterile petri dish under a Nikon SMZ1000 stereo microscope. Samples were first cleaned using distilled water and datable material identified and picked out using fine forceps in preparation for pre-treatment and dating. Samples were then sealed in 5ml glass vials and sent off to Beta Analytical for Carbon dating, together with a sealed bulk sample of humic rich sediment. In the event, Beta recommended using the bulk humic sediment as the quantity of picked organic matter was too low after acid treatment, for reliable dating. The specific Beta reports are available on request which details the processing and Calibration used in the analysis.

The calibrated bulk organic sediment date for the bottom of the Pales Dyke section (Beta – 397875), is Cal **375 BC** (Cal BP 2325) with a 95% range of 395 BC to 350 BC (Cal BP 2345 to 2300), 295 BC to 230 BC (Cal BP 2245 to 2180) and Cal 220 BC to 210 BC (Cal BP 2170 to 2160). The second ample recovered from the ditch:natural geology interface and independent of the previous sample, was dated to (Beta-420095) Cal **400 BC** (Cal BP 2350) with a 95% range of 480 BC - 390 BC (Cal BP 2430 to 2340). This puts the age of the sediments in the lowest layer of the Pales Dyke within the Middle Iron Age (400 – 100 BC). The sediments, are interpreted as in-washed soil material, and may therefore reflect erosion of earlier material from within the ditch banks. The independent samples are within the same period which provides confidence that the dates are accurate for that stratigraphic layer. Thus whilst we are unable to say that this date is a minimum for the construction of the ditch (*sensu stricto*). However, this is also true of the pottery material found in the in-washed soils by Time Team survey. Thus as such the precise date for the Pales Dyke remains inconclusive, but these new dates provide strong evidence that they may have a Middle Iron Age origin.

The evidence for the age of the Pales Dyke is conflicting. Looking at the earliest dates, we have historical reference to it in the 12th Century (1173 AD); Thetford ware pottery c. 11th Century (Time Team excavations) and Romano-British (1st-4th Century AD) based on West's excavation notes. The Middle Iron Age dates reported in this study, pushes the potential origin back a further 400-800 years. A few Iron Age finds have been recorded in the area around Dunwich, notably a coin in the Westwood marshes to the north, and pottery on the sandy hills adjacent to the Dunwich river crossing (Dymond & Martin, 1989). Iron Age fortifications are rare in east Suffolk, with the nearest located at Burgh, near Woodbridge (Dymond & Martin 1989). If correct, Dunwich would be an early and extensive Iron Age fortified settlement, located adjacent to a port on the Dunwich/Blyth river. Subsequent evidence suggests it existed in the Romano-British period and Saxon period when we know Dunwich was a growing port. It seems most likely that the ditch is earlier than the medieval origins assumed before, which is supported in part by the early date for Duck

Street (675 AD) and due to evidence of a Middle-Late Saxon retting pit in the marshes adjacent to St James street (485-1025AD).

4.2 Duck Street

Duck Street is shown on the Agas map of 1589 AD, as an eastern spur off the road that ran along the line of the Pales Dyke (Figure 1). Duck Street parallels St James' and Scott's Road, running east into the town centre, to the south of St Peters Church. It was not a major road (c.3.8m wide), and did not puncture the Pales Dyke.

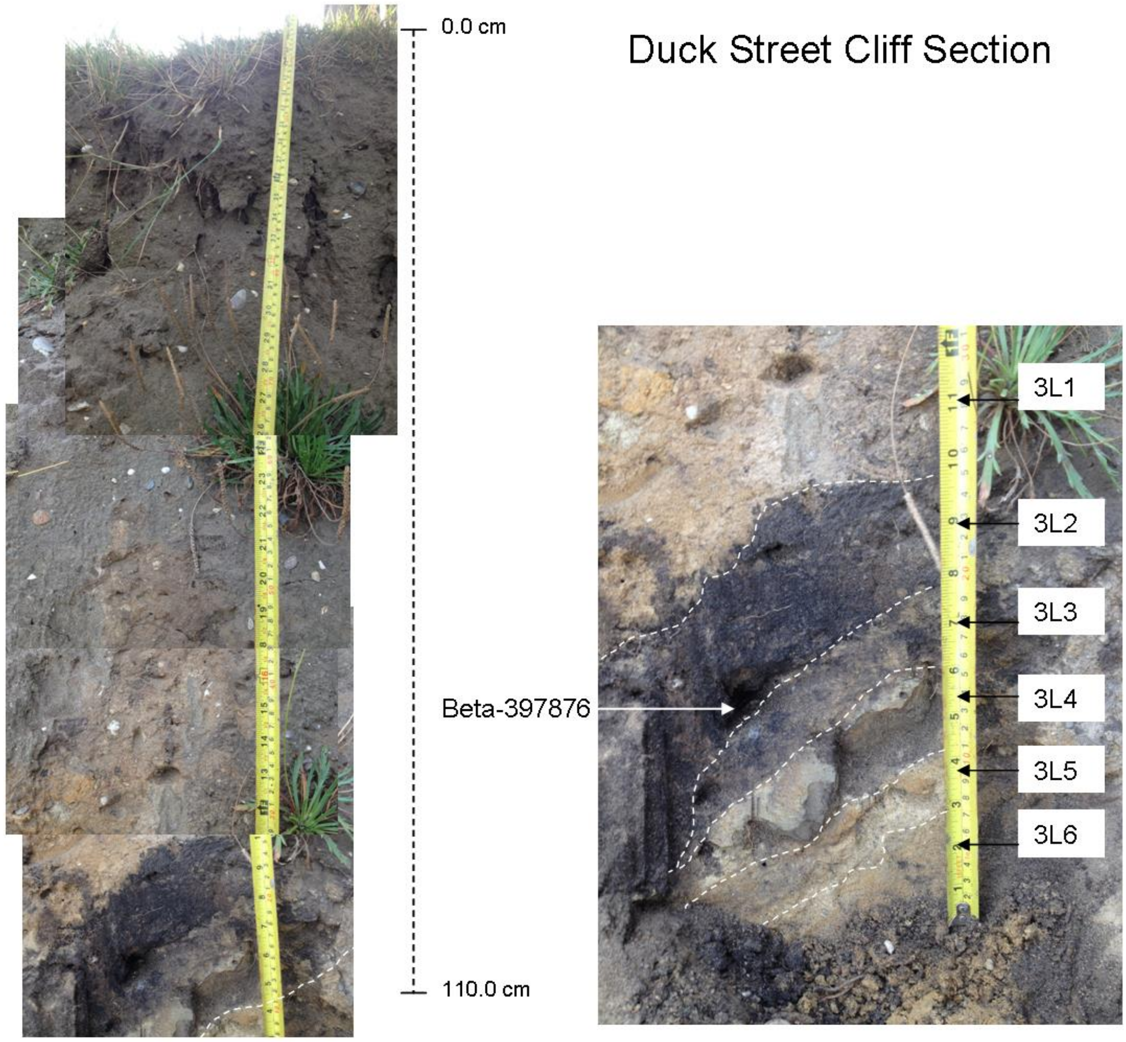


Figure 6: Stratigraphy of the Duck street cliff section. Left shows the context for the section, right shows the stratigraphic layers (details in Appendix 1.0) at the bottom of the section, including the location of the radiocarbon dated sample. 3L5-3L6 is in-situ cliff material.

The site of Duck street was located visually and by GPS at TM47778 70947. It consisted of a 3.8m wide deeper layer of humic sandy loam topsoil relative to adjacent sections exposed in the cliff (Figure 6). A Section was cleaned at the interface of the undisturbed geology (3L5/6) and the humic sandy loam soil, interpreted to be the bottom of the road section (3L4-1). Of interest is a compact clay rich layer (3L4) at the base of the section which might be an attempt to compact the road surface. Above this layer is a silty-clay with patches of humic rich materials (3L3). These humic rich sediments form a concentrated discrete layer (3L2) from which we took two samples for Radiocarbon dating. Above this humic rich layer the soil is a sandy loam with small rounded-sub-rounded pebbles. No evidence of a pavement of coarser stones was present.

The two samples were processed following the same procedure as outlined in the Pales Dyke Section above. Organic matter sample size was again too small and so bulk humic rich sediment was used (Table 1; Appendix 1.0).

The calibrated bulk organic sediment date for the bottom of Duck Street cliff section (Beta – 397876), is Cal **675 AD** (Cal BP 1275) with a 95% range of Cal 655 AD to 725 AD (Cal BP 1295 to 1225), Cal 740AD to 770 AD (Cal BP 1210 to 1180). This puts the bottom sediments of the road firmly in the Middle Saxon period (400-1066 AD), during a time when the kingdom of East Anglia had been firmly established and St Felix had established a Bishopric (c.630AD) at Dunmoc (Dymond & Martin 1989). The sediments appear to be discrete, representing a local concentration of humic material within the inwashed soil. Thus while the same criticism of the sample (potentially older material washed into the road) can be made, the date does accord with the known presence of a Saxon settlement at Dunwich.

4.3 St James Street

St James Street (TM47804 71037) is clearly visible in the cliff section as a shallow depression aligned with the existing path that occupies the old street. A clear transition exists between the base geology (in this case a yellow sand) and humic brown sandy silt of the in-washed sediment, which includes pebbles and sandy silts with evidence of coal (Figure 7). The latter prevented acquisition of a radiocarbon date from this feature. Thus no date was established for the road which was said to be one of the main thoroughfares into the town. An additional attempt to secure a sample from the section revealed the presence of larger fragments of coal. Subsequent excavations in 2015 have suggested that the road cutting post-dates the medieval town.

4.4 Summary

The attempts to secure dateable materials from road and Pales Dyke sections have proved successful to a point. Access to some sections is safe and repeatable. It is possible to locate the base of the road and Pales Dyke sections relative to in-situ geology. Furthermore we have demonstrated that it is possible to secure dates based on bulk organic sediments. The main problem with the approach is the limited sections that were permitted to be worked on for reasons of concern for cliff erosion. Similarly, the materials may represent older sediment washed in to a later road/ditch cutting. Cleaning of a wider section would help provide evidence for the origin of the sediment within the road / ditch sections. Similarly, wider cleaning of the section face may reveal in-situ organic material (nuts, plant fragments) that could be more robustly dated (although the criticism would pertain). In the end, we recovered two dates. Both are earlier than hitherto found and support an earlier origin to the town of Dunwich.

Figure 7: St James Street cliff section showing context (left) and detail of the bottom sediment section including stratigraphic layers (details in Appendix 1.0). Location of coal deposit is shown which precluded radiocarbon dating. Section 1L5 is in-situ cliff material.

5.0 The Stratigraphy and Pollen analysis of the Dunwich Marshes: Core 4

5.1 Introduction

Stratigraphical survey of the Dunwich Estuary (Sear, 2015) revealed a number of interesting sediment profiles which have potential for establishing the changing historic environment of Dunwich and estuary, That is, especially pertaining to the local vegetation and land use of the near region and of the history of estuarine development. Multidisciplinary studies are being used comprising detailed description and analysis of the sediments, pollen and diatom analysis and radiocarbon dating, the latter to provide an absolute chronology of marine and brackish water incursions. Subsequently, these palaeodata will be compared and integrated within the historical documentation available for the port of Dunwich. This report presents the first stage of this analysis dealing with the stratigraphy, pollen analysis and vegetation dynamics of the site.

5.2 Core Transects and site

Two core transects were collected over the period 2010-2015. Detailed analysis of Transect Dun2015 and specifically Cores Dun4 and Dun6 were performed under contract for the Touching-the-Tide HLF project. Figure 8 shows the locations of the cores collected as part of an undergraduate dissertation project supervised by Professor David Sear (Wright 2011); only stratigraphic analysis are reproduced for this transect. The mapping shows the location of the core site Dun4, to be positioned in an area of former estuary, most likely salt marsh or grazing marsh. It is likely the site was inundated by salt water at very high tides and from fluvial runoff during rain driven flooding. The location relative to historic Dunwich, shows that the core site was formerly protected by Cock and Hen hills (upwards of 40ft high) and the lower lying ground associated with the northwest of the town. This area was stripped of soil and vegetation during the storm of 1740 (Gardner 1754). It is conceivable that some of this material was redeposited over the area of the core site. The position of Core 4 is located west and slightly north of the former enclosure of the Maison Dieu hospital, and north of the main St James Street. It is possible that the area was formerly used to gain access to the Hospital during high tide, when the core site would have been intertidal mudflats.

The site of the 2015 transect and cores Dun4 and Dun 6 are shown in Figure 9 The 1754 sketch reported in Gardner (1754), shows the area around the core site to be freshwater reed bed with adjacent grazing marsh and some (brackish?) pools. In the 1880 photograph, the site is landward of the scene, but the image shows extensive shingle and sand associated with the gravel barrier, and grazing marsh behind. The 1945 Air photo shows the site to be grazing marsh much as it is today.

5.3 The stratigraphy

The basic stratigraphy of the Dunwich river estuary is typical of other coastal sediment stacks (Figure 8). At Minsmere, woody peat indicative of freshwater floodplain woodland gives way to blue-grey estuary muds created by a marine transgression around c.3200BP (1250BC), which lasted until c.400BP (1550AD) when freshwater peats again appear, often associated with evidence of higher energy incursions, notable siltyclay and sandy-silt banks (Lloyd et al., 2011). In the Blyth estuary, Brew et al. (1992) report the same transgression occurring around c.4300BP, noting that the precise date depends on the development of barriers at the estuary mouth and the availability of clastic material. Thereafter, freshwater peat dominated often associated with *Phragmites* (common Reed) and where grazed and drained, the top sediments are of partly oxidised peat. Figure 9b shows a transect across the Dunwich river valley, collected by Wright (2011). This clearly shows the estuary mud following an earlier valley form, dipping to a low point near core A1C3, east of the location of the current Dunwich river near A1C4.

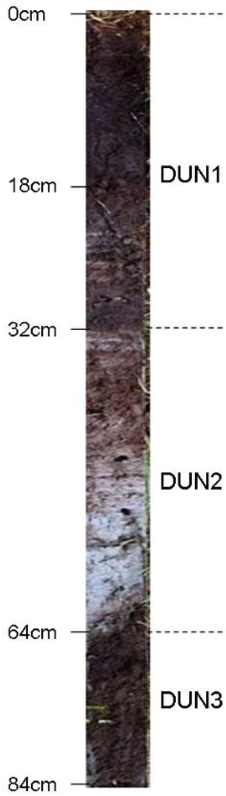
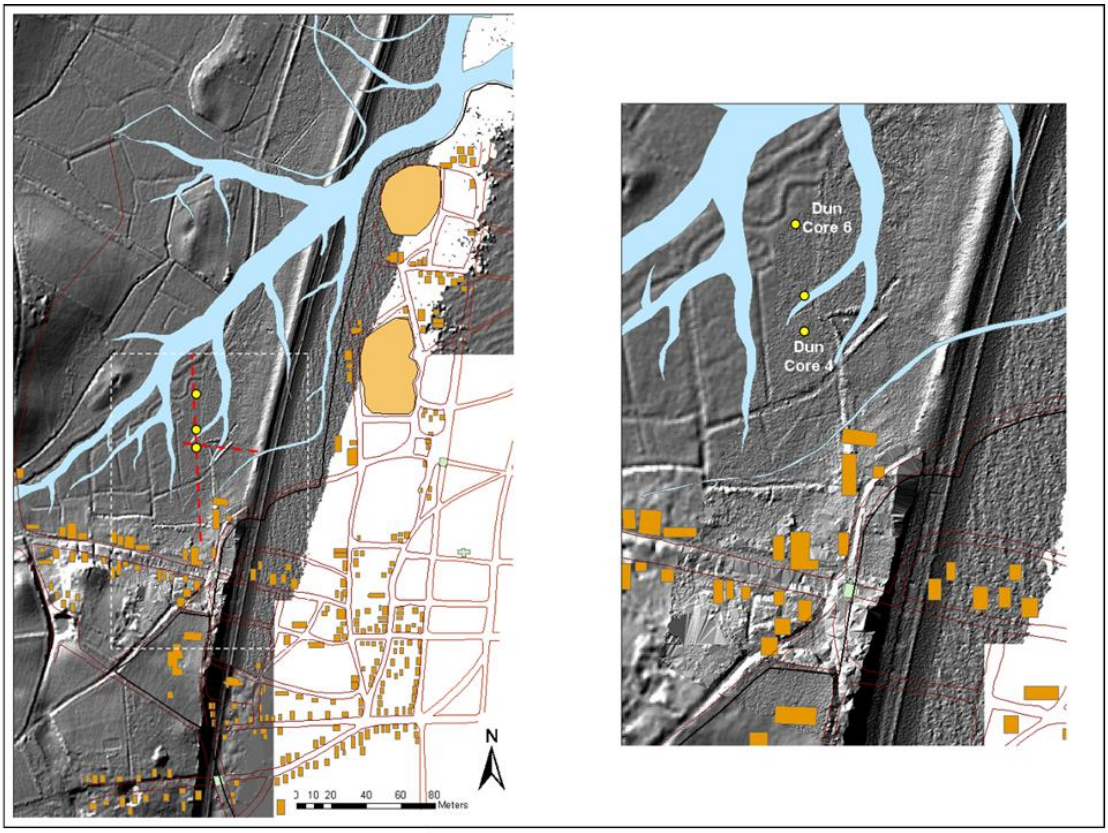


Figure 8: Dun4 Core showing the lower (bottom of figure) organic sediments from the hemp retting pit, overlain with saltmarsh and mudflat sediments (bluey-grey). The laminated organics and silts progress up into a dark humic freshwater marsh horizon at the top of the core (upper part of figure. Sections DUN 1-3 are detailed in Table 3.

The core transect collected in 2015, runs north from the bottom of the gardens located on the north side of St James street, to just south of the Dunwich river. Figure 9b shows the 2m LiDAR elevations dipping rapidly off the sandy-gravel a



b

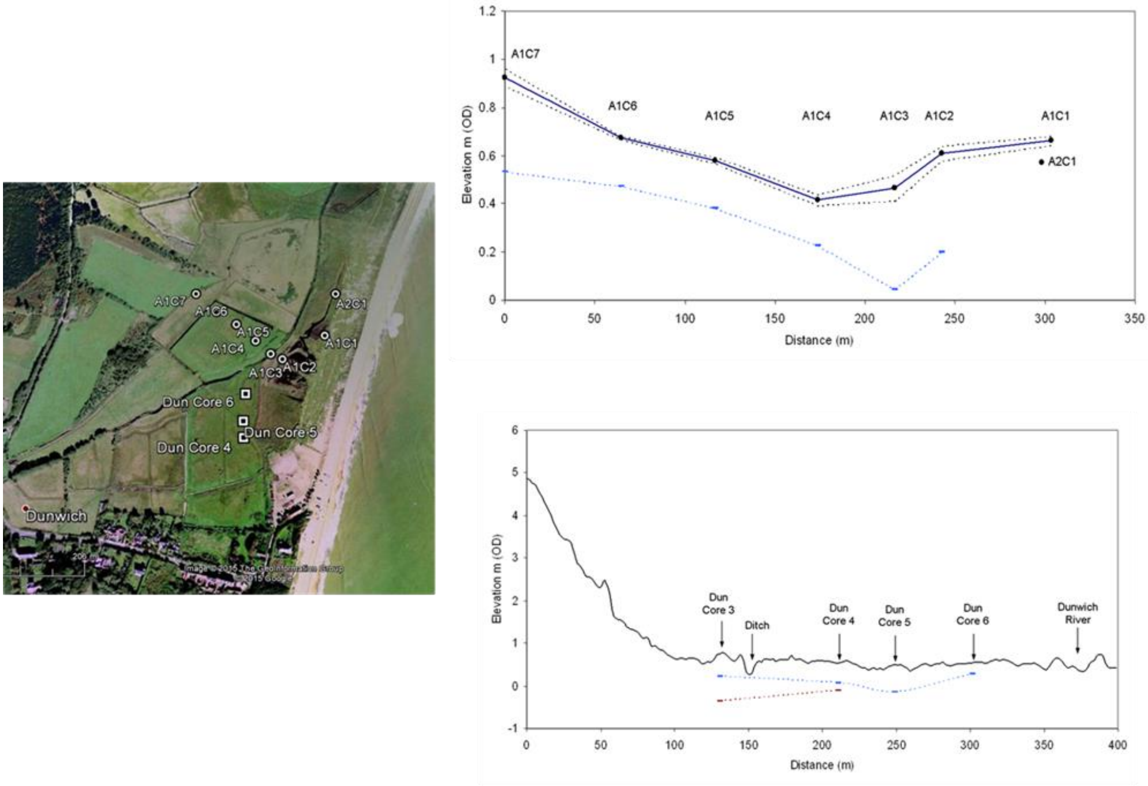


Figure 9: Location of core transects in relation a) in relation to local LiDAR elevation and landscape features from the old town of Dunwich and the current position of the gravel barrier and sea and, b) to a contemporary air photograph of the landscape, and EA LiDAR based elevations. Transect of cores A1C1 – A1C7 cut across the Dunwich river floodplain. Transect Dun4-Dun6 cut north from the margins of the Maison Dieu hospital land towards the Dunwich river.

ridge onto the marches. The top of the estuary blue-grey clay dips towards the Dunwich river with evidence of a shallow channel around Core Dun5. This corresponds with a channel shown on the 1587 Agas map (Figure 9a) and visible on air photos (Figure 9b). Core Dun4 (1°37'53.82"E, 52°16'46.44"N) sits on the southern margin of this shallow channel at a surface elevation of 0.56m O.D. (0.24m above local MHWL), at a point where the underlying peat surface rises. The estuary blue-grey clay, though not shown in the Figure, pinches out at around 100m north along the transect.

Two cores have been examined in detail (cores 4 and 6) for both stratigraphy and sub-fossil pollen and spores. Core 6 proved to have little pollen and although the stratigraphy has been described this is not discussed here. Core 4 proved to be of greater interest in having a basal organic unit (Figure 7). The profile also produced sufficient pollen and spores to allow construction of a pollen diagram (section 3 below). The stratigraphy of core 4 is described in table 1 below and Figure 7).

Depth metres	**Munsell colour**	**Description**
0.0-0.02	10YR 2/1	Upper rooted humic layer of present marsh community. Matted roots within detrital peat matrix
0.07-0.02	10YR 2/2	Granular/blocky peat. Dark, detrital.
0.17-0.07	10YR 2/2-10YR2/1	Dark detrital peat.
0.20-0.17	10YR 2/2	Sandy silt. Coarse humic. Broadly laminated. Medium to dark brown.
0.21-0.20	Transition	Transition
0.255-0.21	10YR 4/2	Grey/brown, coarsely laminated silt.
0.31-0.255	10YR 2/2	Peat. Fibrous, coarse with occasional sand and small gravel. Some roots.
0.32-0.31		Transition
*c.*0.61.5-0.32	10YR 4/2 to 3/2 with 10YR 5/1	As below but generally paler grey/brown. Coarsely laminated. Pale grey and grey brown laminae. Silt
0.60		Peaty inclusions. Dark.
0.63-0.61.5		Transition
0.86-0.615	10YR 2/1 to 10YR 2/2	Dark brown/black detrital peat. Fibrous.
0.86		Base of profile

Table 2: Sediment stratigraphy of Dunwich Core 4.

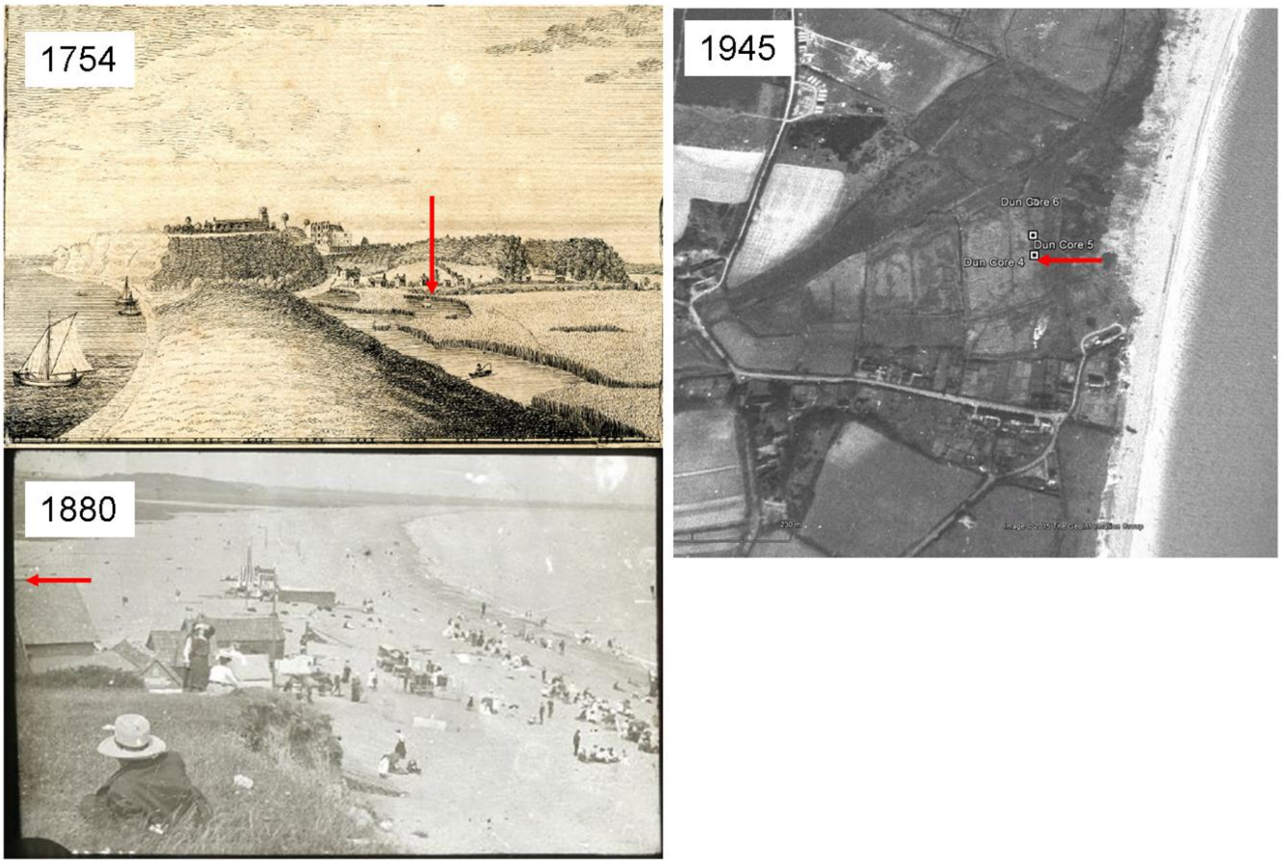


Figure 10: Views of the area around the 2015 core transect, showing evidence of freshwater reed marshes in 1754, clastic overwash in 1880 and grazing marsh in 1945. 1880 photograph is from the Dunwich Museum online collection, The 1754 sketch is from Gardner (1754), and the 1945 aerial photograph is from Google Earth historical imagery, original source being the RAF.

5.4 Pollen analysis of core 4

Pollen cores 4 and 6 were obtained using a large Dutch Gouge corer and have been analysed. The latter, core 6, proved unsatisfactory with only small numbers of pollen found. These traces comprised largely very occasional Chenopodiaceae (goosefoot, orache and samphire) from salt marsh (halophytic) communities, coniferous pollen and re-worked pre-Quaternary palynomorphs. There was insufficient pollen to enable even small assessment style pollen counts. This paucity of pollen is attributed to rapid deposition. Core 4 proved more satisfactory with a basal humic unit overlain by sediment of brackish and marine origin signifying a marine transgressive event.

5.4.1 Pollen method

Samples of 1.5ml volume were processed using standard techniques for the extraction of the sub-fossil pollen and spores (Moore and Webb 1978; Moore *et al.* 1992). The sub-fossil pollen and spores were identified and counted using Nikon and Olympus biological research microscope. Pollen counts of up to 400 grains of dry land taxa per level was counted (the sum). All spores and pollen of marsh taxa (largely Cyperaceae), fern spores and miscellaneous elements (largely pre-Quaternary palynomorphs) were also counted for each of the samples analysed. A pollen diagram has been plotted using Tilia and Tilia Graph (figure 10a and 10b). Percentages have been calculated in as follows:

Sum =	% total dry land pollen.
Marsh/aquatic herbs =	% tdlp + sum of marsh/aquatics.
Spores =	% tdlp + sum of spores
Misc. =	% tdlp + sum of misc. taxa.

Taxonomy, in general, follows that of Moore and Webb (1978) modified according to Bennett *et al.* (1994) for pollen types and Stace (1992) for plant descriptions. An extensive pollen and spore reference collection was available to aid identification where required. These procedures were carried out in the Palaeoecology Laboratory of the Department of Geography, University of Southampton.

5.4.2 The pollen data

Pollen preservation was found to be variable as might be expected from the contrasting humic sediment at the base of the profile and the more minerogenic, overlying silt and clay of salt marsh and mud flat origin. However, the pollen spectra obtained show interesting and significant changes throughout the c.0.9m of sediment. These changes have been described as local pollen assemblage zones (l.p.a.z.) DUN4: 1-5 from the base of the profile at 0.90m upward. These are defined and described in table 3 below and shown graphically in Figure 11.

Local Pollen Assemblage Zone	***Palynological characteristics***
l.p.a.z. DUN4: 5 14cm to 4cm *Pinus*	Pine values increase to a peak of 28% at 8cm. Arboreal pollen remains consistent but at low levels with *Betula, Picea, Ulmus Ilex* and *Alnus* present. *Quercus* remains at c.10% throughout. Herbs remain dominant with Poaceae most important to highest values in the upper sample (80%). Lactucoideae of the preceding zone are diminished. Cyperaceae pollen values, *Pteridium aquilinum* spore numbers and pre-Quaternary palynomorphs also show reductions
	DUN4: 3 is delimited by increasing values of Poaceae and

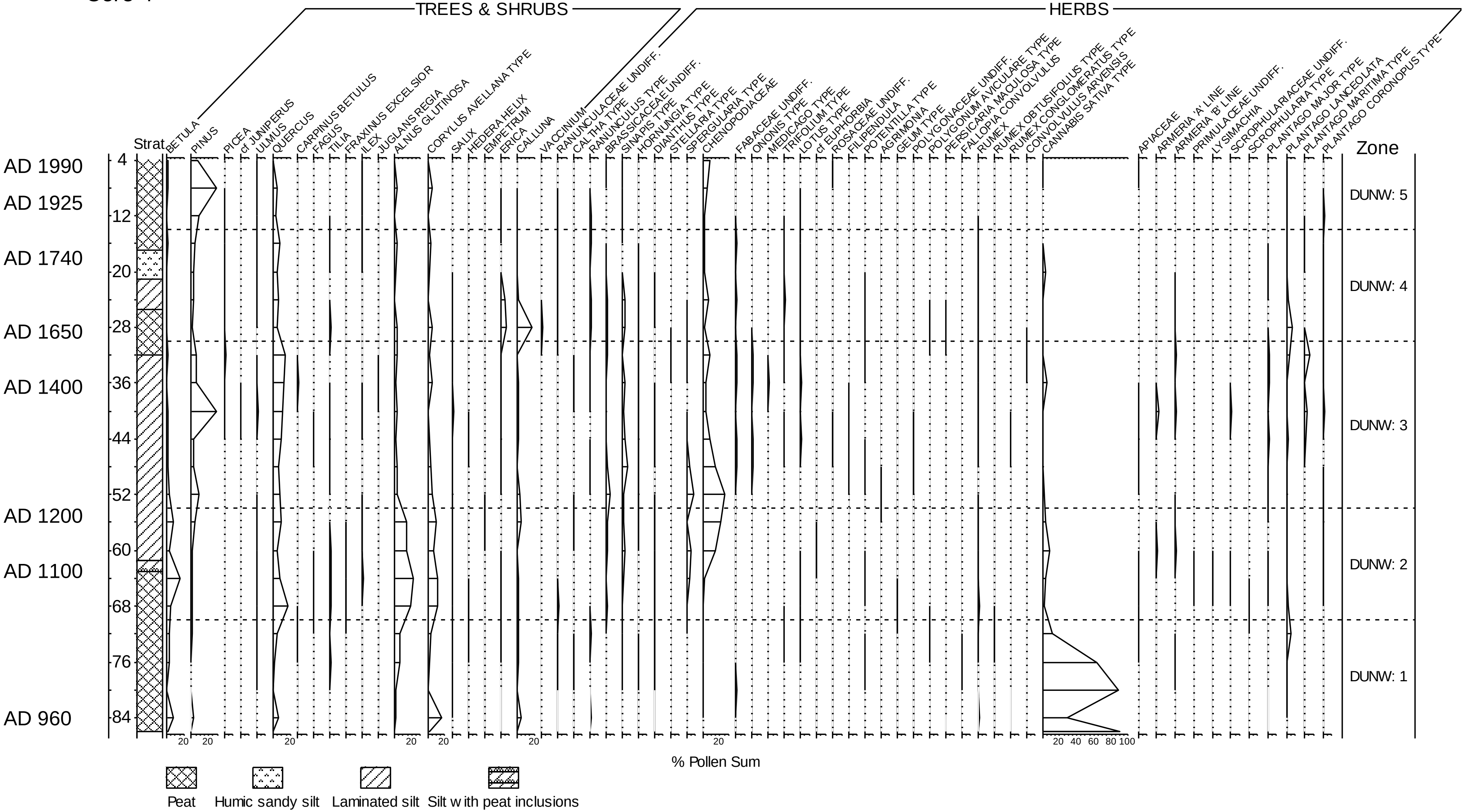
l.p.a.z DUN4: 4 4cm to 14cm Poaceae-Lactucoideae	Lactucoideae, the latter peaks to 30% at 24cm. Arboreal and shrubs are at low levels and comprise *Betula*, *Quercus* (7-8%), *Alnus* (2-3%) and *Corylus avellana* type (2-3%). *Pinus decreases from the preceding zone* and prior to expansion in zone 5 above. Small numbers of *Picea* are present. Dwarf shrubs include *Calluna* (peak to 20%) and *Erica* (5%) especially in the lower part of the zone. Herbs are dominant and include Poaceae to its maximum values (75%), *Cereal* type, *Secale cereale*, Lactucoideae (noted) *Cannabis sativa* (<3%) and a range of other taxa. Sporadically occurring including *Polygonum aviculare* type, *Persicaria maculosa* type and Asteraceae types. Marsh taxa are important and dominated by Cyperaceae (to 49%) with small numbers of *Potamogeton* type. Fern spores include *Pteridium aquilinum* with occurrence as in zone 3 below and only small numbers of *Dryopteris* type. Pre-Quaternary palynomorphs are present with some increase at the top of the zone (to 8%).
l.p.a.z DUN4: 3 54 to 30cm Lactucoideae-Poaceae-Cyperaceae	There are reductions in *Quercus and Corylus avellana* type whilst *Pinus* values expand (to av. values of 10% and peak to 29%). Other arboreal taxa comprise low levels of *Tilia, Fraxinus, Fagus, Carpinus* and occasional *Juglans regia, Ilex* and *Picea* at the top of the zone. Herbs remain dominated by Poaceae (c. 70%) with increasing numbers of Lactucoideae (to 20%), Chenopodiaceae values remain high (to 30%) and decline upwards along with *Spergularia* type (to 8%). There is a small peak of *Plantago lanceolata* (to 6%) across the zone 3-4 boundary. The halophytes, *Armeria* 'A' and 'B' line, *Plantago maritima* and *Aster* type are present. Freshwater marsh taxa comprise largely Cyperaceae which increase in importance to the top of the zone (to a peak of 45%). There are occasional *Potamogeton* type (incl. *Triglochin*) and *Typha latifolia*. Monolete *Dryopteris* type spores decline to low levels after peaks at the top of zone 2 and base of zone 3. There is some expansion of *Pteridium aquilinum* (to 12%). There are high values of pre-Quaternary palynomorphs at the base of the zone with a maximum of 48% sum + misc.
l.p.a.z. DUN4: 2 70 to 54cm Chenopodiaceae-Poaceae	This zone is delimited by increasing values of Chenopodiaceae to a maximum of 30% at 54cm. There is a corresponding increase of *Spergularia* (to 9%). Herbs are dominant with Poaceae (peak to 58%) most important. Other herbs include *Cereal* type, *Ranunculus* type, Lactucoideae, *Bidens* type. *Medicago* and *Lotus* type (small peak at 44cm). *Cannabis sativa* type remains present but at considerably lower levels than in zone 1 (to 11% in lesser peak at 56-60cm). Tree pollen show increases with

	Alnus (to 18%) *Corylus avellana type (11%) a*nd *Quercus* (peak to 18%). Other trees and shrubs include *Betula* (to 13%) and *Pinus* (increasing at the top of the zone to *c.*6%). Marsh taxa comprise Cyperaceae with increasing values (peak to 40% at top of zone), *Caltha* type, and *Potamogeton* type (peak to *c.*20%) at 60cm. Ferns comprise *Dryopteris* type declining throughout whilst *Pteridium aquilinum* and *Polypodium* are also present in small numbers. Pre-Quaternary pollen palynomorphs peak to high values (50% Sum + Misc.) at 52cm.
l.p.a.z. DUN4: 1 86 to 70cm *Cannabis sativa*	This basal zone is characterised by extremely high values of *Cannabis sativa* (hemp) pollen (to 90% at 86cm and 60% at 76cm). Values subsequently decline markedly at the end of the zone. Tree and shrub pollen includes *Betula* (<5%), *Quercus* (<10%) and *Corylus avellana* type (to 15% at 84cm). Dwarf shrubs include *Calluna* (to 5%). Poaceae are present at values of c. 20% at 84cm increasing to *c.* 30% by the end of the zone. Other herb pollen taxa include occasional Brassicaceae, Chenopodiaceae (top of zone), *Potentilla* type, *Rumex Cirsium* and Lactucoideae. Cyperaceae (sedge) is present to a maximum of 20% at 84cm with occasional *Typha latifolia* and *Typha angustifolia/Sparganium* type. Ferns comprise significant *Dryopteris* (to 40%) with some *Pteridium aquilinum* (6%) and occasional *Osmunda regalis*.

Table 3: Pollen zonation of Dunwich Core 4.

Dunwich

Core 4



Dunwich Cont.

Core 4

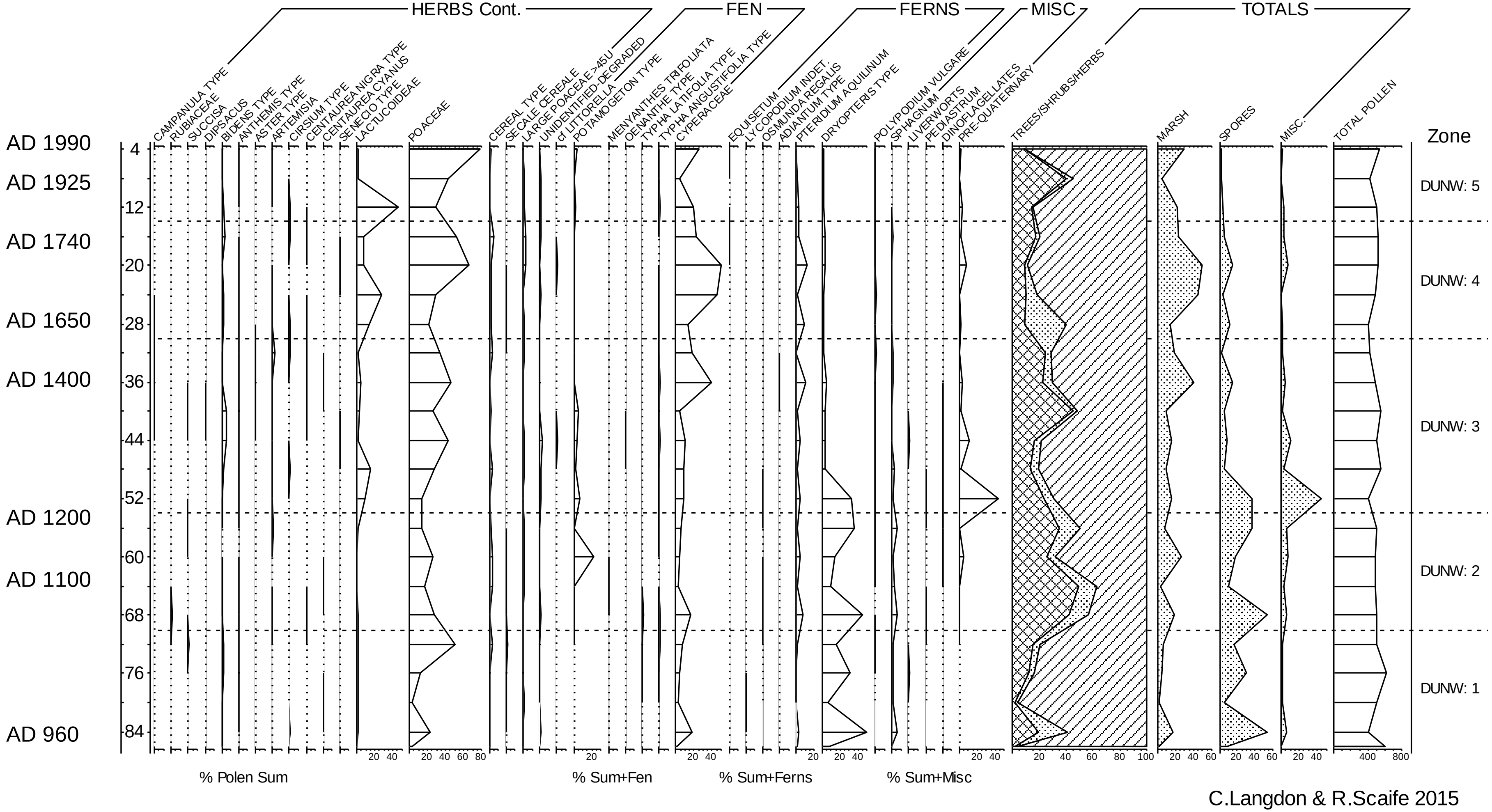


Figure 11: Pollen diagram for the Dun-Core 4 showing vegetation changes associated with environmental transitions from terrestrial *Cannabis* rich peat, through saltmarsh and tidal mudflats into reed swamp and grazing pasture at the top of the core. The chronology of the core profile is provided by 2 Radiocarbon dates, DUN84 and DUN 64, and the rise of Pine and Spruce pollen towards the top of the core that provide a chronomarker of c. AD 1700 onwards. The top of the core at 0cm is live vegetation and dates to the current century. The date at 1850AD is based on an SCP profile from Rollo (2012) constructed from a core located close to Dun6.

5.4.3 The vegetation and environment

Given the historic date/age of the sediment profile, that is spanning the last millennium, it is not surprising that the overall character of the vegetation landscape was one of openness with open agricultural habitats in evidence. There is, however, a background of woodland and tree growth also represented in this otherwise agrarian landscape.

The pollen data can be viewed in terms of the on-site vegetation and other wetland vegetation which was fluvially transported to the site and pollen representing the surrounding area of the site and in some cases from more regional sources. These aspects are discussed.

The on-site vegetation elements: The changing sediment character and overall stratigraphy reflect the environment of deposition and thus, the character of the vegetation and vegetation communities which colonised the site. As a result of the stratigraphical variations, the taphonomy is complex.

The site of Core 4 proved interesting having a basal, peat/organic unit (c. 0.60cm to the base at 0.8m. Such basal units tend to be of late middle to late Bronze Age date throughout southern and Eastern England and developed in response to rising sea level and subsequent transgression. Here, however, the organic unit is of historic date (385-1150AD 95% extremes) and appears to have been a pond which was subsequently inundated sometime after c.1050AD. As described below, this wet depression was also interesting proving to have been a hemp (*Cannabis sativa*) processing (retting) site. This was substantiated by the presence of *Cannabis* achenes in these levels (see below). Pollen (l.p.a.z. DUN4: 1) indicates that this depression or pond supported a grass-sedge fen. There is surprisingly little evidence of freshwater aquatic macrophytes and this may be due to polluted water through hemp processing. Occasional cysts of freshwater *Pediastrum* were however, recorded in this basal pollen zone.

At 0.64m (Date c.1100AD) there was a significant change of environment with change to minerogenic sediment with a horizon of reworked, transitional peat and sediment. The peat containing elements of pollen from l.p.a.z. 1 (mainly *Cannabis sativa*). This was clearly a brackish or marine transgressive event which resulted in the formation of salt marsh and mud flat on and nearby the site. L.p.a.z DUN4: 2-3 contain much palynological evidence for such habitats with strong representation of halophytes which include especially, Chenopodiaceae (goosefoot, orache and samphire), *Spergula* (spurrey), *Armeria* (thrift and/or sea lavender), *Plantago maritima* (sea-plantain) and *Potamogeton* type. The latter taxon includes both pond weed and sea arrow grass and it is the latter which was probably part of the halophytic/salt marsh habitat. With this transgression, the change to mineral sediment also demonstrates the erosion and transport of earlier sediment containing geological palynomorphs. High values of these at c. 0.52m indicate that the site was mud flat at this time. During this zone/phase, deposition was stable with the accretion of blue-grey sediment of typical salt marsh origin.

Towards the top of l.p.a.z. DUN4: 3, there is evidence of declining importance of salt marsh and a recursion to a more freshwater habitat. From c.0.44m, sedge pollen (Cyperaceae) start to become important replacing the Chenopodiaceae and *Potamogeton/Triglochin* pollen which otherwise characterise this zone. Increases of Lactucoideae (dandelion types from the dry-land zone) and the on-site sedges characterise l.p.a.z. 4 which shows a change to a more freshwater fen with sedges and other reed swamp elements (bulrush) or a flood plain habitat. Stratigraphically, this was also a phase of less stability with alternating peat, humic silt and sand lenses. The latter may be associated with flood events.

A preliminary investigation of the diatoms showed their absence throughout most of the profile. A series of 13 samples was examined and only at c.30cm were frustules found. The assemblage was almost wholly *Diploneis* cf *didyma* which is characteristic of salt marsh and it is probable that these diatoms were the product of nearby remaining salt marsh and/or ephemeral incursions of brackish water carrying halophytic taxa. Examination of diatoms in other core profiles from the same region also showed poor preservation or absence of diatom assemblages. Post depositional, unsatisfactory preserving conditions are clearly to blame for their absence, probably though alkalinity and the solution or abrasion of diatom frustules in the minerogenic sediment.

The dry-land, terrestrial zone: The most interesting and important aspect of this profile is the dominance of hemp (*Cannabis sativa*) pollen in the basal organic sediment of l.p.a.z. DUN4: 1. Such high pollen values are rare and only occur where cultivation and processing has taken place or from specific circumstances where pollen analysis has been carried out on rope/cordage or from ships caulking (Scaife 2005). Here, it appears that this site from which this core was obtained was used for retting to obtain fibre for rope making. This is not unprecedented in East Anglia being discussed by Godwin (1967a, 1967b) and subsequently by Bradshaw *et al*. 1982. Traditionally, hemp crop was left in ponds and wet ditches for some weeks or months adjacent to places of cultivation to separate the bast fibres. This was clearly the case at this site. This would have been especially important for rope production in Dunwich and most probably for maritime use. Palynologically, the pollen is indeterminable from hop pollen (*Humulus lupulus*) in sub-fossil state; the morphology is similar due to close botanical relationship. Here, achenes (seeds) of hemp were also found and radiocarbon dated (Table 1, Appendix 1.0). Hemp was an especially important crop to the extent that edicts especially by Henry VIII to ensure fibre for rope making to support the English fleets. Thus, it is clear that fields adjacent to this sample site were used for cultivation at this time (AD 970-1100) and the adjacent wetland used for retting of fibre. This was the non-toxic variety!

The substantial numbers of pollen mask the background and more regional vegetation components. However, during this phase and in the overlying zones/levels the pollen data show a typical late historic environment. That is, mixed arable and pasture and some retained woodland. Oak and hazel were the principal woodland components (as in L.P.A.Z. DUN4: 2) and this probably represents remaining managed, coppice with standards, woodland also of use for shipbuilding and other more domestic uses (building timbers, hurdles and wattle). Small pollen numbers of ash (*Fraxinus*), lime/linden (*Tilia*), holly (*Ilex*) and beech (*Fagus*) are from occasional local growth. These taxa are markedly under represented in pollen spectra (Andersen 1970, 1973). There is a single record of walnut (*Juglans regia*) occurring in l.p.a.z. DUN4: 3. which attests to a post Roman date for this introduced tree.

Agriculture: Apart from the hemp cultivation discussed, the herb pollen spectra show predominantly pasture with some cereal elements. The latter are, however, less well represented than the former in pollen assemblages unless cultivation is in very close proximity to the sample site. Grass pollen is dominant throughout and although a proportion of this pollen will have derived from the on-site vegetation, along with ribwort plantain (*Plantago lanceolata*) and other herb overall, this suggests stronger pastoral land use in the nearby region.

Pine pollen is present throughout the profile. In l.p.a.z. DUN4: 3, this may be attributed to the typical over representation in fluvial, especially marine sediment due to the buoyancy of the saccate pollen. However, in l.p.a.z. DUN4: 5, there is a significant increase of pine and also the presence of spruce. The latter is non-native and along with pine these represent plantation. The pine rise from c. AD 1700 is seen in many pollen diagrams of the recent historic period (Long *et al.* 1999) and is attributed initially to planting of exotic conifers in parks and gardens after popularity resulting from John Evelyn's treatise *Sylva.* Subsequently, pine also increases in importance from forestry plantation and this may be the case here from AD 1920. The pollen is anemophilous and is of more regional rather than local origin.

5.5 Sand Grains and Storms

Within the literature it has been well acknowledged that an analysis of the sediment, especially particle size, can give an indication of storm events. This has frequently been used to identify past hurricanes on the American coast (Bierman et al, 2010; Bland et al 1989; Bryan et al., 2001; Fearn and Liu, 1993; Fearn and Liu 2000; Niering and Warren, 1993). A particle size analysis

is useful as mean grain size and sorting are hydraulically controlled, this can be positively correlated with the energy of the environment. Therefore, sand grain analysis can be used to identify storm events (Bellucci et al., 2011; Dawson et al., 2004), because between storm events there is a slower deposition of sediments than during flood events. During flood events coarse grained particles are deposited at a faster rate forming a layer of coarser sediment (Bakker et al., 2011; Bierman et al., 2010). Coastal back barrier marches such as those at Dunwich are a low energy environment that allows high energy deposits to be well preserved within the stratigraphy record (Birch et al., 2010;Bland et al., 1989). Since storms are the major forcing along barrier coasts (Andrade et al., 2004) and because during storms wave activity erodes sediment from the overwashed beach and deposits it in the form of an overwash fan, this sediment will spread out to form a sand layer on top of the finer sediment, preserving a record of those events in the march sediments (Bryan et al., 2001; Fearn and Liu, 1993). Transport of sediment to a point in a coastal marsh will also depend on the effectiveness of any barriers – thus at Dunwich, coarse sediment delivery to the core site will be controlled not only by height of the tide+waves, but also by the elevation of the gravel barrier.
Transport of sands, silts and clays into the marsh at Dunwich occurs though processes of gravel barrier breaching and overwash. Coarser silts and sands are deposited rapidly once the breach is made and often create fans akin to deltas since the breaching also results in development of back marsh flooding. Finer sediments (silts and clays), are transported further back into the marsh owing to their transport in suspension. An additional factor at the Dunwich site will be the distance of the gravel barrier from the core site. Sear et al., (2012) document the progressive erosion of the coastline at the Dunwich site, which has the effect of bringing the core site (DUN4) closer to the gravel barrier/coastline. We can develop a conceptual model for the site, whereby progressive roll back of the gravel barrier over the past 800 years (See Pye and Blott (2009), produces a slow increase in grainsize deposited at the site. Measurement of overwash fans at the Dunwich site and other similar barriers, show that coarse sediments (sands) can extend up to 350m into the marsh; finer suspended sediments extend much further, although there is little published on this process.

Figure 8a, shows that the core site was also protected by two hills (Cock and Hen hills) although the ground between them was lower (Sear et al., 2011). Gardner's (1753) account describes the damage created by this storm:

"………The sea raged with such fury that Cock and Hen hills which the preceding summer were upwards of 40ft high had their heads levelled with their basis, and the ground all about them rent and torn, that the foundations of St Francis chapel which had lain between the hills and the secret repositories of the dead were exposed to open view, several skeletons on the ouze, divested of their coverings, some keeping in pretty good order, others scattered as the surges carried them".

Physically this has two important impacts; first the protection of the core site afforded by this higher land is removed, so that subsequent storms are likely to have been overwashing the area seaward of the core site on a more frequent basis. Secondly, the supply of sandy and finer sediments resulting from the destruction of the hills will have resulted in higher sedimentation rates in the back marsh area. Similarly, it is likely that the old quay, St Francis chapel site and Cock and Hen hills were an area of redundant land, with secondary heath cover. This is likely to explain the presence of heather pollen and fragments in the 1740 storm sediments identified in the core.

Sand grain analysis was undertaken at 1cm intervals down the core to the interface of the organic deposit at 64cm (DUN 1/2 transition). Two methods of particle size analysis were undertaken; standard particle size analysis using a SATURN-2 laser granulometer to give quantitative measures of all particle sizes in a sample, and secondly a sand count based on methods developed by Bjorck et al (2006).

The core was prepared appropriately by taking the outer layer off so that any contamination from bringing the core up was removed. The following steps were then taken to analyse the core:

1. The core was divided in to 1cm square sections.

2. The sections were dried in the oven just below 1500C. Their weights both before and after were taken.

3. Each samples was wet sieved with distilled water through a 63μ sieve.

4. The material left in the sieve was dried below 1500C and then weighed.

5. Dry sieved samples through a 150μ sieve. Both sizes of sample were weighed.

6. The sediment left above 150μ was placed in a slide and using a microscope the amount of sand grains for each 1cm section was counted.

Particle size analysis was undertaken a Coulter LS 13 320 Single-Wavelength Laser Diffraction Particle Size Analyzer, which determines the dimensions of individual particles 0.375-2000μm. Samples were digested in Hydrogen Peroxide (H_2O_2) to remove the organic component, dispersed and sonicated in Calgon ($Na_6O_{18}P_6$). Results are the averaged of three repeats to minimise intra-sample noise. Particle size frequency statistics were calculated using the geometric formulae of Folk and Ward (1957) with the GRADISTAT 8.0 software (Blott and Pye, 2001).

To account for the change in proximity to the coast, we derived an adjustment factor based on the visible trend in decreasing clay content recorded in the marsh sediments. Our hypothesis is that the decline in finer clay content o the marsh sediments at the site reflects the increasing energy of the events depositing the sediments. This occurs due to the increasing proximity to the coastline and overwash, and the progressive decline in lower energy deposition from fluvial events as the Blyth and Dunwich river mouth shifts north. Figure XX shows the age:depth model for the core and the curve fitted through the slay data using a LOESS smoother. This curve was used to weight the percentage sand and sand grain counts – such that earlier events were increased and more recent events decreased in weight to reflect proximity (over representation) of the barrier and coastline. We refer to these as sand indices.

Figure 12 shows the reconstructed sand indices for DUN4 core. As expected sand deposition increases up the core. In both raw data and weighted results, it is possible to identify discrete sand peaks that correspond with either periods of increased storminess (e.g. late 17th century early 18th century) Figure 13, or with individual storms (e.g. A.D. 1740). The record suggests that the storm of AD1328 which blocked the harbour at Dunwich, is recorded along with a large discrete event in the early – mid 15th century. A period 1540-1575 marks a series of large storms at Dunwich that destroyed St Johns church South and Gilden gates. The record picks out two periods of increased storm activity also reported independently from wind blown sands in Swedish peat bogs (Bjork et al 2006) and in the records of ships logbooks (Wheeler 2010). This phase (1680-1745) corresponds with a known increase in cold temperatures and storminess within the Little Ice Age (Trouet et al., 2012). At Dunwich this period saw accelerated cliff erosion with the loss of St Peter's church (1688-1703) the Gaol (1715) and the Town hall (1716). The later phase of increased sand deposition in the early 19th century and a smaller phase in the late 19th century are also well documented at Dunwich. In the late 19th century rapid cliff erosion is recorded and captured in a series of iconic photographs charting the demise of All Saints church.

Whilst no clear climatic trends are apparent, the storm dates and erosion dates reported at Dunwich 70% are associated with positive phase winter NAOi – a climate state that is associated with northerly tracking low pressure cyclonic weather patterns that generate N - NE winds in the North Sea, and higher waves at Dunwich (Trouet et al 2012, Sear et al 2012, Pye and Blott 2009).

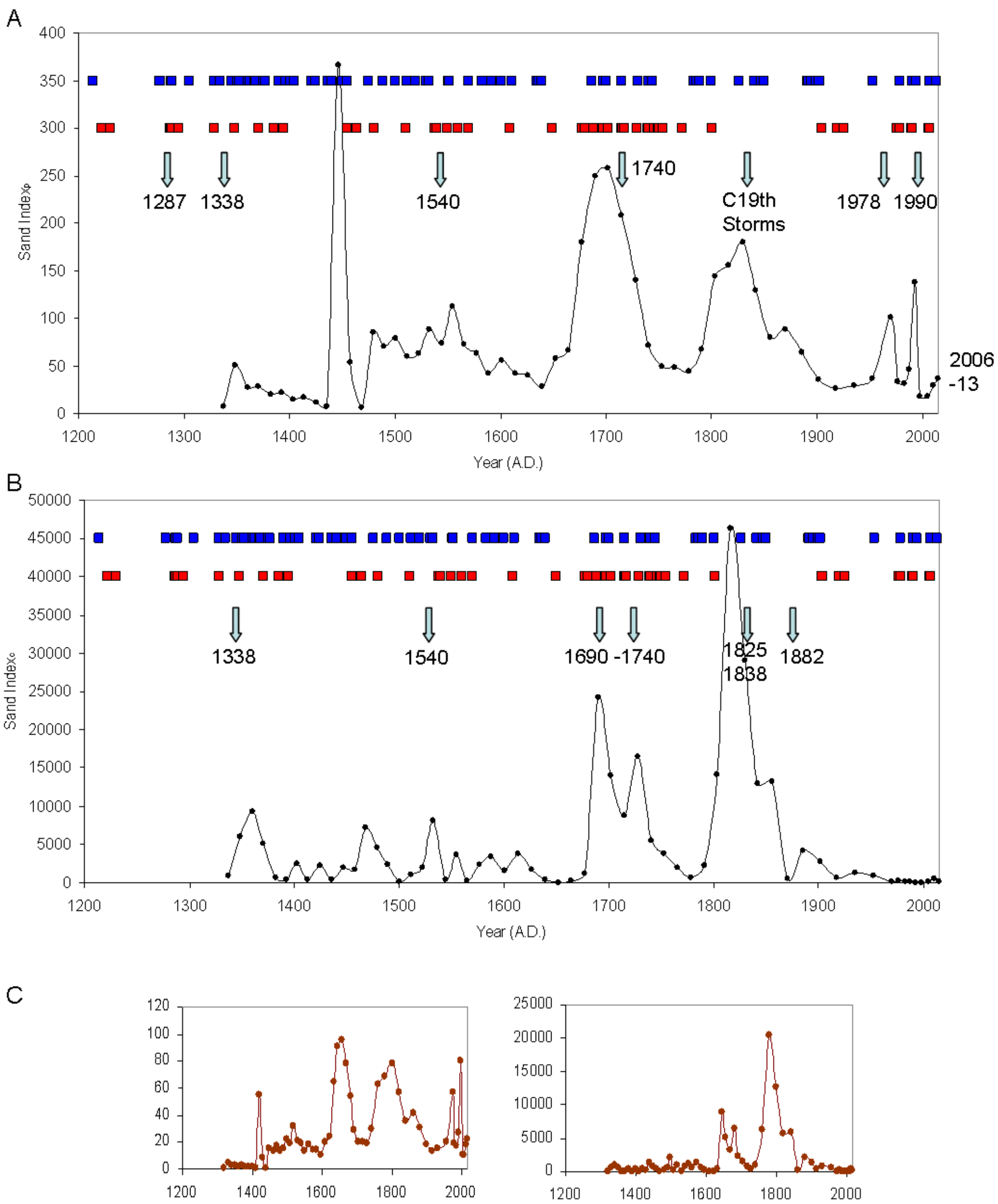


Figure 12: A) Shows the percentage of sand in marsh sediment layers, weighted for distance from coastline. B) Shows sand grain counts per cm weighted or distance from coast. The two bottom figures (C) show the raw data, (sand count on right). Blue squares are documented east coast floods and red squares are documented cliff erosion events at Dunwich. Our analysis starts after the storms of the 13th century but both records capture what is likely to be the storm of 1328, a series of large storms or periods of storminess in the 17th – 18th century and again in the 19th century. More recent storms are also present, although the 1953 event was not so large at Dunwich.

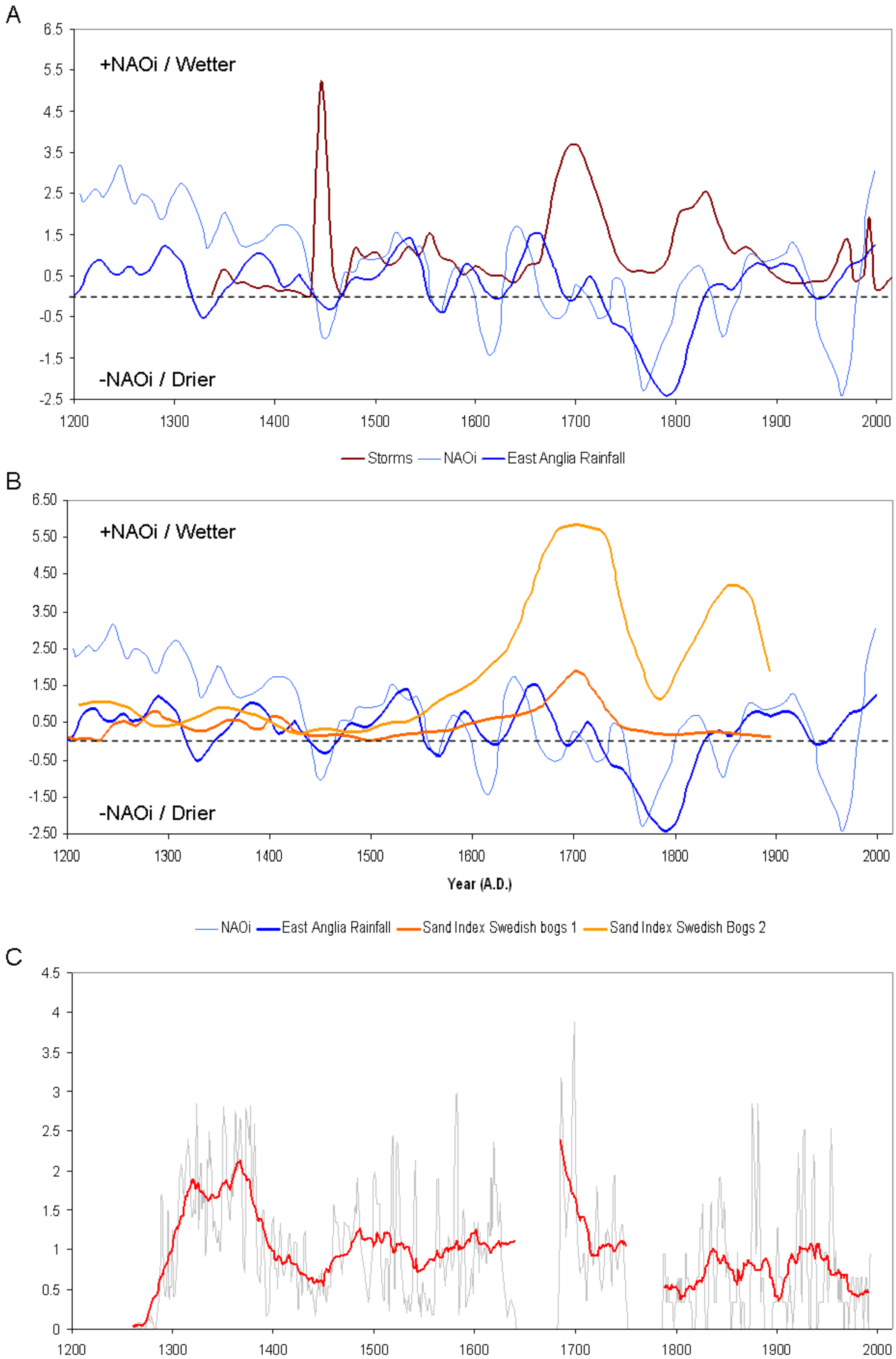


Figure 13: Dunwich sand record compared to a range of climate proxy data. A) illustrates the relationship between NAOI winter North Atlantic Oscillation Index (Trouet et al., 2009), and Precipitation reconstructed from Tree rings for East Anglia (Cooper et al., 2013). B) Shows how wind blown sand recorded in Swedish west coast peat bogs match the storm sands in the Dunwich marsh record. C) is a composite figure of storminess indices based on damage to coastal infrastructure (pre 1700 Galloway 2013, DeKraker 2004), gales recorded from ships logs (1680-1750 Wheeler et al., 2010) and gale records for the UK (Zhong &

Tooley 2003). Phases of storminess in the Southern North Sea correspond to some of the storms recorded in the Dunwich core.

5.6 Summary

Marsh sediments contain a record spanning the full history of Dunwich. Our research has demonstrated that these sediments can be used to reconstruct regional and local changes in land cover, and from these infer periods of environmental change and potentially industry within the immediate vicinity. Moreover, the presence of distinct higher energy sediment layers of silt and sands demonstrate that it is possible to identify periods of enhanced storminess and individual storms resulting in overwash of the gravel barrier. The analysis of core Dun4, is nationally of interest as it contains evidence of only the third UK example of a retting pit for the production of hemp fibres used in rope and sail making. The association with a major international port makes this highly likely. The period of retting appears to continue from early Saxon to early medieval, before a major marine transgression, perhaps associated with storm action around the 12th-14th century, resulted in a change to salt marsh and mudflat environments at the site. This phase of estuarine habitat continued until c.1650, when freshwater marsh again occupied the site – which is shown on the AD 1754 sketch in Gardner (1754). This phase was interrupted by a period of episodic higher energy deposition (silt-clay laminations), culminating in a major event recorded as a sandy-silt layer. This layer is also seen in the Core sample recovered by Rollo (2012) some 20m north of Dun4. Preliminary evaluation strongly points towards the phase of increased storminess 1680-1740 culminating in the storm event of AD 1740, which Gardner (1754), records as washing across the adjacent land seaward of the core, stripping the soil and vegetation, and depositing it landward. The presence of *Calluna* and other heath pollen may represent this stripped soil and vegetation.

The environment at the core site stabilised, and returns to freshwater peat representative of the current reed beds and grazing marsh. This accords with Gardner's (1754) sketch, which shows the site to be dominated by reed beds and small pools of open (fresh-brackish?) water. Further phases of storminess are recorded during this latter period – in the early and later 19th Century, and again in the late 1970's and early 1990's. Recent storms (2006, 2013) arenot evident as discrete sand layers although the proportion of and in surface sediments is increasing.

5.7 Further Research

The environmental history recorded in the marsh sediments and dating of the prod and Pales Dyke has provided fresh evidence for the presence of a Saxon port, and have independently confirmed the sequences of storms recorded in the historical record. Furthermore, the cores are continuous and coherent, offering the best available evidence for environmental change at the site during the development and decline of the town. Additional analysis should focus on the following;

(1) Replicate core analysis from a site with higher rates of sediment accumulation that would permit higher resolution analysis of changes in the marsh environment.
(2) Further analysis of marine microfossils (foraminifera / dinoflagellate cysts) in the Dun-core4 record to quantify changes in freshwater-marine-freshwater.

6.0 Conclusion

The research reported supports several conclusions;

- The sediment deposits in and adjacent to Dunwich provide a valuable additional source of historical evidence that shed light on the industry, environmental change and chronology of the site.

- Additional research effort should be targeted at the road and Pales Dyke before those features WITHIN the town boundary are lost to the sea, which Sear et al (2012) project will occur within 50-80 years.

- The dates obtained for this project strongly point towards an early (Saxon) settlement, with evidence that the Pales Dyke ditch may have had earlier origins in the Middle Iron Age. The existence of a retting pit with materials dating from the 5th – 11th century, a road dated to the 7th century all support the presence of a large port at Dunwich in the Saxon period.

- The pollen data show a typical late historic environment. That is, mixed arable and pasture and some retained woodland with oak and hazel as the principal woodland components.

- Marsh sediments have been shown to provide a history of environmental change that reveals incursion by the sea into the area of retting after c. AD 1100-1250, and transition back to freshwater reed marsh around AD 1600-1650. There is evidence of storm activity throughout the core with phases of increased storminess in the early 14th-15th Century, the early 18th Century (including strong evidence for the AD 1740 storm), early 19th and late19th century storms and more recent events (1978, 1990). The transition from freshwater retting pit to marine saltmarsh and estuary mud is rapid and possibly results from storms breaching a gravel barrier/spit. The transition to freshwater marsh is more gradual, punctuated by a short marine incursion before storm events overwash the area and freshwater conditions dominate thereafter.

- We have achieved the two main aims of the project although limited additional analysis is required to fully understand the environmental archive in the marsh core.

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Appendix 1.0: Cliff Section Stratigraphy (see Figures 5-7).

SITE	Dunwich
CLIENT	Touching The Tide Project
CONTACT	Bill Jenman
FIELD STAFF	Professor David Sear, Dr Hal Voepel
LOCATION	Site 1: St James Street Cliff Exposure
POSITION	TM47804 71037
ALTITUDE	16m
SITE TYPE	Exposed section through cliffs
PURPOSE	Collection of material for dating bottom/construction of feature
STRATIGRAPHY	Depths below ground surface in centre of St James St exposure
1L1	152 cm - Light Brown soil , Sa/Si <60% rounded pebbles
1L2	160 cm - Brown soil Sa/Pebbles <40% rounded pebbles
1L3	161 cm - Dark Orange/Black Sand
1L4	173 cm - Orange yellow sandy gravel, <30% rounded pebbles
1L5	173+ cm -Yellow/Orange Sand Natural Geology

SITE	Dunwich
CLIENT	Touching The Tide Project
CONTACT	Bill Jenman
FIELD STAFF	Professor David Sear, Dr Hal Voepel
LOCATION	Site 2: Pales Dyke Cliff Exposure
POSITION	TM47743 70702
ALTITUDE	27m
SITE TYPE	Exposed section through cliffs
PURPOSE	Collection of material for dating bottom/construction of feature
STRATIGRAPHY	Depth below ground surface in Pales Dyke
2L1	395 cm - Brown sandy soil few stones
1L2	403 cm - Dark organic rich sand layer
2L3	410 cm - Yellow grange sand with large gravels - rounded
2L4	430 cm - Indurated orange sandy gravel. Gravels rounded.

SITE	Dunwich
CLIENT	Touching The Tide Project
CONTACT	Bill Jenman
FIELD STAFF	Professor David Sear, Dr Hal Voepel
LOCATION	Site 3: Duck/King Street Cliff Exposure
POSITION	TM47778 70947
ALTITUDE	29m
SITE TYPE	Exposed section through cliffs
PURPOSE	Collection of material for dating bottom/construction of feature
STRATIGRAPHY	Depth below ground surface centre of King/Duck St
3L1	87 cm - Brown sandy soil with isolated <5% flints - sub-rounded
3L2	96 cm - Dark organic black sand
3L3	99 cm - Light brown andy silt with dark organic/burnt patches
3L4	103 cm - Grey/brown compacted clay/silt, no gravels
3L5	110 cm - Yellow orange sandy clay (natural geology?)
3L6	110+cm - Yellow sand (natural geology) no gravels

Dunwich 2015 Pales Dyke Re-sample

SITE	Dunwich
CLIENT	Touching The Tide Project
CONTACT	Bill Jenman
FIELD STAFF	Professor David Sear, Mr John Prior, Mr Sam Hill
LOCATION	Site 2: Pales Dyke Cliff Exposure
POSITION	TM47743 70702
ALTITUDE	27m
SITE TYPE	Exposed section through cliffs
PURPOSE	Collection of material for dating bottom/construction of feature
STRATIGRAPHY	Depth below ground surface in Pales Dyke
Site 2	**Deposit**
0-30	Sandy-silt organic stained soil with some small flints
30-80	Building rubble including tiles, mortar and large flints
80-330	Sandy humic rich soil with distributed matrix supported small-medium gravels
330	Bottom of ditch fill (sample taken for 14C analysis)
330-470	Yellow-orange matrix supported gravels
470-480	Orange-yellow matrix supported small gravels
480-530	Orange framework supoprted gravels. Insitu leaf fragments at 490cm
530+	Orange-yellow sands