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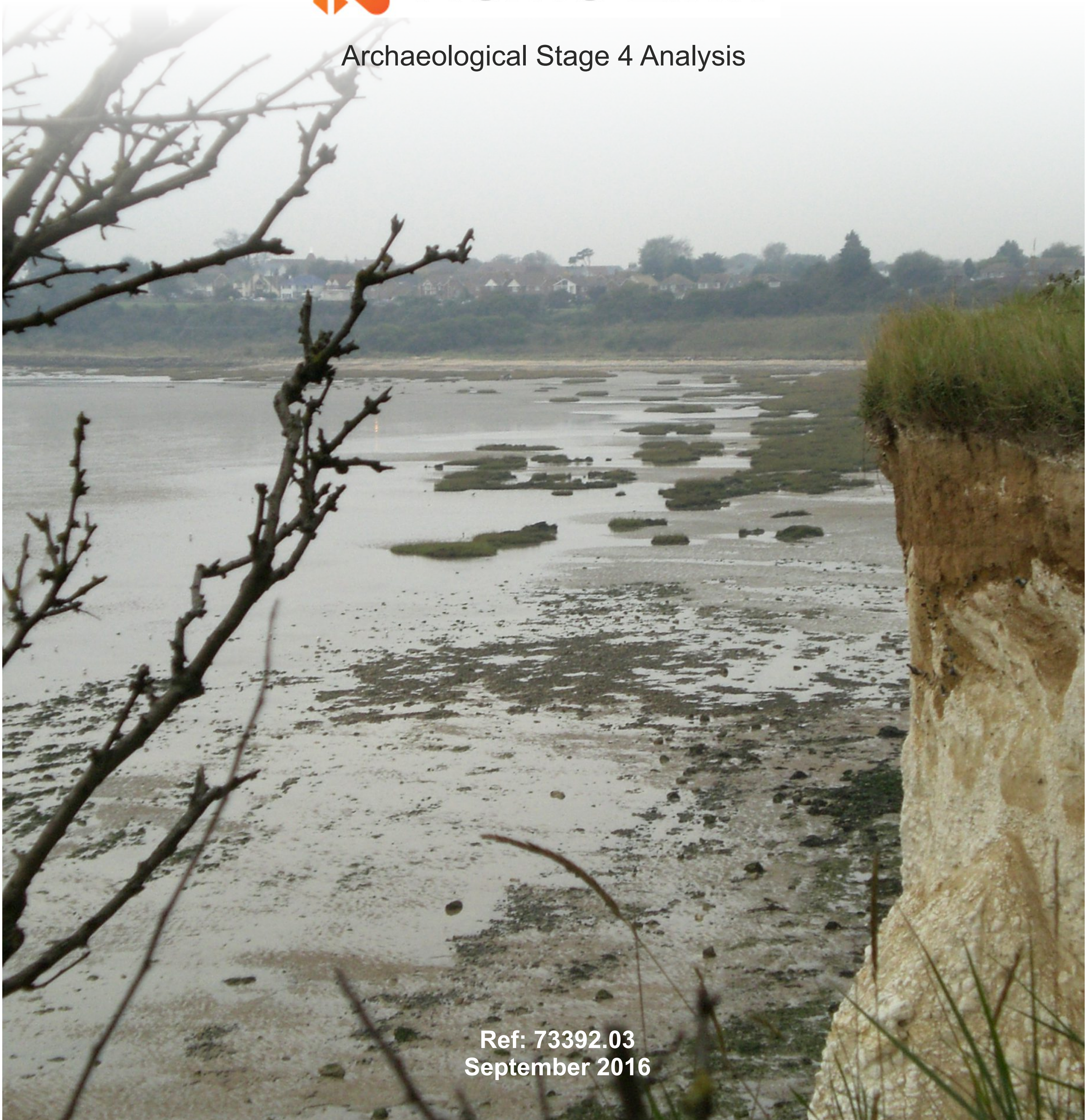
Nemo Link®

Archaeological Stage 4 Analysis



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geoservices

Archaeological Stage 4 analysis

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Nemo Link

Archaeological Stage 4 analysis

Contents

Figures

Nemo Link

Archaeological Stage 4 analysis

1.1 Summary

A programme of archaeological analysis has been undertaken upon a series of samples from vibrocore, **VC7,** collected during offshore cable route survey works undertaken by the Nemo Link project in 2010. This vibrocore is located *c*.12km east of Ramsgate along the route of the Nemo Link UK-Belgium Electrical Interconnector on the margins of a palaeochannel feature which was identified from geophysical data. The vibrocore has undergone archaeological Stage 4 analysis at the request of English Heritage as it contained prehistoric terrestrial deposits which had the potential to provide palaeoenvironmental information of archaeological interest that would significantly add to the archaeological record.

This Stage 4 analysis of the recovered core material was undertaken following Stages 1 to 3. Stage 1 comprised a review of geotechnical core logs to select suitable samples for further work. Stage 2 comprised detailed geoarchaeological recording of the vibrocore samples and identification of suitable samples for Stage 3 work. The Stage 3 assessment focussed on vibrocore **VC7** the purpose of which was to evaluate the potential of the sediments within that vibrocore to contribute to archaeological knowledge and to identify further analytical study. The Stage 3 assessment included radiocarbon dating and assessment of the sediments for floral (charcoal, pollen and diatoms) and faunal (insects, molluscs, ostracods and foraminifera) remains. The Stage 4 analysis has involved the full analysis of the sediments for remains of archaeological interest including pollen, microcharcoal, molluscs and ostracods as agreed with English Heritage via email and telephone conversations.

The results of the Stage 4 palaeoenvironmental analyses show successive environments including an early Holocene freshwater channel and freshwater pool within a wooded river valley that has become progressively vegetated. This Boreal woodland comprised predominantly pine and hazel typical of the Early Mesolithic period. The increasing amounts of vegetation has led to peat formation, with the two radiocarbon dates from the peat deposit indicating that this terrestrial environment dates from around *c*.10,000 years ago, equivalent the early Mesolithic archaeological period, a period of known human occupation on both sides of the North Sea where people were following a predominantly hunter gatherer lifestyle. Potential evidence of human activity in the form of charcoal which may have formed as a result of forest clearance by burning and/or the use of wood for fuel has been recovered from the sediments. Based on the analysis of microcharcoal within the sediments, it is not possible to discriminate between charcoal formed through natural process or anthropogenic activity in this instance. The well preserved remains of pollen, ostracods, molluscs and foraminifera are considered to be highly significant in the understanding of this early Mesolithic environment. This peat deposit has been truncated by sea level rise with subsequent deposition evident of outer estuarine and shallow marine environments in the late Mesolithic period.

The unique offshore location of this detailed sequence of deposits, from a previously unknown palaeovalley, make this analysis of great interest to both archaeologists and Quaternary geologists alike. The results will be published in a suitable journal (*Archaeologia Cantiana*).

Nemo Link

Archaeological Stage 4 analysis

1.2 Acknowledgements

Wessex Archaeology is grateful to PMSS for commissioning the sample assessment on behalf of National Grid Nemo Link Ltd. (NGNLL). Wessex Archaeology would like to thank Rachel McCall of PMSS for her help and support in undertaking the project.

The palaeoenvironmental sample analyses were carried out by Robert Scaife, Jack Russell, Chris Stevens and Sarah Wyles. The radiocarbon dating was undertaken at the Scottish Universities Environmental Research Centre (SUERC), East Kilbride under the supervision of Gordon Cook.

This report was written by Jack Russell and figures were produced by Kitty Foster. The project was managed for Wessex Archaeology by Jack Russell.

Nemo Link

Archaeological Stage 4 analysis

2 INTRODUCTION

2.1.1 Wessex Archaeology (WA) was commissioned by National Grid Nemo Link Ltd. (NGNLL) via TUV SUD PMSS to undertake Stage 4 archaeological analysis of samples taken from vibrocore **VC7** (**Figure 1**), recovered during a programme of geotechnical investigations on the route of the proposed Nemo Link, UK-Belgium Electrical Interconnector. The Nemo Link electrical interconnector cable will extend approximately 130km between Pegwell Bay in Kent to West-Zeebrugge in Belgium. The Nemo Link will comprise subsea and underground cables connected to a converter substation in each country. The stages and level of analysis have been undertaken in line with relevant industry guidance (Gribble and Leather 2011) and consultation with English Heritage and the Marine Management Organisation.

2.1.2 Prior to this Stage 4 work, Stages 1 to 3 comprised a review of core data which included a Stage 1 review of on-board sampling geotechnical vibrocore logs. 10 additional vibrocores were collected for Stage 2 recording which was undertaken at Wessex Archaeology during 2010 (Wessex Archaeology 2011a). As a result of the Stage 2 work vibrocore **VC7** was selected for this Stage 3 archaeological assessment as it contained deposits that were thought to relate to former, now submerged terrestrial environments. The presence of peat within the vibrocore highlighted the time when this area was dry land and suitable for human occupation, and its survival suggested high potential for the survival of other archaeological material. The deposits were thought to have the potential to contain both *in situ* and derived archaeological material, alongside preserved organic remains of potential importance to the palaeoenvironmental record (Wessex Archaeology 2011b).

2.1.3 The Stage 3 assessment work comprised the evaluation of the sediments within vibrocore **VC7** regarding their potential to contribute to archaeological knowledge and to identify areas for further analytical study. The Stage 3 assessment included radiocarbon dating and assessment of the sediments for floral (charcoal, pollen and diatoms) and faunal (insects, molluscs, ostracods and foraminifera) remains. The results of the Stage 3 assessment indicated the well preserved remains of pollen, ostracods, molluscs and foraminifera within terrestrial and freshwater and shallow marine sediments, with waterlogged plant remains taken from freshwater peat radiocarbon dated to the early Mesolithic period. (Wessex Archaeology 2011b).

2.1.4 The Stage 4 analysis has involved the full analysis of the sediments for remains of archaeological interest including pollen, microcharcoal, molluscs, foraminifera and ostracods as agreed with English Heritage via email and telephone conversations. The scope of work was set out in a letter dated 28th November 2013 (ref: SE/Cable). It was agreed that the radiocarbon dating undertaken at Stage 3 was robust and no further scientific dating was required.

2.1.5 Vibrocore **VC7** is located *c*.12km east of Ramsgate within a palaeovalley feature identified within the geophysical survey work (Wessex Archaeology 2011a). The corrected water depth below Lowest Astronomical Tide recorded on the vibrocore log was 26.2m below LAT. This depth has been converted to 28.78m below OD using the published figure of Chart Datum being 2.58 metres below Ordnance Datum (m below OD) at the port of Ramsgate (Admiralty Chart 1828). The location of the vibrocore is shown on **Figure 1** and in the table below.

Vibrocore	**WGS84 UTM Zone 31N**		**Depth**	
	Easting	Northing	mbLAT	mbOD
VC7	404296	5686691	26.2	28.78

3 BACKGROUND

3.1 Archaeological Work and Stages

3.1.1 The Desk Based Assessment (DBA) for the Nemo Link Project was conducted in support of the environmental impact assessment and presented a detailed archaeological assessment of the scheme area (Wessex Archaeology 2011a) and is not repeated here. The DBA also detailed the results of the Stage 1 review of geotechnical data and a Stage 2 recording of 10 vibrocores which was used in conjunction with the geophysical data to assess the potential for prehistoric archaeological and palaeoenvironmental material within sediments along the proposed route. The results of the Stage 2 recording gave rise to a series of recommendations for further Stage 3 palaeoenvironmental assessment which was conductedduring 2011. The results of the Stage 3 assessment are contained within an Archaeological Stage 3 Assessment report (WA 2011b). The stages of archaeological mitigation are detailed below.

- Stage 1: archaeological assessment of geotechnical logs – a review of all the vibrocore fieldwork logs (102) upon completion of the geotechnical ground investigation. Of these, ten were positioned specifically to assess sediments identified as having archaeological potential. The sediments described within the vibrocores were then correlated to the sedimentary units observed within the geophysical data;

- Stage 2: archaeological recording of available vibrocores (10) – detailed description of the sediments contained within the cores; identification of sediments with archaeological potential; interpretation of sedimentary descriptions to place them within a stratigraphic framework. The sediments described within the vibrocores were then assigned to sedimentary units based on the observed sedimentary characteristics and compared with the sub-bottom profiler geophysical survey data;

- Stage 3: subsampling, scientific dating and assessment of vibrocore **VC7**. This comprised two radiocarbon dating samples; assessment for presence of floral (charcoal, pollen and diatoms) and faunal (insects, molluscs, ostracods and foraminifera) remains.

- Stage 4: the current stage including the analyses of pollen, microcharcoal, foraminifera, ostracods and molluscs. These analyses include detailed taxonomic identification, relative abundances and identification of taphonomic processes to place into palaeoenvironmental and archaeological context the significance of the recovered faunal and floral remains.

- Stage 5: publication and dissemination of the results.

3.2 Geology and Geoarchaeology

3.2.1 The broad geological sequence across the entire Nemo Link route from Pegwell Bay in Kent to the West-Zeebrugge in Belgium has been interpreted from the scheme geophysical and geotechnical survey data (Wessex Archaeology 2011a) and with reference to the work of the British Geological Survey (Cameron *et al*. 1992). The interpreted geological sequence has been grouped (Wessex Archaeology 2011a) into five units which area summarised in the table below.

Unit	Description
1	Recent (Holocene) seabed sediments, gravelly shelly sand.
2	Post-Devensian terrestrial and estuarine clay, silt and fine sand with organic inclusions and peat layers
3	Eocene clay (**London Clay Formation**)
4	Palaeocene sand and sandy clay (**Thanet Formation**)
5	Campanian (Upper Cretaceous) Chalk

3.2.2 Not all of the sequence described above was present across the entire survey area, with some units being only sporadically present.

3.2.3 **VC7** is located at the eastern edge of a palaeochannel feature (numbered **WA7500** on the multibeam bathymetric data and on the sub-bottom profiler data (Wessex Archaeology 2011a). The palaeochannel is delineated in a northwest to southeast direction and is approximately 250m in width. The channel can be traced for approximately 500 metres, the width of the multibeam bathymetric survey corridor at this location (**Figure 1**).

3.2.4 As the palaeochannel feature is visible on the multibeam bathymetric survey data, this indicates that the upper part of it (*c*.4m in depth) remains unfilled. The sub bottom profiler data indicates that up to 8m of sediment infill exists within the feature at its deepest point. The total depth of the feature (filled and unfilled) is approximately 12 metres.

3.2.5 Although it cannot be traced further than the survey corridor (500 metres), this small section of a palaeochannel feature, is likely to form part of a comparatively minor tributary within the southeastern part of the wider and now submerged drainage system of the Thames basin as described by D'Olier (1972). The chronology of this wider system is complex including multiple cut and fill events relating to Quaternary transgressive and regressive sea level cycles which have been identified onshore (Bridgland 1994) and to a lesser extent offshore (Bridgland 1992; Dix and Sturt 2011). The current hypothesis is that these channel systems may be long lived and potentially predate the Anglian glaciation but have been repeatedly reactivated and so the fill may be of a very different age to the channel's incision (Dix and Sturt 2011). It is therefore not possible to confidently ascribe the incision of palaeochannel **7500** to a particular geological age.

3.2.6 At location **VC7** geoarchaeological recording details a sedimentary sequence comprising Chalk putty (**Unit 5/2**) overlain by channel edge alluvial and peat deposits (**Unit 2**) which are in turn overlain by recent (Holocene) seabed sediments (**Unit 1**). The recorded sediments and their depths below OD within vibrocore **VC7** are shown in **Figure 1** (photographic log) and **Figure 2**.This sequence is summarised below with reference to the unitary interpretation in the table above.

Unit 5/2: Chalk putty (34.80 to 34.68m below OD)

3.2.7 This unit, recorded at the base of the sequence comprised a grey and white chalk mix with occasional flint inclusions. The unit was 0.18m in thickness, although was recorded at the base of the vibrocore and was not fully penetrated. The unit was interpreted as Upper Cretaceous Chalk bedrock which has been periglacially weathered into "Chalk putty" probably during the last glacial period (Marine Isotope Stage 2 (MIS 2)), the Devensian.

Unit 2: Peat and Alluvium (34.68 to 31.19m below OD)

3.2.8 This unit can broadly be split into two subunits. From 34.68 to 34.08m below OD a 0.6m thick sequence of freshwater channel edge and peat deposits was recorded. The alluvial deposits were recorded from 34.68 to 34.48m below OD comprising organic and peaty silts indicative of relatively slow flowing, channel edge alluvial deposition. Above this from 34.38 to 34.08m below OD there was a dark brown peat recorded containing visible remains of reeds (*Phragmites*) and numerous molluscs. The peat was 0.3m in thickness and has been truncated with vertical molluscan burrows frequent upon its surface. These deposits were interpreted as possible early post glacial/ early Holocene alluvium and peat.

3.2.9 These outer estuarine and shallow marine deposits overlying the peat were recorded from 34.08 to 31.19m below OD and comprised a 2.89 m thick sequence of grey silty sands and gravels. This part of the unit was interpreted as indicative of Holocene outer estuarine and shallow marine deposition.

Unit 1: Sand and Gravel (31.19 to 28.78m below OD).

3.2.10 This unit, the uppermost deposit, comprised shelly sand and gravels and was 1.43m in thickness. Frequent marine molluscs were recorded within the sediment. The unit was interpreted as Holocene seabed sediment.

4 METHOD

4.1.1 Subsamples were taken from relevant deposits in order to provide chronological and environmental information taking into account the results of the various assessments undertaken at Stage 3 (Wessex Archaeology 2011b). The positions and depths of the samples are shown on **Figure 2** and within **Appendices 1** to **4** and are in line with what was agreed with English Heritage in correspondence dated 28th November 2013 (ref: SE/Cable) and relevant guidance.(English Heritage 2007and 2011). Bayesian Modelling was also undertaken on the radiocarbon dates suggested in an email from Historic England dated 25th May 2015 (see Results section 4.1.2 and **Appendix 2**).

Pollen and Microcharcoal

4.1.2 Standard techniques for pollen concentration of the sub-fossil pollen and spores were used on these sub-samples of 1.5 ml. volume (Moore and Webb 1978; Moore *et al*. 1992). A total of 500 grains pollen grains per level were counted where preservation allowed. Fern spores and other miscellaneous elements were recorded outside of this sum. Microscopic charcoal of both angular and rounded/spheroidal form was also recorded. A pollen diagram (**Figure 4**) was produced using Tilia and Tilia Graph data plotting software, with percentages for the principal groups calculated as detailed in **Appendix 2**.

4.1.3 Taxonomy followed that of Moore and Webb (1978) modified according to Bennett *et al.* (1994) for pollen types and Stace (1991) for plant descriptions. These procedures were carried out in the Palaeoecology Laboratory of the School of Geography and Environment (PLUS), University of Southampton.

Microfauna (Ostracods and Foraminifera)

4.1.4 Sediment samples of *c*.40ml were disaggregated in a weak solution of Hydrogen Peroxide and water, then wet sieved through a 63µm sieve. The sediment was dried and sieved through 500µm, 250µm, 125µm sieves. Microfossils were picked out under 10-60x magnification and transmitted and incident light using a Vickers binocular microscope. Specimens were extracted and placed in card slides for identification. Identification and environmental interpretation of ostracods followed Athersuch *et al*. (1989) and Meisch (2000) and of foraminifera (Murray 1979; 1991).

Molluscs

4.1.5 The samples of 120 to 250 ml. were processed through flotation through a sieve of 250µm mesh sizes. The apical and diagnostic mollusc fragments samples were extracted from the flots and residues. The recovered shells were identified and quantified using stereo incident light microscopy at magnifications of up to x40 using a Leica MS5 microscope and with reference to modern reference collections where appropriate. The results have been tabulated below Habitat preferences follow those described by Kerney (1999) and Barrett and Yonge (1958).

Artefact sieving

4.1.6 The remaining sediment from vibrocore **VC7** was bagged in 0.1m sections and transferred to the environmental department at WA and wet sieved through a nest of sieves in accordance with standard artefactual recovery procedures. The mesh sizes used were 10mm, 4mm and 1mm). The residues were scanned for archaeological material.

5 RESULTS

5.1.1 The results of the previous assessments of palaeoenvironmental material are summarised below (waterlogged plants, insects and diatoms), where pertinent, and are given in detail in the previous assessment report (Wessex Archaeology 2011b). The radiocarbon dating results are represented in **Appendix 1**. This section details the results of the Stage 4 analyses of pollen, foraminifera, ostracods and molluscs (sample depths shown on **Figure 2**) with full analytical results given in **Appendices 2** to **4**.

Radiocarbon dating

5.1.2 Two samples, identified as suitable plant stems by an archaeobotanist (Dr Chris Stevens) were submitted for radiocarbon dating, from 34.13m and 34.38m below OD (Wessex Archaeology 2011b). The radiocarbon determinations were calibrated using OxCal 4.1.7 (Bronk Ramsey 2001; 2009) and the IntCal09 calibration curve (Reimer *et al.* 2009) and are quoted in the form recommended by Mook (1986) with the end points rounded outward to 10 years The lower sample at 34.38m below OD comprised plant stems and returned a date of 8915±30 SUERC-36006 (8240-7960 cal. BC; 10190 to 9910 cal. BP). The upper sample at 34.13m below OD dating returned a date of 8855±35 SUERC-36005 (8210-7820 cal. BC; 10160 to 9770 cal. BP). These dates are equivalent to the early Holocene geological epoch and the early Mesolithic archaeological period. The probability distribution for the dates is shown in **Appendix 1**. The dates were also Bayesian modelled which showed that whilst the dates are in the correct stratigraphic sequence by age (that is, the older date is lower in the sequence), the results indicate that they *could* be of a broadly similar age. Unfortunately, both dates coincide with a plateau in the calibration curve at 8200 to 7950 cal. BC (see **Appendix 1**), which limits any greater precision in sequencing the dates.

Pollen and microcharcoal

5.1.3 Pollen and spores were recovered from all of the (14) samples processed (for full results see **Appendix 2**). Overall, pollen was not abundant in any of the samples and was particularly sparse in the lower minerogenic humic and basal silt (below *c.* 34.60m below OD) and in the upper alluvial sample (34.06m below OD) overlying the peat. The intercalated peat at 34.43m below OD to 34.08m below OD is extremely humified and detrital. Whilst the substantial numbers of fern spores will have originated from on-site growth, these are resilient and may be over represented through differential preservation. The well-preserved spores have their perine remaining showing that marsh fern (*Thelypteris palustris*) was an important component of the ground flora. Undifferentiated (*Dryopteris* type) spores are likely to be referable to this fern.

5.1.4 Four local pollen assemblage zones (***l.p.a.z.***) were identified predominantly by their dominant tree pollen taxa, delimiting the principal palynological changes found in this profile. These pollen zones are summarised in the table below and shown on **Figure 4**.

l.p.a.z.	***Depth in metres (m) below OD***	***Dominant tree pollen taxa***
l.p.a.z 4	34.20 to 34.00m	*Pine (Pinus), elm (Ulmus) oak (Quercus) and hazel (Corylus avellana* type)
l.p.a.z 3	34.27 to 34.20m	Elm (*Ulmus*), oak (*Quercus*), hazel (*Corylus avellana* type)
l.p.a.z 2	34.5 to 34.27m	Pine *(Pinus) and Hazel (Corylus avellana* type)
l.p.a.z 1	34.65 to 34.54m	Pine *(Pinus)*

5.1.5 Within ***l.p.a.z 1*** between 34.65 and 34.54m below OD, pine (*Pinus*) was the dominant tree pollen taxon with some hazel (*Corylus avellana* type) also present. Occasional grasses (Poaceae) and sedges (*Cyperaceae*) and fern spores (*Dryopteris*) were recorded.

5.1.6 Above this within ***l.p.a.z 2*** from 34.5 to 34.27m below OD pine (*Pinus*) and Hazel (*Corylus avellana* type) were the dominant tree pollen taxa with elm (*Ulmus*) and oak (*Quercus*) also recorded. Grasses (Poaceae), ferns (*Dryopteris*) and algae cysts (*Pediastrum*) were also present with declining numbers of sedges (Cyperaceae) noted.

5.1.7 Within ***l.p.a.z 3*** from 34.27 to 34.20m below OD elm (*Ulmus*), oak (*Quercus*), hazel (*Corylus avellana* type) were the dominant tree pollen type with pine (*Pinus*) and willow (*Salix*) also included. An increase in wetland/marsh taxa was noted including sedges (Cyperaceae) bulrush (*Typha* spp.) with grasses (Poaceae) aster (Asteraceae) and ferns (*Dryopteris*) also present.

5.1.8 The uppermost zone, ***l.p.a.z 4*** from 34.65 to 34.54m below OD included pine (*Pinus*), elm (*Ulmus*) oak (*Quercus*) and hazel (*Corylus avellana* type) as the dominant tree pollen species recorded with grasses (Poaceae), goosefoots (Chenopodiaceae) algal cysts (*Pediastrum*), sedges (Cyperaceae), bulrush (*Typha* spp.) and ferns (*Dryopteris* and *Thelypteris palustris*) also noted. The uppermost sample within this zone was also notable for containing the highest concentrations of hazel (*Corylus avellana* type).

5.1.9 All samples were examined for microscopic charcoal. This was recorded as angular and spherical types (**Figure 4**). Counts were made and calculated in relation to the dry-land pollen sum to provide relative abundance. The latter (spherical) are considered to be transported in a similar airborne fashion to pollen which are of comparable sizes. Microscopic charcoal fragments appear throughout both the peat and the minerogenic sediment. It is noted that some small pieces of charcoal were also recovered during the

Stage 3 assessment although too small for species identification (Wessex Archaeology 2011b).

5.1.10 Microscopic charcoal was recorded within all of the samples investigate for pollen analysis (**Figures 2** and **4**). Microscopic charcoal was present throughout the core both from peat and mineral sediment although was less frequent within the organic peat sediments.

Microfauna (Ostracods and Foraminifera)

5.1.11 The sequence investigated for ostracods and foraminfera from vibrocore **VC7** comprised 15 samples between 34.63 to 31.58m below OD (for full results see **Appendix 3**). Whilst some samples were barren of foraminifera and ostracods, an obvious freshwater (from 34.63m to 34.13m below OD) to marine (34.08 to 31.58m below OD) sequence was noted.

5.1.12 The lowest samples at 34.63, 34.48, 34.38, 34.26 and 34.25m below OD contained very few microfaunal remains. Occasional non-marine “freshwater” ostracods were recovered (*Limnocythere sp.*) and other remains such as freshwater molluscs (*Bithynia* sp., *Planorbis* sp. and plants (*Chara*) were recovered. Reworked Cretaceous microfossils (predominantly foraminifera) were noted at these levels.

5.1.13 At 34.18 and 34.13m below OD some interesting and well preserved non-marine “freshwater” ostracod assemblages were recovered. The ostracods included *Candona neglecta*, *Notodromas monacha* and *Metacypris cordata*. These species were notably were often represented by united carapaces, indicative of an autochthonous (*in situ*) assemblage.

5.1.14 Above these levels from 34.08 to 31.58m below OD a diverse assemblage of estuarine and shallow marine ostracods and foraminfera were recorded. The ostracod assemblage was dominated by *Cyprideis torosa* smooth form and foraminifera were abundant and well preserved at these levels including species of *Ammonia* and *Elphidium*.

Molluscs

5.1.15 Eight samples from vibrocore **VC7** were investigated for their molluscan content (between 34.53 and 33.88m below OD (for full results see **Appendix 4**). At 34.53 to 34.58m below OD, at 34.48 to 34.53m below OD and at 34.38 to 34.43m below OD the samples contained almost equal numbers of land snails (*Carychium minimum, Succinea/Oxyloma* sp. and *Vertigo substriata*) and freshwater aquatic species (*Bithynia* sp*.* and *Valvata cristata. Galba truncatula* and *Anisus leucostoma*). The sample at 34.28 to 34.33m below OD included a small assemblage of predominantly freshwater aquatic species including *Valvata cristata* and an anomalous singular occurrence of *Peringia/Ecrobia,* the latter being indicative of brackish or saltwater environments. At 34.18 to 34.23 and 34.13 to 34.18m below OD the samples contained high quantities of aquatic molluscs including *Bithynia tentaculata* and *Valvata cristata.*

5.1.16 In the samples from 33.98 to 34.03m below OD and 33.93 to 33.88m below OD a clear change was noted with large quantities of marine and brackish water molluscs recorded. The assemblages at these levels were dominated by shells of Laver spire shell (*Peringia ulvae*). There were also a number of shells of spine snail (*Ecrobia ventrosa)*, cockle (*Cerastoderma edule*), *Cerastoderma/Cardium* sp., *Scrobicularia/Tellina* type, mussel (*Mytilus edulis*), saddle oyster (*Anomia ephippium*), top shells (*Gibbula* sp.), rough periwinkle (*Littorina saxtilis*), the Rissoidae family and carpet shells (Veneracea). There was also a shell of *Littorina littoralis* and of sting winkle (*Ocenebra erinacea*) in the lower sample and shells of variegated scallop (*Chlamys varia*) and *Tellina crassa* in the upper sample.

Artefact sieving

5.1.17 No artefacts were noted from the scanning the sample residues from vibrocore **VC7**

Previous assessments

5.1.18 Assessment for waterlogged plants, insects and diatoms were undertaken during Stage 3 (Wessex Archaeology 2011b) and due to the paucity and absence of these remains no further analysis was required. The locations of the assessment samples are shown on **Figure 2** and the results of which are summarised below.

5.1.19 Four samples (at 34.23 to 34.28m; 34.13 to 34.18m; 32.89 to 32.99m and 31.38 to 31.48m below OD) were assessed for their plant macrofossil, insect and charcoal content. The sample at the base of the sequence contained numerous unidentified stem and root fragments and a single hazelnut (*Corylus*). Above this at 34.13 to 34.18m below OD some remains of reeds (*Phragmites*) and seeds of mint (*Mentha* spp.) were recovered. At 32.89 to 32.99m below OD no plant remains were recovered. The uppermost sample at 31.38 to 31.48m below OD contained some plant root and stem fragments; additionally in this sample charcoal was recovered in small quantities, although the specimens were too small for identification purposes. No insect remains were recovered from any of the four samples. Insect remains are typically fragile and sometimes sparse within deposits thus reducing the possibility of their recovery within a vibrocore sample.

5.1.20 Eight samples (taken at 34.63m, 34.48m, 34.38m, 34.28m, 34.13m, 33.98m, 33.00m and 31.58m below OD) were assessed for their diatom content (**Figure 2**) (Wessex Archaeology 2011b). All eight samples were barren of diatoms except for a single valve of a freshwater diatom species *Synedra rumpens*, at 33.00m below OD which was thought to be possibly contaminant within the sample as it was a singular occurrence of a fragile taxon.

6 DISCUSSION

6.1.1 The Stage 4 analytical work has enhanced the understanding of the environmental remains (pollen, molluscs, microcharcoal foraminifera and ostracods) identified during the Stage 3 assessment within an archaeological and palaeoenvironmental context. From a geological perspective the succession of sediments recorded within the analysed vibrocore, **VC7** are best understood with reference to known relative sea levels. The sedimentary units and boundaries can be placed within a chronostratigraphic framework related to sea level rise known as a sequence stratigraphy (Miall 1991). The incision of the palaeochannel (**WA7000**), the boundary between the Chalk bedrock and Unit 2 (see sub bottom profiler data example, **Figure 1**) delineates the low stand system tract (LST). The base of the channel is noted to be elevated at around 36m below OD. Sea levels are known to have reached *c*.120m lower than that of today at the last glacial maximum at *c*. 18,000 years BP (Siddal *et al.* 2003) (**Figure 3**). Assuming that the channel is a terrestrial fluvial feature, as the palaeoenvironmental analyses of pollen, ostracods and molluscs of the earliest infilling sediments suggest, then incision must have occurred when relative sea level was at *c*. 40m below OD or lower. The most recent period in which sea level was at this level was at this level was *c*. 11000 years BP (Shennan and Horton 2002; **Figure 3**), which gives a *terminus ante quem* date for the incision of this feature. This period equates to the end of MIS 2 or Devensian period and in archaeological terms it relates to the end of the transition between the late Upper Palaeolithic to early Mesolithic archaeological period.

6.1.2 Evidence of an initially cold climate is recorded within the vibrocore as between 34.68 and 34.80m below OD (the base of the vibrocore) where the Chalk bedrock was noted to have been periglacially frost weathered to form “chalk putty” (Wessex Archaeology 2011b). The subsequent deposition of alluvial channel edge deposits and peat formation (^{14}C dated within this study to between 10190 and 9770 cal. BP) are indicative of an ameliorating climate during the Holocene. These sediments are truncated as delineated by the wave cut platform at 34.12m below OD (**Figure 2**), which with the overlying sandy sediments are indicative of the Holocene sea level rise, the sequence stratigraphic transgressive systems tract (TST).

6.1.3 Whilst it is tempting to view the multibeam bathymetric data showing palaeochannel **7500** (**Figure 1**) as a relict terrestrial landscape, it should be noted that the effects of sea level rise and marine processes may have had a significant effect on the morphology of the feature. The period of final submergence of the area coincides with two major Holocene geological ‘events’: the ‘8.2ka event’, a *c*. 160 year period of climatic cooling; and the ‘Storegga slide’, a tsunami event created by a submarine landslide (which is thought to have occurred at a similar time, at around 8100 BP) (Bondevik *et al*. 1997, Weninger *et al*. 2008). Evidence of these events have been identified in Holocene sediments (comprising distinctive poorly sorted coarse grained marine sediments) around the North Sea however no deposits relating to these events have been interpreted so far from the **VC7** location.

6.1.4 The results of the palaeoenvironmental analyses (pollen, ostracods, foraminifera and molluscs) confirm the broader geological and sequence stratigraphic interpretation but crucially add much detail about the past environment. The pollen analysis indicates vegetation changes which are typical of the early part of an interglacial. That is, the pre-temperate zone with seral changes in the principal woodland components as they re-established after the close of a cold stage/glacial phase, which is confirmed by ^{14}C dating. The pollen remains are of great interest as they are derived from and are indicative both the on-site and surrounding woodland environment. There is a clear sequence of woodland development, diagnostic of the early Holocene, Boreal period. At the base of the sequence (***l.p.a.z. 1***: 34.65 to 34.54m) pine (*Pinus*) is dominant at a date before 9000 BP (estimated 9500 BP). At this time, there are traces of hazel (*Corylus avellana*), probably from more regional, expanding growth, although occasional local growth cannot be ruled out. The molluscs recovered at these levels and above (34.58 to 34.38m below OD) were indicative of a well vegetated, slowly flowing aquatic environment with muddy substrates within an area of damp or marshy grassland with some seasonal flooding. More localized pollen remains including grasses (Poaceae), sedges (Cyperaceae), willow (*Salix*) and aquatic pollen and spores were recovered indicative of the on-site wetland environment. This is corroborated by the channel edge alluvial deposits interpreted from the geoarchaeological recording of the sediments (Wessex Archaeology 2011b).

6.1.5 Increasing vegetation is recorded up profile and although pine (*Pinus*) remained the dominant tree pollen taxon (***l.p.a.z. 2***: 34.27 to 34.20 m below OD) hazel (*Corylus avellana*) became fully established on and near the site at *c*. 9000BP. This formed the classic Boreal pine-hazel woodland described by Godwin (1956, 1975), the so-called Flandrian Chronozone 1b which is (along with ***l.p.a.z. 1***) based on the pollen flora likely to be early Mesolithic in date. During this phase of pine (*Pinus*) - hazel (*Corylus avellana*) domination, there are the first traces of oak (*Quercus*) and elm (*Ulmus*) as they migrated into the region from 34.42m below OD and 34.35m below OD respectively. These progressively out competed pine (*Pinus*) becoming more important from 34.38m below OD corresponding to the inception of peat deposition and radiocarbon dated to 8915+/-30 BP (SUERC-36006) (8240-7960 cal. BC; 10190-9910 cal. BP).

6.1.6 Above these levels hazel (*Corylus avellana*) continued to dominate the tree pollen (***l.p.a.z. 3***: 34.27 to 34.20m below OD). It is interesting to note that a hazelnut shell was recovered during the Stage 3 assessment from a sample taken at 34.23 to 34.28m below OD (Wessex Archaeology 2011b) as this is further evidence of hazel (*Corylus avellana*) at these levels. Oak (*Quercus*) and elm (*Ulmus*) were established on drier zones within the region, some pine (*Pinus*) however remained. This may be reflected in the highly detrital character of the upper peat levels suggesting a dry (but damp) carr type woodland dominated by hazel (*Corylus avellana*) with willow (*Salix*) and a strong ground flora of ferns (*Thelypteris palustris*). The latter, as noted, are probably over represented due to the resilience of their spores in what was probably a micro-biologically active habitat during the warmer seasons when the water table was lower.

6.1.7 The uppermost pollen zone identified (***l.p.a.z. 4***: 34.20 to 34.00m below OD) marks a distinct change with pollen recovered indicative of a, wet sedge and reed fen habitat. Sedges (Cyperaceae) with iris, bur reed and/or lesser reed mace (*Sparganium/Typha angustifolia*), common reedmace (*Typha latifolia*) and areas of open/standing water indicated by pondweed (*Potamogeton* type), bog bean (*Menyanthes trifoliata*) and algal *Pediastrum*. Common reed (*Phragmites australis*) stems and a seed of mint (*Mentha* sp.) were recovered from a sample at 34.13m to 34.18m below OD during the Stage 3 assessment (Wessex Archaeology 2011b). The molluscan assemblages recovered from depths between 34.23 to 34.13m below OD include molluscs such as *Bithynia tentaculata* and *Valvata cristata* indicative of a wetter freshwater environment at these levels including slowly flowing or still, well vegetated body of fresh water probably with a muddy substrate. Peat deposition is still recorded at these levels with a common reed (*Phragmites australis*) stem at 34.13m below OD returning a date of 8855±35 SUERC-36005 (8210-7820 cal. BC; 10160 to 9770 cal. BP). At 34.18 and 34.13m below OD some most interesting ostracod faunas were recovered. At 34.18 the fauna included *Candona neglecta* although the dominant ostracod was *Metacypris cordata* which was represented by whole carapaces, indicative of an autocthonous fauna. Above this at 34.13m below OD a similar fauna was recorded including *Notodromas monacha* and *Metacypris cordata,* both represented by whole carapaces. These species are together indicative of deposition within a still, shallow well vegetated freshwater body probably with floating vegetation.

6.1.8 An unusual occurrence of *Fagus sylvatica* (beech) was recorded at 34.13m below OD during the Stage 3 assessment (Wessex Archaeology 2011b). Further analysis and greater pollen counts at this level have not confirmed this occurrence (**Appendix 2**). It is possible that it was misidentified during the Stage 3 assessment. The species is at present not known in this period at these latitudes.

6.1.9 The two radiocarbon dates from the peat have been plotted against a relative sea level rise curve based upon Shennan and Horton (2002) and Siddal *et al*. (2003) (**Figure 3**). The elevation and dates are very close to the interpreted mean sea level for the period. It is noted that the peat has probably suffered from post depositional compaction which is likely to have reduced its elevation by up to 2 metres (Allen 2000).

6.1.10 The rapid sea level rise noted during the Mesolithic archaeological period is shown on **Figure 3**. This is recorded in the truncation of the freshwater peat deposit and subsequent deposition of outer estuarine and shallow marine deposits recorded within vibrocore **VC7** from 34.08m to 31.19m below OD. The molluscs, foraminfera and ostracods are together indicative of deposition in an outer estuarine environment of near to normal marine salinities at these levels, with evidence of increasing marine influence up profile. The pollen remains at these levels, whilst they differ slightly, are characteristically Mesolithic in date including hazel (*Corylus avellana*), oak (*Quercus*), elm (*Ulmus*) and birch (*Betula*).

Some indication of surrounding saltmarsh was indicated by the presence of fat hen (Chenopodiaceae), sedges (Cyperaceae) and grasses (Poaceae).

6.1.11 Other examples of offshore peat deposits include the submerged forest recorded at Cockleshell Hard on the eastern tip of the Isle of Grain (Devoy 1979, 1980 and 1982). More recent work on these deposits in advance of the BritNed High Voltage interconnecting electricity cable indicated a submerged forest at *c*.28.5 m below OD (Russell *et al*. 2011) This sequence contained pollen, diatoms, foraminifera, ostracods, molluscs, charcoal and waterlogged plants indicative of a submerged oak (*Quercus*) and hazel *(Corylus avellana*) forest with the development of brackish creeks. Radiocarbon dating was undertaken on an oak (*Quercus* sp.) acorn cup, which returned a result of 8018± 45BP, which was calibrated to 9030-8720 cal. BP; 7080-6770 cal. BC, which is within the Early Mesolithic period (see **Figure 3**).

6.1.12 Work in advance of the export cable route for the London Array Offshore Windfarm (c. 10km north of Herne Bay, Kent) has also indicated Mesolithic terrestrial environments in the form of saltmarsh peats at 15.08m below OD dated to 7680±35BP; (6600-6460 cal. BC; 8550 to 8400 cal. BP) and at 8.12m below OD dated to 6925±35 BP (5890-5730 cal. BC; 7840 to 7689 cal. BP) (Wessex Archaeology 2009). These dates are equivalent to the late Mesolithic period and are plotted on **Figure 3**. These offshore sequences from this study are likely to correlate with the estuarine alluvial deposits overlying the peat within vibrocore **VC7**.

6.1.13 Although dating has not been undertaken on the estuarine and marine sediments between 34.08m to 31.19m below OD, it is conjectured that a wide embayment was present in the area during the later Mesolithic period (Coles 1998; Perkins 1998; Moody 2008) of which **VC7** would be located in the northern part. The pollen data suggests that the estuarine and marine sediments at around 34.00m below OD are likely to be of Mesolithic date.

6.1.14 The shallow marine deposits at the top of the core, whilst more recent in origin, are of note as they may have been originally part of shallow marine and/or beach deposits as there is no direct sediment input into the area today (Cameron *et al*. 1992).

6.1.15 The terrestrial deposits such as peat give an indication that the region could potentially have been colonised during the late Upper Palaeolithic and early Mesolithic period by anatomically modern humans during their recolonisation of Britain which is known to have occurred after *c.* 14,700 BP as the climate ameliorated (Jacobi and Higham 2009). Peat deposits are well known from the North Sea, having been trawled up by fishermen, who name peat ‘moorlog’. One of the most famous archaeological finds from the southern North Sea (c. 100km north of **VC7**) is the barbed antler harpoon point (of late Upper Palaeolithic/Mesolithic type) found in 1931 within a lump of peat by Captain Pilgrim Lockwood aboard the trawler *Colinda* on the Leman and Ower bank which alerted archaeologists to the potential of the area (Godwin and Godwin 1933). Clement Reid published a remarkably accurate account of the palaeoenvironment of the southern North Sea in his book *Submerged Forests* (Reid 1913) in which he lists not only the plant material from “moorlog” but also species identifications of bones trawled from the area. It is in honour of the work of Reid that the archaeologist Bryony Coles later coined the term “Doggerland” to refer to the area which was once colonised by humans (Coles 1998) which she defines it as “the region now submerged by the North Sea”. **VC7** is therefore at the southern edge of the area described by Coles as “Doggerland”.

6.1.16 Whilst no prehistoric archaeological remains were recovered during this work and no prehistoric finds have been recovered in the immediate vicinity of palaeochannel **7500**, archaeological remains typical of the Mesolithic period have previously been recovered from offshore locations including Mesolithic tranchet axes from the Outer Thames Estuary of the North Kent coast. These tranchet axes or adzes are known as "Thames picks" as many have been found within the Thames drainage basin and they are thought to be chronologically equivalent to the Danish Ertebølle culture (Jacobi 1982).

6.1.17 It is worth noting that archaeological material becomes more frequent in Kent after *c*.8000BP and it is postulated that this may be either due to a real increase in population or a loss of lower-lying land (as is represented at the site of vibrocore **VC7** *c*.12km east of Ramsgate) due to sea level rise (Williams 2007). It is also at this time that Britain becomes an island and the uniquely British lithic industry (geometric microliths) appears. This lithic industry appears at about the same time as Britain became separated from mainland Europe by rising sea levels for the last time, the evidence of which is preserved within the assessed sediments of vibrocore **VC7**.

6.1.18 The presence of charcoal was noted during the Stage 3 assessment (Wessex Archaeology 2011b) and was thought to be potentially indicative of occupation in the area. Mesolithic burning has always been well established from charcoal analyses in upland areas of the UK (e.g. Simmons 1996) but has only now become increasingly recognised within the lowland setting (eg. Mellars and Dark 1998; Barnett 2009; Grant and Waller 2011). However the extent to which deliberate burning has taken place in areas now deeply buried within a maritime setting is poorly understood although likely to be extensive given the findings from along the coastal edge (e.g. Bell *et al.* 2006; Russell *et al.* 2011). Further analysis of microcharcoal has been undertaken in this study (**Figure 4**) which has demonstrated charcoal is present throughout the sequence investigated. However, the type and concentrations of microcharcoal noted were likely derived from airborne and fluvial transport with no obvious pattern commensurate with obvious anthropogenic burning.

6.1.19 The results of this work have enabled the greater understanding of the preservation and nature of submerged prehistoric environments in the Southern North Sea/Outer Thames Estuary area. The deposits have been fully investigated including scientific dating and analyses which have significantly enhanced the palaeoenvironmental and archaeological record. Some uncertainties however remain over the processes by which charcoal has been incorporated in the sediments and the identification of beech (*Fagus sylvatica*) during the Stage 3 work. It is recommended that the work is published in *Archaeologia Cantiana* (see **Appendix 5**).

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8 APPENDIX 1: RADIOCARBON DATING

Chris Stevens revised by AJ Barclay (2.5.16)

Introduction

Two samples of short-lived material from waterlogged sub-samples within vibrocore **VC7** (at 34.38m below OD and 34.13m below OD) were extracted for radiocarbon dating. In the case of the upper sample from 34.13m below OD m the material comprised fragments of common reed (*Phragmites australis*) stems. In the lower sample the material was of unidentified stem material. The material was carefully extracted from horizontally bedded peat and identification undertaken so that only stem material was selected for dating and any root material avoided.

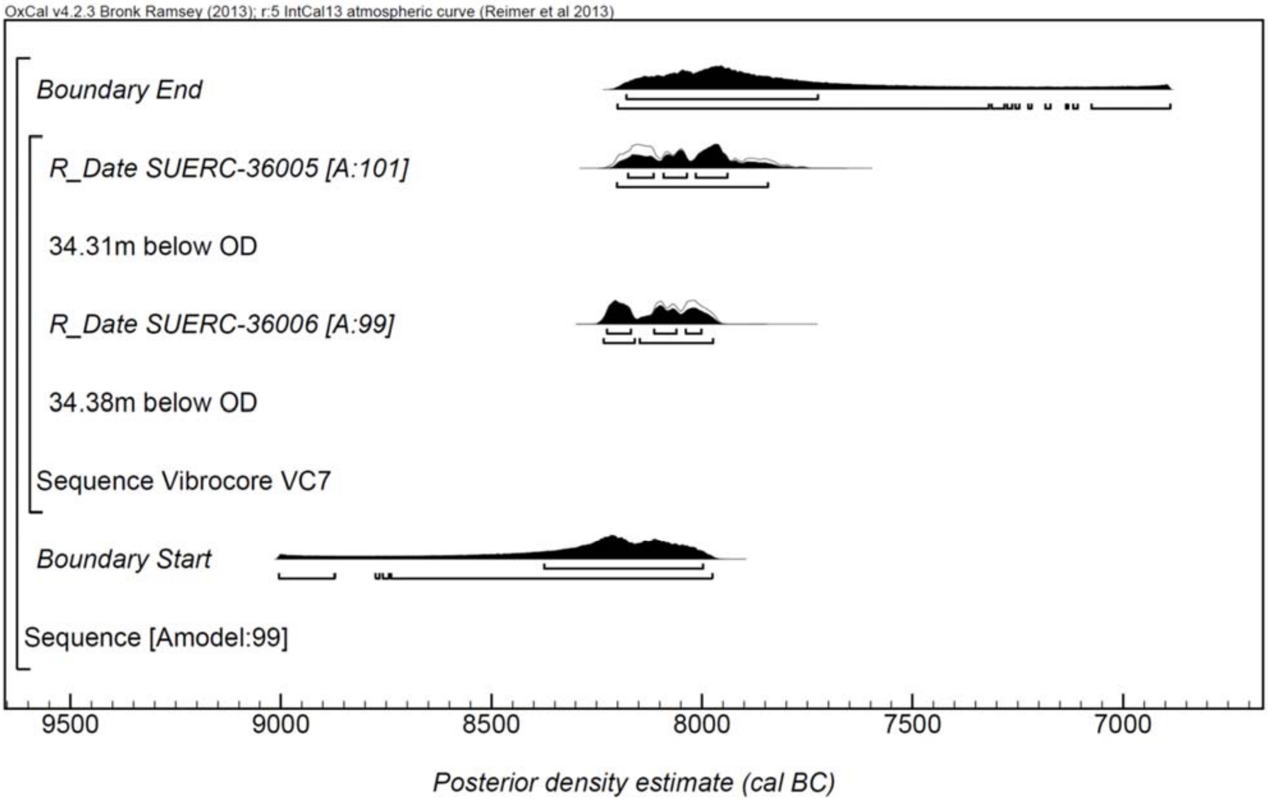
The samples were identified and submitted to the Scottish Universities Environmental Research Centre, East Kilbride (SUERC) for radiocarbon dating.

Results

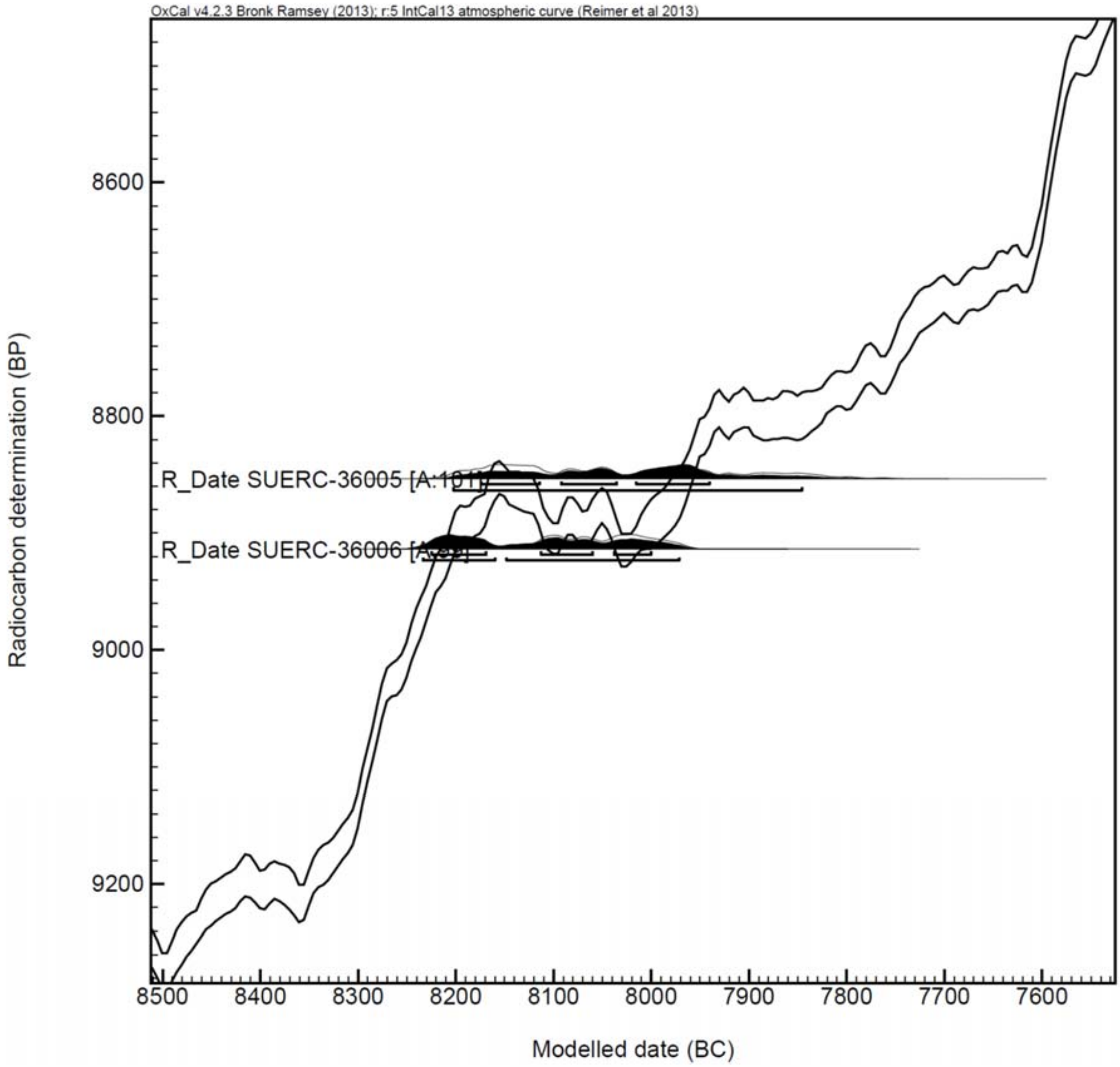
The radiocarbon determinations were calibrated using OxCal 4.2.3 (Bronk Ramsey 2001; 2009) and the IntCal013 calibration curve (Reimer *et al.* 2013) and are quoted in the form recommended by Mook (1986) with the end points rounded outward to 10 years and are shown in the table and diagrams below

Depth	Identification	Laboratory Code	$\delta^{13}C$	Date BP	95% confidence
Vibrocore VC7					
34.13m below OD	Stem of *Phragmites australis*	SUERC-36005	-25.0 (assumed)‰	8855±35	8210-7840 cal. BC 10160-9770 cal. BP
34.38m below OD	Indet waterlogged stem	SUERC-36006	-28.7‰	8915±30	8240-7960 cal. BC 10190-9910 cal. BP

Radiocarbon determinations from vibrocore VC7



Probability distribution for dates from vibrocore VC7



Probability distribution for dates from vibrocore VC7 plotted on the calibration curve

Despite the dates being in the correct stratigraphic sequence by age (is, the older date is lower in the sequence), the results are statistically consistent (χ^2 Test: T'=1.7; T' (5%) = 3.8; df-1; Ward and Wilson 1978). This indicates that they could be of a broadly similar age. Unfortunately both dates coincide with a plateau in the calibration curve at 8200 to 7950 cal. BC (see probability distribution plot above), which limits any greater precision in sequencing the dates.

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Abbreviations

AD: *Anno Domini,* In the Year of our Lord
BC: Before Christ
BP: Before Present (where present=AD1950)
Cal.: Calibrated

9 APPENDIX 2: POLLEN AND MICROCHARCOAL ANALYSIS

Rob Scaife

Introduction

The preliminary analysis of the sample series taken from vibrocore VC7 by Grant (2011) established that sub-fossil, spores and microscopic charcoal were present. Radiocarbon dates of 8855+/-35 (SUERC-36005) and 8915+/-30 BP (SUERC-36006) show this sequence to be of early Holocene, Boreal (Flandrian Ib/c) age, that is, archaeologically, the early Mesolithic. A more detailed study of sediments between 34.06m below OD and 34.66m below OD has been carried out and a pollen diagram has been produced (**Figure 4**) which illustrates the changing vegetation in response to post-glacial tree migration and establishment in the southern North Sea Basin.

Method

Standard techniques for pollen concentration of the sub-fossil pollen and spores were used on these sub-samples of 1.5 ml. volume (Moore and Webb 1978; Moore *et al*. 1992). A total of 500 grains pollen grains per level were counted where preservation allowed. Fern spores and other miscellaneous elements were recorded outside of this sum. Microscopic charcoal of both angular and rounded/spheroidal form was also recorded. A pollen diagram (**Figure 4**) was produced using Tilia and Tilia Graph with percentages for the principal groups calculated in the following manner:

Sum =	% Dry land pollen (tdlp)
Marsh =	% Sum + marsh pollen.
Ferns =	% Sum + sum of fern spores
Misc. =	% Sum + sum of misc. taxa
Charcoal	% Sum + Charcoal

Taxonomy, in general, follows that of Moore and Webb (1978) modified according to Bennett *et al.* (1994) for pollen types and Stace (1991) for plant descriptions. These procedures were carried out in the Palaeoecology Laboratory of the School of Geography and Environment (PLUS), University of Southampton.

Results

Pollen and spores were recovered from all of the (14) samples processed. Overall, pollen was not abundant in any of the samples and was particularly sparse in the lower minerogenic humic and basal silt (below *c.* 34.60mOD) and in the upper alluvial sample (34.06m below OD) overlying the peat. The intercalated peat at 34.43m below OD to 34.08m below OD is extremely humified and detrital. Whilst the substantial numbers of fern spores come from on-site growth, these are resilient and may be over represented through differential preservation. The well-preserved spores have their perine remaining showing that *Thelypteris palustris* (marsh fern) was an important component of the ground flora. Undifferentiated (*Dryopteris* type) spores are likely to be referable to this fern.

Four local pollen assemblage zones (l.p.a.z.) have been recognised delimiting the principal palynological changes found in this profile. These are described in the table below.

l.p.a.z.	***Palynological characteristics***
l.p.a.z 4	The upper sample (34.06m below OD) differs from the main part of the zone in having higher values of *Corylus avellana* type (37%), lower *Pinus* (15%),

34.20 to 34.00m below OD *Pinus-Ulmus-Quercus*-Corylus *avellana* type. Peat and overlying silt	Poaceae (11%), Chenopodiaceae (4%), *Pediastrum* and substantial numbers of pre-Quaternary palynomorphs (40% Sum + Misc.). As a single level, a local pollen assemblage zone was not designated. Throughout the main part of this zone, *Corylus avellana* type decreases (15%) while *Pinus* recovers (peak to 70%). *Quercus* has highest values (18%). *Ulmus* remains (2-3%) but with some reduction in the middle of the zone. There is an increase in herb pollen diversity with higher values of fen/marsh taxa Cyperaceae (peak to 34%), *Typha latifolia* (3%) and *Typha angustifolia* type (2-3%). The substantial numbers of fern spores (*Dryopteris* type) remain high throughout the peat and decline into the overlying minerogenic sediment. *Thelypteris palustris* is present in this zone and it is probable that much of the non-differentiated spores are also referable to this taxon.
l.p.a.z. 3 34.27 to 34.20m below OD *Ulmus-Quercus-Corylus avellana* type. Humified, detrital peat	*Pinus* values (15%) decline in response to expansions of *Corylus avellana* to maximum value (65%). *Ulmus* (11%) and *Quercus* (6%) are established. *Salix* (5%) is present. There are few herbs with occasional Poaceae and Asteraceae types. There is some increase in wetland/marsh taxa with Cyperaceae (10%) and incoming of *Typha angustifolia*/*Sparganium* type. There is a marked expansion of fern spores of monolete *Dryopteris* type to extremely high values (99% sum + fern spores) in the upper part of the zone and overlying l.p.a.z 4 .
l.p.a.z. 2 34.5 to 34.27m below OD *Pinus-Corylus avellana* type Humic silt and overlying peat	*Pinus* values remain consistently high (*c*. 60-70%) although there is some decline over the preceding zone. *Corylus avellana* type increases in importance from the preceding zone (20-30%). *Ulmus* is incoming at the base of the zone (34.50m below OD) followed by *Quercus* at -34.42mOD. There are few herbs with reduced values from l.p.a.z. 1. Poaceae are consistent while Cyperaceae decline to low values and absence. *Dryopteris* type (c. 15%) is the only fern spore and is probably referable to *Thelypteris palustris*. There are occasional *Pediastrum* cysts. Reworked pre-Quaternary palynomorphs decline to absence.
l.p.a.z. 1 34.65 to 34.54m below OD *Pinus* Lower Silt and humic Silt	Overall, pollen diversity is low. *Pinus* is dominant with high values (88%). *Corylus avellana* type (to 7%) has lowest values in this profile and starting to increase in value. There are few herbs with occasional/sporadic occurrences and only Poaceae (4%) and Cyperaceae (41%) have more than individual occurrences. The latter declines to small values in the subsequent zone. There are occasional fern spores of *Dryopteris* type. Abundant pre-Quaternary palynomorph (25%) values decline upward with change from mineral to more humic sediment.

Interpretation and Discussion

Clement Reid (1913) initially recognised the significance of submerged peat in the southern North Sea (Dogger Bank). Erdtman (1925) carried out a preliminary analysis of 'moorlog' (peat) as part of his early understanding of the character and spreading of Europe's Prehistoric vegetation. Maglemosian artefacts associated with this 'Moorlog' were dredged up (Godwin and Godwin (1933) and clearly pertained to the pre-submergence of the North Sea Basin and the more recently described Doggerland of Coles (2000). These deposits were fitted by Godwin into his pollen zonation scheme as being of pre-Boreal, Zone IV and early Boreal, Zone V (Godwin 1943, 1945). Since this pioneer work, the presence of earlier cold stage/glacial and interglacial sediment profiles has been established (Cameron *et al* 1987; Scourse *et al*. 1998; Scaife, 2006 (Humber), 2006a, b (Pakefield), 2008 (Lynn and Inner Dowsing), 2009 (Walney), 2010 (NW Kent, site 70050), 2103a (Outer Thames). Recent development of wind farms and associated infrastructure has been responsible for a plethora of geological data from the North Sea Basin. This includes aspects of palaeoecological analyses and radiocarbon dating establishing geochronology of environmental change. Early Holocene pollen data which are comparable with this present study have been obtained which establish the early Holocene environment and changing woodland vegetation structure of the early post-glacial period (Scaife 2006a, 2013b, 2014; Wolters 2010). This study adds valuable data to the developing model of post-glacial dynamic woodland and environment of the early Mesolithic.

The profile examined here (**VC7**) shows vegetation changes which are typical of the early part of an interglacial. That is, the pre-temperate zone with seral changes in the principal woodland components as they re-established after the close of a cold stage/glacial phase. This is confirmed as of early Holocene age with two radiocarbon dates obtained. At, 34.13m below OD with a measurement of 8855+/-35 BP (SUERC-36005) (8210-7820 cal. BC; 10160-9770 cal. BC) and at 34.38m below OD of 8915+/-30 BP (SUERC-36006) (8240-7960 cal. BC 10190-9910 cal. BP).

The seral vegetation succession: There is a clear sequence of woodland development which is diagnostic of the early Holocene, Boreal period (Fl. Ib-c). Initially (l.p.a.z. 1) pine (*Pinus*) is dominant at a date before 9000BP (estimated 9500 BP). This probably superceded pioneer juniper scrub and birch woodland after the close of the Devensian cold stage (not seen in this profile) at *c.* 10,000BP. At this time, there are traces of hazel, probably from more regional, expanding growth, although occasional local growth cannot be ruled out

Pine remained dominant (l.p.a.z. 2) as hazel became fully established on and near the site at *c*. 9000BP. This formed the classic Boreal pine-hazel woodland described by Godwin (1956, 1975) although it still remains unclear as to the interaction of the two tree taxa. This is Flandrian Chronozone Ib, archaeologically, along with l.p.a.z.1, the early Mesolithic.

During the phase of Pine-hazel domination, there are the first traces of oak (*Quercus*) and elm (*Ulmus*) as they migrated into the region from 34.42m below OD and 34.35m below OD respectively. These progressively out-competed pine becoming more important from 34.38m below OD radiocarbon dated to 8915+/-30 BP (SUERC-36006) (8240-7960 cal. BC; 10190-9910 cal. BP).

Hazel (*Corylus avellana*) continued to become dominant (l.p.a.z. 3) on-site with oak and elm established on drier zones within the region. Some pine, however, remained. This may be reflected in the highly detrital character of the upper peat levels suggesting a drier but still damp carr type woodland dominated by hazel with willow and a strong ground flora of ferns (*Thelypteris palustris*). The latter, as noted, are probably over represented due to the resilience of their spores in what was probably a micro-biologically active habitat during the warmer seasons when the water table was lower.

In l.p.a.z. 4 (34.2m below OD upwards), the local habitat changed probably as a consequence of eustatic change. Positive sea level change resulted in the local habitat becoming wetter with a consequent change from the on-site damp woodland to a more open, wet sedge and reed fen habitat. Sedges (Cyperaceae) with iris, bur reed and/or lesser reed mace (*Sparganium/Typha angustifolia*), common reedmace (*Typha latifolia*) and areas of open/standing water indicated by pondweed (*Potamogeton* type), bog bean (*Menyanthes trifoliata*.) and algal *Pediastrum*. This occurred at 8855+/-35 BP (34.13m below OD) (SUERC-36005) (8210-7820 cal. BC; 10160-9770 cal. BP).

The uppermost (single level) at 34.00m below OD is interesting and may mark a further significant environmental change. There is a change to more minerogenic sediment type. In this sample, Chenopodiaceae (goosefoot, orache and samphire) are present which may be attributed to halophytic salt marsh plants and thus indicative of final marine transgression. The much-increased number of reworked pre-Quaternary palynomorphs is typical of salt marsh and mud flat sedimentation.

These data are in accord with data from a range of pollen sequences from Southern and South East England which show the arrival of the principal tree taxa into the region (Scaife 1980, 1982; Waller

1993). Bennett and Preece (1998) and Preece and Bridgland (1999) provide the most comprehensive review of the Late Devensian and early Holocene flora based on data from Holywell Coombe (Channel Tunnel). Relevant to this study are the arrival and dominance times of the early Holocene flora.

- *Betula-Pinus* (9530+/-75 BP)
- Start of *Corylus avellana* expansion (9460+/-140 BP)
- *Corylus avellana* - *Ulmus*. (8630+-120 BP to 7650+/-80 BP)

Clearly, birch (*Betula*), as noted, is not present here and the start of the sequence described falls within the period of dominant Pine woodland at *c.* 9,000 BP and before. The arrival times of hazel are commensurate and early for this interglacial period. The first occurrence of elm at **VC7** is at *c*. 9,000BP and slightly ahead of oak although both taxa become more or less of equal importance between 8900 and 8855 BP. Grant (2011) drew attention to two grains of beech (*Fagus*). None was found in this study in spite of the larger pollen counts obtained and concerted scanning of slides..

Microscopic charcoal

All samples were examined for microscopic charcoal. This was recorded as angular and spherical types (**Figure 4**). Counts were made and calculated in relation to the dry-land pollen sum to provide relative abundance. The latter (spherical) are considered to be transported in a similar airborne fashion to pollen which are of comparable sizes. Microscopic charcoal fragments appear throughout both the peat and the minerogenic sediment and some charcoal was also recovered during plant macrofossil processing.

Other than the obvious conclusion that microscopic charcoal is present, the following aspects of charcoal analysis have also been considered

- The marine minerogenic sediment elements of the sequence, especially, are likely to contain reworked carbonaceous material. That is coal from Palaeozoic lithology from the North and Tertiary lignite from the London Basin and near continent.

- Early Holocene sediment such as found here, especially from a reduced environment, frequently contain pyritised organic material. This appears as black isotropic particles.

- Manganese particle also appear as small black smuts.

- The carbonaceous particles may come from natural and human instigated fires

Microscopic charcoal is definitely present here and has been identified during the investigation of plant macrofossils. However, microcharcoal is significantly present throughout the core both from peat and mineral sediment although the former has less. The possibility of both airborne and fluvial transport thus occurs. Whether human or natural causation is responsible is enigmatic. Examination of human impact through fire during this, the early Mesolithic period, is difficult if not impossible without very detailed analysis at a very close spaced sample interval. That is, because the traditional view of Mesolithic impact is of hunting and foraging with ephemeral encampments. To see any impact of these in such lowland pollen study would be unlikely with very short term and seasonal encampments. Here, there are no distinct phases which may be attributed to human activity.

Alternatively, it can be suggested that Mesolithic activity was more far reaching with widespread burning as part of a hunting regime. Rawitscher (1945) initially suggested this from his observations on hazel scrub colonisation after fire and proposed that the early Boreal hazel maximum, seen here, may be of anthropogenic causation. More recent discussion has also centred on changes in Boreal woodland influenced by fire (Grant changes in Boreal woodland influenced by fire (Grant and Waller 2010). As such, it remains unclear whether the charcoal concentrations recovered reflect human activity or natural fire. However, whichever, there is evidence that fire played an important role in the early Boreal landscape.

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10 APPENDIX 3: MICROFAUNA (OSTRACODS AND FORAMINIFERA) ANALYSIS

Jack Russell

Introduction

Fifteen sediment subsamples from vibrocore **VC7** have been analysed for the presence and environmental significance of their microfaunal contents, predominantly foraminifera and ostracods. The subsamples were chosen based upon the microfaunal assessment undertaken in 2011 (Wessex Archaeology 2011) and and accordance with advice from English Heritage. The vibrocore sample derives from a geotechnical investigation in the area of the Nemo Link UK to Belgium interconnecting cable route in the English Channel off East Kent. The subsamples consisted of clay, silt, sand and peat deposits elevated at the following depths given in metres below Seabed (m below SB) and metres below Ordnance Datum (m below OD).

5.85m below SB; 34.63m below OD
5.70m below SB; 34.48m below OD
5.60m below SB; 34.38m below OD
5.50m below SB; 34.28m below OD
5.45m below SB; 34.25m below OD
5.40m below SB; 34.18m below OD
5.35m below SB; 34.13m below OD
5.30m below SB; 34.08m below OD
5.25m below SB; 34.03m below OD
5.20m below SB; 33.98m below OD
5.15m below SB; 33.93m below OD
5.10m below SB; 33.88m below OD
5.05m below SB; 33.83m below OD
4.22m below SB; 33.00m below OD
2.80m below SB; 31.58m below OD

Ostracods were recorded in 11 of the 15 samples and foraminifera in 12 of the 15 samples. Both ostracods and foraminifera, where present were generally well preserved.

Method

Sediment samples of *c*.40ml were disaggregated in a weak solution of Hydrogen Peroxide and water, then wet sieved through a 63µm sieve. The sediment was dried and sieved through 500µm, 250µm, 125µm sieves. Microfossils were picked out under 10-60x magnification and transmitted and incident light using a Vickers binocular microscope. Specimens were extracted and placed in card slides for identification. Identification and environmental interpretation of ostracods follows Athersuch *et al*. (1989) and Meisch (2000) and for foraminifera (Murray 1979; 1991).

Results

Abundance and presence/absence of microfaunal remains within the samples is summarised below and shown in **Table 1** (ostracods) and **Table 2** (foraminifera).

At 34.63m below OD a few ostracods were recovered although these were predominantly fossilised (Upper Cretaceous) forms. One non fossil specimen of the genus *Limnocythere* was recovered. Foraminifera were also recovered and these were also (Upper Cretaceous) fossilised forms. At 34.48, 34.38 and 34.28m below OD no ostracods were recovered. A few fossilised Upper Cretaceous foraminifera were recovered. Other remains within this sample included freshwater molluscs samples and at 34.28m below OD plants included an oognium (the female reproductive organ) of the freshwater plant *Chara.*

At 34.18 and 34.13m below OD some well preserved ostracod assemblages were recovered. The ostracods included Candoniid forms including *Candona neglecta* at 34.18m below OD and the non-marine species *Notodromas monacha* and *Metacypris cordata*. These were often represented by united carapaces, indicative of an autochthonous (*in situ*) assemblage. One fossilised (Upper Cretaceous) ostracod was recovered. Plant remains and freshwater molluscs were also noted to be frequent within these samples. No foraminifera were recovered other than one fossilised specimen at 34.18m below OD.

At 34.08m below OD a clear change was noted - large and diverse assemblages of estuarine and shallow marine foraminifera and ostracods were present in this part of the core. The ostracods included *Cyprideis torosa* (smooth form), *Elofsonella* sp., *Leptocythere* sp., *Leptocythere pellucida*., *Loxoconcha elliptica* and *Loxoconcha rhomboidea* Foraminifera were abundant and well preserved within the sample and included species of the genera *Ammonia* (including *Ammonia batavus*) and *Elphidium*, *Astergerinata mamilla*, *Buliminella elegantissima*, *Haynesina germanica*, *Jadammina macrescens* and *Rosalina* sp..

The samples at 34.03, 33.98, 33.88, 33.83 and 31.58m below OD contained similar assemblages of outer estuarine and shallow marine ostracods and foraminifera and differed from the sample at 34.08 as they contained Miliolid foraminifera. The ostracods were relatively abundant and well preserved including *Aurila convexa*, *Cyprideis torosa* (smooth form), *Elofsonia* sp. *Eucythere* sp., *Heterocythereis albomaculata*, *Hirschmannia viridis*, *Leptocythere* spp., *Loxoconcha* spp. *Palmoconcha* sp., *Paracytherois flexuosa*, *Propontocypris* sp. and *Semicytherura* sp.. Foraminifera were abundant and well preserved at these levels and comprised species of *Ammonia* and *Elphidium*, *Astergerinata mamilla*, *Buliminella elegantissima, Haynesina germanica*, *Jadammina macrescens, Rosalina* sp. and Miliolids. The Miliolid foraminifera included *Massilina secans*, *Miliolinella subrotunda*, *Quinqueloculina dimidiata* and *Quinqueloculina seminulum.* A sample at 33.93m below OD contained an unusually small fauna consisting of a singular specimen of the foraminfera *Elphidium cuvillieri.* This sample however (in common with the samples at 34.03, 33.98, 33.88, 33.83 and 31.58m below OD) contained frequent broken estuarine and marine molluscs including *Cerastoderma edule*, *Pholas dactylus, Ostrea edulis* and *Scrobicularia* sp. The uppermost sample at 31.58m below OD was noted to have the highest proportion of Miliolid foraminifera.

Discussion

Arguably, now in a marine context, the most interesting part of the sequence from vibrocore VC7 is the lower part which includes freshwater ostracod faunas between from 34.63 to 34.13m below OD. At the base of the sequence from 34.63 34.23m below OD unfortunately very few microfaunal remains were recovered. Of what was recovered many specimens were Upper Cretaceous fossilised forms no doubt reworked from the underlying Chalk bedrock. One singular occurrence of the ostracod Limnocythere sp. at 34.63m below OD is of interest and hints at the non-marine “freshwater” depositional environment indicated by the other remains such as Planorbid molluscs and the operculae and apices of the mollusc Bithynia. The plant remains found within these samples were noted to increase up profile. A shallow, vegetated, channel edge, backwater possibly periodically cut-off freshwater environment is tentatively interpreted at these levels.

At 34.18 and 34.13m below OD the most interesting ostracod faunas were recovered. At 34.18 the fauna included *Candona neglecta* although the dominant ostracod was *Metacypris cordata* which was represented by whole carapaces, indicative of an autocthonous fauna. Above this at 34.13m below OD a similar fauna was recorded including *Notodromas monacha* and *Metacypris cordata,* both represented by whole carapaces*. Metacypris cordata* lives mainly amongst littoral vegetation in still and slow water flowing waterbodies, predominantly ponds and lakes where it is found in shallow water depths up to around 10m. The species is common today in lakes in Austria, Romania and England, where it is found within organogenic sediment and amongst the root masses and stems of water lilies and reed beds. It has been recorded in Romanian lakes amongst floating vegetation (*Carex*, *Typha* and *Phragmites*) (Danielopol and Vespremeanu 1964). Of particular interest is it’s record in the English Lake District where it was found at 8 of 75 investigated sites reelecting its preference for ion rich waters with pH>7. In addition to the highly dissolved ion content (particularly Calcium and Magnesium), these sites are characterised by marginal bogs and fens and in some cases such as Skelsmergh Tarn floating fens (Danielpool *et al*. 1996) similar to that recorded within the Romanian lakes. *Notodromas monacha* lives in both permanent and temporary waterbodies, preferring shallow water with rich vegetation on the littoral zones of lakes and ponds. The species can tolerate a slight increase in salinity (3‰).They are excellent swimmers found amongst aquatic vegetation close to and at the surface membrane of the water, where it feeds, upside down on bacteria which colonise the air/water interface. The species can survive dessication although it has only been recorded from waterbodies which dry in the summer months (rather than for longer periods). *Candona neglegta*, another dessication resistant species is known to inhabit a wide range of environments including springs, brooks, wells, ponds and ditches and also found the littoral and profundal zones of lakes. *Candona neglegta* can also tolerate slightly brackish water and is not uncommon in the Baltic Sea (Meisch 2000) with a maximum recorded salinity tolerance of 16‰ for *Candona neglecta* (Hiller 1972).

Overall these faunas at 34.18 and 34.13m below OD indicate deposition within a warm, shallow, vegetated, still, freshwater body. This assemblage is likely to relate to a post-glacial/early Holocene “cordata” fauna indicative of environmental changes from oligotrophic to trophic conditions noted in North Western Europe lake deposits (Boomer 2002).

The upper samples between at 34.08 and 31.58m below OD contain similar assemblages indicative of a marine transgression at these levels. The foraminifera are dominated by Rotaliid forms of the genera *Ammonia* and *Elphidium* . There were no Miliolid foraminifera recorded at 34.08m below OD which indicates a more brackish environment at this level. Other species indicative of saltmarsh and brackish estuarine conditions were present throughout this upper sequence from 34.18 to 34.13m below OD including *Jadammina macrescens*, and *Haynesina germanica*. The Miliolid foraminifera recorded at the upper levels (from 34.03 to 31.58m below OD) included *Massilina secans*, *Miliolinella subrotundata* and *Quinqueloculina dimidiata and Quinqueloculina seminulum* reaching their maximum relative abundance in the uppermost sample at 31.58m below OD. The ecophenotypical variant of *Ammonia beccarii* with the distinctive umbilical boss, (*Ammonia batavus*) indicates a marine connection and together the foraminifera indicate an estuary mouth depositional environment at near to normal marine salinities fringed by brackish marsh environments. The ostracods at these levels are dominated by the smooth form of *Cyprideis torosa* including adult and instar stages and some united carapaces. This ostracod is known as an indicator of estuarine environments and is capable of withstanding extreme fluctuations in salinity. Although *Cyprideis torosa* is a euryhaline taxon that can occur in freshwater to hypersaline conditions (60‰) the smooth form is usually found at salinities of greater than 5‰ (normal marine salinities are 30-35‰). Experiments have shown that the morphology (smooth or noded carapace) is thought to be controlled by a physiological response to salinity (Boomer 2002) rather than balanced genetic polymorphism (ie natural selection) as previously thought (Kilyeni 1972). Other ostracods are indicative of a range of environments including shallow marine *(Aurila convexa, Loxoconcha rhomboidea, Leptocythere pellucida and Paracytherois flexuosa*) estuarine (*Loxoconcha elliptica, Hirschmannia viridis*) and shallow sublittoral and intertidal (*Hemicythere villosa*) environments together support the interpretation of deposition within estuary mouth/shallow marine environment at these levels.

Summary

- A small vegetated freshwater lake containing the ostracods *Metacypris cordata* and *Notodromas monacha* is interpreted at 34.18 and 34.13m below OD
- A significant change to estuarine and shallow marine conditions is noted between 34.08 to 31.58m below OD with slight increase marine conditions noted up profile.

•

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m below SB	5.85	5.7	5.6	5.5	5.45	5.4	5.35	5.3	5.25	5.2	5.15	5.1	5.05	4.22	2.8
Ostracoda / m below OD	34.63	34.48	34.38	34.28	34.23	34.18	34.13	34.08	34.03	33.98	33.93	33.88	33.83	33	31.58
Aurila convexa													x		
Candona sp.										o					
Candona neglecta						x									
Candoniids							x								
Cyprideis torosa smooth								xx	x	x		xx	x	xx	xx
Elofsonella sp.								x	xx						
Elofsonia sp.												x			
Eucythere sp.												x			
Hemicythere villosa														x	
Heterocythereis albomaculata														x	
Heterocythereis sp.															o
Hirschmannia viridis										x					
Leptocythere spp.								x		x					o
Leptocythere pellucida								x	x			x	xx	x	
Limnocythere sp.	o														
Loxoconcha elliptica								o						x	
Loxoconcha rhomboidea								x	x			o		o	x
Loxoconcha sp.										x					
Metacypris cordata						xx	x								
Notodromas monacha							x								
Palmoconcha sp.														x	
Paracytherois flexuosa									o						
Propontocypris sp.												o		o	o
Semicytherura sp.										x				x	
Xesteloberis								o							
Broken/Unidentified							x	x		x		x	x	x	
Fossilised ostracods	x														

Table 1. Ostracods, vibrocore VC7.
Abundance:
o - present
x – 2-9 specimens
xx – 9-50 specimens
xxx – greater than 50 specimens

m below SB	5.85	5.7	5.6	5.5	5.45	5.4	5.35	5.3	5.25	5.2	5.15	5.1	5.05	4.22	2.8
Foraminifera / m below OD	34.63	34.48	34.38	34.28	34.23	34.18	34.13	34.08	34.03	33.98	33.93	33.88	33.83	33	31.58
Ammonia spp.										x				xx	xx
Ammonia batavus								xx	x	xx		xx	x	xx	xx
Ammonia beccarii								xx		xx		xx	x	xx	xx
Astergerinata mamilla										x			x		
Buliminella elegantissima								o				x			
Elphidium sp.								x		xx			x	x	xx
Elphidium crispum										x		xx	x		
Elphidium cuvillieri											o				
Elphidium gerthi														x	
Elphidium macellum										x				x	x
Fursenkoiina fusiformis															
Gavelinopsis praegeri													x		
Haynesina germanica								x	x	xx		xx	x	xx	xx
Jadammina macrescens								x	x	xx		xx	x	xx	xx
Lagena semistriata														x	
Lagena spp.															o
Miliolids									xx	xx		xx		xx	xxx
Massilina secans									o			xx			
Miliolinella subrotunda										x				x	xx
Quinqueloculina dimidiata									o			x	x		
Quinqueloculina seminulum									o			xx	x		
Quinqueloculina sp.										x				x	xx
Rosalina sp.								x							o
Rotaliid													x	xx	xx
Fossil foraminifera	xx	x	x				o		o			x	o		
Unidentified										x					

Table 2.Foraminfera, vibrocore VC7.

Abundance:
o - present
x – 2-9 specimens
xx – 9-50 specimens
xxx – greater than 50 specimens

11 APPENDIX 4: MOLLUSC ANALYSIS

Sarah F Wyles

Introduction

A series of eight samples were selected for the analysis of the preserved molluscan remains from vibrocore **VC7** from the geotechnical investigations of the NemoLink UK-Belgium interconnector.

The samples of between 120 and 250 ml were taken from eight points within the vibrocore (see table below). The samples were processed for the recovery of molluscan remains.

Methods

The samples were processed through flotation through a sieve of 0.25mm mesh sizes. The apical and diagnostic mollusc fragments samples were extracted from the flots and residues. The recovered shells were identified and quantified using stereo incident light microscopy at magnifications of up to x40 using a Leica MS5 microscope and with reference to modern reference collections where appropriate. The results have been tabulated below Habitat preferences follow those described by Kerney (1999) and Barrett and Yonge (1958).

Results

The small assemblages from **VC7** at 34.53 to 34.58m below OD, at 34.48 to 34.53 m below OD and at 34.38 to 34.43 m below OD contained almost equal numbers of land snails and aquatic species. The land snail assemblages appear to be indicative of a damp or marshy grassland environment as suggested by the presence of *Carychium minimum, Succinea/Oxyloma* sp. and *Vertigo substriata*, all species typical of marshy and damp environments. The freshwater species included species which favour well vegetated, slowly flowing aquatic environments with muddy substrates, such as *Bithynia* sp. and *Valvata cristata. Galba truncatula* and *Anisus leucostoma*, however, are more reflective of areas of temporary flooding and marshy grassland.

The very few shells recovered from 34.28 to 34.33m below OD included the aquatic species *Valvata cristata* and *Peringia/Ecrobia* sp.. *Peringia* and *Ecrobia* are indicative of brackish or saltwater environments.

The sample from 34.18 to 34.23m below OD produced a moderately high number of shells of predominantly aquatic species (97%), while a larger assemblage of shells of only aquatic species was observed in the sample from 34.13 to 34.18m below OD. These aquatic species were those found in freshwater rather than brackish or saltwater environments. These assemblages are dominated by species which favour well vegetated, slowly flowing aquatic environments with muddy substrates, such as *Bithynia tentaculata* and *Valvata cristata* although there were some species which prefer areas of temporary flooding and seasonal desiccation.

Large quantities of shells of saltwater or brackish environments were recorded in the samples from 33.98 to 34.03m below OD and 33.93 to 33.88m below OD. No shells of land snails or freshwater species were recovered. The assemblages were dominated by shells of *Peringia ulvae*. There were also a number of shells of *Ecrobia ventrosa*, cockle (*Cerastoderma edule*), *Cerastoderma/Cardium* sp., *Scrobicularia/Tellina* type, mussel (*Mytilus edulis*), saddle oyster (*Anomia ephippium*), top shells (*Gibbula* sp.), rough periwinkle (*Littorina saxtilis*), the Rissoidae family and carpet shells (Veneracea). There were also a shell of *Littorina littoralis* and of sting winkle (*Ocenebra erinacea*) in the lower sample, and shells of variegated scallop (*Chlamys varia*) and *Tellina crassa* in the upper sample.

Peringia ulvae is typically found on muddy or silty surfaces in estuaries, intertidal mudflats and salt marshes and is restricted to brackish or salt water. *Ecrobia ventrosa* however inhabits areas of low to moderate salinities in quiet estuaries, ponds behind shingle bars, and lagoons and drainage ditches in coastal marshes.

Scrobicularia and *Tellina* can inhabit thick mud and muddy sand in estuarine and intertidal conditions, whereas mussels tend to inhabit rocky open shores or rocks within sheltered harbours and estuaries. Variegated scallops can be recovered from the lower shore or below usually on a rocky substrate while cockles can be found in sandy mud on the middle shore or below. Top shells can inhabit the lower part of rocky shores and below and Rissoidae can favour shallow marine environments.

Discussion

The local environment indicated by the mollusc assemblages from **VC7** at 34.38 to 34.58m below OD appears to be one of a well vegetated, slowly flowing aquatic environment with muddy substrates within an area of damp or marshy grassland with some seasonal flooding.

At 34.13 to 34.23m below OD there was an increase in the fresh water environment, with it mainly appearing to be a slowly flowing or still, well vegetated body of fresh water probably with a muddy substrate. There is no indication of any tidal influence within the aquatic environment at this date.

There is a marked transition from this environment to one of saltwater/brackish water at 33.83 to 34.03m below OD. The mollusc assemblages appear to be indicative of a muddy outer estuarine and shallow marine environment.

References

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Core	VC7	VC7	VC7	VC7	VC7	VC7	VC7	VC7
Metres below Ordnance Datum	34.53-34.58	34.48-34.53	34.38-34.43	34.28-34.33	34.18-34.23	34.13-34.18	33.98-34.03	33.83-33.88
Metres below Seabed	5.75-5.80	5.70-5.75	5.60-5.65	5.50-5.55	5.40-5.45	5.35-5.40	5.20-5.25	5.05-5.10
Volume (ml)	175	175	125	175	150	120	175	250
LAND SNAILS (MNI)								
Carychium cf. *minimum* Müller	-	1	1	-	-	-	-	-
Carychium tridentatum (Risso)	3	1	-	-	-	-	-	-
Succinea/Oxyloma spp.	2	5	-	-	-	-	-	-
Cochlicopa spp.	1	1	-	-	-	-	-	-
Vertigo cf. *substriata* (Jeffreys)	-	1	-	-	-	-	-	-
Vertigo spp.	1	-	-	-	-	-	-	-
Vallonia costata (Müller)	-	1	-	-	-	-	-	-
Vallonia spp.	-	-	-	-	1	-	-	-
Dercoceras/Limax	2	2	1	-	-	-	-	-
Trochulus hispidus (Linnaeus)	1	1	-	-	-	-	-	-
Cepaea/Arianta sp.	-	1	-	-	1	-	-	-
Aquatic Snails (MNI)								
Valvata cristata Müller	4	7	-	1	47	77	-	-
Bithynia tentaculata (Linnaeus)	-	-	-	-	1	6	-	-
Bithynia spp.	2	2	-	-	6	35	-	-
Bithynia opercula	9	9	2	-	15	160	-	-
Galba truncatula (Müller)	1	-	3	-	3	1	-	-
Lymnaea palustris (Müller)	-	-	-	-	-	1	-	-
Radix balthica (Linnaeus)	-	-	-	-	-	2	-	-
Lymnaea/Galba/Radix spp.	-	2	-	-	2	-	-	-
Planorbis planorbis (Linnaeus)	1	-	-	-	2	4	-	-
Planorbis carinatus Müller	-	-	-	-	-	2	-	-
Anisus leucostoma (Millet)	1	-	-	-	1	9	-	-
Bathyomphalus contortus (Linnaeus)	-	-	-	-	1	3	-	-
Gyraulus crista (Linnaeus)	-	1	-	-	1	3	-	-
Hippeutis complanatus (Linnaeus)	-	1	-	-	-	4	-	-
Planorbids	1	-	-	-	2	-	-	-
Acroloxus lacustris (Linnaeus)	-	-	-	-	-	2	-	-
Pisidium spp.	-	1	1	-	-	-	-	-
Peringia ulvae	-	-	-	-	-	-	25	55
Ecrobia ventrosa	-	-	-	-	-	-	2	7
Peringia/Ecrobia sp	-	1	-	1	-	-	180	271
Chlamys cf. *varia*	-	-	-	-	-	-	-	3
Chlamys sp.	-	-	-	-	-	-	-	1
Cerastoderma edule	-	-	-	-	-	-	1	4

Core	VC7	VC7	VC7	VC7	VC7	VC7	VC7	VC7
Metres below Ordnance Datum	34.53-34.58	34.48-34.53	34.38-34.43	34.28-34.33	34.18-34.23	34.13-34.18	33.98-34.03	33.83-33.88
Metres below Seabed	5.75-5.80	5.70-5.75	5.60-5.65	5.50-5.55	5.40-5.45	5.35-5.40	5.20-5.25	5.05-5.10
Volume (ml)	175	175	125	175	150	120	175	250
Cerastoderma/Cardium sp.	-	-	-	-	-	-	4	11
Tellina cf. *crassa*	-	-	-	-	-	-	-	2
Tellina/Scrobicularia type	-	-	-	-	-	-	2	13
Mytilus edulis	-	-	-	-	-	-	1	4
Anomia ephippium	-	-	-	-	-	-	1	1
Gibbula sp.	-	-	-	-	-	-	5	2
Littorina cf. *saxtilis*	-	-	-	-	-	-	3	3
Littorina cf. *littoralis*	-	-	-	-	-	-	1	-
Rissoidae	-	-	-	-	-	-	18	30
Veneracea	-	-	-	-	-	-	9	8
Ocenebra erinacea	-	-	-	-	-	-	1	-
Operculum	-	-	-	-	-	-	-	2
Taxa	11	16	4	2	9	12	12	11
Total (MNI)	20	29	6	2	68	149	253	415
Total (MNI) Land snails	10	14	2	0	2	0	0	0
Total (MNI) Aquatic snails	10	15	4	2	66	149	253	415

Molluscs from VC7

Key: MNI = minimum number of individuals

12 APPENDIX 5: PUBLICATION SYNOPSIS

Publication Synopsis for *Archaeologia Cantiana*

Title – Mesolithic geoarchaeological investigations in the Outer Thames Estuary

Jack Russell

Wessex Archaeology

Introduction – [100 words]

Project Background [300 words]

- Windfarm/cabling engineering
- Geotechnical work
- Planning

Archaeological Background [300 words]

- Mesolithic archaeology general (marine)
- Marine prehistoric archaeology (southern North Sea)
- Mesolithic archaeology Kent/Essex coast

Palaeoenvironmental backround [200 words]

- relative sea level
- past environments

Methods [400 words]

- Vibrocoring
- Staged approach Stages 1 through 4 assessment - analysis

Results [750 words]

- Geoarchaeology sediments and stratigraphy
- Pollen
- Diatoms
- Foraminfera/Ostracods
- Molluscs
- Plant macrofossils

Discussion (750 words)

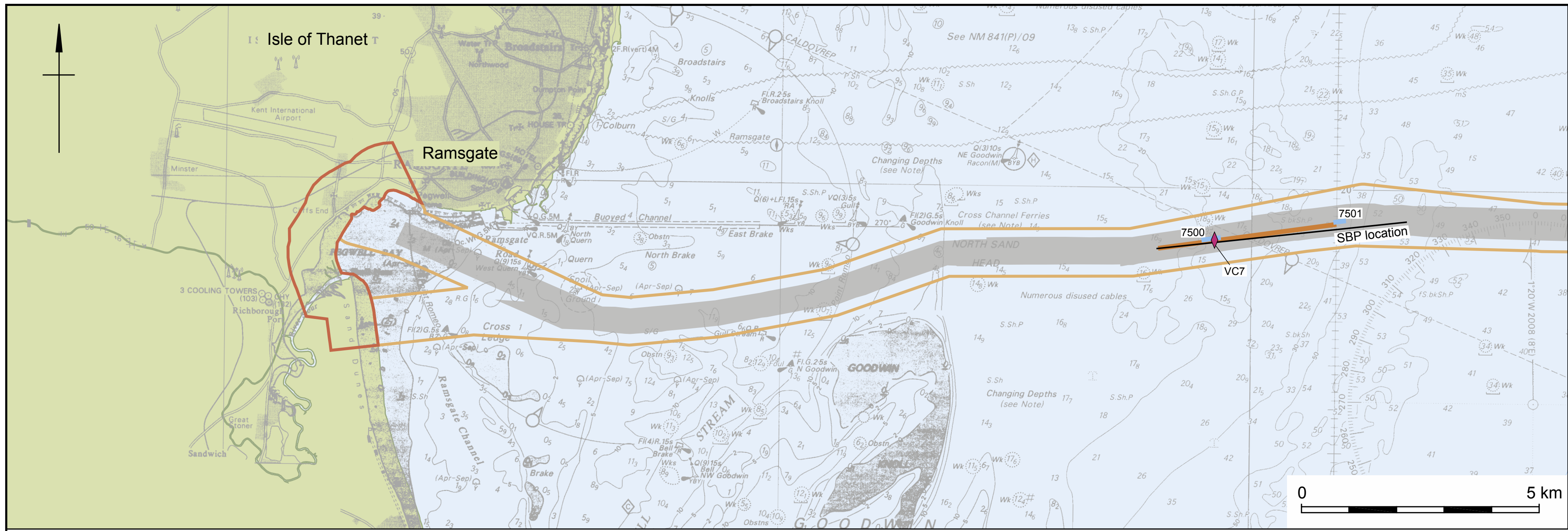
- Sea level/ past environment
- Offshore prehistory (Southern North Sea/ Outer Thames Estuary)
- Mesolithic archaeology (predominantly Kent but also Essex/ Northern Europe)

- Lessons learned/future research

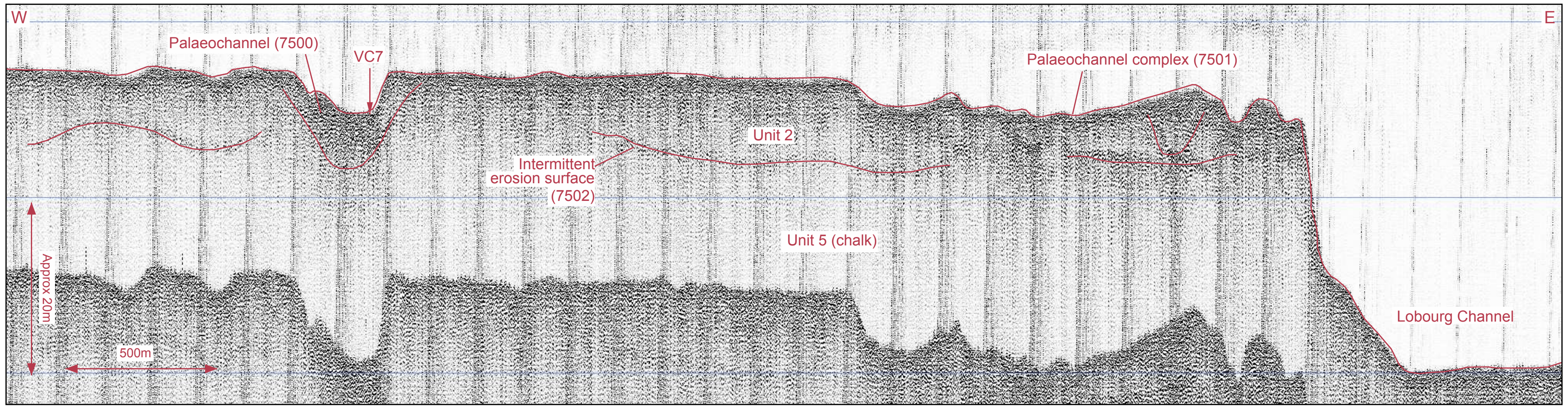
Acknowledgements [200 words]

Illustrations (tbc)

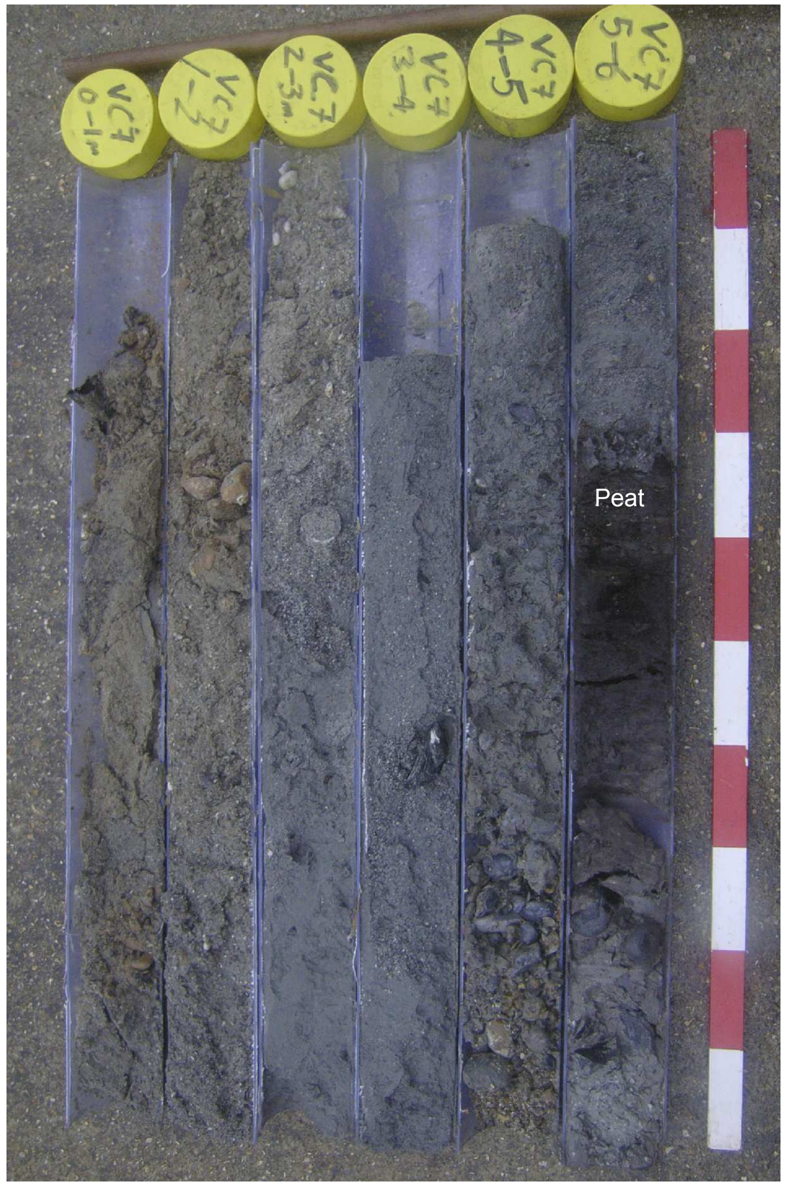
- Location map
- Diagram showing radiocarbon dates vs stratigraphy
- Pollen diagrams
- Diatom diagrams



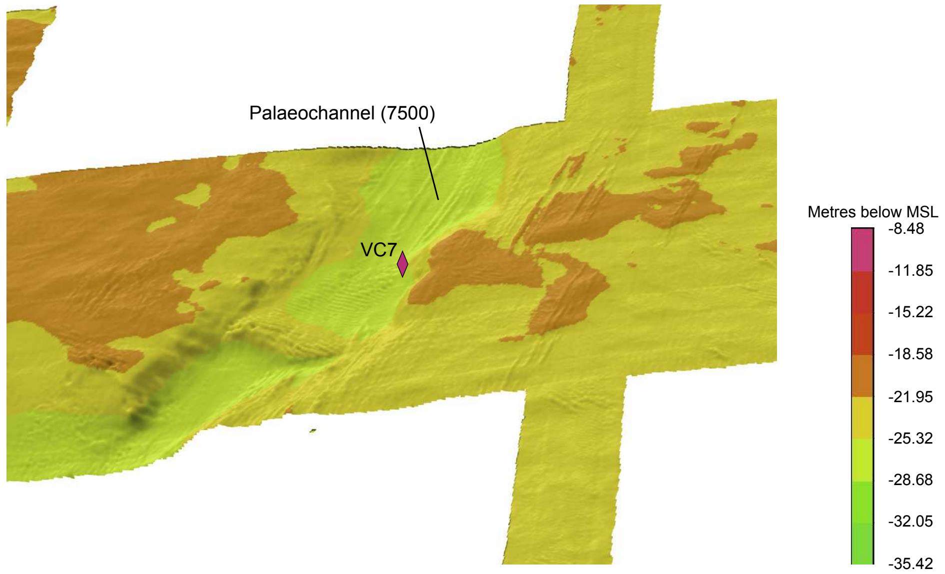
Site location



Sub-bottom profiler data example



VC7 photographic log

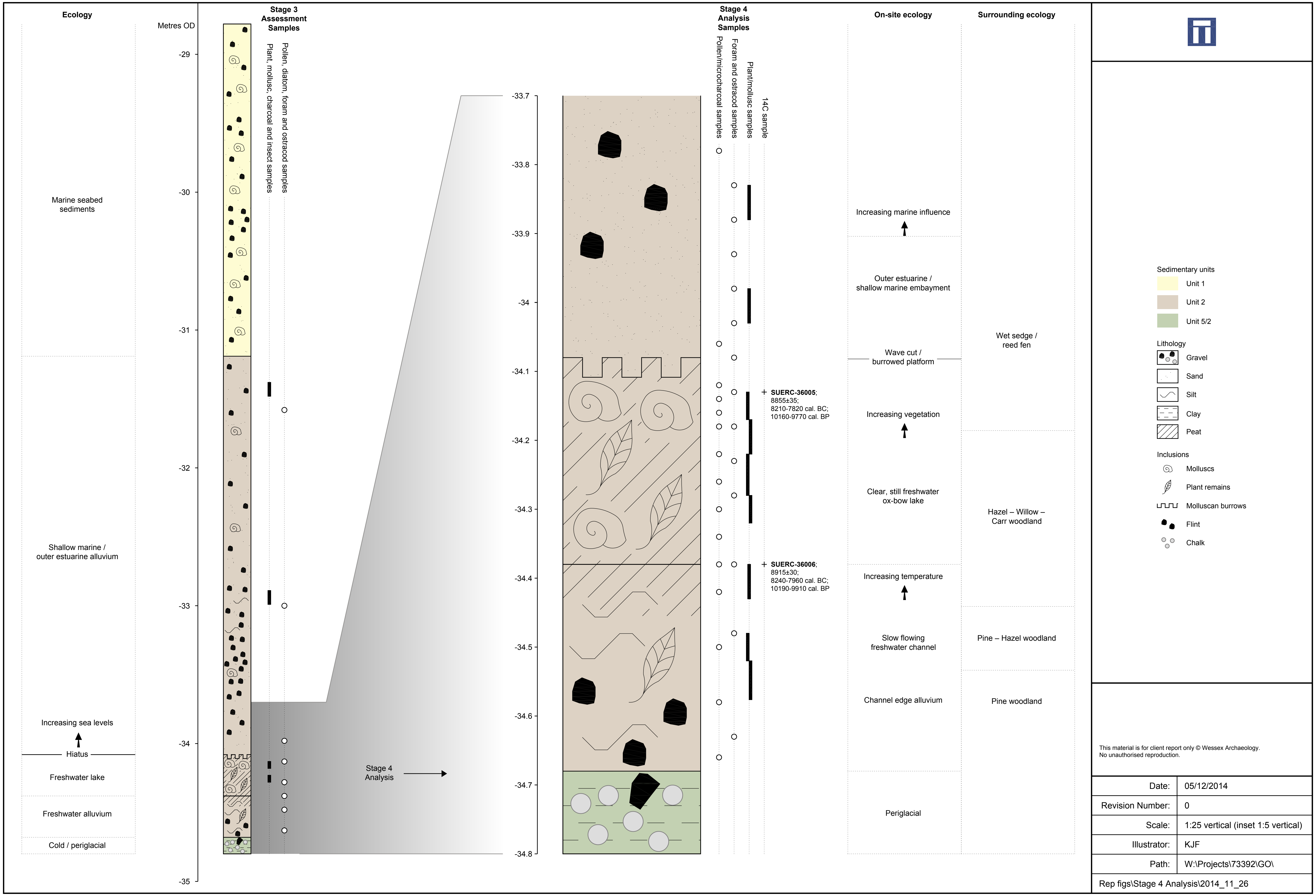


Multibeam bathymetry (facing north at x10 vertical exaggeration)

Drawing Projection: UTM WGS84 Z31N
Admiralty Chart 323 (dated 2008)

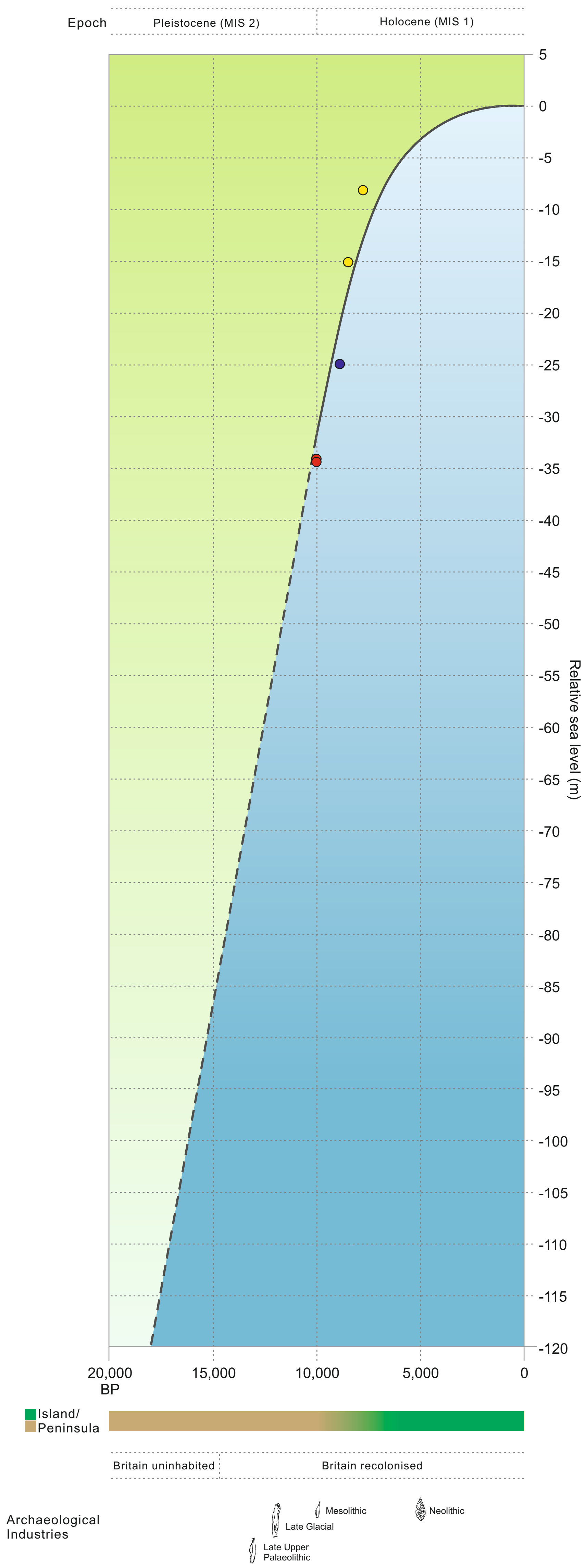
- Kent Landfall Study Area
- English Waters Study Area
- 12 nautical mile limit (approximate location)
- Geophysical Extents
- Palaeochannel at surface
- Erosion surface
- Vibrocore location

Date:	26/11/2014	Revision Number:	0
Scale:	SBP 1:20,000, Location inset 1:125,000 @A3	Illustrator:	KJF
Path:	W:\Projects\73392\Graphics_Office\Rep figs\Stage 4 Analysis\2014_11_26		



Vibrocore VC7, sediments and samples

Figure 2

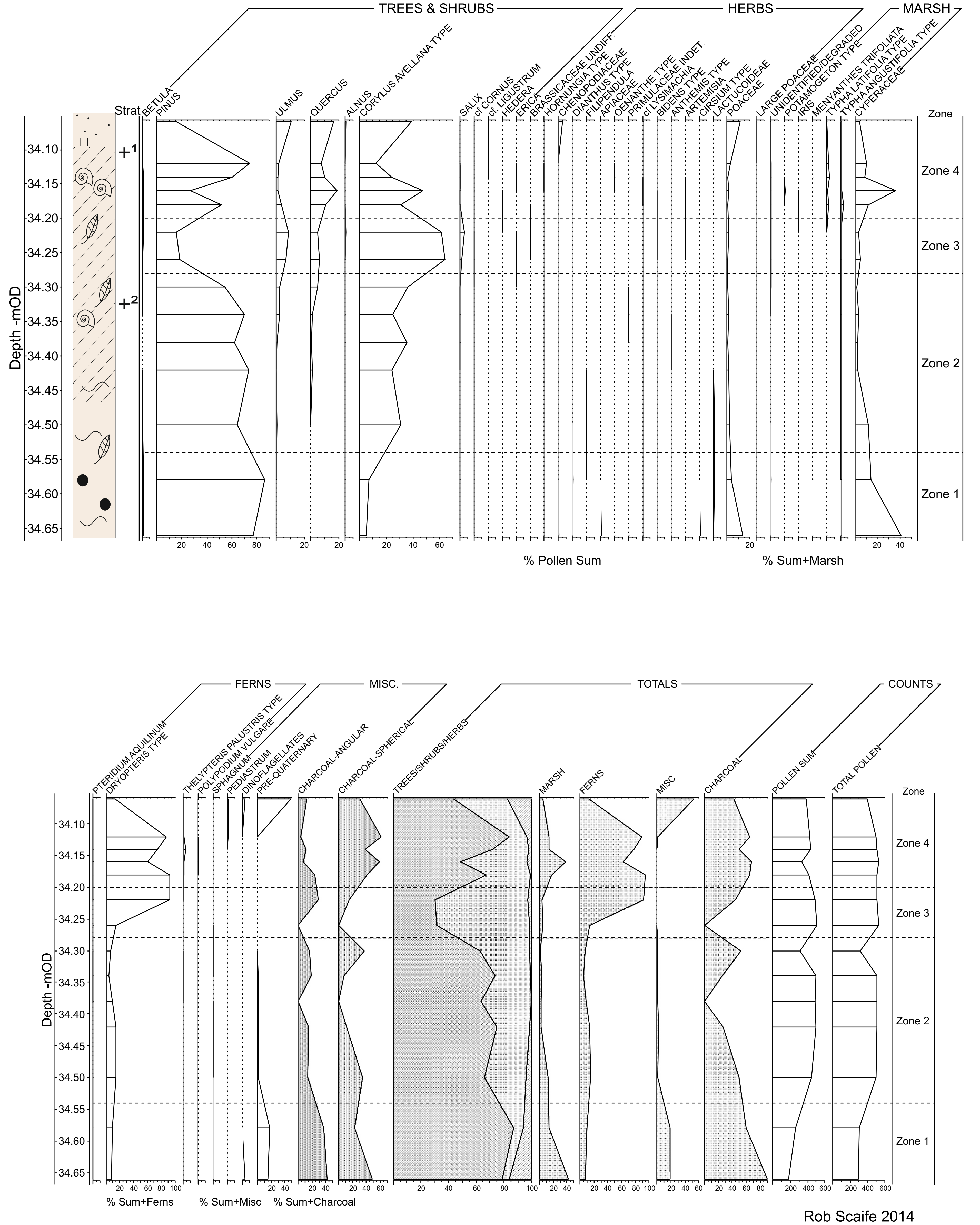


Relative sea level from Shennan and Horton, 2002
Relative sea level extrapolated from Siddal *et al.*, 2003
Project NEMO ^{14}C dates
London Array OWF ^{14}C dates (WA, 2009)
Britned Interconnector ^{14}C dates (Russell, 2011)

Date:	26/11/2014	Revision Number:	0
Scale:	N/A	Illustrator:	KJF
Path:	W:\Projects\73392\Graphics_Office\Rep figs\Stage 4 Analysis\2014_11_26		

Sea level curve and radiocarbon dates

Figure 3



Sedimentary units

Unit 2

Lithology

Sand

Gravel (flint)

Silt

Peat

Inclusions

Plant remains

Molluscs

C14

+1 **SUERC-36005**; 8855±35; 8210-7820 cal. BC; 10160-9770 cal. BP

+2 **SUERC-36006**; 8915±30; 8240-7960 cal. BC; 10190-9910 cal. BP

Date:	26/11/12	Revision Number:	0
Scale:	N/A	Illustrator:	KJF
Path:	W:\Projects\73392\Graphics_Office\Rep figs\Stage 4 Analysis\2014_11_26		

VC7 pollen and microcharcoal diagram

Figure 4

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