DONG ENERGY

Gunfleet Sands 3 Demonstration Project

Stage 4 Geoarchaeological Analysis Report

June, 2017

MARITIME ARCHAEOLOGY LTD

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Non-technical summary

This report presents a Stage 4 geoarchaeological assessment (analysis and dating) for the Gunfleet Sands 03 (GFS03) Demonstration Project on behalf of DONG Energy ("the Client"). This work forms the final part of the archaeological WSI Work Package 1 - *Archaeological Assessment of Boreholes/ Vibrocores* with the aim of developing a deposit model for the Project Site.

The staged approach to the archaeological and palaeoenvironmental investigation of the cores is outlined below and explained in: *Historic and Offshore Geotechnical Investigations and Historic Environment Analysis guidance* (COWRIE, 2011).

The four Stages are:

- Stage 1 – Archaeological review of geotechnical logs and (where practical) archaeological presence during core extraction (MA Ltd., 2012b, 2012c);
- Stage 2 – Splitting and recording cores (MA Ltd. 2012b, 2012c);
- Stage 3 – Sub-sampling and assessment (MA Ltd. 2013), and;
- Stage 4 – Analysis and dating (this report).

Prior to the installation of the Project and the offshore export cable connecting GFS03 to an onshore substation, an archaeological review and assessment of boreholes collected onshore and vibrocores collected along the offshore export cable route was undertaken (Geoarchaeological assessment Stages 1 -3: MA Ltd., 2012b, 2012c and 2013). The cores were collected in order to mitigate the impact of the Demonstration Project and the export cable route installation by providing archaeological information as specified in the Archaeological Written Scheme of Investigation (WSI) (MA Ltd., 2012d).

Through a Stage 2 assessment of the cores, a relatively uniform sequence of deposits was identified. These appeared to be associated with both Holocene and Pleistocene channels and were thought likely to be representative of in-fill deposits that demonstrate a long sequence of development (MA Ltd., 2012b 2012c). In order to fully understand the deposits and the evidence the cores provide on the palaeoenvironmental and geomorphological development of this area, further sampling and assessment was recommended.

The aims of the Stage 3 geoarchaeological assessment were to sub-sample and assess the sediments present in the cores for environmental indicators and identify sediments that contain material that could yield useful palaeoenvironmental and geomorphological information. The results from the Stage 3 assessment indicated that the sub-sampled sediments contained useful environmental indicators. This was visible in the pollen, diatom, foraminifera and plant records. The sub-samples showed that the sediments were generally coastal sediments containing marine plants, various foraminifera, molluscs and diatoms.

The Stage 4 geoarchaeological analysis (this report) follows the recommendations previously made by MA Ltd. (MA Ltd., 2013). The key aim of Stage 4 is to provide an account of the successive environments within the coring area, a model of environmental change over time, and an outline of the archaeological implications of the analysis.

This Stage 4 analysis has confirmed that the Holocene deposit formed in a wetland estuarine environment that became inundated around 7081-6831 Cal BC (SUERC-54108). The ecology represented by diatoms, microfauna, pollen, and macrofossils, shows that the area was mainly a brackish coastal saltmarsh with a possible freshwater input. The proximity

of the site to dry land and woodlands is indicated by regional flora comprising oak (*Quercus*) and hazel (*Corylus*) also with some indications of elm (*Ulmus*) and beech (*Fagus*). The archaeological record from this period has demonstrated both estuarine and freshwater settings that are attractive for human occupation.

The Stage 4 geoarchaeological assessment of sub-samples from the collected cores has identified an area of high archaeological potential. While much of the relict landscape has eroded away, pockets of organic rich sediments associated with cultural landscapes remain.

2 Introduction

Maritime Archaeology Ltd. (MA Ltd.) has been commissioned by DONG Energy to provide an archaeological analysis of sub-samples derived from boreholes and vibrocores collected onshore and offshore along the export cable route related to the Gunfleet Sands 3 Demonstration Project. This report details the analysis and dating of sub-samples derived from the cores with the aim of providing an account of the successive environments within the Project Site.

2.1 Brief Scheme Background

The Gunfleet Sands (GFS) offshore wind farm, is located approximately 8.5 km southeast of Clacton-on-Sea in Essex. It consists of the operational GFS 1 and GFS 2 projects. Consent was granted for GFS 1 in 2004 and for GFS 2 in 2008. The combined GFS 1 and 2 projects consist of 48 operational turbines. The development is situated within the 12 nm territorial limit of England.

In August 2010, DONG Energy was awarded a demonstration lease by The Crown Estate for a site to the south-west of the GFS 2 array to construct two demonstration turbines. This is known as the Gunfleet Sands 3 - Demonstration Project (GFS 3), (**Figure 1)**. The majority of the GFS 3 site (approximately 80%) lies within the originally consented GFS 2 site. The GFS 3 turbines required an additional export cable to connect the turbines to land as the cable associated with GFS 1 and 2 was not sufficient to allow maximum capacity use of the GFS 3 turbines.

An Environmental Statement (ES) was initially produced for GFS 3 when it was planned to utilise the existing export cable from GFS 1 and 2 (DONG Energy, 2010); this drew on works previously undertaken in relation to the GFS 1 and 2 sites. However, due to the requirement for an additional export cable, the Marine Management Organisation (MMO) requested an addendum to the ES to cover the revised scope of works for the entire GFS 3 scheme. DONG Energy has produced two addendum reports:

- GFS 3 Onshore Addendum (considering all work above Mean High Water Spring (MHWS) (DONG Energy, 2011a); and
- GFS 3 Offshore Addendum (considering all work below MHWS) (DONG Energy, 2011b).

The Onshore and Offshore ES Addendum documents identify the known and potential archaeology within the development area, review potential impacts and put forward mitigation proposals.

Further survey data was gathered in 2011 in the near-shore zone and in 2012 along the cable route for the purposes of planning the final path of the export cable route. An archaeological review of the data was undertaken by Maritime Archaeology Ltd in July, 2012 (MA Ltd., 2012a).

The geoarchaeological and palaeoenvironmental potential has previously been assessed by MA Ltd., *Gunfleet Sands 3: Demonstration Project- Assessment of Onshore Core Samples* (MA Ltd., 2012b) focused on Stage 2 assessment of the cores collected from the onshore area, *Gunfleet Sands 3: Demonstration Project- Archaeological Assessment of Offshore*

Geotechnical Cores (MA Ltd., 2012c) assessed the 18 vibrocores collected in the offshore zone for Stage 2 archaeological potential. *Gunfleet Sands 3: Demonstration Project - Stage 3 Geoarchaeological Assessment Report* (MA Ltd., 2013) describes the results of sub-sampling and assessment of the sediments present in the cores for environmental indicators.

This Stage 4 report follows the recommendations put forward by MA Ltd. in 2013 (MA Ltd., 2013) regarding the environmental indicators identified during the geoarchaeological Stage 3 assessment.

2.2 PROJECT DESIGN DETAILS

The GFS 3 project involved the construction of two steel monopiles with a 6 m diameter within the previously consented area of GFS 2. The test turbines were installed in January 2013 and officially inaugurated in September 2013. The construction design utilises one layer of scour protection around the turbine bases up to a radius of 20-25 m. The turbines are connected to land through an export cable which reaches landfall at the Martello Bay coach and car park to the east of the junction of West Road and Hastings Avenue, Clacton-on-Sea, Essex. An initial archaeological and palaeoenvironmental review of the onshore cable route and transition jointing bay was undertaken by MA Ltd. in 2012 (MA Ltd., 2012b).

Installation of the GFS 3 export cable between the marine and terrestrial area required Horizontal Directional Drilling (HDD) to establish a landfall under the beach. The wind turbine generators are connected to the substation with a three core export transmission cable. From this point the cable was laid for approximately 9 km until it reached the wind turbines located circa 8.5 km southeast of Clacton-on-Sea.

2.2.1 Geotechnical campaigns

During the two geotechnical campaigns, a total of five cone penetration tests (CPTU), one MOSTAP, seven boreholes and 18 offshore vibrocores were collected in the development area (**Figure 2** and **3**).

Four boreholes (101A_1, 101A_2, 101B and 103) and two CPTU tests (101 and 101a) were drilled within the Transition Jointing Bay (TJB) and the associated mud-pit. Within the northern area of the terrestrial cable trench, three boreholes (104-106) were drilled to a depth that reached the London Clay at 4-5.2 m. Four CPTU tests (112B, 112C, 112D and 112E) were collected within the intertidal zone (sea defence to surf zone). A MOSTAP sample was taken coincident with CPTU 112D.

Along the export cable route, three vibrocores (113, 114 and 115) were drilled within the area of the planned HDD works. The vibrocores were drilled to depths between 2.10 - 2.22 m below seabed. Seven vibrocores (201-207) were positioned along the export cable route based on the seismic interpretation undertaken by Wessex Archaeology (DONG Energy, 2011b) in order to target potential pre-historic channel deposits.

Five additional vibrocores (301-305) were collected for geotechnical purposes; the locations of the cores have been determined by engineering requirements. All the geotechnical cores discussed above were reviewed for archaeological potential (MA Ltd., 2012b, 2012c).

Sub-samples from the above cores were gathered as a part of this assessment based on the results previously recommended (MA Ltd., 2012c).

2.3 AGREED MITIGATION APPROACH

This Stage 4 geoarchaeological assessment follows the recommendations previously made by MA Ltd. (MA Ltd., 2013).

This work forms part of Work Package 1 (*Archaeological Assessment of Boreholes/ Vibrocores*) with the aim of developing a deposit model for the development area. The staged approach to the archaeological and palaeoenvironmental investigation of the cores is outlined below and within the agreed WSI for the development (MA Ltd., 2012d).

The 4 Stages are:

- Stage 1 – Archaeological review of geotechnical logs and (where practical) archaeological presence during core extraction (MA Ltd., 2012b, 2012c)
- Stage 2 – Splitting and recording geotechnical/ archaeological cores (MA Ltd. 2012b, 2012c)
- Stage 3 – Sub-sampling and assessment (MA Ltd., 2013)
- Stage 4 – Analysis and dating (this report)

The compensatory mitigation of impact on palaeoenvironmental deposits is based on the idea that while the deposits will be impacted by the development, the sediments recovered as a result of such impact contain a potential for increased human knowledge in relation to palaeolandscapes. Such increased knowledge is deemed to offset low level impact if the assessment results are used to develop a deposit model (or sedimentary sequence model) and are released into the public domain.

2.4 PROJECT AIMS AND OBJECTIVES

The aim of Stage 4 is to provide an account of the successive environments within the coring area, a model of environmental change over time, and an outline of the archaeological implications of the analysis.

The objectives of the Stage 4 analysis are to:

- further characterise and date submerged sedimentary deposits and prehistoric features;
- identify a date for the marine inundation of the area and increase the understanding of the changing landscape;
- contribute in-depth ecological and environmental information for the study area, and;
- develop the understanding of potential for early human occupation in the Clacton Channels area.

3 Methodology

3.1 Approach

MA Ltd. is a Registered Organisation with the Institute for Archaeologists (IfA). MA Ltd. conducts all projects and negotiations in accordance with the guidance and principles established in the IfA's *Code of Conduct* (2013) and *Code of approved practice for the regulation of contractual arrangements in archaeology* (2008).

This project has been formulated according to the approach and best-practice contained in IfA *Standard and Guidance for historic environment desk-based assessment* (2012), *Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Sector* (COWRIE, 2011) and English Heritages' documents; *Geoarchaeology- Using Earth Sciences to understand the archaeological record* (English Heritage, 2007), *Guidelines for the Curation of Waterlogged Macroscopic Plant and Invertebrate Remains* (English heritage, 2008) and *Environmental Archaeology – A guide to the Theory and Practice of Methods, from Sampling and Recovery to Post-excavation* (English Heritage, 2011).

3.2 Sampling strategy

As stated in the GFS 3 Geoarchaeological Stage 3 Assessment report (MA Ltd., 2013), cores 202A, 207, 304 and 101B and the Units within the cores (**Figure 4**) were selected for Stage 4 analysis as the cores demonstrated sufficient material and were therefore likely to successfully yield information suitable for dating and further environmental analysis. The alluvial sequence (Unit 6), including the alluvial deposit with organic banding (Unit 5) and the basal gravely sequence (Unit 4), appeared to be comparable to the Holocene sediments also encountered on the onshore area (MA Ltd, 2012d). The Stage 3 assessment showed that Units 6 and 5 are probably marine/wetland deposited sediment, containing a high amount of environmental indicators. In contrast, Unit 4 has been understood as a Holocene lag deposit and appears to contain little material worthy of further analysis (MA Ltd, 2013). The alluvial Unit 3 and the basal gravel Unit 2 are more likely to be related to the earlier Pleistocene Clacton Channel deposit. The Stage 3 assessment located some environmental evidence in Unit 3, but as the preservation conditions in the sediment were poor it was doubtful that any further analysis of the deeper sediments was to be beneficial (MA Ltd, 2013), and therefore no further sampling was undertaken on Units 2-4.

Consequently, samples focused on dating and analysing Units 5 and 6 to enable a relative sequence to be constructed. In turn, these results have aided the understanding of the stratigraphic relationships and changes within the sedimentary features and the marine inundation of the area.

3.3 Pollen

Pollen is a valuable tool for reconstructing past environments. It can provide an understanding of the environmental landscape, economy and prehistoric human culture (English Heritage, 2011). Pollen are produced by higher plants (Vascular plants) and can, with the help of wind and/or water, travel relatively far. Pollen should therefore ideally be analysed with other environmental proxy evidence in order to gain a comprehensive understanding of the deposits (English Heritage, 2011).

For this Stage 4 assessment, sediment samples of 1.5 - 2 ml volume were processed using standard techniques for the extraction of the sub-fossil pollen and spores (Moore and Webb 1978; Moore *et al.,* 1991). Where pollen was present, a total pollen count of between 150-260 well preserved grains per sample was conducted. All fern spores and pre-Quaternary palynomorphs were also counted for each of the samples analysed.

The pollen count data is included in **Appendix I.** There were too few pollen samples to justify drawing pollen diagrams. These procedures were carried out in the Palaeoecology Laboratory of the Department of Geography, University of Southampton.

The full specialist report produced by Dr. Rob Scaife of the pollen analysis is available in **Appendix I.**

3.4 DIATOMS

Diatoms are freshwater and marine algae. As the species are habitat-specific they can be used to indicate water quality, water temperature and salinity, nutrient and mineral levels, acidity and degree of oxygenation. Diatoms are most useful when investigating coastal and estuarine sites, providing data on marine influence and phases of sea-level change (English Heritage, 2011)

A total of 12 sub-samples were examined for their diatom content. Examination of these were undertaken primarily to establish whether diatoms were present in the sediments and, if so, to indicate the depositional environment; that is, to reconstruct the aquatic environment. At this site the former salinity conditions are of particular relevance for the geoarchaeological investigation.

Diatom preparation, counting and analysis followed standard techniques (Battarbee *et al*., 2001). Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendey (1964), Werff & Huls (1957-1974), Hartley *et al*., (1996), Krammer & Lange-Bertalot (1986-1991) and Witkowski *et al*., (2000). Diatom species' salinity preferences are discussed in part using the classification data in Denys (1992), Vos & de Wolf (1988, 1993) and the halobian groups of Hustedt (1953 and 1957:199). Diatom data were plotted using the 'C2' program (Juggins, 2003).

The full specialist report of the diatom analysis produced by Dr. Nigel Cameron is included as **Appendix II**.

3.5 MICROFAUNA: FORAMINIFERA AND OSTRACODS

Foraminifera are particularly valuable at coastal sites where changes in freshwater and marine influence are important. Foraminifera are marine protists that survive best in non-acidic conditions. They are found in habitats ranging from salt marshes to the deep oceans. Ideally foraminifera should be analysed in conjunction with diatoms (English Heritage, 2011).

Ostracods are small (normally < 2 mm), bivalve crustaceans with calcareous shells, that survive almost any non-acidic, water-lain deposit. Ostracod analyses can reveal subtle changes in environments and should be considered as a useful technique to complement mollusc, diatom and foraminiferan analyses (English Heritage, 2011).

For the Stage 4 analysis a total of 12 samples from 4 cores were analysed. The samples were dried and then a small amount of sodium carbonate was added to disperse any clay fraction. After leaving to soak in hot water over night, the sample was then washed through a 75 µm sieve and residues saved for final drying in the oven. Next, each residue was put through a nest of small sieves (>500, >250, >150 µm) with a base pan. A little residue at a time from each grade was sprinkled onto a tray and a representative selection of foraminifera and ostracods was picked out under a binocular microscope and stored in a 3x1" faunal slide for archive purposes. Notes were made of the "organic remains" that were seen and these were logged on a presence(x)/absence basis, whereas the foraminifera and ostracod species were logged semi-quantitatively.

The full specialist report of the microfauna analysis produced by Dr. John Whittaker is presented in **Appendix III**.

3.6 MOLLUSCS

Mollusc shells are used to reconstruct past environments and to help model land and coastal changes over time. Molluscs can be found with straight or coiled shells, called gastropods, or with paired shells, called bivalves. They live in a wide range of conditions in fresh, brackish and salt water and on land. Each part of the land and coast usually has a characteristic range of snail species, and some species live only in specific conditions (English Heritage, 2011).

Only samples from vibrocore 304 were analysed for mollusc content. The mollusc's samples were washed through a 0.5 mm or a 75 µm sieve to remove fine sediment, leaving coarse sediment and calcareous shell material from *Bivalvia* and *Gastropoda*. When the samples were dry they were checked in a sorting tray, and individual specimens were removed for identification using a Kyowa SDZ PL microscope.

Where feasible, the shells were identified to species level to provide an indication of habitat and environment.

The full specialist report of the mollusc analysis produced by Dr. Simon Bray is included as **Appendix IV**.

3.7 MACROSCOPIC PLANTS AND INSECT REMAINS

Macroscopic plant remains are most commonly preserved by waterlogging or by mineralisation. Fruits, seeds, flowers, leaves, stems, insects, molluscs, etc., are all valuable indicators when reconstructing past landscape.

The review of the macroscopic plant and insect remains for this Stage 4 analysis was undertaken to collect organic material suitable for dating and to identify macrofossils for an increased understanding of the environment.

The samples were prepared by initial disaggregation in water and then sieved in a 2000 µm sieve. Material larger than 2000 µm was inspected for large plant and organic remains and the residual was saved. The resultant material was collected and assessed.

The full specialist report of the macroscopic plants and insect remains analysis produced by Julie Jones is presented in **Appendix V**.

3.8 RADIOCARBON DATING

Organic sub-samples collected during the macroscopic plant and insect analysis that had the potential to yield reliable dates were analysed by the Scottish Universities Environmental Research Centre (SUERC) C14 laboratory in Glasgow. Six samples were sent for dating. Three of the samples contained enough material for Accelerator Mass Spectrometry (AMS) measurements.

The c14 age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error. The carbon isotope ratios have been measured against Vienna Pee Dee Belemnite (VPDB)

The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal v4). Marine calibration curve based on Reimer et al (2013).

The full specialist report from the c14 dating is presented in **Appendix VI**.

3.9 INTERPRETATION OF THE RESULTS

The results from the specialists' reports were assessed and reviewed against the current understanding of the Pleistocene and Holocene sediments within the development area (MA Ltd., 2012b & 2012c, MA Ltd., 2013).

4 Results

Section 4 summarises the results from the sample analyses. Detailed methodology, individual analysis and discussion of results can be found in **Appendices I-VI**.

4.1 POLLEN

The section below summarises the result from the pollen analysis. For a full report refer to **Appendix I**.

The Stage 4 analysis showed that Holocene pollen is absent in cores 202A, 304 and 104. These profiles are very minerogenic with little humic content. Whilst pollen can be recovered from such sub-marine sediment, this is very infrequent, especially in sediment profiles from the North Sea where preservation is notoriously variable. The absence of pollen and/or differential preservation in favour of spores and pre-Quaternary palynomorphs is attributed to the poor preserving environment (chemical and mechanical deterioration) and/or phases of rapid sedimentation.

Core 101B

Three samples have been examined showing pollen to be well preserved and relatively abundant in this profile. This is largely due to the organic character of the sediment. Overall, herbs are dominant due to the strongly autochthonous component. Total pollen counts of up to 260 pollen grains were made.

The characteristics of the pollen assemblages are:

Trees and shrubs: Arboreal pollen is more abundant in the basal sample (4.10 m) with *Pinus* (pine), *Quercus* (oak) and *Corylus avellana* type (hazel or bog myrtle). There are also small numbers/sporadic occurrences of *Picea* (spruce), *Ulmus* (elm) and possible *Fagus* (beech). There are fewer tree and shrub pollen in the upper samples although *Abies* (fir) is noted at 3.70 m and *Alnus* (alder) is present.

Herbs: All samples are dominated by *Chenopodiaceae* (goosefoot, oraches and samphire) with *Poaceae* (grasses). Other herbs include, along with the *Chenopodiaceae*, a strong halophytic element with *Plantago maritima* (sea plantain), *Armeria* (sea lavender or thrift), *Spergularia* (spurrey) and possibly less discernible types (through pollen morphology) such as the *Asteraceae* taxa. Other than halophytes, *Plantago lanceolata* (ribwort plantain) and cereal type are also recorded.

Aquatic and marsh: Apart from the autochthonous halophytes, numbers and diversity of aquatic taxa are low with *Cyperaceae* (sedges), *Potamogeton* type (pondweed but may be *Triglochin*/arrow grass) and cysts of freshwater algal *Pediastrum* (esp. the basal sample at 4.10 m).

Ferns: Only the lower sample at 4.10 m has any appreciable representation of fern spores. These comprise largely monolete forms of *Dryopteris* type (typical ferns). Other fern taxa include *Pteridium aquilinum* (bracken) and *Polypodium* (polypody fern).

Miscellaneous: With the exception of the more organic upper sample at 3.10 m, there are substantial numbers of reworked pre-Quaternary palynomorphs. These are especially abundant in the lowest sample (4.11 m). There are also Hystrichospheres/Dinoflagellates which are also thought to be reworked and some *Pediastrum* (noted above).

Core 207

This is a thin humic silt and peat horizon of some 15 cm thickness. Four samples were examined of which three contained pollen but in low numbers. Overall, these are dominated by autochthonous salt marsh plants with a moderate representation of tree taxa from off-site regional sources. Total counts of between 150 and 250 pollen grains were made.

The characteristics of the pollen assemblages are as follows.

Trees and shrubs: *Quercus* and *Corylus avellana* are the most consistent types. However, *Ulmus*, *Pinus* and *Tilia* (lime/linden) are also of note. There are occasional occurrences of *Alnus* and *Salix* (willow at 0.74-6 m).

Herbs: Halophytes comprising *Chenopodiaceae* are dominant in all of the samples with very high numbers. Other salt marsh taxa include *Armeria* 'A; and 'B' line and *Potamogeton* type which may be *Triglochin maritima*. Other than these, the herb diversity is small with only small numbers of *Poaceae* and occasional *Cyperaceae*.

Ferns: Numbers of fern spores are generally small with *Dryopteris* type most important in the lowest sample (0.70-0.72 m). Occasional *Pteridium aquilinu*m and *Polypodium* are present.

For a complete analysis of the samples, refer to **Appendix I**.

4.2 DIATOMS

The samples selected and prepared for diatom analysis and a summary of the diatom assessment results are shown in **Table 1** below, for the full report refer to **Appendix II**.

Diatoms were absent in seven of the 12 samples examined. Of the remaining samples, only three have useful numbers which allowed numerical counts to be made, whilst other samples provide useful environmental indicators.

Three samples were analysed from Vibrocore 101B (D10, D11 and D12). The diatom assemblages are dominated by brackish-marine, mesohalobous diatoms which increase from 40% at the base of the sequence to 90% of the total diatoms at the top of the sequence. The abundance of this open water, polyhalobous species at the base of the sequence suggests that initially there was a greater input of diatoms from deeper water. However, inputs of both aerophilous and acidophilous oligohalobous indifferent diatoms, which reach a maximum of 12% at the base of the core, reflect the in-wash of terrestrial material.

For a complete analysis of the samples, refer to **Appendix II**.

Table 1 Summary of sub-samples analysed for diatom content.

Vibrocore	Sample No.	Diatoms	Diatom Numbers	Quality of Preservation	Diversity	Assemblage type	Potential for % count
202A	D1	-	-	-	-	-	none
202A	D2	-	-	-	-	-	none
202A	D3	-	-	-	-	-	none
207	D4	+	v low	v poor	v low	bk mar	low
207	D5	-	-	-	-	-	none
304	D6	+	ex low	ex poor	ex low	mar	none
304	D7	-	-	-	-	-	none
304	D8	-	-	-	-	-	none
304	D9	-	-	-	-	-	none
101B	D10	+	Mod	mod	mod	bk mar	analysed
101B	D11	+	Low	poor	mod	bk mar	analysed
101B	D12	+	Low	poor	mod	bk mar fw	analysed

4.3 MICROFAUNA: FORAMINIFERA AND OSTRACODS

The microfaunas present evidence for the coastal geography at various times as the sea-level was rising rapidly in the Holocene. This section summarises the results from the microfauna analysis. For the full report, refer to **Appendix III**.

The microfauna assemblage from vibrocore 101B indicates that at the time of lower sea-level the environment was a brackish estuarine mudflat, subsequently becoming a saltmarsh. Vibrocore 202A showed four species of foraminifera and three ostracod species that indicate a brackish mudflat or protected creek (suggested by large numbers of the ostracod (*Cyprideis torosa*), fringed with mid-high saltmarsh. One large *Bithynia operculum* was located in the lowermost sample of Vibrocore 202A which might suggest a freshwater environment, or it could be derived from a much older (Pleistocene) sediment.

Vibrocore 304 contained a rich fauna of brackish and outer estuarine/marine foraminifera and ostracods at the top layres. As well as abundant foraminifera of brackish mudflats and low saltmarsh. The three lower samples from 304 only contained limited fossil assemblages.

Table 2 Summary of sub-samples analysed for foraminifera and ostracods.

Vibrocore	Depth below ground level	Depth below O.D.	Plant debris	Insect remains	Brackish foraminifera	Brackish ostracods	*Bithynia opercula*	Serpulid worm tubes	*Charophyte oogonia*	Outer estuarine/ marine foraminifera	Outer estuarine/ marine ostracods
101B	3.40-3.41m	-5.79/-5.80m	x	x	x						
101B	4.10-4.11m	-6.49/-6.50m	x		x	x					
207	0.70-0.71m	-7.55/-7.56m	x	x	x						
207	0.80-0.81m	-7.65/-7.66m	x		x						
207	0.89-0.90m	-7.74/-7.75m	x								
202A	3.10-3.11m	-12.98/-12.99m	x	x	x	x					
202A	3.50-3.51m	-13.38/-13.39m	x								
202A	3.89-3.90m	-13.77/-13.78m	x				x				
304	3.60-3.61m	-18.77/-18.78m	x	x	x	x	x	x	x	x	x
304	4.09-4.10m	-19.26/-19.27m	x		x	x					
304	4.20-4.21m	-19.37/-19.38m	x			x					

4.4 MOLLUSCS

Samples from differing Horizons of core 304 were investigated for species representation and related habitat indications after the microfaunal analysis discovered a very rich assemblage of molluscs in the uppermost layers of core 304. Two samples from the interval were analysed with results that indicate a greater saline incursion for the shallower horizon.

S. planorbis and *Spirorbid* tubes were identified, indicating sea water incursion and the morphological change and seawater transgression noted elsewhere in the results. These species are able to penetrate high up estuaries, such as salt wedge types (where a river flows directly into the sea).

The results suggest:

- The lower horizon comprises a suite of species representative of a more brackish/freshwater influenced habitat with rich fine sediment;

- Indication of predator prey interactions is further representative of silt/mud habitat and a stable community;
- Later communities appear to indicate an incursion of higher salinity water indicated by a slight decline in *Hydrobidae*, but more importantly increase in *S. planorbis* potentially associated with a salt wedge, and evident *Spirorbid* tubes;
- The incursion of marine waters is concomitant with formerly observed patterns of seawater inundation in the Thames Estuary as the Holocene progressed.

For a complete analysis of the samples, refer to **Appendix IV**.

4.5 MACROSCOPIC PLANTS AND INSECT REMAINS

Analysis of macro and microfossils was undertaken on 10 samples from boreholes 304, 101B, 207 and 202A to provide a preliminary picture of the palaeo-vegetation and environment and to increase the understanding of environment change. The macroscopic plant and insect remains analysis confirmed that the sediments are generally indicative of marine and wetland environments with regions of woodland ponds, marsh and grassland.

Table 3 summaries the results from the macroscopic analysis. For the full specialist report, refer to **Appendix V**.

Table 3 Summary of sub-samples analysed for macrofossils.

Core (Depth in core)	**Macrofossils (quantity)**	**Wood**	**Other remains**
101B	Monocot stem fragments: *Alchemilla* sp. (2) *Apium graveolens* (2) *Potentilla* sp. (1) *Salicornia europaea* s.s. (16) *Urtica dioica* (2) *Ranunculus acris/repens/ bulbosus* (1) *Ranunculus sceleratus* (3 + 3 halves) *Rubus* sect. *Glandulosus* (1 fragment) *Schoenoplectus tabernaemontani* (4) Poaceae (charred) (2) *Callitriche* spp (5) *Juncus* spp (Occasional) *Ranunculus* subg. *Batrachium* (1 + 3 halves)		Beetles (rare) Mites (occasional) Charcoal (rare)
207 (0.7-0.9)	*Poaceae indet* (2) *Salicornia europaea* (4) *Sambucus nigra* (1 fragment) *Suaeda maritima* (1 + 1 fragments) *Triglochin maritime* (2)	Large wood fragments (4) Small wood fragments (6)	Small charcoal fragments (rare) Foraminifera (frequent)
202A (3.09-3.28)	*Atriplex spp (2)* *Hyosycamus niger (6)* *Mentha sp (1)* *Moehringia trinervia (3)* *Salicornia europaea (2)* *Sambucus nigra (1* fragment*)* *Scleranthuus annuus (1)* *Suaeda maritime (19)*	Small wood fragments from (Frequent) Roundwood fragment, possibly alder (1) Roundwood fragment (1) Wood fragments, occasionally small roundwood (c.120)	Charcoal fragments (20) Snails (rare) Beetle fragments (rare) Ostracods (rare) Fish bone fragment (1)

202A (3.28-3.48)	*Salicornia europaea (1)*	Roundwood fragments (4) Small wood fragments (c.100)	
202A (3.48-3.66)		Wood fragments at 3.54m (6) Additional wood frags possibly partially mineral replaced. Small wood frags (c.80)	Ostracods (rare)
202A (3.66-3.80)		Small roundwood fragments, some with bark, (c.100)	
202A (3.80-3.91)		Small wood fragments, some with bark (c.30)	
304 (3.6-3.77)	*Atriplex spp (5)* *Chara spp (occasional)* *Moehringia trinervia (3)* *Ruppia c.f maritima (19)* *Ruppia c.f. cirrhosa (9)* *Sambucus nigra(1)* *Suaeda maritime (3)*	Small wood fragments (c.150)	Charcoal fragments (63) Snails (frequent) Bivalves (few) Foraminifera (occasional) Ostracods (occasional)
304 (3.77-4.0)			Charcoal (rare) Snails (c.50)
304 (4.10-4.28)		Roundwood with bark. Possibly alder (1) Small wood fragments (16) Small root fragments	Snails (2) Bivalve (1)

4.6 RADIOCARBON DATING

Six samples of wood were submitted for c14 analysis; three of the samples contained inadequate amounts of carbon to produce a c14 date. The remaining three were successfully dated, as summarised in **Table 4**. Calibration curve based on Reimer et al (2013).The results confirm that Units 5 is of Holocene date. For the full laboratory report, refer to **Appendix VI**.

Table 4 Summary of radiocarbon results.

Sample ID	SUERC code	Depth -OD	Core	Depth in core (m)	Result BP	δ13C relative to VPDB	Date (Cal BC)	Confide-nce levels
GFS 501	SUERC-54107	18.77-18.94	304	3.60-3.77	7980 ± 29	-26.6 ‰	7046-6774	95.4%
GFS 502	SUERC-54108	19.30-19.38	304	4.10-4.28	8055 ± 28	-25.0 ‰ (assumed)	7081-6831	95.4%
GFS 503	SUERC-54109	12.97-13.16	202A	3.09-3.28	7487 ± 28	-25.4 ‰	6430-6254	95.4%
GFS 504	-		202A	3.48-3.66	Insufficient carbon	-	-	
GFS 505	-		202A	3.80-3.91	Insufficient carbon	-	-	
GFS 506	-		207	0.70-0.90	Insufficient carbon	-	-	

5 Discussion

This Stage 4 interpretation is based on the results from this analysis as well as previous knowledge of the area presented by MA Ltd. (2012b, 2012c and MA Ltd., 2013).

The aim of a geoarchaeological Stage 4 analysis is to provide an account of the successive environments within the coring area, a model of environmental change over time, and an outline of the archaeological implications of the analysis. This has been accomplished by undertaking a number of geoarchaeological specialist analyses focused on sediments previously assessed (MA Ltd., 2013) to yield as much information as possible.

The objectives of stage 4 analysis were to:

a. further characterise and date submerged sedimentary deposits and prehistoric features;

b. identify a date for the marine inundation of the area and increase the understanding of the changing landscape;

c. contribute in-depth ecological and environmental information for the study area, and;

d. develop the understanding of potential for early human occupation in the Clacton Channels area.

5.1 Objective A- Character and date of sedimentary deposits

The sedimentary units have been discussed at length in previous reports (2012b, 2012c and MA Ltd., 2013) and are summarised in **Table 5**.

As established in the GFS 3 geoarchaeological Stage 3 assessment, the alluvial sequence (Unit 6), including the alluvial deposit with organic banding (Unit 5) and the basal gravely sequence (Unit 4), are similar to the Holocene sediments also encountered on the onshore area (MA Ltd, 2012d). The Stage 3 assessment showed that Units 6 and 5 contained a high amount of environmental indicators. In contrast, Unit 4 has been interpreted as a Holocene lag deposit and appears to contain little palaeo-environmental material worthy of further analysis (MA Ltd, 2013). The alluvial Unit 3 and the basal gravel Unit 2 are more likely to be related to the earlier Pleistocene Clacton Channel deposit.

The Stage 4 sampling focused on dating Units 5 and 6. This enabled a relative sequence to be constructed and aid the understanding of the stratigraphic relationships and changes within the sedimentary features and the marine inundation of the area.

This Stage 4 analyses have confirmed that Unit 5 is a Holocene deposit formed in a wetland environment (saltmarsh) that migrated up fluvial channels landward as the sea-level rose. Core 304 shows that the onset of the brackish water saltmarsh has been dated to 8055 ± 28 BP (conventional radiocarbon date) (7081-6831 Cal BC, 95.4% confidence level) (SUERC-54108). This deposit is associated with a relict Pleistocene channel some 6 km offshore, 19.35 m below OD. The ecology of Unit 5, indicated by diatoms, microfauna, pollen and plants, shows that the unit represents a brackish saltmarsh lying close to the palaeo-coastline with a possible freshwater input in proximity to dry land and woodlands. Local or regional flora was comprised of oak (*Quercus*) and hazel (*Corylus*), also with some indications of elm (*Ulmus*) and beech (*Fagus*). The continuing rise in sea level eventually results in an inundation of the estuarine saltmarsh within a century as indicated by a c14 date from near the top of the unit (SUERC-54107). The marsh becomes covered by Unit 6 which is interpreted as a riverine alluvium with a costal input as reflected in the microfaunal diatom record from sample D6, core 207.

As the marine transgression continues and coastline advances upslope across exposed land-surfaces, these are cleared of organic cover and replaced by the Holocene sand and silts of Unit 7. This unit sits directly on the basal London Clay of Unit 1. However, cores 207, 202A and 101B contain sediments that retain elements of the Holocene landscape and the estuarine sequences comparable to those described in core 304 above. Material from core 202A which was recovered 4 km offshore and at a depth of 13.6 m below OD, included Unit 7 and Unit 5 deposits that have survived in a Pleistocene palaeo-channel. Closer to the current shoreline, the Pleistocene deposits have been replaced by the Holocene Units 5 and 6. These units lie below Holocene marine material of Unit 7. The survival of Units 5 and 6 is most probably due to their relationship with estuaries or sand-bar features adjacent to the shore which provided shelter. Units 4 and 5 continue under the current coastline where they are capped by modern reclamation.

For an in depth discussion of the local ecology as interpreted from the Stage 4 assessment, refer to **Section 4.3.**

Table 5 Sediment Units identified in the Study Area.

Unit	Interpretation
8. Marine sand	Seabed sediment.
7. Holocene deposit	Holocene seabed sediments.
6. Holocene marine deposits/estuarine alluvium	Marine and estuarine deposits laid down in the Holocene.
5. Holocene humic clays	Peat and organic material forming due to rising ground water levels during the Holocene.
4. Holocene lag deposit	Concentration of gravel enhanced by the removal of fine sediment, water accumulated during the Holocene.
3. Pleistocene marine deposits/estuarine alluvium	Pleistocene marine and estuarine deposits. Low energy in nature.
2. Pleistocene lag deposit	Concentration of gravel enhanced by the removal of fine sediment, water accumulated during the Pleistocene.
1. London Clay	Ypresian (Lower Eocene Epoch)

5.2 Objective B- Identifying a date for the marine inundation of the area

The Holocene period is dominated by the marine transgression that followed the end of the Devensian/Wechselian Glacial maximum. The marine transgression caused rapid flooding as large volumes of water were released from the ice sheets. The rising water encroached on large areas of land, separating mainland Europe from the UK around 7,500 years ago to form the North Sea (Stride, 1989; Shennan *et al*., 2000). The sea continued to grow at a rapid pace for the next two and a half millennia.

The marine transgression slowed markedly in the Mid-Holocene (c. 5,000 BP) when it reached a height a few metres below current levels. Coincident with this increase was a rise in tidal range and tidal current strengths (Shennan *et al*., 2000).

Evidence for the initial inundation of the Clacton area derives from core 304 where the microfaunal analysis identified an early Holocene, brackish, sheltered mudflat sequence. Core 304 was collected 6 km from the current coastline. A c14 date collected at 4.10-4.28 m in core 304 (19.27-19.45 m below OD) was dated to 8055 ± 28 BP (conventional radiocarbon date) (7081-6831 Cal BC, 95.4% confidence level) (SUERC-54108).

Microfauna in samples taken from 4.09-4.10 m (19.26-19.27 m OD), 4.20-4.21 m (19.30-19.38 m OD) and 4.27-4.28 m (19.44-19.45 m OD) contained a very noded (juvenile) *Cyprideis torosa*. This can indicate a very low brackish salinity (below 5-6 ‰). The molluscs analysed from core 304 (3.60-3.77 m) also indicates a brackish environment with a gradual marine inundation of the area. The c14 result for the depth 18.77-18.94 m below OD (3.60-3.77 m core depth) was dated to 7980 ± 29 BP (conventional radiocarbon date) (7046-6774 Cal BC, 95.4% confidence level) (SUERC-54107). This date correlates with the termination of alluvial saltmarsh sediments which were inundated soon after.

In core 202A, collected from shallower water, two kilometres closer to shore, one large *Bithynia operculum,* a freshwaters snail, was found in a sample from 3.89-3.90 m (13.77-13.78m OD). This suggests a freshwater environment, although it could be derived from a much older (Pleistocene) sediment. Either way, the find is consistent with the data from the sediment sequences. The radiocarbon date from 3.09-3.28 m in core 202A (12.97-13.16 m OD was dated to 7487 ± 28 BP (conventional radiocarbon date) (6460-6254 Cal BC, 95.4% confidence level) (SUERC-54109). This demonstrates a rapid rise in sea level of approximately 6 m in 500 years.

5.3 OBJECTIVE C- IN DEPTH ECOLOGICAL AND ENVIRONMENTAL INFORMATION

Following the last ice age, c. 11,000 years ago, the environment of the Essex coast and the North Sea was considerably different from what we see today. When the glaciers retreated further north a barren landscape was left where the main geological components comprised London Clay together with finer sand and gravel deposited by the melting glacier. Over the next several thousand years the deposits were colonised by increased vegetation that advanced north from more temperate latitudes as the climate warmed. With the vegetation came new migrations of animals and humans (Momber, 2014; Gaffney *et al*., 2009). Sea level rise during this period resulted in a progressive advance of the coastline upslope on the sides of the expanding North Sea.

This Stage 4 analysis has resulted in a greater understanding of the local environment during the Holocene around the Clacton-on-Sea area, implying its suitability for human occupation.

The analyses of core 304 have resulted in the interpretation of the environment as an outer estuarine/marine area of brackish standstill water, possibly a mudflat or saltmarsh with a small river or pond close located to woodland around 7000 BC. When the sea ingressed landward the environment was replaced by a wetter and much more saline environment.

The analysis of core 202A includes an interesting sample collected from the boundary between Unit 5 and Unit 3 where one large *Bithynia operculum* was identified which would suggest freshwater if the channel was fluvial prior to the build-up of saltmarsh. Other results from 202A confirm the change from a coastal saltmarsh into a brackish mudflat or protected creek fringed with mid-high saltmarsh.

Vibrocore 207, recovered from less than 2 km offshore contained environmental evidence at a depth of 7.5 m below OD that indicated an alluvial deposit and a mid-high saltmarsh moving towards a shallow tidal saltmarsh that was replaced by a saltmarsh dominated by goosefoot, orache and/or samphire. It contained a range of other halophytic plants such as thrift/sea lavender and spurrey.

Diatom samples from Vibrocore 101B show abundance of open water, polyhalobous species at the base of the sequence 4.10-4.11 m (6.49 m O.D), suggesting that there was an input of diatoms from deeper water. However, inputs of both aerophilous and acidophilous oligohalobous which reach a maximum of 12% at the base of the core (4.10-4.11 m), reflect an in-wash of terrestrial material. Pollen samples from the same core also indicate a freshwater input at 4.10-4.11 m. Based on the height below OD, this freshwater and terrestrial input reflects the change from a coastal saltmarsh to a dry costal environment. This would have occurred at the time when the rate of sea level rise had slowed and was relatively stable.

Interpretation of the Stage 4 core analysis indicates a Mesolithic coastal landscape dominated by saltmarshes and estuarine environments that migrated up an established fluvial channel as the sea level rose. There were areas of dry land in the proximity where hazel and oak forests were dominant in dryer areas and elm and alder carr in wetter locations. This kind of habitat is often closely associated with Mesolithic occupation debris as further discussed in **Section 4.4.2.**

5.4 OBJECTIVE D - UNDERSTANDING THE POTENTIAL FOR EARLY HUMAN OCCUPATION

The material recovered in the vibrocores and boreholes from the Project Site has provided new information about the changing environment that has informed our understanding of the potential for human occupation.

5.4.1 Palaeolithic

The earliest evidence of human occupation in the UK was found less than 75 miles from Clacton, at Happisburgh, Norfolk where lithics date to 814,000–970,000 BP, representing the oldest hominin site north of the Alps (Parfitt *et al.* 2010). At Pakefield, 50 miles to the north in Suffolk, struck flints have been found eroding from a landscape that is over 700,000 years old (Parfitt et al. 2005). Occupation of the British landmass appears, therefore, to have occurred on a sporadic basis since the Early Pleistocene. Around 400 Ka., during the Hoxian interglacial, Clacton became a focal point of Lower Palaeolithic activity (Stringer, 2006). The inhabitants left behind evidence of core and flake working, with the absence of handaxes—generally a central aspect of Lower Palaeolithic lithic assemblages--defining this culture as as Clactonian. This was in fact the type-site of this lithic industry, the significance of which is still debated (McNabb 2007).

The south east of England continued to be a major gateway to the UK throughout the Palaeolithic and was repeatedly occupied when climatic conditions were suitable (Westley and Bailey, 2013). Discoveries in the marine dredging area 240, over 22 m below CD and 8 miles off Yarmouth, provide an example of human exploitation adjacent to a flood plain that became estuarine, then coastal until it was covered by the rising sea (Tizzard *et al.*, 2011). Evidence indicates this submerged site dates to between 250 and 200 ka ((Tizzard et al. 2014).

The last glaciation was the Devension which reached its maxima around 22,000 years ago when sea levels were about 120 m lower than today. Britain was devoid of occupation at this time but it was not long before the Homo sapiens of the Upper Palaeolithic moved into England from the adjacent lowlands. These lands were to become the North Sea (Peeters and Momber, 2014).

The most significant Palaeolithic material from the Clacton area consists of 37 handaxes, one roughout, one core, ten retouched flakes, 19 flakes and one Levallois core (NMR Unique Identified 389527). This indicates the possibility of both Lower and Upper Palaeolithic activity (Wymer, 1999). Further south there is a cluster of Palaeolithic sites and numerous artefacts, including the wooden spear found in 1911 at Lions Point to the south of Clacton (Allington-Jones 2015), currently the earliest evidence for wood working in Britain at c.420ka. Palaeolithic cultures predate the Holocene deposits but remains are often associated with fluvial or beach deposits. The possibility exists that lithic artefacts could lie in Unit 3.

5.4.2 Mesolithic

As the landscape warmed in the Mesolithic and temperatures rose to an average of 0 degrees in the winter and 17 degrees in the summer (Fitch & Gaffney, 2011), pioneering forests of pine and birch became established. The continued amelioration of the climate meant that hazel, oak and elm began to dominate in southerly regions. In the Clacton-on-Sea area this is reflected in the pollen samples from core 207 where evidence of a well-drained soil would have supported oak and hazel woodland with some other types such as elm, alder and beech. There were also major changes in the species of animals during this period, as a warm climate and forestation resulted in the loss of large late Pleistocene herds of megafauna (Momber, 2014).

The analysis has shown that the area was a rich coastal environment with freshwater rivers or lakes in close proximity to forests. Throughout the Mesolithic the tidal coastline fostered the development of saltmarsh, freshwater swamps, fen and mudflats that migrated inland as the sea rose.

Early Mesolithic activity is often associated with lowland, lacustrine and riverine sites such as Starr Carr and the Kennet Valley (Day & Mellors, 1994; Chattertton, 2003; Fitch & Gaffney, 2011). These landscapes would have been similar to the Study Area during the early Mesolithic period when the sea was many miles further from the current coast. From the late Mesolithic, as the sea inundated the lowland plains, a clear association between human activity and coastal locations develops (Momber, 2013; Fitch & Gaffney, 2011; Waddington, 2007).

The Mesolithic period, between c.10,000 BC and 4,000 BC, is characterised by a hunter-gatherer subsistence economy with an attraction to marine resources (Bell & Warren, 2013). Communities are believed to have moved around the landscape in a seasonal pattern but evidence continues to surface indicating sedentism in resource rich areas. At Lunt Meadows, Merseyside, three structures created a settlement for several families (Museum of Liverpool, 2014). It is also believed that a variety of different site types were used including large home bases and smaller specialised sites for manufacture of tools, or accessing particular food opportunities, including seasonal fish runs (Fitch & Gaffney, 2011; Momber *et al* 2001). The landscape characterised by the sediment sequences recorded in the cores is one that was known to attract Mesolithic hunter gatherers. It is not surprising that individual worked tools have not been covered in the cores as their footprint is so small, however, the discovery of charcoal in several locations (207, 202A and 304) can be indicative of human activity.

Mesolithic technology is characterised by microliths, small blades and occasional axes, many of which have been found in the Clacton region (Bridgeland, 1999). The National Monument Record (NMR) holds records for 154 Mesolithic finds in Essex of which 20 were found in the district of Tendring, where Clacton-on-Sea is located. The finds include seven Trancet axes, one decorated pebble, one mace head, one Thames Pick and several larger collections of flints from the Mesolithic and Neolithic including a possible flint working site at Harwich (NMR Unique Identifier 389735). These artefacts provide evidence for an ongoing human presence within this landscape during the Mesolithic period.

6 Conclusions

The results presented in this Stage 4 report are based on analysis of terrestrial and marine sediments. The analysis has demonstrated that the sub-sampled sediments contained enough environmental proxies to provide a detailed interpretation of the Mesolithic landscape. This is visible in the pollen, diatom, foraminifera and macro-fossil records.

The analysis confirms that Unit 5 is a Holocene deposit formed in a wetland, estuarine environment. The deeper parts of the study areas at c.19.3 m below OD became inundated around 7081-6831 Cal BC (SUERC-54108). Sea level rise in the order of 1 m per hundred years pushed the alluvial complexes landward until transgression slowed around 5,000 years ago. The ecology of Unit 5, as represented by diatoms, micofauna, pollen and plant macrofossils, shows that the unit represents a brackish coastal saltmarsh with a possible freshwater input. The proximity to dry land and woodlands is indicated by regional flora comprising oak (*Quercus*) and hazel (*Corylus*) also with some indications of elm (*Ulmus*) and beech (*Fagus*).

Unit 6 has been interpreted as a river alluvium, as reflected in the microfaunal record from Vibrocore 207, with costal influx as represented by a diatom fragment (sample D6). These environments have complex ecotonal zones that offer a variety of resources. The archaeological record from this period has demonstrated that both estuarine and freshwater settings are attractive for human occupation. This assertion is bolstered by the presence of charcoal on the Holocene humic clays of Unit 5. These organic clays were formed by rising sea level, creating a relatively wet and lightly vegetated landscape, and greatly reducing the possibility that charcoal is present due to natural fire events. They were laid down adjacent to salt-marsh that would have been rich in wildfowl, fish and were attractive to larger mammals. The charcoal could be natural but the context within which they were located, the relatively high concentration in the top 17 cm of unit 5, core 304 (63 fragments), increases the probability that there was anthropogenic activity.

The Stage 4 geoarchaeological assessment of sub-samples from the collected cores has identified an area of high archaeological potential. While much of the relict landscape has eroded away, pockets of organic rich sediments associated with cultural landscapes remain. It is these areas that have the potential to preserve prehistoric archaeological material.

7 Further research potential

The Stage 4 geoarchaeological assessment of sub-samples from the collected cores has identified an area of high archaeological potential.

To disseminate the results from this Stage 4 report to the widest audience possible the work undertaken during all of the geoarchaeological stages (1-4) may be published in an archaeological journal. The article would focus on placing the Project Site within the wider research context and aim to answer current archaeological research questions regarding Mesolithic coastal and inland movements, patterns and influences and how environmental changes affected Mesolithic communities. A published article would enhance the understanding of the Clacton-on Sea area and its archaeological potential and importance to the archaeological community and beyond.

Furthermore it should be noted that the vibrocores in the offshore zone were collected in a North-South line, providing one profile of the palaeolandscape. If further opportunity arises, the results from potential future development projects in this region should be assessed, dated and compared to geoarchaeological results from this report. This should also include surrounding offshore developments, such as Gunfleet Sands 1 - 2 (DONG Energy) and Dredging Area 240 (Tizzard, 2013), as well as other future developments along the Essex coast. In so doing, this will result in a broader view of the Palaeolithic and Holocene environment.

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9 Figures

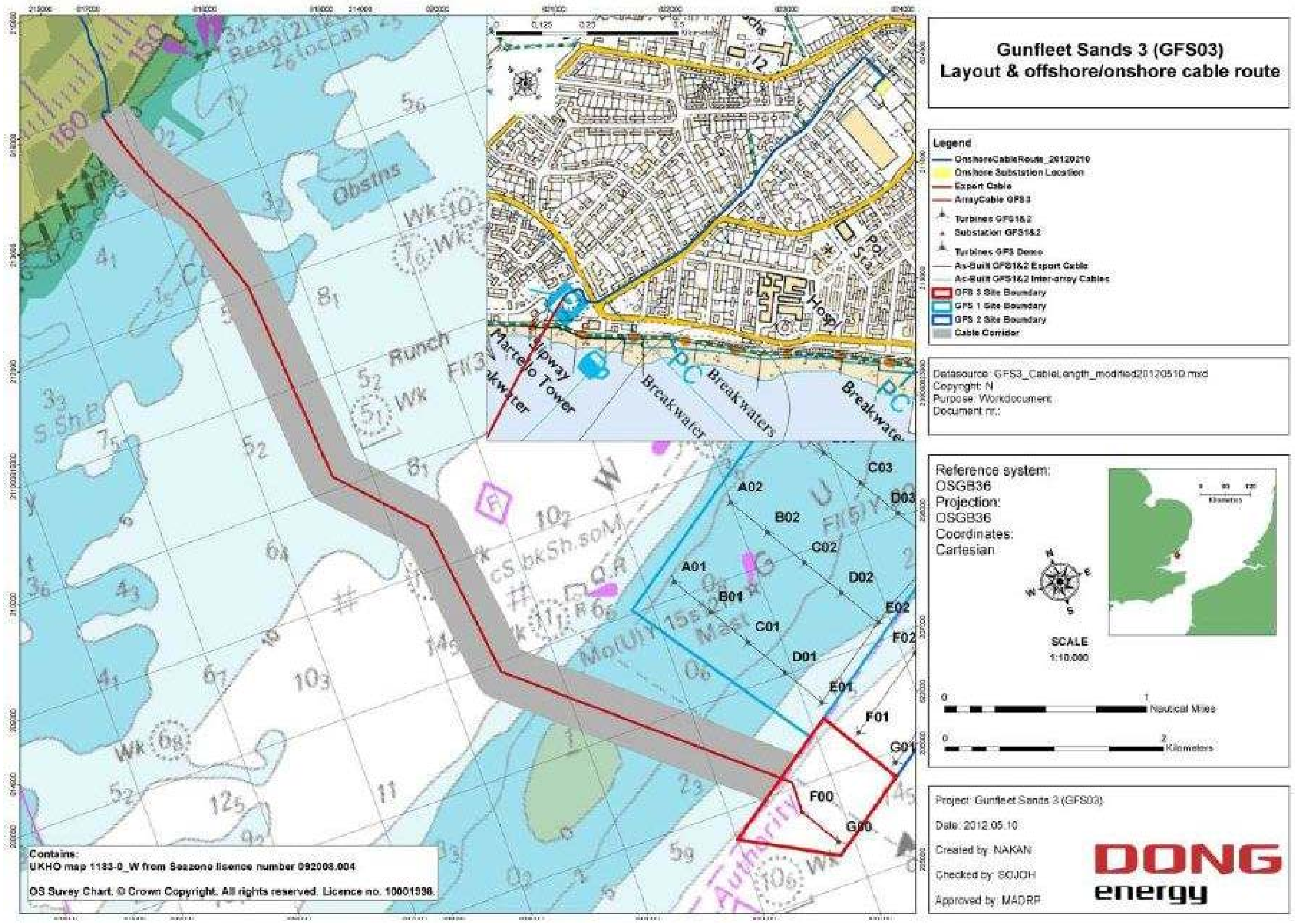

Figure 1 Detail of the scheme plan

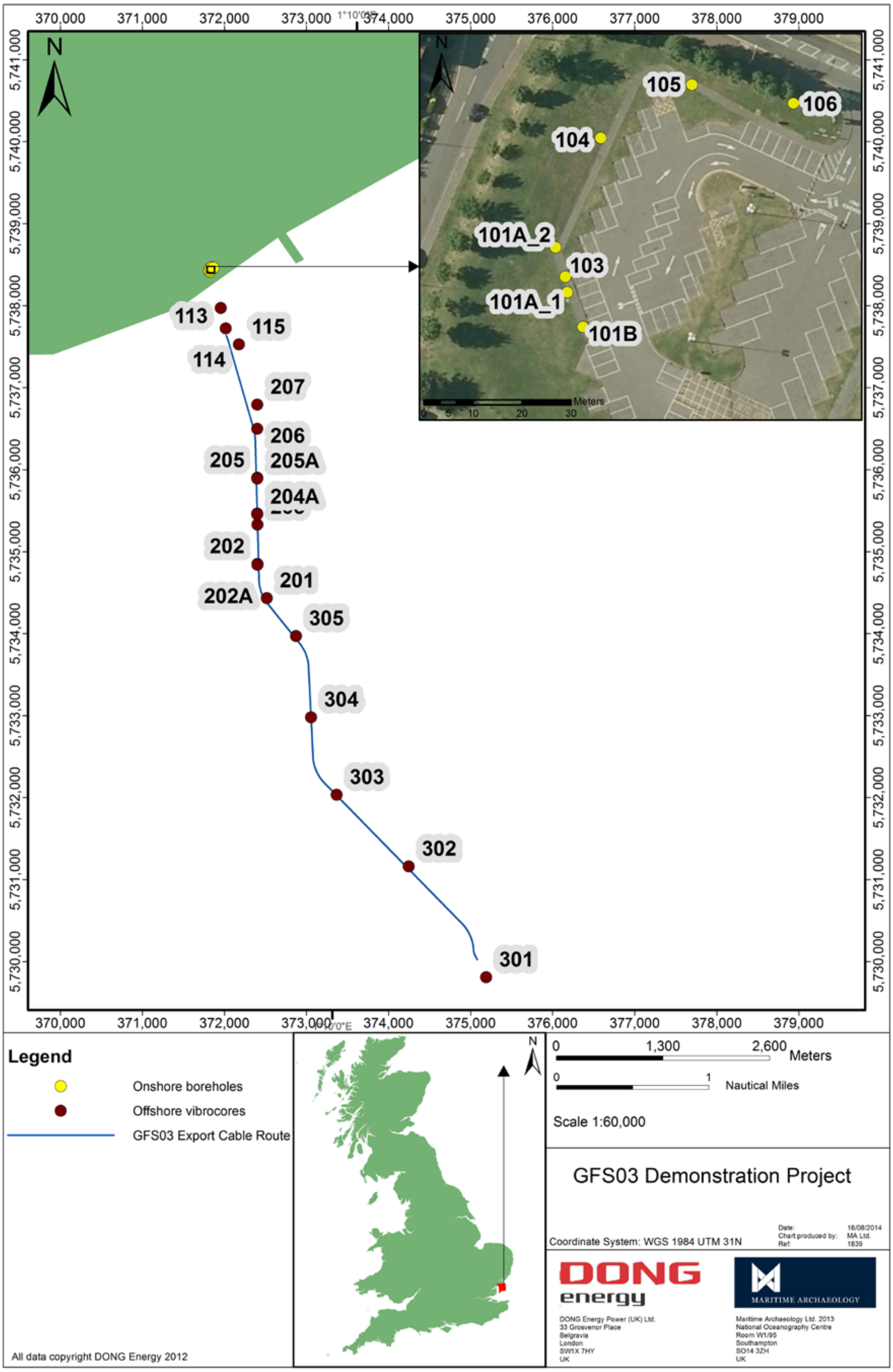

Figure 2 Location of all boreholes and vibrocores

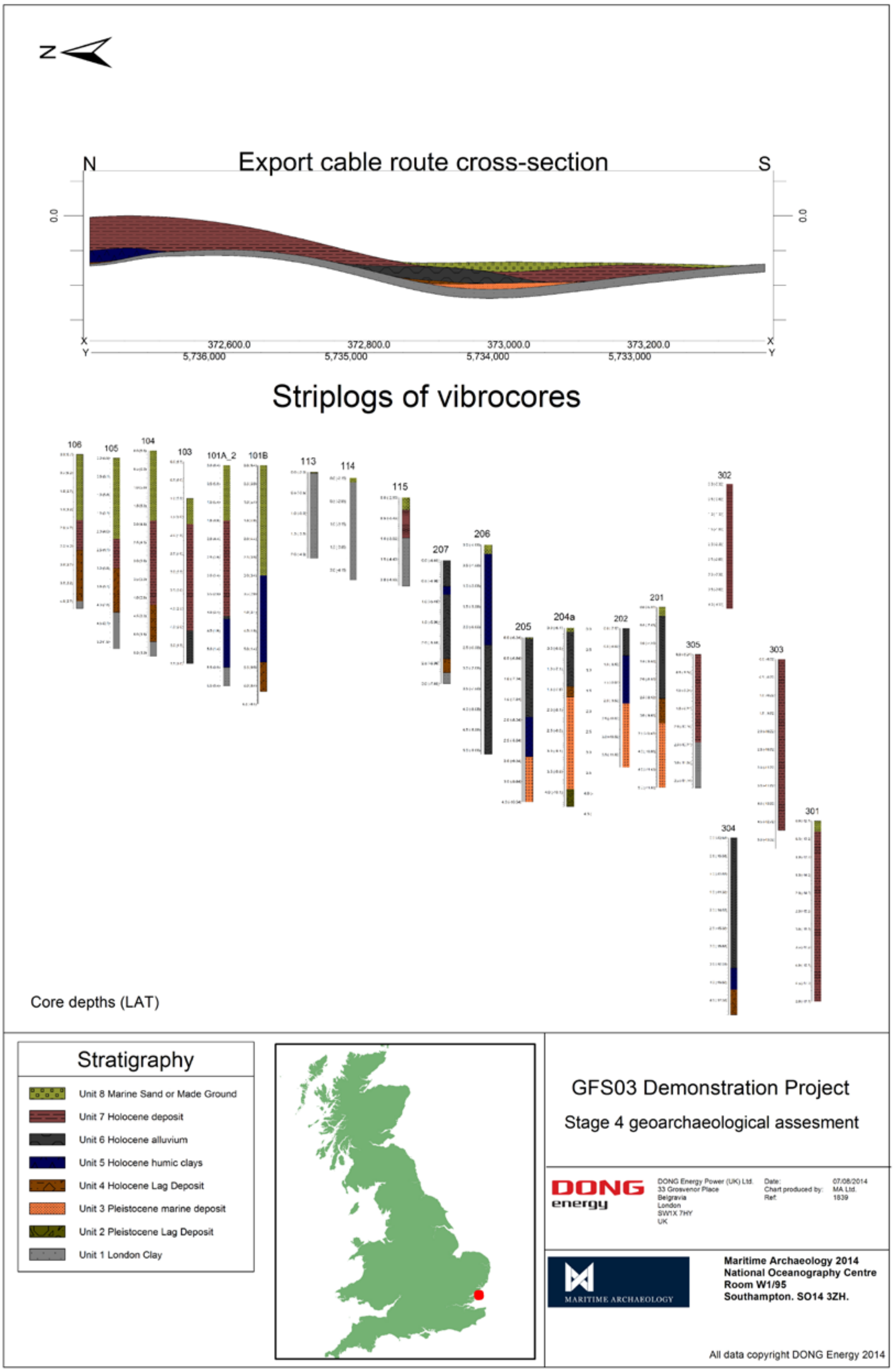

Figure 3 Export Cable Route cross-section and striplogs

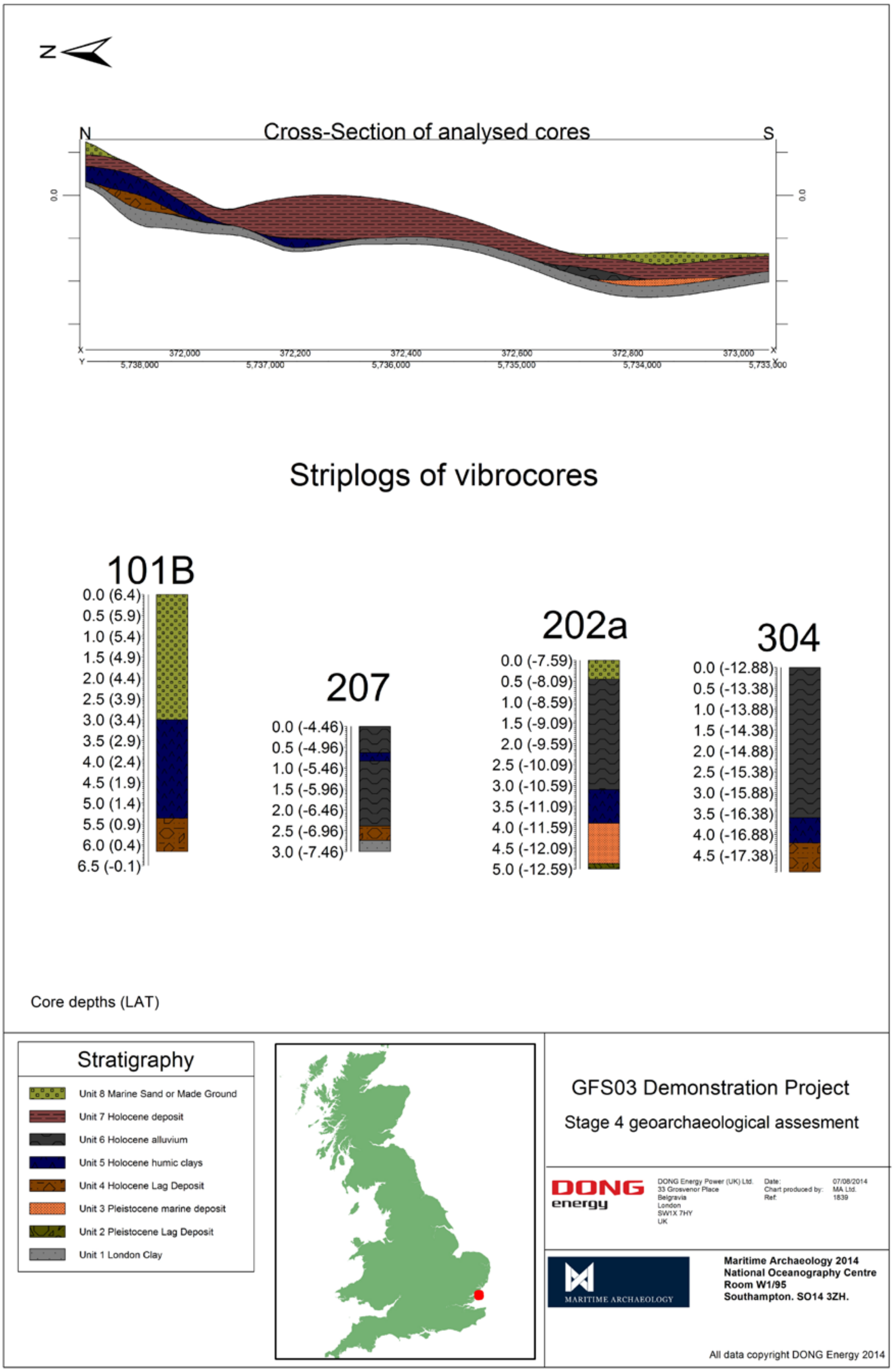

Figure 4 Cross-section and striplogs of analysed cores

10 Appendix I- Pollen assessment analysis.

Gunfleet (GFS03): Pollen Assessment Analysis

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2014

1.) Introduction

Preliminary pollen analysis has been undertaken on samples from boreholes 101B, 202A, 304, 207 and BH4. The study was undertaken to determine presence or absence of sub-fossil pollen and spores and, if present, to provide a preliminary picture of the palaeo-vegetation and environment of the site and local environs during the time-span represented by the sediments and potential for fuller analysis.

2.) Pollen Procedures

Sediment samples of 1.5- 2ml volume were processed using standard techniques for the extraction of the sub-fossil pollen and spores (Moore and Webb 1978; Moore *et al.* 1992). Where pollen was present in BH101B and BH207, a total pollen (assessment) count of between 150-260 grains per sample was counted according to preservation. All fern spores and pre-Quaternary palynomorphs were also counted for each of the samples analysed. There were too few samples to warrant drawing of pollen diagrams for the two profiles and thus, the pollen count data are given in tables 1 and 2 below. These procedures were carried out in the Palaeoecology Laboratory of the Department of Geography, University of Southampton.

3.) The pollen data

Sediment sub-samples for assessed for pollen were taken by Christin Heamagi from:

Core 202A: 3.34m; 3.42m, 3.50m; 3.58m, 3.66m; 3.74m.

Core 101B: 3.10-3.11m; 3.70-3.71m; 4.10-4.11m

Core 207: 0.64-0.66m; 0.70-0.72m; 0.74-0.76m; 0.77-0.79m.

Core 304: 3.75-3.76m; 3.85-3.86m; 3.05-3.96m; 4.05-4.06m; 4.10-4.11m

BH4: 0.28-0.29m; 0.36-0.37m; 0.42-0.43m; 0.72-0.73m.

3.i.) A note on profiles 202A, 304 and BH4.

Holocene pollen was absent in columns 202A, 304 and BH4. These profiles are very minerogenic with little humic content. Whilst pollen can be recovered from such sub- marine sediment, this is unfortunately not frequent and especially in the case of sediment profiles from the North Sea where preservation is notoriously variable. The absence of pollen and/or differential preservation in favour of spores and pre-Quaternary palynomorphs is attributed to the poor preserving environment (chemical and mechanical deterioration) and/or phases of rapid sedimentation.

Samples from these cores were scanned in detail and only in one sample at 3.34m from core 202A, were a small number (3) of pollen grains and occasional fern spores observed. These comprised oak (*Quercus*), hazel (*Corylus avellana* type) and *Dryopteris* type. Pollen numbers are clearly too sparse to obtain even basic counts from his sample and no real interpretation can be made.

3.ii.) Core 101B

Three samples have been examined and pollen is well preserved and relatively abundant in this profile. This is largely due to the organic character of the sediment. Overall, herbs are dominant due to the strong autochthonous component. Total pollen counts of up to 260 pollen grains were made. Pollen count data are given in table 1 below.

Depth m	***3.10-3.11***	***3.70-3.71***	***4.10-4.11***
Trees and Shrubs			
Betula	*1*	*3*	
Pinus	*3*	*7*	*18*
Abies		*1*	
Picea			*1*
Ulmus	*1*		*1*
Quercus	*9*	*11*	*35*
Fagus			*1*
Alnus	*3*	*12*	*1*
Corylus avellana type	*5*	*13*	*15*
Hippophae rhamnoides			*1*
Herbs			
Ranunculus type			*1*
Chenopodiaceae	*78*	*111*	*65*
Spergularia type	*1*	*1*	*1*
Rumex			*3*
Armeria 'B' line		*3*	
Plantago lanceolata	*3*	*1*	*3*
Plantago coronopus type			*2*
Plantago maritima	*4*	*1*	*7*
Rubiaceae			*1*
Bidens type	*3*	*7*	*1*
Anthemis type	*1*	*1*	
Senecio type	*1*		*1*
Artemisia			*1*
Lactucoideae	*25*	*1*	*1*
Poaceae	*58*	*26*	*37*
Cereal type		*1*	*1*
Large Poaceae	*3*	*3*	*1*

Ferns			
Dryopteris type	*5*	*5*	*53*
Pteridium aquilinum	*3*		*1*
Polypodium	*1*	*5*	
Aquatic/mire			
Cyperaceae	*62*	*2*	*5*
Potamogeton/Triglochin		*1*	*3*
Miscellaneous			
Sphagnum	*1*	*1*	
Pediastrum		*3*	
Pre-Quaternary	*5*	*74*	*384*
Hystrichospheres		*8*	*23*

Table 1: Pollen count data from Borehole 101B

The characteristics of the three pollen assemblages are:

Trees and shrubs: Arboreal pollen is more abundant in the basal sample (4.10m) with *Pinus* (pine), *Quercus* (oak) and *Corylus avellana* type (hazel or bog myrtle). There are also small numbers/sporadic occurrences of *Picea* (spruce), *Ulmus* (elm) and possible *Fagus* (beech). There are fewer tree and shrub pollen in the upper samples although *Abies* (fir) is noted at 3.70m and *Alnus* (alder) is present.

Herbs: All samples are dominated by Chenopodiaceae (goosefoot, oraches and samphire) with Poaceae (grasses). Other herbs include, along with the Chenopodiaceae, a strong halophytic element with *Plantago maritima* (sea plantain), *Armeria* (sea lavender or thrift), *Spergularia* (spurrey) and possibly less discernible types (through pollen morphology) such as the Asteraceae taxa. Other than halophytes, *Plantago lanceolata* (ribwort plantain) and cereal type are also recorded.

Aquatic and marsh: Apart from the autochthonous halophytes, numbers and diversity of aquatic taxa are low with Cyperaceae (sedges), *Potamogeton* type (pondweed but may be *Triglochin*/arrow grass) and cysts of freshwater algal *Pediastrum* (esp. the basal sample at 4.10m).

Ferns: Only the lower sample at 4.10m has any appreciable representation of fern spores. These comprise largely monolete forms of *Dryopteris* type (typical ferns). Other fern taxa include *Pteridium aquilinum* (bracken) and *Polypodium* (polypody fern).

Miscellaneous: With the exception of the more organic upper sample at 3.10m, there are substantial numbers of reworked pre-Quaternary palynomorphs. These are especially abundant in the lowest sample (4.11m). There are also Hystrichospheres/Dinoflagellates which are also thought to be reworked and some *Pediastrum* (noted above).

3.ii.a.) Interpretation

The pollen data can be considered in terms of the on-site and off site components.

On site: The very substantial numbers of Chenopodiaceae (goosefoot, orache, samphire) and other halophytes (*Armeria*, *Plantago maritima* and *Spergularia*), all demonstrate an on-site salt marsh or possible mud flat vegetation community. The predominantly organic character of the sediment negates the latter. This is consistent throughout the profile and clearly shows a marine/brackish habitat. It can be noted that *Armeria* is poorly represented in pollen assemblages and the sporadic record here at 3.70m is an especially good indicator of salt marsh. Slightly higher numbers of *Pediastrum* in the basal sample may suggest more freshwater input. The upper sample at 3.10m has high values of Cyperaceae which may indicate a developing freshwater fen.

Regional/off-site component: The autochthonous component with high pollen numbers masks the background, terrestrial element derived from the non-salt marsh habitat. The pollen data show, however, a local dry land and regional flora comprising oak (*Quercus*) and hazel (*Corylus*) woodland also with some indications of elm (*Ulmus*) and beech (*Fagus*). This evidence for woodland is clearer in the lower sample. Fluvial as well as airborne transport may have been a factor in this. Small numbers of alder (*Alnus*) and pine (*Pinus*) are not considered to have been of local significance as these taxa are anemophilous and produce copious quantities of wind-borne pollen. Pine pollen may also be significantly over represented in fluvial and marine environments with the saccae allowing pollen to float, also over great distances. The individual records of non-native spruce (*Picea*) and *Abies* (fir) are attributed to long distance marine transport. These latter are well preserved and are not reworked pre-Quaternary forms.

In addition to the woodland flora, there is also tentative evidence for agriculture and thus, a late prehistoric or historic age for the sediment. Ribwort plantain (*Plantago lanceolata*) is present and along with a proportion of the grasses indicates open grassland/pasture. Cereal type pollen at 4.10m (the lower sample) is thick walled (exine) with large porus and annulus and is most probably cereal rather than large Poaceae (recorded here as

>*c.*45 microns) with thin pollen walls and less robust pore structure. The latter were also recovered and are from certain wild grasses which also have cereal pollen sized grains (e.g. *Glyceria fuitans* and *Ammophila arenaria*).

Thus, these preliminary data suggest that there was a mix of woodland with open agricultural land.

3.iii.) Borehole 207

This is a thin humic silt and peat horizon of some 15cm thickness. Four samples were examined of which three contained pollen but in low numbers. Overall, these are dominated by autochthonous, salt marsh plants with a moderate representation of tree taxa from off-site regional sources. Total counts of between 150 and 250 pollen grains were made. Pollen count data are given in table 2 below.

Depth m metres	***0.64-0.66***	***0.70-0.72***	***0.74-0.76***
Trees and Shrubs			
Betula	1		
Pinus	14	3	13

Ulmus	3	4	8
Quercus	35	41	29
Tilia	4	5	2
Alnus	1	3	5
Corylus avellana type	12	31	3
Salix			1
Herbs			
Brassicaceae		1	
Chenopodiaceae	122	157	82
Armeria 'A' line			1
Armeria 'B' line		1	
Plantago maritima		1	
Lactucoideae			1
Poaceae	9	4	5
Large Poaceae		1	
Unidentified/degraded	1		2
Ferns			
Dryopteris type	3		17
Pteridium aquilinum	1	3	1
Polypodium	1		1
Aquatic/mire			
Cyperaceae	1		
Potamogeton/Triglochin	2		
Miscellaneous			
Sphagnum	1		
Pre-Quaternary	5		12
Hystrichospheres	1		

Table 2: Pollen count data from Borehole 207.

The characteristics of the three pollen assemblages are as follows.

Trees and shrubs: Quercus and *Corylus avellana* are the most consistent types. However, *Ulmus, Pinus* and *Tilia* (lime/linden) are also of note. There are occasional occurrences of *Alnus* and *Salix* (willow at 0.74-6m).

Herbs: Halophytes comprising Chenopodiaceae are dominant in all of the samples with very high numbers. Other salt marsh taxa include *Armeria* 'A; and 'B' line and *Potamogeton* type which may be *Triglochin maritima.* Other than these, the herb diversity is small with only small numbers of Poaceae and occasional Cyperaceae.

Ferns: Numbers of fern spores are generally small with *Dryopteris* type most important in the lowest sample (0.70-0.72m). Occasional *Pteridium aquilinum* and *Polypodium* are present.

3.iii.a.) Interpretation

The pollen data can be viewed in terms of the on site vegetation habitat/communities and that pollen which derives from the terrestrial zone. As with profile 101B (3.ii. above), the former comprise salt marsh halophytes (goosefoot, orache, samphire). These are dominant in all of the samples with values which show that this community existed on the sample site and was responsible for this humic accumulation. *Armeria* 'A' and 'B' line (thrift and sea lavender) are poorly represented in pollen assemblages and are a similarly good indicator of a salt marsh habitat.

Compared with 101B, there are larger numbers of tree and shrub pollen. Oak and hazel are the most consistent, but compared with 101B, elm (*Ulmus*) and lime (*Tilia*) are also important. The latter (lime) is poorly represented in pollen spectra (Andersen 1970, 1973) and as such, it may have been a more important constituent of the near regional woodland than the otherwise small numbers of pollen suggest.

The values of lime and elm, and the almost absence of herb pollen taxa observed in 101B, may indicate that this sequence is of earlier date. Both elm and lime, along with the other trees are consistent with middle a Holocene (Atlantic; Flandrian Chronozone II) date. That is, prior to the Neolithic Elm decline at *c.* 5,500-5,000BP. However, pollen analysis is not a technique for dating and radio carbon dating will establish and absolute chronology for these humic/organic contexts.

4.) Summary and conclusions

The following principal findings have been made.

Pollen analysis was undertaken to establish if sub-fossil pollen and spores are present in these sediment cores. Of the five cores analysed, only 101B and 207 proved satisfactory with preserved sub-fossil pollen and spores.

The pollen assemblages from both 101B and 207 clearly show an on-site salt marsh habitat dominated by goosefoot, orache and/or samphire with a range of other halophytic plants such as thrift/sea lavender, spurrey. Other taxa which are less easy to define ecologically, may also have been part of this community.

The surrounding region of well drained soil supported oak and hazel woodland probably with some other types such as elm, alder (in wetter valleys) and beech.

In Borehole 207, there are greater numbers of lime and elm pollen. This may indicate an earlier and perhaps middle Holocene (Atlantic) age whereas 101B with possible evidence of cereal cultivation and open ground suggesting a late prehistoric or even historic age.

Possible cereal pollen was found in the basal sample of 101B and along with ribwort plantain and a proportion of the grass pollen possibly indicates mixed arable-pastoral economy. This, therefore, suggests a late prehistoric or historic age.

Profiles 202A, 304 and BH4 were all highly minerogenic and with the exception of very sporadic oak and hazel pollen in Core 202A at 3.34m, were devoid of Holocene pollen. The profiles do, however, contain very robust, reworked pre-Quaternary palynomorphs.

5.) Suggestions for additional work

Clearly, only profiles 101B and 207 contain sufficient sub-fossil pollen to yield any worthwhile data. The study of these profiles has produced useful information and it is suggested that if additional pollen samples at a standard sample interval of 8cm with 4cm intervals (for 101B) where applicable, were to be carried out, pollen counts should be increased to the standard 400 or more grains per level for both profiles where preservation allows. This should add further taxonomic detail and statistical validity to the data.

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11 Appendix II- Diatom assessment analysis.

Diatom assessment and analysis of samples from The Gunfleet Sands 03 Project

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Introduction

Diatom slides were prepared from twelve samples. These were selected from four onshore and offshore Vibrocore sequences (202A, 207, 304 & 101B) taken at the Gunfleet Sands site near Clacton-on-Sea, Essex. The sediments are Holocene silty clays with pockets of organic material, marine deposits and estuarine alluvium. Preliminary diatom assessment had been carried out on a number of samples including those from Vibrocore 101B (Christin Heamagi pers. comm.).

The purpose of the carrying out diatom assessment of new sequences and analysis of at least one core is to investigate if diatom assemblages are present and, for those samples analysed, to reconstruct the aquatic environment. At this site the former salinity conditions are of particular relevance for the geoarchaeological investigation.

Methods

Diatom preparation, counting and analysis followed standard techniques (Battarbee *et al.* 2001). Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendey (1964), Werff & Huls (1957-1974), Hartley *et al.* (1996), Krammer & Lange-Bertalot (1986-1991) and Witkowski *et al.* (2000). Diatom species' salinity preferences are discussed in part using the classification data in Denys (1992), Vos & de Wolf (1988, 1993) and the halobian groups of Hustedt (1953, 1957: 199), these salinity groups are summarised as follows:

1. Polyhalobian: >30 g l^{-1}
2. Mesohalobian: 0.2-30 g l^{-1}
3. Oligohalobian - Halophilous: optimum in slightly brackish water
4. Oligohalobian - Indifferent: optimum in freshwater but tolerant of slightly brackish water
5. Halophobous: exclusively freshwater
6. Unknown: taxa of unknown salinity preference.

Diatom data were plotted using the 'C2' program (Juggins 2003).

Results & Discussion

The samples selected and prepared for diatom analysis are shown in Table 1 below. A summary of the diatom assessment results is shown in Table 2. Figure 1 and Figure 2 (emf files attached) are diatom species and summary halobian group diagrams for the diatom percentage analyses of Vibrocore 101B.

Table 1. Gunfleet Sands 03 (GFS3) Diatom sample numbers and sample depths (taken from sample bags) of material prepared for diatom analysis.

Vibrocore	UCL Lab Sample No.	Top sample depth (m)	Bottom sample depth (m)
202A	D1	3.10	3.11
202A	D2	3.50	3.51
202A	D3	3.89	3.90
207	D4	0.70	0.71
207	D5	0.89	0.90
304	D6	3.60	3.61
304	D7	3.85	3.86
304	D8	4.09	4.10
304	D9	4.27	4.28
101B	D10	3.10	3.11
101B	D11	3.70	3.74
101B	D12	4.10	4.11

Table 2. Summary of diatom evaluation results for Gunfleet 03 (GFS3) (+ diatoms present; - diatoms absent; ex extremely; fw freshwater; bk brackish; mar marine; mod moderate)

Diatom Sample No.	Diatoms	Diatom Numbers	Quality of Preservation	Diversity	Assemblage type	Potential for % count
D1	-	-	-	-	-	none
D2	-	-	-	-	-	none
D3	-	-	-	-	-	none
D4	+	v low	v poor	v low	bk mar	low
D5	-	-	-	-	-	none
D6	+	ex low	ex poor	ex low	mar	none
D7	-	-	-	-	-	none
D8	-	-	-	-	-	none
D9	-	-	-	-	-	none
D10	+	mod	mod	mod	bk mar	analysed
D11	+	low	poor	mod	bk mar	analysed
D12	+	low	poor	mod	bk mar fw	analysed

Diatom assessment and analysis of each core is discussed below.

202A

Three samples were prepared for diatom assessment from the 202A Vibrocore sequence. Diatom assemblages are absent from all three samples (D1, D2 and D3). The absence of diatoms from these samples is probably the result of the loss of diatoms through valve breakage and dissolution (Flower 1993, Ryves *et al.* 2001).

207

Two samples were prepared for diatom evaluation from the 207 Vibrocore sequence. Diatoms are present in sample D4 (0.70 m) and are absent from sample D5 (0.89 m).

There are a very low number of diatoms in sample D4, the quality of preservation is very poor and the diversity is very low (Table 2). The benthic mesohalobous (brackish-marine) diatom *Diploneis didyma* is the dominant diatom. As a result of the very poor quality of preservation the few other diatom valves or fragments present in D4 could only be identified to the generic level (*Diploneis* sp.) or with poorer resolution (unknown Naviculaceae, indeterminate centric species)

The diatom assemblage of D4 which is dominated by *Diploneis didyma*, a benthic, mud-surface species, indicates a shallow water but fully tidal environment.

304

Four samples were prepared for diatom evaluation from the 304 Vibrocore sequence. An extremely low number of very poorly preserved diatoms are present in sample D6 (3.60 m). Diatoms are absent from samples D7, D8 and D9.

As a result of the very poor quality of preservation in D6 the diatom fragments present could only be identified with poor resolution (indeterminate fragment, indeterminate centric species). However, a central area fragment of the coastal marine planktonic species *Paralia sulcata* was identified in sample D6.

101B

Three samples from 101B (D10, D11 and D12) from 3.10 m to 4.10 m depth were analysed for diatoms. Diatom numbers vary from moderate to low and the quality of diatom preservation is moderate to poor (Table 2). Diatom species diversity is moderately high in all three samples.

The most common diatoms in all three samples are in the brackish-marine, mesohalobous group. Mesohalobous diatoms comprise from 40% of the total diatoms at 4.10 m to 68% at 3.70 m to 90% of the total at the top of the sequence. The majority of the mesohalobous taxa are benthic, epipelic (mud surface) diatoms. The most common of these are *Diploneis didyma, Caloneis westii, Nitzschia navicularis* and *Scoliopleura tumida*. Open water, planktonic diatoms in the mesohalobous group, such as *Cyclotella striata* are relatively uncommon. The benthic mesohalobous diatoms represent shallow water, tidal habitats.

Polyhalobous, marine diatoms are most common at 4.10 m where they comprise 27% of the diatom assemblage, declining to 17% at 3.70 m and 6% at 3.10 m. The most common polyhalobous diatom is the planktonic coastal species *Paralia sulcata.* The abundance of this open water species at the base of the sequence indicates a greater input of diatoms from deeper, salt water and declines towards the top of the core. Polyhalobous to mesohalobous diatoms also reach a maximum (6%) at the base of the sequence. These include open water, planktonic diatoms such as *Actinoptychus undulatus* and *Pseudopodosira westii*; and benthic marine brackish diatoms such as *Diploneis smithii* and *Navicula marina*. However, at the base of the core the input of oligohalobous indifferent, freshwater diatoms is also at a maximum of 12%. These oligohalobous indifferent taxa are mostly aerophilous (diatoms that are tolerant of desiccation and live in semi-terrestrial habitats) or acidophilous taxa that may be associated for example with peatland habitats. The aerophilous group include *Hantzschia amphioxys, Pinnularia borealis* and *Pinnularia subcapitata*. Acidophilous freshwater taxa include *Eunotia bilunaris, Eunotia pectinalis* and *Eunotia praerupta*. The maximum of aerophilous and acidophilous diatoms at 4.10 m probably reflects the inwash of terrestrial material into the sedimentary environment

Conclusions

1. Diatoms slides have been prepared and assessed or analysed from twelve samples taken from four Vibrocore sequences from the Gunfleet Sands 03 (GFS3) site.
2. Diatoms are absent from three samples from Vibrocore 202A. The absence of diatoms from this sequence and other samples is probably the result of taphonomic processes rather than the absence of diatoms from water-lain sediments.
3. Diatoms are absent from sample D3 in Vibrocore 207. A poorly preserved diatom assemblage is present in sample D4. The diatom assemblage of D4 is dominated by the mesohalobous diatom *Diploneis didyma*. This is a benthic, mud surface and is associated with shallow water, tidal habitats.
4. Four samples were prepared from Vibrocore 304. Diatoms are absent from samples D7, D8 and D9. A very poorly preserved diatom assemblage present in sample D6 includes a fragment of the coastal planktonic species *Paralia sulcate*.
5. Three samples were analysed from Vibrocore 101B. The diatom assemblages are dominated by brackish-marine, mesohalobous diatoms which increase from 40% at the base of the sequence to 90% of the total diatoms at the top of the sequence. The mesohalobous diatoms are mostly benthic, shallow water taxa. Polyhalobous diatoms, and in particular *Paralia sulcata*, decline from a total of 27% at 4.10 m to 6% at 3.10 m. The abundance of this open water, polyhalobous species at the base of the sequence suggests that initially there was a greater input of diatoms from deeper water. However, inputs of both aerophilous and acidophilous oligohalobous indifferent diatoms, which reach a maximum of 12% at the base of the core, reflect the inwash of terrestrial material.

Acknowledgements

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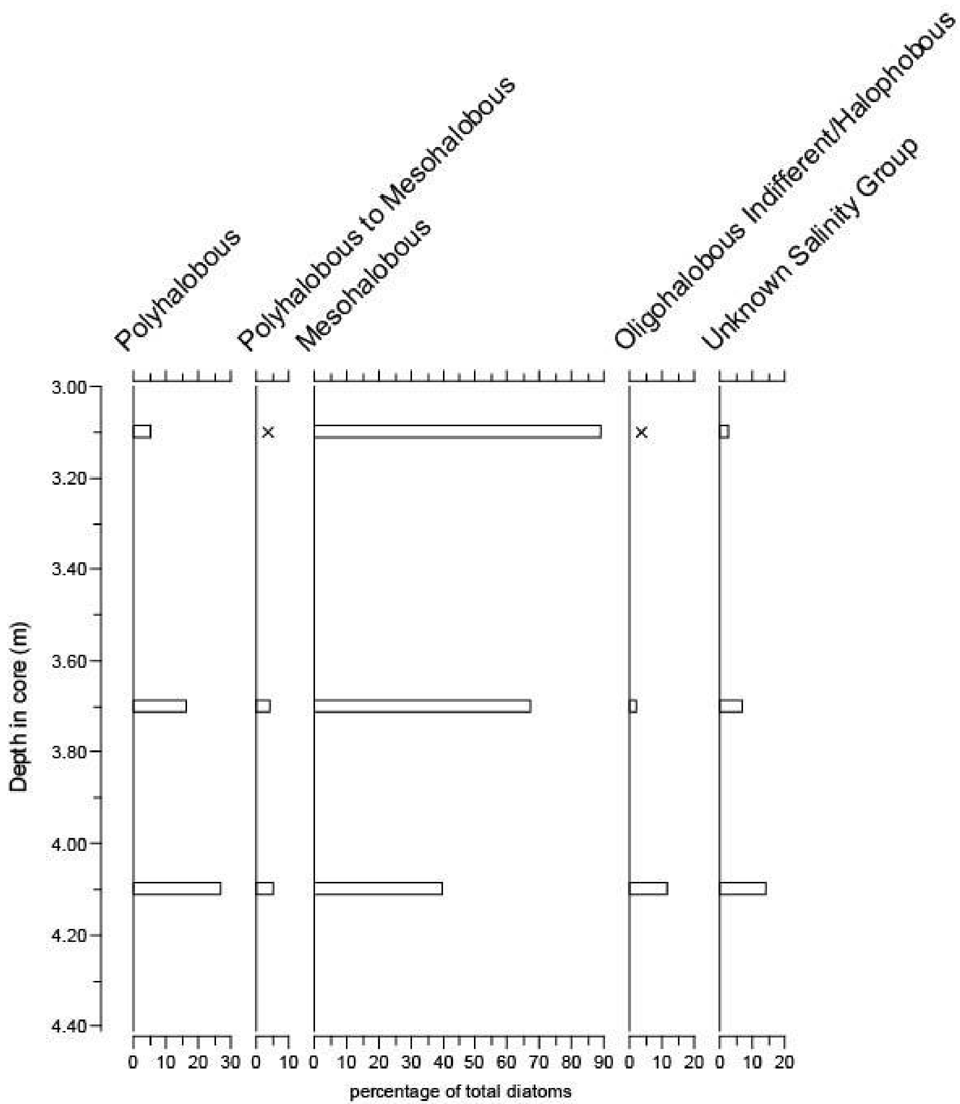
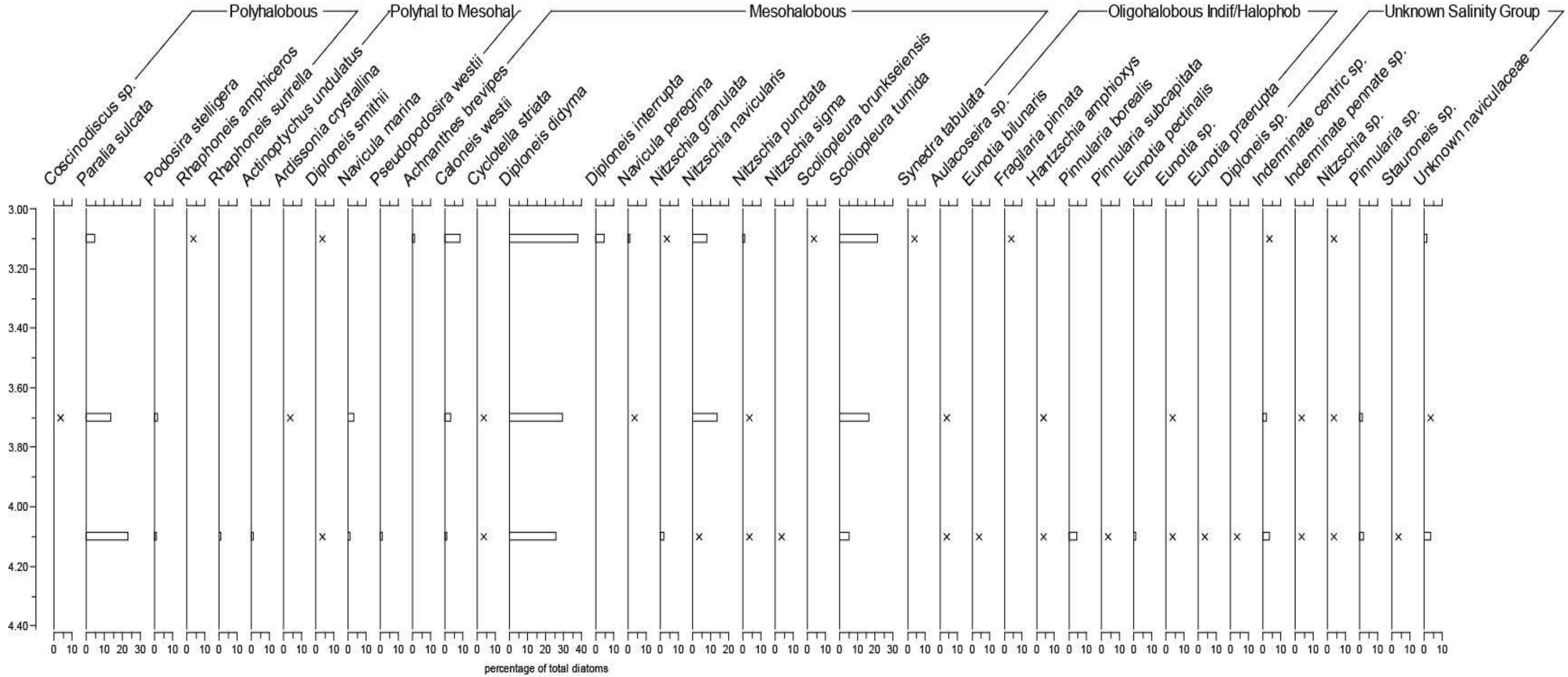

Polyhalobous
Polyhalobous to Mesohalobous
Mesohalobous
Oligohalobous Indifferent/Halophobous
Unknown Salinity Group
Depth in core (m)
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
0 10 20 30
0 10
0 10 20 30 40 50 60 70 80 90
0 10 20
0 10 20
percentage of total diatoms


Polyhalobous
Polyhal to Mesohal
Mesohalobous
Oligohalobous Indif/Halophob
Unknown Salinity Group
Coscinodiscus sp.
Paralia sulcata
Podosira stelligera
Rhaphoneis amphiceros
Rhaphoneis surirella
Actinoptychus undulatus
Ardissonia crystallina
Diploneis smithii
Navicula marina
Pseudopodosira westii
Achnanthes brevipes
Caloneis westii
Cyclotella striata
Diploneis didyma
Diploneis interrupta
Navicula peregrina
Nitzschia granulata
Nitzschia navicularis
Nitzschia punctata
Nitzschia sigma
Scoliopleura brunkseiensis
Scoliopleura tumida
Synedra tabulata
Aulacoseira sp.
Eunotia bilunaris
Fragilaria pinnata
Hantzschia amphioxys
Pinnularia borealis
Pinnularia subcapitata
Eunotia pectinalis
Eunotia sp.
Eunotia praerupta
Diploneis sp.
Indeminate centric sp.
Indeminate pennate sp.
Nitzschia sp.
Pinnularia sp.
Stauroneis sp.
Unknown naviculaceae
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
percentage of total diatoms

12 Appendix III- Microfauna assessment analysis.

GFS03 WINDFARM CABLE ROUTE, GUNFLEET SANDS, OFFSHORE CLACTON-ON-SEA, ESSEX: REPORT ON THE MICROFAUNA FROM FOUR CORES

by John E. Whittaker

INTRODUCTION

Some 12 samples from 4 cores were received from Christin Heamagi (Maritime Archaeology Ltd.) on 20th March 2014. They were taken along a proposed underwater cable route for an offshore windfarm (GFS03) on Gunfleet Sands, Clacton-on-Sea, Essex. Three are vibrocores – 207, 202A and 304 – and are situated respectively, 1.5km, c.4.0km and 5.5km offshore, whereas the final one, 101B, is from a borehole taken on land where the cable comes ashore. Other vibrocores were taken during the project but the present ones were selected specifically to investigate various features that had been identified by the geophysical survey (especially possible Pleistocene palaeochannels), and to further the understanding of the changing environment, especially at a time in the Holocene when the coastal geography was rapidly evolving as sea-level rose. The present report presents the results of a microfaunal environmental survey of the 12 samples, concentrating in particular on the foraminifera and ostracods (as well as recording other “organic remains” of ecological potential). It forms part of a comprehensive multidisciplinary survey, including plants, pollen, molluscs, etc. As of July 24th 2014 some radiocarbon dates became finally available from vibrocores 304 and 202A (C. Heamagi, pers. comm.), which have lead to some revision of the enclosed report. The implications are discussed further under the Results section.

MATERIALS & METHODS

Core 101B (onshore)

Depth in core	Depth below O.D.	Weight processed
3.40-3.41m	5.79-5.80m	10g
4.10-4.11m	6.49-6.50m	10g

Vibrocore 207 (1.5km offshore)

Depth in core	Depth below O.D.	Weight processed
0.70-0.71m	7.55-7.56m	25g
0.80-0.81m	7.65-7.66m	10g
0.89-0.90m	7.74-7.75m	60g

Vibrocore 202A (4km offshore)

Depth in core	Depth below O.D.	Weight processed
3.10-3.11m	12.98-12.99m	50g
3.50-3.51m	13.38-13.39m	75g
3.89-3.90m	13.77-13.78m	55g

Vibrocore 304 (5.5km offshore)

Depth in core	Depth below O.D.	Weight processed
3.60-3.61m	18.77-18.78m	50g
4.09-4.10m	19.26-19.27m	50g
4.20-4.21m	19.30-19.38m	10g
4.27-4.28m	19.44-19.45m	65g

The samples were placed in ceramic bowls and dried in an oven; any large pieces of sediment having been broken up by hand. A small amount of sodium carbonate was added (to disperse any clay fraction) and hot water was poured on them. They were then left to soak overnight. Washing was through a 75 micron sieve using hand-hot water, the resulting residues being decanted back into the bowls for final drying in the oven. The residues were stored in labelled plastic bags to await examination. Next each residue was put through a nest of small sieves (>500, >250, >150 microns) with a base pan. A little residue at a time from each grade was sprinkled onto a tray and a representative selection of foraminifera and ostracods was picked out under a binoculsr microscope and stored in a 3x1" faunal slide for archive purposes. Notes were made of the "organic remains" that were seen and these were logged on a presence(x)/absence basis, whereas the foraminifera and ostracod species were logged semi-quantitively, as seen on Figures 1-4 which accompany this report.

RESULTS

It was feared that some of the samples, particularly from cores 101 and 202A, were not in the best of preservation – they either had mould growing on them or were quite dry (Christin Heamagi, pers. comm.). Moreover, the amount of sediment provided for some of the samples was very small indeed (only 10g in four cases), but this was all that was available. Nevertheless, the microfaunas, when present, proved to be well preserved and enough was always available to enable ecological assemblages to be recognised and described in these cases. The microfaunas of the four cores are now described in the following order - from onshore (101B) and then in a proceeding distance offshore (respectively, 207, 202A and 304). The results are shown in four tables (Figures 1-4) on which the "organic remains" are shown first, on a presence/absence basis, and then foraminiferal and ostracod species are listed semi-quantitively (one specimen/present/common/abundant-superabundant), suitably grouped and colour-coded to shown their ecological signature at a glance. Foraminiferal ecology follows Murray (1979; 2006) and for the ostracods, Athersuch, Horne & Whittaker (1989). More detailed ecological information of the main species found in the Gunfleet Sands cores is contained in the Appendix at the end of this report.

Core 101B

Situated onshore, presumably by the present shoreline in the vicinity of where the cable comes ashore. Even though the two samples were extremely small the microfaunas present were more than enough to characterised the environment of deposition (Figure 1). The sequence, which is now 5.79-6.50m below O.D., was at the time (of lower sea-level) a brackish estuarine mudflat, and then subsequently becoming a saltmarsh. No radiocarbon dates are available for this core.

Vibrocore 207

Situated 1.5km offshore, the three sediment samples are from a sequence now situated between 7.55 and 7.75m below O.D. The top two samples (7.55-7.66m below O.D.) both contained agglutinating foraminifera typical of mid-high saltmarsh (Figure 2). This would appear to be situated at the margins of an estuary at a lower sea-level than that in 101B. The lowest of the three samples (from 7.74-7.75m below O.D.), instead of being very organic, is a clean silty sand containing but a little plant debris. This may be river alluvium of the same estuary and date the saltmarsh above, but there is as yet no further evidence. Radiocarbon dating is clearly necessary but an attempt, based on wood said to come from 0.70-0.90m in the core (7.55-7.75m below O.D.) unfortunately contained insufficient carbon (C. Heamagi, pers. comm.).

Vibrocore 202A

From approximately 4.0km offshore, the three samples examined are situated 12.98-13.78m below

O.D. The results of the microfaunal survey are shown in Figure 3. Only the environment of deposition of the topmost sample (from 12.98-12.99m below O.D.) could be ascertained for certain. Four species of foraminifera and three ostracod species indicate a brackish mudflat or protected creek (suggested by large numbers of the ostracod Cyprideis torosa), fringed with mid-high saltmarsh. There were even a few brackish hydrobid molluscs also present. The two samples below were clean silty sands and barren of any foraminifera or ostracods. This may refer to the same estuary, although whether it was tidal at this time cannot be ascertained. One large Bithynia operculum in the lowermost sample might suggest a freshwater environment, or it could be derived from a much older (Pleistocene) sediment. A radiocarbon date was finally achieved from wood from 3.09-3.28m in the core (12.97- 13.16m below O.D.) which was dated as 6430-6254 Cal BC (approximately 7500 yrs BP) (C. Heamagi, pers. comm.). However two other attempts from lower in the core (at 3.48-3.66m and 3.80- 3.91m) contained insufficient carbon, so we are no wiser about the age of that interval, which sadly contained neither foraminifera or ostracods.

Vibrocore 304

Sited 5.5km offshore. Four samples were examined covering the interval 18.77-19.45m below O.D. The results are shown in Figure 4. This proved to be the most interesting of the four cores examined. The uppermost sample contained a very rich assemblage of molluscs (including hydrobids, Littorina, and cockles, to name but a few). The residue from this sample, on the suggestion of Christin Heamagi, was subsequently sent to the mollusc specialist Simon Bray of Southampton, who has since reported on it in detail. The sample also contained very many spirorbid worm tubes, some charophyte oogonia (either with the outer calyx still present, or with only the organic inner layer preserved), and a rich fauna of brackish and outer estuarine/marine foraminifera and ostracods. The colour-coding in Figure 4 highlights the main components of the microfauna. Further information about many of the main species present are listed in the Appendix below. As well as abundant foraminifera of brackish mudflats and low saltmarsh (colour-coded light grey) there are vast numbers of miliolid foraminifera (colour-coded blue) which cling to marine algae or seagrass, and the brackish ostracod Xestoleberis nitida, which lives on algal mats in sheltered mudflats. This assemblage, including many of the other components, is almost identical to that which lives today on algae and seagrass in the eastern part of the Fleet lagoon in Dorset (a locality of which I have much experience), in salinities of c.20‰. Some of the other species, with normally an outer estuarine/marine signature, also seems to support these quite high brackish salinities. With its distance from the present shoreline and depth of deposition, the sequence could date from quite early in the Holocene. The occurrence, albeit of only one specimen, of the Lusitanian ostracod Aurila arborescens (colour-coded yellow on Figure 4) may support this. Its only other known occurrence from the North Sea area is that of Vork & Thomsen (1996) from 5900-6800 BP in Denmark, at the time of the postglacial temperature maximum. Wood from this upper interval (from 3.60-3.77m (18.77-18.94m below O.D.) has now been dated at 7046-6774 Cal BC (approximately 8000 yrsBP), so it is indeed early Holocene, albeit older than the Danish occurrence of A. arborescens. It is clear, however, by now the Straits of Dover were open.

The three lower samples from core 304 (interval 19.26-19.45m below O.D.) present a totally different facies, of sand and pebbles. Its only fossils, apart from a little plant debris, are fragmentary and worn molluscs and some small estuarine foraminifera. A clue to its provenance may lie in a few very noded (juvenile) Cyprideis torosa. This occurrence of noded valves usually indicates a very low brackish salinity below 5-6‰, (but this noding is not entirely due to salinity). The specimens of C. torosa are completely smooth where they occur elsewhere in the Gunfleet Sands cores, as invariably they are in present populations from similar estuaries in SE England today. Initially, in the earlier version of this report, I suggested that those from 19.30-19.31m below O.D. are identical to the noded populations of C. torosa that occur in the Thames-Medway of MIS 11 and 9 (but NOT subsequently), where a maximum of seven sites on the valve are noded, and thus could indicate the presence of a Pleistocene Channel belonging to either of these ages; indeed, the estuary at both these times, particularly the Clacton Channel (MIS 11) was close by (Bridgland et al., 1999). When finally a radiocarbon date was achieved (C. Heamagi, pers.comm.), said to come from wood from 4.10-4.28m in the core (19.27-19.45m below O.D.), it also proved to be early Holocene, hardly older than the uppermost, richly fossiliferous samples described above – it was dated as 7081-6830 Cal BC (approximately 8100 yrs BP). Maybe some of the sparse microfossils from this lower interval are (partly) reworked.

In conclusion, the microfaunas of the Gunfleet Sands cores present some interesting evidence for the coastal geography at various times in the Holocene, as the sea-level was rising rapidly. Hopefully, other inputs from the multidisciplinary study will now serve to enhance these environmental reconstructions further, and coupled with successful radiocarbon dating, put them into a more reliable time sequence.

Foraminiferal ecology

APPENDIX

The best information on their ecology and distribution is to be found in Murray, (1979) and in “Appendix I, Ecological Data” of Murray (2006), from which the following is derived.

Jadammina macrescens: Epifaunal on decaying vegetation and infaunal down to 60cm, an herbivore and detrivore. Widespread on high to mid saltmarsh.

Trochammina inflata: Epifaunal and infaunal down to 60cm. An herbivore and detrivore. Widespread on high to mid saltmarshes.

Ammonia sp.: Infaunal and herbivores; common in sediments with highly variable mud and total organic carbon contents; mid-low saltmarsh to subtidal, in salinities not usually below 10‰; also able to tolerate low oxygen. [The small, flat unornamented form, referred to here as Ammonia sp., are difficult to name specifically (they are most probably A. aberdoveyensis) but they usually indicate low brackish conditions, as in estuarine tidal mudflats and low-mid saltmarsh].

Elphidium williamsoni: Infaunal and an herbivore; common in sediments with highly variable mud and TOC contents; mid-low saltmarsh, intertidal to subtidal; euryhaline.

Haynesina germanica: Infaunal, an herbivore on diatoms and cyanobacteria; common in sediments with highly variable mud and TOC contents; mid-low saltmarsh, intertidal to subtidal; euryhaline.

Miliolids: Comprises mainly Quinqueloculina spp. Essentially epifaunal species, clinging to seaweeds. They are all inner shelf species, colonizing the mouths of estuaries and lagoons. Can also be brought in on floating algae.

Ostracod ecology

Information on the ostracods is from Athersuch, Horne & Whittaker (1989) for the brackish and marine species

Xestoleberis nitida: The only true brackish xestoleberid. A phytal species living on algal mats in mudflats and creeks.

Leptocythere spp.: An excellent genus for ecological reconstruction as the many species have particular niches. Two species found here - Leptocythere castanea and L. lacertosa - are both euryhaline estuarine taxa, living on tidal mudflats.

Cyprideis torosa: A mud-crawler characteristic of protected estuarine creeks. Can tolerate a wide range of brackish salinities, the shell can develop nodes below c. 5‰.

Loxoconcha elliptica: A fast swimmer on the mud/water interface. Found in estuarine mudflats all over Europe.

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9th April 2014

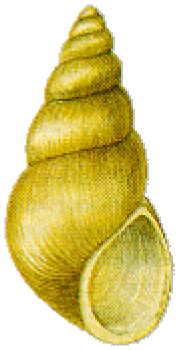
Revised 25th July 2014

13 Appendix IV- Molluscan assessment analysis.

Molluscan Fauna,

Gunfleet Sands.

Report to Maritime Archaeology Ltd.



Hydrobia ulvae

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Ref: Maritime Archaeology, Gunfleet, May 2014

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Introduction

Molluscan faunal remains taken from a vibrocore sample (No. 304) site at Gunfleet Sands off Clacton were assessed for species composition. The range of fauna taken from, for example, core samples can indicate the habitat and environmental conditions from where they were collected. Using this method, changes in environmental conditions in relation to context *may* indicate changes in paeleoclimates, local hydrology and shore exposure and salinity environments amongst other factors. The data, however, should be treated with caution as all fauna are part of the historical death assemblage which can be transported through wave action rather than indicate residency at a site, however species abundances and general knowledge of the area can be used to give an overview of prevalent conditions during the period relevant to the sample.

Methods

A sample from core 304 from the 3.6-3.77m horizon was supplied with fine material resident. This was washed through a 0.5mm sieve to remove fines thus leaving coarse sediment and calcareous shell material from Bivalvia and Gastropoda. The sample was allowed to fully dry over a two day period to enable ease of sorting. Subsequently the material was checked in a sorting tray, and individual specimens were removed for identification using a Kyowa SDZ PL microscope.

After the 3.6-3.77 sample had been sieved, a sample from core 304 from the 3.60-3.61m horizon was delivered by post. This appears to have been pre-sieved to remove much of the fine material, however, it is possible that this may have been over a .063mm sieve as many fines were retained. There was far less material in this sample, and initial inspection indicated less molluscan individuals of the types seen in the 3.60-3.77 sample, perhaps indicating an abiotic change. The sample was placed on a white tray and individual specimens were picked and removed for subsequent identification as above.

As indicated, where feasible, shells were identified to species level. This information has been used in conjunction with detail from the supplied microfauna text to provide an indication of habitat and environment.

Results

3.60-3.61 sample – not sieved for this report. Visual inspection showed a relatively high content of fine material and numerous fragments of the common cockle (*Cerastoderma edule*) and one small individual of the edible periwinkle (*Littorina littorea*). Inspection under the microscope revealed abundant quartz/silica sediment, some rounded through saltation/erosion. There were numerous further fragments of *C. edule* and smaller individuals of *L. littorea,* plus what may be a fragment of the bivalve *Scrobicularia plana* (peppery furrow shell). The sample contained abundant *Hydrobia ventrosa* (*Ventrosa ventrosa* (WoRMS, 2014)) and to a lesser extent *H. ulvae* (Laver spire shell - *Peringia ulva* (WoRMS, 2014)). *Hydrobia. ventrosa* appeared more abundant than *H. ulvae*; note, several of the gastropod individuals had encrustations, possibly bryozoan species (indet). Planorbidae were present, likely to be ***Skeneopsis planorbis* (a marine species that "*is able to penetrate well into estuaries via the high*-salinity *water that is present at depth*" (Barnes, 1994)) and common spiral forms of serpulid worms (Spirorbids); identification to species level was not possible. Finally rare *Retusa obtusa* (**Arctic barrel-bubble) **were noted, though this identification would ideally need full confirmation through inspection of soft body parts.**

3.60-3.77 sample – sieved through 0.5mm sieve. Visual inspection indicated slightly coarser material with juvenile and adult fragments of *C. edule* and *L. littorea.* Microscope inspection showed a similar species assemblage to the 3.60-3.61 horizon. *H. ventrosa* were notably more abundant than *H. ulvae, R. obtusa* were again rare. Some of the silica sediment were slightly more coarse, however please note that this sample was supplied at a different volume to the one received by post (which, as noted above, may have had differing sieve treatment). This may also account for the fact that Hydrobidae species were generally more abundant (i.e. as an artefact of greater sample volume). The exception to the similarity was that the species *S. planorbis* was less abundant perhaps indicating less marine ingress, or a significant channel morphology change (see discussion) and that the spirorbid cases were apparently absent.

Habitat indications

In conjunction with work undertaken on foraminifera (text supplied) aims of this work were to provide information of the molluscan fauna taken from the core number 304 at both horizons.

In terms of physical habitat indications, in general the faunal content of both horizons were similar though the absence of Spirorbids and less *S. planorbis* from the 3.60-3.77 sample perhaps indicates a less saline habitat than that of the 3.60-3.61 sample, which may relate to gradual tidal inundation of the area (D'Olier, 1972) or general channel morphology change. In addition, *H. ventrosa* appeared more abundant in the 3.60-3.77 sample and having a tolerance for lower salinity than *H. ulvae* (see Green, 1968) may give further indication of greater freshwater influence in this horizon.

Littorina littorea were not abundant in either sample, both being dominated by Hydrobidae, and it is known that Hydrobidae species require a dominance of fine sediments which are organically rich, conversely *L. littorea* show a "*strong preference*" for gravels (Frid and James, 1988). After sieving, the fine material from the 3.60-3.77 sample, it seems underlying silica gravels were present below a layer of fine silts presumably organically rich. In this habitat, with brackish influence, *R. obtusa* will also exist predating on both Hydrobidae species (Tyrell Smith, 1967; Chambers, 2008) and foraminifera (Smith, 1967) amongst others.

As indicated above, the Planorbidae species *S. planorbis* and the presence of Spirorbid tubes appears to indicate a greater saline incursion for the later horizon. In particular *S. planorbis* appears able to penetrate high up estuaries, presumably of a salt wedge type (where a river flows directly into the sea), and it is known that a few Spirorbid species "*may be found in brackish waters, particularly on hard substrata in the mouths of estuaries*" (Barnes, 1994) further indicating sea water incursion and the morphological change and seawater transgression noted in the area (D'Olier, 1972).

Conclusions

Samples from differing Horizons of Core 304 at Gunfleet Sands off Clacton on Sea were investigated for species representation and related habitat indications. Results suggest:

- The lower horizon comprised a suite of species representative of a more brackish/freshwater influenced habitat with rich fine sediment;
- Indication of predator prey interactions is further representative of silt/mud habitat and a stable community;

- Later communities appear to indicate an incursion of higher salinity water indicated by a slight decline in Hydrobidae, but more importantly increase in *S. planorbis* potentially associated with a salt wedge, and evident Spirorbid tubes;
- The incursion of marine waters is concomitant with formerly observed patterns of seawater inundation in the Thames Estuary as the Holocene progressed.

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14 Appendix V- Macrofossil assessment analysis.

Clacton-on-Sea, Essex Macro and microfossils from vibrocore deposits and suitability for radiocarbon dating.

Results by: Julie Jones, April 2014 Edited by Christin Heamagi, July 2014

Introduction

Analysis of macro and microfossil as was undertaken on 10 samples from boreholes 304, 101B, 207 and 202A. The study was undertaken to determine presence or absence of primarily plant and insect remains and if present, to provide a preliminary picture of the palaeo-vegetation and environment and to increase the understanding of the changing environment. The samples were also assessed for material suitable for c14 dating. The results are presented below.

Methodology

The samples were floated and sieved though a 2mm sieve. In samples where organic material suitable for dating was identified, the material was separated and stored.

Results

Table 1 below presents the plant, and wood taxa as well as other remains noted in the samples.

Clacton-on-Sea, Essex Macro and microfossils from vibrocore deposits and suitability for radiocarbon dating
Results by: Julie Jones, April 2014 Edited by Christin Heamagi, July 2014
Introduction
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Methodology
The samples were floated and sieved though a 2mm sieve. In samples where organic material suitable for dating was identified, the material was separated and stored.

Results
Table 1 below presents the plant, and wood taxa as well as other remains noted in the samples.

Core 101B

The sample contained laminations of organic material within these. Despite the large initial volume of material processed (4500ml), only 63ml remained after processing. This was predominantly small monocotyledon stem fragments with a small suite of plant taxa.
Of the seeds not extracted, 2 species are aquatics and therefore not suitable for dating and *Juncus* are small, flimsy seeds which would provide little additional weight.

Core 207

The bulk of the small float from this core was wood and woody root fragments. The 4 bigger wood fragments in Jar 1 will possibly provide sufficient weight for dating. The charcoal fragments and seeds were not of sufficient weight to be worth extracting.

Core 207
The bulk of the small float from this core was wood and woody root fragments. The 4 bigger wood fragments in Jar 1 will probably provide sufficient weight for dating. The charcoal fragments and seeds were not of sufficient weight to be worth extracting.

Core 304
This sample included thousands of small snails, thought to represent c10 different species, with some bivalves. These came from a narrow band 14-15mm thick, 4cm from the top of the sample and were revealed on breaking open the block of clay.

Table 1 Results from the taxa analysis

Core (Depth in core)	**Macrofossils (quantity)**	**Wood**	**Other remains**
101B (3.10-4.65)	Monocot stem fragments: *Alchemilla* sp. (2) *Apium graveolens* (2) *Potentilla* sp. (1) *Salicornia europaea* s.s. (16) *Urtica dioica* (2) *Ranunculus acris/repens/ bulbosus* (1) *Ranunculus sceleratus* (3 + 3 halves) *Rubus* sect. *Glandulosus* (1 fragment) *Schoenoplectus tabernaemontani* (4) Poaceae (charred) (2) *Callitriche* spp (5) *Juncus* spp (Occasional) *Ranunculus* subg. *Batrachium* (1 + 3 halves)		Beetles (rare) Mites (occasional) Charcoal (rare)
207 (0.7-0.9)	*Poaceae* indeterminate (2) *Salicornia europaea* (4) *Sambucus nigra* (1 fragment) *Suaeda maritima* (1 + 1 fragments) *Triglochin maritime* (2)	Large wood fragments (4) Small wood fragments (6)	Small charcoal fragments (rare) Foraminifera (frequent)

202A (3.09-3.28)	*Atriplex spp (2)* *Hyosycamus niger (6)* *Mentha sp (1)* *Moehringia trinervia (3)* *Salicornia europaea (2)* *Sambucus nigra (1* fragment*)* *Scleranthuus annuus (1)* *Suaeda maritime (19)*	Small wood fragments from (Frequent) Roundwood fragment, possibly alder (1) Roundwood fragment (1) Wood fragments, occasionally small roundwood (c.120)	Charcoal fragments (20) Snails (rare) Beetle fragments (rare) Ostracods (rare) Fish bone fragment (1)
202A (3.28-3.48)	*Salicornia europaea (1)*	Roundwood fragments (4) Small wood fragments (c.100)	
202A (3.48-3.66)		Wood fragments at 3.54m (6) Additional wood frags possibly partially mineral replaced. Small wood frags (c.80)	Ostracods (rare)
202A (3.66-3.80)		Small roundwood fragments, some with bark, (c.100)	
202A (3.80-3.91)		Small wood fragments, some with bark (c.30)	
304 (3.6-3.77)	*Atriplex spp (5)* *Chara spp (occasional)* *Moehringia trinervia (3)* *Ruppia c.f maritima (19)* *Ruppia c.f. cirrhosa (9)* *Sambucus nigra(1)* *Suaeda maritime (3)*	Small wood fragments (c.150)	Charcoal fragments (63) Snails (frequent) Bivalves (few) Foraminifera (occasional) Ostracods (occasional)
304 (3.77-4.0)			Charcoal (rare) Snails (c.50)

304 (4.10-4.28)		Roundwood with bark. Possibly alder (1) Small wood fragments (16) Small root fragments	Snails (2) Bivalve (1)

Interpretation

(Christin Heamagi)

The macroscopic plant and insect remains analysis confirmed that the sediments are generally indicative of marine and wetland environments with regions of woodland ponds, marsh and grassland.

The macrofossil assemblage from 101B shows abundant material from Common Glasswort associated with saline environments, such as seacoasts and salt marshes. The sample also contains 4 examples of *Schoenoplectus tabernaemontani* a member of the Sedge family that grows in moist and wet habitats, and sometimes in shallow water. Other macrofossils recorded in smaller numbers, as presented in Table 1, are characteristic of plants living in wetlands, saltmarshes, grasslands, or in mud, ponds and riverbeds.

Vibrocore 207 only contained a total of 10 identifiable macrofossils or fragments of macrofossils. The Common Glasswort is again seen in larger numbers (4) than the rest of the fragments identified. The diminutive material in 207 indicates a wet environment where taxa like *Suaeda Maritima, Troglochin maritimum* and *Sambucus nigra can* cultivate.

Core 202A did contain a satisfactory amount of material between 3.09 and 3.28 m but only one macrofossil between 3.28 and 3.48 (*Salicornia europaea*). The lower samples from vibrocore 202a did not contain any identifiable material but did contain some wood fragments and a few roundwood fragments. Between 3.28 and 3.48 the taxa is mainly made up of *Suaeda Maritima (annual seablite)*, a shrub plant that thrives in salt marshes. Further macrofossils indicate a varied environment with plants from wet, dry, wooded and marine environments.

Identifiable macrofossils were only recorded between 3.60-3.77 m in vibrocore 304. The material is abundant in Beaked Tasselweed *(Ruppia maritima*) that grows in coastal brackish waters, such as marshes. Other species identified ranges from spiral ditchgrass (*Ruppia cirrhosa*) that grows in freshwater bodies, such as lakes to spiral tasselweed (*Moehringia trinervia*) a submerged aquatic species growing in saline ponds and lagoons. The lower sediments (3.77-4.28 m) only contained a few unidentifiable wood and roundwood fragments.

Appendix 1

Plant macrofossils identified, with Latin names and brief habitat description

	Common name	**Habitat**
Alchemilla spp	Lady's-mantle	Various
Apium graveolens L.	Wild Celery	ws
Atriplex spp.	Orache	CDn
Callitriche spp.	Water-starwort	A or on mud
Chara spp.	Stonewort	A
Hyosycamus niger L.	Henbane	D, maritime sand/shingle
Juncus spp.	Rush	GMRw
Mentha sp.	Mint	various
Moehringia trinervia (L.)Clairv.	Three-nerved Sandwort	WH - shady
Poaceae indet	Grass	G
Potentilla sp.	Cinquefoil	various
Ranunculus acris/repens/bulbosus	Meadow/Creeping/ Bulbous Buttercup	DG
Ranunculus subg. *Batrachium* (DC.)A.Gray	Water Crowfoot	APR
Ranunculus sceleratus L.	Celery-leaved Buttercup	MPR
Rubus sect. *Glandulosus* Wimmer & Grab	Bramble	DHSW
Ruppia c.f *maritima* L.	Beaked Tasselweed	P - brackish
Ruppia c.f. *cirrhosa* (Petagna)Grande	Spiral Tasselweed	P - brackish
Salicornia europaea L.	Common Glasswort	all levels of saltmarsh
Sambucus nigra L.	Elder	DHSWn
Schoenoplectus tabernaemontani (C.Gmelin)Palla	Common Club-rush	BPRs
Scleranthuus annuus L.	Annual Knawel	do - sandy
Suaeda maritima (L.)Dumort	Annual Sea-blite	mid/lower SM
Troglochin maritimum L.	Sea Arrowgrass	SM & salt sprayed G
Urtica dioica L.	Common Nettle	DGHWp

Habitats

A: Aquatic
B. Bankside
C: Cultivated/Arable
D: Disturbed
F. Fens/Bogs
G: Grassland
H: Hedgerow
M: Marsh
P: Ponds, ditches - stagnant/slow flowing water
R: Rivers, streams
S: Scrub
W: Woodland

n: nitrogen rich soils
o: open habitats
p: phosphate rich soils
s: coastal
w: wet/damp soils

15 Appendix VI- Radiocarbon dating certificates.

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RADIOCARBON DATING CERTIFICATE

23 July 2014

Laboratory Code	SUERC-54107 (GU34415)
Submitter	Christin Heamagi Maritime Archaeology Ltd. Room W1/95 National Oceanography Centre, Empress Dock, Southampton,, SO14 3ZH
Site Reference	GFS03
Context Reference	304
Sample Reference	GFS 501
Material	wood
δ^{13}C relative to VPDB	-26.6 ‰
Radiocarbon Age BP	7980 ± 29

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

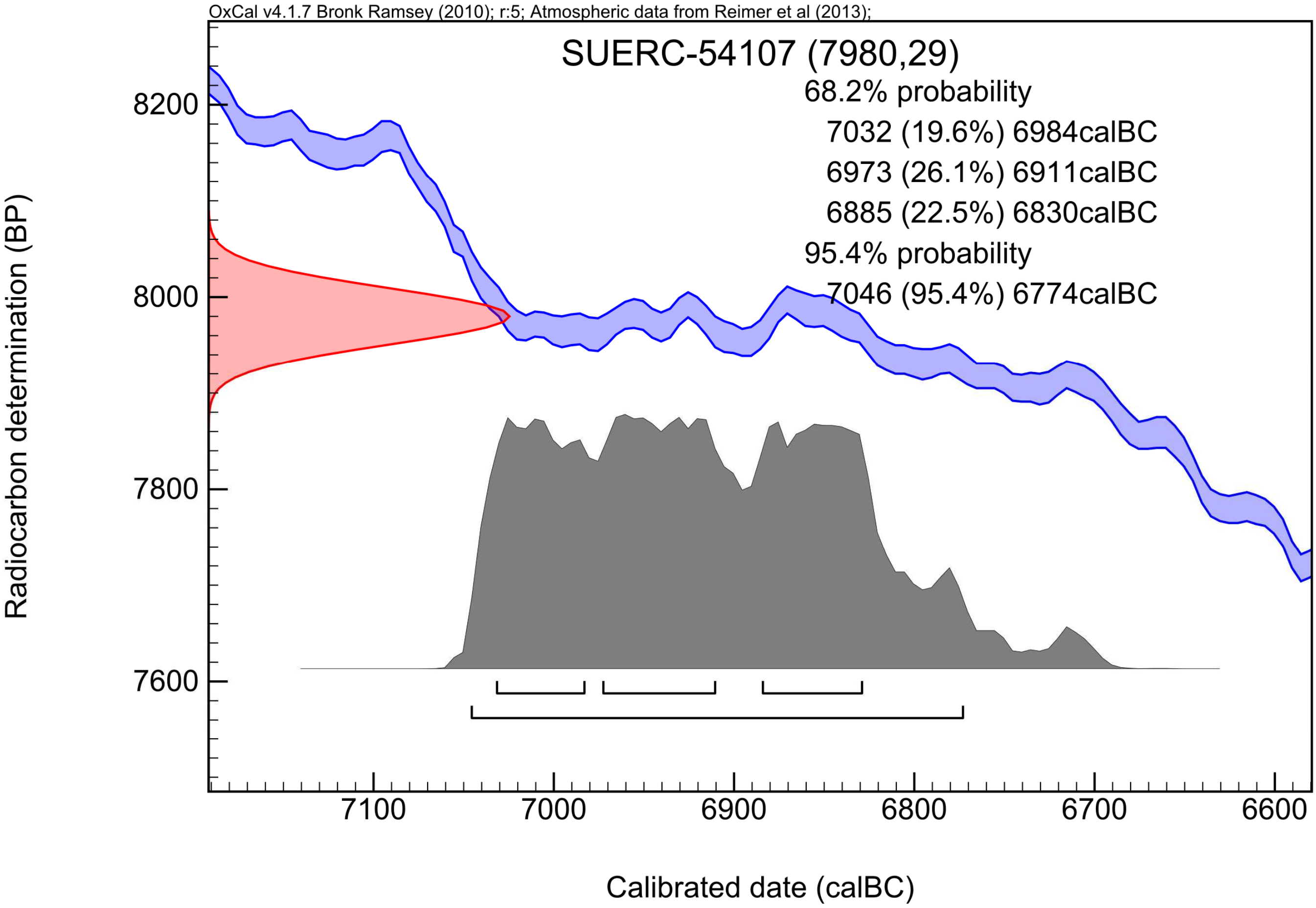
The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after the SUERC code. The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or telephone 01355 270136 direct line.

Conventional age and calibration age ranges calculated by :- B Tagney Date :- 23/07/2014

Checked and signed off by :- E. Dunbar Date :- 23/07/2014

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

23 July 2014

Laboratory Code SUERC-54108 (GU34416)

Submitter
Christin Heamagi
Maritime Archaeology Ltd.
Room W1/95
National Oceanography Centre,
Empress Dock, Southampton,, SO14 3ZH

Site Reference GFS03
Context Reference 304
Sample Reference GFS 502

Material wood

δ^{13}C relative to VPDB -25.0 ‰ assumed

Radiocarbon Age BP 8055 ± 28

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

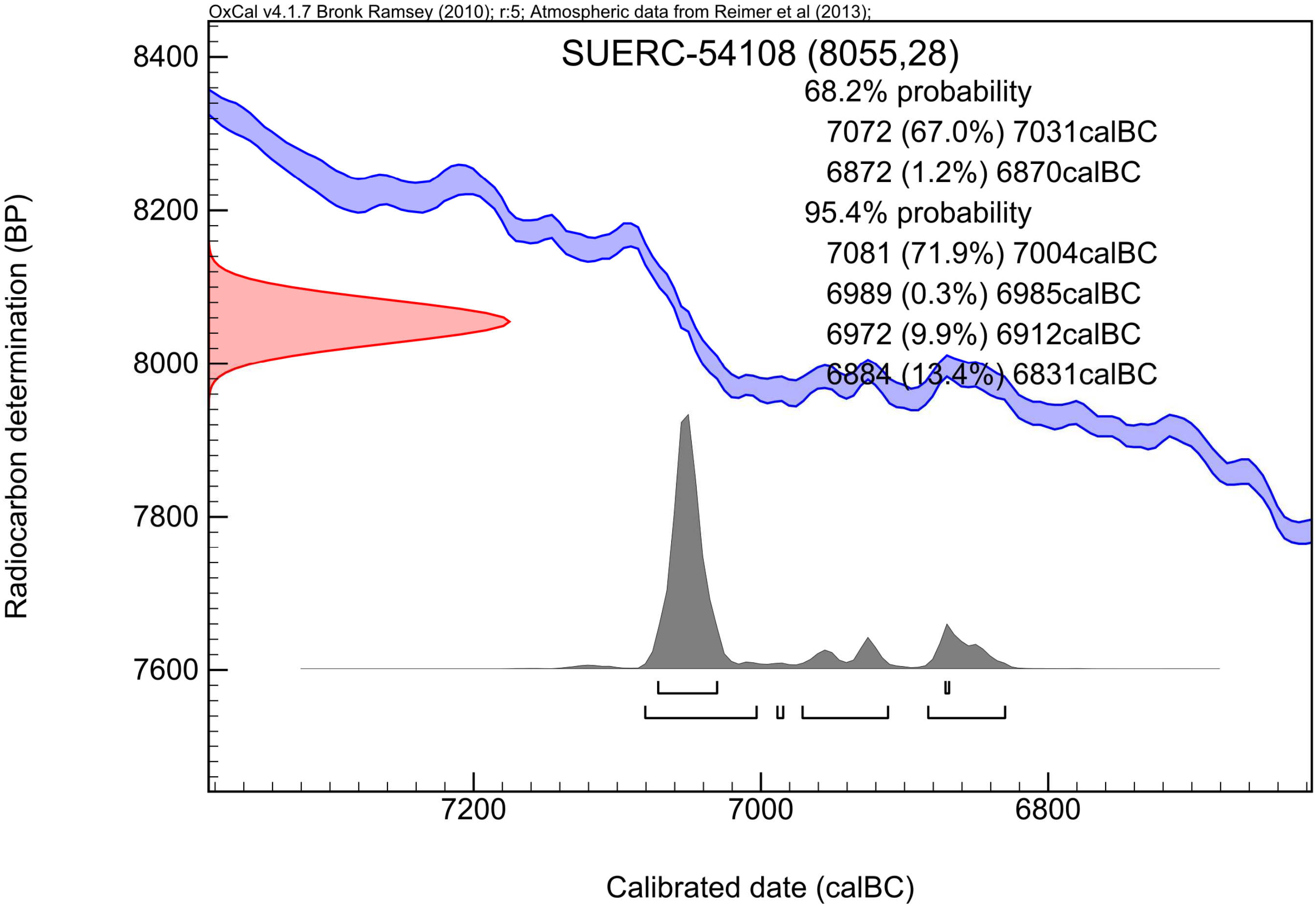
The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after the SUERC code. The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or telephone 01355 270136 direct line.

Conventional age and calibration age ranges calculated by :- [signature] Date :- 23/07/2014

Checked and signed off by :- E. Dunbar Date :- 23/07/2014

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

23 July 2014

Laboratory Code	SUERC-54109 (GU34417)
Submitter	Christin Heamagi Maritime Archaeology Ltd. Room W1/95 National Oceanography Centre, Empress Dock, Southampton,, SO14 3ZH
Site Reference	GFS03
Context Reference	202A
Sample Reference	GFS 503
Material	wood
$\delta^{13}C$ relative to VPDB	-25.4 ‰
Radiocarbon Age BP	7487 ± 28

N.B. The above ^{14}C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.

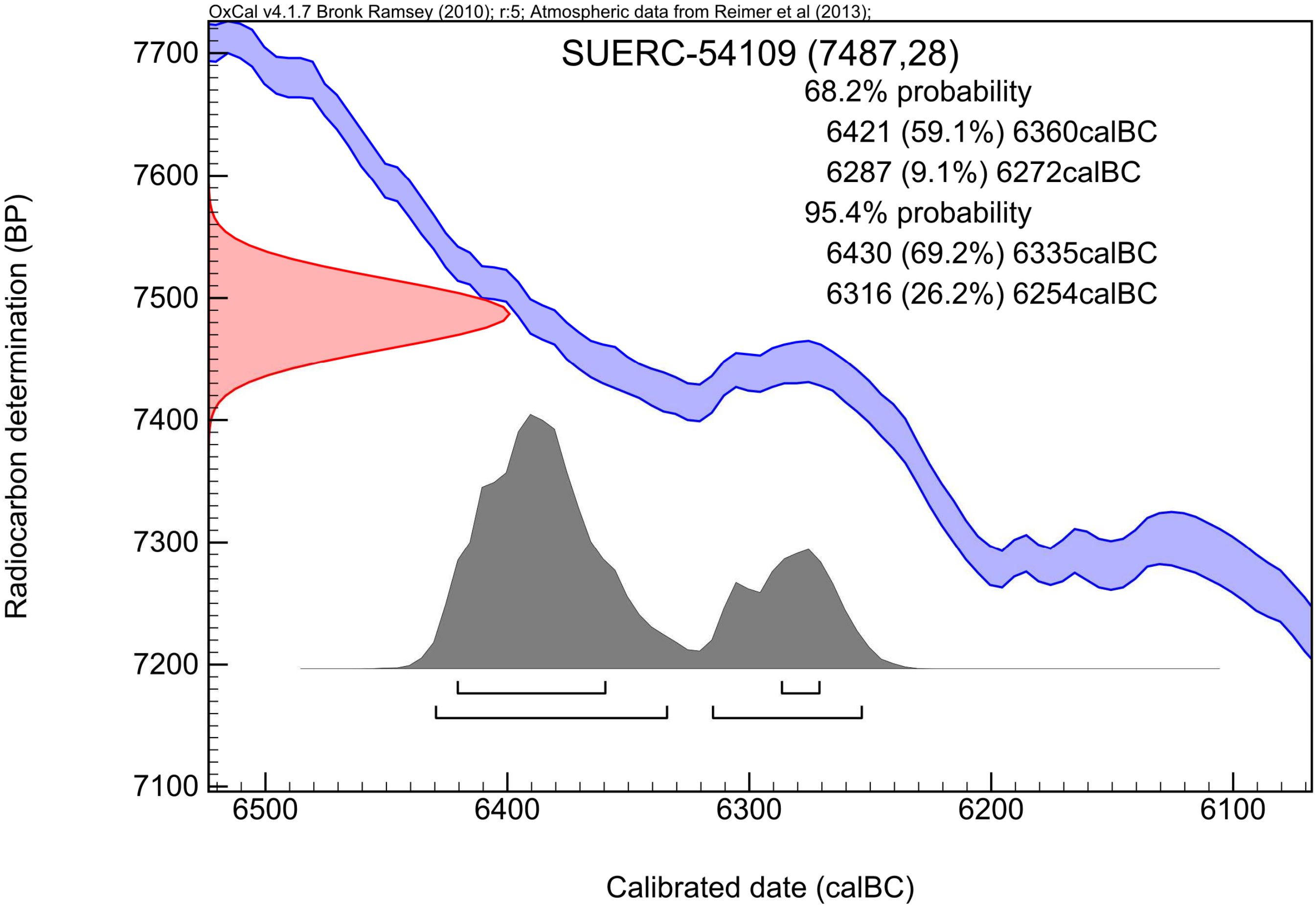
The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after the SUERC code. The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or telephone 01355 270136 direct line.

Conventional age and calibration age ranges calculated by :- B Tagney Date :- 23/07/2014

Checked and signed off by :- E. Dunbar Date :- 23/07/2014

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

23 July 2014

Laboratory Code	GU34418
Submitter	Christin Heamagi Maritime Archaeology Ltd. Room W1/95 National Oceanography Centre, Empress Dock, Southampton,, SO14 3ZH
Site Reference	GFS03
Context Reference	202A
Sample Reference	GFS 504
Material	wood
Result	Failed: insufficient carbon.

N.B. Any questions directed to the Radiocarbon Laboratory should quote the GU coding given above.

The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or telephone 01355 270136 direct line.

Checked and signed off by :- E. Dunbar

Date :- 23/07/2014

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RADIOCARBON DATING CERTIFICATE

23 July 2014

Laboratory Code	GU34419
Submitter	Christin Heamagi Maritime Archaeology Ltd. Room W1/95 National Oceanography Centre, Empress Dock, Southampton,, SO14 3ZH
Site Reference	GFS03
Context Reference	202A
Sample Reference	GFS 505
Material	wood
Result	Failed: insufficient carbon.

N.B. Any questions directed to the Radiocarbon Laboratory should quote the GU coding given above.

The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or telephone
01355 270136 direct line.

Checked and signed off by :- E. Dunbar

Date :- 23/07/2014

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RADIOCARBON DATING CERTIFICATE

23 July 2014

Laboratory Code	GU34420
Submitter	Christin Heamagi Maritime Archaeology Ltd. Room W1/95 National Oceanography Centre, Empress Dock, Southampton,, SO14 3ZH
Site Reference	GFS03
Context Reference	207
Sample Reference	GFS 506
Material	wood
Result	Failed: insufficient carbon.

N.B. Any questions directed to the Radiocarbon Laboratory should quote the GU coding given above.

The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or telephone 01355 270136 direct line.

Checked and signed off by :- E. Dunbar

Date :- 23/07/2014