AGGREGATE LEVY SUSTAINABILITY FUND
MARINE AGGREGATE AND THE HISTORIC ENVIRONMENT

SEABED PREHISTORY: GAUGING THE EFFECTS OF MARINE AGGREGATE DREDGING

ROUND 2
FINAL REPORT

VOLUME VI: HUMBER

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Summary

This study forms Volume VI of the 'Seabed Prehistory: Gauging the Effects of Marine Aggregate Dredging - Final Report' commissioned by English Heritage (EH) and undertaken by Wessex Archaeology (WA). It was funded through Round 2 of the Aggregate Levy Sustainability Fund (ALSF) distributed by the Department for Environment, Food and Rural Affairs (DEFRA). The 'Final Report' comprises of eight volumes based on previous reports accomplished by WA for either EH or the Mineral Industry Research Organisation (MIRO), as part of Round 1 or Round 2 of the ALSF project 'Seabed Prehistory'.

The Humber area was selected for study as it represented an aggregate dredging area with different geological setting, and as such archaeological potential, to the previously studied areas. The study area of 6km x 1.2km lies to the south of the Humber Estuary and is situated between and partly within two dredging areas approximately 16km off the coast of Lincolnshire. The study area was chosen as a result of prospective survey lines and as being representative of the general geology of the area.

The geophysical survey methodology comprised a bathymetric survey to establish water depths and seabed morphology across the study area, a sidescan sonar survey to record the seabed sediments and further highlight the seabed morphology and a shallow seismic survey to identify individual sub-seabed horizons that were then modelled.

Based on the geophysical data interpretation vibrocore locations were proposed within the area. The aims of the vibrocore survey were to calibrate the geophysical data with regard to stratigraphy, to help provide a relative chronology for the area, i.e. to identify the relationship between palaeogeographic features, to provide an absolute timescale of the depositional processes through appropriate dating techniques, and to provide evidence for the environmental reconstruction of the depositional environments.

A grab sampling survey was also undertaken in order to locate any exposed fine grained deposits and/or prehistoric remains within the upper sediment layers of the seabed.

The geophysical and vibrocore data show a sedimentary sequence dating from the Devensian glaciation. The data show deposition of fluvioglacial sediments deposited as the ice sheet retreated and subsequent reworking and deposition of shallow marine/sublittoral sediments associated with the continuing inundation/marine transgression during the late Mesolithic period.

OSL and radiocarbon dates were taken from vibrocore samples. Although a number of dates came out reversed they are considered to be reliable on the millennial scale as shallow marine deposits at *c*. 20m below OD in the North Sea would be expected to date to the late Mesolithic period. The fact that the dates are reversed is most likely due to reworking of the sediments in a shallow marine context. The dates do however confirm that this reworking has probably occurred during or slightly after the late Mesolithic period.

Potential for *in situ* prehistoric archaeological remains in this area is low. This is due to the deposits either being glacial or shallow marine in origin. There is however potential for reworked Palaeolithic and Mesolithic archaeological material to be present within marine aggregate deposits. If this material exists it is likely to be reworked into the shallow marine and glaciofluvial sands and gravels identified within the area. No artefacts of prehistoric origin were recovered from the grab samples or vibrocores; however these represent a very small percentage of the area surveyed.

The methodology of combining geophysical and geotechnical surveys proved successful in assessing the archaeological potential of the study area. Furthermore, an assessment of the effect of line-spacing on the interpretation was carried out during the interpretation phase of the project. It was shown that although using 25 x 100m grid line spacing would improve the resolution of the interpretation, all features observed on the smaller grid were observed on the 50 x 100m grid as well. As such, it is considered that a 50 x 100m grid is suitable for identifying submerged landscapes.

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Acknowledgements

The Mineral Industry Research Organisation (MIRO) commissioned this project on behalf of the former Office of the Deputy Prime Minister (ODPM), now Department for Communities and Local Government (DCLG). Wessex Archaeology (WA) would like to thank Derren Creswell for his help and support throughout the project.

The geophysical fieldwork was undertaken by Louise Tizzard, Cristina Serra, Dr Stephanie Arnott and Dr Paul Baggaley of WA onboard the R/V *Wessex Explorer*. WA would like to thank the crew of the vessel for their assistance during the fieldwork. Louise Tizzard and Dr Stephanie Arnott carried out the geophysical processing.

The geotechnical survey was undertaken by Gardline Surveys Ltd. onboard the S/V *Flatholm* (vibrocore survey) and the *George D* (grab sampling survey). The vibrocoring programme was supervised by Jack Russell of WA. WA would like to thank the crew of the vessels and Gardline Surveys for their assistance during this phase of the fieldwork. Processing and interpretation of the cores were carried out by Jack Russell and Niall Callan. Processing and interpretation of the grab samples were carried out by Margaret Christie and Labhaoise McKenna.

Pollen and diatom assessment were conducted by Dr Robert Scaife of Southampton University. Foraminifera and ostracod assessments were conducted for WA by Jack Russell. Radiocarbon dating analysis was conducted by the Scottish Universities Environment Research Centre (SUERC). The Optical Stimulated Luminescence (OSL) dating was carried out by Richard Bailey at Royal Holloway College, University of London. Jessica Grimm and Dr Christopher Stevens of WA identified the animal bone and plant macrofossils, respectively.

We would also like to thank the WA ALSF steering group composed of Dr Ian Selby (Hanson Aggregates Marine), Dr Andrew Bellamy (United Marine Aggregates), Mark Russell (British Marine Aggregates Producers Association), Dr Bryony Coles (University of Exeter) and Dr Brian D'Olier for their comments and guidance on this phase of the project.

Louise Tizzard and Jack Russell compiled this report. Figures were compiled by Kitty Brandon and Karen Nichols. Dr Dietlind Paddenberg edited the report and Stuart Leather managed the project for WA.

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1. INTRODUCTION

1.1. PROJECT BACKGROUND

1.1.1. In 2005, Wessex Archaeology (WA) was commissioned by English Heritage (EH) to compile the final synthesis of the research project 'Seabed Prehistory – Gauging the Effects of Marine Aggregate Dredging'. The project synthesis was funded through Round 2 of the Aggregate Levy Sustainability Fund (ALSF) distributed by the Department for Environment, Food and Rural Affairs (DEFRA) (see **Volume I**).

1.1.2. Round 1 of the 'Seabed Prehistory' project was undertaken between 2003 and 2004 as part of the Sustainable Land Won and Marine Dredged Aggregate Minerals Programme (SAMP), funded by Round 1 of the Aggregate Levy Sustainability Fund (ALSF) and administered by MIRO on behalf of the former Office of the Deputy Prime Minister (ODPM), now Department for Communities and Local Government (DCLG).

1.1.3. The project was extended to Round 2 in order to assess the application of the Round 1 methodologies to aggregate dredging zones with different geoarchaeological characteristics. Round 2 comprised different components, each component funded through either EH or MIRO, under the ALSF funding for Round 2. Each component was an independent stand alone project, resulting in the eight volumes of this report. **Table VI.1** provides an overview of all volumes of 'Seabed Prehistory: Gauging the Effects of Marine Aggregate Dredging - Final Report', **Volumes I-VIII** (Wessex Archaeology 2007a).

Volume	Title
I	Introduction
II	Arun
III	Arun Additional Grabbing
IV	Great Yarmouth
V	Eastern English Channel
VI	**Humber**
VII	Happisburgh and Pakefield Exposures
VIII	Results and Conclusions

Table VI.1: Overview of the volume structure of this report.

1.1.4. This report is **Volume VI** in the series and sets out the Round 2 investigations into the Humber area. It is an updated version of a previous 'Seabed Prehistory' project report for MIRO (Wessex Archaeology 2007b) and provides details on the acquisition, processing and interpretation of geophysical and geotechnical data in a specific area of seabed south of the Humber Estuary, in order to address its potential prehistoric deposits.

1.2. STUDY AREA

1.2.1. The Humber area was selected for study as it represented an aggregate dredging area with different geological setting, and as such archaeological potential, to the previously studied areas (**Volumes II-V**). Two geophysical prospection lines were acquired prior to selecting the study area itself. A north-south orientated line was run to the west of the dredging licence area 106. An east-west orientated prospective line was run to the south of the Humber Estuary. Based on initial interpretation of this data a study area was selected that was representative of the geology of the area.

1.2.2. The study area lies to the south of the Humber Estuary and is situated between the two dredging areas 197 and 106 (currently licensed to United Marine Dredging and Hanson Aggregates Marine Limited, respectively) approximately 16km off the coast of Lincolnshire. The study area overlaps dredging area 106 by approximately 500m (**Figure VI.1**).

1.2.3. The Humber study area comprises a 6km x 1.2km rectangle delimited by the coordinates provided in **Table VI.2** (WGS 84, UTM Zone 31) (**Figure VI.2**).

Easting	Northing
332472	5921678
333629	5921945
335016	5916074
333793	5915802

Table VI.2: Coordinates of the Humber study area (WGS 84, UTM zone 31).

1.3. GEOARCHAEOLOGICAL BACKGROUND

1.3.1. Throughout the Pleistocene the study area has been severely affected by periods of glaciation which have shaped the landscape. Generally, the geology of the area comprises pre-Tertiary rocks (Upper Cretaceous Chalk) underlying a thickness of Pleistocene glacial till, which in turn underlies Holocene marine sediments (Cameron *et al.* 1992).

1.3.2. During the latter part of the Cromerian Complex (during a glacioeustatic low sea level stand) the southern North Sea was predominantly occupied by a huge delta complex. One of the major rivers (the Yorkshire) was cut prior to the Cromerian Complex and existed where the river Humber is now situated.

1.3.3. The advance of the continental ice sheets during the Anglian Glaciation (OIS 12) completely re-modelled the landscape, with the older river course destroyed or buried and an entirely new landscape formed beneath the ice by glacial and fluvioglacial erosion and deposition. Following the Hoxnian interglacial, during the Wolstonian Stage (OIS ?6 or 8), the study area was covered by ice. This had similar effects on the landscape as the Anglian Glaciation, again causing major landscape re-modelling.

1.3.4. During the Devensian there are considered to be three major phases of glaciation in the North Sea basin (Carr *et al.* 2006). The Ferder glacial episode in the Early Devensian (OIS 4), the Cape Shore glacial episode (OIS 3) during the Mid- to Late-Devensian and the Bolders Bank glacial episode in the Late-Devensian (OIS 2). Within the study area only the remnants of this third major ice sheet advance are represented in the form of the Bolders Bank Formation.

1.3.5. The Bolders Bank Formation is a sub-glacial till and exists as a large lobe that extends 50km offshore from northeast England before spreading out over a large area of the southern North Sea. The formation comprises dark brown over-consolidated fine-grained diamicton with sub-rounded and sub-angular clasts of predominantly chalk, flint and sandstone. The clasts are mainly sourced from the east coast of England with a subsidiary lithic igneous and metamorphic component of Scottish origin. The Bolders Bank Formation is generally massive in structure with occasional sandy interbeds. Diamicton refers to distinctive sediment comprising unsorted gravel, sand and mud in various proportions (Cameron *et al.* 1992).

1.3.6. As the Bolders Bank Formation represents the erosion of a former landsurface there is little potential for pre-Devensian archaeological artefacts to remain *in situ*, however, derived artefacts transported by the ice sheet may remain.

1.3.7. The surface of the Bolders Bank Formation is likely to be modified by small channels and depressions created by meltwater and fluvioglacial processes as the ice sheet began to retreat. Within the channels, carved out by the meltwater, sands and gravels would have been deposited. By the end of the Dimlington Stadial at around 13,000 BP (*c.* 13,400 cal. BC) no ice would have remained over the study area and a periglacial landscape would have prevailed (Coles 1998).

1.3.8. Previous surveys in the area have illustrated completely infilled depressions located in a dredging area off the Humber Estuary (Bellamy 1998, figure 4). The upper surface of the infill is considered to be truncated by a ravinement surface formed during the last marine transgression. The infill sediments comprise coarse-grained sediments and on-lapping fine-grained sediments. These depressions are likely to be formed associated with the retreat of the glacial ice-front. Outwash plains can develop along the margins of ice sheets where braided rivers form numerous outlets along the ice fronts. Deposition of fine-grained sediments indicates slower meltwater flow than that of the deposition of the coarser sediments.

1.3.9. Holocene sediments are expected to cover the study area overlying the Bolders Bank Formation and are likely to comprise 1-2m of sandy gravelly sediments (Cameron *et al*. 1992). The sediments are generally thin, and like the whole of the North Sea, very little sediment is transported to or deposited in the area despite strong tidal currents. Most of the sediments in the area were probably already present before the last marine transgression which began to inundate the area around 9,000 BP (*c.* 8,200 cal. BC) (Jelgersma 1979).

1.3.10. According to the general sea level curves for the southern North Sea, the study area would have presented a shallow marine coastal environment by 7,500 BP (*c.* 6,400 cal. BC), and by 5,000 BP (*c.* 3,700 cal. BC) the coastline would have been in a similar location to its present day position (Jelgersma 1979).

1.3.11. The gravel fraction of the Holocene sediments is thought to have arisen as lag deposits derived from moraines or outwash fans (Robinson 1968; Veenstra 1971). Some gravel may also be derived from erosion of the till underlying the offshore area (Cameron *et al*. 1992). Wenban-Smith (2001) suggests that the gravels are glaciagenic outwash gravels and can be related to the general period of the peak of the last glaciation (OIS 2). The sand fraction is also thought to be derived from glacial sediments. Shell fragments are usually low in marine aggregates in this area reflecting their terrestrial/fluvial origins. Any local concentrations of shelly fragments are likely due to marine re-working.

1.3.12. Coles (1998) suggests that areas of the North Sea were populated during the Mesolithic period. In 1931 a Mesolithic bone harpoon point dating to 11,740±150 BP (11,950 – 11,340 cal. BC) was trawled from a peat deposit in the Leman and Owers Bank area *c.* 60km north-east of the study area at a depth of around 36m (Louwe Koojmans 1970; Verhart 1995). Further examples of worked flint and bone artefacts were trawled up around Brown Ridge and Dogger Bank in the southern North Sea (Louwe Koojmans 1970; Verhart 1995; Flemming, 2002).

2. SURVEY METHODOLOGIES

2.1. Overview

2.1.1. The geophysical survey methodology comprised a bathymetric survey to establish water depths and seabed morphology across the study area, a sidescan survey to record the seabed sediments and further highlight the seabed morphology and a shallow seismic survey to identify individual sub-seabed horizons that were then modelled.

2.1.2. Based on the geophysical data interpretation vibrocore locations were proposed within the area. The aims of the vibrocore survey were to calibrate the geophysical data with regard to stratigraphy, to help provide a relative chronology for the area, i.e. to identify the relationship between palaeogeographic features, to provide an absolute timescale of the depositional processes through appropriate dating techniques, and to provide evidence for the environmental reconstruction of the depositional environments.

2.1.3. A grab sampling survey was also undertaken in order to locate any exposed fine grained deposits and/or prehistoric remains within the upper sediment layers of the seabed.

2.2. Geophysical Survey

Technical Specifications

2.2.1. WA carried out the geophysical survey off the coast of Lincolnshire aboard the R/V *Wessex Explorer* between the 7th and 13th June 2006.

2.2.2. Throughout the survey all coordinates were expressed in WGS84, UTM zone 31N.

2.2.3. Bathymetry, sub-bottom profiler and sidescan sonar data were acquired on all survey lines simultaneously. On north-south orientated lines the line spacing was 50m and on the east-west orientated lines the line spacing was 100m. Approximately 250 line kilometres of data were collected during the survey. In addition, a small sub-area (inner study area) of 2km x 0.4km was chosen in the south of the study area where additional lines were run resulting in a 25m line spacing for the north-south orientated lines (**Figure VI.2**). These extra lines were run in order to assess whether 25m line spacing would provide more detail on the submerged landscape compared to 50m line spacing (**Section 4.1**).

2.2.4. Onboard the R/V *Wessex Explorer* positioning was provided by a Leica MX412 DGPS Professional navigator system. The navigation data for this survey was recorded digitally using Ilex Harbourman software and a position was logged every second. The positioning system, echosounder and tow fish were all interfaced into this system ensuring the navigation parameters were consistent for all equipment throughout the survey.

2.2.5. Single beam bathymetric data was recorded throughout the survey and was acquired using a Knudsen 320M single beam echosounder. The echosounder transducer was mounted to the survey vessel, and the transducer draught was measured and entered into the echosounder to obtain depths relative to the sea-surface. A TSS DMS 2.05 motion sensor was rigidly mounted above the transducer to measure the vertical displacement (heave) and attitude (roll/pitch) of the vessel; this data was interfaced with the echosounder. The accuracy of the draught and velocity offsets of the echosounder were checked regularly throughout the survey using the bar check method.

2.2.6. The corrected bathymetric data were recorded digitally and interfaced with the navigation data using Ilex Harbourman software and on the echosounder paper trace.

2.2.7. All depth references have been reduced to Ordnance Datum Newlyn (OD). The depth data were tidally reduced using observed water levels acquired using a Valeport Midas Water Level Recorder and tidally adjusted making reference to the local tide gauge (at Immingham) data. Chart Datum (Immingham) relative to Ordnance Datum (Newlyn) is -3.9m.

2.2.8. Sub-bottom profiler data were acquired using a surface-tow boomer system. An Applied Acoustic Engineering AA200 surface-tow boomer plate housed on a catamaran with an EG&G 265 eight element external hydrophone array was used throughout the survey. The boomer plate and hydrophone were towed approximately 15 metres behind the vessel to starboard and port respectively with a separation of approximately four metres. The offsets of the tow point to the echosounder were measured for use in the data processing.

2.2.9. An Edgetech 4200-FS dual frequency digital sidescan sonar was used during this survey. This system collects data at 120kHz and 410kHz simultaneously. Digital dual frequency systems are widely used in the marine aggregate industry for both prospecting and seabed sediment mapping. The Edgetech 4200-FS is a new system which enables different range settings to be applied to the different frequencies. This allows high frequency data to be acquired at a short range resulting in higher resolution data, whilst simultaneously recording low frequency long range data.

2.2.10. The sidescan sonar towfish was towed directly behind the survey vessel. The data quality was optimised by adjusting the height of the fish by changing the length of the tow-cable (between 14 and 20m) to account for changes in water depth and vessel speed.

2.2.11. High frequency data was acquired at a range of 75m; low frequency data was acquired at a range of 150m. This ensured full seabed coverage at both frequencies for the study area.

2.2.12. The data were collected digitally on a workstation using Coda GeoSurvey software in *.xtf format and stored on hard disk as date/time referenced files for post-processing and the production of sonar mosaics.

Geophysical Data Processing

2.2.13. The single beam echosounder data were processed using Ilex Harbourman software. This included correcting the data for tides and editing any erroneous points from the data. The data was gridded to one metre cells and the processed bathymetry data was then exported as an ASCII text file for interpretation.

2.2.14. The processed single beam echosounder data was input into Fledermaus software and a surface was created. Fledermaus is a 3D-visualisation and analysis software package. This software can create 3D solid surfaces for any set of data containing points with an x, y and z value. These surfaces are made by gridding the data and interpolating between the data points before shading the surface with a user selected colour file so that the colours represent the relative heights over the surface. This 3D surface can then be explored and visualised in conjunction with other relevant geo-referenced data sets.

2.2.15. A cell size and weighting must be selected when gridding a data set. The chosen cell-size is the minimum value that can be used to ensure that data can be assigned to each cell. This value will vary depending on the line spacing used and the distance between data points. The resulting surface will be made up of rectangles corresponding to the cell size. The heights between neighbouring cells will be averaged over the number of adjacent cells corresponding to the weighting value. The weighting value affects the smoothing of the data. The higher the weighting value used, the smoother the data will appear. If there is a large number of closely spaced x, y, z points then small cell sizes can be used and a surface containing a high resolution of horizontal spatial detail can be produced.

2.2.16. In data sets with relatively large gaps between the data points, such as the single beam bathymetry dataset, a large cell size must be used to prevent holes appearing in the surface. For the single beam bathymetry dataset a cell size of 20m and a weighting of three was used. The use of these values ensured full coverage of the surface without overly smoothing the data.

2.2.17. The processing of the digital seismic data was undertaken using Coda Geosurvey software, which is a standard package for processing and interpreting single channel seismic data. This software allows the data to be replayed one line at a time with user selected filters and gain settings in order to optimise the appearance of the data for interpretation. Coda Geosurvey then enables an interpretation to be applied to a line of data by identifying and selecting boundaries between layers.

2.2.18. Coda Geosurvey software, however, does not show the position of any boundary already identified on any intersecting lines. This is because Coda Geosurvey treats every survey line as an individual data file. Therefore, care needs to be taken when interpreting the data in order to ensure consistency in the interpretation between lines of data.

2.2.19. The seismic data is collected and interpreted with two-way travel time (TWTT) along the z-axis, not depth. Therefore, to convert the TWTT to the interpreted boundaries into depths the velocity of seismic waves through the geology must be known or estimated. For this project the velocity of the seismic waves was estimated to be 1600 m/s which is a standard estimate for shallow, unconsolidated sediments of the type being studied in this survey (Sheriff and Geldart 1983; Telford *et al.* 1990).

2.2.20. Once the seismic data had been interpreted the position of the boundaries could be exported in the form of x, y, z text files where z was now the calculated depth in metres not the TWTT. These data were then imported in Fledermaus software to produce 3-D images of each layer interpreted sub-seabed.

2.2.21. The sidescan sonar data was acquired and post-processed using Coda Geosurvey software and a sonar mosaic of the seafloor was produced.

2.3. GEOTECHNICAL SURVEY

Vibrocore Survey and Specifications

2.3.1. Based on an initial interpretation of the geophysical data, eight vibrocore locations were determined (**Figure VI.2**). The vibrocoring was undertaken by Gardline Surveys between the 20th and 22nd July 2006 from the S/V *Flatholm*.

2.3.2. A high powered vibrocore unit with a 5m core barrel was used for the survey. Date, time, position and water depth at each site were recorded.

2.3.3. A total of 16 vibrocores were acquired at the eight specified locations, because at each location one core specifically collected for optically stimulated luminescence dating (OSL) was acquired in addition to the regular core. After the fieldwork was completed the cores were transported to WA's environmental processing laboratory, where the cores were archaeologically recorded. One core from each site was split longitudinally, photographed and logged. The core logs provided details of the depth to each sediment horizon, the character and the form of the sediment (**Appendix I**). Sedimentary characteristics recorded included texture, colour and depositional structure.

2.3.4. The logs were then compared in terms of their vertical distribution throughout the study area. This was achieved by adjusting the water depths for tides and plotting the cores in sections referenced to OD heights.

2.3.5. The depositional and sedimentary boundaries identified in the core logs were then compared with the geophysical data interpretation in order to characterise the geophysical units identified at the core locations and to extrapolate the units throughout the site.

2.3.6. Environmental samples were taken from relevant deposits in order to provide chronological and environmental information relating to their formation, in accordance with the sampling strategy outlined in the Project Design (WA 2005). The selections were made on the basis of the sediment identified from the archaeological recording of the vibrocores and analysis of the geophysical data. Seven major sedimentary units were identified in the vibrocores, of which certain units (e.g. Unit A; Chalk) were considered unlikely to contain archaeologically interesting environmental remains and other units (e.g. Unit E; sand) were considered likely to contain archaeologically interesting environmental remains.

Grab Sampling Survey and Processing

2.3.7. The grab sampling was undertaken by Gardline Surveys between the 20th and 22nd July 2006 from the vessel *George D*. The locations of the grab samples were selected during the geophysical survey. A grid was defined with samples taken at 100 metre centres, and the x, y and z position of each sample was recorded during the survey. The grid (**Figure VI.2**) is delineated by the coordinates provided in **Table VI.3** (WGS 84, UTM Zone 31).

Eastings	Northings
333713	5917099
334593	5917301
334793	5916435
333908	5916214

Table VI.3: Coordinates of the Humber grab sampling area (WGS 84, UTM zone 31).

2.3.8. The grab samples were acquired using a Hamon grab. On recovery the samples were put into plastic tubs for storage and transportation.

2.3.9. Each sample was transferred to the environmental department at WA and wet sieved through a nest of sieves in accordance with standard artefactual recovery procedures. The mesh sizes used were 10mm, 4mm and 1mm. The less than 1mm residues were discarded in conjunction with standard artefactual sieving procedures.

2.3.10. The greater than 10mm, 4-10mm and 1-4mm residues were scanned for archaeological material. Archaeological finds including flint, bone, slag, clinker, glass, burnt stone and ceramic building material (CBM) were retained for further analysis.

3. RESULTS

3.1. GEOPHYSICAL DATA

Bathymetry

3.1.1. Within the study area water depths varied between 13.3m and 32.9m below OD (**Figure VI.3**). The seabed generally deepened east to west across the area. The shallowest depths were associated with the ridges of sandwaves. Three prominent sandwaves were observed orientated west to east across the site. The sandwaves were up to 3m high.

Sidescan Sonar

3.1.2. The sidescan sonar data indicated a homogenous covering of sediment over the entire site. The seismic nature of the data suggested sediment types of sands and gravels. The boundaries of the three sandwaves were observed, and areas of seabed ripples were also noted (**Figure VI.4**). Sediment streaking, probably caused by the prevailing sea bottom currents in the area, was observed, generally orientated south-west to north-east (**Figure VI.4**).

3.1.3. To the north-east of the study area two areas of high reflectivity were noted orientated north to south (**Figure VI.4**). These reflectors represent evidence of seabed scars, probably caused by dredging. This section of the study area lies within dredging licence area 106. The effect of these scars was observed in the bathymetry data as slight depressions (**Figure VI.3**) and on the sub-bottom profiler data as uneven seabed.

3.1.4. Nine anomalies were observed on the seabed within the study area. The objects are relatively small (less than 7m diameter) and although none have been identified as wrecks, these anomalies are possibly anthropogenic debris.

Sub-bottom Profiler

3.1.5. Six units marked by five distinct reflectors were observed on the sub-bottom profiling geophysical data. These units have been labelled **Units A** to **F**; **Unit A** is the deepest unit, **Unit F** the uppermost. **Unit B** is divided into two sub-units **Bi** and **Bii**. The reflectors marking the base of each of these units (**Unit B to F**) have been mapped and modelled and are shown in **Figure VI.5**. This figure shows the extent of each unit and their depths below OD.

3.1.6. **Unit A** is the deepest observed unit. The base of this unit is below the depth of penetration and is not observed on the seismic data. The unit is comprised of a series of parallel and sub-parallel reflectors and is observed throughout the study area. This unit has been interpreted as the bedrock layer and is likely to be Upper Cretaceous Chalk.

3.1.7. **Unit B** overlies **Unit A** and is divided into two sub-units. The deeper unit (**Unit Bi**) is generally acoustically transparent with localised low amplitude reflectors. The upper unit (**Unit Bii**) comprises a series of low-amplitude, parallel and sub-parallel reflectors. **Unit B** is interpreted as a layer of till and is considered to be the Bolders Bank Formation.

3.1.8. The base of **Unit B** (top of **Unit A**) is an undulating surface observed throughout the study area between 24.5m and 33.0m below OD (**Figure VI.5a**). Generally, this surface is observed at 27m below OD to the north of the study area deepening to 28m below OD to the south. Localised areas in the north of the study area are observed at 24.5m below OD. Two prominent geological features are observed affecting this surface. In the north a semi-circular feature is observed and is marked by a deepening of 2m compared to the surrounding surface. This is thought to be a slumping feature rather than one created as part of the landscaping caused by the ice sheet. Internal reflectors of **Unit Bi** appear to be parallel to the basal reflector indicating that the feature was formed after deposition of **Unit Bi**. The second feature is a channel feature in the south of the area orientated west to east. The feature is up to 4m deep and up to 400m wide (**Figure VI.5a**). The surface marking the base of **Unit B** is observed cutting into **Unit A** sediments. As such, it is likely that this channel was caused by scouring at the time of, or prior to, the deposition of the overlying till, possibly formed as the ice sheet extended across the North Sea basin.

3.1.9. Although **Unit B (i and ii)** is observed throughout, the internal reflector marking the top of **Unit Bi** and the base of **Unit Bii** is not observed throughout the study area (**Figure VI.5b**). The surface layer is observed between 21.3 and 29.2m below OD (4 - 11m sub-seabed). **Unit Bii** comprises a unit of faint parallel reflectors, appearing more structured than **Unit Bi**. This is interpreted as a sub-unit of till, possibly a second phase of deposition.

3.1.10. The top of **Unit B** has been significantly reworked by a series of processes marked by the deposition of **Units C, D** and **E**. The first phase of reworking observed is marked by the base of **Unit C**. The base of **Unit C** is an undulating surface cutting into **Unit B** (**Figure VI.6**). The base of **Unit C** is only observed to the extreme north and the southern half of the study area (**Figure VI.5c**). The depth of this layer varies between 17.9m and 26.3m below OD generally deepening from north to south. In the south of the area a channel is observed orientated south-west to north-east (**Figure VI.5c**). The channel is approximately 200m wide and 3m deep and is considered to be formed by fluvial processes.

3.1.11. **Unit C** is an acoustically transparent unit (**Figure VI.6**) varying in thickness; less than one metre thick where subsequent reworking has taken place to approximately 4m thick where the unit lies directly beneath modern sediments (**Unit F**). It is considered that the base of the unit was formed by fluvioglacial processes as the ice sheet retreated from the area creating an undulating and channelled surface. The sediments in **Unit C** are likely to comprise fluvioglacial sands and gravels.

3.1.12. **Unit D** is an acoustically chaotic unit with numerous strong reflectors observed throughout (**Figures VI.6-7**). Given the seismic nature it is considered that the unit comprises coarse sands and gravels. **Unit D** is only observed in two areas: a small area in the north of the study area, and a larger area in the south (**Figure VI.5d**). The base of the unit to the north lies between 17.3 and 22.0m below OD and appears to form a north-south orientated channel up to 2m deep cutting into **Unit B**. **Unit C** is not observed in the area and it is possible that the **Unit C** sediments have been completely removed or reworked during or prior to the deposition of **Unit D**. To the south of the study area the base of **Unit D** is observed between 18.3 and 25.0m below OD (**Figure VI.5d**). Two shallow channels are observed up to 300m wide and up to 4m deep orientated north-west to south-east. The southernmost channel continues the form of the channel observed at the base of **Unit C** at similar depths below OD (**Figures VI.5c-d**). This indicates that a channel infilled by **Unit C** sediments was then reworked and removed by the deposition of **Unit D**.

3.1.13. **Unit E** is observed in the central section of the study area **(Figure VI.5d)**. The base of the unit is observed between 18.1m below OD to the north and south of the area and 26.7m below OD in the central area. **Unit E** is generally acoustically transparent and varies between less than one metre and 8m thick. Where the unit thickens prograding structure is observed indicating a preferential depositional direction (**Figure VI.8**). The unit is likely to be composed of fine- to coarse-grained sand.

3.1.14. Within the study area **Units D** and **E** do not overlap and are observed at similar depths below OD (**Figures VI.5d-e**). The units have been interpreted as separate units based solely on their seismic character. Given the similarity in depths it is possible that these sediments represent a continuous period of deposition/reworking with a lateral sediment change across the study area. It is considered that **Units D** and **E** represent deposition associated with the onset of the last marine transgression.

3.1.15. **Unit F** is the uppermost unit and generally comprises a thin layer (less than 2m thick) covering the study area, thickening where sandwaves and sand ripples are present (**Figure VI.8**). The base of this unit varies between 15.6m and 26.7m below OD. Generally, the base of this unit deepens to the west of the study area (**Figure VI.5f**).

3.1.16. **Unit F** is interpreted as modern seabed and is likely to comprise a sand and gravel lag deposit. The formation of sandwaves (**Figure VI.8**) indicates that there is likely to be some sediment movement in the area.

3.2. GEOTECHNICAL DATA

Vibrocores

3.2.1. The vibrocores were located at eight specified positions across the study area (**Figures VI.9-11**). Five major sedimentary units were identified from eight vibrocores. These have been ascribed sedimentary units comparable to those recorded within the seismic data. This correlation is shown in **Figures VI.12-13.** The sedimentary units are shown in their relative vertical positions in **Figures VI.9-10**.

Unit Bi (24.25m to 24.42m below OD) sandy silty clay

3.2.2. This unit was stiff reddish and greyish brown sandy and silty clay with very frequent rounded to angular inclusions of chalk, coal and sandstone. This unit was recorded in vibrocores **VC2** and **VC4 (Figures VI.9** and **VI.11, Appendix I)**. The base of this unit was not recorded. This unit is interpreted as glacial till or diamicton.

Unit Bii (20.69m to 24.27m below OD) clay

3.2.3. This unit was stiff/compact brown/greyish brown clay with rounded to angular inclusions of chalk, flint, coal, sandstone, mudstone and igneous/metamorphic erratics. This unit was recorded in vibrocores **VC2**, **VC3**, **VC4**, **VC5** and **VC8** **(Figures VI.9-11**). The base of this unit was recorded in vibrocores **VC2** and **VC4**. Microlaminae were recorded in vibrocore **VC2**. This unit is interpreted as glacial till or diamicton.

Unit C (21.64m to 22.45m below OD) gravelly sand

3.2.4. This unit was brown silty gravelly sand. The gravel included flint, sandstone and chalk. This unit was recorded in vibrocore **VC2** only (**Figures VI.9** and **VI.11)**. There was a notable absence of molluscan remains in this deposit compared to other gravels and sands in the vibrocores. This unit was interpreted as glaciofluvial outwash sands.

Unit D (19.16m to 23.21m below OD) sandy gravel/gravelly sand

3.2.5. This unit was greyish brown sandy gravel and gravelly sand including rounded to angular flint, quartz, mudstone and sandstone. Marine molluscs were common and one organic remain was recovered from vibrocore **VC1** at 22.66m below OD. This unit was recorded in vibrocores **VC1**, **VC4** and **VC7 (Figures VI.9-11)**. The unit is interpreted as shallow marine/sublittoral sands and gravels.

Unit E (19.16m to 23.21m below OD) sand

3.2.6. This unit was greyish brown sand including laminae of coal and silty sand. Molluscs were common in this unit, mostly broken including *Mytilus edulis* and *Cardium edule.* The unit occurred in vibrocores **VC1**, **VC3**, **VC5** and **VC7** (**Figure VI.10**). This unit is interpreted as shallow marine/sublittoral sands.

Unit F (16.52m to 21.64m below OD) sandy gravel

3.2.7. This unit was loose greyish brown sandy gravel and gravelly sand. The gravel component consisted predominantly of rounded to subrounded flint with quartz, coal, sandstone, mudstone and erratic metamorphic/igneous rocks. Marine molluscs were common and often broken including *Mytilus edulis*, *Pholas dactylus*, *Littorina littoralis*, *Cardium edule*, *Macoma baltica* and *Pecten* sp. This unit was recorded in all of the vibrocores (**Figures VI.9-11**) and interpreted as a lag deposit of shallow marine sands and gravels.

Grab Samples

3.2.8. 100 grab samples were sieved and scanned for archaeological material. No prehistoric archaeological finds were recovered. There were however some contents of note including bone, fossils, slag, clinker and coal (**Appendix II**).

3.2.9. The samples were approximately 5 to 8 litres in size. All of the samples contained gravel and sand in varying proportions. The gravel component consisted of rounded to subangular flint, chalk, quartz, coal, sandstone, mudstone, metamorphic and igneous rocks. Marine shell was common within the samples. The sand included these elements and crushed shell.

3.2.10. Two small bone fragments were recovered. In sample **H70** the proximal end of a small mammal humerus was recovered. Sample **H95** contained a rib from a medium sized fish.

3.2.11. 61 fossils were recovered from 41 samples. Crinoids were the most common with significant numbers of the genus *Pentacrinites* present. Mollusca were common including cephalopods (belemnites) and occasional gastropods. Fossil coral and occasional echinoid fragments were also recorded.

3.2.12. Slag was recovered from 14 samples (**Appendix I**). These were usually small amounts of less than one gram. It is probable that this relates to industrial shipping activities.

3.2.13. Clinker (vitrified organic material) was recovered from two samples **H68** and **H94**. This material is probably derived from rake outs of ships engines.

3.2.14. Coal was recovered from all of the samples. It is not clear whether this represent industrial shipping waste or material reworked by natural processes from Carboniferous deposits.

3.3. ENVIRONMENTAL ASSESSMENTS

3.3.1. Subsamples from vibrocores **VC3**, **VC4** and **VC8** were assessed for pollen (**Appendix III**), diatoms (**Appendix IV**), foraminifera (**Appendix V**) and ostracods (**Appendix VI**). The samples were assessed with regard to presence and preservation and potential archaeological and environmental significance of the sediments.

Pollen

3.3.2. Twelve subsamples were assessed for pollen. Of these samples only two contained enough pollen for meaningful counts to be made (**Appendix III**). One sample from **Unit Bii** at 21.47m below OD in vibrocore **VC8** (**Figure VI.9**) contained pine (*Pinus*), hazel (*Corylus avellana*) and alder (*Alnus*) indicative of a pine-hazel forest typical of the early Holocene (Flandrian Chronozone 1b; Boreal period; *c.* 8,000-9,000 BP/6,800 – 8,200 cal. BC) (**Appendix III**). The only other sample containing significant amounts of pollen was the sample from **Unit E** in vibrocore **VC3** (**Figure VI.10**) at 21.95m below OD. This sample contained oak (*Quercus*), alder (*Alnus glutinosa*) hazel (*Corylus avellana*) and lime (*Tilia*) indicative of an oak-hazel woodland which may indicate a Flandrian chronozone III age, i.e. post-Atlantic and post elm decline, probably dating to the Neolithic or Bronze Age *c.* 5,500-3,000 BP/4,300 – 1,200 cal. BC (**Appendix III**).

3.3.3. Pollen counts were low and as such no further analysis was undertaken. Pollen is not considered to be a reliable dating method, however in the absence of other absolute dates it can provide a useful relative dating mechanism.

Diatoms

3.3.4. No diatoms were recovered from the 12 subsamples (**Appendix IV**). This is probably due to preservational conditions.

Foraminifera

3.3.5. Fourteen samples from **Units Bii**, **C**, **D**, **E** and **F** were assessed for their foraminiferal content. Of these, ten contained foraminifera. Samples from **Units Bii** and **C** contained no foraminifera. Sedimentologically these deposits are thought to be glacial in origin and are thus unlikely to contain *in situ* foraminifera.

3.3.6. Samples producing foraminifera taken from **Unit D** (**VC1** 22.53m below OD, **VC4** 22.62m below OD) are indicative of shallow marine environments. These samples are dominated by Miliolids and species of the genus *Ammonia* common in shallow marine/sublittoral environments (**Appendix V**).

3.3.7. Samples from **Unit E** produced similar shallow marine and sub littoral assemblages of foraminifera. In this unit, one sample was of particular note at 21.95m below OD in vibrocore **VC3** because it contained some salt marsh indicator species (*Trochammina inflata* and *Jadammina macrescens*) in addition to the shallow marine/sublittoral forms. It is considered that these indicators have been reworked into a shallow marine/sublittoral context.

3.3.8. One sample from **Unit F** (**VC4** at 21.02m below OD) produced similar shallow marine/sublittoral foraminifera. The assemblages recovered from **Units D**, **E** and **F** are all shallow marine sublittoral assemblages and are foraminiferally indistinct.

Ostracods

3.3.9. Fourteen samples were assessed for their ostracod content from **Units Bii**, **C**, **D** and **E** and **F**. Samples from **Units Bii** and **C** produced no ostracods. One sample from **Unit D** produced ostracods (**VC1** at 22.53m below OD) including *Aurila woutersi* which is known to inhabit marine, phytal, littoral and shallow sublittoral environments (**Appendix VI**).

3.3.10. Ostracods recovered from samples in **Units E** and **F** also produced similar assemblages of shallow marine sublittoral ostracods including *Aurila woutersi*. Most of the assemblages were dominated by adult forms indicating reworking of the sediment (**Appendix VI**).

Other

3.3.11. Marine molluscs were observed during logging and fragments of these were recovered from subsamples taken for foraminifera and ostracods in **Units D**, **E** and **F**. The sample at 21.95m below OD in vibrocore **VC3** (**Appendix V**) contained Hydrobid molluscs and plant macrofossils indicative of reworked terrestrial, estuarine and coastal environments.

3.4. DATING

Radiocarbon (^{14}C) Dating

3.4.1. Three mollusc shells were submitted for radiocarbon (^{14}C) dating. These mollusc shells were extracted from the recorded vibrocores (**Appendix I**). Specimens chosen were from **Unit D** and these exhibited minimal abrasion with the expectation that this would reduce any potential error introduced by reworking. The full results are given in **Appendix VII** and are shown on **Figures VI.9-10**. At 22.54m below OD in **VC4** a tellin (*Macoma* sp.) gave a radiocarbon date of 7,780±35 BP (6,380 – 6,210 cal. BC, SUERC-12311). At 19.16m below OD in **VC7** a topshell (*Gibbula* sp.) gave a radiocarbon date of 6,390±35 BP (5,000 – 4,800 cal. BC, SUERC – 12312). At 19.76m below OD in **VC7** a bivalve (*Venus verrucosa*) gave a radiocarbon date of 5,605±35 BP (4,150 – 3,970 cal. BC, SUERC – 12316). These dates fall within the late Mesolithic/ early Neolithic time period.

Optically Stimulated Luminescence (OSL) Dating

3.4.2. Six samples were submitted for optically stimulated luminescence (OSL) dating. The full results are given in **Appendix VIII** and are shown on **Figures VI.9-10**. The samples were chosen on the basis of the geophysical and geotechnical descriptions of the sediments (**Appendix I**). These samples were extracted from duplicate cores taken specifically for OSL dating.

3.4.3. Three samples were taken from **Unit D**. The sample at 22.54m below OD in **VC4** produced a date of 47.4±6.8 ka. At 20.67m below OD in **VC7** a date of 5.7±0.5 ka was generated. At 19.47m below OD in **VC7** the sample was dated to 6.9±0.6 ka.

3.4.4. Two samples were taken from **Unit E**. The sample at 20.44m below OD in **VC3** produced a date of 6.4±0.6 ka. At 18.27m below OD in **VC7**, a date of 7.7±0.7 ka was generated.

3.4.5. One sample was taken from **Unit F** at 21.31m below OD in **VC2** which gave a result of 5.6±0.5 ka. All of these dates fall within the late Mesolithic time period except for the sample at 22.54m below OD in **VC4**. The date of this sample (47.4±6.8 ka) would correspond to the Upper Palaeolithic/OIS 3 time period.

4. METHODOLOGICAL ASSESSMENT

4.1. GEOPHYSICAL SURVEY

Analysis of Line Spacing

4.1.1. One of the aims of the ‘Seabed Prehistory’ project was to assess the geophysical methodologies for evaluating prehistoric seabed deposits. In Round 1 of the ‘Seabed Prehistory’ project an assessment of survey strategies was undertaken for the Palaeo-Arun (**Volume II**). This involved an investigation into the use of linear- or grid-based surveys processed at varying line spacings to establish which method provided the detail required to identify and interpret submerged landscapes. The interpreted surface data was input into visualisation software (I.V.S. Fledermaus software package) and gridded into a surface using the methodology as described in **Section 2.2**.

4.1.2. The assessment concluded that a grid-based survey methodology was desirable; although similar geomorphic features were observed on both the grid-based and linear-based datasets, the increased data collected during a grid-based survey resulted in a higher resolution dataset producing a more defined palaeo-geomorphology interpretation. An assessment of the modelling of different line-spacings (50m x 50m, 100m x 100m and 200m x 200m) concluded that models at 200m x 200m spacing produced less resolute data and affected the quality of the interpretation. The 50m x 50m grid is the most resolute and therefore this dataset is most likely to identify small palaeogeographic features.

4.1.3. These results were taken into account when designing the survey plan for the Humber survey. Due to the size of the study area and time constraints, rather than a 50m x 50m survey grid, a 50m x 100m grid was used. As the Round 1 project concluded that a grid of 100m x 100m would produce an adequate dataset of palaeogeographic interpretation, any submerged landscapes would be identified using a grid of 50m x 100m.

4.1.4. In order to assess whether using a smaller line-spacing would improve the interpretation in the Humber data a small sub-area was selected in the south of the general study area (**Figure VI.2**) and data were acquired at an increased line-spacing. Additional north-south orientated lines at 25m line spacing were acquired in this sub-area (**Table VI.4**).

Easting	Northing
333983	5918431
334407	5918427
334883	5916435
334442	5916332

Table VI.4: Coordinates of the Humber sub-area where line-spacing was increased to 25m line spacing (WGS 84, UTM zone 31).

4.1.5. Two layers have been interpreted and processed at 50m and 25m line spacing: the seabed and the base of **Unit D** layer. These layers are discussed in detail in **Section 3.1**. The data was interpreted in Coda Geosurvey software and the results were exported in x, y, z format. The x, y, z files were imported into Fledermaus and surfaces were created. The interpretation of these layers is discussed in detail in **Section 5**. Images of both layers at 50m x 100m grid and 25m x 100m are illustrated in **Figure VI.14**.

4.1.6. In each of the images (**Figure VI.14**) digital artefacts (i.e. ridges representing features that are not real) can be seen along the direction of the survey lines. This is a result of selecting a cell size smaller than the line spacing on the grid. However, if a grid size the same or larger than the line spacing was selected, although there would be no digital artefacts the data layer, would have lower resolution and features could be missed.

4.1.7. The seabed surfaces at each grid-spacing have been processed at different cell sizes reflecting the number of x, y, z points. The surface with the larger grid size is processed with a larger cell size as there are less x, y, z points. The 50m x 100m surface was processed using a 20m cell size and a weighting of 3; the 25m x 100m surface was processed using a 12m cell size and a weighting of 3. These cell sizes and weights were chosen through a process of trial and error after examining the data in order to give surfaces with the best possible level of detail while at the same time giving the fewest holes in the surface as possible.

4.1.8. Within the study area the seabed depth varies between 9.8m and 14.8m below OD. Generally, the water depth varies between 12m and 14.8m below OD with the deepest area observed in the central section of the study area (**Figures VI.14a-b**). The shallowest depth is associated with a sandwave observed in the northern section of the area. This feature stands around 2.2m proud of the seabed. The sandwave is observed on each geophysical dataset.

4.1.9. As the site is generally flat and featureless the increased resolution resulting from the smaller grid size does not appear to increase the quality of data for interpretation. However, noticeable differences are observed over the sandwave feature. Although the dimensions and height of the sandwave are the same in both datasets, the definition of the edges of the sandwave is greatly increased when using the smaller grid-size (**Figure VI.14b**). No features are observed on the smaller gridded dataset that are not observed on the 50m x 100m grid.

4.1.10. The base of **Unit D** layer covers the southern section of the study area. The depth to the layer varies between 14.2m and 21.1m below OD. Small differences in depth occur between the two gridded datasets, however the error is less than 5cm and therefore not considered significant. Two channels are observed orientated east to west across the site, marking the deepest sections of the layer (**Figures VI.14c-d**). There are three smaller features observed lying to the north of the southernmost channel feature, where the layer is 1.5m shallower than the surrounding layer. Due to the cell-size used and the relatively small feature, the width of the feature is noticeably different in each dataset. For example, the northernmost of these features has measured dimensions of 43.5m x 53.0m on the 50m x 100m grid dataset and 29.8m x 52.5m on the 25m x 100m grid dataset. The difference in the dimensions is a result of more data points per cell along the x-axis in the smaller grid dataset resulting in a more resolute dataset. However, the length dimensions do not vary because the number of data points along the y-axis does not increase. Although the features are more resolute there are no features observed in the 25m x 100m grid that are not also seen in the 50m x 100m grid dataset.

4.1.11. Data gaps are observed in the 50m x 100m grid in the base of **Unit D** dataset (**Figure VI.14c**). These holes are apparent in the 50m x 100m grid dataset because one line of data was of poor quality and could not be confidently interpreted in this small section. As such there were not enough data points to ensure full coverage for the grid size. However, the additional data points provided by the additional interpretation at 25m line spacing infilled the gap in data and ensured full coverage of the area.

4.1.12. Although the 25m x 100m grid dataset improves the data quality by increasing the resolution of the data, there is no evidence in the Humber dataset to suggest that in the small sample area chosen features observed in the smaller grid dataset are not observed in the large grid dataset. This indicates that using a grid size of 50m x 100m will provide a useable dataset for interpretation of data with all key features visible.

4.1.13. The data resolution could be further improved by decreasing the distance between the lines on the east – west orientated lines (e.g. 50m x 50m grid). However, the Round 1 project concluded that a grid of 100m x 100m will produce an adequate dataset for palaeogeographic interpretation, and as such a smaller grid of 50m x 100m was deemed suitable.

5. DISCUSSION AND CONCLUSIONS

5.1. INTERPRETATION

5.1.1. **Unit A** is not observed in any of the vibrocores; the top of the bedrock layer is deeper than the maximum penetration of the vibrocore. The bedrock in this area is likely to be Upper Cretaceous Chalk (Cameron *et al.* 1992).

5.1.2. **Unit B** was observed throughout the study area on the sub-bottom profiler data and was observed in all of the vibrocores with the exception of **VC7**. From the vibrocores this unit is identified as glacial till and is generally composed of stiff, compact clay with inclusions of chalk, mudstone and igneous rock. In **VC2** two distinct layers of till are observed. The lower layer contains inclusions and the upper sub-unit is described as homogenous, stiff and compact with fewer inclusions. These sub-units are likely to equate to the **Units Bi** and **Bii** observed in the geophysical layer. The presence of chalk inclusions in the till indicates sub-glacial till entrainment from the underlying bedrock.

5.1.3. **Unit Bi** was recorded in **VC2** (**Figure VI.9** and **VI.11**, **Appendix I)** and **VC4** (**Figure VI.9, Appendix I).** Sedimentologically distinguishing characteristics of this unit from **Unit Bii** are very frequent chalk inclusions and a lack of sedimentary architecture. The sedimentological characterisation and stratigraphic position of this sediment would fit with the description of the Bolders Bank formation as outlined by Cameron *et al.* (1992).

5.1.4. **Unit Bii** is also interpreted as Bolders Bank Formation although it differs sedimentologically from Unit **Bi** in that it contains fewer inclusions and some faint sedimentary architecture including microlaminae.

5.1.5. **Unit C** is observed in **VC1** and **VC2** comprising silty, gravely sands with rounded to angular gravel including flint, sandstone and chalk. This is consistent with the seismic nature of the unit. Based on the geotechnical data the unit is thought to be fluvioglacial channel infill. This agrees with the geophysical data interpretation that the base of this unit was cut by fluvioglacial processes as the ice sheet retreated.

5.1.6. **Unit D** is observed in **VC7** and comprises gravely sands and sandy gravels with marine shells indicating a sublittoral or beach deposit. The coarse nature of this unit is illustrated in the geophysical data by the observed strong chaotic reflectors.

5.1.7. **Unit E** is observed in **VC1**, **VC3** and **VC8** and is generally composed of sand with small inclusions of coal and crushed shell. The finer-grained sediment is illustrated in the geophysical data by an acoustically transparent unit.

5.1.8. **Unit F** is the uppermost and therefore most recently deposited unit. This unit is observed throughout the study area on the geophysical data and at each vibrocore location.

5.1.9. The geophysical and geotechnical data correlate well in the majority of the cores. Generally, the units interpreted on the geophysics based on acoustic nature have also been identified in the cores (**Figures VI.12-13**). The depths of the unit boundaries vary and this is a likely function of the vertical resolution of the seismic data, the distance from the core location to seismic data, and the undulating nature of the boundaries over short distances. The vertical resolution of the boomer data is approximately 0.4m. Sedimentary layers thinner than 0.4m are unlikely to be distinguishable on the data. Also, an average speed of sound velocity of 1600 m/s through the sediments has been used, and slight variations in the seismic velocity will result in subtle depth changes that may be apparent when comparing the depths of boundaries to the vibrocore.

5.1.10. Discrepancies between the depths to the base of units in the vibrocores vary between 0.2m and 0.8m. The greatest difference (0.8m) is observed at the location of **VC8**. The base of **Unit F** is observed on the geophysics at 1.6m sub-seabed, whereas in **VC8** the base of the unit is observed at 0.8m sub-seabed, a difference of 0.8m. **VC8** is located 20m north of the geophysics data shown in **Figure VI.13**. Interrogation of the seismic data indicates that **Unit F** thins to the north of the seismic line, reducing the difference between the data and the vibrocore to less than 0.4m. Therefore, the large difference in depths in this case is likely to be due to the changing landscape within a relatively short distance and highlights the need for care when comparing vibrocore data and seismic data.

5.1.11. In the instance of **VC1**, **VC4** and **VC7** there are discrepancies between the units observed in the geophysical and geotechnical data (**Figure VI.12-13**). In **VC1** and **VC4 Unit D** is observed in the vibrocores but not on the geophysics (**Figure VI.12**). For example, in **VC4 Unit D** is only 0.14m thick. As this is less than the vertical resolution of the boomer data it is unsurprising that this unit was not distinguishable on the seismic data.

5.1.12. At the locations of **VC4** and **VC7** the discrepancies are observed within **Unit E** and **Unit F.** The unit identified in **VC4** as **Unit F** has been interpreted on the geophysics as two units (**Unit F** overlying **Unit E) (Figure VI.12)**. In **VC7** it is the other way round: what was interpreted on the geophysics as one unit (**Unit F),** has been interpreted in the vibrocore as two units (**Unit F** overlying **Unit E) (Figure VI.13)**. This further highlights the difficulty in interpreting reworked sediment boundaries in both the cores and on the geophysics.

5.2. CHRONOLOGY

5.2.1. The radiocarbon dates (from **Unit D**) all fall within the late Mesolithic period. The radiocarbon dates are however reversed in vibrocore **VC7** (**Figure VI.10**). This may either be due to an incorrect date or, more likely, through reworking of molluscan material.

5.2.2. Foraminifera, ostracods, sediments and molluscan remains indicate that **Unit D** is a shallow marine/sublittoral deposit. Comparison of the radiocarbon dates and the depths of the samples relative to sea level curve data for the southern North Sea (Jelgersma 1979; Shennan *et al*. 2002) would indicate that a late Mesolithic date would be expected for a shallow marine/sublittoral deposit.

5.2.3. Five of the six OSL dates for **Units D**, **E** and **F** also fall within the late Mesolithic period (**Figures VI.9-10**; **Appendix VIII**). **Units D**, **E** and **F** are also considered to be shallow marine/sublittoral deposits. **Figures VI.9-10** show the comparison between OSL and radiocarbon dates. Vibrocore **VC7** demonstrates that the OSL and radiocarbon dates are both reversed suggesting reworking of the sediment or wrong dates.

5.2.4. One OSL date (47.4±6.8 ka) at 22.54m below OD in **VC4** (**Appendix VIII**, **Figure VI.9**) is enigmatic. This is possibly an example of considerably older sediment being reworked without being exposed to sunlight.

5.2.5. Relative pollen dating (**Appendix III**) is also of interest. The sample in **VC3** at 21.95m below OD containing oak (*Quercus*), alder (*Alnus glutinosa*), hazel (*Corylus avellana*) and lime (*Tilia*) indicative of an oak-hazel woodland and dated to *c.* 5,500-3,000 BP (*c.* 4,300 – 1,200 cal. BC) is below the OSL sample in the same unit suggesting an age of 6.4±0.6 ka. This is an indication of date reversal probably due to reworking of shallow marine sediments. The pollen sample in **Unit Bii** (glacial till) indicating an early Holocene date is also enigmatic as the till in this area is thought to have formed during the Devensian (Cameron *et al.* 1992). It is however possible that some redeposition of the till (**Unit Bii**) has occurred during the early Holocene which might explain this unusual result.

5.2.6. In conclusion, although the OSL and radiocarbon dates are reversed they are considered reliable on the millennial scale. That is to say that shallow marine deposits at *c*. 20m below OD in the North Sea would be expected to date to the late Mesolithic period. The fact that the dates are reversed is most likely due to reworking of the shallow marine sediments during the marine transgression. The dates do however confirm that this reworking has probably occurred during or slightly after the late Mesolithic period.

5.3. Archaeological Potential

5.3.1. The data showed a succession of sediments within the study area. Bedrock (Upper Cretaceous Chalk) is overlain by till deposited during the last glacial episode, which is in turn overlain by reworked deposits associated with the marine inundation. According to the dating of samples from the vibrocores, this inundation occurred during the late Mesolithic period, which is confirmed by general sea level curves for the area (**Section 5.2.2**).

5.3.2. Potential for *in situ* prehistoric archaeological remains in this area is low. This is due to the deposits either being glacial (**Units B** and **C**) or shallow marine (**Units D**, **E** and **F)** in origin. There is however potential for reworked Palaeolithic archaeological material to be present within **Units B** and **C** and potential for reworked Palaeolithic and Mesolithic material to be present within **Units D**, **E** and **F**. No artefacts of prehistoric origin were recovered from the grab samples or vibrocores; however these represent a very small percentage of the area surveyed.

5.4. METHODOLOGICAL CONCLUSIONS

5.4.1. Geophysical and geotechnical survey techniques were successfully used to assess the geology and archaeological potential of an area of seabed off the Lincolnshire coast. Although the study site is considered to have low archaeological potential the methodology of combining geophysical, vibrocore and grab sampling surveys proved successful in assessing this potential.

5.4.2. An assessment of the effect of line-spacing on the interpretation was carried out during the interpretation phase of the project. It was shown that although using 25 x 100m grid line spacing would improve the resolution of the interpretation, all features observed on the smaller grid were observed on the 50 x 100m grid as well. As such, it is considered that a 50 x 100m grid is suitable for identifying submerged landscapes.

5.5. RECOMMENDATIONS FOR FURTHER WORK

5.5.1. Nine seabed anomalies were observed on the sidescan sonar data. These have not been investigated fully as it does not fall under the remit of this report. However, none of the anomalies are identified as wrecks although they may represent anthropogenic debris. Further work would be required to ascertain the true nature of these anomalies.

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APPENDIX I: VIBROCORE LOGS

VC1

Depth below seabed (m)	Depth below OD (m)	Description
0.00-0.83	18.33-19.16	10YR 4/3 Brown sandy (mc) gravel. Gravel is 2-25mm diam, Flint (70%) Quartz (20%) other sedimentary sandstone, coal (5%) other ?metamorphic/igneous (5%) subrounded to sub angular slightly sorted. No sedimentary architecture. Occasional broken marine shell. Fairly compact. Abrupt boundary.
0.83-4.23	19.16-22.56	10YR 6/2 Light brownish grey sand (fm). Sand is opaque ?Quartz (80%) black ?coal/mica(15%) red sandstone (5%). Very occasional small rounded pebbles (flint/sandstone 0.83-0.90) <5mm diameter. Coal laminations/pockets (<4mm thick at 3.53, 3.76, 3.82-3.85, 3.90, 4.03. From 4.06 to 4.21 the coal laminations are more profuse with angled banding. Coal <3mm diameter mostly circa 1mm diameter. Specks of coal throughout deposit. Occasional finely crushed shell throughout. Abrupt boundary
4.23-4.88	22.56-23.21	10YR 5/3 Brown sandy (fm) gravel. Gravel is flint (60%), quartz (10%), grey mudstone (5%) brown sandstone (5%), black ?igneous/metamorphic (5%) unidentified (15%) rounded-angular (<35mm). Poorly sorted. Broken bivalve at 4.43m. Organic ?root/stem at 4.33. ?Marine gastropod 4.33.

VC2

Depth below seabed (m)	Depth below OD (m)	Description
0.00-2.36	19.28-21.64	10YR 5/3 Brown sandy (fmc) gravel (fm). Gravel is rounded to subangular (<30mm diameter) brown/black ?metamorphic/igneous (50%), flint (40%), quartz (10%). Sand is quartz (60%) black/red ?coal/mica/sandstone (40%). Frequent broken shell. Winkle at 0.54. Scallop at 1.05. ?whelk at 1.10, bivalve at 1.20. Mussel, piddock at 1.32. Cockles from 1.73-1.80. Tellin at 2.31. Cockle at 2.35. 0-0.53 sandy gravel. 0.53-1.05 gravelly sand with pockets of fine gravel sorted from 0.56-0.70. 1.05 to 2.36 sandy gravel. Poorly sorted very little structure except for gravel pockets. Abrupt boundary.
2.36-3.17	19.28-21.64	7.5Y 4/2 Brown slightly silty gravelly sand (fm). Gravel occasional-moderate (<20mm diam) rounded to angular including flint, sandstone, chalk. Sorted. Compact. No sedimentary architecture. Abrupt boundary
3.17-4.09	21.64-22.45	7.5Y 4/2 Brown silty clay. Stiff. Compact. Very occasional small (<1mm) chalk flecks. Microlaminae visible. Abrupt boundary.
4.09-4.98	22.45-24.26	7.5Y 4/2 Clay. Stiff. Compact. No inclusions. Laminae/microlaminae visible. Lighter/darker bands (0.5-15mm). One 2mm diam lump of coal at 4.94. Gradual boundary.
4.98-5.14	24.26-24.42	5YR 4/4 Reddish brown sandy clay. Frequent small (<5mm) rounded to angular chalk (90%). Coal, red/green sandstone (10%). Homogenous. Stiff. Compact.

VC3

Depth below seabed (m)	Depth below OD (m)	Description
0.00-1.40	18.68-20.08	10YR 5/2 Greyish brown sandy gravel. Composed predominantly of sub-rounded flint, quartz and igneous rock (>20mm). Moderately loose. Moderate inclusions of marine shell (>5mm). Gravel fines up from 1.40m, well sorted. Abrupt boundary.

Depth below seabed (m)	Depth below OD (m)	Description
1.40-3.23	20.08-21.91	Medium-grained sand. Colour ranges from 10YR 4/2 dark greyish brown to 10YR 5/3 brown with some mottling of 2.5Y 6/4 light yellowish brown. Composed primarily of flint and quartz. Friable. Beds of coal (>1mm thick) at 1.46, 1.55, 1.75 and 1.99m. Silty sand layers (1mm thick) at 2.12 and 2.15m. Moderately sorted. Abrupt boundary.
3.23-3.36	21.91-22.04	2.5Y 4/2 Dark greyish brown silty sand. Composed primarily of flint and quartz. Friable. Very frequent inclusions of coal, laid down in horizontal beds (>3mm thick). Infrequent inclusions of sub-rounded flint and sandstone (>4mm). Well sorted. Abrupt boundary.
3.36-4.22	22.04-23.10	10YR 4/2 Dark greyish brown clay. Compact. Occasional inclusions of angular chalk (>3mm), sub-angular mudstone and igneous rock (>2mm). Beds of sand (up to 30mm thick) at 3.48, 3.74, 3.95, 4.03, 4.18, and 4.20m. Horizontal laminations observed in clay. Unsorted. Clear boundary.
4.22-4.56	23.10-23.34	10YR 5/3 Brown sandy clay. Compact. No visible structure. Very infrequent inclusions of chalk (>1mm).

VC4

Depth below seabed (m)	Depth below OD (m)	Description
0.00-0.24	19.22-19.46	10YR 5/3 Brown sandy (mc) gravel (fm). Gravel is rounded to subrounded (<15mm) flint (50%), black metamorphic (30%), quartz (20%). Poorly sorted. Fairly loose. No sedimentary architecture. Common broken shell including scallop. Abrupt boundary.
0.24-2.62	19.46-21.84	10YR 5/2 Greyish brown sand (fmc). Sand is quartz (50%) black/red (50%). Occasional to moderate flint (<60mm)-one large flint cobble, coal and quartz (<10mm) rounded to subangular. Common broken shell. Cockle at 1.19. Massive. Diffuse boundary.
2.62-3.30	21.84-22.52	10YR 5/2 Greyish brown sandy (fmc) gravel (fm). Gravel is subrounded-angular (<20mm). Flint (80%) Quartz (15%) black ?igneous/metamorphic (5%). Sorted. Moderate broken shell. Top shell at 2.70, 3.23. Abrupt boundary.
3.30-3.44	22.52-22.66	10YR 5/2 Greyish brown gravelly (fm) sand (f). Gravel is flint (70%), quartz (20%) including rose quartz. Poorly sorted. Moderate broken shell including whole ?tellin at 3.34. Very abrupt boundary. Mostly sand from 3.40 to 3.44. No sedimentary architecture. Abrupt boundary.
3.44-5.02	22.66-24.24	7.5Y 4/2 Brown silty clay. No inclusions. Microlaminae throughout. Some noticeable c.10mm lighter bands (3.77, 4.85). Abrupt boundary.
5.02-5.05	24.24-24.27	10YR 3/2 Very dark greyish brown silty clay. Frequent small (<2mm) rounded-subangular chalk. Moderate coal flecks. Massive.

VC5

Depth below seabed (m)	Depth below OD (m)	Description
0.00-1.48	16.52-18.00	10YR 5/3 Brown gravelly sand (mc). Loose. Gravel is flint (60%), quartz (10%). Coal/sandstone (30%). Rounded (predominantly) to angular. Moderately sorted. 0.77-1.33 poorly sorted with larger gravel (<3mm) and sand (fm). Feintly visible bedding of alternating finer sands and gravels. Top shell at 1.18. Occasional broken/worn marine shell. Abrupt boundary.
1.48-2.26	18.00-18.78	10YR 4/3 Brown gravelly sand (m). Fairly loose. Gravel is flint (50%), quartz (30%), ?metamorphic/black (20%). Rounded to angular (<10mm) sand/small gravel predominantly quartz. Occasional marine shell broken/worn. Fining up sequence. Increasing gravel 1.70-2.26. Sorted. Clear boundary.

Depth below seabed (m)	Depth below OD (m)	Description
2.26-4.17	18.78-20.69	10YR 4/3 Brown gravelly sand (m). Fairly loose. Sand is predominantly quartz. Occasional subangular flint (<10mm), rounded ?metamorphics (<10mm). Very occasional coal (<20mm). Occasional broken mairne shell Cockle at 3.07, turritellid at 3.11, worn/broken mussel at 3.17. Moderately sorted. Pockets of gravel (fm) 2.50-2.55, 2.80-2.90, 3.06-3.13 and 3.21-3.28. Abrupt boundary.
4.17-5.12	20.69-21.64	5YR 3/3 Dark reddish brown clay. Very compact. Frequent chalk (<10mm) occasional flint, red sandstone, grey mudstone, coal and ?metamorphics. One large subangular ?igneous cobble (100mm diameter).

VC6

Depth below seabed (m)	Depth below OD (m)	Description
0.00-0.14	20.65-20.79	10 YR 5/2 Greyish brown sandy gravel. Loose. Composed primarily of sub-rounded igneous pebbles (>5mm) and sub-rounded flint (>3mm) Occasional inclusions of marine shell (>3mm). Well sorted. Gradual boundary.
0.14-0.49	20.79-21.14	10 YR 4/2 Dark greyish brown sand. Friable. Composed primarily of flint, quartz and igneous rock. Occasional inclusions of sub-angular flint (>15mm) and sub-rounded igneous rock (>15mm). Occasional inclusions of coal in fine layers at 0.18, 0.21 and 0.23m. Pocket of loose gravel (primarily flint, quartz and igneous rock) from 0.35 to 0.41m. Sorted. Clear boundary.
0.49-0.88	21.14-21.53	10YR 5/3 Brown sandy gravel. Moderately loose. Composed primarily of quartz and flint (>2mm). Occasional inclusions of sub-angular flint (up to 20mm). Infrequent inclusions of sub-rounded mudstone (>2mm) and marine shell (>10mm). Moderately sorted. Sharp boundary.
0.88-1.38	21.53-22.03	10 YR 4/3 Brown clay. Compact. Homogenous in structure, except for patches of sandy clay at 0.92 and 1.07m. Very fine laminations observed within clay. Unsorted. Gradual boundary.
1.38-1.87	22.03-22.52	10YR 4/3 Brown clay. Compact. Very frequent inclusions of angular chalk (>10mm). Occasional inclusions of decayed mudstone (>10mm) and shale (>10mm). Mottled with 10YR 5/6 yellowish brown from 1.45 to 1.47m and from 1.79 to 1.87m. Well sorted. Clear boundary.
1.87-3.14	22.52-23.79	10YR 4/2 Dark greyish brown clay. Compact. Moderate inclusions of angular chalk (>10mm). Infrequent inclusions of sub-angular igneous rock (>15mm). Homogenous.

VC7

Depth below seabed (m)	Depth below OD (m)	Description
0.00-0.93	16.73-17.66	2.5Y 4/2 Dark greyish brown gravelly sand with a patch of mottled 7.5YR 6/8 reddish yellow gravelly sand from 0.07 to 0.11m. Medium-grained. Fairly loose. Predominantly sub-angular quartz, occasional inclusions of coal (1mm) and flint (>5mm). Infrequent inclusions of marine shell. Moderately sorted, except for pockets of loose sandy gravel from 0.19 to 0.35m and from 0.74 to 0.93m. Theses pockets of sandy gravel are predominantly composed of fine quartz with inclusions of sub-rounded sandstone and mudstone (up to 40mm) and sub-angular flint (>20mm). Clear boundary.
0.93-2.43	17.66-19.16	2.5Y 5/2 Greyish brown sand. Predominantly quartz and flint. Fairly loose. Occasional inclusions of fine-grained coal (>1mm) and marine shell (>3mm). Very infrequent inclusions of flint cobble (>30mm). Layer of compact fine-grained silt at 1.73m (1mm thick) and at 2.00m. Small patch of organic material sampled at 1.92m. Well sorted. Clear boundary.

Depth below seabed (m)	Depth below OD (m)	Description
2.43-2.71	19.16-19.44	10YR 5/2 Greyish brown gravelly sand. Coarse-grained. Loose. Predominantly flint and quartz. Moderate inclusions of fine particles of flint, quartz and sandstone (>2mm). Occasional inclusions of sub-angular flint (>30mm), quartz (>20mm) and coal (>10mm). Infrequent fragments of marine shell (>20mm). Moderately sorted. Gradual boundary.
2.71-3.87	19.44-20.60	10YR 5/2 Greyish brown sandy gravel. Fine-grained. Loose. Predominantly quartz and flint with occasional sandstone. Frequent inclusions of marine shell (>1mm) with infrequent larger fragments or intact shells (>25mm). Moderate sub-angular and sub-rounded flint (30mm), occasional sub-rounded quartz (>15mm), infrequent sub-rounded sandstone (>10mm). Sorted.

VC8

Depth below seabed (m)	Depth below OD (m)	Description
0.00-0.50	18.21-18.71	10 YR 4/2 Dark greyish brown gravelly sand. Medium-grained. Friable. Composed primarily of flint and quartz with some sandstone and igneous rock. Occasional inclusions of marine shell and sandstone fragments (>3mm). Infrequent inclusions of sub-rounded quartz (>10mm). Sorted. Clear boundary.
0.50-0.83	18.71-19.04	10YR 4/3 Brown sandy gravel. Moderately loose. Composed primarily of flint and quartz with some igneous rock. Frequent inclusions of sub-angular flint (>30mm), moderate inclusions of sub-angular igneous rocks (>30mm), occasional inclusions of sub-angular sandstone (>10mm), occasional marine shell fragments (>20mm). Sorted. Clear boundary.
0.83-3.15	19.04-21.36	Mottled sand, medium-grained. Colour ranges from 10YR 4/1 dark grey, 2.5Y 4/3 olive brown, 2.5Y 6/4 light yellowish brown. Composed primarily of flint and quartz. Moderate inclusions of coal, laid down in beds (10mm thick) at 1.46, 1.51, 1.58, 1.60, 2.25, 2.33, 2.38, 2.44 and 2.64m. Moderate inclusions of sub-angular quartz (>5mm), flint (>2mm) and marine shell (>2mm) in a layer (>40mm thick) at 2.27m. Layer of silty sand (>15mm thick) at 2.24m. Moderately sorted. Sharp boundary.
3.15-3.34	21.36-21.55	7.5YR 4/6 Strong brown clay. Very compact. Occasional inclusions of chalk (>2mm) between 3.16 and 3.20m. Very fine layers (1mm thick) of sandy clay at 3.25m. Sorted. Clear boundary.
3.34-3.83	21.55-22.04	10YR 4/3 Brown clay. Compact. Very frequent inclusion of angular chalk (>30mm), occasional sub-rounded mudstone (>20mm) and igneous rock (>5mm). Mottled with 2.5 YR ¾ dark reddish brown from 3.46 to 3.61m. Mottled with 2.5Y 5/6 light olive brown from 3.78 to 3.84m. Well sorted. Gradual boundary.
3.83-4.21	22.04-22.42	10YR 4/2 Dark greyish brown clay. Very compact. Occasional inclusions of angular and sub-angular chalk (>10mm), infrequent inclusions of angular flint and igneous rock (>3mm). Sorted.

APPENDIX II: GRAB SAMPLES

Sample Number	Easting	Northing	Slag	Clinker	Coal	Fossils	Bone	Plant Remains
H1	333911.2	5916208	1		1	1		
H2	334010	5916246			1	3		
H3	334117.9	5916262			1	1		
H4	334214.3	5916282			1			
H5	334315.4	5916314	1		1			
H6	334409	5916333			1			
H7	334510	5916349			1			
H8	334606.2	5916374	1		1	1		
H9	334708.1	5916394			1			
H10	334800.5	5916424			1	1		
H11	333901.7	5916313			1			
H12	333998.8	5916339			1			
H13	334096.3	5916356				2		
H14	334194.8	5916386			1	1		
H15	334290.3	5916410	1		1	2		
H16	334388.4	5916425			1			
H17	334486.6	5916451	1		1	3		
H18	334583	5916475			1			
H19	334684.9	5916497			1			
H20	334771.3	5916512			1	1		
H21	333873.8	5916416			1			
H22	333981.3	5916445			1			
H23	334073.7	5916463	1		1			
H24	334172.3	5916482			1			
H25	334270.6	5916505	1		1			
H26	334360.9	5916526			1			
H27	334465.7	5916555			1			
H28	334547.6	5916576			1			
H29	334655.7	5916593			1			
H30	334755.9	5916616			1	1		
H31	333856.8	5916508			1	2		
H32	333953.4	5916534			1			
H33	334050.2	5916559			1	3		
H34	334149	5916578			1			
H35	334247.4	5916600			1	1		
H36	334336.9	5916623			1			

Sample Number	Easting	Northing	Slag	Clinker	Coal	Fossils	Bone	Plant Remains
H37	334439.8	5916645			1			
H38	334536.4	5916668						
H39	334633.9	5916692			1	2		
H40	334731.7	5916711			1			
H41	333837.9	5916611			1	1		
H42	333930	5916633			1			
H43	334028.5	5916654			1	1		
H44	334124.5	5916675	1		1			
H45	334222.1	5916698			1			
H46	334316.8	5916723			1			
H47	334415.9	5916746			1			
H48	334517.6	5916767			1			
H49	334612.5	5916788			1	1		
H50	334712.5	5916811			1			
H51	333810.9	5916706			1			
H52	333909.6	5916728	1			1		
H53	334004.8	5916747			1	1		
H54	334102.4	5916772	1		1			
H55	334200.7	5916793			1			
H56	334295.1	5916816			1			
H57	334395	5916839			1			1
H58	334488.7	5916860			1			
H59	334584	5916879			1	1		
H60	334688	5916910			1			
H61	333787	5916804			1			
H62	333884.7	5916822	1		1	1		
H63	333983.3	5916847			1	2		
H64	334082	5916870			1			
H65	334179.1	5916894			1			
H66	334274.5	5916914			1			
H67	334373	5916939	1		1			
H68	334469.5	5916956		1	1			
H69	334556.6	5916979			1			
H70	334665.5	5917003			1		1	
H71	333761.8	5916896			1			
H72	333862.2	5916923			1	1		
H73	333958.6	5916946			1			
H74	334061.6	5916967			1	2		
H75	334156.6	5916990			1			

Sample Number	Easting	Northing	Slag	Clinker	Coal	Fossils	Bone	Plant Remains
H76	334252.5	5917014			1	1		
H77	334351.9	5917034			1	1		
H78	334446.1	5917055			1	1		
H79	334544.2	5917080			1	1		
H80	334642.8	5917102			1			
H81	333743.9	5916997			1			
H82	333840.7	5917017			1	1		
H83	333939.3	5917042			1			
H84	334036.1	5917065			1			
H85	334133.5	5917087			1	3		
H86	334230.7	5917110			1	4		
H87	334327.9	5917133			1	2		
H88	334425.9	5917155			1	1		
H89	334522.5	5917176			1			
H90	334617.8	5917202			1	2		
H91	333719.9	5917093			1			
H92	333818.2	5917117			1			
H93	333916.3	5917140			1	2		
H94	334013.4	5917162	1	1		1		
H95	334109.6	5917184			1	1	1	
H96	334207.1	5917207			1			
H97	334305.5	5917229	1		1			
H98	334403.8	5917251			1	3		
H99	334499.9	5917274			1			
H100	334596.4	5917299			1			

APPENDIX III: POLLEN ASSESSMENT

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1.) Introduction and Objectives

Sediment sub-samples from cores taken offshore from the Humber coast have been examined for their sub-fossil pollen, spore and diatom content. The principal aims of the study were defined as follows:

* to ascertain presence or absence of microfossils in the sediments and preservation.

* if present, to provide a preliminary statement of the pollen/vegetation taxa present.

* to determine the potential of the sites/cores for fuller analysis which would provide a palaeo-vegetation history for the area which could be correlated within the developing regional model of Holocene vegetation and Flandrian transgression.

2.) The Samples

Pollen sub samples from five cores were examined. These are detailed as follows.

VC1 at 1.04, 2.60 and 4.20m
VC2 at 2.45 and 3.09m.
VC3 at 2.07 and 3.27m.
VC4 at 1.08 m.
VC7 at 1.75 and 1.99m

These samples are of fine to medium grained silts which are intercalated within sands of calcareous (shell/foram nature).

3.) Pollen Extraction

Samples of 3ml volume were prepared using standard techniques (Moore and Webb 1978; Moore *et al.* 1992) with extended HF digestion of Si. and micromesh sieving for removal of clay. Little organic material remained and this (with pollen) was counted using a biological microscope at magnifications to x1000.

4.) Pollen Preservation

Pollen was found to be extremely poorly preserved in all samples examined. Absolute pollen numbers are extremely small or absent. Consequently, only limited pollen assessment counts were possible from two samples. That is, those at 3.27m in VC3 and at 3.26m in VC8.

5.) The Pollen Data

Pollen data obtained from the two samples are given in table 1 below.

Core	**VC3**	**VC8**
Sample	**3.27m**	**3.26m**
Trees		
Betula		1
Pinus	1	24
Abies	1	1
Picea		1
Quercus	11	1
Tilia	1	
Alnus glutinosa	22	3
Corylus avellana type	9	1
Herbs		
Rosaceae cf. *Geum*		1
Plantago lanceolata	1	
Taraxacum type		1
Poaceae	3	1
Unidentified degraded	1	
Spores		
Dryopteris type	8	1
Thelypteris palustris	1	
Sphagnum	1	1
Misc.		
Pediastrum		8
Pre-Quaternary	45	737

Table 1*: Raw pollen counts obtained from Vibrocore samples VC3 and VC8*

5.a.) Sample 9 VC3 at 3.27m.

Trees are dominant with few herbs. *Alnus glutinosa* (Alder), *Corylus avellana* type (hazel/bog myrtle) and *Quercus* (oak) are most important. There are individual occurrences of *Pinus* (Pine), *Abies* (fir) and *Tilia* (Lime/linden) and Herbs comprise a small number of Poaceae (grasses) and a single grain of *Plantago lanceolata* type. Spores of ferns include monolete forms (*Dryopteris* type) and *Thelypteris palustris*.

5.b.) Sample 8 VC8 at 3.26m.

Trees are dominant with being *Pinus* the most important taxon. In addition are small numbers of *Alnus glutinosa* (alder) and *Corylus avellana* type (most probably hazel but may also include bog myrtle). There are individual occurrences of conifers *Picea* (Spruce) and *Abies* (fir) and *Betula*

(Birch), and *Quercus* (Oak). There are few herbs and spores with only single occurrences of a small number of taxa. Cysts of algal *Pediastrum* are present indicating a freshwater component.

6.) Interpretation

Because of the paucity of pollen found negating larger pollen counts/sums to be obtained, little interpretation can be made.

There are few herbs in either sample and as far as can be ascertained, tree and shrub pollen predominate.

The sample from VC3 appears to have *Quercus* (oak), *Alnus glutinosa* (alder) and *Corylus avellana* (hazel) as its principal constituents. There is also a trace of *Tilia* (lime/linden). This assemblage would suggest a younger age for this sample than that from VC8. Absence of elm and the presence of *Plantago lanceolata* (ribwort plantain; albeit a single grain) may indicate a Flandrian chronozone III age; that is, post Atlantic and post Elm decline probably Neolithic or Bronze Age.

The sample from VC3 has a notably different flora to that described above. Here, *Pinus* (pine) is of greater significance along with *Corylus avellana* and lesser numbers of *Alnus glutinosa* and *Quercus* (only a single grain). This assemblage is more typical of the early Holocene (Flandrian Chronozone Ib; Boreal period) when pine-hazel forest was dominant.

In both samples, single grains of *Abies* are present and also a single grain of *Picea* in VC8. Neither genus is native to this region during the present, Holocene period. Although there are a substantial number of reworked/derived pre-Quaternary palynomorphs, these grains appeared 'fresh'. It is possible that the occurrence of these is due to the reworking of earlier Pleistocene sediments when these taxa were native and/or from long distance marine transport.

7.) Conclusions and Suggestions for Additional Analysis

Pollen is extremely poorly preserved in these sediments. Only two less than adequate assessment pollen counts were possible from the 12 samples examined. These appear to be of different ages showing different ecological settings. An earlier sample (VC8) may be of early Holocene, Boreal age whilst a later sample may be of late-prehistoric date (VC3). The former has pine hazel woodland whilst the latter has deciduous, oak, alder and hazel woodland.

Because of the extremely poor pollen preservation, it is not felt that any additional work need be carried out on these sediments/cores.

8.) References

Moore, P.D. and Webb, J.A., 1978, *An illustrated guide to pollen analysis*, London: Hodder and Stoughton.

Moore, P.D., Webb, J.A. and Collinson, M.E., 1991, *Pollen analysis.* Second Edition.

APPENDIX IV: DIATOM ASSESSMENT

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All twelve of the samples analysed for pollen (**Appendix III**) were also examined for diatoms. The aim being to establish presence or absence in the sediments of the different vibrocores. If present, diatoms can provide information relating to salinity and water quality.

Preparation followed standard procedures for removal of humic material from samples of ca. 0.2ml using Hydrogen peroxide. Residues were mounted on a cover slip, air dried and mounted in Naphrax. Examination was carried out using a high power binocular microscope equipped with phase contrast.

No diatom frustules were found in any of the samples. As with the pollen (**Appendix III**), preserving conditions were probably very poor. In this case, this is attributed to the coarseness of the sediments (sand) deposited in a medium energy environment. No additional work is required.

APPENDIX V: FORAMINIFERA ASSESSMENT

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Introduction

Fourteen sub-samples taken from vibrocores **VC1**, **VC2**, **VC3**, **VC4**, **VC7** and **VC8** have been assessed for the presence, preservation and environmental significance of their foraminiferal content. The samples were selected from fine grained elements of sedimentary Units Bii (till), C (glaciofluvial outwash), D, E and F (shallow marine/lag) deposits.

Method

Sediment was wet sieved through a 63µm sieve to remove the silt and clay fractions. The sediment was dried and sieved through 500µm, 250µm, 125µm sieves. Foraminifera were picked out under 10-60x magnification under transmitted and incident light using a Meiji EMT microscope. Where possible fifty specimens per sample were picked out and kept in card slides. Identification follows Murray 1973 and interpretation of their ecology follows Murray 1991.

Results

The results of the assessment are presented in Table 1.

VC1

Foraminifera were relatively common from these samples. The samples at 1.04m, 2.60m and 4.20m showed high numbers of species of the genus *Ammonia* including *Ammonia batavus.* The samples contained many Miliolids including species of the genus *Quinqueloculina*. These species are indicative of outer estuarine and shallow marine conditions.

VC2

One sample at 2.50m produced no foraminifera.

VC3

Three samples at 2.07, 3.14 and 3.27m were processed. The sample at 3.14m produced no foraminifera. At 2.07m foraminifera were present in low numbers including species of *Ammonia*, *Elphidium* and Miliolids. These are indicative of shallow marine conditions. The sample at 3.27m contained higher numbers of foraminifera including species of *Ammonia*, *Elphidium* and Miliolids. In this sample *Jadammina macrescens* and *Trochamina inflata* were present which are brackish water and tidal marsh indicator species. Interestingly the sample contained a large amount of coal and Hydrobid molluscs. Some plant macrofossils were also present in this samples including *Ajuga* sp, *Ruber* sp. *Atriplex* sp. and *Potamogeton* sp. These plants are indicative of terrestrial, freshwater and saltmarsh environments. The overall sample is very mixed and those terrestrial and saltmarsh elements would appear to be reworked into a shallow marine context.

VC4
Two samples were processed from **VC4** at 1.80m and 3.40m. The sample at 1.80m contained very low numbers of shallow marine foraminifera (*Ammonia batavus*, *Quinqueloculina dimidiata* and *Quinqueloculina oblonga*). The sample at 3.40m contained low numbers of foraminifera including species of *Ammonia* and Miliolids.

VC7
Three samples were processed from **VC7** at 1.75, 1.99 and 2.83m. The samples at 1.75 and 1.99m contained shallow marine indicators including species of *Ammonia* and Miliolids. The sample at 2.83m produced no foraminifera.

VC8
Two samples were processed from **VC8** at 2.24m and 3.26m. At 2.24m species of *Ammonia* and Miliolids were abundant indicative of nearshore and shallow marine environments. At 3.26m no foraminifera were recovered.

Discussion
The foraminiferal assemblages recovered from the vibrocores are remarkable similar. The most productive samples have come from sedimentary Units D and E – shallow marine sands. The samples show remarkable uniformity usually dominated by *Ammonia batavus.* This species is known to prefer marine and inner shelf environments (Murray 1979). Miliolids including species of the genera *Quinqueloculina* and *Miliolinella* were generally common throughout these samples. They are all indicative of marine and inner shelf environments (Murray 1979). There is no marked difference between Units D and E. Unit F also contained low numbers of shallow marine foraminifera.

Occasional indicators of brackish water were present in most of the samples and these are likely to be reworked into shallow marine sediments. This was most pronounced in the sample at 3.27m in vibrocore **VC3**. This sample contained the shallow marine foraminifera common in other samples (*Ammonia batavus* and Miliolids). In addition to this, the sample contained the salt marsh indicator species – *Jadammina macrescens* and *Trochammina inflata* and relatively high numbers of brackish water species of Ammonia (*Ammonia tepida*, *Ammonia limnites* and *Ammonia aberdoveyensis*). Molluscs with a preference for brackish water (Hydrobids) and terrestrial, freahwater and salt marsh loving plants (*Ajuga* sp., *Ruber* sp. *Atriplex* sp. and *Potamogeton* sp.) all indicate reworking of terrestrial, brackish, salt marsh and freshwater environments into a marine context.

No foraminifera were recovered from Units C or Bii both interpreted sedimentologically as glacially induced deposits and therefore unlikely to contain any *in situ* foraminifera.

In conclusion, the samples producing foraminifera are shallow marine deposits. The assemblages show significant reworking of taxa as would be expected in a shallow marine context.

References

Murray, J.W., 1979, *British Nearshore Foraminiferids,* London: Academic Press.

Murray, J.W., 1991, Ecology and Palaeoecology of Benthic Foraminifera, Harlow: Longman Scientific.

Table 1: Foraminifera per sample and sedimentary unit in vibrocores VC1, VC2, VC3, VC4, VC7 and VC8

Vibrocore	**VC1**	**VC1**	**VC1**	**VC3**	**VC3**	**VC4**	**VC4**	**VC7**	**VC7**	**VC8**
Sedimentary unit	**E**	**E**	**D**	**E**	**E**	**F**	**D**	**E**	**E**	**E**
Sample depth (m)	**1.04**	**2.6**	**4.2**	**2.07**	**3.27**	**1.8**	**3.4**	**1.75**	**1.99**	**2.24**
Ammonia sp. juvenile					x					
Ammonia aberdoveyensis	x	x	x	x	x		x	x	x	x
Ammonia batavus	xxx	xx	xxx	xx	x	x	x	xx	x	xx
Ammonia limnites	x	x	x		x					
Ammonia tepida	x	x	x		x				x	x
Astergerinata mamilla			x							
Brizalina variabilis			x							x
Cibicides lobatulatus	x	x	x	x	x			x		x
Elphidium sp.			x		x			x		
Elphidium crispum	x	x		x			x			
Elphidium excavatum								x		
Elphidium gerthi										x
Elphidium incertum	x			x						
Elphidium macellum							x			
Elphidium oceanensis										x
Gavelinopsis sp.									x	
Glabratella millettii	x									x
Jadammina macrescens	x	x	x	x	x					
Miliolinella subrotundata		x	x		xx			x		x
Oolina sp.	x									
Patellina corrugata				x						
Pateoris hauerinoides					xx					
Quinqueloculina bicornis	x	x	x					x		x
Q. bicornis var. *angulata*	x	x	x		x		x	x		
Quinqueloculina cliarensis		x	x							
Quinqueloculina dimidiata			x			x	x	x	x	x
Quinqueloculina lata	x								x	
Quinqueloculina oblonga					x					
Quinqueloculina seminulum	x	x				x			x	
Quinqueloculina sp.	xx	x	xx	x	x		x	x	x	x
Quinqueloculina subrotundata				x						
Rosalina sp.							x			
Rosalina williamsoni	x									xx
Trochammina inflata					x		x	x		x
Fossils	x	x	x	x	x		x	x	x	x

Abundance:
x – 1-9 specimens
xx – 9-50 specimens
xxx – greater than 50 specimens

APPENDIX VI: OSTRACOD ASSESSMENT

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Introduction

Fourteen sub-samples taken from vibrocores **VC1**, **VC2**, **VC3**, **VC4**, **VC7** and **VC8** have been assessed for the presence, preservation and environmental significance of their ostracod content. The samples were selected from fine grained elements of sedimentary Units Bii (till), C (glaciofluvial outwash), D, E and F (shallow marine/lag) deposits

Method

The sediment was wet sieved through a 63µm sieve to remove the silt and clay fractions. The sediment was dried and sieved through 500µm, 250µm, 125µm sieves. Foraminifera were picked out under 10-60x magnification under transmitted and incident light using a Meiji EMT microscope. Where possible fifty specimens per sample were picked out and kept in card slides. Identification and interpretation of ecology follows Athersuch *et al.* 1987 and Meisch 2000.

Results

The presence and absence of ostracods per sample are shown in Table 1.

VC1

Three samples were processed from **VC1** at 1.04, 2.6 and 4.2m. All were dominated by adult forms of *Aurila woutersi*, a marine, phytal littoral and sublittoral taxa. Other marine sublittoral taxa present included *Aurila convexa, Acanthocythereis dunelmensis*, *Bythocythere robinsoni, Krithe praetexta* and species of the genera *Cytherois*, *Hemicythere* and *Paracytherois*. One specimen of the brackish water indicator *Cyprideis torosa* was recovered from the sample at 2.60m. At 4.20m the sample was dominated by *Aurila woutersi* including whole carapaces. Molluscs were common in the samples at 1.04 and 4.20m. At 1.04m bivalves, gastropods and sponge spicules were present. At 4.20m the sample contained significant numbers of marine bivalve molluscs, sponge spicules and coal including Carboniferous megaspores.

VC2

Two samples were processed from **VC2** at 2.50 and 3.14m which produced no ostracods. The sand fraction of these samples comprised significant amount of igneous and metamorphic rocks including quartz. Other sedimentary rocks were present including conglomerate and sandstone.

VC3

Two samples were processed from **VC3** at 2.07 and 3.27m. The sample at 2.07m produced a very low abundance and monospecific assemblage consisting of two adult forms of *Aurila woutersi*. Sponge spicules were also retrieved from this sample. At 3.27m, a diverse assemblage of adult mostly marine sublittoral forms were present including *Aurila woutersi*, *Aurila convexa*, *Jonesia acuminata*, *Leptocythere pellucida, Robertsonites tuberculatus* and *Sahnicythere retroflexa*. This sample also contained a large amount of coal and more recent plant macrofossils. These species, commonly associated with woodland and scrub, included *Ajuga* sp. (bugle), *Rubus* sp. (bramble); possible saltmarsh; *Atriplex* sp., *Suaeda/Salicornia* (sea-blite/glasswort); and fresh and/or brackish water, *Potamogeton* sp. (pondweed) and *Najas* sp. (Naiads). Broken marine molluscs were also common in this sample.

VC4

Two samples were processed from **VC4** at 1.8 and 3.4m, neither of which produced any ostracods. Other remains were encountered in the samples including juvenile molluscs (marine bivalves and gastropods including *Cardium edule*, *Ostrea edulis* and *Littorina littoralis*) and barnacle (*Semibalanus* sp.) plates.

VC7

Three samples were processed from **VC7** at 1.75, 1.99 and 2.83m. At 1.75m a few marine sublittoral taxa were recovered including *Aurila woutersi*, *Hemicythere rubida* and *Hemicythere villosa*. In this sample bivalve molluscs and sponge spicules were also present. At 1.99m a few broken and unidentifiable ostracods were recovered. The sample at 2.83m produced no ostracods although did contain some broken marine molluscs.

VC8

Two samples were processed from **VC8** at 2.24 and 3.26m. At 2.24m some adult shallow marine and sublittoral species were present including *Aurila woutersi*, *Hemicythere rubida* and *Hemicythere villosa*. In this sample marine molluscs and sponge spicules were also present. No ostracods were recovered from the sample at 3.26m.

Discussion

Relating these samples to the sedimentary units provides a framework for discussing the environmental significance of the recovered fauna. One sample from Unit Bii in **VC8** produced no ostracods which is not surprising as this unit of clay with microlaminar structure is interpreted as glacial till. Given the inclusions of sedimentary rocks within till it would be possible for reworked specimens to be present. Two samples from Unit C were also processed from **VC2** and contained no ostracods. This sandy gravel unit was interpreted as glacio-fluvial channel infill. No environmental remains were recovered from this unit and this is probably due to the grain size of the sediment. Ostracod carapaces rarely survive in gravel due to attrition.

Of the samples from Unit D (**VC1**, **VC4** and **VC7**) interpreted as shallow marine/sublittoral sands only the sample in **VC1** at 4.20m produced a significant fauna. This was dominated by the species *Aurila woutersi* and included whole carapaces which signifies that this fauna is probably *in situ*. *Aurila woutersi* is a marine, phytal, littoral and shallow sub littoral taxa which is presently only known from southern Britain (Athersuch *et al*. 1989).

Seven samples from Unit E also interpreted as shallow marine sands produced similar marine sublittoral fauna including *Aurila woutersi*, *Aurila convexa*, *Bythocythere robinsoni*, *Hemicythere rubida*, *Hemicythere villosa*, *Jonesia acuminata*, *Paracytherois* sp., *Paradoxostomata*, *Robertsonites tuberculatus*, *Sahnicythere retroflexa*, *Sarsicytheridea* sp. Most of the specimens were adult forms and single valves which are indicative of a reworked fauna. This would be usual in a sandy shallow marine context as this higher energy environment would cause some reworking and more fragile juvenile valves to be broken or to become suspended. *Hemicythere villosa* in **VC8** is of interest as it is often associated with Sabellaria reefs. One *Cyprideis torosa*, a brackish water indicator, was recovered from **VC1** at 2.5m. Although this is a single occurrence and probably reworked, it is indicative of brackish environments nearby. The sample from Unit F produced no ostracods probably due to higher energy deposition.

The ostracod fauna is largely shallow marine and sublittoral and is present in Units D and E. The radiocarbon dating of marine shell (SUERC-12311 and SUERC-12316**, Appendix VII**) suggests that Units D and E date to approximately the late Mesolithic/Neolithic period. Relating these dates to known sea levels and the OD depths of the samples confirms the suggestion that these deposits are shallow marine/sublittoral deposits which formed during the late Mesolithic. Given the lack of terrestrial/fluvial/estuarine deposits surveyed and sampled it is not considered that further work should be undertaken on ostracods from an archaeological point of view unless it can be proven that archaeological material is or could be recovered from these contexts.

References

Athersuch, J., Horne, D.J. and Whittaker, J.E., 1989, *Marine and Brackish Water Ostracods,* Synopses of the British Fauna (New Series) No. 43. Leiden/New York/København/Köln: E.J. Brill.

Meisch, C., 2000. *Freshwater Ostracoda of Western and Central Europe*, Süßwasserfauna von Mitteleuropa 8/3. Heidelberg/Berlin: Spektrum Akademischer Verlag.

Table 1: Ostracods per sample in vibrocores VC1, VC3, VC7 and VC8

Vibrocore	**VC1**	**VC1**	**VC1**	**VC3**	**VC3**	**VC7**	**VC8**
Sedimentary unit	**E**	**E**	**D**	**E**	**E**	**E**	**E**
Sample depth (m)	**1.04**	**2.6**	**4.2**	**2.07**	**3.27**	**1.75**	**2.24**
Acanthocythereis dunelmensis			1				
Aurila convexa	2				2	1	
Aurila woutersi	11	4	14	2	5	1	2
Bythocythere robinsoni			1				
Cyprideis torosa		1					
Cytherois sp.						2	1
*Hemicythere s*p.			1		1	1	
Hemicythere rubida							1
Hemicythere villosa							2
Jonesia acuminata					2		
Krithe praetexta			1				
Leptocythere pellucida					2		
Loxoconcha sp.					2		
Paracytherois	2	1	1				
Paradoxostomata					2	2	
Robertsonites tuberculatus					1		
Sahnicythere retroflexa					1		
Sarsicytheridea sp.							2

APPENDIX VII: RADIOCARBON (^{14}C) DATING

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The aim of dating was to attempt to relate the inundation of the North Sea in this area and the associated palaeo-environmental information to known epochs (i.e. the Mesolithic or Allerød or Ipswichian). The sediments were largely inorganic providing very limited material to submit for radiocarbon dating.

Marine shell was selected and every species chosen on the basis that they were totally marine; thus sampling the marine ^{14}C reservoir and not a combination of the marine and terrestrial radiocarbon reservoirs. Although calibration and limitation of our knowledge of the past marine reservoir is limited, it is considered that this will not affect the broad chronological resolution required by these result.

The shells selected were *Tellin* sp., *Gibbula* sp. and *Venus verrucosa* all from gravely marine to sublittoral sand. The specimens were selected and examined by J. Russell and considered to be 'fresh' and not weathered thus removing the likelihood of significant residuality, and thus the dated items were likely to date the deposition of the deposit within a century. Samples from two cored sequences were submitted in an attempt to correlate beds between cores, and examine relative rate of deposition in another (**VC7**). The radiocarbon results have been calibrated with the marine data presented by Stuiver *et al.* (1998) and performed on OxCal ver 3.9 (Bronk Ramsey 1995; 2001) and are expressed at the 95% confidence level with the end points rounded outwards to ten years following the form recommended by Mook (1986) (Table 1) and as probability distribution in figure 1.

The results indicate the marine/littoral sandy deposits dated in both sequences generally belong to the earlier post glacial period and generally equate to the Atlantic climatic phase or later Mesolithic. However considerable caution should be exercised as our assumption that there was little residuality is patently incorrect. The samples from two different, albeit similar, strata were separated by 0.61m of sediment in **VC7** at 3.03m and 2.43m. However the upper shell is nearly one millennium (*c.* 950 years) earlier than the shell in the deposit 0.61m deeper. On this basis our assumption that the little wear relates to little residuality is wrong in this instance and thus cannot be assumed of any of the deposits. As such these radiocarbon results are useful in indicating that the deposition of the sandy deposits occurred in the Holocene. The shells relate to the Atlantic or later Mesolithic period (*c.* 6,200-4,000 cal. BC), and deposition of the sandy marine or sublittoral deposits occurred at or after that period. We cannot however, rule out the fact that these deposits could be considerably younger and contain derived and residual material.

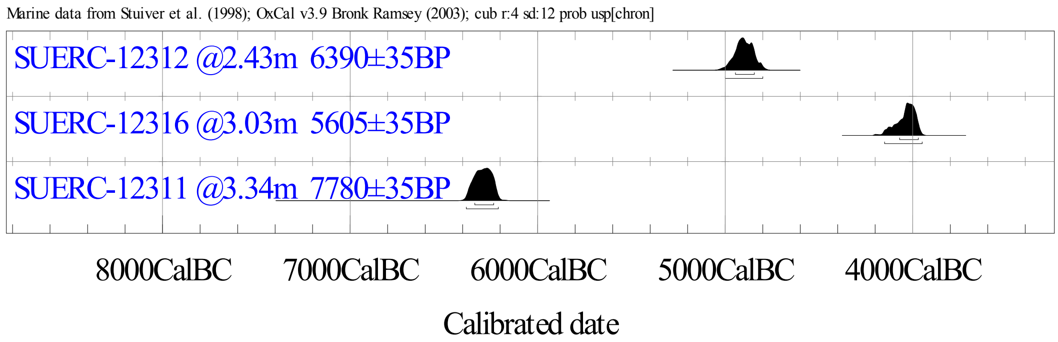

Figure 1. Calibrated radiocarbon results of shell dates from the Humber survey area.

Core hole	*Depth (m below seabed)*	*Depth (m below OD)*	*Material*	*Lab no*	*Result no*	δC^{13} *‰*	*Result BP*	*Cal. date*
VC4	3.34	22.54	Tellin in gravely sand (marine/[sub]littoral)	GU-14779	SUERC-12311	-2.3	7780±35	6380-6210
VC7	2.43	19.16	Topshell *Gibbula* sp. in gravely sand (marine/[sub]littoral)	GU-14780	SUERC-12312	-2.2	6390±35	5000-4800
VC7	3.03	19.76	*Venus verrucosa* in sandy gravel (marine/[sub]littoral)	GU-14781	SUERC-12316	-1.0	5605±35	4150-3970

Table 1. Radiocarbon results of shell dates from the Humber survey area.

References

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Mook, W.G., 1986, 'Business meeting: recommendations/resolutions adopted by the twelfth International Radiocarbon Conference', *Radiocarbon* 28:799.

Stuiver M., P.J. Reimer and T.F.Braziunas 1998 High-precision radiocarbon age calibration for terrestrial and marine samples, Radiocarbon, 40(3), 1127-1151

APPENDIX VIII: OPTICALLY STIMULATED LUMINESCENCE (OSL) DATING

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Six samples from VC2, 3, 4 and 7 were prepared for OSL dating (VC2a 2m, VC3a 1.8m, VC4a 3.37m, VC7a 1.4m, VC7a 2.6m and VC7a 3.8m).

All were subsampled from the cores provided, and only the middle of the core was used to reduce the likelihood of incorporating any light-contaminated edge material. Sample preparation was standard, and began with removal of carbonates and organics with HCl and H_2O_2.

Subsequently samples were sieved to 150-212µm to isolate the size fraction to be dated. Heavy minerals were removed by flotation in sodium polytungstate, and samples were finally etched with HF for 45 minutes (to remove the outer alpha-irradiated rind and any remaining feldspars) and given a final sieving.

Dosimetry was provided by ICP-MS and -AES at Royal Holloway, University of London, and saturated moisture contents were measured to calculate attenuation effects.

All samples were mounted on aluminium discs with Silkospray^{TM}, and were analyzed on a Riso TL-DA-15 with blue diode stimulation at 470nm, with luminescence measured with a 9235QA photomultiplier tube, shielded by two 3 mm thick Hoya U-340 filters. At least 10 aliquots were measured for each sample, using SAR protocols (Murray and Wintle, 2000, 2003; Wintle and Murray, 2006). All samples were preheated to 240°C for 10s prior to measurement. An elevated test dose of 16.5 Gy was used to maximize signal-noise ratio, and a preheat of 220°C for 10s was used for the test dose measurements.

Most samples provided closely distributed Gaussian distributions of replicate equivalent dose (D_e) measurements, offering a high degree of confidence in the results. A multimodal distribution for VC4a 3.37m was dealt with by the use of the Finite Mixture Model (Galbraith and Green, 1990). Using these methods the following results were achieved:

Core	Sample ID	Depth (m below OD)	Age (ka)	Error (ka)	Comment
VC2a	2M	21.31	5.6	0.5	
VC3a	1.8M	20.44	6.4	0.6	
VC4a	3.37M	22.54	47.4	6.8	Firm maximum age - could possibly be a little younger, but older than Holocene
VC7a	1.4M	18.27	7.7	0.7	
VC7a	2.6M	19.47	6.9	0.6	
VC7a	3.8M	20.67	5.7	0.5	

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