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Race Bank Offshore Wind Farm

Stage 3 Palaeoenvironmental Assessment

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geoservices

Race Bank Offshore Wind Farm

Stage 3 Palaeoenvironmental Assessment

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Summary

Wessex Archaeology was commissioned by DONG Energy to undertake a Stage 3 palaeoenvironmental assessment of vibrocore and borehole samples from the site of the proposed Race Bank Offshore Windfarm.

The Stage 3 palaeoenvironmental assessment has comprised the palaeoenvironmental assessment of suitable material for recovering floral (plants, charcoal, pollen and diatoms) and faunal (insects, molluscs, ostracods and foraminifera) remains and included radiocarbon dating of samples. The assessment was undertaken upon vibrocore samples from the export cable route (**VC-EX-021** and **VC-EX-034**) and from boreholes in the wind farm area (**BH-CPT-01**, **BH-CPT-11**, **BH-CPT-14** and **BH-G01**) derived from two separate geotechnical surveys undertaken in 2010 and 2013 respectively.

The palaeoenvironmental assessment results were mixed. Whilst diatoms were absent from the assessed samples, some good assemblages of molluscs, plant remains, pollen, foraminifera and ostracods were recorded, with the best sequence investigated being from location **BH-G01**, which is located in the northern part of the proposed wind farm area. The radiocarbon dates obtained from the samples ranged from the Early Mesolithic to the post-medieval periods (*c*. 9000 years to 300 years ago). There were some problems encountered with the radiocarbon dating. Three samples failed from borehole **BH-G01** due to insufficient carbon being present within the samples. In addition two samples from vibrocores (**VC-EX-021** and **VC-EX-034**) produced results that were much younger than expected and it is considered likely that these samples have been contaminated.

The geoarchaeological interpretation from the two geotechnical surveys have also been combined into a deposit model taking into account both the archaeological interpretation of sub-bottom geophysical data from the site and information obtained from the British Geological Survey data.

Whilst some interesting Mesolithic sequences have been assessed here, the samples are not deemed to be suitable for further Stage 4 analytical work. Any further analytical work, if warranted, would be undertaken on better (undisturbed) samples from future geotechnical campaigns, if undertaken. No further geotechnical surveys are currently planned.

Race Bank Offshore Wind Farm

Stage 3 Palaeoenvironmental Assessment

Acknowledgements

Wessex Archaeology is grateful to DONG Energy for commissioning the Stage 3 palaeoenvironmental assessment of vibrocore and borehole samples.

The Stage 3 palaeoenvironmental assessment, and processing of samples was undertaken by Rob Scaife (pollen and diatoms), Jack Russell (foraminifera and ostracods) and Sarah Wyles (molluscs and waterlogged plants). The radiocarbon dating was undertaken at the Scottish Universities Environmental Research Centre (SUERC), East Kilbride under the supervision of Gordon Cook.

This report was written by Jack Russell and figures were prepared by Kitty Brandon. The project was managed for Wessex Archaeology by Stephanie Arnott and Caroline Budd.

Race Bank Offshore Wind Farm

Stage 3 Palaeoenvironmental Assessment

1 INTRODUCTION

1.1.1 Wessex Archaeology (WA) was commissioned by DONG Energy Ltd. to undertake Stage 3 palaeoenvironmental assessment of core samples taken from geotechnical investigations on the site of the proposed Race Bank Offshore Wind Farm and associated export cable route, hereafter "the site". The site is located approximately 30km north east of Wells-next-the-Sea, off the north Norfolk coast bounded by the Race Bank (to the south) and North Ridge (to the north) sand banks. The export cable route runs in a southwesterly direction from this location for approximately 60km towards the Wash with its landfall located just east of the mouth of the River Nene (**Figure 1**).

1.1.2 This study forms part of an ongoing programme of geoarchaeological works for the proposed Race Bank Offshore Wind Farm. Previous work has included an Archaeological Assessment (WA 2008), Stage 1 Archaeological Assessment of CPT and borehole logs (WA 2010a), Stage 2 Recording of Borehole Samples (WA 2010b) and an additional Stage 1 and 2 Geoarchaeological Assessment of vibrocore samples (WA 2014a).

1.1.3 The current Stage 3 work combines the recommendations detailed in two Written Schemes of Investigation (WSI) (WA 2012a and WA 2014b). The WSIs included proposals to review the Race Bank geotechnical investigations as they provide an opportunity to review the geological sequence from a geoarchaeological perspective to help gauge the archaeological and palaeoenvironmental potential of the site, with regard to any possible evidence of prehistoric activity within and adjacent to the site.

1.1.4 To help frame geoarchaeological investigations of this nature, WA has developed a five stage approach, encompassing different levels of investigation appropriate to the results obtained, accompanied by formal reporting of the results at the level achieved. The stages are summarised in **Appendix 1**.

1.1.5 A Method Statement (WA 2012b) detailing the geoarchaeological review and use of geotechnical data and samples was produced which sets out the aims and objectives of this work:

1.2 Aim and Objectives

1.2.1 The aim of the investigation proposed here is to make maximum archaeological use of the Race Bank OWF geotechnical investigations. The objectives are as follows:

- To generate geoarchaeological data for archaeological assessment;
- To obtain sub-samples of sequences of archaeological interest that can be considered in decisions about palaeoenvironmental assessment, analysis and scientific dating;

- To enhance the results of the geophysical assessment undertaken during the preparation of the Environmental Statement (WA 2008);
- To enhance the results of additional geophysical assessments due to be undertaken; and
- To mitigate the potential negative impacts of the construction of the scheme on archaeology and cultural heritage.

1.3 Geoarchaeological Background

1.3.1 The following background summarises the geological formations known to exist at the site. The age estimates are given related to the established British and Northwest European stage names. Within the Pleistocene epoch these are also supplemented, where known, with the now more prevalent and comparable Marine Isotope Stages (MIS), where odd numbers indicate an interglacial period and even numbers a glacial period. Ages in years within the Pleistocene epoch are expressed in, thousands of years ago (ka) and within the Holocene epoch as years before present (BP).

1.3.2 The geological bedrock throughout this entire area of the southern North Sea is Upper Cretaceous (Campanian) Chalk, the upper surface of which provides a distinctive lower boundary, on both seismic records and in boreholes, for the Pleistocene and more recent sequences present in the area.

1.3.3 The overlying Pleistocene sediments can be of varying thickness throughout the region, ranging from a thin veneer (and occasionally absent within major erosion features such as Silver Pit) to greater than 100m thick (Cameron *et al.* 1992). The nature of these sediments reflects the repeated glacial/interglacial cycles that have occurred in this area since the Anglian Period (*c*. 478 ka), which have resulted in the deposition of sequences of lodgement and ablation tills punctuated by episodes of erosion by glacial outwash and deposition of shallow marine sediments. These sequences are generally separated by marked erosion surfaces created by repeated ice sheet advance. Overlying Chalk bedrock in the area are three major Pleistocene formations of note; the Swarte Bank, the Egmond Ground formation and the Bolders Bank formation. The formations have been cored by the British Geological Survey in some areas of the North Sea where microfossil analyses and stratigraphic relationships have been used to determine the ages of the formations (Hopson *et al*. 1991, Cameron *et al.* 1992).

1.3.4 The Swarte Bank formation comprises the infill of sub glacial valley systems originally cut during the Anglian glaciation and infilled during the early part of the Wolstonian period (MIS 10 to 9; *c*.350 to 280ka). The basal sediments of the Swarte Bank formation comprise gravels, sands and stiff grey diamictons overlain by glaciolacustrine and glaciomarine sands and muds. The Egmond Ground Formation is up to 16m in thickness and comprises sands and gravels thought to be marine in origin. The formation is thought to be of Wolstonian age (MIS 8; *c*. 280 to 250 ka).

1.3.5 Across all of the site, the British Geological Survey has mapped the Bolders Bank formation (Cameron *et al.* 1992, Brown 1986). This blanket of glacial till is extensive, overlying earlier Pleistocene formations and outcropping near the seabed surface. The formation comprises stiff red brown gravelly, sandy clays containing erratics including chalk, red-brown sandstone, grey mudstone and other metamorphic and igneous rocks. The formation is similar to the Hunstanton till of East Anglia and the tills of Holderness north of Spurn point. The formation is thought to be of late Devensian age (MIS 2; *c.* 18 ka).

1.3.6 Whilst not mapped in the area by the British Geological Survey (Cameron *et al.* 1992, Brown 1986), incised into the Bolders Bank formation are known scaphiform glacial valleys which are in places infilled with the Botney Cut formation. These valleys are up to 60m in depth and 4km in width. The basal fill of the Botney Cut formation comprises red brown gravelly, sandy clays which are lithologically indistinct from the Bolders Bank formation (Cameron *et al*. 1992). The upper part of the Botney Cut formation comprises laminated sands and clays thought to have formed in glaciolacustrine and occasionally glaciomarine environments. The formation is thought to be of Devensian to possibly Early Holocene age (*c*. 18 to 12ka).

1.3.7 Whilst the exact geomorphology of the areas in the early Holocene, particularly the location and elevation of areas higher ground (which may have been subject to subsequent marine erosion) is unknown, it is possible to guess, based on current bathymetry and with reference to known sea level curves (Shennan *et al*. 2000, 2002; Ward *et al*. 2006) when the area would have become submerged for the last time. Sea level curves indicate that the wind farm site would have been completely inundated by the most recent marine transgression by approximately 6,000 BP (Jelgersma 1979, Shennan *et al* 2002, Ward *et al*. 2006). Holocene terrestrial environments were indicated by the identification of scattered, relict palaeochannels within the survey area during the geophysical data assessment (WA 2008) (see inset **Figure 2**).

1.3.8 The recent seabed sediments of the area mainly comprise reworked deposits of sand and gravel, with the formation of large-scale stable bedforms such as Race Bank and North Ridge sandbanks. These comprise sands and gravels and which are generally less than 2m in thickness where they are associated with the Bolders Bank formation (Cameron *et al*. 1992, Brown 1986).

2 METHODOLOGY

2.1 Deposit Model

2.1.1 The sediments which were recorded during the Stage 1 and 2 geoarchaeological work from the boreholes (WA 2010b) and vibrocores (WA 2014a) have been combined in a Rockworks database. Transects showing both vibrocores and boreholes from both investigations are now shown on **Figures 2** to **9**. The sediments have been grouped following the most recent geoarchaeological interpretation (WA 2014a) and with reference to the formations mapped by the British Geological Survey (Brown 1986, Cameron *et al.* 1992) and the interpretation of sub bottom geophysical data (WA 2008).

2.1.2 Both geotechnical surveys were originally recorded with depths relative to Chart Datum (CD). These depths have been converted with reference to Ordnance Datum (OD) by using the difference between LAT (Lowest Astronomical Tide) which is equivalent to Chart Datum (CD) at the nearest coastal stations used during the vibrocore and borehole surveys at Kings Lynn and Skegness respectively. They have been converted to OD so that they are comparable to each other, to onshore datasets and datasets regarding palaeo sea levels (Ordnance Datum being equivalent to Mean Sea Level).

2.2 Geoarchaeological Subsampling

2.2.1 Geoarchaeological subsampling is routinely undertaken on undisturbed core samples where small subsamples are taken from specific depths. A limited number of suitable undisturbed samples were available for subsampling. Subsequent to the Stage 2 recording work, many of the undisturbed core samples including all of the vibrocore samples were subjected to extensive geotechnical testing and sampling. This process involved removing the undisturbed sediment from the core samples and bagging them in

0.5m to 1m sections, some of which were then destructively tested. Of those that remained, the bagged samples therefore often contained large amounts (typically 5 to 10 litres) of mixed sediment. By cross referencing the more interesting and thicker layers with the results of the Stage 2 geoarchaeological work (WA 2010b, 2014a) it was possible to gain some acceptable assessment subsamples from the bagged samples. It is noted however that the process of bagging core samples introduces the possibility of contamination within the samples (i.e. mixing layers together). Some of the borehole samples provided better undisturbed core sequences to subsample from (e.g. borehole **BH-G01**) although there were gaps in the sequence as the boreholes were not originally continuously sampled.

2.2.2 Subsamples were taken from the geotechnical samples taken from both the vibrocore and borehole surveys. The Stage 3 subsampling was undertaken from the following borehole and vibrocore locations, shown on **Figure 2** and in the table below:

Borehole/Vibrocore ID	WGS84 UTM Zone 31N		Seabed Depth (m below OD)
	Easting	Northing	
VC-EX-21	318270	5868118	11.93
VC-EX-34	321315	5873334	26.93
BH-CPT-01	359483	5899409	21.05
BH-CPT-11	358583	5904620	24.95
BH-CPT-14	352699	5907228	17.75
BH-G01	353905	5907279	23.75

2.2.3 Subsamples were taken from relevant deposits in order to provide chronological and environmental information relating to their formation. The selections were made on the basis of the sediment identified from the geoarchaeological recording of the samples. Samples taken were targeted at sediments thought to be of potential geological, geoarchaeological and palaeoenvironmental interest. The positions and depths of the samples are shown on **Figures 4**, **7**, **8** and **9** and are also listed in the next section of this report.

2.3 Stage 3 Palaeoenvironmental assessment and dating

2.3.1 In order to maintain an ability to easily cross reference the samples with the original geotechnical data, the depths of the assessed samples are generally given in metres below Seabed (m below SB) in this section. The samples are also shown on **Figures 4, 7, 8** and **9** with reference to the updated deposit model and with reference to OD.

Foraminifera and Ostracods

2.3.2 Fourteen sediment samples from vibrocores **VC-EX-021** and **VC-EX-034** and boreholes **BH-CPT-01**, **BH-CPT-11**, **BH-CPT-14** and **BH-G01** of approximately 25cm^3 were taken for foraminifera and ostracod assessment. The samples consisted of organic clay, silt, sand and peat deposits and were from the following locations and depths in metres below seabed (m below SB).

- **VC-EX-034**: 0.3 to 0.7m and 2 to 2.7m below SB
- **VC-EX-021**: 0.6m and 1.7 to1.95m below SB
- **BH-CPT-01**: 0 5 to 0.85m below SB
- **BH-CPT-11**: 0.35 to 0.45m and 1.52m below SB
- **BH-CPT-14**: 19.69m below SB

- **BH-G01**: 4.82, 5.28, 5.7, 7.9, 8.24 and 8.73m below SB

2.3.3 Sediment samples of *c*.25g were disaggregated in a weak solution of Hydrogen Peroxide and water, then wet sieved through a 63µm sieve. The sediment was dried and sieved through 500µm, 250µm, 125µm sieves. Microfossils were picked out under 10-60x magnification under transmitted and incident light using a Vickers binocular microscope. Specimens were extracted and placed in card slides for identification. Identification and environmental interpretation of ostracods follows Athersuch *et al*. (1989) and Meisch (2000) and of foraminifera (Murray 1979; 2006).

Pollen and Diatoms

2.3.4 Fourteen sediment samples from vibrocores **VC-EX-021** and **VC-EX-034** and boreholes **BH-CPT-01**, **BH-CPT-11**, **BH-CPT-14** and **BH-G01** of approximately $4cm^3$ were taken for pollen and diatom assessment. Samples were taken from the following vibrocore and borehole locations and depths:

- **VC-EX-034**: 0.3 to 0.7m and 2 to 2.7m below SB
- **VC-EX-021**: 0.6m and 1.7 to1.95m below SB
- **BH-CPT-01**: 0 to 0.85m below SB
- **BH-CPT-11**: 0.35 to 0.45m and 1.52m below SB
- **BH-CPT-14**: 19.69m below SB
- **BH-G01**: 4.82, 5.28, 5.7, 7.9, 8.24 and 8.73m below SB

2.3.5 The pollen and diatom samples were sent to the University of Southampton for preparation. Pollen sub-samples of $2cm^3$ were processed using standard techniques for the extraction of the sub-fossil pollen and spores (Moore and Webb 1978; Moore *et al.* 1992). Micromesh sieving (10µm) was also used to aid with removal of the clay fraction from these largely minerogenic sediments. The pollen and spores were identified and counted using an Olympus biological research microscope fitted with Leitz optics. A pollen sum of up to 150 grains per sample level was counted where preservation allowed. Other, miscellaneous microfossils including substantial numbers of algal *Pediastrum* and pre-Quaternary palynomorphs were also recorded. Data, where appropriate are presented in pollen diagram form (**Figure10**). The former have been plotted using Tilia and Tilia Graph. Percentages were calculated as follows:

- Sum= % total pollen.
- Spores = % total pollen + sum of spores.
- Miscellaneous = % total pollen + sum of misc. taxa

2.3.6 Diatom preparation followed standard techniques: the oxidation of organic sediment, removal of carbonate and clay, concentration of diatom valves and washing with distilled water. Two coverslips, each of a different concentration of the cleaned solution, were prepared from each sample and fixed in Naphrax, a mounting medium of a suitable refractive index for diatom microscopy. Slides were scanned at magnifications of x400 and x1000 under phase contrast.

Waterlogged Plant Remains and Molluscs

2.3.7 Eight samples from vibrocores **VC-EX-021** and **VC-EX-034** and boreholes **BH-CPT-01**, **BH-CPT-11**, **BH-CPT-14** and **BH-G01** were assessed for the recovery, survival and potential of waterlogged plant remains and molluscs. The samples were from the following locations and depths:

- **VC-EX-034**: 2-2.7m below SB

- **VC-EX-021**: 0.6m below SB
- **BH-CPT-01**: 0-0.85m below SB
- **BH-CPT-11**: 0.35 to 0.45m below SB
- **BH-CPT-14**: 19.69m below SB
- **BH-G01**: 4.82, 5.28, 5.7, 7.9, 8.24 and 8.73m below SB

2.3.8 The samples were processed by wet-sieving using a 0.25mm mesh size. The samples were visually inspected under a x10 to x40 stereo-binocular microscope to determine if waterlogged plant remains and molluscs were preserved. Nomenclature for waterlogged plant remains follows that of Stace (1997). Nomenclature and habitat preferences of molluscs follows that of Anderson (2005), Kerney (1999) and Barrett and Yonge (1958).

Radiocarbon dating

2.3.9 A total of eight samples were taken for radiocarbon dating from vibrocores **VC-EX-021** and **VC-EX-034** and boreholes **BH-CPT-01**, **BH-CPT-11**, and **BH-G01**. The samples were from the following locations and depths:

- **VC-EX-034**: 2 to 2.7m below SB
- **VC-EX-021**: 0.6m below SB
- **BH-CPT-01**: 0 to 0.85m below SB
- **BH-CPT-11**: 0.35 to 0.45m below SB
- **BH-G01**: 4.82 to 4.92m, 7.82 to 7.92m, 8.63 to 8.73m and 8.73m below SB

2.3.10 Radiocarbon dating samples were selected from the samples that had been processed for foraminifera, ostracods, waterlogged plant and molluscan assessment. Suitable material was identified under a microscope and stored in glass tubes and proloc bags for delivery to the Radiocarbon Dating Facility at the Scottish Universities Environmental Research Centre (SUERC), East Kilbride, Scotland (**Appendix 3**).

3 RESULTS

3.1 Stage 3 Palaeoenvironmental Assessment and dating

3.1.1 The subsampled levels taken from vibrocores **VC-EX-021** and **VC-EX-034** and boreholes **BH-CPT-01**, **BH-CPT-11**, **BH-CPT-14** and **BH-G01** are shown in relation to the deposit model on **Figures 4, 7, 8** and **9**. The results of the sampling were mixed, ranging from total absence to some well-preserved assemblage. Diatoms were notably absent from all of the assessed samples.

Pollen

3.1.2 Pollen was recovered from the samples from borehole **BH-G01** but was absent from the samples within vibrocores **VC-EX-021** and **VC-EX-034** and boreholes **BH-CPT-01**, **BH-CPT-11** and **BH-CPT-14**. Within borehole **BH-G01** pollen was preserved within the samples at 4.82, 5.28, 5.7, 7.9, 8.24 and 8.73m below SB. Pollen frequency was notably low in the samples and obtaining assessment counts of 100-150 pollen grains was difficult. Taxonomic diversity was also low and the pollen spectra were dominated by trees and shrubs with few herbs present. The sequence showed little change throughout and therefore pollen zones have not been assigned. Pollen data is presented in **Figure 10** with data plotted using Tilia and Tilia Graph.

3.1.3 The characteristics of the pollen assemblages from borehole **BH-G01** were as follows. Trees and shrubs recorded included *Pinus* (pine; to 25%), *Quercus* (oak; to 27%) and *Corylus avellana* type (hazel; to 54%), which were dominant, with important numbers of

Ulmus (elm; *c*.5% but 10% at the top of the profile). Other taxa included *Betula* (birch; 5%) and *Alnus* (alder; peak to 15%) and individual occurrences of *Picea* (spruce) and *Tilia* (lime/linden) were also recorded. There was a general paucity of herb taxa with only Poaceae (grasses; to 15%) and Chenopodiaceae (goosefoot, orache and samphire; to 5%) recorded, the latter being more important in the upper levels. Other herbs are assignable to the on-site wetland habitat and comprised occasional Cyperaceae (sedges) and *Potamogeton* type (arrow grass or pondweed) in the lower levels and *Typha angustifolia*/*Sparganium* type (reed mace and/or bur reed; 2% in base). Ferns recorded included monolete *Dryopteris* types (typical ferns; 9% at base) and were most important with occasional *Pteridium aquilinum* (bracken) and *Phyllites* type (Harts tongue fern) also in evidence. There were substantial numbers of derived/reworked pre-Quaternary palynomorphs (to 35% Sum + Misc.) recorded within the sequence and also cysts of algal *Pediastrum* (to 7%) and probably reworked geological Dinoflagellates/Hystrichospheres.

3.1.4 Interpretation of the pollen data can be considered in relation to that coming from the on-site vegetation of the mire and pollen deriving from the drier land of nearby and more regional sources. The taphonomy may also be complicated by fluvial transport as well as via normal airborne means. The on-site vegetation is poorly represented with few herbs present. However, the on-site habitat appears to have been open with grasses (Poaceae) sedges (Cyperaceae) and reed mace/bur reed (*Typha angustifolia* type), possibly fen with indications of standing freshwater with algal *Pediastrum* cysts present. Small numbers of alder (*Alnus*) and a peak at 5.3m below SB are from damp woodland but as a high pollen producer and being anemophilous, this suggests that alder growth was not of local importance. Chenopodiaceae (goosefoot, orache and samphire) were present in small numbers throughout with higher values in the basal and lower levels (5.3-4.8m and at 8.7m below SB). This may be evidence of halophytic, salt marsh and/or mud flat vegetation.

3.1.5 Within the wider terrestrial zone the pollen assemblages are dominated by trees and shrubs with almost no herbs present. These assemblages are typical of warm stage (interglacial) pre-temperate woodland with pine (*Pinus*), oak (*Quercus*), elm (*Ulmus*) and hazel (*Corylus*). There are smaller numbers of birch (*Betula*) alder (*Alnus;* noted above), lime (*Tilia*) and spruce (*Picea*) pollen. These latter are more diagnostic of the mid-temperate phases of an interglacial period, but as noted, the taphonomy may have been influenced by reworking of older sediment or from fluvial (especially marine) transport. There is little overall change in this woodland throughout the profile and as such, this suggests that deposition may have been rapid, perhaps in response to positive eustatic change.

Diatoms

3.1.6 Diatoms were absent in all of the fourteen samples assessed from **VC-EX-021** and **VC-EX-034** and boreholes **BH-CPT-01**, **BH-CPT-11**, **BH-CPT-14** and **BH-G01**. Detailed examination of the slides revealed no identifiable fragments of diatom frustules. The absence of diatoms may reflect unfavourable conditions for diatom silica preservation (Flower 1993, Ryves *et al.* 2001). Given the ubiquity of diatoms in natural water bodies, the absence here in the sediment samples assessed can be attributed to taphonomic processes. This may be the result of diatom silica dissolution and breakage caused by factors such as high sediment alkalinity, high acidity, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, or physical damage to diatom valves from abrasion or wave action.

Foraminifera and Ostracods

3.1.7 The results of the microfaunal assessment are shown in tabular form in **Appendix 2**. Within borehole **BH-G01** some well preserved foraminifera and ostracod faunas were recovered which were quite similar to each other. All were dominated by brackish and marine forms and in particular the foraminiferal species *Ammonia beccarii*.

3.1.8 Overall, **BH-G01** contained the best preserved and most abundant faunas of foraminifera and ostracods. Largely similar faunas were recovered from all six samples assessed. These were generally dominated by the foraminifera *Ammonia beccarii* and the ostracod *Cyprideis torosa* which are together a clear indicators of an estuarine, brackish, tidal environment, with generally less marine influence and species than seen in the other samples investigated in this study. Most of the specimens *Cyprideis torosa* were of the smooth form however within the sample at 8.24m below seabed the noded form was noted. It is thought that *Cyprideis* develops nodes in very low salinities. *Loxoconcha elliptica* was a notable ostracod recorded in most of the samples which is also a brackish water species confined to estuaries and lagoons and usually found associated with algae and mud. The upper three samples contained some marine species including Miliolids which may well have been transported into an estuarine environment. There is therefore some indication of a slightly increasing marine influence up profile in this sequence from borehole **BH-G01**.

3.1.9 Some of the samples from the boreholes foraminifera were absent or very rare. Within borehole **BH-CPT-01** the sample at 0 to 0.85m below SB contained no foraminifera or ostracods. Some organic (plant remains) were however noted within the sample. Within borehole **BH-CPT-11** at 0.35-0.45m below SB no foraminifera or ostracods were recovered although some organic (plant) remains were noted within the sample. At 1.52m below SB three (Cretaceous) fossil foraminifera and one broken and unidentifiable ostracod valve were recovered.

3.1.10 Within borehole **BH-CPT-14**, the sample at 19.69m below SB contained foraminifera and ostracods in small numbers. The small assemblage comprised marine and occasional brackish forms. A singular occurrence of the foraminfera *Ammonia beccarii* was recorded. A few ostracod valves including *Hirschmannia viridis* and *Leptocythere* sp. were recovered, which together are indicative of shallow marine and brackish environments. *Hirschmannia viridis* is known to colonise the weed rich littoral fringes of both shallow marine and brackish environments.

3.1.11 From the two samples assessed within vibrocore **VC-EX-021** both foraminifera and ostracods were recovered. At 0.6m below SB the microfaunal assemblage was dominated by predominantly marine and occasional brackish forms. The foraminifera recovered were dominated by *Ammonia beccarii* variant *batavus, Cibicides lobatulatus* Miliolids (including *Quinqueloculina* sp. and *Miliolinella* sp.). Species of *Elphidium* (including *Elphidium gerthi*) were also present. Ostracods were rare but included valves of *Leptocythere tenera*, *Palmoconcha laevata*and *Propontocypris* sp. Within the sample at 1.7 to 1.95m below SB the microfaunal assemblage was dominated by predominantly marine and occasional brackish forms. The foraminifera recovered were dominated by *Ammonia beccarii* variant *batavus* and Miliolids (including *Quinqueloculina* sp. and *Miliolinella* sp.). *Bucella frigida* was also present. Ostracods were common in the sample and included valves of *Bythocythere* sp., *Cyprideis torosa*, *Cytheropteron*, *Eucythere* sp., *Leptocythere* sp., *Loxoconcha elliptica* and *Propontocypris* sp..

3.1.12 From the two samples assessed within vibrocore **VC-EX-034** both foraminifera and ostracods were recovered. Within the sample at 0.3 to 0.7m below SB the microfaunal assemblage was dominated by predominantly marine and occasional brackish forms. The foraminifera recovered included *Ammonia beccarii* variant *batavus* with species of *Elphidium* (including *Elphidium macellum*), Miliolids (including *Quinqueloculina* sp.) and *Lamarckina haliotidea* also present. Ostracods were rare but included valves of *Cytheropteron* sp., *Leptocythere* sp. *Loxoconcha elliptica* and *Semicytherura* sp. At 2.0 to 2.7m below SB the microfaunal assemblage was dominated by predominantly marine and occasional brackish forms. The foraminifera recovered included *Ammonia beccarii* variant *batavus* with species of *Elphidium* (including *Elphidium macellum*) Miliolids (including *Quinqueloculina* sp.) and *Lamarckina haliotidea* also present. Ostracods were rare but included valves of *Cytheropteron* sp., *Loxoconcha elliptica* and *Semicytherura* sp..

Waterlogged Plants and Molluscs

3.1.13 Organic material comprising fragments of stems and rootlets were recorded in low levels in all eight of the samples. A few seeds of sedge (*Carex* sp.) and of pond weed (*Potamogeton* sp.) were recorded in the sample from **BH-G01** at 8.63-8.73m below SB. This may be indicative of a fresh-water environment with some marshy grassland in the vicinity.

3.1.14 Shells were observed in five of the samples, those from **BH-G01**, **VC-EX-21** and **VC-EX-34**. The mollusc assemblages contained shells of only aquatic species, predominantly those of marine species. The results are shown in the table below.

Borehole/Vibrocore	**BH-G01**	**BH-G01**	**BH-G01**	**BH-CPT-01**	**BH-CPT-11**	**BH-CPT-14**	**VC-EX-21**	**VC-EX-34**
Depth mbelow SB	8.63-8.73	7.82-7.92	4.82-4.92	0.00-0.85	0.35-0.45	19.65-19.75	0.6	2.00-2.70
Volume	300ml	250ml	375ml	175ml	250ml	400ml	400ml	800ml
Waterlogged material								
< 2mm root/stem matter	+	+	+	+	+	+	+	+
> 2mm root/stem matter	+	-	-	+	+	+	-	-
Carex sp.	+	-	-	-	-	-	-	-
Potamogeton sp.	+	-	-	-	-	-	-	-
Molluscs								
Ecrobia/Peringia sp.	-	-	-	-	-	-	+	-
Cerastoderma	-	-	+	-	-	-	+	+
Tellina/Scrobicularia	-	+	+	-	-	-	+	+
Mytilus edulis	+	-	-	-	-	-	+	+
Littorina sp.	-	-	-	-	-	-	+	+
Littorina obtusata	-	+	-	-	-	-	-	-
Balanus sp.	-	-	+	-	-	-	-	-
Rissoidae	-	+	-	-	-	-	+	+

3.1.15 The assemblages from **BH-G01** included a number of shells of *Scrobicularia/Tellin a* type, of cockle (*Cerastoderma* spp.), mussel (*Mytilus edulis*), periwinkles (*Littorina* sp.), barnacles (*Balanus* sp.) and of the Rissoidae family of gastropod molluscs. *Scrobicularia* and *Tellina* can inhabit thick mud and muddy sand in estuarine and intertidal conditions, whereas mussels tend to inhabit rocky open shores or rocks within sheltered harbours and estuaries. Cockles can be found in sandy mud on the middle shore or below and periwinkles are mainly found on rocky shores in the higher and middle intertidal zone, while Rissoidae can favour shallow marine environments.

3.1.16 A similar species range was recorded in the samples from **VC-EX-21** and **VC-EX-34**. There were also a few shells of *Ecrobia/Peringia* sp. noted in the sample from **VC-EX-21**. *Peringia ulvae* is typically found on muddy or silty surfaces in estuaries, intertidal mudflats and salt marshes and is restricted to brackish or salt water. *Ecrobia ventrosa* however inhabits areas of low to moderate salinities in quiet estuaries, ponds behind shingle bars, and lagoons and drainage ditches in coastal marshes.

Radiocarbon dating

3.1.17 A total of eight samples were submitted for radiocarbon dating. Due to a failed sample from **BH-G01** at 8.73m below SB two further samples at the base of that sequence (at 7.82-7.92 and 8.63-8.73m below SB) were submitted which also unfortunately failed. The failed samples from **BH-G01** (at 8.73 and 8.63 to 8.73m below SB) failed due to insufficient carbon being present within the material.

3.1.18 The other samples which were successful are shown in conjunction with the raw, calibrated and plotted results In **Appendix 3**. The dates were calibrated against the Marine13 radiocarbon curve (Reimer *et al*. 2013) using the program OxCal 4.1.7 (Bronk Ramsey 2010) and using a delta –R value of zero. These results are summarised in the table below.

Borehole/ Vibrocore	Depth (m below SB)	Depth (m below OD)	Id.	Lab ref.	$\delta^{13}C$	Date BP	CalibrationAD/ BC	calibration BP
							(2 sig. 95.4%)	(2 sig. 95.4%)
VC-EX-21	0.6	12.53	cockle shell x 1	SUERC_59063	1.8‰	660±29	cal. AD 1550-1700	250-400 cal. BP
VC-EX-34	2.00-2.70	28.93-29.63	cockle shell x 1	SUERC_59064	1.9‰	3933±29	2090-1870 cal. BC	4040-3820 cal. BP
BH-G01	4.82-4.92	28.57-28.67	cockle shell frags x 3	SUERC_59065	1.7‰	5497±30	4010-3810 cal. BC	5960-5760 cal. BP
BH-G01	8.73	32.48	*Phragmites*	FAILED				
BH-CPT-01	0.0-0.85	21.05-21.90	stem fragments	SUERC_59066	28.9‰	7965±30	7040-6710 cal. BC	8990-8660 cal. BP
BH-CPT-11	0.35-0.45	21.55-21.65	*Phragmites*	SUERC_59067	26.9‰	8038±30	7070-6830 cal. BC	9020-8780 cal. BP
BH-G01	7.82-7.92	31.57-31.67	tellin shell x 1	FAILED				
BH-G01	8.63-8.73	32.38-32.48	stem fragment	FAILED				

3.1.19 From the export cable route vibrocores, two samples were submitted. From vibrocore **VC-EX-21** at 0.6m below SB a marine shell (*Cerastoderma* sp.) returned a date of 660±29BP SUERC-59063 (cal. AD 1550-1700; 250-400cal. BP) equivalent to the post-medieval archaeological period. Within vibrocore **VC-EX-34** at 2.00 to 2.70m below SB a marine shell (*Cerastoderma* sp.) returned a date of 3933±29BP SUERC-59064 (4040-3820 cal. BP; 2090-1870cal. BP) equivalent to the Early Bronze Age archaeological period.

3.1.20 Three samples gave positive results from the windfarm area. Within borehole **BH-G01** at 4.82 to 4.92m below SB some marine shell fragments (*Cerastoderma* sp.) returned a date of 5947±30BP SUERC-59065 (4010-3810cal. BC; 5960-5760cal. BP) equivalent to the Late Mesolithic archaeological period. Within borehole **BH-CPT-01** at 0.00 to 0.85m below SB some plant stem fragments returned a date of 7965±30BP SUERC-59066 (7040-6710cal. BC; 8990-8660cal. BP) equivalent to the Early Mesolithic archaeological period. Within borehole **BH-CPT-11** at 0.35 to 0.45m below SB some reed stem fragments (*Phragmites* sp.) returned a date of 8038±30BP SUERC-59067 (7070-6830cal. BC; 9020-8780cal. BP) also equivalent to the Early Mesolithic archaeological period.

4 DISCUSSION

4.1.1 The geological sequence penetrated by the two geotechnical surveys (including boreholes and vibrocores) have been interpreted and combined. The borehole survey covered the proposed wind farm area and the vibrocore survey covered both the wind farm and export cable route areas (**Figure 2**). These have been found to comprise Chalk Bedrock overlain by Pleistocene (including the Swarte Bank, Egmond Ground the Bolders Bank formation) and Holocene sediments (organic and alluvial channel sequences) and by more recent seabed sediment. The most interesting sediments, from both an archaeological and geoarchaeological perspective, available for Stage 3 sampling were the Holocene sediments, identified within boreholes **BH-G01**, **BHCPT-01**, **BH-CPT-11** and **BH-CPT-14** and vibrocores **VC-EX-021** and **VC-EX-034**.

4.1.2 Across the windfarm area some palaeochannel features were identified within sub-bottom profiler geophysical data (WA 2008) (see inset **Figure 2**). The channels are intermittent and only occasionally correlate with the geotechnical locations. Borehole **BH-CPT-14** is located on the northern edge of the largest of the identified palaeochannels which runs in a west to east direction at the western side of the wind farm site, where it meets the northern bifurcation of the export cable route (**Figure 2**). No suitable material was recovered from this location for radiocarbon dating. However, palaeoenvironmental samples contained a small microfaunal assemblage of foraminifera and ostracods indicative of shallow marine/estuarine environment at 19.69m below SB (*c*. 37.44m below OD) at this location. Very few other palaeoenvironmental remains were present within the assessed samples from this location. By comparing the elevation of this shallow marine/ estuarine environment with known Holocene sea levels in the area (Jelgersma 1979, Shennan and Horton 2002 and Ward *et al*. 2006), these types of environments would be expected to have developed at these elevations at *c*.10,000 to 9,000 years BP. This is equivalent the Early Mesolithic archaeological period.

4.1.3 The oldest reliably dated sediments within this study were from locations **BH-CPT-01** and **BH-CPT-11**. The sample investigated from location **BH-CPT-01** at 0.00 to 0.85m below SB (17.30 to 18.15m below OD) contained very few identifiable palaeoenvironmental remains although some plant stem fragments were recorded and returned a radiocarbon date of 7965±30BP SUERC-59066 (7040-6710cal. BC; 8990-8660cal. BP), equivalent to the Early Mesolithic archaeological period. A similar date was returned from a sample of *Phragmites* reed from **BH-CPT-11** at 0.35 to 0.45m below SB (21.55 to 21.65m below OD) which returned a date of 8038±30BP SUERC-59067 (7070-6830cal. BC; 9020-8780cal. BP), also equivalent to the Early Mesolithic archaeological period. Very few palaeoenvironmental remains were noted from this location although the identification of *Phragmites* reeds point towards a wetland environment. The radiocarbon dates from both of these locations are of interest from an archaeological perspective and indicate the preservation of Early Mesolithic terrestrial environments at these locations.

4.1.4 Borehole **BH-G01** contained the greatest abundance of and the best preserved sequence of palaeoenvironmental remains. The investigated sequence came from samples between 4.82 and 8.73 m below SB (28.57 and 32.48m below OD). The plant macrofossil remains from the investigated sequence at this location included typical wetland plants such as sedge (*Carex* sp.) and leaves and stems of the common reed (*Phragmites*) which are both indicative of the on-site wetland environment. Pollen remains derived from the on-site habitat also included wetland plants such as grasses (Poaceae), sedges (Cyperaceae) and reed mace/bur reed (*Typhaangustifolia* type). The Chenopodiaceae (goosefoot, orache and samphire) recorded are evidence suggestive of halophytic, salt marsh and/or mud flat vegetation. Whilst no diatoms were present, the foraminifera and ostracod microfossil faunas, which are dominated by the foraminifera *Ammonia beccarii* and the ostracod *Cyprideis torosa,* are collectively clear indicators of an estuarine, brackish and tidal environment. Similarly the molluscan faunas which included of shells of Scrobicularia/Tellina type, of cockle (*Cerastoderma* spp.), of the Rissoidae family, mussel (*Mytilus edulis*), periwinkles (*Littorina* sp.) and barnacles (*Balanus* sp.) were also indicative of estuarine and brackish conditions. Although there were some occasional indications of surrounding freshwater habitats noted such as freshwater with algal *Pediastrum* cysts present and occasional seeds of pondweed. These elements were likely transported into the estuarine and marsh sediments by fluvial processes.

4.1.5 Several attempts to date the base of the sequence within borehole **BH-G01** (between 7.82 and 8.73m below SB; 31.57 to 32.48m below OD) were unsuccessful, being due to insufficient carbon in the samples. However, similar to **BH-CPT-14,** the type of environment and the elevation of these marsh and tidal/estuarine sediments can be compared to the known sea levels and would be expected to date to *c*. 9000 years BP, equivalent to the Mesolithic archaeological period. The microfaunal remains (particularly the increase in numbers of Miliolids) indicate that the on-site marsh and tidal environment became slightly more open to marine influence through time, as would be expected in a sequence induced by Holocene sea level rise. The surrounding environment is indicated by the pollen assemblages dominated by trees and shrubs with almost no herbs present. These assemblages are typical of warm stage (interglacial) pre-temperate woodland with pine (*Pinus*), oak (*Quercus*), elm (*Ulmus*) and hazel (*Corylus*). There are smaller numbers of birch (*Betula*), alder (*Alnus*), lime (*Tilia*) and spruce (*Picea*) pollen. These latter are more diagnostic of the mid-temperate phases of an interglacial period, but as noted, the taphonomy may have been influenced by reworking of older sediment or from fluvial (especially marine) transport.

4.1.6 Radiocarbon dating of the upper part of the investigated sequence within borehole **BH-G01** was more successful. At 4.82 to 4.92m below SB (28.57 to 28.67m below OD) some marine shell fragments (*Cerastoderma* sp.) returned a date of 5947±30BP SUERC-59065 (4010-3810cal. BC; 5960-5760cal. BP) equivalent to the Late Mesolithic archaeological period. At these depths a slightly earlier date would be expected when comparing the type of environment to known sea level data for the period (Jelgersma 1979, Shennan and Horton 2002; Ward *et al*. 2006). In addition the pollen data, whilst not an accurate form of dating, has the main attributes of an early post-glacial pre temperate phase. The presence of oak and elm especially, and to some extent hazel, along with pine suggest the latter part of the pre-temperate phase, equivalent to Flandrian Chronozone Ic in the scheme of West (1970).

4.1.7 The results of the palaeoenvironmental assessment and dating from the export cable corridor vibrocore samples (**VC-EX-34** and **VC-EX-21**) provided some interesting results. A mollusc shell (*Cerastoderma* sp.) from vibrocore **VC-EX-34** at 2.00 to 2.70m below SB (28.93 to 29.63m below OD) returned a date of 3933±29BP SUERC-59064 (4040-3820 cal. BP; 2090-1870cal. BP) equivalent to the Early Bronze Age archaeological period. The molluscs, foraminifera and ostracods from this location were indicative of shallow marine, estuarine and mudflat environments. These are environments which would be unlikely to be present in the Early Bronze Age periods at these depths in this location when compared to the data of the known Holocene sea level rise (Jelgersma 1979, Shennan and Horton 2002, Ward *et al*. 2006) which indicates this type of environment at c. 9000 BP.

4.1.8 Within vibrocore **VC-EX-21** at 0.6m below SB (12.53m below OD) a marine shell (*Cerastoderma* sp.) returned a date of 660±29BP SUERC-59063 (cal. AD 1550-1700; 250-400cal. BP), equivalent to the post-medieval archaeological period. Whilst few plant remains were recovered, similar to **VC-EX-34**, the molluscs, foraminifera and ostracods recovered were indicative of shallow marine, brackish estuarine and coastal environments. Again at these depths this type of environment would be expected at a much earlier date, *c*.7,500 years BP, when compared to the known Holocene sea level rise (Jelgersma 1979, Shennan and Horton 2002). The area is known from historical documents to have been fully marine during the post-medieval archaeological period; therefore the radiocarbon date is at odds with the palaeoenvironmental remains from this location.

4.1.9 There are a number of possible reasons why the dates (from the export cable route vibrocores **VC-EX-21** and **VC-EX-34**) appear too young. Both are from shell, and the shell itself may have been infiltrated by younger carbon which has been recorded within marine contexts before on porous materials such as shell and bone (Busschers *et al*. 2013), although notably on older material. As *Cerastoderma* can burrow, it is possible that younger shells can be present within older sediments. In this case however it is considered most likely (given the bagging process which was undertaken during the geotechnical testing) that younger material, including molluscs, had been accidentally mixed in during the geotechnical sampling process which contaminated the samples.

4.1.10 Whilst there have been some difficulties dating some of the material from the samples, there would appear to be some sequences of Mesolithic date across the site which are of interest when set within their wider context. A large amount of literature regarding the possibility of Mesolithic occupation in the North Sea has been produced (e.g. Coles 1998, Flemming 2004 and Waddington 2007) although none covers the site in detail. The existence of Holocene terrestrial (fluvial, estuarine and coastal) environments and the probability that these areas have been inhabited has been inferred at a broad scale by relatively shallow bathymetric data and by finds made by fishermen of terrestrial sediments such as peat, terrestrial mammal bones and prehistoric archaeological finds across the Southern North Sea (e.g. Reid 1913, Godwin and Godwin 1933, Coles 1998, Gaffney *et al*. 2009). The sediments from the Race Bank Offshore Windfarm and cable route vibrocores and boreholes therefore provide interesting and more detailed information on the palaeoenvironments of Mesolithic cultures in the North Sea basin.

4.1.11 Of particular note during the Mesolithic period is a major Holocene geological “event” known as the ‘Storegga slide’, a tsunami event created by a huge submarine landslide which is thought to have occurred at *c*.8100 BP (Bondevik *et al*. 1997, Weninger *et al*. 2008). This event is thought to have had major implications for Mesolithic communities in the North Sea area and is thus of great archaeological interest. No evidence of this event was recorded within the samples but the radiocarbon dates both pre and postdate this event. This suggests therefore that terrestrial sediments of early Mesolithic date predating the tsunami event are unaffected on the site.

4.1.12 It should be mentioned that no prehistoric archaeological finds have been recovered, either previously or from the current samples from within the site. In addition no other obvious indications of human occupation such as charcoal were recorded within the samples investigated here. The samples do however represent a very small percentage of the total area of the site and therefore this apparent absence of evidence does not prove evidence of absence of human occupation of the site. It is possible that the terrestrial environments (e.g. peat deposits) and features (e.g. palaeochannels) identified during this study and within the geophysical data (WA 2008) could contain prehistoric archaeological remains and as such the results of this study can inform any further required archaeological mitigation on the site regarding the possibility of prehistoric archaeological remains.

5 RECOMMENDATIONS

5.1.1 The extensive geotechnical testing undertaken on many of the samples prior to this work has unfortunately reduced the utility of the samples for Stage 4 palaeoenvironmental work. Specifically, many of the originally undisturbed core samples were excavated, bagged and disturbed and also appear to have been contaminated. The samples therefore do not have any potential for further Stage 4 analysis.

5.1.2 Clearly there are some interesting Holocene sequences across the windfarm and export cable route area which are indicated by the Stage 1 to 3 work undertaken to date. Therefore it is recommended that any further analysis be performed on undisturbed samples from any further planned geotechnical campaigns, if undertaken.

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7 APPENDIX 1: GEOARCHAEOLOGICAL STAGES

Stage 1: Planning	Onshore desk-based archaeological assessment of samples and logs generated by geotechnical contractors. This assessment shall establish the presence and location of sediment units with likely archaeological, palaeo-environmental and/or dating potential, as a basis for deciding what Stage 2 archaeological recording is required. The Stage 1 report shall state the scale of Stage 2 work proposed. Should no further works be required a brief Stage 1 report outlining the results of the assessment shall be prepared.
Stage 2: Core / Sample Recording	Each sample containing sediment units identified as having archaeological, palaeo-environmental or dating potential in Stage 1 will be cleaned and recorded (in the case of cores these will be split, with half of each core recorded). The stratigraphy of each sample shall be recorded, a basic sediment description for each of the units shall be made and those units of particular archaeological/palaeo-environmental interest shall be highlighted. The Stage 2 report shall state the nature and scope of any Stage 3 analyses required to characterise and interpret the sediment units in order to build an outline Quaternary deposit model and thus identify areas of potential archaeological significance.
Stage 3: Sub-sampling and Assessment	Sub-sampling and assessment of any units of archaeological and/or palaeo-environmental interest. Sub-samples for the assessment of microfossil environmental indicators (pollen, diatoms, ostracods and/or foraminifera) shall be taken from one core-half/area of sample, with the other core-half / sample retained intact should further sub-sampling be required. Assessment will comprise analysis (identification and quality of preservation) of a series of sub-samples to enable the value of the palaeo-environmental material surviving within the samples to be identified. Sub-samples shall also be taken and retained at this stage in case radiocarbon dating is required during Stage 4. The Stage 3 report shall set out the results of each laboratory assessment together with an outline of the archaeological implications of the combined results, and will indicate whether and Stage 4 work is warranted.
Stage 4: Analysis and Dating	Full analysis of pollen, diatoms and/or foraminifera assessed during Stage 3. Typically, Stage 4 shall be supported by radiocarbon dating of suitable sub-samples. Should Stage 3 assessment indicate that there is no further analytical work required on the microfossil assemblages, consideration shall still be given for a programme of radiocarbon analyses to provide a chronological framework for the deposits encountered unless no suitable samples could be procured. The Stage 4 report shall provide an account of the palaeo-environment(s) at each relevant coring location within a chronological framework (absolute or relative) and an outline of the archaeological implications of the analysis.

Final Reporting	If the archaeological results are sufficiently significant, a final report shall be compiled covering all aspects of the palaeo-topography and prehistory of the area affected by the development, incorporating the results of each stage. If the archaeological results are not significant then the relevant Stage Report(s) shall constitute the final documents for the investigation. If required, the Final Report shall include relevant data generated by the baseline assessment and geophysical (sub-bottom) review, in order to place the results of the sample recording and analysis within the context of the broad pattern of deposits within the area. The report shall comprise as detailed a Quaternary deposit model for the area as possible, and address the implications of that model in terms of archaeological potential.

8 APPENDIX 2: FORAMINIFERA AND OSTRACOD ASSESSMENT

Borehole (BH)/Vibrocore (VC)	BH-G01	BH-G01	BH-G01	BH-G01	BH-G01	BH-G01	BH-CPT-01	BH-CPT-11	BH-CPT-11	BH-CPT-14	VC-EX-21	VC-EX-21	VC-EX-34	VC-EX-34
m below SB	4.82	5.28	5.7	7.9	8.24	8.73	0-0.85	0.35-0.45	1.52	19.69	0.6	1.7-1.95	0.3-0.7	2-2.7
Foraminfera														
Ammonia beccarii	xxx	xxxx	xxx	xx	xx	xx				o				
Ammonia beccarii var *batavus*											xx	xx	xx	xx
Brizalina variabilis														
Bucella frigida												o		
Cassidulina obtusa														
Cibicides lobatulatus			o								xx			
Elphidium sp.					o								x	x
Elphidium macellum													x	x
Elphidium crispum														
Elphidium gerthi											o			
Elphidium incertum														
Elphidium williamsoni	x	x	o		o									
Fursenkoina fusiformis														
Glabratella milletti														
Haynesina germanica	x			o		o								
Haynesina orbiculare														
Haynesina sp.														
Jadammina macrescens														
Lagena sp.														
Lamarckina haliotidea													o	
Miliolids	x		x								xx	xx	x	xx
Miliolinella sp.											x	x		
Quinqueloculina sp.	x		x								xx	xx	x	xx
Rotaliid	x									o				x

Fossil									x	o				
Unidentified	x													
Ostracods														
Aurila sp.														
Bythocythere sp.														
Candona sp.		o	o		o							o		
Cyprideis torosa smooth	o	x	x	xx		x						o		
Cyprideis torosa noded					x									
Cytheropteron sp.		o	x									x	o	o
Eucythere sp.						o						x		
Hirschmannia viridis	x	o								o				
Leptocythere lacertosa														
Leptocythere pellucida														
Leptocythere sp.	x	xx	o	o						o		x	o	
Leptocythere tenera											o			
Loxoconcha elliptica	x	x	x		x							x	o	o
Loxoconcha rhomboidea			x											
Palmoconcha laevata											x			
Propontocypris sp.											x	x		o
Semicytherura sp.			o										o	
Unidentified /juvenile	x	xx	x	o					o		x	x		

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

9 APPENDIX 3: RADIOCARBON DATING

Scottish Universities Environmental Research Centre
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RADIOCARBON DATING CERTIFICATE

30 March 2015

Laboratory Code	SUERC-59063 (GU36916)
Submitter	Sarah F. Wyles Wessex Archaeology Portway House Old Sarum Business Park Salisbury, SP4 6EB
Site Reference	Race Bank North Sea
Context Reference	core VCEX21 core 0.6 (VCEX2)1_ 0.6
Sample Reference	62559_VCEX21_ 0.6
Material	marine shell : cockle shell
δ^{13}C relative to VPDB	1.8 ‰
Radiocarbon Age BP	660 ± 29

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

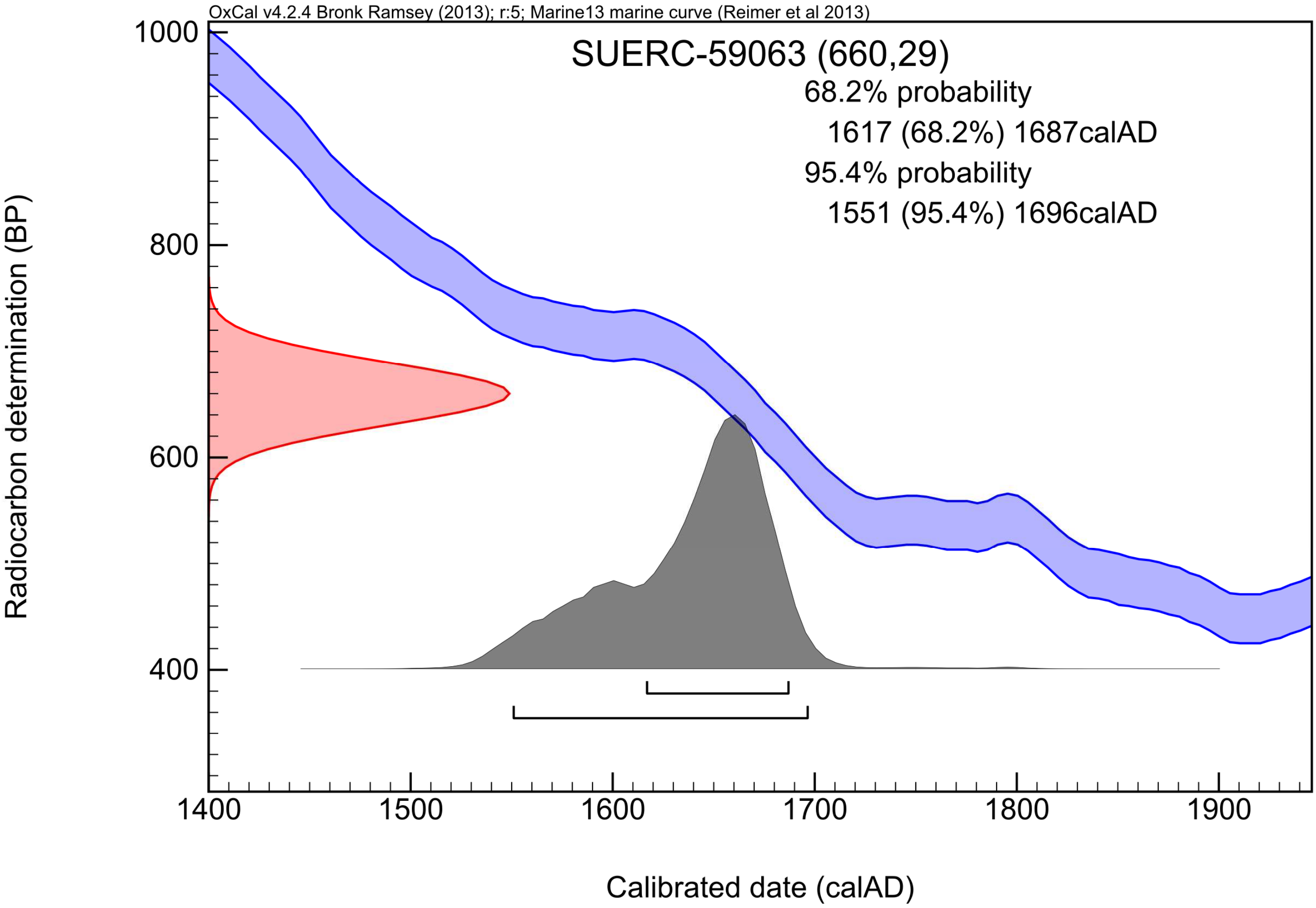
The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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

Conventional age and calibration age ranges calculated by :- E. Dunbar Date :- 30/03/2015

Checked and signed off by :- P. Naysmith Date :- 30/03/2015

Calibration Plot



Scottish Universities Environmental Research Centre

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RADIOCARBON DATING CERTIFICATE

30 March 2015

Laboratory Code	SUERC-59064 (GU36917)
Submitter	Sarah F. Wyles Wessex Archaeology Portway House Old Sarum Business Park Salisbury, SP4 6EB
Site Reference	Race Bank North Sea
Context Reference	core VCEX34 core 2.00-2.70 (VCEX3)4_2.00-
Sample Reference	62559_VCEX34_2.00-2.70
Material	marine shell : cockle shell
$\delta^{13}C$ relative to VPDB	1.9 ‰
Radiocarbon Age BP	3933 ± 29

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

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

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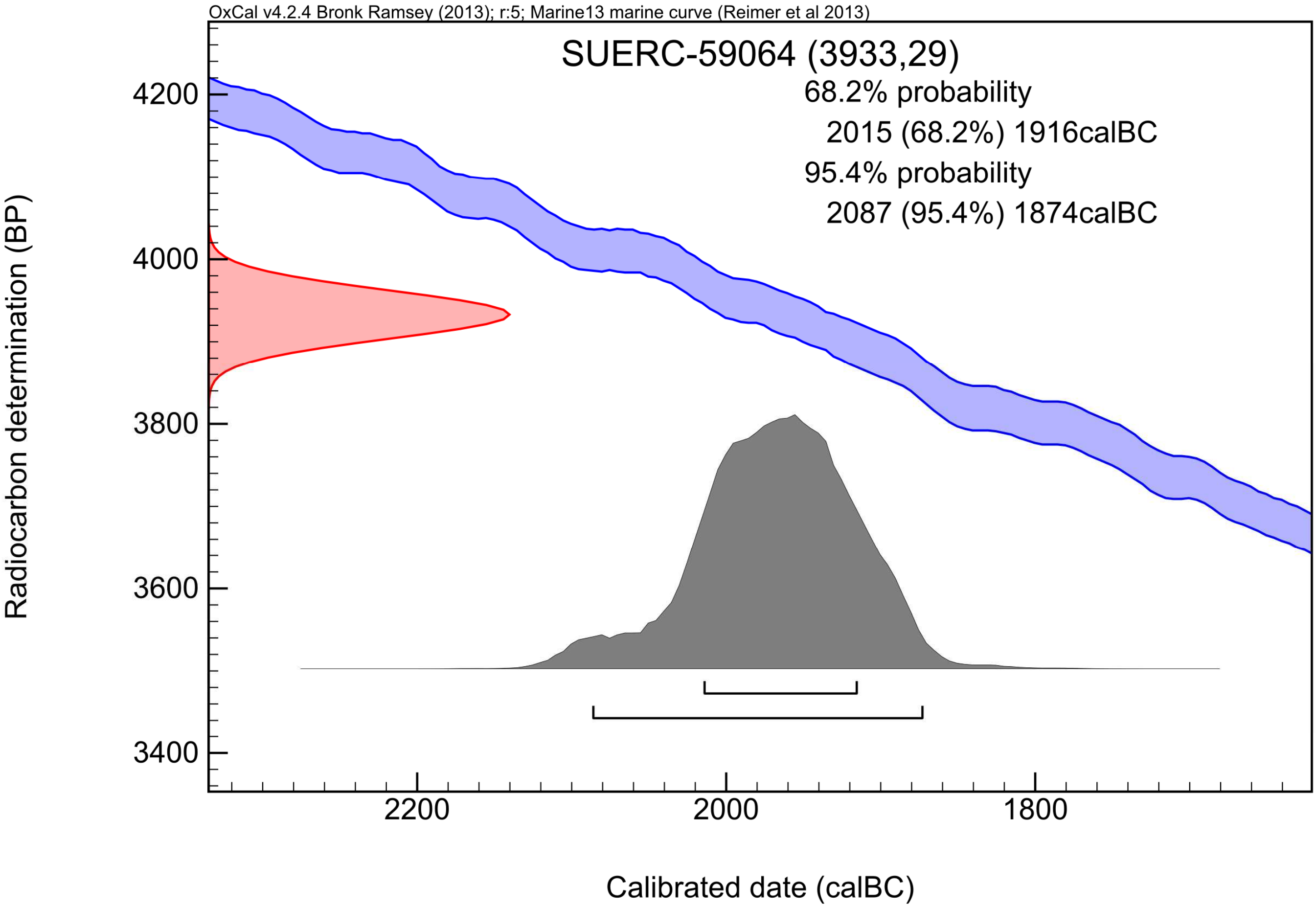
Conventional age and calibration age ranges calculated by :- E. Dunbar Date :- 30/03/2015

Checked and signed off by :- P. Naysmith Date :- 30/03/2015

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

30 March 2015

Laboratory Code	SUERC-59065 (GU36918)
Submitter	Sarah F. Wyles Wessex Archaeology Portway House Old Sarum Business Park Salisbury, SP4 6EB
Site Reference	Race Bank North Sea
Context Reference	core BHG01 core 4.82-4.92 (BHG01)_4.82-4
Sample Reference	62559_BHG01_4.82-4.92
Material	marine shell : cockle shell frag
$\delta^{13}C$ relative to VPDB	1.7 ‰
Radiocarbon Age BP	5497 ± 30

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

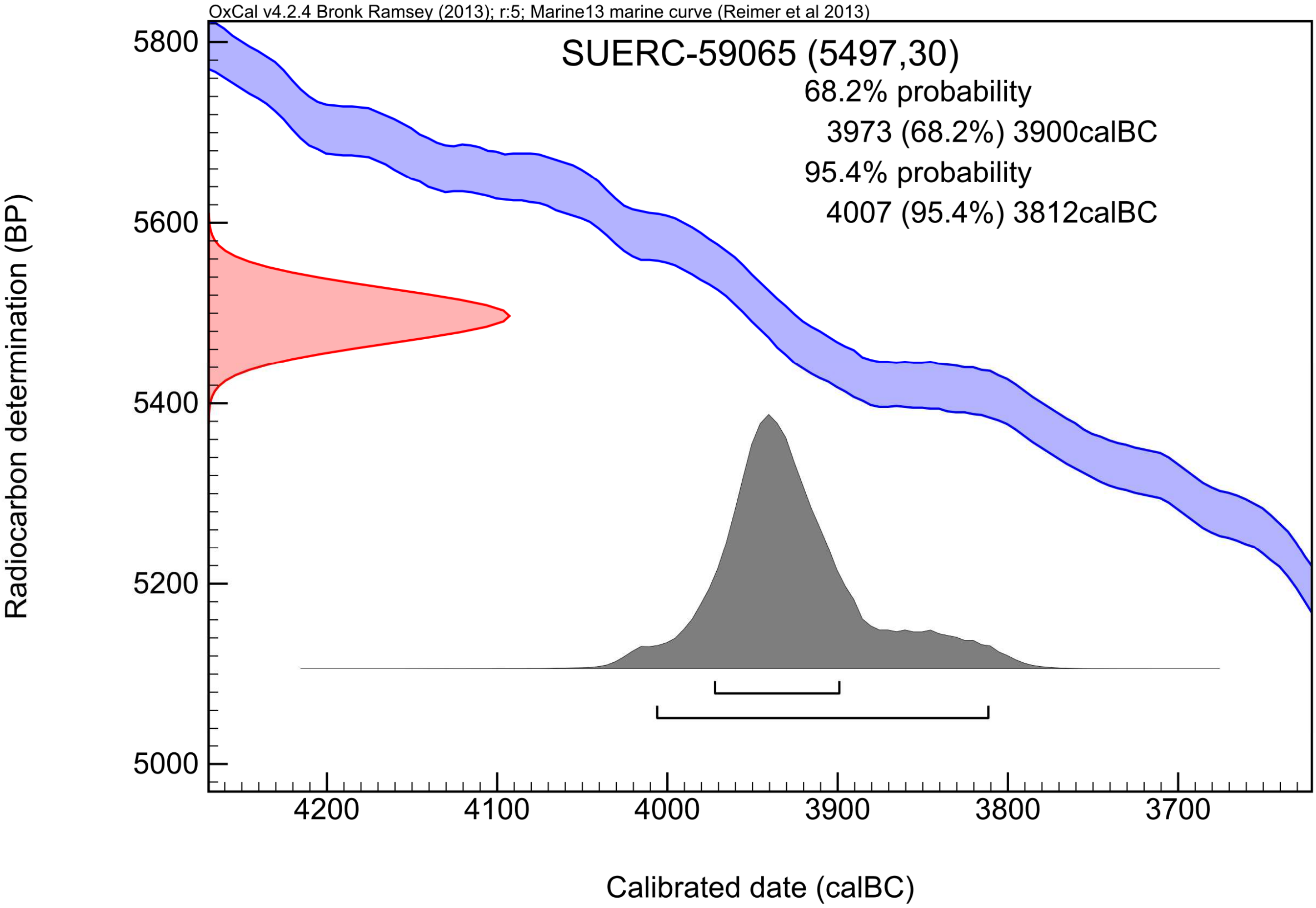
The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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

Conventional age and calibration age ranges calculated by :- E. Dunbar   Date :- 30/03/2015

Checked and signed off by :- P. Naysmith   Date :- 30/03/2015

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

30 March 2015

Laboratory Code	GU36919
Submitter	Sarah F. Wyles Wessex Archaeology Portway House Old Sarum Business Park Salisbury, SP4 6EB
Site Reference	Race Bank North Sea
Context Reference	core BHG01 core 8.73 (BHG01)_8.73
Sample Reference	62559_BHG01_8.73
Material	Waterlogged plant remains : Phragmites
Result	Failed: insufficient carbon.

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

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

Checked and signed off by :- P. Naysmith

Date :- 30/03/2015

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RADIOCARBON DATING CERTIFICATE

30 March 2015

Laboratory Code	SUERC-59066 (GU36920)
Submitter	Sarah F. Wyles Wessex Archaeology Portway House Old Sarum Business Park Salisbury, SP4 6EB
Site Reference	Race Bank North Sea
Context Reference	core BHCPT01 core 0.0-0.85 (BHCPT)01_0.0-
Sample Reference	62559_BHCPT01_0.0-0.85
Material	Waterlogged plant remains : stem frags
δ^{13}C relative to VPDB	-28.9 ‰
Radiocarbon Age BP	7965 ± 30

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

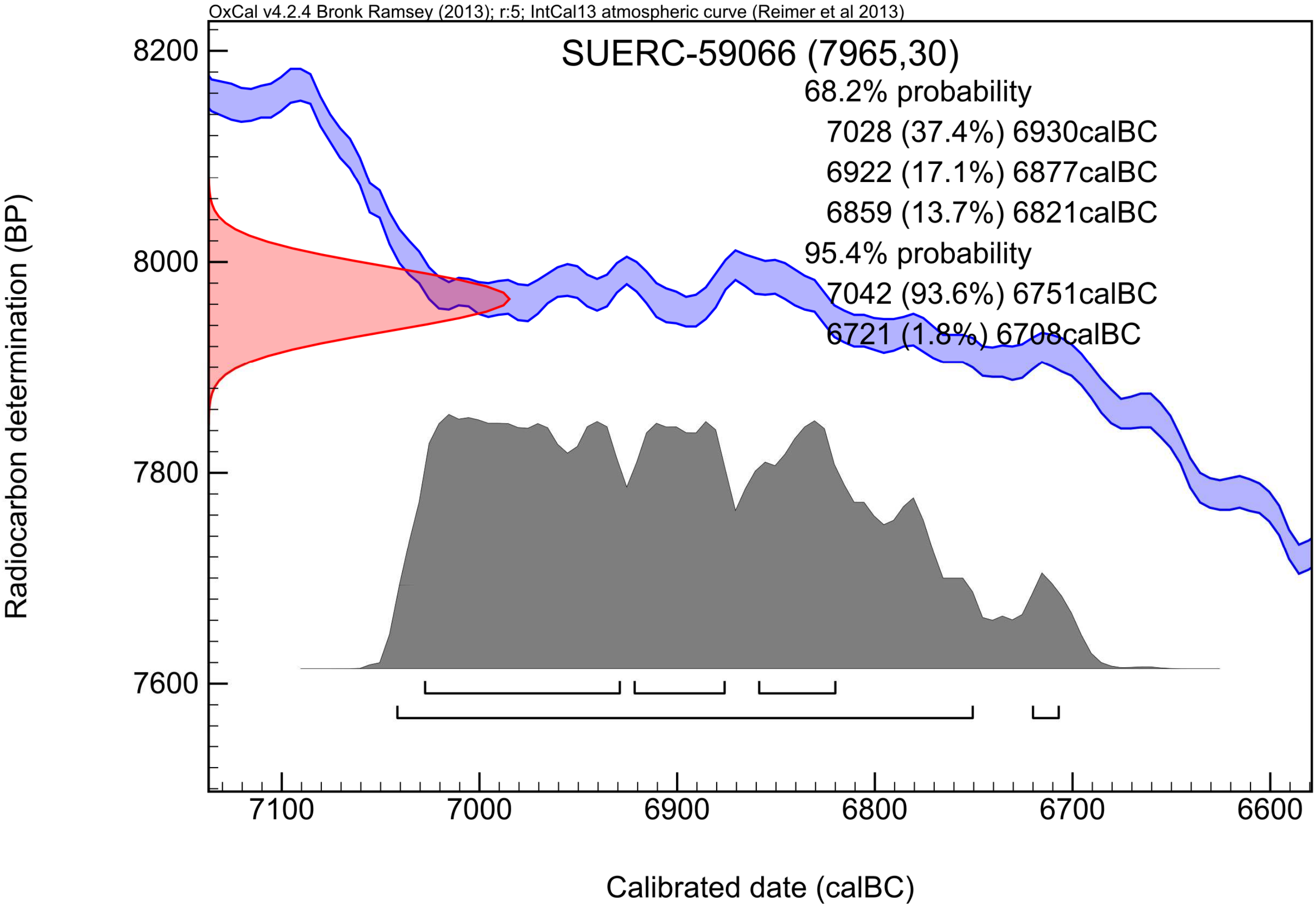
The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

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

Conventional age and calibration age ranges calculated by :- E. Dunbar Date :- 30/03/2015

Checked and signed off by :- P. Naysmith Date :- 30/03/2015

Calibration Plot



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RADIOCARBON DATING CERTIFICATE

30 March 2015

Laboratory Code	SUERC-59067 (GU36921)
Submitter	Sarah F. Wyles Wessex Archaeology Portway House Old Sarum Business Park Salisbury, SP4 6EB
Site Reference	Race Bank North Sea
Context Reference	core BHCPT11 core 0.35-0.45 (BHCPT)11_0.35
Sample Reference	62559_BHCPT11_0.35-0.45
Material	Waterlogged plant remains : Phragmites
$\delta^{13}C$ relative to VPDB	-26.9 ‰
Radiocarbon Age BP	8038 ± 30

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

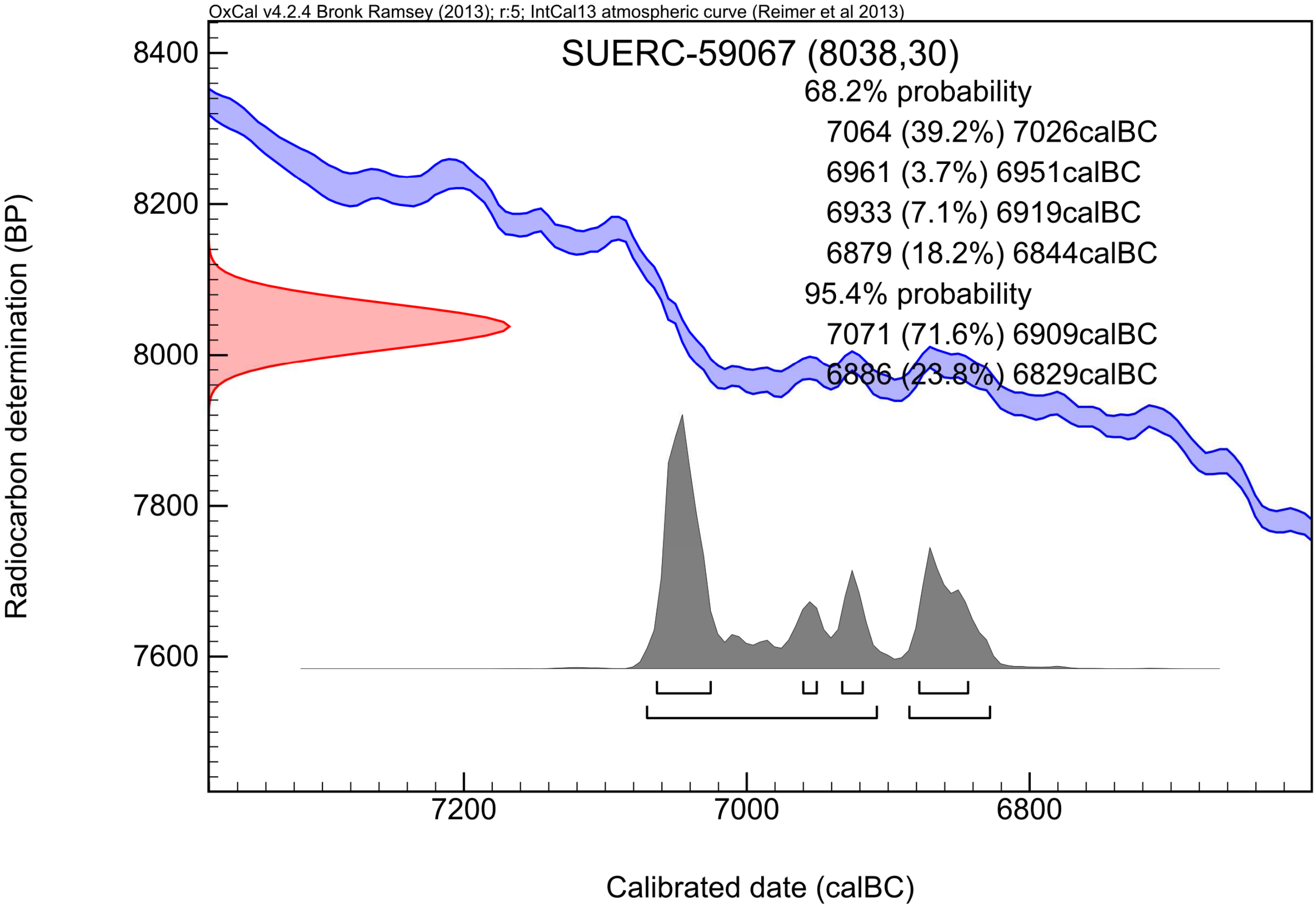
The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

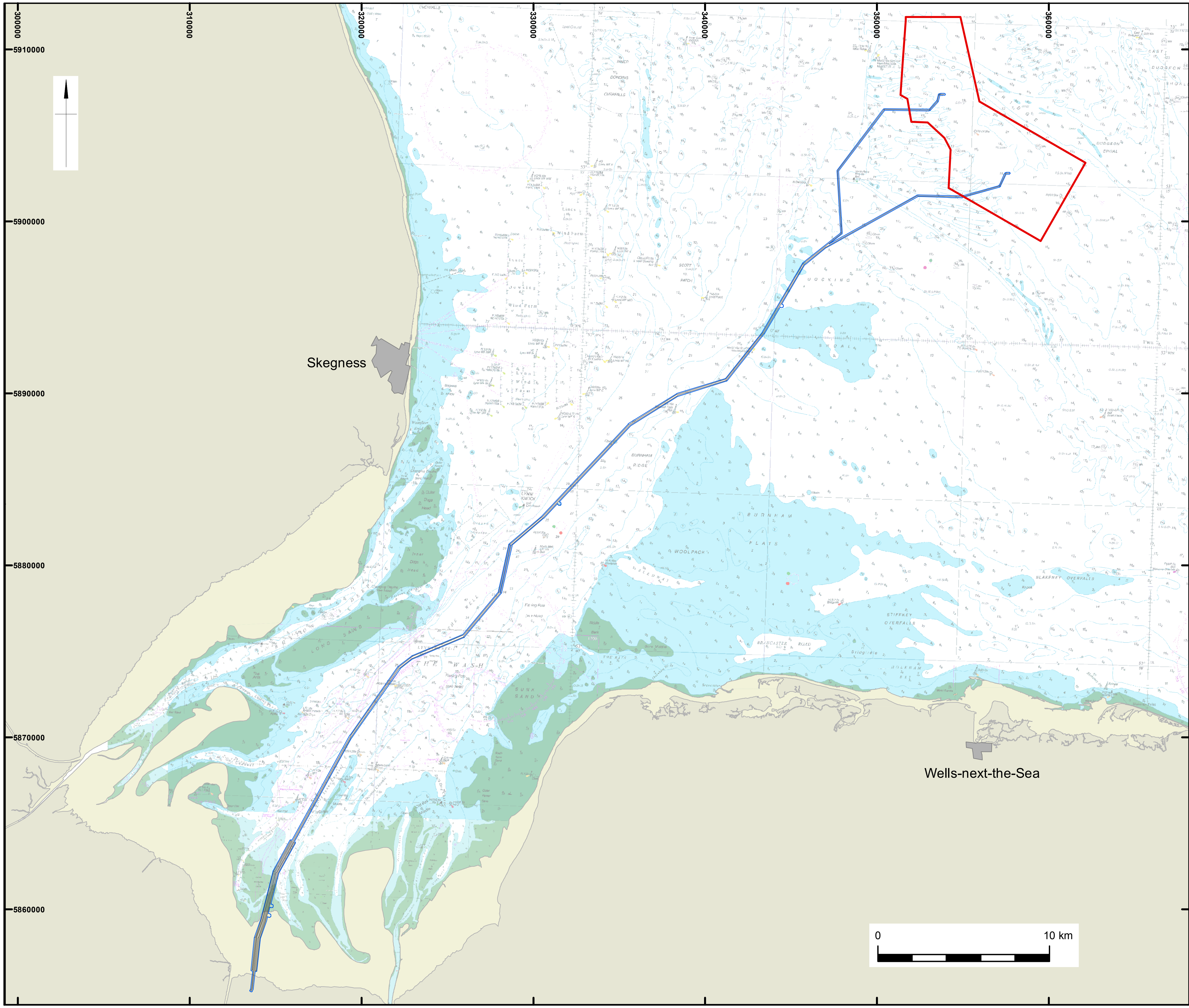
Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after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

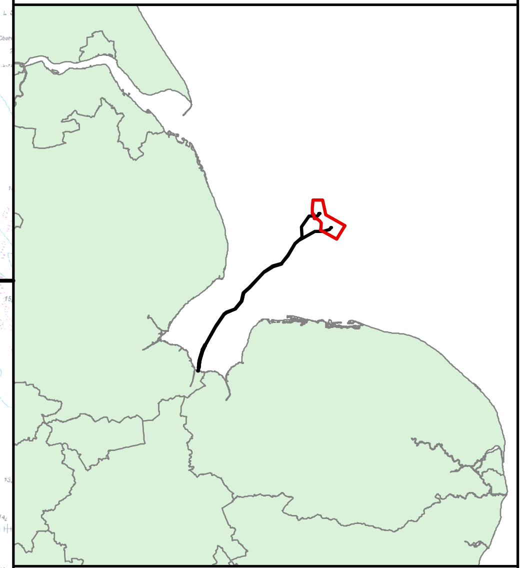
Conventional age and calibration age ranges calculated by :- E. Dunbar   Date :- 30/03/2015

Checked and signed off by :- P. Naysmith   Date :- 30/03/2015

Calibration Plot







Race Bank Offshore Wind Farm

Export Cable Route

Archaeological Study Area

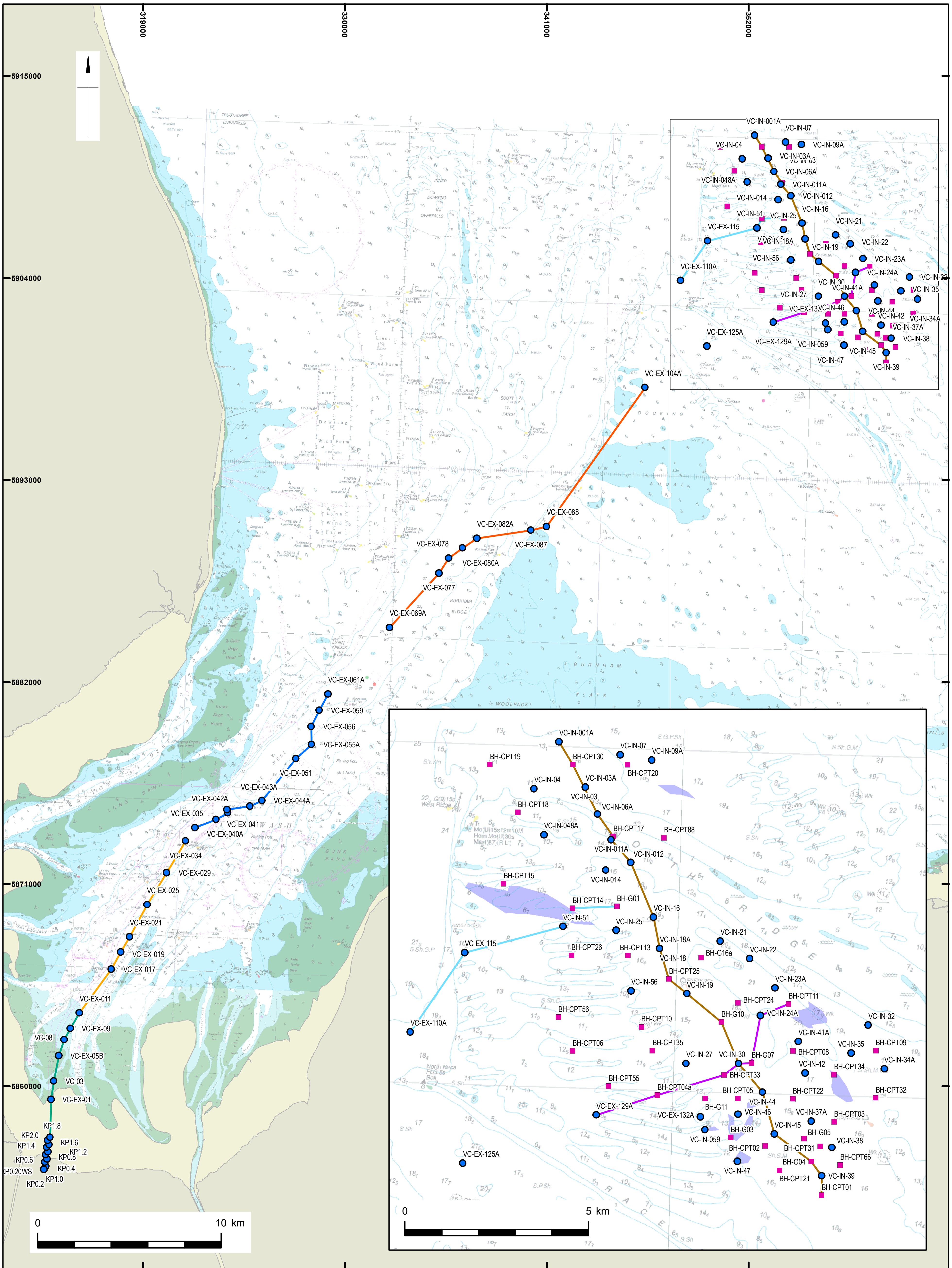
Drawing projection: ETRS89 UTM31N

Date:	05/06/2015
Revision Number:	0
Scale:	1:225,000 at A3
Illustrator:	KL/KJF
Path:	W:\Projects\106940\G_O\

Report figs\Geotech Stage 3\2015_06_03

Archaeological Study Area

Figure 1



Drawing projection: UTM WBS84 z31N

Vibrocore (WA 2014)	Transect 1	Transect 5	
Borehole (WA 2010a)	Transect 2	Transect 6	
Palaeochannels	Transect 3	Transect 7	
	Transect 4		

Date:	25/06/2015	Revision Number:	1
Scale:	1:200,000 & 1:100,000 at A3	Illustrator:	KL/KJF
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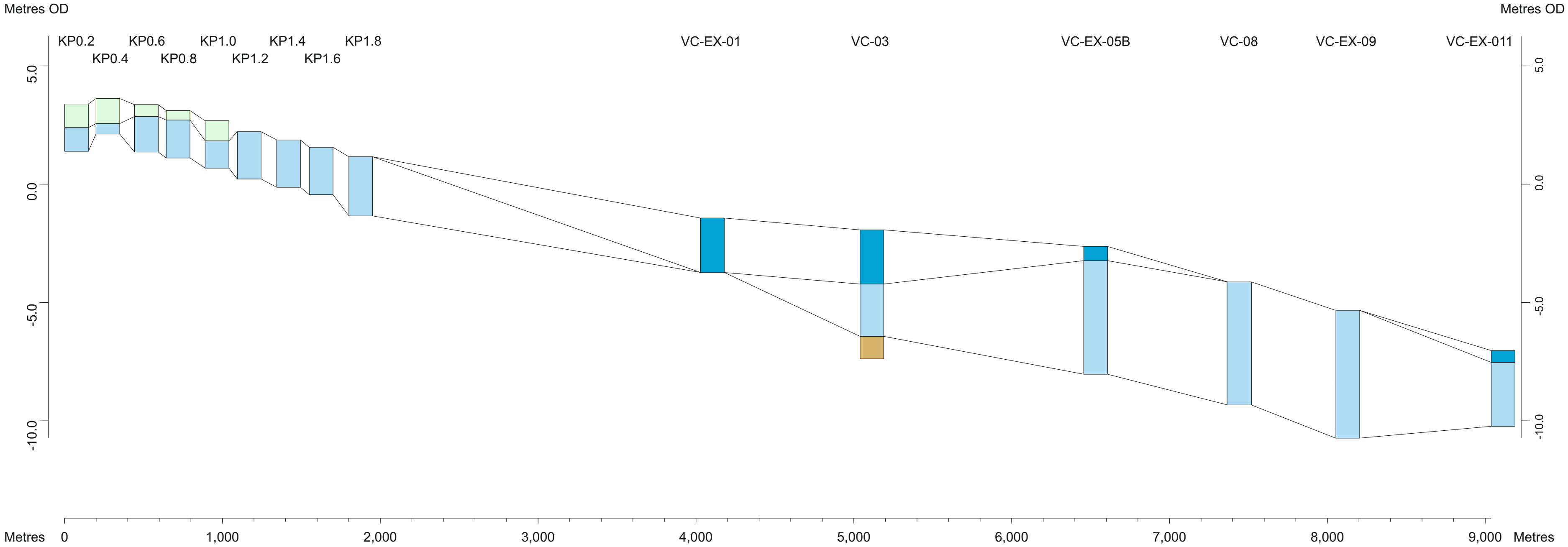
Vibrocore, borehole and transect locations

Figure 2



Recent saltmarsh
Recent seabed sediments
Holocene alluvium
Holocene organic deposits
Devensian glacial till
Pleistocene sediments
Chalk bedrock

Date:	04/06/2015	Revision Number:	0
Scale:	see above	Illustrator:	KL/KJF
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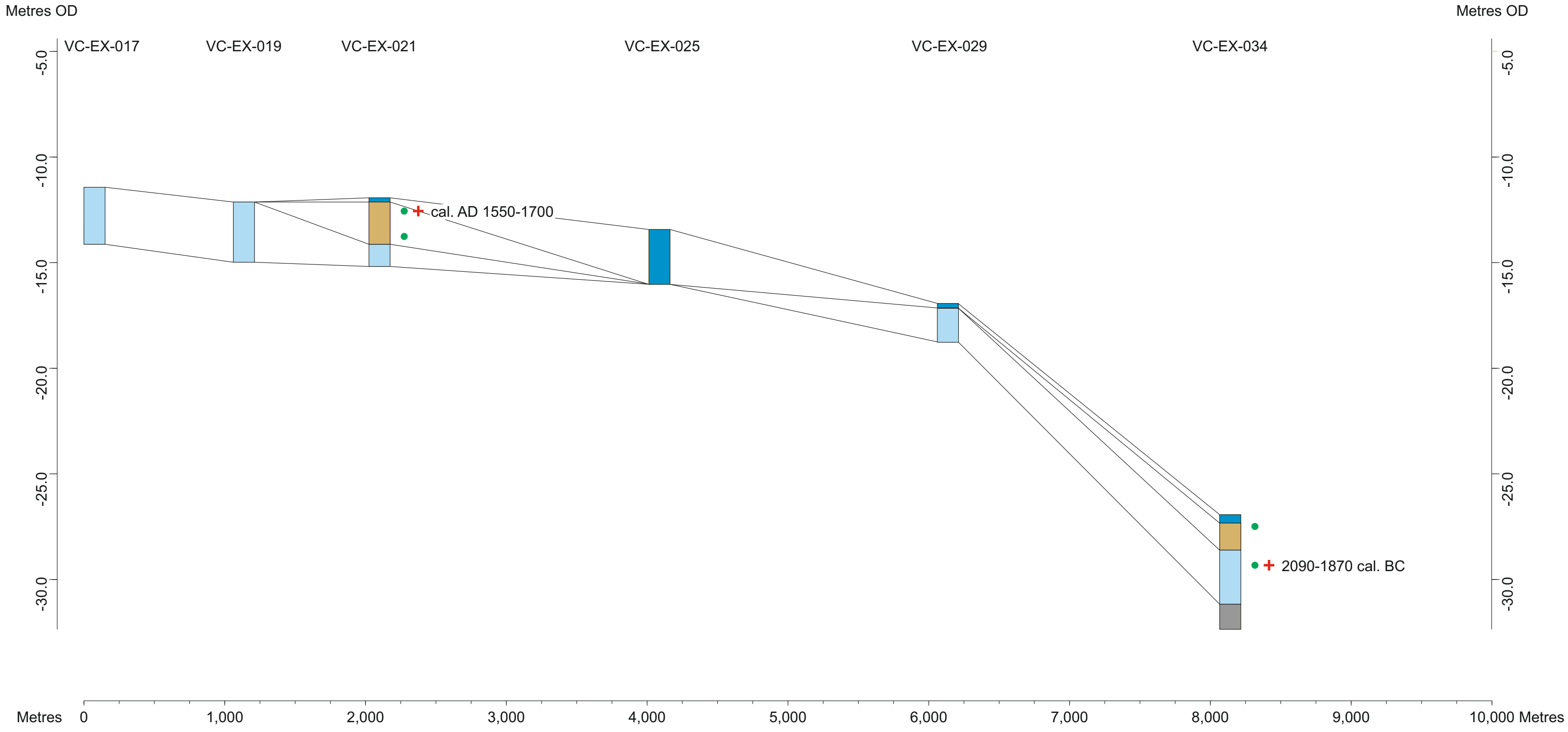
Transect 1

Figure 3



- Recent seabed sediments
- Holocene alluvium
- Holocene organic deposits
- Devensian glacial till
- Pleistocene sediments
- Chalk bedrock
- ● Stage 3 palaeoenvironmental sample
- + Radiocarbon date

Date:	04/06/2015	Revision Number:	0
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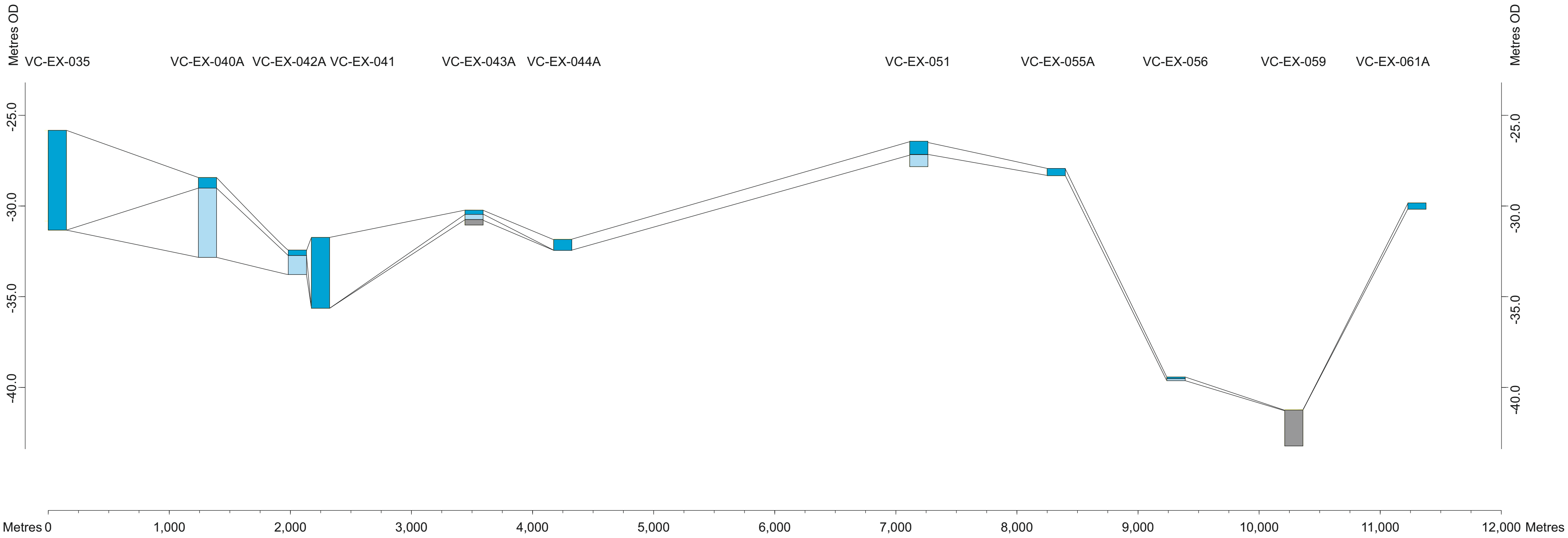
Transect 2

Figure 4



- Recent seabed sediments
- Holocene alluvium
- Holocene organic deposits
- Devensian glacial till
- Pleistocene sediments
- Chalk bedrock

Date:	04/06/2015	Revision Number:	0
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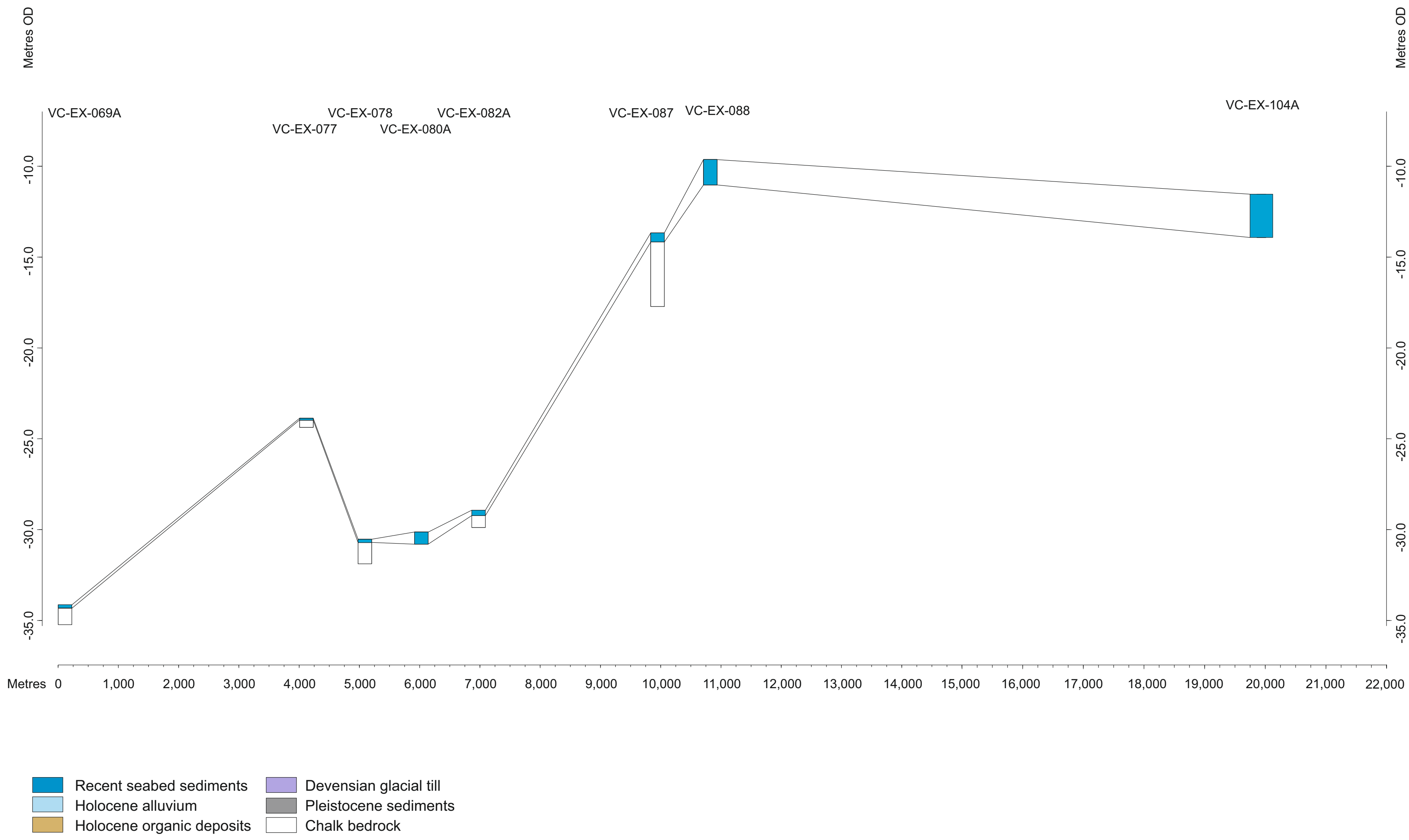
Transect 3

Figure 5



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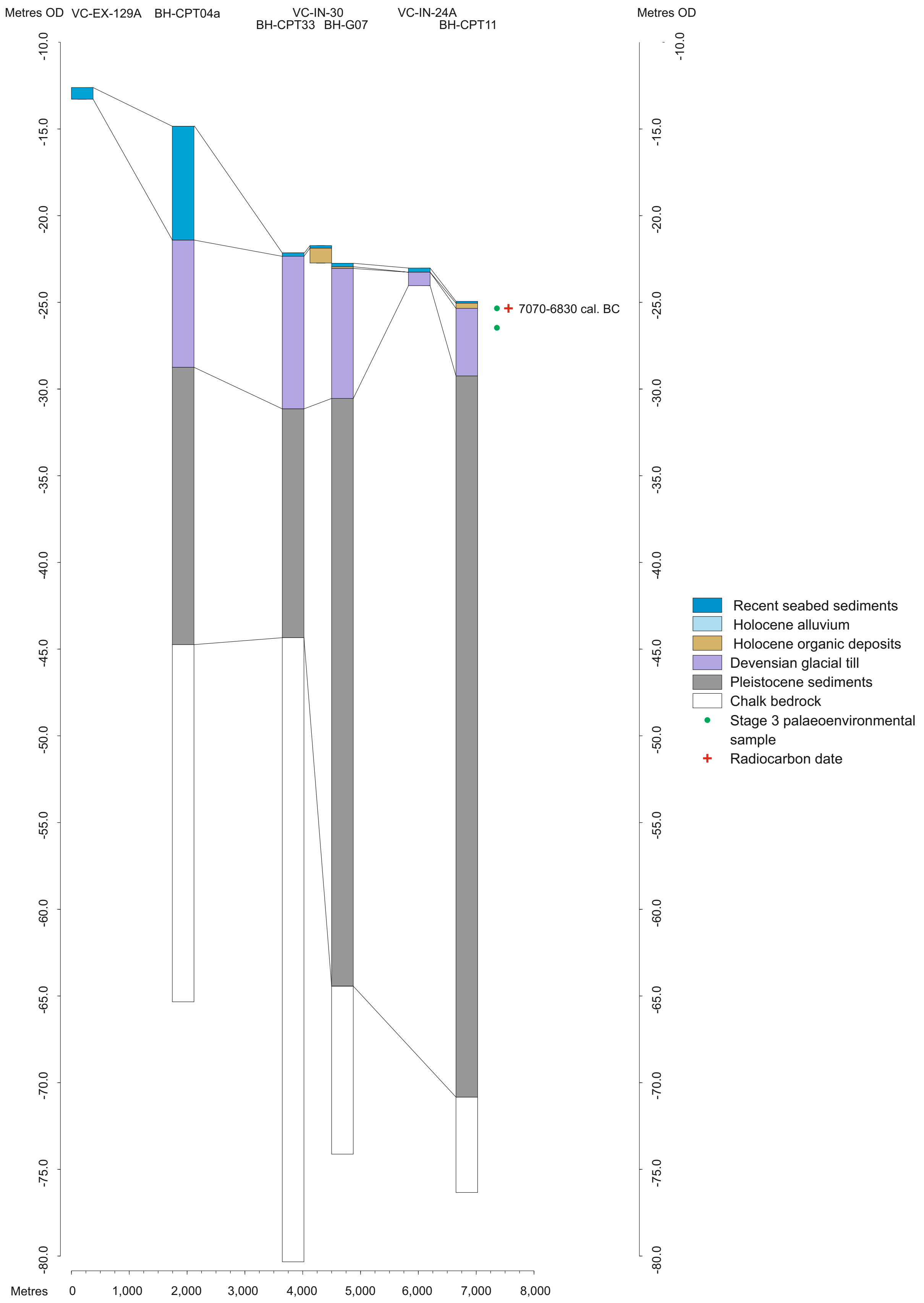
Transect 4

Figure 6



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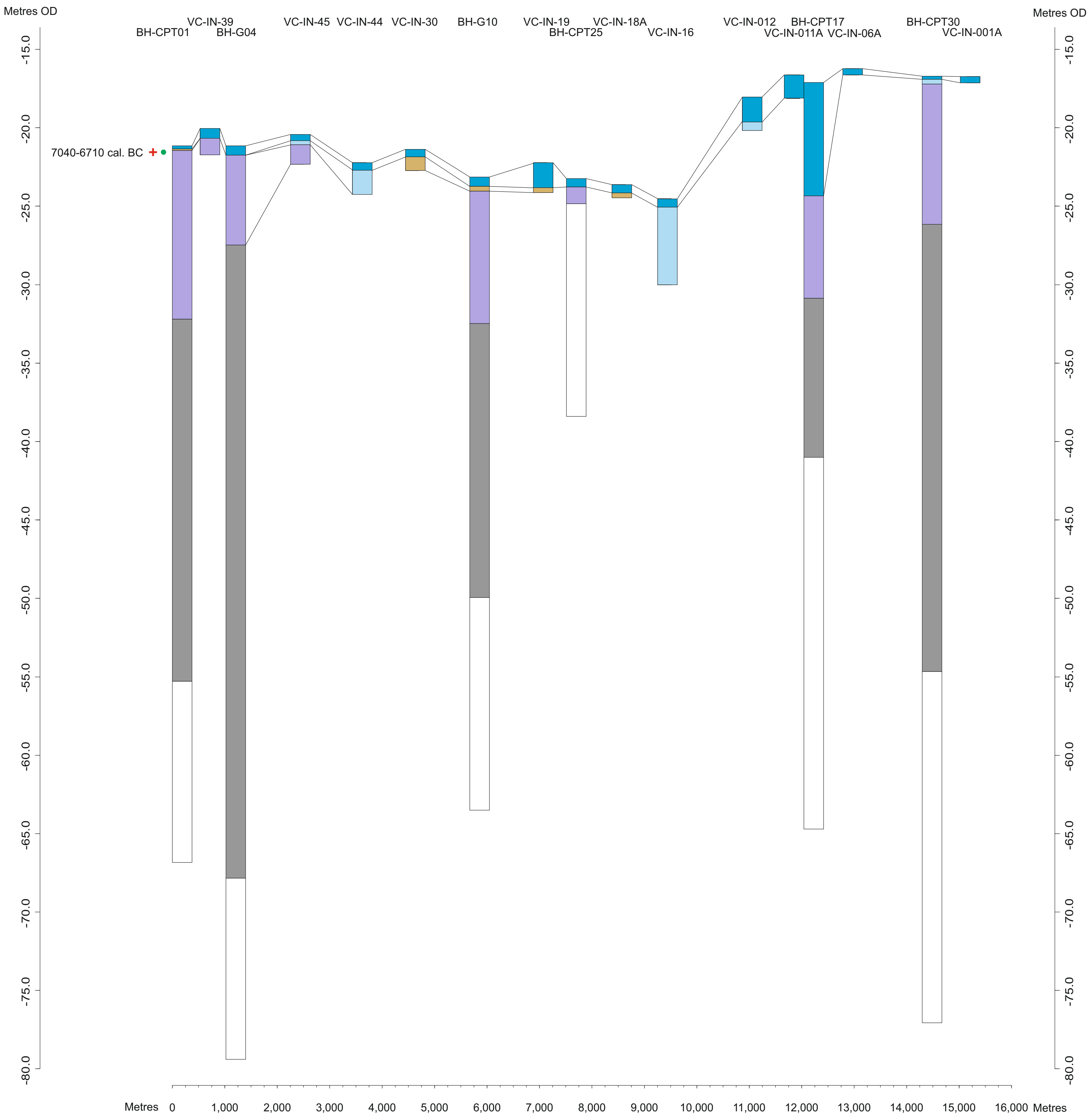
Transect 5

Figure 7



- Recent seabed sediments
- Holocene alluvium
- Holocene organic deposits
- Devensian glacial till
- Pleistocene sediments
- Chalk bedrock
- Stage 3 palaeoenvironmental sample
- Radiocarbon date

Date:	03/06/2015	Revision Number:	0
Scale:	see above	Illustrator:	KL/KJF
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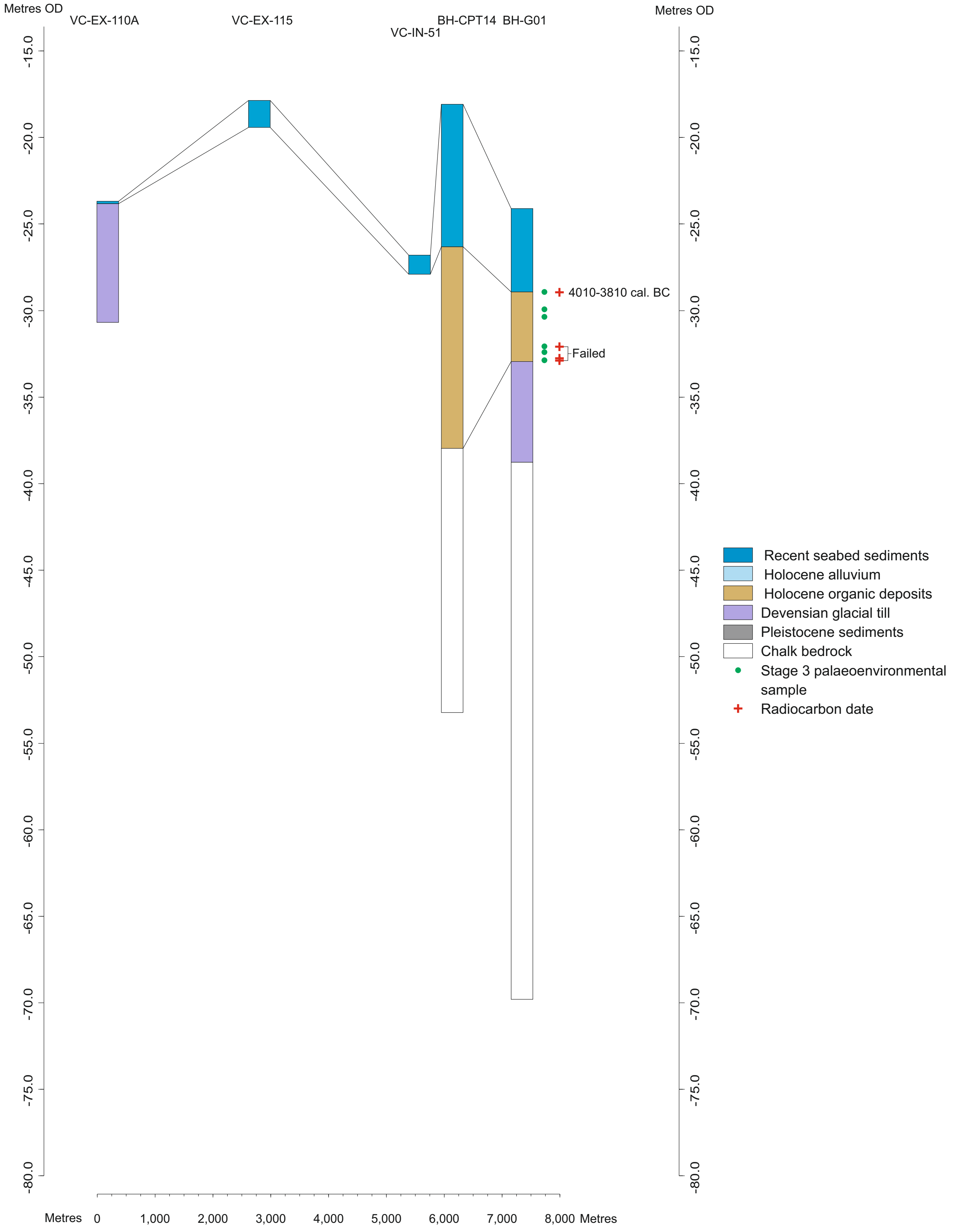
Transect 6

Figure 8



Date:	04/06/2015	Revision Number:	0
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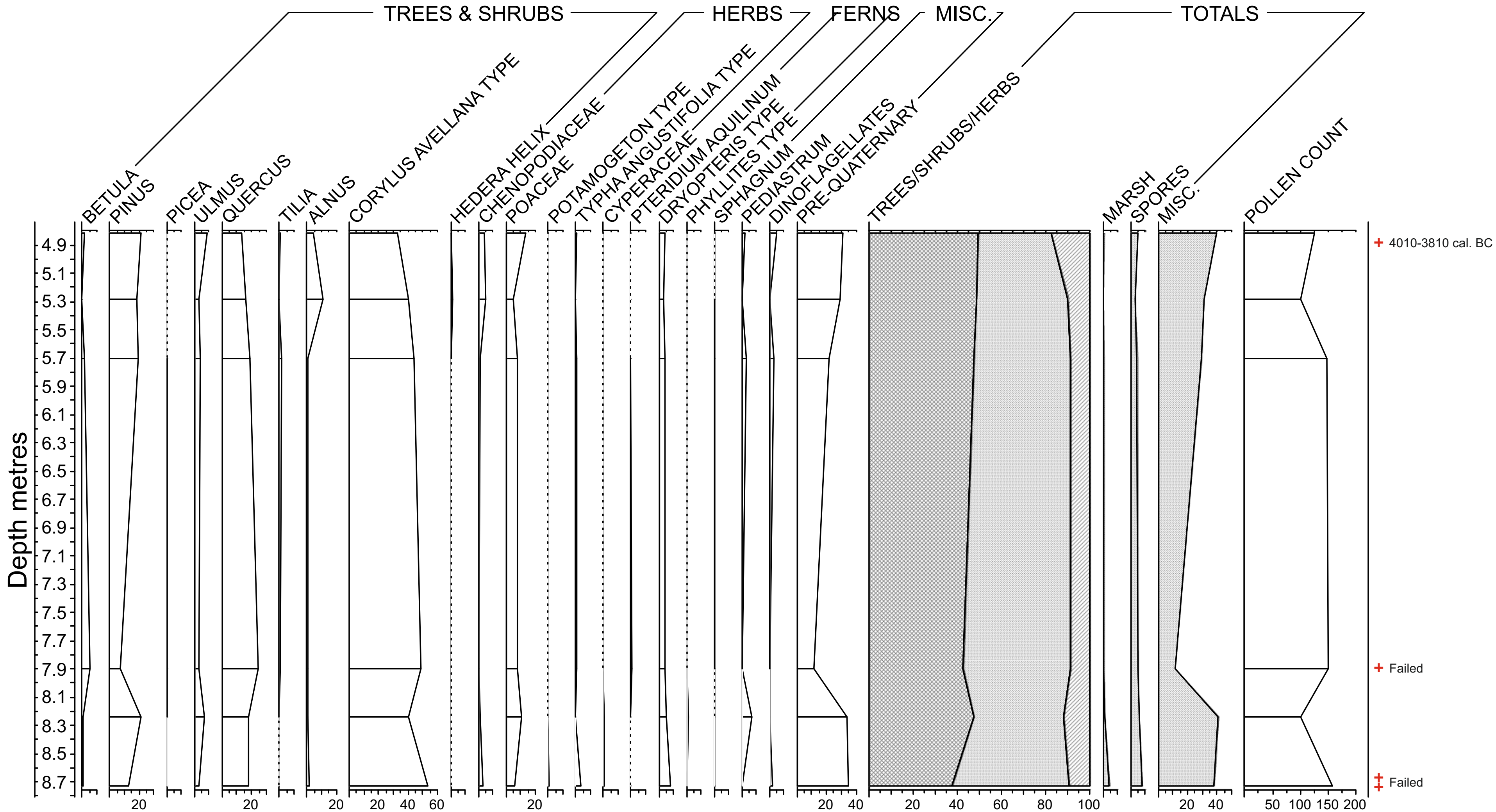
Transect 7

Figure 9



Rob Scaife 2015

+ Radiocarbon date

Date:	04/06/2015	Revision Number:	0
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Pollen diagram **BH-G01**

Figure 10