Wessex Archaeology

The Bristol Port Company Habitat Creation Scheme
Steart Peninsula, Somerset

Preliminary Geoarchaeological Assessment

Ref: 70944.01

June 2011

The Bristol Port Company
Habitat Creation Scheme

Steart Peninsula
Somerset

Preliminary Geoarchaeological Assessment

Draft Report

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THE BRISTOL PORT COMPANY
HABITAT CREATION SCHEME

STEART PENINSULA
SOMERSET

PRELIMINARY GEOARCHAEOLOGICAL ASSESSMENT

Ref: 70944.02

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Summary

This report was commissioned by The Bristol Port Company and summarises geoarchaeological assessment work in advance of a Proposed Ecological Habitat Creation scheme on the Steart Peninsula, Somerset. Seven major sedimentary Units have been identified within the site using data derived from geotechnical, geaoarchaeological and archaeological investigations in the area. These Units are:

- Unit J Jurassic bedrock,
- Unit H Quaternary glacial and marine sediments,
- Unit G Quaternary fluvial sediments,
- Unit D Holocene estuarine alluvium,
- Unit C Holocene (Neolithic) peat and alluvium,
- Unit B Estuarine alluvium (Sub-Unit Bii) and alluvial soils (Sub-Unit Bi),
- Unit A which comprises Sub-Units of the most recent Holocene sedimentation on site including coastal deposition of gravel (Sub-Unit Ai) and modern soil formation across the terrestrial part of the site (Sub-Unit Aii)

Four archaeological boreholes (**WA2011_BH109**, **WA2011_BH110**, **WA2011_BH111** and **WA2011_BH112)** have been geoarchaeologically recorded with the results incorporated into the sedimentary framework. Two boreholes (**WA2011_BH109** and **WA2011_BH112**) were selected for programme of scientific dating (OSL and ^{14}C) and environmental assessments (pollen, diatoms, foraminifera, ostracods, waterlogged plants, molluscs, charcoal and insects).

This assessment has confirmed the presence of well preserved Pleistocene and Holocene deposits beneath the scheme area. These deposits include a substantial peat of Neolithic date within which there is an increased potential for the presence and survival of archaeological material, the type of which is rare and of high value.

The results of the OSL dating indicate that Pleistocene and Holocene sediments dating from at least the Middle Palaeolithic (Oxygen Isotope Stage 6) (Unit H) to the Romano-British periods (Unit Bi) are present within the scheme area. Radiocarbon dating indicates that peats within Unit C are Neolithic in date. Environmental samples from Units H, D, C and B contained pollen, diatoms, foraminifera, ostracods and waterlogged plants indicative of coastal, estuarine and saltmarsh environments.

In order to finalise understanding of the palaeolandscape and potential archaeological remains preserved within it to a level sufficient to mitigate the likely impact of the proposed scheme further detailed analysis is required. This analysis would largely utilise existing

palaeoenvironmental samples with the acquisition of a small number of additional samples from boreholes at specific locations. The analysis would concentrate on providing the detailed information suitable for consumption by the regional and national academic audience in the context of the ongoing research into estuarine archaeology as set out in the regional research framework.

THE BRISTOL PORT COMPANY
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This report was commissioned by The Bristol Port Company. The geoarchaeological boreholes were undertaken by CJ Associates. Wessex Archaeology would like to acknowledge the assistance of the staff of these two organisations.

The sedimentary descriptions, sediment subsampling, foraminifera and ostracod assessments were taken by Jack Russell. Dr Nigel Cameron undertook diatom assessment, Dr Michael Grant undertook the pollen assessment, Dr Chris Stevens undertook the waterlogged remains and molluscan assessment. Material for radiocarbon dating was identified by Dr Chris Stevens. The radiocarbon dating was undertaken at the Scottish Universities Environmental Research Centre (SUERC) under the supervision of Dr Gordon Cook. Dr Chris Stevens calibrated the radiocarbon dates. Material for OSL dating was selected by Jack Russell and the dating undertaken by Dr Philip Toms at the University of Cheltenham and Gloucester.

Jack Russell compiled this report and Linda Coleman prepared the illustrations. Abigail Rolland managed the project for Wessex Archaeology.

THE BRISTOL PORT COMPANY HABITAT CREATION SCHEME

STEART PENINSULA SOMERSET

PRELIMINARY GEOARCHAEOLOGICAL ASSESSMENT

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1. PROJECT BACKGROUND

1.1. Introduction

1.1.1. Wessex Archaeology (WA) was commissioned by The Bristol Port Company (TBPC) to undertake geoarchaeological work in advance of a Proposed Ecological Habitat Creation scheme on the Steart Peninsula, Somerset ('the scheme'). This work has included assessment of geotechnical data, the retrieval of four archaeological boreholes (boreholes **WA2011_BH109**, **WA2011_BH110**, **WA2011_BH111** and **WA2011_BH112**) and subsequent geoarchaeological recording and assessment of subsamples retrieved from the boreholes.

1.1.2. Previous and ongoing archaeological work for the Steart Peninsula has included a Heritage Assessment (WA 2009a), and extended Heritage Assessment (WA 2009b), a pilot geophysical survey (Wessex Archaeology 2011a) watching briefs of geotechnical works (Wessex Archaeology 2009c and 2011b) and an archaeological site evaluation (Wessex Archaeology 2011c).

1.1.3. Geotechnical data acquired as part of previous site investigations for the Environment Agency including the North Clyce Outfall project (Fugro 2007) and Steart Coastal Management Project (Fugro 2009) has been incorporated into the geoarchaeological assessment. The geotechnical works in the area undertaken as part of the Bristol Port Company Proposed Ecological Habitat Creation (CJ Associates 2011b; CJ Associates 2011c; Lankelma 2011) scheme have also been geoarchaeologically assessed.

1.1.4. This report comprises a summary of the geoarchaeological assessment, subsample assessment and review of geotechnical data for the area.

1.2. Geological Background

1.2.1. The proposed scheme area lies on flat pasture elevated at around 5 to 6 metres above Ordnance Datum. It is within the northwestern edge of the valley of the river Parrett which at this point flows (*c.*1km southwest of the scheme area) in a southwest to northeasterly direction towards Burnham-on-Sea where it converges with the Bristol Channel and the river Brue at between Steart and Berrow flats. The northern boundary of the scheme area is demarked by the Bristol Channel and low hills surround the scheme area to the east and west. (**Figure 1**).

1.2.2. The solid geology beneath the area generally consists of Mercia Mudstone Group (Triassic mudstone, shale and conglomerate) and the Lower Lias (Jurassic Limestone and Shale) (Geological Survey 1957 and Brown 1980).

1.2.3. Pleistocene sediments in the area that overlie bedrock include 2km southeast of the area, the Burtle Beds (sands and gravels containing marine and freshwater faunas) and 0.5km to the west of the area, undifferentiated Head deposits.

1.2.4. Within the surrounding area the solid geology is typically overlain by alluvial sediment interspersed with peat layers. The alluvium is described by the British Geological Survey as marine and estuarine alluvium of the Somerset Levels including grey clays with some silts and sands. The peat is recorded to lie locally at the base of the sequence and is exposed, from time to time on the foreshore near Hinkley Point (Brown 1980) where a "Submarine Forest" has been recorded (inset **Figure 1**). This peat has been dated at 8365±100BP. A more extensive peat lies at around the level of Ordnance Datum and yielded a date of 4200±100BP (Brown 1980).

1.2.5. The British Geological Survey have recorded the elevation of the upper surface of Holocene estuarine alluvium in the Somerset Levels at around 6 metres above Ordnance Datum which is also the level of High Water Spring Tides (HWST). Marine incursions do not however affect most of the area due to storm gravel beach deposits, blown sand, man made works and extensive tidal flats which are widespread along the west facing coastline (Brown 1980).

1.2.6. Pebbles, formed by the abrasive wave action on limestone cliffs, are transported eastwards along the North Somerset Coast to the Steart Peninsula, forming mobile ridges that can be transported shoreward as well as alongshore (HR Wallingford 2002: 12). The pebble ridge at Catsford Common migrated nearly 190 metres eastwards between 1957 and 1964, while at Wall Common the movement was under 20 metres (*ibid*). Also during this period, the marsh retreated while the upper foreshore accreted.

1.2.7. The soil on scheme area is recorded as the 81 Downholland 1 association, which is a typical humic-alluvial gley soil (Soil Survey of England and Wales 1983).

2. AIMS AND OBJECTIVES

2.1.1. The aims and objectives of this study are set out in the Written Scheme of Investigation (Wessex Archaeology 2011) in conjunction with the geotechnical watching brief. The specific aims and objectives of this geoarchaeological assessment are repeated below:

2.2. AIMS

2.2.1. Overall the aim of the package of phased archaeological evaluative surveys, of which this project forms part, is to gather additional baseline information to enable the value of the heritage resource to be established and appropriate mitigations strategies put in place in the context of the Environmental Impact Assessment of the scheme. The overall evaluation strategy is guided by two research aims agreed in consultation with the curators. Those aims are:

- To date the chronology of land reclamation on the Steart Peninsula; and
- To understand and date the environmental changes within which the reclaimed landscape developed.

2.3. OBJECTIVES

2.3.1. Each phase of the evaluation is designed to provide information which will help to achive these key aims. The following section sets out the specific objectives of the archaeological watching brief and geoarchaeological assessment.

2.3.2. The core logs from the boreholes across the Scheme area will be assessed to help develop an understanding of the geomorphological characteristics of the area within the scheme area, with specific reference to evidence for Holocene development.

2.3.3. To achieve a better understanding of the palaeoenvironmental development of the peninsula sub-samples will be taken from two of the four archaeological boreholes taken along the transect. This will be achieved by scientifically dating samples and carrying out environmental assessment.

3. METHODOLOGY

3.1. ASSESSMENT OF GEOTECHNICAL DATA

3.1.1. Geotechnical data, including borehole and test pit logs acquired as part of previous site investigations including the Environment Agency's North Clyce Outfall project (Fugro 2007) and Steart Coastal Management Project (Fugro 2009), have been incorporated into the geoarchaeological assessment.

3.1.2. The geotechnical works in the scheme area have included test pit logs (CJ Associates 2011c), borehole logs (CJ Associates 2011b) and CPT (cone penetrometer test) logs (Lankelma 2011) have also been geoarchaeologically assessed. The locations are shown on **Figure 1**. No location or elevation data was available for the CPT logs (Lankelma 2011) and they have been plotted on **Figure 1** in relation to their proposed location as of December 2010 (ABPMer 2010)

3.1.3. Due to the high number of geotechnical investigations in the area, an identification code including the client and year has been suffixed to the geotechnical identification code so that it can be easily referred to. For example the identification code of borehole "BH1" from the Environment Agency North Clyce Outfall project (Fugro 2007) is referred to as "**EA2007_BH1**". A full list of identification codes, borehole, CPT and test pit locations is given in **Appendix 1**.

3.1.4. The sediments identified within these logs have been grouped into a sedimentary Unitary framework, consisting of Units and Sub-Units (Units A to J) in order to form a deposit model of the area. This work forms part of a wider study incorporating geotechnical data from the rest of the Steart Peninsula and some sedimentary Units (e.g. Units E and F) do not occur in the scheme area but are included for reference.

3.1.5. This Unitary system also incorporates the information acquired from the geoarchaeological boreholes taken as part of this projects (**WA2011_BH109**, **WA2011_BH110**, **WA2011_BH111** and **WA2011_BH112**) previous archaeological watching briefs (Wessex Archaeology 2009a, 2011), geophysical surveys (Wessex Archaeology 2011a) and published geological maps of the area British Geological Survey (Brown 1980).

3.2. GEOARCHAEOLOGICAL BOREHOLE RECORDING

3.2.1. Four geoarchaeological boreholes **WA2011_BH109**, **WA2011_BH110**, **WA2011_BH111** and **WA2011_BH112**), were drilled by CJ Associates on the 17th to 24th March 2011 (CJ Associates 2011a).

3.2.2. Core and bulk samples were recovered to the laboratory at Wessex Archaeology during March 2011. Using the geotechnical logs as a guide, four core samples were selected for Optically Stimulated Luminescence (OSL) dating, two from borehole **WA2011_BH109** and two from borehole **WA2011_BH112**. These were set aside for delivery to a laboratory at the University of Cheltenham and Gloucester for OSL sampling and subsequently geoarchaeologically recorded.

3.2.3. The remaining core samples were longitudinally split using an angle grinder and prised open with care to preserve sedimentary structure. The bulk samples stored in plastic bags and plastic pots were opened and cleaned to reveal uncontaminated sediment where necessary and geoarchaeologically recorded.

3.2.4. The geoarchaeological descriptions are given in full in **Appendix 2.** Sedimentary descriptions provided details of the depth to each sediment horizon and the character of the sediment. Sedimentary characteristics were recorded including texture, colour, stoniness and depositional structure (*cf.* Hodgson 1976).

3.2.5. The sediments described within the samples were then grouped into a number of sedimentary Units (and Sub-Units) based on the observed sedimentary characteristics.

3.2.6. During the geoarchaeological recording sediment subsamples were taken from the core samples. Eight samples, four from borehole **WA2011_BH109** and four from borehole **WA2011_BH112** were selected for macrofossil (waterlogged plants, mollusc, charcoal, insects) and microfossil (pollen, diatom, foraminifera and ostracod) assessment. Four samples, two from borehole **WA2011_BH109** and two from borehole **WA2011_BH112** were selected for radiocarbon ^{14}C dating. The locations of the assessed boreholes are given in the table below and on **Figure 1**.

Borehole ID	Easting	Northing	top (m aOD)
WA2011_BH109	324603	145111	5.72
WA2011_BH110	324659	144989	5.8
WA2011_BH111	324763	144821	5.75
WA2011_BH112	324854	144637	5.65

3.2.7. The subsample locations and depths are shown on **Figure 6**. The specific depths of the samples are also given below and in **Appendices 3** to **7**.

3.2.8. Subsamples were taken predominantly from the core samples to gain accurate depths, stratigraphic control and avoid sample contamination. Where core sample recovery was not achieved (usually with the deeper sediments) some bulk samples were subsampled. Due to the extremely wet and muddy on-site sampling conditions it was considered possible that some of the bulk samples were contaminated although every effort was made to gain uncontaminated subsamples where necessary from these levels.

3.3. Radiocarbon Dating

3.3.1. Four radiocarbon samples were submitted to the Scottish Universities Environmental Research Centre (SUERC) for dating. The selected samples were horizontally bedded *Phragmites* reed stems from peat/ peaty deposits from **WA2011_BH109** (at 0.67 and 1.44m above OD; Unit C) and **WA2011_BH112** (6.50, 0.15m below OD, 1.61, 3.85m above OD; Unit C). For full methodological details see **Appendix 3**.

3.4. Optically Stimulated Luminescence (OSL) Dating

3.4.1. Four sediment samples were submitted to the University of Cheltenham and Gloucester for OSL dating. The samples selected were minerogenic sediments towards the top and bottom of the sedimentary sequences within boreholes **WA2011_BH109** (at 4.00 to 3.94m above OD, Sub-Unit Bi and 1.63 to 1.68m below OD, Unit H) and **WA2011_BH112** (4.95 to 4.85m above OD, Sub-Unit Bi and 0.55 to 0.61m below OD, Unit C). For full methodological details, see **Appendix 4**.

3.5. Pollen Assessment

3.5.1. Eight sediment subsamples of approximately 4cm^3 were assessed for their pollen contents from boreholes **WA2011_BH109** (3.42, 1.42 and 0.67m above OD; 1.08m below OD) and **WA2011_BH112** (6.50, 0.15m below OD, 1.61, 3.85m above OD). Standard techniques were used for the extraction of sub-fossil pollen from the sediment which was undertaken in the laboratory of the University of Reading. The specific methods used for extraction and calculating the relative abundances of pollen are detailed in **Appendix 5**.

3.6. Diatom Assessment

3.6.1. Eight sediment subsamples of approximately 4cm^3 were assessed for the presence and preservation of diatoms from boreholes **WA2011_BH109** (3.42, 1.42 and 0.67m above OD; 1.08m below OD) and **WA2011_BH112** (6.50, 0.15m below OD, 1.61, 3.85m above OD).

3.6.2. Preparation comprised digestion of humic/organic material using hydrogen peroxide and gentle centrifugation and washes in water. Samples were then dried on microscope cover-slips and mounted on microscope slide using Naphrax mounting medium. Examination was carried out at high power x400 and x1000 using a biological microscope (**Appendix 6**).

3.7. Foraminifera and Ostracod Assessment

3.7.1. Ten sediment subsamples were assessed for the presence and preservation of foraminifera and ostracods. Four samples from borehole **WA2011_BH109** (2.28 to 3.08, 1.08m below OD , 1.34 and 2.30m above OD) and six from borehole **WA2011_BH112** (at 6.25 to 6.65, 0.78, 0.75m below OD, 0.92, 1.74.and 3.84m above OD).

3.7.2. Sediment samples of approximately 10cm^3 (2cm^3 for samples in **WA2011_BH112** at 0.78, 0.75m below OD) were treated with a weak solution of hydrogen peroxide and wet sieved through a 63µm sieve. Foraminifera and ostracods were picked out and identified using a Vickers binocular microscope under 10-60x magnification and transmitted and incident light (**Appendix 7**).

3.8. Waterlogged Plants, Molluscs, Charcoal and Insects

3.8.1. Four sediment samples were assessed for the presence and preservation of waterlogged plants, molluscs, charcoal and insects. Two samples from borehole **WA2011_BH109** (0.72 to 0.62m above OD and 1.52 to 1.42m above OD) and two samples from borehole **WA2011_BH112** (0.7 to 0.75m below OD and 1.64 to 1.60m above OD).

3.8.2. The sediment samples of 100 to 250cm^3 were processed by wet sieving over a 250µm sieve. The samples were then visually inspected under using a stereo-binocular microscope using x10 to x40 magnification (**Appendix 8**).

4. RESULTS

4.1. Geotechnical data assessment and Geoarchaeological borehole recording

4.1.1. The results of the geotechnical data assessment and geoarchaeological borehole recording have been amalgamated into a deposit model consisting of nine major sedimentary Units (Units A to J), the letter I (i) has not been used as the sub-Units are suffixed with Roman numerals (i,ii etc).

4.1.2. A selection of boreholes and test pits profiles (**Figures 2 – 6)** illustrate the relationship between the sedimentary Units and Sub-Units which are also summarised below.

4.1.3. The interpretation of geotechnical borehole and test pit data presented here is noted to potentially need refining. That is, for example, fine peat layers indicative of terrestrial land surfaces, were noted within the geoarchaeologically recorded boreholes to be in some instances no more than 20mm in thickness. Geotechnical borehole logs generated at the same locations did not contain this data and it is considered possible that peat deposits are more widespread than indicated by the geotechnical logs.

Unit J Limestone Bedrock

4.1.4. Unit J comprised limestone, recovered as gravel in some of the boreholes. The Unit is interpreted as Early Jurassic (Lower Lias) bedrock. The Unit was not penetrated to any great depth within any of the boreholes. The surface level of Unit J increases in depth across the scheme area from north to south (see **Figure 2**) getting deeper with proximity to the present active channel of the River Parrett. The bedrock surface was recorded at 1.05m above OD in borehole **BPC2011_BH101** (**Figure 4**) and, **BPC2011_BH101** and 6.55m below OD in borehole **WA2011_BH112** (**Figures 2** and **6**).

Unit H gravel, sand, silt and clay

4.1.5. This Unit comprised clay, silts sand and gravel with organic inclusions. It was described predominantly from bulk samples. It is considered possible that this Unit related to Pleistocene sedimentation and has potentially been subject to marine and periglacial processes. It may be equivalent to the so-called Burtle Beds, which are mapped, outcropping to the southeast of the Study Area by the British Geological Survey (Brown 1980).

Unit G Gravel and sand

4.1.6. This Unit comprised gravel and sand and occurred in boreholes **WA2011_BH111** and **WA2011_BH112**. The Unit contained no visible environmental remains and is thought most likely to be Pleistocene or Early Holocene fluvial, possibly glaciofluvial alluvium. The possibility that the Unit relates to coastal and marine sedimentation is also noted.

Units E and F Silt, clay and peat

4.1.7. These Units comprised silts, clays and peats at an elevation of between 7m and 10m below OD. The silt, clay and peat layers are interpreted as Holocene estuarine alluvium and peat, and are likely to have formed under similar environmental conditions to Units C and D (se below) but of potentially greater age due to their depth. These Units were identified from geotechnical data which came from beyond the footprint of the scheme area.

Unit D Silt and clay

4.1.8. This Unit comprised soft silty clays and clayey silts with frequent organic inclusions including roots. The Unit was separated from Subunit Bii by Unit C in most of the boreholes (**Figures 2** to **5**) It was however sedimentologically indistinct from Subunit Bii. It was therefore difficult to interpret in boreholes where Unit C was absent. This was the case in borehole **BPC2011_106**; **Figure 3** and **BPC2011_BH108**; **Figure 4.** The Unit was interpreted as Holocene estuarine alluvium.

Unit C Silt, clay and peat

4.1.9. This Unit comprised peats and intercalated silts and clays. The Unit was recorded in a number of the borehole cores from across the sampled area (**Figure 1**). The thickest peat deposit recorded within the scheme area (1.9m thicj) was recorded in borehole **BPC 2011_BH106** (**Figure 2**, **Transect 2**). The Unit was interpreted as Holocene peat with intercalated estuarine alluvium.

Sub-Unit Bii Silty Clay and Clayey silt

4.1.10. This Sub-Unit comprised soft silty clays and clayey silts which occurred in all of the boreholes and test pits (where deep enough). Frequent organic remains including peaty layers, plant remains and roots were recorded. The Unit was interpreted as Holocene estuarine alluvium.

Sub-Unit Bi Oxidised silty clay and clayey silt

4.1.11. This Sub-Unit comprised mottled grey/brown and brown occasionally fine sandy silts and clays with some roots and occasional organic inclusion. The Unit is interpreted as an alluvial gley soil, developed upon estuarine alluvium. The Unit was recorded in most of the test pits and boreholes (except **BPC2011_TP102,** where it has presumably been eroded by marine processes).

4.1.12. The Unit was generally recorded as between 1 and 2m in thickness achieving a maximum thickness of 3.63m in borehole **WA2011_BH112**.

Sub-Unit Aiv Made ground

4.1.13. This Sub-Unit consists of sand, gravel, clay and concrete. It was not recorded in the scheme area but recorded southeast of the area close to the River Parrett within test pit **EA2007_TP2**.

Sub-Unit Aiii Sand

4.1.14. This Sub-Unit comprised blown sand has not been identified in any of the geotechnical investigations within the scheme area, although was recorded in geotechnical investigations in the coastal part of the Steart Peninsula to the northeast of the Study Area (Wessex Archaeology *forthcoming*).

Sub-Unit Aii Sand, silt and clay

4.1.15. This Sub-Unit, the uppermost sedimentary Unit across the terrestrial areas was recorded as a modern gley soil and is shown in profile in **Figure 2** (**Transects 1**, **2** and **3**). It was recorded in almost all of the test pits and boreholes across the whole area except on the foreshore (**BPC2011_TP101** and **BPC2011_TP102**).

Sub-Unit Ai Gravel

4.1.16. This Sub-Unit comprised sandy gravel and was recorded in one test pit only, **BPC2011_TP102** located in the intertidal zone. It is interpreted as a gravel (possibly storm) beach and is shown in profile on **Figure 2** (**Transect 2**).

4.2. RADIOCARBON DATING

4.2.1. The results of the dating have been calibrated using OxCal 4.1.5 (Bronk Ramsey 2001; 2009) using the IntCal09 atmospheric and marine09.14 calibration curve respectively (Reimer *et al.* 2009). The results are given in the table below in **Appendix 2** and are also shown on **Figure 6.**

Depth aOD	Identification	Laboratory Code	δ13C	Date BP	calibration BC (2 sig. 95.4%)	calibration BP (2 sig. 95.4%)
BOREHOLE BH109						
1.44m	*Phragmites*	SUERC-34106	-27.1‰	3980±35	2580-2340 cal. BC	4530-4290 cal. BP
0.67m	*Phragmites*	SUERC-34105	-27.5‰	5020±35	3950-3700 cal. BC	5900-5650 cal. BP
BOREHOLE BH112						
1.74m	cf. *Phragmites*	SUERC-34108	-26.8‰	4145±35	2880-2620 cal. BC	4830-4560 cal. BP
1.6m	*Phragmites*	SUERC-34107	-26‰	4715±35	3640-3370 cal. BC	5590-5320 cal. BP

4.2.2. Within borehole **WA2011_BH109** at 0.67m above OD a *Phragmites* reed stem returned a date of 5020±35 BP (Before Present = before 1950AD) (5900-5650 cal. BP; 3950-3700 cal. BC) which is equivalent to the Early Neolithic archaeological period. At 1.44m above OD within the same borehole a *Phragmites* reed stem returned a radiocarbon date of 3980±35 BP (4530-4290 cal. BP; 2580-2340 cal. BC) which is equivalent to the Late Neolithic archaeological period.

4.2.3. Within borehole **WA2011_BH112** at 1.60m above OD a *Phragmites* reed stem returned a date of 4715±35 BP (5590-5320 cal. BP; 3640-3370 cal. BC) which is equivalent to the Early Neolithic archaeological period. At a depth of 1.74m above OD, within the same borehole a *Phragmites* reed stem returned a date of 4145±35 BP (4830-4560 cal. BP; 2880-2620 cal. BC) which is equivalent to the Late Neolithic archaeological period.

4.3. OSL DATING

4.3.1. Four samples were submitted for OSL dating. The results are given below, in **Appendix 4** and are also shown on **Figure 6**. The results of the OSL dating are conventionally reported, rounded to the nearest 100 years, in thousands of years ago (ka), calibrated from the year 2011 (when the samples were taken).

4.3.2. Within borehole **WA2011_BH109** at 1.52 to 1.42m below OD the sampled sediment returned a date of 149 ± 22 ka (c. 127000 – 171000 BP) which is equivalent to the Middle Palaeolithic archaeological period (Lab Code GL10081).

4.3.3. Within borehole **WA2011_BH109** at 4.00 to 3.94m above OD the sampled sediment returned a date of 2.6 ± 0.2 ka (c. 2400 - 2800 BP) which is equivalent to the Late Bronze and Iron Age archaeological periods (Lab Code GL10080).

4.3.4. Within borehole **WA2011_BH112** at 6.20 to 6.26m below OD the sampled sediment returned a date of4.2 ± 0.3 ka (c. 3900 - 4500 BP) which is equivalent to the Late Neolithic archaeological period (Lab Code GL10083).

4.3.5. Within borehole **WA2011_BH112** at 4.95 to 4.85m above OD the sampled sediment returned a date of 1.8 ± 0.2 ka (c. 1600 – 2000 BP) which is equivalent to the late Iron Age and Romano British archaeological periods (Lab Code GL10082).

4.4. POLLEN

4.4.1. Within borehole **WA2011_BH109**, pollen concentrations were variable with three of the four samples containing pollen (no pollen was recovered from the sample at 0.67m above OD), with the highest concentrations recorded within peat in the sample at 1.42m above OD. The three samples containing pollen included high amounts of Poaceae (grasses) with Cyperaceae (sedges), *Quercus* (oak) and *Corylus avellana*-type (hazel) also common.

4.4.2. There was a strong presence of woodland taxa in the three samples (at 3.42m, 1.42m and 1.08m below OD) with *Quercus* and *Corylus avellana*-type within all samples, along with an increase in *Salix* (willow) and *Alnus glutinosa* (alder) towards the top of the sequence (**Appendix 5**).

4.4.3. Within borehole **WA2011_BH112** the sample at the base of the sequence at 6.5m below OD contained a very low concentration of poorly preserved grains including *Pinus sylvestris* (pine) and Poaceae.

4.4.4. Above this at 0.15m below OD and 1.61m above OD pollen concentrations were highest within the peat (1.61m above OD). High quantities of Chenopodiaceae were noted within the estuarine alluvium (at 0.15m below OD). Both assemblages were dominated by Poaceae with *Quercus*, *Alnus glutinosa* and *Corylus avellana*-type also present in notable amounts (**Appendix 5**).

4.5. DIATOMS

4.5.1. Within borehole **WA2011_BH109**, diatoms were present in all four samples and were most frequent in the basal sample at 1.08m below OD. Diatom preservation was moderately good with a relatively high species diversity recorded. The basal sample at 1.08m below OD within **WA2011_BH109** contained a marine-brackish diatom assemblage with a dominant mesohalobous benthic component including *Diploneis didyma* and *Nitzschia punctata*. The diatoms of this assemblage were interpreted as being consistent with a tidal mudflat environment. Above this at 0.67m above OD was dominated by the epipelic (mud surface) species *Campylodiscus echeneis*. This benthic diatom assemblage was interpreted as typical of brackish-marine, shallow water habitats.

4.5.2. At 1.34m above OD the most common diatom taxa recorded were *Epithemia turgida,* and halophilous epiphyte, and *Fragilaria construens* var. *venter*, a diatom with broad salinity tolerance. The poor quality of preservation is reflected in the common occurrence of undifferentiated *Fragilaria* sp. Marine diatoms were also present in this sample. The uppermost sample in **BH109** (at 3.42m above OD) contained a diatom assemblage dominated by polyhalobous diatoms (*Paralia sulcata*, *Cymatosira belgica*, *Podosira stelligera*, *Rhaphoneis surirella*, *Thalassionema nitzschiodes*, *Actinoptycus undulatus*). Low numbers of mesohalobous benthic diatoms were also present. (**Appendix 6**).

4.5.3. Within borehole **WA2011_BH112** (**Appendix 6**). Diatoms were present in all four samples. In the middle two samples from the sequence, at 0.92m above OD and at 1.61m above OD, diatom numbers were relatively high with relatively good diatom preservation and moderately high species diversity. In the basal sample, at 6.50m below OD, the diatoms were poorly preserved with low diatom numbers. In the uppermost sample, at 3.84m above OD, diatom numbers were low and the quality of valve preservation was poor, with low species diversity.

4.5.4. The basal sample at 6.50m below OD small numbers of robust but poorly preserved marine (*Podosira stelligera, Paralia sulcata, Rhaphoneis* sp.) and benthic mesohalobous (*Nitzschia navicularis*) diatoms were present. In at 0.92m above OD the well preserved diatom assemblage was dominated by open water, (and some non-planktonic) marine taxa such as *Paralia sulcata*, *Cymatosira belgica*, *Rhaphoneis minutissima*, *Campylosira cymbelliformis*, *Rhaphoneis surirella*, *Nitzschia panduriformis* and *Actinptychus undulatus*. Benthic, mesohalobous taxa are present but are generally less abundant than the marine component; these taxa include *Nitzschia navicularis* (common), *Diploneis aestuari*, *Diploneis didyma* and *Scoliopleura tumida*.

4.5.5. Above this, at 1.61m above OD, there appeared to be a shift from the dominance of polyhalobous diatoms (the planktonic species *Paralia sulcata* and *Podosira stelligera* are present), whilst mesohalobous, benthic diatoms become more common (*Nitzschia navicularis, Nitzschia granulata,* *Diploneis didyma, Nitzschia punctata, Navicula marina*). In the uppermost sample at 3.84m above OD the most common species is the planktonic polyhalobous diatom *Paralia sulcata* with *Rhaphoneis amphiceros* also present. The mesohalobous benthic diatoms *Diploneis didyma* and *Nitzschia navicularis* were also present.

4.6. Foraminifera and Ostracods

4.6.1. Within borehole **WA2011_BH109**, Foraminifera and/or ostracods were present in two of the four samples (**Appendix 7**). At 2.28 to 3.08m below OD a small well preserved foraminiferal assemblage was recorded including *Ammonia beccarii*, *Haynesina germanica* and *Jadammina macrescens*. Ostracods were abundant within the sample although were represented by reworked fossilised (?Jurassic) forms. Non fossilised plant remains were also recoded within the sample.

4.6.2. Ostracods were not present within the sample at 1.08m below OD. At this level a large and generally well preserved foraminiferal assemblage was recorded including mainly Rotaliid forms dominated by the taxon *Haynesina germanica.* Other species present included *Trochammina inflata*, *Elphidium williamsoni*, *Jadammina macrescens*, and *Ammonia beccarii*. Other material noted within the sample included frequent plant remains and seeds including *Juncus* sp. and radiate diatoms. At 1.34m above OD and 3.42m above OD no foraminifera or ostracods were recovered

4.6.3. Within borehole **WA2011_BH112** Foraminifera and/or ostracods were present in all of the samples except at 1.74m above OD (**Appendix 7**).

4.6.4. The basal sample at 6.35 to 6.65m below OD contained a mix of terrestrial elements including moderate amounts of (non-fossilised) plants and marine faunal remains including echinoid spines, sponge spicules and fish bones and teeth. These marine faunal remains however are fossilised (from ?Jurassic limestone). Ostracods were rare within the sample however a few stray marine and brackish valves were present including *Cytheropteron* sp. and *Elofsonia* sp..

4.6.5. At 0.78 and 0.75m below OD, the two small samples with clearly visible ostracod faunas noted during the OSL sampling, contained predominantly *Cyprideis torosa* indicative of brackish water environments. Above this level at 0.92m above OD the sample contained a small fauna of Rotaliid foraminfera (*Elphidium gerthi*, *Elphidium* sp., and *Haynesina germanica*). Ostracods were also present in small number including *Cyprideis torosa* and *Elofsonia baltica* indicative of brackish and estuarine environments.

4.6.6. Within the uppermost levels sampled within borehole **WA2011_BH112** (at 1.74m above OD and at 3.84m above OD) no ostracods were recovered. A small assemblage foraminifera were present (*Haynesina germanica* and *Elphidium* sp.) at 3.84m above OD indicative of brackish and estuarine environments.

4.7. Waterlogged Plants, Charcoal, Molluscs and Insects

4.7.1. Within borehole **WA2011_BH109**, the lower sample at 0.72 to 0.62m above OD contained several coastal and marine indicative plants including seeds of sea blite (*Suaeda maritima*) sea aster (*Aster tripolium*). Other plant remains included species of the genus *Juncus*, Cyperaceae possibly grey club rush (*Schoenoplectus tabernaemontani*) or saltmarsh flat-sedge (*Blysmus* sp.) and single seed of common nettle (*Urtica dioica*) was also present.

4.7.2. The sample at 1.52 to 1.42m above OD contained a number of waterlogged plants including seeds of goosefoots (Chenopodiaceae), water-crowfoot (*Ranunculus*) seeds of bulrush (*Typha* sp.) possible seed of bogbean (*Menyanthes trifoliata*). Other remains within this sample included Bryozoan statoblasts and occasional waterflea eggs. The plants were more generally indicative of freshwater environments and disturbed ground, although a number are also known from saltmarsh and brackish environments. The foraminifera *Trochammina inflata*, a high salt marsh dwelling taxon was also recorded in this sample indicating that whilst it is possible that freshwater marshland and pools were developing at this level, a clear connection to the marine environment, probably at the highest tides is still indicated. Apart from the waterflea eggs, no insect, charcoal or molluscan remains were recovered from these samples (**Appendix 8**).

4.7.3. Within borehole **WA2011_BH112** (**Appendix 8**) the lower sample from 0.70 to 0.75m below OD had high numbers of seeds of red goosefoot (*Chenopodium rubrum*), along with a few seeds of mint (*Mentha* sp.), orache (Atriplex *sp.)* and nightshade (*Solanum* sp.). Also present were two gametes of stonewort (*Chara* sp.). Taken together these elements would all indicate a more likely freshwater environment, with tracts of highly disturbed grassland.

4.7.4. The upper sample at 1.64m to 1.60m above OD contained only two tentatively identified fragments of plant remains, these were a possible fragment of bramble (*Rubus* sp.) and a possible fragment of a Brassicaeace capsule perhaps *Raphanus*, but too fragmented and poorly preserved for identification.

4.7.5. No remains of molluscs, insects or charcoal were seen within these samples

5. DISCUSSION

5.1.1. The results of the geoarchaeological assessment have indicated a complex history of depositional environments within the scheme area. The deposit model produced provides at present a simplified grouping indicating a succession of glacial, fluvial, marine, estuarine, marsh and terrestrial environments which have developed over the Pleistocene and Holocene epochs. The relationship of the sedimentary Units and Sub-Units to equivalent deposits described in the area by the British Geological Survey (Brown 1980) 40km northeast of the area on the Welsh Coast (Allen and Rae 1987) and 11km southwest of the area in the Somerset Levels (Coles and Coles 1986) is given below:

Units/Sub-Units	Date	Interpretation (this study)	British Geological Survey (Brown 1980)	Allen and Rae (1987)	Coles and Coles (1986)
Sub-Unit Ai		Gravel beach	Storm gravel/beach deposits	-	-
Sub-Unit Aii		Modern gley soil	-	-	-
Sub-Unit Aiii		Sand	Blown sand	-	-
Sub-Unit Aiv		Made Ground	-	-	-
Sub-Unit Bi		Gley alluvial soil	Holocene alluvium and Peat	Rumney Formation /Wentlooge palaeosol	-
Sub-Unit Bii		Estuarine alluvium		Upper Wentlooge	-
Unit C		Peat and alluvium		Middle and Lower Wentlooge	*Phragmites* peat
Unit D		Estuarine alluvium			Marine Clay
Units E and F		Peat and alluvium			-
Unit G		Fluvial gravel	Sand and gravel	-	-
Unit H		Pleistocene clay/sand	Burtle beds/Head deposits	-	Sandy Burtle
Unit J		Limestone Bedrock	Jurassic bedrock (Lower Lias)	-	-

5.1.2. It is noted that within single boreholes, for example, successive estuarine and marsh environments are seen on a millimetre scale. Given the difference in age *(c.*1000 years) of radiocarbon dates of *Phragmites* reeds dated from peats within Unit C, elevated within 0.8m of each other in borehole WA2011**_BH109**, some caution has been exercised extrapolating the data across the entire study area.

5.1.3. The types of environments encountered within this study, for example saltmarsh and tidal mudflats, can develop asynchronously across coastal areas. These have been grouped into broader patterns for the purposes of deposit modelling. This sedimentation can be related to sea level rises and falls over the period, an approach known as sequence stratigraphy (Miall 1999).

5.1.4. The sedimentary and geological Units recorded within the scheme area are discussed below in relation to their interpretation and their potential archaeological and palaeoenvironmental interest.

Unit J

5.1.5. Unit J has been interpreted as Jurassic bedrock and was recovered in some of the deeper boreholes as limestone gravel. The British Geological Survey have mapped the area as the Blue Lias formation (Brown 1980) which generally consists of alternating beds of shale and limestone. The top of this Unit marks the extent of the Pleistocene valley system of the rivers Parrett and Brue which presently converge to the west of the scheme area near Burnham-on-Sea (inset **Figure 1**). **Figure 2** shows the increasing depth of the bedrock surface in a northeast to southwest direction across the scheme area. This slope is also interestingly apparent in the direction of drainage of the (most recent) unfilled palaeochannels visible on the DEM model (**Figure 1** and Wessex Archaeology 2009b, 2010). The bedrock was reached at 2.88m below OD (8.60m below present Ground Level) in borehole **WA2011_BH109**, This depth corresponds to a geophysical layer noted in the pilot geophysical survey (Wessex Archaeology 2011a).

Unit H

5.1.6. Unit H is interpreted as relating to Pleistocene sedimentation within the area. In Unit H a sample assessed for foraminifera and ostracods in borehole **WA2011_BH109** contained reworked fossilised (lower Jurassic ?*Ogmoconchella* sp.) ostracods and a small foraminiferal fauna, which were thought to potentially be contaminant within the sample (**Appendix 7**).

5.1.7. The results of the environmental assessments of this Unit are inconclusive, including material from glacial, estuarine and shallow marine environments indicative of a reworked mix of material relating to both Pleistocene glacial and interglacial cycles. The OSL dating indicates that the sediment is likely to date from OIS6/5e (c. 127000 – 171000 BP) or earlier. It is possible that Unit H may form part of the formation known as the "Burtle Beds" which contain a mix of glacial and marine material (BGS) and have been recorded elsewhere within the Somerset Levels. This is confirmed by other studies the Burtle Beds (Brown 1980). There are undifferentiated Head deposits (Brown 1980) of which this Unit make also be contemporary. Given its reworked nature, it is not considered likely that *in situ* archaeological remains will occur within this deposit.

5.1.8. The surface of the Burtle Beds, where it outcrops to the east of the scheme area is however well known to contain prehistoric archaeological remains (Clark 1933).

Unit G

5.1.9. Unit G is thought to be a late Pleistocene or Early Holocene (?glacio) fluvial deposit. Although noted to be potentially of coastal or marine origin, it does in either case represent a high energy waterlain deposit. Any archaeological remains contained within this Unit are likely to be *ex situ* and of the more robust variety (e.g. flint tools). This deposit may be equivalent to Pleistocene terrace gravels as described by Allen and Rae (1987). It has not been recorded by the British Geological Survey in the area (Brown 1980).

Units F and E

5.1.10. Units F and E are not discussed in detail here as they occur outside of the scheme area. They relate to Holocene estuarine alluvium and peat deposits and are likely to contain similar archaeological and palaeoenvironmental material as Units D, C and Sub-Unit Bi, discussed below. These Units occur between *c.*5 and 10m below OD to the southwest of the scheme area and contain terrestrial elements such as wood and peat. Relating this to Holocene sea level rise (Shennan et al. 2002) indicates the Units are likely to date to early Holocene possibly Mesolithic terrestrial and brackish/marine environments.

Unit D

5.1.11. Samples within the Unit in borehole **WA2011_BH109** contained diatoms indicative of marine and brackish environments consistent with estuarine alluvium. It is likely to be equivalent to the Middle Wentlooge (Allen and Rae 1987) and to the "Marine Clay" recorded within the Somerset levels (Coles and Coles 1986). It is overlain by peat (Unit C) which has been dated to the early Neolithic (at 0.67m above OD; 5020±35 BP; 5900-5650 cal. BP; 3950-3700 cal. BC).

Unit C

5.1.12. The peats of Unit C, as recorded within the four geoarchaeologically recorded boreholes (**Appendix 2**), predominantly comprise the preserved and degraded remains of *Phragmites ?australis* (common reed); a "*Phragmites*" peat. Horizontally bedded stems from the peat were selected for radiocarbon dating (**Appendix 3**).

5.1.13. Within borehole **WA_BH109** the peat dating to the early Neolithic (at 0.67m above OD; 5020±35 BP; 5900-5650 cal. BP; 3950-3700 cal. BC) contained some waterlogged remains indicative of freshwater marsh habitats, although the diatoms and foraminifera contained at this level clearly point towards a marine connection (possibly within the reach of the highest tides at this point). Above this the late Neolithic peat (dated at 1.44m above OD; 3980±35 BP; 4530-4290 cal. BP; 2580-2340 cal. BC) contained a more coastal and marine flora, with sedges dominant within many of the samples, indicative of a brackish reed swamp.

5.1.14. The lower peat (presently undated at -0.63 to -0.75m below OD) within borehole **WA2011_BH112** contained a mix of brackish and freshwater elements, with a hyper abundance of the ostracod *Cyprideis torosa* clearly indicative of brackish water, probably tidal creek environment developing within a marsh environment. Above this the estuarine silts and clays have been OSL dated at -6.20 to -6.26m OD to 4.2 ± 0.3 ka (c. 3900 - 4500 BP) which is equivalent to the Late Neolithic archaeological period. This date is somewhat enigmatic as the overlying peats have been dated at 1.60m OD to 4715±35 (5590-5320 cal. BP; 3640-3370 cal. BC) and at 1.74m OD; 4145±35; 4830-4560 cal. BP; 2880-2620 cal. BC). Whilst still Neolithic in date it is considered that the OSL date is too young and that the radiocarbon dates are secure. The reason for this is unknown. It is possible that the core sample from which this date derives is contaminated with younger sediment.

5.1.15. This upper peat at 1.61m above OD (within borehole **WA2011_BH112**) contained brackish tolerant diatoms and occasional coastal type plant remains indicative of a saltmarsh environment at this level.

5.1.16. Pollen from Unit C in both boreholes contained a flora indicative of surrounding vegetation of oak (Quercus) and hazel (*Corylus avellana*) woodland with a decline in the levels of elm (*Ulmus*). This is potentially evidence of the so-called mid-Holocene elm decline (Parker 2001) noted up profile in both boreholes which has been recorded elsewhere at similar dates at Westward Ho! (Scaife 1987), and Beckett & Hibbert, 1979). This is interpreted as possibly due to woodland clearance in "upland" areas (Wilkinson and Straker 2000).

5.1.17. Similar evidence for potential saltmarsh at an unknown date as seen within **WA2011_BH109** at 0.72 to 0.62m above OD was recovered in a Test Pit (**Figure 4**, **EA 2009_TP8**) at 2.8 to 2.9m above OD (Wessex Archaeology 2009) This test pit was subject to and archaeological watching brief and subsequent environmental sampling (Wessex Archaeology 2009).

5.1.18. By the early Neolithic, the rate of sea level rise, had dramatically slowed and it is this process, noted around the southern coast of Britain (Shennan *et al.* 2002), that has lead to the development of peat deposits (Haslett *et al*. 2000). The known sea level data for the area (Shennan *et al*. 2002) indicate mean sea levels (roughly equivalent to the level of Ordnance Datum today) in the Bristol Channel were approximately 3 to 5 metres below those of the present day during the Neolithic. This is confirmed by the environmental data and Neolithic radiocarbon dates recorded from boreholes **WA2011_BH109** and **WA2011_BH112** which indicate evidence of wetland and marsh environments elevated within the tidal frame. It is also noted that the Bristol Channel has at present one of the largest tidal ranges in the world (*c*. 15m) and that this may also have been the case during the Neolithic. The fact that these peats are intercalated towards the coast is likely a result of the proximity of the sea during the Neolithic period. Similar sequences of intercalated peats and silts have been noted elsewhere around the coast of the Britain and Europe and are noted to be controlled by both long term sea level rise and local palaeogeography (Allen 2003).

5.1.19. Units D, C are equivalent to the succession of marine clay and *Phragmites* peat (containing a Neolithic trackway) described c. 10km southwest of the scheme area in the Somerset Levels by Coles and Coles (1986). They are also equivalent to the so-called Middle Wentlooge formation as described on the fringes of the Severn Estuary c. 40km northeast of the scheme area by Allen and Rae (1987). The Middle Wentlooge formation is characterised by a series of intercalating estuarine alluvial silt and peat deposits of varying date. The sequence of peats recorded within the Wentlooge formation is very similar to that recorded in this study, in particular with thicker peat deposits noted closer to dryland edges (e.g. **BPC2011_BH106**, **Figures 1** and **3**).

Unit B (Sub-Units Bii and Bi)

5.1.20. Unit Bii interpreted as estuarine alluvium is equivalent to the Upper Wentlooge formation as described by Allen and Rae (1987). These deposits of the Upper Wentlooge are thought to post-date peat formations of Bronze Age and Iron Age date in the area. Sub-Unit Bi has been deposited under similar conditions with a subsequent soil formation. OSL dating of Sub-Unit Bi in within borehole **WA2011_BH109** at 4.00 to 3.94m OD returned a date of 2.6 ± 0.2 ka (c. 2400 - 2800 BP) equivalent to the Late Bronze and Iron Age archaeological periods which is likely to represent deposition of estuarine alluvium rather than the subsequent soil formation (Sub-Unit Bi).

5.1.21. Sub-Unit Bi has been OSL dated in borehole **WA2011_BH112** at 4.95 to 4.85m OD to 1.8 ± 0.2 ka (c. 1600 – 2000 BP) which is equivalent to the late Iron Age and Romano British archaeological periods. This date is thought however to be possibly contaminated by pedogenesis (**Appendix 4**) and can therefore not be used as a secure date at this level. The date is however equivalent to the (Roman) Wentlooge palaeosol as described by Allen and Rae (1987). The Wentlooge palaeosol formed on the surface of the Upper Wentlooge, on the Welsh coast contains a system of deep drainage ditches resulting from the land drainage during the Romano-British period (Bell 1999).

5.1.22. The known medieval remains from the surface of Sub-Unit Bii are also of interest as medieval buildings known from the Welsh Coast on the surface of the so called Rumney formation of 14th century date (Allen 1987; Allen and Rae 1987). It is noted that the medieval buildings recorded by archaeological evaluation have been constructed at the level of the surface of Unit Bi (walls 404 and 408, **Figure 3**).

Unit A

5.1.23. Units Ai and Aiii, gravel beach and blown sand are mapped by the British Geological Survey (Brown 1980) and are at present undated. Sub-Unit Ai was recorded overlying Sub-Unit Bii (**Figure 4**), but its relationship with the gley soils, Sub-Units Bi and Sub-Unit Aii was unproven. These deposits are considered key to understanding the land reclamation of the area which has included formation of alluvial gley soils of Sub-Unit Bi and Aii.

6. ARCHAEOLOGICAL POTENTIAL AND RECOMMENDATIONS

6.1.1. The results of the geoarchaeological assessment of geotechnical data have been interpreted to provide an initial understanding of the prehistoric landscape represented by the sediment sequence beneath the scheme area. This understanding, supported by radiocarbon and OSL dates, has revealed a prehistoric landscape including a Neolithic land surface which can be identified at a number of locations across the scheme area.

6.1.2. The results of environmental assessment of samples (plant macrofossils, molluscs, insects, charcoal, pollen, diatoms, foraminifera and ostracods) indicate that material suitable for detailed analysis (plant macrofossils, pollen, diatoms, foraminifera and ostracods) are present within the deposit sequence at these levels. Analysis of these types of data should provide a more comprehensive understanding of prehistoric land use and past land and seascape development particularly in relation to sea levels of the area.

6.1.3. Evidence of deposition and soil formation which have developed as part of the more recent reclaimed landscape was identified across the scheme area in the geotechnical data. OSL dating and archaeological evidence suggests estuarine alluvial deposition was occurring within the study area into the later prehistoric periods (late Bronze age/Early Iron age) with more recent terrestrial activity evident with Roman pottery and medieval buildings present within the scheme area. The results of environmental assessment from these levels indicate that there are few environmental remains preserved within these upper deposits relating to the more recent land reclamation of the scheme area.

6.1.4. The dating, geoarchaeological and environmental assessments indicate that in order to fully understand the original aims of the research, analysis of samples (plant macrofossils, pollen, diatoms, foraminifera and ostracods) and further scientific dating is required. The following discussion relates to specific sedimentary units, the likely impact of the development upon them and recommendations of further work to achieve the original aims of the research.

6.1.5. The lower Units J, H, G and D are unlikely to be adversely affected by the proposed development, but data from these Units should be incorporated into the overall deposit model in order to understand the palaeogeographic development of the scheme area. For example the surface of bedrock, Unit J marks the maximum extent of the valley of the River Parrett, and appears to have affected even the most recent drainage patterns noted as palaeochannels on the DEM data (WA 2009b).

6.1.6. Units C, B and A are most likely to be adversely affected by the development. Their archaeological potential and recommendations for further work are discussed in more detail below.

6.1.7. The most palaeoenvironmentally and geoarchaeologically interesting part of the sequence is Unit C, the Neolithic peats and intercalated alluvial silts and clays. Some good samples of these deposits are stored at Wessex Archaeology from boreholes (**WA2011_BH109**, **WA2011_BH110**, **WA2011_BH111** and **WA2011_BH112**). These peats have generally been recorded between 4 and 5 metres below present ground surface in the area. There are some notable exceptions. In the western part of the scheme area at location **EA 2009_TP8** (**Figure 4**) the peat surface was recorded at 2.9m below the surface.

6.1.8. Peat representative of Unit C was recorded 0.8m below the present surface in borehole **BPC2011_TP1** located within the foreshore (**Figure 3**). This surface is noted to be within the intertidal zone and at the time the test pit was undertaken the surface was recorded 2.47m above OD. It is possible that the OD level of the surface may change at this location given the dynamic nature of the environment in which it resides.

6.1.9. The thickest peat deposit was recorded as 1.9m thick and located in the southern part of the survey area (**BPC 2011_BH106**). Additional samples in this area would greatly enhance the understanding of the area particularly regarding the vegetational history and possibly anthropogenic activity. It is also noted that the peat is 3.8m below the present ground surface in this area. The Unit was normally recorded in the area at 4 to 5m below ground surface.

6.1.10. Peats at these levels (around the level of Ordnance Datum) have been recorded at Westward Ho!, north Devon (Scaife *et al*. 1987), the Glastonbury levels, Somerset (Coles and Coles 1986) and within the so called Wentlooge formation (Allen and Rae 1987) on the coast of Wales. The peats within Unit C are not as thick as those within the Glastonbury levels but are *Phragmites* peat, which are of similar composition the Neolithic peats containing the Neolithic wooden trackway known as the "Sweet track" (Coles and Coles 1986). It is noted that the Steart Peninsula would have been connected to the Somerset levels during the Neolithic period. The quality and quantity of Neolithic (and Bronze age) waterlogged archaeological remains within Somerset is noted to be very high despite only a small proportion of the Somerset wetlands having been archaeologically investigated (Brunning 2000).

6.1.11. The archaeological potential of Sub-Unit Bii Unit is quite complex. It dates from the Neolithic to early Iron Age (and possibly later in some areas) and may therefore contain material relating to maritime and coastal activities from these periods. It is equivalent to minerogenic sediments known as the Upper Wentlooge formation (Allen and Rae 1987). Some quite unusual archaeological material has been discovered from similar deposits along the coast of Wales particularly at Peterstone Wentlooge the type site of the so called Wentlooge formation with archaeological remains such as fishtraps and maritime wooden remains (see Bell 1997, Bell 2000 and Bell and Neuman 1997).

6.1.12. Sub-Unit Bi, a thick alluvial soil in boreholes **WA2011_BH109** and **WA2011_BH112**, is likely to date subsequent to its deposition as estuarine alluvium in the early Iron Age (the most secure OSL date obtained within the Unit borehole 109). This Unit can be traced across the entire scheme area and has developed upon estuarine alluvium as a result of (natural and anthropogenic) land reclamation in the area. The medieval enclosure and buildings (WA 2011c) give an indication that this soil formed at that location (see **Figures 1** and **3**) by the medieval period indicating land reclamation had already begun by that time. Remains similar to the types in Bi predating the soil formation and relating to its original deposition as estuarine alluvium (e.g. waterlogged organic) remains may be contained within this Sub-Unit. Whilst the Unit does not offer the greatest potential of the investigated sediments in terms of palaeoenvironmental remains, further work is recommended, particularly dating in order to understand the more recent land reclamation of the scheme area.

6.1.13. Sub-Unit Ai, and Aiii comprise the surface sediments on the foreshore and relate to coastal and marine sedimentation. Sub-Units Ai and Aiii were only recorded in a few of the test pits on the foreshore and northern part of the scheme area. It is likely that the chronology of the natural development of a beach shingle forming a spit (Unit Ai) and blown sand (Sub-Unit Aiii) along the west to east axis on the coastal, northern part of the scheme area is key to the chronology and sedimentation within the main scheme area. Utilisation of this naturally formed barrier is likely to have influenced the pattern of historic land reclamation in the scheme area. It is also possible that some of the shingle deposits may be related to documented storm events (Haslett and Bryant 2007).

6.1.14. Modern (alluvial gley) soil formation (Sub-Unit Aii) is recorded landward of the seawall within the scheme area. The medieval masonry structures recorded in the archaeological evaluation (Wessex Archaeology 2011) were encountered just below this modern soil (Sub-Unit Aii).

6.1.15. Overall these Sub-Units (Ai, Aii and Aiii) comprise the current surface sediments across the scheme area. An OSL date from Sub-Units Ai and Aii is undertaken would provide important information at the ‘top’ of the sedimentary sequence. No samples suitable for this work currently exist so further geotechnical investigations on scheme area should take account of this potential requirement.

6.1.16. Further analysis of assessed samples (and further interstitial samples) from Units D, C and B from boreholes **WA2011_BH1109** and **WA2011_BH112**, is recommended. The requirements for analysis for each type of environmental remains (pollen, diatoms, foraminifera, ostracods, waterlogged plants, charcoal, molluscs and insects is set out in the individual Appendices (**Appendices 4** to **8**)

6.1.17. Whilst it is not within the remit of this report, it is noted that remains of maritime activities (wooden vessels) from the Mesolithic onwards may be preserved within the sediments on scheme area (Units D, C and B). A relatively recent (late 19th Century) shipwreck, the *Trio* is preserved within alluvial sediments *c.*1km southeast of the scheme area (Wessex Archaeology 2010).

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APPENDIX 1: BOREHOLE TEST PIT AND CPT LOCATIONS

ID	Easting	Northing	m aOD	Reference
WA2011_BH109	324603	145111	5.72	CJ Associates (2011a)
WA2011_BH110	324659	144989	5.8	CJ Associates (2011a)
WA2011_BH111	324763	144821	5.75	CJ Associates (2011a)
WA2011_BH112	324854	144637	5.65	CJ Associates (2011a)
BPC2011_BH101	324859	145144	5.85	CJ Associates (2011b)
BPC2011_BH102	324688	145103	5.88	CJ Associates (2011b)
BPC2011_BH103	324561	145209	5.77	CJ Associates (2011b)
BPC2011_BH104	325858	144849	5.84	CJ Associates (2011b)
BPC2011_BH105	324974	144397	5.73	CJ Associates (2011b)
BPC2011_BH106	324381	144440	5.63	CJ Associates (2011b)
BPC2011_BH107	323791	144627	5.57	CJ Associates (2011b)
BPC2011_BH108	323786	145313	6.03	CJ Associates (2011b)
BPC2011_TP101	324724	145399	2.47	CJ Associates (2011c)
BPC2011_TP102	324720	145283	3.48	CJ Associates (2011c)
BPC2011_TP103	324786	145086	5.69	CJ Associates (2011c)
BPC2011_TP104	324605	145108	5.7	CJ Associates (2011c)
BPC2011_TP105	324965	144936	5.75	CJ Associates (2011c)
BPC2011_TP106	325319	144916	5.93	CJ Associates (2011c)
BPC2011_TP107	324662	144987	5.72	CJ Associates (2011c)
BPC2011_TP108	324762	144819	5.66	CJ Associates (2011c)
BPC2011_TP109	324853	144634	5.63	CJ Associates (2011c)
BPC2011_TP110	324718	144659	5.52	CJ Associates (2011c)
BPC2011_TP111	324439	144679	5.77	CJ Associates (2011c)
BPC2011_TP112	324342	145034	5.64	CJ Associates (2011c)
BPC2011_TP113	324216	145064	5.81	CJ Associates (2011c)
BPC2011_TP114	324227	144605	5.51	CJ Associates (2011c)
BPC2011_TP115	325593	144830	5.89	CJ Associates (2011c)
EA2009_BH1	324689	144785	5.65	Fugro (2009)
EA2009_TP1	323781	145452	6.45	Fugro (2009)
EA2009_TP2	324300	144775	5.45	Fugro (2009)
EA2009_TP3	324466	145195	6.05	Fugro (2009)
EA2009_TP5	325012	144841	5.75	Fugro (2009)
EA2009_TP8	325437	145091	5.8	Fugro (2009)
BPC2011_CPT101				Lankelma (2011)
BPC2011_CPT101A				Lankelma (2011)
BPC2011_CPT102				Lankelma (2011)
BPC2011_CPT102R				Lankelma (2011)
BPC2011_CPT103				Lankelma (2011)
BPC2011_CPT104				Lankelma (2011)
BPC2011_CPT105				Lankelma (2011)
BPC2011_CPT105A				Lankelma (2011)
BPC2011_CPT106				Lankelma (2011)
BPC2011_CPT106A				Lankelma (2011)
BPC2011_CPT107				Lankelma (2011)
BPC2011_CPT108				Lankelma (2011)
BPC2011_CPT109				Lankelma (2011)
BPC2011_CPT110				Lankelma (2011)
BPC2011_CPT111				Lankelma (2011)
BPC2011_CPT112				Lankelma (2011)

BPC2011_CPT112A				Lankelma (2011)
BPC2011_CPT113				Lankelma (2011)
BPC2011_CPT113A				Lankelma (2011)
BPC2011_CPT114				Lankelma (2011)
BPC2011_CPT115				Lankelma (2011)
BPC2011_CPT115A				Lankelma (2011)
BPC2011_CPT116				Lankelma (2011)
BPC2011_CPT117				Lankelma (2011)
BPC2011_CPT118				Lankelma (2011)
BPC2011_CPT118A				Lankelma (2011)
BPC2011_CPT119				Lankelma (2011)
BPC2011_CPT120				Lankelma (2011)
BPC2011_CPT120A				Lankelma (2011)
BPC2011_CPT120B				Lankelma (2011)
BPC2011_CPT120C				Lankelma (2011)
BPC2011_CPT121				Lankelma (2011)
BPC2011_CPT121A				Lankelma (2011)
BPC2011_CPT122				Lankelma (2011)
BPC2011_CPT122A				Lankelma (2011)
BPC2011_CPT123				Lankelma (2011)
BPC2011_CPT123A				Lankelma (2011)
BPC2011_CPT124				Lankelma (2011)
BPC2011_CPT124A				Lankelma (2011)
BPC2011_CPT125				Lankelma (2011)
BPC2011_CPT125A				Lankelma (2011)
BPC2011_CPT126				Lankelma (2011)

APPENDIX 2: GEOARCHAEOLOGICAL DESCRIPTIONS

Borehole WA_BH109

Depth mbGL		Depth mOD		Sediment description, sample type - bag (b), core (c) and pot (p)	Unit
from	to	from	to		
0	0.5	5.72	5.22	(b) 10YR 3/2 Very dark greyish brown slightly sandy silty clay. Sand is fine grained. Wet sticky. Grass at top. Block structure. Modern roots/live worms. ***Modern soil***	Aii
0.5	0.72	5.22	5	(b) 10YR 4/2 Dark greyish brown silty clay. Wet. Compact. Mottled 50% orange. 5% pores Occasional to moderate roots. Feint laminated horizontal structure. Occasional manganese precipitate. ***Gley soil***	Bi
0.72	1.59	5	4.13	GAP	
1.59	1.92	4.13	3.8	(c) 10YR 4/2 Dark greyish brown silty clay. Wet. Compact. Mottled 50% orange. 5% pores. .Massive. Occasional manganese precipitate. ***Gley soil***	Bi
1.92	2.05	3.8	3.67	GAP	
2.05	2.15	3.67	3.57	(c)10YR 4/2 Dark greyish brown silty clay with modern roots/organics, ***disturbed/redrill***	Bi
2.15	2.42	3.57	3.3	(c) 10YR 4/1 Dark grey silty clay. Waterlogged. Stiff. Feint horizontal laminar structure delineated by organics including Phragmites sp. and organic remains (2.36 to 2.39m). ***Estuarine alluvium***	Bii
2.42	2.51	3.3	3.21	GAP	
2.51	2.93	3.21	2.79	(c) 2.5Y 5/1 Grey silty clay. Rapidly oxidises brown upon aerial contact. Wet. Stiff. Massive. Occasional organic inclusions (at 2.41m). ***Estuarine alluvium***	Bii
2.93	3.02	2.79	2.7	GAP	
3.02	3.44	2.7	2.28	2.5Y 4/1 Grey clayey silt. Wet, soft. Frequent organics (mostly brown/black degraded *Phragmites* sp.). Massive. ***Estuarine alluvium***	Bii
3.44	3.51	2.28	2.21	GAP	
3.51	3.93	2.21	1.79	(c)2.5Y 4/1 Grey slightly clayey silt. Wet. Massive. Vertical roots/root and?stem holes especially from 3.65 to 3.93. Frequent organic remains. ***Estuarine alluvium/marsh***	Bii
3.93	4.02	1.79	1.7	GAP	
4.02	4.12	1.7	1.6	(c) Mixed: 2.5Y 5/1 Grey clayey silt. Wet. Massive/10YR 2/1 Very dark brown peat. Very frequent plant remains including *Phragmites* sp. ***Disturbed/redrill***	Bii
4.12	4.39	1.6	1.33	(c) 10YR 2/1 Very dark brown peat. Very frequent Phragmites sp. Horizontal bands of 10YR 4/1 Dark grey organic/humic silt at 4.22 to 4.24, 4.30 to 4.34m. 2cm boundary. ***Phragmites peat***	C
4.39	4.44	1.33	1.28	(c) 5Y 5/1 Grey silty clay. Wet. Stiff/Compacted. Frequent organics/reeds. Horizontally bedded laminar structure. ***Estuarine alluvium***	C
4.44	4.56	1.28	1.16	GAP	
4.56	4.72	1.16	1	(c) Mixed: 5Y 5/1Grey organic clayey silt/Brown peat and wax. ***Disturbed/redrill.***	C
4.72	4.94	1	0.78	(c) 5Y 5/1 Grey silty clay. Wet. Stiff. Occasional degraded organic remains and roots throughout. Feint microlaminar horizontally bedded structure visible where dried. ***Estuarine alluvium***	C
4.94	5	0.78	0.72	GAP	
5	5.1	0.72	0.62	(p)10YR 2/1 Black peat. Compacted. Very frequent plant remains (often brown in colour), horizontally bedded including *Phragmites* sp.. ***Phragmites peat*** (note:top of pot assumed to be at 5m below GL.)	C
5.1	5.51	0.62	0.21	GAP (assumed peat from drillers log)	
5.51	5.94	0.21	-0.22	(c) 5Y 5/1 Grey slightly clayey silt. Wet. Soft. Feint microlaminar horizontally bedded structure noted where sediment has dried.. Moderate degraded organics and root holes noted. Well preserved large vertically delineated root at 5.88 to 5.92m. ***Estuarine alluvium***	D

5.94	6	-0.22	-0.28	(c) 5Y 4/1 Grey slightly clayey silt. Wet. Soft. Very frequent well preserved organics and ?roots. Some organics are horizontally bedded. ***Estuarine alluvium***	D
6	6.02	-0.28	-0.3	GAP	
6.02	6.43	-0.3	-0.71	(c) 5Y 4/1 Grey slightly clayey silt. Wet. Soft. Very frequent well preserved organics and ?roots, especially from 6.52 to 6.70m. Some organics are horizontally bedded. ***Estuarine alluvium***	D
6.43	7.01	-0.71	-1.29	GAP	
7.01	7.12	-1.29	-1.4	(c) Dark grey gravelly slightly clayey fine sandy silt. Wet. Soft. Occasional small gravel to 4mm diameter including sandstone. Mixed with lighter grey silt. ***Disturbed/redrill***	D
7.12	7.18	-1.4	-1.46	Disturbed mix of above and below.	
7.18	7.44	-1.46	-1.72	(c) Grey silty clay. Stiff. Wet. Mottled darker/lighter clay. Massive. Occasional gravel including subrounded limestone and sandstone (at 7.18 to 7.23, 60mm diameter sandstone cobble) and small. Occasional black/brown degraded organics. ***Periglacial soil/ bedrock mix***	H
7.44	7.5	-1.72	-1.78	GAP	
7.5	8	-1.78	-2.28	(p) 5Y 6/1, 5Y 5/1 Grey slightly gravelly sandy silt. Wet. Soft. Slightly darker "humic" bands. Gravel is concreted lumps of ?limestone grit up to 20mm diameter. Sample contaminated with modern organics including grass. ***Periglacial soil/ bedrock mix***	H
8	8.8	-2.28	-3.08	(p) 5Y 5/1, 5Y 4/1 Dark grey slightly gravelly sandy silt. Gravel is subrounded up to 4mm diameter including concreted limestone, darker "organic" layers/ silty layers visible. Occasional contamination by recent organic material including grass. ***Periglacial soil/ bedrock mix***	H

Borehole WA_BH110

Depth mbGL		Depth mOD		Sediment description, sample type - bag (b), core (c) and pot (p)	Unit
from	to	from	to		
0.62	0.85	5.18	4.95	(c) 10YR 4/2 Greyish brown slightly sandy clayey silt. Siff. Massive. Mottled grey/brown (50:50). Micropores c. 5%. Moderate roots especially (0.62 to 0.67). Disturbed by wax intrusion. ***Gley soil***	Bi
0.85	1.08	4.95	4.72	GAP	
1.08	1.42	4.72	4.38	(c) 10YR 4/2 Greyish brown clayey silt. Stiff. Massive. Mottled grey/brown (15:85) Micropores c. 5%. Occasional modern roots. Manganeses precipitate occasional. Occasional small gastropods. Grey around root holes. ***Gley soil***	Bi
1.42	1.6	4.38	4.2	Mixed brown silty clay/grass. ***Disturbed by drilling.***	
1.6	1.93	4.2	3.87	(c) 10YR 3/2 Very dark greyish brown silty clay. Stiff.Massive. Mottled grey/brown (10:90). Vertical root holes, grey. Occasional to moderate small gastropods. 3% micropores. Slightly blocky structure. ***Gley soil***	Bi
1.93	2.02	3.87	3.78	GAP	
2.02	2.42	3.78	3.38	10YR 4/1 Dark grey silty clay. Soft to firm. Occasional organic remains ?roots (at 2.54m). Frequent root holes. Mottled grey/brown (60:40). Micropores c.3%. Feint laminar horizontally bedded structure apparent. ***Gley soil***	Bi
2.42	2.54	3.38	3.26	GAP	
2.54	2.65	3.26	3.15	(c) Brown clay/wax. Disturbed by drilling.	
2.65	2.86	3.15	2.94	(c) 10YR 4/2 Dark greyish brown silty clay. Soft to firm. Occasional roots. Moderate root holes. S% micropores. Motteld grey/brown (25:75). Slightly blocky structure. 1.5cm boundary. ***Gley soil***	Bi
2.86	2.95	2.94	2.85	(c) 10YR 5/1 Grey slightly sandy silty clay. Sand is fine grained. Soft to firm. Microlaminar horizontally bedded structure. 10mm thick peaty organic band at 2.89m. ***Organic estuarine alluvium***	Bii
2.95	3.07	2.85	2.73	GAP	
3.07	3.42	2.73	2.38	(c) 10YR 4/2 Dark greyish brown silty clay. Firm/Stiff. Feint microlaminar horizontally bedded structure. Slightly disturbed from 3.07 to 3.10m Occasional black organic inclusions. ***Estuarine alluvium***	
3.42	3.53	2.38	2.27	GAP	

3.53	3.75	2.27	2.05	10YR 4/1 Dark grey silty clay. Soft to firm. Frequent organics including horizontally bedded reeds especially from 3.70 to 3.75m. Vertical/diagonal roots occasional. 50mm boundary. ***Estuarine alluvium***	Bii
3.75	3.82	2.05	1.98	(c) 10YR 2/1 Black peat. Slightly disturbed. Visible horizontally bedde plant re,aind including *Phragmites* sp. 40mm boundary. ***Phragmites peat***	C
3.82	3.92	1.98	1.88	(c) 10YR 4/1 Dark grey silty clay. Frequent organic, especially from 3.82 to 3.89m including horizontally bedded reeds and roots. ***Estuarine alluvium***	C
3.92	4.02	1.88	1.78	GAP	
4.02	4.1	1.78	1.7	(c) 10YR 4/1 Dark grey silty clay. Soft to firm. Contains suspiciously shaped "tubular" and rounded organic peat clay inclusions up to 80mm in length.***Estuarine alluvium ?Disturbed by drilling?***	C
4.1	4.14	1.7	1.66	(c) 10YR 2/1 Black peat/10YR 4/1 Dark grey silty clay. Disturbed, around a diagonal fissure and contains frequent ostracods. ***Peat, disturbed by drilling***	C
4.14	4.34	1.66	1.46	10YR 4/1 Dark grey silty clay including round and tubular blobs of 10YR 2/1 black peat uo to 120mm in length. One gastropod ?*Limnaea* at 4.25m.(BOUNDARY) ***Estuarine alluvium and reworked peat***	C
4.34	4.43	1.46	1.37	10YR 2/1 Black peat. Visible horzontally bedded plant remains including *Phragmites* sp. and some grey clay (intrusive from drilling?)***Phragmites peat***	C
4.43	4.52	1.37	1.28	GAP	
4.52	4.79	1.28	1.01	(c) 10YR 4/1 Dark grey clayey silt/ 10YR 2/1 Black peaty clay in blobs and layers. Some horizontal structure apparent. Soft. Wet. 20mm boundary/fissure. ***?Disturbed by drilling/ Estuarine alluvium***	C
4.79	4.93	1.01	0.87	(c) 10YR 5/1 Grey silty clay. Stiff Some feint horizontal bedding noted. Occasional organics and peat inclusion. Sulphurous odour. ***Estuarine alluvium***	C
4.93	5.01	0.87	0.79	GAP	
5.01	5.26	0.79	0.54	(c) 10YR 5/1 Grey silty clay. Soft to firm. Massive. Occasional small peaty organic inclusions. Abrupt 0mm boundary. ***Estuarine alluvium.***	
5.26	5.42	0.54	0.38	(c) 10YR 2/1 Black peat. Very frequent organics including horizontally bedded reeds, *Phragmites* sp. especially from 5.32 to 5.42m. ***Phragmites peat***	C
5.42	5.52	0.38	0.28	GAP	
5.52	5.94	0.28	-0.14	(c) 10YR 3/2 Brown, grading to 10YR 4/3 Brown clayey gravelly sand. Sand is fine, medium and coarse, predominantly medium grained. Slightly sorted. Gravel is subrounded to subangular up to 65mm diameter and comprising a range of lithologies including sandstone and limestone. Occasional black organics ?roots from 5.52 to 5.78. Fining upwards.***Bedrock/soil/periglacial?***	H
5.94	6	-0.14	-0.2	GAP	
6	6.1	-0.2	-0.3	Mixed green, light grey, brown gravelly clayey sand. Disturbed. Occasional black organic inclusions. Sand is medium grained. Occasiona subangular tlo subrounded gravel up to 40mm indiameter including sandstone, limestone and quartz. ***?Bedrock/periglacial***	H
6.1	6.5	-0.3	-0.7	GAP	
6.5	7	-0.7	-1.2	2.5Y 4/1 Dark grey sandy silt. Wet. Soft. Sand is fine to medium grained and streaked with light grey clay/silt and occasonal organics. ***?Bedrock/periglacial***	H
7	7.5	-1.2	-1.7	2.5Y 4/1 Dark grey gravelly sandy silt. Wet. Soft. Occasional gravel, subrounded, up to 35mm diameter including sandstone. Light grey clay streaks. "Organic" look". ***?Bedrock/periglacial***	H
7.5	8.2	-1.7	-2.4	2.5Y 4/1 Dark grey gravelly sandy silt. Wet. Soft. Ver occasional gravel, subrounded, up to 10mm diameter including sandstone. Light grey clay streaks. "Organic" look". ***?Bedrock/periglacial***	H

Borehole WA_BH111

Depth mbGL		Depth mOD		Sediment description, sample type - bag (b), core (c) and pot (p)	Unit
from	to	from	to		

0.05	0.19	5.7	5.56	(c)10YR 3/3 Dark brown humic silt. Very frequent roots. 15% micropores. Block structure. 80mm boundary. ***Modern humic gley soil***	Aii
0.19	0.31	5.56	5.44	(c) 10YR 4/2 Dark greyish brown clayey silt. Stiff Moderate to frequent roots. 5 %micropores. Mottled grey/brown (65:35) increasing brown mottling up profile. Manganese precipitate. ***Gley soil***	Bi
0.31	0.64	5.44	5.11	GAP	
0.64	0.92	5.11	4.83	(c) 10YR 4/2 Dark greyish brown clayey silt. Stiff Moderate roots. 3% micropores. Mottled grey/brown (65:35) increasing brown mottling up profile. Manganese precipitate. ***Gley soil***	Bi
0.92	1.02	4.83	4.73	Gap	
1.02	1.43	4.73	4.32	(c) 10YR 4/2 Dark greyish brown clayey silt. Stiff Moderate roots. 3% micropores. Mottled grey/brown (35:65). Manganese precipitate. ***Gley soil***	Bi
1.43	1.5	4.32	4.25	GAP	
1.5	2	4.25	3.75	(b) 10YR 4/2 Dark greyish brown clayey silt. Stiff Moderate roots. 3% micropores. Mottled grey/brown (60:40). Manganese precipitate. ***Gley soil***	Bi
2	2.01	3.75	3.74	GAP	
2.01	2.44	3.74	3.31	(c) 10YR 4/2 Dark greyish brown clayey silt. Stiff. 3% micropores. Mottled grey/brown (50:50) , increasingly grey down profile. Organic spot at 2.38m. ***Gley soil***	Bi
2.44	2.52	3.31	3.23	GAP	
2.52	2.94	3.23	2.81	(c) 10YR 4/1 Dark grey clayey silt. Soft. Wet. Moderate organic black spots. Turns brown upon aerial exposure. Feint horizontal microlaminar structure. ***Estuarine alluvium***	Bii
2.94	3.11	2.81	2.64	GAP	
3.11	3.42	2.64	2.33	(c) 10YR 4/1 Dark grey clayey silt. Soft. Wet. Frequent organic black spots. Turns brown upon aerial exposure. Feint horizontal microlaminar structure. Slightly disturbed by drilling. ***Estuarine alluvium***	Bii
3.42	3.52	2.33	2.23	GAP	
3.52	3.92	2.23	1.83	(c) 10YR 4/1 Dark grey clayey silt. Soft. Wet. Frequent organic black spots. Peaty/organic layer 10mm in thickness at 3.67m. Turns brown upon aerial exposure. Feint horizontal microlaminar structure. Slightly disturbed by drilling. ***Estuarine alluvium***	C
3.92	4.03	1.83	1.72	GAP	
4.03	4.1	1.72	1.65	(c) 10YR 4/1 Dark grey slightly silty sand. Sand is medium grained. Wet. Soft. Moderate black organics ?roots. Slightly sorted. Occasional small gravel subrounded to subangular up to 12mm diametert including sandtone. 20mm wavy boundary. ***Transition***	C
4.1	4.42	1.65	1.33	(c) 10YR 3/3 Clayey sand. Wet stiff. Moderate large vertical roots. Mottled 15% grey. Blocky structure. Sand is fine medium and coarse, predominantly medium grained.. Occasional gravel subrounded to subangular up to 20mm diameter including quartz and sandstone**.** ***Alluvial soil***	C
4.42	4.52	1.33	1.23	GAP	
4.52	4.89	1.23	0.86	(c) 7.5YR 4/3 slightly clayey gravelly sandWet. Soft to firm. Sand is fine medium and coarse, predominantly medium grained. Sorted.. Gravel is subrounded to subangular up to 80mm diameter frequent especially from 4.52 to 4.63m. Occasional organic patches. Coarsening upwards. ***Disturbed. ?Glaciofluvial alluvium***	G
4.89	6	0.86	-0.25	GAP	
6	6.5	-0.25	-0.75	2.5Y 5/3 Light olive brown clay. Stiff. Wet. Mottled with 2mm thick grey clay lenses/layers. ***?Bedrock/periglacial***	H
6.5	7	-0.75	-1.25	2.5Y 5/3 Light olive brown clay. Stiff. Wet. Mottled with 2mm thick grey clay lenses/layers. ***?Bedrock/periglacial***	H
7	7.5	-1.25	-1.75	2.5Y 5/3 Light olive brown clay. Stiff. Wet. Mottled with 2mm thick grey clay lenses/layers. Contains occasional small pebbles/organics ?Contaminated. ***?Bedrock/periglacial***	H
7.5	8	-1.75	-2.25	2.5Y 5/3 Light olive brown clay. Stiff. Wet. Up to 10mm thick grey clay lenses/layers. Occasional small angular limestone up to 5mm diameter. ***?Bedrock/periglacial***	H

8	9	-2.25	-3.25	2.5Y 5/3 Light olive brown silty clay. Stiff. Wet. Up to 10mm thick grey clay lenses/layers. Occasional small angular limestone up to 5mm diameter. ***?Bedrock/periglacial***	H
9	9.6	-3.25	-3.85	2.5Y 5/3 Light olive brown silty clay. Stiff. Wet. Up to 10mm thick grey clay lenses/layers. Occasional small angular limestone up to 5mm diameter. ***?Bedrock/periglacial***	H

Borehole WA_BH112

Depth mbGL		Depth mOD		Sediment description, sample type - bag (b), core (c) and pot (p)	Unit
from	to	from	to		
0.08	0.32	5.57	5.33	(c) 10YR 4/2 Dark greyish brown silty clay. Stiff. Waterlogged. Blocky structure. Frequent roots/ degraded plant remains. Humic. ***Modern humic gley soil***	Aii
0.32	0.51	5.33	5.14	GAP	
0.51	0.94	5.14	4.71	(c) 10YR 4/2 Dark greyish brown silty clay. Stiff. Waterlogged. Grey/brown (50:50) mottled appearance. 5% micropores. Slightly blocky structure. Occasional roots. ***Gley soil***	Bi
0.94	1.02	4.71	4.63	GAP	
1.02	1.44	4.63	4.21	10YR 4/2 Dark greyish brown silty clay. Stiff. Waterlogged. Grey/brown (50:50) mottled appearance. 5% micropores. Slightly blocky structure. Occasional roots. ***Gley soil***	Bi
1.44	1.53	4.21	4.12	GAP	
1.53	1.91	4.12	3.74	(c) 10YR 4/2 Dark greyish brown silty clay. Stiff. Waterlogged. Grey/brown (10:90) mottled appearance. 5% micropores. Slightly blocky structure. Very occasional roots. ***Gley soil***	Bi
1.91	2.09	3.74	3.56	GAP	
2.09	2.4	3.56	3.25	(c) 10YR 4/2 Dark greyish brown silty clay. Wet. Stiff (2.23 to 2.29m disturbed by drilling, with modern organic material present). Mottled grey/brown (35:65). Organic spots throughout frequent between 2.31 and 2.35 (30%). Vertical roots throughout. ***Gley soil***	Bi
2.4	2.52	3.25	3.13	GAP	
2.52	2.94	3.13	2.71	(c) 5Y 4/1 Dark grey silty clay. Frequent vertical root holes throughout. Massive. Feint microlaminar horizontal structure. Oxidises brown upon aerial contact. Slight poprous/ blocky structure. ***Estuarine alluvium with poorly developed soil***	Bii
2.94	3.06	2.71	2.59	GAP	
3.06	3.25	2.59	2.4	(c) Disturbed brown/grey silty clay , mixed including grass. ***Estuarine alluvium disturbed by drilling.***	Bii
3.25	3.4	2.4	2.25	(c) 5Y 4/1 Grey slightly sandy silty clay. Waterlogged. Firm. Vertical roots. Feint laminar horizontal structure. Sand is fine grained. ***Estuarine alluvium***	Bii
3.4	3.59	2.25	2.06	GAP	
3.59	3.64	2.06	2.01	(c) Mixed 5Y 4/1 grey/2.5Y 4/2 Dark greyish brown clayey silt. Wet. Soft. ***Estuarine alluvium disturbed by drilling***	Bii
3.64	3.89	2.01	1.76	(c) 5Y 4/1 Grey silty clay. Waterlogged. Stiff. Frequent plant remains especially from 3.74 to 3.89m. Laminar horizontal bedding delineated by organic remains. Becoming mottled 10 YR 3/2 Dark greyish brown towards base of Unit (3.86m downwards). 6cm boundary. ***Estuarine alluvium with subaerial exposure***	Bii
3.89	3.91	1.76	1.74	(c) 3/1 Dark olive very humic slightly clayey peaty silt. Very frequent horizontally bedded plant remains including *Phragmites* sp. and occasonal wood fragments. ***Phragmites peat with ?transgressive minerogenic sediment.***	C
3.91	4.01	1.74	1.64	GAP	
4.01	4.03	1.64	1.62	5Y 3/1 Very dark grey silty peat. Abundant degraded organic remains including *Phragmites* sp. Wet. Soft. 0.5cm boundary. ***Phragmites peat with ?transgressive minerogenic sediment***	C
4.03	4.08	1.62	1.57	2.5Y 2/1 Black peat. Occasional fine grey silty layers. Abundant degraded and preserved organic remains including *Phragmites* sp. 2cm boundary. ***Phragmites peat***	C

4.08	4.44	1.57	1.21	(c) 5Y 5/1 Grey slightly clayey silt. Wet. Compact. Firm. Moderate organic remains including roots and horizontally bedded *Phragmites* sp. ***Estuarine alluvium***	C
4.44	4.59	1.21	1.06	GAP	
4.59	4.68	1.06	0.97	(c) Mix of 5Y 5/1 Grey clayey silt and 5Y 2.5/1 Black peat. ***Estuarine alluvium. Disturbed/ redrill.***	C
4.68	4.88	0.97	0.77	(c) 5Y 5/1 Grey clayey silt. Wet. Compact. Occasional organics, some horizontally bedded, some roots. Generally massive. ***Estuarine alluvium***	C
4.88	5.15	0.77	0.5	GAP	
5.15	5.43	0.5	0.22	(c) 5Y 4/1 Dark grey very clayey slightly sandy silt. Waterlogged. Stiff. Moderate organics, mostly vertical roots.Massive. ***Estuarine alluvium***	C
5.43	5.51	0.22	0.14	GAP	
5.51	5.6	0.14	0.05	(c) Mix of wax brown peat and grey clay/silt. ***Estuarine alluvium Disturbed redrill***.	C
5.6	5.91	0.05	-0.26	(c) 5Y 4/1 Dark grey clayey silt. Waterlogged. Stiff. Occasional black degraded organics. Massive. ***Estuarine alluvium***	C
5.91	6.01	-0.26	-0.36	GAP	
6.01	6.08	-0.36	-0.43	(c) 10YR 2/2 Very dark brown/10YR 2/1 black peat., 10YR 5/3, (6.06-6.08m) Brown humic slightly clyey silt including frequent ostracods. ***Peat redrilled***	C
6.08	6.28	-0.43	-0.63	(c) 2.5Y 4/1 Dark grey clayey silt. Soft. Wet. Moderate organics including black peat pieces.Massive. 3cm angled boundary. ***Estuarine alluvium***	C
6.28	6.4	-0.63	-0.75	(c) 10YR 2/1 Black peat with brown 10YR 3/2 hroizontally bedded section. Turns black upon aeral exposure. Occasional lenses of grey silty clay at 6.34, 6.38, 6.39, 2 to 3mm in thickness. plant remains are identifiable including Phragmites sp. Boundary 7mm including ostracods. ***Phragmites peat***	C
6.4	6.44	-0.75	-0.79	(c) 5Y 4/1 Dark grey and 10YR2/2 Very dark brown humic clayey silt including ostracods at the upper 6.4 to 6.42 contact. "Peaty" feel. ***?Organic estuarine alluvium***	C
6.44	6.5	-0.79	-0.85	GAP	
6.5	7	-0.85	-1.35	(b) 5Y 4/1 Dark grey gravelly silty sand. Sand is fine, medium and coarse , predominantly medium grained. Gravel is subangular to subrounded up to 65mm in diameter and of a mix of lithologies including mudstone, sandstone, quartz and limestone. Occasional black ?organic patches. ***?Glaciofluvial alluvium***	G
7	7.5	-1.35	-1.85		
7.5	8	-1.85	-2.35	(p) 7.5YR 4/1 Dark grey slightly silty sandy gravel. Wet. Sand is fine medium and coarse grained. Gravel is subrounded to subangular, up to 60mm in diameter and a mix of lithologies including sandstone, mudstone and shale. Some modern contamination within this sample. ***Glaciofluvial alluvium***	G
8	8.5	-2.35	-2.85	(p) 7.5YR 4/1 Dark grey slightly silty sandy gravelGravel is subrounded to subangular, up to 40mm in diameter and a mix of lithologies including sandstone, mudstone, shale and quartz. ***Glaciofluvial alluvium***	G
8.5	9	-2.85	-3.35	(p) 7.5YR 4/1 Dark grey slightly silty sandy gravel. Gravel is subrounded to subangular, up to 40mm in diameter and a mix of lithologies including sandstone, mudstone, shale and quartz. ***Glaciofluvial alluvium***	G
9	9.1	-3.35	-3.45	GAP	
9.1	9.5	-3.45	-3.85	(p) 2.5Y 3/1 Very dark grey clayey silt. Dark organic patches. Some feint organics visible. ***?Contaminated ?Alluvium***	H
9.5	10	-3.85	-4.35	(p) 2.5Y 3/1 Very dark grey clayey silt. Dark organic patches. Some feint organics visible. ***?Contaminated ?Alluvium***	H
10	10.5	-4.35	-4.85	(p) 2.5Y 3/1 Very dark grey clayey silt. Dark organic patches. Some feint organics visible. ***?Contaminated ?Alluvium***	H
10.5	11	-4.85	-5.35	(p) 2.5Y 3/1 Very dark grey slightly clayey sandy silt. Sand is fine, medium and coarse, predominantly fine grained. Occasional small subangular to subrounded gravel up to 4mm diameter includin limestone. "Organic" black patches. ***Alluvium***	H
11	11.5	-5.35	-5.85	(p) 2.5Y 3/1 Very dark grey clayey silt. Massive. Dark black "organic"patches. Occasinal small gravel. ***Alluvium***	H

11.5	12	-5.85	-6.35	(p) 2.5Y 3/2 Very dark greyish brownbclayey silt. Organic look, Granular inclusions up to 2mm diameter of concreted clay/silt. Wet. Soft. ***Alluvium***	H
12	12.3	-6.35	-6.65	(p) 2.5Y 3/1 Very dark grey slightly sandy clayey silt. Wet. Soft. Organic black patches. ***Alluvium/soil***	H

APPENDIX 3: RADIOCARBON DATING

Dr Chris J. Stevens

Introduction

Suitable material from four waterlogged samples, two from each Borehole BH109 and BH112, was extracted for radiocarbon dating. The material in all cases were fragments of common reed (*Phragmites australis*) stems.

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

Results

The radiocarbon determinations were calibrated using OxCal 4.1.7 (Bronk Ramsey 2001; 2009) and the IntCal09 calibration curve (Reimer *et al.* 2009) and are quoted in the form recommended by Mook (1986) with the end points rounded outward to 10 years. (**Table 1; Figure 1**).

All four of the results indicated that the material had accumulated over one to two millennia during the Early to Late Neolithic between 3950 to 2340 cal. BC.

References

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Depth aOD	Identification	Laboratory Code	$\delta^{13}C$	Date BP	calibration BC (2 sig. 95.4%)	calibration BP (2 sig. 95.4%)
BOREHOLE BH109						
1.44m	*Phragmites* stems	SUERC-34106	-27.1‰	3980±35	2580-2340 cal. BC	4530-4290 cal. BP
0.67m	*Phragmites* stems	SUERC-34105	-27.5‰	5020±35	3950-3700 cal. BC	5900-5650 cal. BP
BOREHOLE BH112						
1.74	cf. *Phragmites* stems	SUERC-34108	-26.8‰	4145±35	2880-2620 cal. BC	4830-4560 cal. BP
1.60	*Phragmites* stems	SUERC-34107	-26‰	4715±35	3640-3370 cal. BC	5590-5320 cal. BP

Table 1 Radiocarbon determinations, all from common reed (Phragmites australis) stems, within Boreholes BH109 and BH112

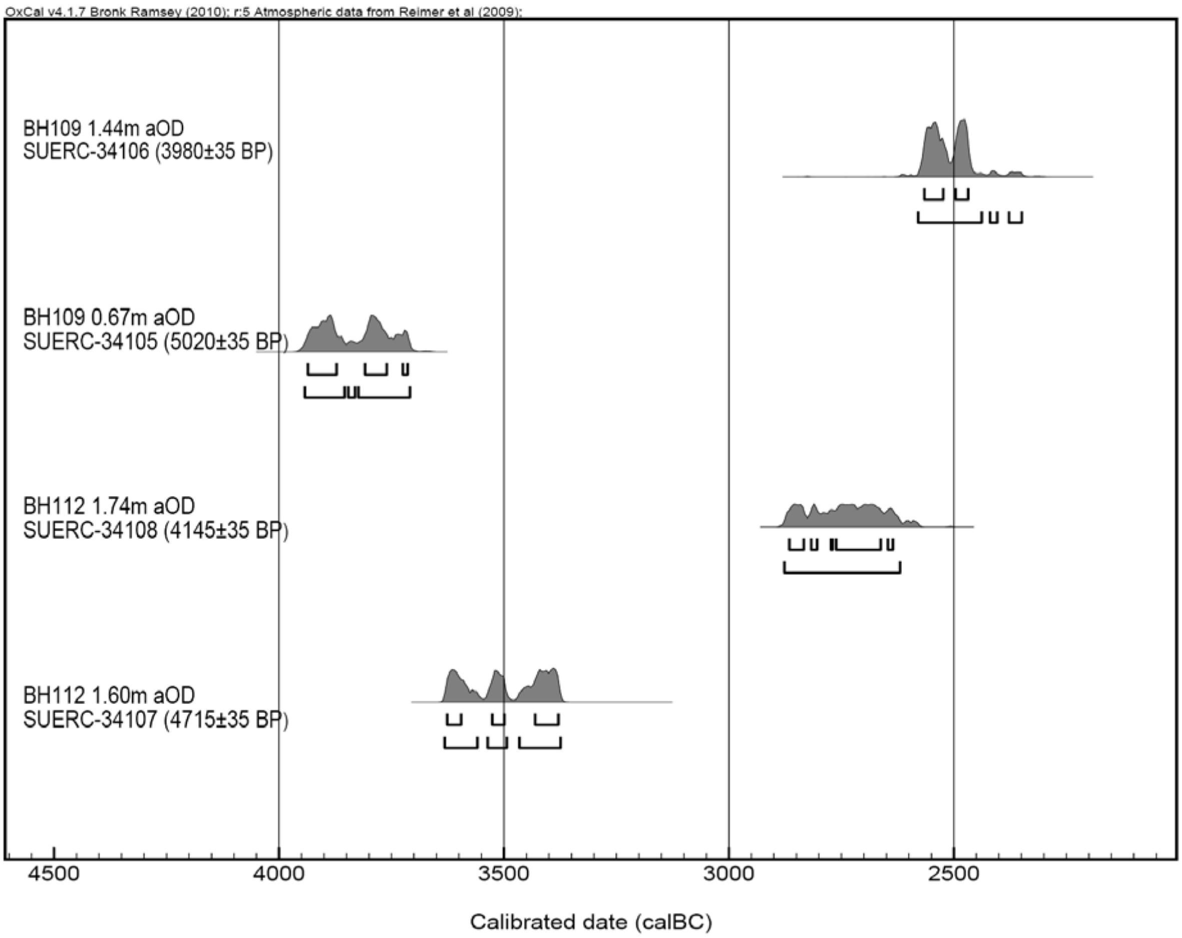


Figure 1 Probability distribution for dates

APPENDIX 4: OSL DATING

Dr P.S. Toms, 29 June 2011
University of Gloucester

Scope of Report

This is a standard report of the Geochronology Laboratories, University of Gloucestershire. In large part, the document summarises the processes, diagnostics and data drawn upon to deliver the data outlined in Table 1. A conclusion on the analytical validity of each sample's optical age estimate is expressed in Table 2; where there are caveats, the reader is directed to the relevant section of the report that explains the issue further in general terms

Field Code	Lab Code	Location	Overburden (m)	Grain size (µm)	Moisture content (%)	NaI γ-spectrometry (in situ)			γ D_r ($Gy.ka^{-1}$)	Ge γ-spectrometry (lab based)			α D_r •	β D_r •	Cosmic D_r ($Gy.ka^{-1}$)	Total D_r ($Gy.ka^{-1}$)			
						K (%)	Th (ppm)	U (ppm)		K (%)	Th (ppm)	U (ppm)							
BH109 1.70-1.78 m	GL10080	51°N, 3°W, 5m	1.74	5-15	25 ± 6	-	-	-	0.95 ± 0.10	2.45 ± 0.11	10.57 ± 0.61	1.85 ± 0.10	0.35 ± 0.05	1.76 ± 0.20	0.16 ± 0.02	3.22 ± 0.23	220	8.3 ± 0.3	2.6 ± 0.2 (0.2)
BH109 7.35-7.40 m	GL10081	51°N, 3°W, 5m	7.38	5-15	25 ± 6	-	-	-	1.14 ± 0.12	1.99 ± 0.09	9.75 ± 0.61	5.46 ± 0.23	0.60 ± 0.08	1.86 ± 0.21	0.07 ± 0.01	3.68 ± 0.25	220	546 ± 73	149 ± 22 (21)
BH112 0.70-0.80 m	GL10082	51°N, 3°W, 5m	0.75	5-15	28 ± 7	-	-	-	0.90 ± 0.10	2.41 ± 0.10	10.33 ± 0.59	1.86 ± 0.10	0.33 ± 0.05	1.65 ± 0.21	0.18 ± 0.02	3.07 ± 0.24	240	5.6 ± 0.2	1.8 ± 0.2 (0.1)
BH112 6.20-6.26 m	GL10083	51°N, 3°W, 5m	6.23	5-15	18 ± 4	-	-	-	1.05 ± 0.09	2.37 ± 0.10	10.42 ± 0.61	2.07 ± 0.11	0.41 ± 0.04	1.91 ± 0.18	0.08 ± 0.01	3.45 ± 0.20	220	14.3 ± 0.6	4.2 ± 0.3 (0.2)

Table 1 D_r, D_e and Age data of submitted samples. Uncertainties in age are quoted at 1σ confidence, are based on analytical errors and reflect combined systematic and experimental variability and (in parenthesis) experimental variability alone (see 6.0). Blue indicates samples with accepted age estimates, red, age estimates with caveats (see Table 2).

Generic considerations	Field Code	Lab Code	Sample specific considerations
Absence of *in situ* γ spectrometry data (see 4.0)	BH109 1.70-1.78 m	GL10080	None
	BH109 7.35-7.40 m	GL10081	Overdispersion of repeat regenerative-dose data (see 3.1.4) Dose response of some aliquots saturated; reported age should be considered a minimum value
	BH112 0.70-0.80 m	GL10082	Overdispersion of repeat regenerative-dose data (see 3.1.4) Possible pedoturbation (see 3.2.2 and 4.0)
	BH112 6.20-6.26 m	GL10083	None

Table 2 Analytical validity of sample suite age estimates and caveats for consideration

1.0 Mechanisms and principles

Upon exposure to ionising radiation, electrons within the crystal lattice of insulating minerals are displaced from their atomic orbits. Whilst this dislocation is momentary for most electrons, a portion of charge is redistributed to meta-stable sites (traps) within the crystal lattice. In the absence of significant optical and thermal stimuli, this charge can be stored for extensive periods. The quantity of charge relocation and storage relates to the magnitude and period of irradiation. When the lattice is optically or thermally stimulated, charge is evicted from traps and may return to a vacant orbit position (hole). Upon recombination with a hole, an electron's energy can be dissipated in the form of light generating crystal luminescence providing a measure of dose absorption.

Herein, quartz is segregated for dating. The utility of this minerogenic dosimeter lies in the stability of its datable signal over the mid to late Quaternary period, predicted through isothermal decay studies (e.g. Smith *et al*., 1990; retention lifetime 630 Ma at 20°C) and evidenced by optical age estimates concordant with independent chronological controls (e.g. Murray and Olley, 2002). This stability is in contrast to the anomalous fading of comparable signals commonly observed for other ubiquitous sedimentary minerals such as feldspar and zircon (Wintle, 1973; Templer, 1985; Spooner, 1993)

Optical age estimates of sedimentation (Huntley *et al*., 1985) are premised upon reduction of the minerogenic time dependent signal (Optically Stimulated Luminescence, OSL) to zero through exposure to sunlight and, once buried, signal reformulation by absorption of litho- and cosmogenic radiation. The signal accumulated post burial acts as a dosimeter recording total dose absorption, converting to a chronometer by estimating the rate of dose absorption quantified through the assay of radioactivity in the surrounding lithology and streaming from the cosmos.

$$\text{Age} = \frac{\text{Mean Equivalent Dose } (D_e, \text{ Gy})}{\text{Mean Dose Rate } (D_r, \text{ Gy.ka}^{-1})}$$

Aitken (1998) and Bøtter-Jensen et al. (2003) offer a detailed review of optical dating.

2.0 Sample Preparation

A total of four sediment samples were submitted from two vibrocores for Optical dating (Table 1). The cores were bisected in daylight to identify the apposite sampling position in consultation with J. Russell, Wessex Archaeology. To preclude optical erosion of the datable signal prior to measurement both lengths of each core were moved into and prepared under controlled laboratory illumination, provided by Encapsulite RB-10 (red) filters. Sediment exposed to daylight during bisection was removed from each sample position to a depth of 10 mm from each bisected face. The remaining sediment was then sectioned into a 50-100 mm length (depending on unit thickness), 40 mm wide sample using aluminium separators to preclude incorporation of material transferred down the core walls during retrieval. Sub-samples of c. 50 g were taken from within each position to establish D_r values.

Each dating sample was then weighed, dried, reweighed and sieved. Fine silt sized quartz, along with other mineral grains of varying density and size, was extracted by sample sedimentation in acetone (<15 µm in 2 min 20 s, >5 µm in 21 mins at 20ºC). Feldspars and amorphous silica were then removed from this fraction through acid digestion (35% H2SiF6 for 2 weeks, Jackson et al., 1976; Berger et al., 1980). Following addition of 10% HCl to remove acid soluble fluorides, grains degraded to <5 µm as a result of acid treatment were removed by acetone sedimentation. Up to 19 aliquots (ca. 1.5 mg) were then mounted on aluminium discs for De evaluation.

All drying was conducted at 40°C to prevent thermal erosion of the time-dependent signal. All acids and alkalis were Analar grade. All dilutions (removing toxic-corrosive and non-minerogenic luminescence-bearing substances) were conducted with distilled water to prevent signal contamination by extraneous particles.

3.0 Acquisition and accuracy of D_e value

All minerals naturally exhibit marked inter-sample variability in luminescence per unit dose (sensitivity). Therefore, the estimation of D_e acquired since burial requires calibration of the natural signal using known amounts of laboratory dose. D_e values were quantified using a single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle 2000; 2003) facilitated by a Risø TL-DA-15 irradiation-stimulation-detection system (Markey *et al.*, 1997; Bøtter-Jensen *et al.*, 1999). Within this apparatus, optical signal stimulation is provided by an assembly of blue diodes (5 packs of 6 Nichia NSPB500S), filtered to 470±80 nm conveying 15 mW.cm^{-2} using a 3 mm Schott GG420 positioned in front of each diode pack. Infrared (IR) stimulation, provided by 6 IR diodes (Telefunken TSHA 6203) stimulating at 875±80nm delivering ~5 mW.cm^{-2}, was used to indicate the presence of contaminant feldspars (Hütt *et al.*, 1988). Stimulated photon emissions from quartz aliquots are in the ultraviolet (UV) range and were filtered from stimulating photons by 7.5 mm HOYA U-340 glass and detected by an EMI 9235QA photomultiplier fitted with a blue-green sensitive bialkali photocathode. Aliquot irradiation was conducted using a 1.48 GBq ^{90}Sr/^{90}Y β source calibrated for multi-grain aliquots of 5-15 µm quartz against the 'Hotspot 800' ^{60}Co γ source located at the National Physical Laboratory (NPL), UK.

SAR by definition evaluates De through measuring the natural signal (Fig. 1) of a single aliquot and then regenerating that aliquot's signal by using known laboratory doses to enable calibration. For each aliquot, 5 different regenerative-doses were administered so as to image dose response. De values for each aliquot were then interpolated, and associated counting and fitting errors calculated, by way of exponential regression (Fig. 1). Weighted (geometric) mean De values were calculated, given sufficient mass, from 12 aliquots using the central age model outlined by Galbraith et al. (1999) and are quoted at 1σ confidence. The accuracy with which De equates to total absorbed dose and that dose absorbed since burial was assessed. The former can be considered a function of laboratory factors, the latter, one of environmental issues. Diagnostics were deployed to estimate the influence of these factors and criteria instituted to optimise the accuracy of De values.

3.1 Laboratory Factors

3.1.1 Feldspar contamination

The propensity of feldspar signals to fade and underestimate age, coupled with their higher sensitivity relative to quartz makes it imperative to quantify feldspar contamination. At room temperature, feldspars generate a signal (IRSL) upon exposure to IR whereas quartz does not. The signal from feldspars contributing to OSL can be depleted by prior exposure to IR. For all aliquots the contribution of any remaining feldspars was estimated from the OSL IR depletion ratio (Duller, 2003). If the addition to OSL by feldspars is insignificant, then the repeat dose ratio of OSL to post-IR OSL should be statistically consistent with unity (Fig. 1 and Fig. 5). If any aliquots do not fulfil this criterion, then the sample age estimate should be accepted tentatively. The source of feldspar contamination is rarely rooted in sample preparation; it predominantly results from the occurrence of feldspars as inclusions within quartz.

3.1.2 Preheating

Preheating aliquots between irradiation and optical stimulation is necessary to ensure comparability between natural and laboratory-induced signals. However, the multiple irradiation and preheating steps that are required to define single-aliquot regenerative-dose response leads to signal sensitisation, rendering calibration of the natural signal inaccurate. The SAR protocol (Murray and Wintle, 2000; 2003) enables this sensitisation to be monitored and corrected using a test dose, here set at 5 Gy (10 Gy for GL10081) preheated to 220°C for 10s, to track signal sensitivity between irradiation-preheat steps. However, the accuracy of sensitisation correction for both natural and laboratory signals can be preheat dependent.

The Dose Recovery test was used to assess the optimal preheat temperature for accurate correction and calibration of the time dependent signal. Dose Recovery (Fig. 2) attempts to quantify the combined effects of thermal transfer and sensitisation on the natural signal, using a precise lab dose to simulate natural dose. The ratio between the applied dose and recovered D_e value should be statistically concordant with unity. For this diagnostic, 6 aliquots were each assigned a 10 s preheat between 180°C and 280°C.

That preheat treatment fulfilling the criterion of accuracy within the Dose Recovery test (Table 1) was selected to generate the final D_e value. Further thermal treatments, prescribed by Murray and Wintle (2000; 2003), were applied to optimise accuracy and precision. Optical stimulation was conducted at 125ºC in order to minimise effects associated with photo-transferred thermoluminescence and maximise signal to noise ratios. Inter-cycle optical stimulation was conducted at 280°C to minimise recuperation.

3.1.3 Irradiation

For all samples having D_e values in excess of 100 Gy, matters of signal saturation and laboratory irradiation effects are of concern. With regards the former, the rate of signal accumulation generally adheres to a saturating exponential form and it is this that limits the precision and accuracy of D_e values for samples having absorbed large doses. For such samples, the functional range of D_e interpolation by SAR has been verified up to 600 Gy by Pawley *et al*. (2010). Age estimates based on D_e values exceeding this value should be accepted tentatively.

3.1.4 Internal consistency

Quasi-radial plots (*cf* Galbraith, 1990) are used to illustrate inter-aliquot D_e variability for natural, repeat regenerative-dose and OSL to post-IR OSL signals (Figs. 3 to 5, respectively). D_e values are standardised relative to the central D_e value for natural signals and applied dose for regenerated signals. D_e values are described as overdispersed when >5% lie beyond $\pm$ 2σ of the standardising value; resulting from a heterogeneous absorption of burial dose and/or response to the SAR protocol. For multi-grain aliquots, overdispersion of natural signals does not necessarily imply inaccuracy. However where overdispersion is observed for regenerated signals, the age estimate from that sample may not be analytically robust. This measure of SAR protocol success at Gloucestershire differs and is more stringent than that prescribed by Murray and Wintle (2000; 2003). They suggest repeat dose ratios should be concordant with the range 0.9-1.1; all samples in this study meet this condition.

3.2 Environmental factors

3.2.1 Incomplete zeroing

Post-burial OSL signals residual of pre-burial dose absorption can result where pre-burial sunlight exposure is limited in spectrum, intensity and/or period, leading to age overestimation. This effect is particularly acute for material eroded and redeposited sub-aqueously (Olley *et al*., 1998, 1999; Wallinga, 2002) and exposed to a burial dose of <20 Gy (e.g. Olley *et al*., 2004), has some influence in sub-aerial contexts but is rarely of consequence where aerial transport has occurred.

Within single-aliquot regenerative-dose optical dating there are two diagnostics of partial resetting (or bleaching); signal analysis (Agersnap-Larsen *et al*., 2000; Bailey *et al*., 2003) and inter-aliquot D_e distribution studies (Murray *et al*., 1995).

Within this study, signal analysis was used to quantify the change in D_e value with respect to optical stimulation time for multi-grain aliquots. This exploits the existence of traps within minerogenic dosimeters that bleach with different efficiency for a given wavelength of light to verify partial bleaching. D_e (t) plots (Fig. 7; Bailey *et al*., 2003) are constructed from separate integrals of signal decay as laboratory optical stimulation progresses. A statistically significant increase in natural D_e (t) is indicative of partial bleaching assuming three conditions are fulfilled. Firstly, that a statistically significant increase in D_e (t) is observed when partial bleaching is simulated within the laboratory. Secondly, that there is no significant rise in D_e (t) when full bleaching is simulated. Finally, there should be no significant augmentation in D_e (t) when zero dose is simulated. Where partial bleaching is detected, the age derived from the sample should be considered a maximum estimate only. However, the utility of signal analysis is strongly dependent upon a samples pre-burial experience of sunlight's spectrum and its residual to post-burial signal ratio. Given in the majority of cases, the spectral exposure history of a deposit is uncertain, the absence of an increase in natural D_e (t) does not necessarily testify to the absence of partial bleaching.

Where requested and feasible, the insensitivities of multi-grain single-aliquot signal analysis may be circumvented by inter-aliquot D_e distribution studies. This analysis uses aliquots of single sand grains to quantify inter-grain D_e distribution. At present, it is contended that asymmetric inter-grain D_e distributions are symptomatic of partial bleaching and/or pedoturbation (Murray *et al*., 1995; Olley *et al*., 1999; Olley *et al*., 2004; Bateman *et al*., 2003). For partial bleaching at least, it is further contended that the D_e acquired during burial is located in the minimum region of such ranges. The mean and breadth of this minimum region is the subject of current debate, as it is additionally influenced by heterogeneity in microdosimetry, variable inter-grain response to SAR and residual to post-burial signal ratios. Presently, the apposite measure of age is that defined by the D_e interval delimited by the minimum and central age models of Galbraith *et al*. (1999).

3.2.2 Pedoturbation
The accuracy of sedimentation ages can further be controlled by post-burial trans-strata grain movements forced by pedo- or cryoturbation. Berger (2003) contends pedogenesis prompts a reduction in the apparent sedimentation age of parent material through bioturbation and illuviation of younger material from above and/or by biological recycling and resetting of the datable signal of surface material. Berger (2003) proposes that the chronological products of this remobilisation are A-horizon age estimates reflecting the cessation of pedogenic activity, Bc/C-horizon ages delimiting the maximum age for the initiation of pedogenesis with estimates obtained from Bt-horizons providing an intermediate age 'close to the age of cessation of soil development'. Singhvi et al. (2001), in contrast, suggest that B and C-horizons closely approximate the age of the parent material, the A-horizon, that of the 'soil forming episode'. At present there is no post-sampling mechanism for the direct detection of and correction for post-burial sediment remobilisation. However, intervals of palaeosol evolution can be delimited by a maximum age derived from parent material and a minimum age obtained from a unit overlying the palaeosol. Inaccuracy forced by cryoturbation may be bidirectional, heaving older material upwards or drawing younger material downwards into the level to be dated. Cryogenic deformation of matrix-supported material is, typically, visible; sampling of such cryogenically-disturbed sediments can be avoided.

4.0 Acquisition and accuracy of D_r value
Lithogenic D_r values were defined through measurement of U, Th and K radionuclide concentration and conversion of these quantities into α, β and γ D_r values external to the quartz grains (Table 1). External α and β contributions were estimated from sub-samples by laboratory-based γ spectrometry using an Ortec GEM-S high purity Ge coaxial detector system, calibrated using certified reference materials supplied by CANMET. γ dose rates can be estimated from *in situ* NaI gamma spectrometry to reduce uncertainty relating to potential heterogeneity in the γ dose field surrounding each sample. Where direct measurements are unavailable as in the present case, laboratory-based Ge γ spectrometry can be used to profile the γ field at intervals within 300 mm above and below of each sample's centre. However, core section length in this study precluded profiling. Estimates of radionuclide concentration were converted into D_r values (Adamiec and Aitken, 1998), accounting for D_r modulation forced by grain size (Mejdahl, 1979), present moisture content (Zimmerman, 1971) and reduced signal sensitivity to α radiation (a-value 0.050 $\pm$ 0.002; Toms, unpub. data). Cosmogenic D_r values were calculated on the basis of sample depth, geographical position and matrix density (Prescott and Hutton, 1994).

The spatiotemporal validity of D_r values can be considered a function of five variables. Firstly, age estimates devoid of *in situ* γ spectrometry data should be accepted tentatively if the sampled unit is heterogeneous in texture or if the sample is located within 300 mm of strata consisting of differing texture and/or mineralogy. However, where samples are obtained throughout a vertical profile, consistent values of γ D_r based solely on laboratory measurements may evidence the homogeneity of the γ field and hence accuracy of γ D_r values. Secondly, disequilibrium can force temporal instability in U and Th emissions. The impact of this infrequent phenomenon (Olley et al., 1996) upon age estimates is usually insignificant given their associated margins of error. However, for samples where this effect is pronounced (>50% disequilibrium between ^{238}U and ^{226}Ra; Fig. 7), the resulting age estimates should be accepted tentatively. Thirdly, pedogenically-induced variations in matrix composition of B and C-horizons, such as radionuclide and/or mineral remobilisation, may alter the rate of energy emission and/or absorption. If D_r is invariant through a dated profile and samples encompass primary parent material, then element mobility is likely limited in effect. Fourthly, spatiotemporal detractions from present moisture content are difficult to assess directly, requiring knowledge of the magnitude and timing of differing contents. However, the maximum influence of moisture content variations can be delimited by recalculating D_r for minimum (zero) and maximum (saturation) content. Finally, temporal alteration in the thickness of overburden alters cosmic D_r values. Cosmic D_r often forms a negligible portion of total D_r. It is possible to quantify the maximum influence of overburden flux by recalculating D_r for minimum (zero) and maximum (surface sample) cosmic D_r.

5.0 Estimation of Age

Age estimates reported in Table 1 provide an estimate of sediment burial period based on mean D_e and D_r values and their associated analytical uncertainties. Uncertainty in age estimates is reported as a product of systematic and experimental errors, with the magnitude of experimental errors alone shown in parenthesis (Table 1). Probability distributions indicate the inter-aliquot variability in age (Fig. 8). The maximum influence of temporal variations in D_r forced by minima-maxima in moisture content and overburden thickness is illustrated in Fig. 8. Where uncertainty in these parameters exists this age range may prove instructive, however the combined extremes represented should not be construed as preferred age estimates. The analytical validity of each sample is presented in Table 2.

6.0 Analytical uncertainty

All errors are based upon analytical uncertainty and quoted at 1σ confidence. Error calculations account for the propagation of systematic and/or experimental (random) errors associated with D_e and D_r values.

For D_e values, systematic errors are confined to laboratory β source calibration. Uncertainty in this respect is that combined from the delivery of the calibrating γ dose (1.2%; NPL, pers. comm.), the conversion of this dose for SiO_2 using the respective mass energy-absorption coefficient (2%; Hubbell, 1982) and experimental error, totalling 3.5%. Mass attenuation and bremsstrahlung losses during γ dose delivery are considered negligible. Experimental errors relate to D_e interpolation using sensitisation corrected dose responses. Natural and regenerated sensitisation corrected dose points (S_i) were quantified by,

$$S_i = (D_i - x.L_i) / (d_i - x.L_i) \quad \textbf{Eq.1}$$

where D_i = Natural or regenerated OSL, initial 0.2 s

L_i = Background natural or regenerated OSL, final 5 s

d_i = Test dose OSL, initial 0.2 s

x = Scaling factor, 0.08

The error on each signal parameter is based on counting statistics, reflected by the square-root of measured values. The propagation of these errors within Eq. 1 generating σS_i follows the general formula given in Eq. 2. σS_i were then used to define fitting and interpolation errors within exponential regressions.

For D_r values, systematic errors accommodate uncertainty in radionuclide conversion factors (5%), β attenuation coefficients (5%), a-value (4%; derived from a systematic α source uncertainty of 3.5% and experimental error), matrix density (0.20 $g.cm^{-3}$), vertical thickness of sampled section (specific to sample collection device), saturation moisture content (3%), moisture content attenuation (2%), burial moisture content (25% relative, unless direct evidence exists of the magnitude and period of differing content) and NaI gamma spectrometer calibration (3%). Experimental errors are associated with radionuclide quantification for each sample by NaI and Ge gamma spectrometry.

The propagation of these errors through to age calculation was quantified using the expression,

$$\sigma y\ (\delta y/\delta x) = (\Sigma\ ((\delta y/\delta x_n).\sigma x_n)^2)^{1/2} \qquad \textbf{Eq. 2}$$

where y is a value equivalent to that function comprising terms x_n and where σy and σx_n are associated uncertainties.

Errors on age estimates are presented as combined systematic and experimental errors and experimental errors alone. The former (combined) error should be considered when comparing luminescence ages herein with independent chronometric controls. The latter assumes systematic errors are common to luminescence age estimates generated by means identical to those detailed herein and enable direct comparison with those estimates.

Fig. 1 Signal Calibration

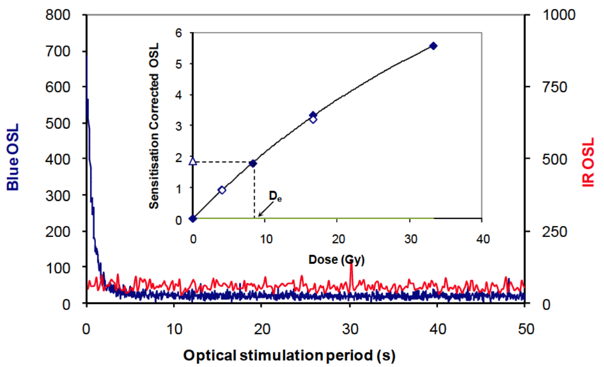


Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from natural irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Low and High Repeat Regenerative-dose Ratio Measures the statistical concordance of signals from repeated low and high regenerative-doses. Discordant data (those points lying beyond ±2 standardised ln D_e) indicate inaccurate sensitivity correction.

Fig. 5 OSL to Post-IR OSL Ratio Measures the statistical concordance of OSL and post-IR OSL responses to the same regenerative-dose. Discordant, underestimating data (those points lying below -2 standardised ln D_e) highlight the presence of significant feldspar contamination.

Fig. 6 Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching followed by insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

Fig. 7 U Activity Statistical concordance (equilibrium) in the activities of the daughter radioisotope ^{226}Ra with its parent ^{238}U may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium; >50%) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates. A 20% disequilibrium marker is also shown.

Fig. 8 Age Range The mean age range provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Fig. 2 Dose Recovery

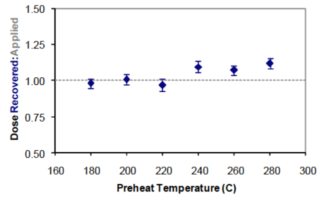


Fig. 3 Inter-aliquot D_e distribution

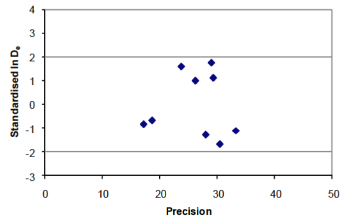


Fig. 4 Low and High Repeat Regenerative-dose Ratio

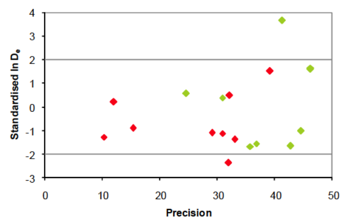
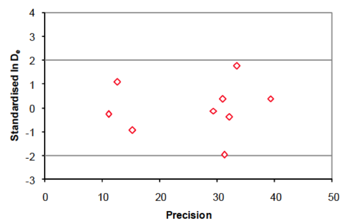


Fig. 5 OSL to Post-IR OSL Ratio



Sample: GL10080

Fig. 6 Signal Analysis

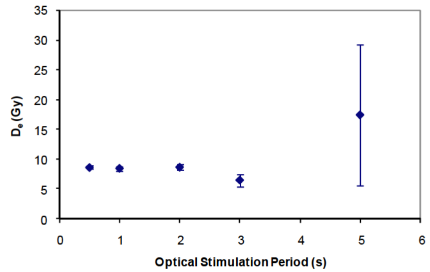


Fig. 7 U Decay Activity

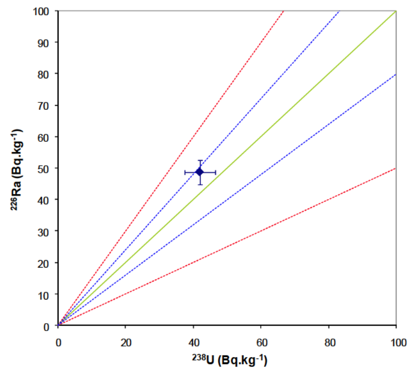


Fig. 8 Age Range

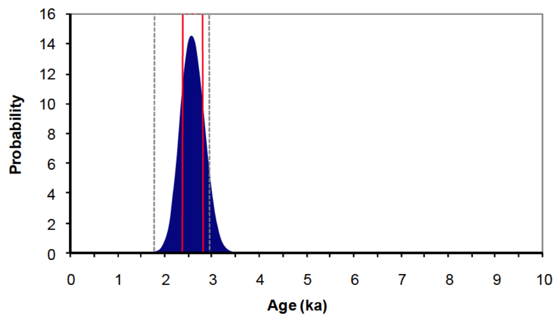


Fig. 1 Signal Calibration

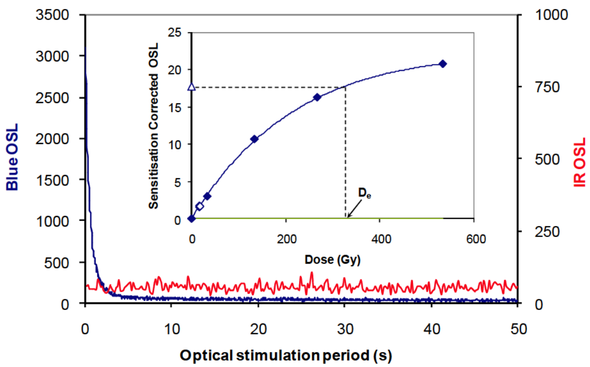


Fig. 2 Dose Recovery

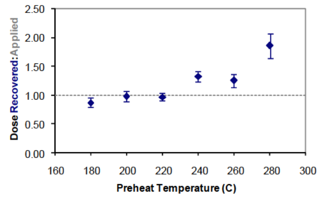


Fig. 6 Signal Analysis

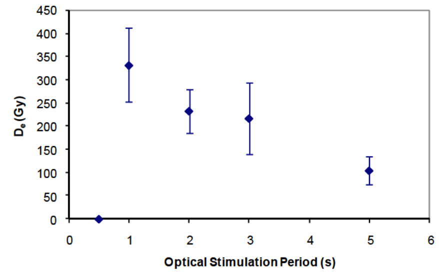


Fig. 3 Inter-aliquot D_e distribution

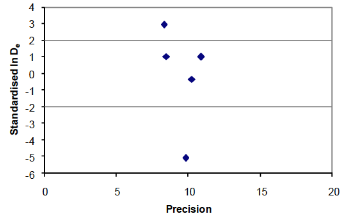


Fig. 7 U Decay Activity

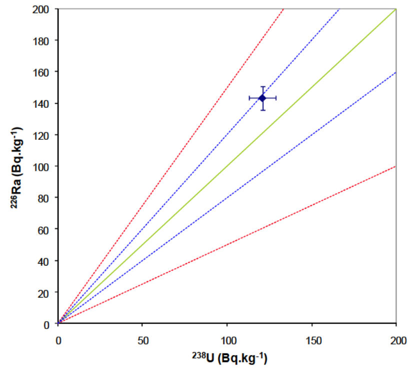


Fig. 4 Low and High Repeat Regenerative-dose Ratio

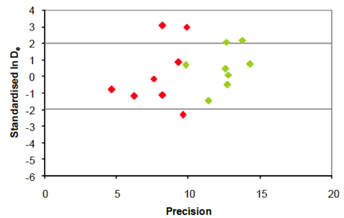


Fig. 5 OSL to Post-IR OSL Ratio

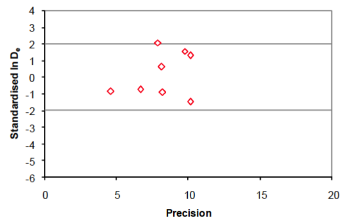
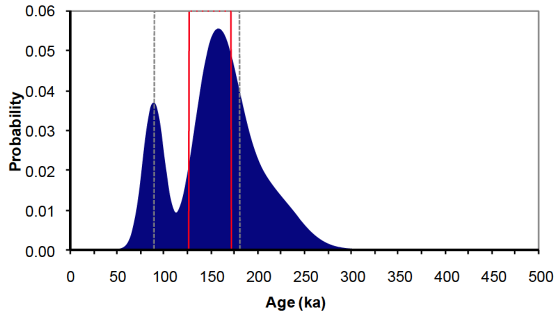


Fig. 8 Age Range



Sample: GL10081

Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from **natural** irradiation. Discordant data (those points lying beyond **±2 standardised ln D_e**) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

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Fig. 6 Signal Analysis Statistically significant increase in **natural** D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from **simulated partial bleaching** followed by insignificant adjustment in D_e for simulated **zero** and **full bleach** conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

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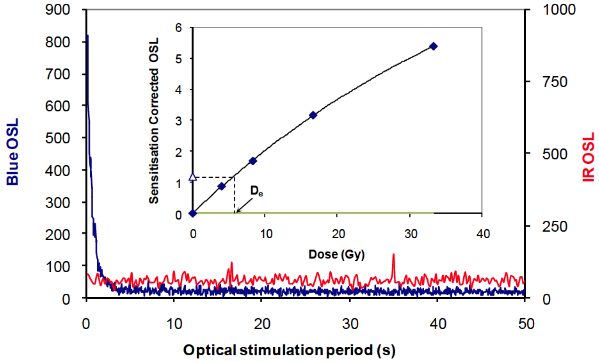
Fig. 8 Age Range The **mean age range** provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The **maximum influence** of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Fig. 1 Signal Calibration



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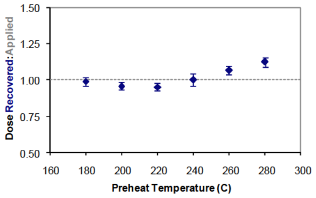


Fig. 3 Inter-aliquot D_e distribution

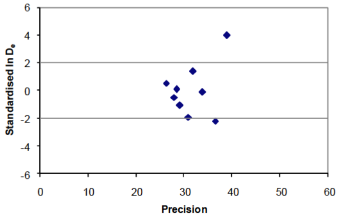


Fig. 4 Low and High Repeat Regenerative-dose Ratio

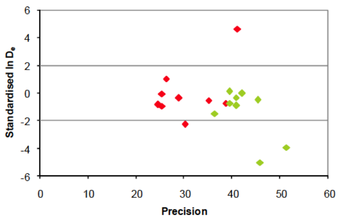
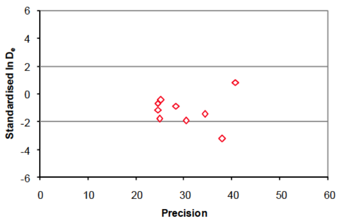


Fig. 5 OSL to Post-IR OSL Ratio



Sample: GL10082

Fig. 6 Signal Analysis

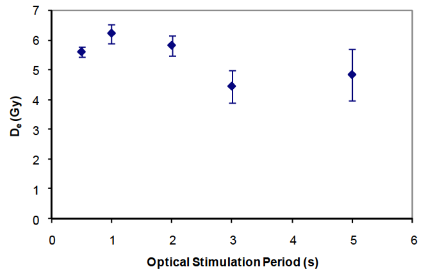


Fig. 7 U Decay Activity

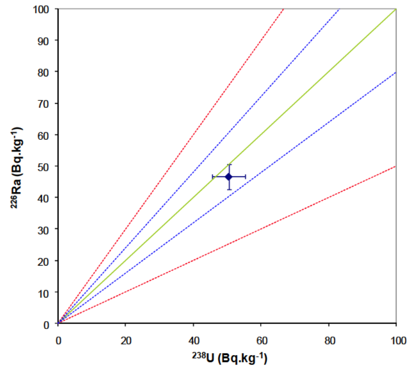


Fig. 8 Age Range

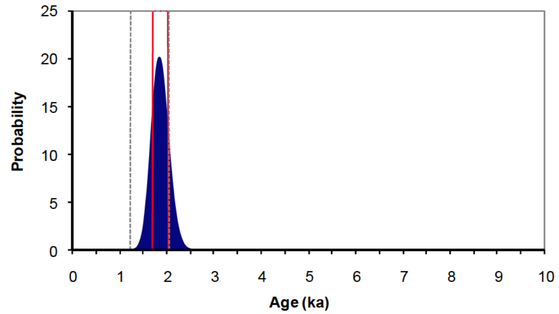


Fig. 1 Signal Calibration

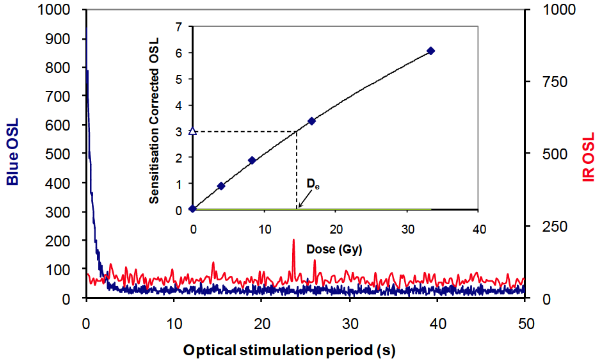


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Fig. 3 Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from natural irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Low and High Repeat Regenerative-dose Ratio Measures the statistical concordance of signals from repeated low and high regenerative-doses. Discordant data (those points lying beyond ±2 standardised ln D_e) indicate inaccurate sensitivity correction.

Fig. 5 OSL to Post-IR OSL Ratio Measures the statistical concordance of OSL and post-IR OSL responses to the same regenerative-dose. Discordant, underestimating data (those points lying below -2 standardised ln D_e) highlight the presence of significant feldspar contamination.

Fig. 6 Signal Analysis Statistically significant increase in natural D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from simulated partial bleaching followed by insignificant adjustment in D_e for simulated zero and full bleach conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

Fig. 7 U Activity Statistical concordance (equilibrium) in the activities of the daughter radioisotope ^{226}Ra with its parent ^{238}U may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium; >50%) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates. A 20% disequilibrium marker is also shown.

Fig. 8 Age Range The mean age range provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The maximum influence of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Fig. 2 Dose Recovery

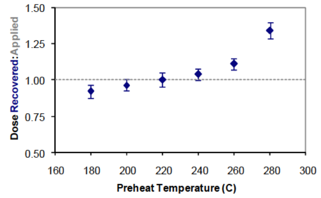


Fig. 3 Inter-aliquot D_e distribution

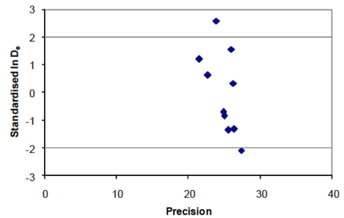


Fig. 4 Low and High Repeat Regenerative-dose Ratio

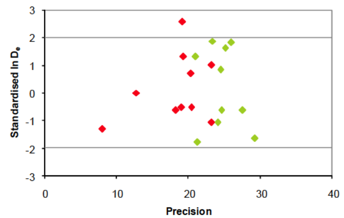
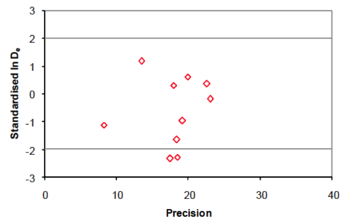


Fig. 5 OSL to Post-IR OSL Ratio



Sample: GL10083

Fig. 6 Signal Analysis

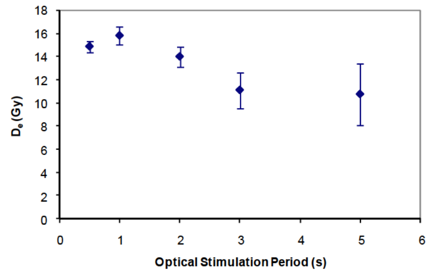


Fig. 7 U Decay Activity

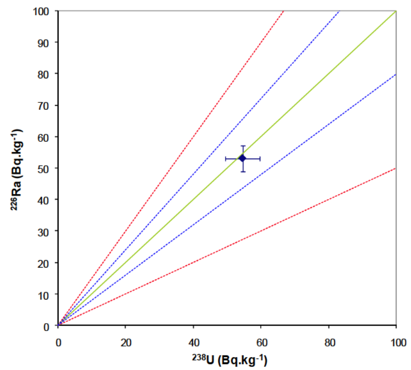
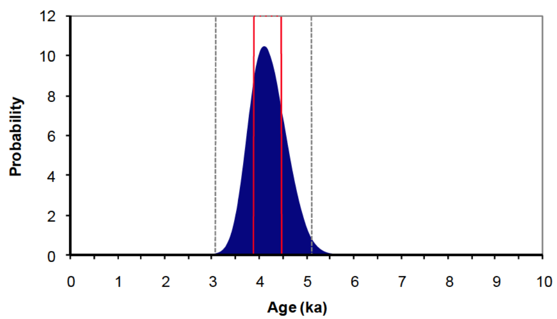


Fig. 8 Age Range



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APPENDIX 5: POLLEN ASSESSMENT

Dr Michael Grant
To be edited, awaiting OSL results due July 2011

Introduction
A pollen assessment has been undertaken upon pollen samples from two stratified borehole sequences. This report contains the results of this assessment upon these samples and provides recommendations for future work.

Methods
Pollen assessment is used to provide information on pollen assemblages from past environments. When a stratified sequence of sediment is investigated, pollen analysis can show how the pollen arriving at the site of deposition has varied over a given time period, and therefore allow interpretations relating to climate change, vegetation history, human activity and the modification of the local environment. Pollen can be preserved in a range of environments, but preservation is principally determined by whether they are anoxic, such as sediments deposited in lakes, fens, mires and buried soils.

Standard preparation procedures were used (Moore *et al*. 1991). $2cm^3$ of sediment will be sampled, with a *Lycopodium* spike (2 tablets from batch 177745) added to allow the calculation of pollen concentrations. All samples received the following treatment: 20 mls of 10% KOH (80°C for 30 minutes); 20mls of 60% HF (80°C for 120 minutes); 15 mls of acetolysis mix (80°C for 3 minutes); stained in 0.2% aqueous solution of safranin and mounted in silicone oil following dehydration with tert-butyl alcohol.

Pollen counting was done at a magnification of x400 using a Nikon SE transmitted light microscope. Determinable pollen and spore types were identified to the lowest possible taxonomic level with the aid of a reference collection kept at Wessex Archaeology. The pollen and spore types used are those defined by Bennett (1994; Bennett *et al*., 1994) with the exceptions given below, with plant nomenclature ordered according to Stace (1997).

The frequent absences of the outer perine (the essential feature for identification) prevented the consistent separation of monoaperturate spores (with the exception of *Polypodium*) and so these are classed as Pteropsida (monolete) indet. Large Poaceae (>32μm diameter) were classified using the scheme of Küster (1988).

A total land pollen (TLP) sum has been adopted in this study with selected taxa excluded which are likely to be over represented due to their local abundance. These exclusions are *Alnus glutinosa* (alder), Cyperaceae (sedge), obligate aquatics, pteridophytes (includes club moss, horsetails and ferns) and bryophyta (mosses). The desired TLP sum during assessment was 100 grains. Due to a number of the counts falling below this total, the results are presented as the number of grains of each taxon in Table 1.

Results
Results of the assessment are given below for each core and the raw pollen counts are shown in Table 1.

- *Borehole BH109*

Pollen (raw counts) assessment results are shown in Table 1. The sediment sample from 0.67m aOD failed to produce a residue so has not been assessed.

Pollen concentrations are variable but are highest within the peat (1.42m aOD), as expected. All three samples assessed contain high amounts of Poaceae (grasses), with Cyperaceae (sedges), *Quercus* (oak) and *Corylus avellana*-type (hazel) also common. Fluctuations in the total number of pollen for each taxa from each sample is related mainly to the depositional environment rather than necessarily reflecting changes within the vegetation of the wider area. For example – the samples taken from estuarine alluvium (3.42m aOD and -1.08m aOD) contain higher amounts of Chenopodiaceae (goosefoot). This commonly indicates brackish conditions within pollen sequences (e.g. Grant *et al.* 2011). In addition, the alluvium often contains reworked pollen derived from various different sources. This may be the reason why there are higher amounts of pteridophytes in the sample from 3.42m aOD along with some re-worked pre-Quaternary spores.

As stated above – fluctuations between adjacent samples in the assessment from this borehole are likely to be determined by the sedimentary environment rather than a true reflection of the changing vegetation within the local and wider area. However, some general trends can be derived from this assemblage. There is a strong presence of woodland taxa in all samples with *Quercus* and *Corylus avellana*-type within all samples, along with an increase in *Salix* (willow) and *Alnus glutinosa* (alder) towards the top of the sequence. The presence of *Ulmus* (elm) in the lower samples may also indicate its presence within the local area. A mid-Holocene reduction in *Ulmus* within pollen sequences is often interpreted as representing the mid-Holocene *Ulmus* decline (Parker *et al.* 2001). Radiocarbon dates from the peat indicate it is 3950-3700 cal. BC (5020±35; SUERC-34105) at 0.67m aOD and 2580-2340 cal. BC (3980±35; SUERC-34106) at 1.44m aOD, indicating these peat span the Early to Late Neolithic periods. However, it is possible that there may be reminents of the decline in *Ulmus* recorded within the sequence, as has been found at sites within the nearby Somerset Levels (e.g. Beckett & Hibbert, 1979) and was also implied for a foreshore sequence at Westward Ho! (Scaife 1987), though this is not directly dated.

The high amounts of Cyperaceae and Poaceae recorded within the sequence indicate that the local environment is fairly open which is due to it being a floodplain environment rather than a reflection of the openess of the surrounding dryland vegetation – ie. most of the pollen from grasses and sedges are derived from the in-situ vegetation. The local presence of Poaceae is clear given the presence of *Phragmites australis* (common reed) within the borehole and their subsequent use to derive the radiocarbon dates. *Sparganium emersum*-type (bur-reeds) area also present indicating a local wetland environment. A single large Poaceae grain was also found at the top of the sequence. These are commonly interpreted as being derived from Cereals due to the similarity of the grain size (poor preservation often means the wall scultpture cannot be used as a diagnostic characteristic). However, using the classification scheme of Küster (1988) this grain can be classified within the *Arrhenatherum*-type group. High percentages of these large Poaceae were also found in laminated estuarine alluvium sequences from the Welsh side of Severn Estuary by Allen and Dark (2008) which to them was unclear of the origin (they discuss sources of cereals at length) but led them also to “urge caution in the interpretation of the presence of ‘cereal-type’ pollen at prehistoric sites in the coastal zone, as there are several potential sources of such pollen, other than actual local cereal cultivation” (Dark & Allen, 2008, 226).

- *Borehole BH112*

Pollen (raw counts) assessment results are shown in Table 1. The sediment samples from 3.85m aOD and -6.5m aOD failed to high enough pollen counts (100 TLP).

The pollen sample from 3.85m aOD is derived from sediments interpreted as a gley soil and is interpreted as having a mottled appearance and blocky structure and has therefore probably been subject to fluctuating water levels and some repeated wetting and drying, leading to further deterioration of the pollen contained within. Few pollen grains were found within the sample assessed and were at a low concentration upon the slides so sufficient counts for assessment were not achieved.

The pollen sample from -6.5m aOD is located below an overlying gravel deposit at -1.35m aOD, which is possibly a Quaternary River Terrace Deposit (probably of Late Glacial / Early Holocene date) the alluvium sampled is clearly of pre-Holocene date and most probably Quaternary or older in origin. The pollen is therefore unsurprisingly poorly preserved and of a very low concentration with the only identifiable grains being those of *Pinus sylvestris* (pine) and Poaceae, with pre-Quaternary spores also present. This sediment therefore has no archaeological potential and may in fact simply be the underlying geology of the site.

Two pollen samples remain from the assessment on BH 112, situated at 1.61m aOD and -0.15m aOD, derived from a peat and underlying estuarine alluvium. Pollen concentrations are again highest within the peat (1.61m aOD). Similar to the sequence from BH109, differences in the pollen assemblage can again be attributed to the difference in depositional environment with higher amounts of Chenopodiaceae within the estuarine alluvium. Similar to BH109 the assemblages are dominated by Poaceae with *Quercus*, *Alnus glutinosa* and *Corylus avellana*-type also present in notable amounts. The pollen assemblages and counts are similar between these two cores with a radiocarbon date from the peat at 1.60m aOD of 3640-3370 cal. BC (4715±35; SUERC-34107), again similar in date with that from BH109, also derived from an *Phragmites australis* stem. An overlying radiocarbon date in BH112 at 1.74m aOD of 2880-2610 cal. BC (4145±35; SUERC-34108) confirms that this peat is of Early to Late Neolithic Date.

Similar to BH109, the high amount of Poaceae, suplemented by the presence of Cyperaceae *Sparganium emersum*-type, indicate that the local environment is fairly open and this is due to it being a floodplain environment rather than a reflection of the openess of the surrounding dryland vegetation.

Potential

The samples from the two boreholes that have yielded sufficient pollen for assessment are shown to have a contemporary pollen assemblage, which is confirmed by the contemporary radiocarbon dates upon the peat. Changes in the pollen assemblage are most likely to be related to changes in the sediments sampled (alluvium or peat) rather than necessarily indicating a change in the vegetation of the wider area. Borehole BH109 appears to provide two distinct peat layers and together cover a slightly wider time period. However, BH112 is a single thicker peat deposit. Therefore BH109 is of greater potential for understanding longer term vegetation changes within the local and wider area. However, BH112 has a single thicker peat which is not interrupted by estuarine alluvium therefore of greater potential for producing a pollen sequence less affected by changes within the local sedimentation over this period. As two samples from BH112 were assessed from areas with very low archaeological potential, the assessment on this core is based purely upon two samples from the centre of the sequence.

Recommendations

Either sequence can provide some significance for understanding the mid-Holocene environment within the Steart Peninsula area. AS the peats in both sequences are very thin (though this may be due to compression by the overlying alluvium), notably the two in BH109, they are unlikely to yield sequences with a temporal span significant enough to understand the changing environment over a broader time span. In addition, unless suitable material is available to radiocarbon date from the alluvium, no further work should be undertaken upon the alluvial sediments as otherwise these cannot be placed within a chronological timeframe with any accuracy.

Either of these two boreholes should only be looked at further if it is not possible to locate contemporary and much thicker Holocene peat sequences within the study area. These are most likely to be located closer to the dryland edge, where there is also greater potential to find evidence of human activity in the past. A pollen sequence derived from freshwater peats rather than estuarine alluvium would provide a more robust basis for providing a narrative on the vegetation history and possible human impact within the area.

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• Borehole	BH109	BH109	BH109	BH109	BH112	BH112	BH112	BH1
Depth (m BGL)	**2.3**	**4.3**	**5.05**	**6.08**	**1.8**	**4.04**	**5.8**	**12.**
Depth (maOD)	**3.42**	**1.42**	**0.67**	**-1.08**	**3.85**	**1.61**	**-0.15**	**-6**
Pinus sylvestris	1	1		6		1	3	7
Ulmus		2		2			1	
Quercus	32	15		17	1	17	17	
Betula	2	1		2		1	2	
Alnus glutinosa	14	10		3		6	17	
Tilia cordata				3		1		
Corylus avellana-type	8	20		7		25	34	
Salix	8	2					1	
Sambucus nigra							1	
Viburnum opulus		1						
Chenopodiaceae	10	7		16		2	15	
Caryophyllaceae undiff.	1							
Rumex sanguineus-type				1				
Vaccinium-type		1						
Calluna vulgaris	1							
Filipendula	1					1		
Rosaceae undiff.	1							
Apiaceae undiff.				1				
Solanum dulcamara	1							
Plantago lanceolata	1					1	1	
Cirsium-type		2						
Solidago virgaurea-type		5		1				
Artemisia-type						1	1	
Cyperaceae undiff.	17	17		10	1	1	8	
Poaceae undiff.	33	46		45	2	53	26	2
Arrhenatherum-type	1							
Sparganium emersum-type	9	1		1	1	1	3	
Polypodium	12	1		4			6	
Pteridium aquilinum	18				1	1	6	
Pteropsida (monolete) indet.	30	1		14	3		12	
Bryophyta	1							
Exotic (*Lycopodium*)	211	18	0	87	22	16	217	13
Corroded	4							
Crumpled							1	
Broken	7							
Total Indeterminable	11						1	
Pre-Quaternary	5							4
Total Pollen Sum	202	133	0	133	9	112	154	9
TLP SUM	101	103	0	101	3	103	102	9
Pollen Concentration (grains cm^{-3})	17791	137315	na	28410	7603	130088	13189	12

Table 1: Pollen (raw counts) from BH109 and BH112.

APPENDIX 6: DIATOM ASSESSMENT

Dr Nigel Cameron

Introduction

Eight sediment sub-samples from the 70944 Steart Peninsula site have been prepared and assessed for diatoms. The samples were taken from two separate boreholes, borehole BH109 and BH112; four samples from each. The sediments in these sequences comprise intertidal saltmarsh/mudflats, peats and estuarine alluvial deposits. The purpose of the diatom assessment is to understand the presence/absence of diatoms within the sequence and the potential of the sediments/samples for further diatom analysis. It is hoped that, if present, the diatoms will inform upon sea level and local environment along with possible comment on chronology, climate and hydrology (Jack Russell pers. comm.). The diatom assessment of each sample takes into account the numbers of diatoms, the state of preservation of the diatom assemblages, species diversity and diatom species environmental preferences.

Methods

Diatom preparation followed standard techniques (Battarbee 1986, Battarbee *et al.* 2001). Two coverslips were made from each sample and fixed in Naphrax for diatom microscopy. A large area of the coverslips on each slide was scanned for diatoms at magnifications of x400 and x1000 under phase contrast illumination.

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

1. Polyhalobian: >30 g l^{-1}

2. Mesohalobian: 0.2-30 g l^{-1}

3. Oligohalobian - Halophilous: optimum in slightly brackish water

4. Oligohalobian - Indifferent: optimum in freshwater but tolerant of slightly brackish water

5. Halophobous: exclusively freshwater

6. Unknown: taxa of unknown salinity preference.

Results & Discussion

Borehole	UCL Lab Diatom Sample Number	Sample Depth (m) below ground level
BH109		
	D17	2.30
	D18	4.30
	D19	5.05
	D20	6.80
BH112		
	D21	1.80
	D22	4.04
	D23	5.80
	D24	12.15

Table 1. Samples from the 70944 Steart Peninsula, Somerset site selected for diatom evaluation (Depths in Boreholes taken from sample bags)

The diatom sample numbers, borehole number and sample depth are shown in Table 1 above. The results of the diatom evaluation for the Steart Peninsula samples are summarised in Table 2 and the diatom species recorded are shown in Table 3 (Excel file attached) along with their halobian classifications.

Diatom Sample No.	Diatoms	Diatom numbers	Quality of preservation	Diversity	Assemblage type	Potential for % count
D17	+	mod/low	poor	low	mar	some
D18	+	low	poor	mod	halophil	low
D19	+	low	poor	low	bk mar	low
D20	+	mod	mod	mod	mar bk	mod
D21	+	low	poor	low	mar bk	low
D22	+	mod	good to poor	mod	bk mar	good
D23	+	high	mod to good	mod high	mar bk	good
D24	+	v low	v poor	low	mar bk	none

Table 2. Summary of diatom evaluation results for 70994 Steart Peninsula, Somerset site (+ present, - absent, mod – moderately high, fw – freshwater, halophil – halophilous, bk – brackish, mar – marine)

Borehole BH109

Diatoms are present in all four samples from BH109. In the basal sample D20 diatom numbers are moderately high with moderately good preservation and relatively high species diversity. There is moderately high potential for percentage counting of D20. In the top four samples assessed from BH109 (D19 – D17) diatom numbers are relatively low, the quality of preservation is poor, with low or moderate species diversity. There is some potential for diatom counting of the top sample (D17) and low potential for percentage diatom counting of D19 and D18.

The basal sample D20 in BH109 contains a marine-brackish diatom assemblage with a mixture of open water polyhalobous taxa (*Paralia sulcata, Cymatosira belgica*) and a dominant mesohalobous benthic component including *Diploneis didyma* and *Nitzschia punctata*. Other mesohalobous and mesohalobous to polyhalobous benthic diatoms present in D20 include *Diploneis smithii, Diploneis aestuari, Navicula digitoradiata, Nitzschia hungarica, Nitzschia navicularis, Rhopalodia musculus* and *Synedra tabulata* (*S.fasciculata*). The diatom composition of this assemblage is consistent with a tidal mudflat environment.

The diatom assemblage of D19 is dominated entirely (*Paralia sulcata* is present) by the epipelic (mud surface) species *Campylodiscus echeneis*. Again this benthic mesohalobous diatom assemblage is typical of brackish-marine, shallow water habitats.

In D18 the most common taxa recorded are *Epithemia turgida,* an halophilous epiphyte, and *Fragilaria construens* var. *venter*, an oligohalobous indifferent diatom with broad salinity tolerance. The poor quality of preservation is reflected in the common occurrence of undifferentiated *Fragilaria* sp. Marine diatoms are present (*Paralia sulcata, Podosira stelligera, Diploneis smithii*) along with benthic (*Anomoeneis sphaerophora, Bacilaria paradoxa, Diploneis interrupta, Nitzschia punctata, Nitzschia navicularis*) and planktonic (*Cyclotella striata*) mesohalobes.

In D17 the top sample in BH109 the diatom assemblage is dominated by polyhalobous diatoms (Paralia sulcata, Cymatosira belgica, Podosira stelligera, Rhaphoneis surirella, Thalassionema nitzschiodes, Actinoptycus undulatus). Low numbers of mesohalobous benthic diatoms are also present (Diploneis aestuari, Nitzschia navicularis and Nitzschia digitoradiata var. minima).

Borehole BH112

Diatoms are present in all four samples from BH112. In the middle two samples from the sequence, D23 and D22, diatom numbers are relatively high with relatively good diatom preservation and moderately high species diversity. There is good potential for percentage diatom counting of D23 and D22. In the basal sample from BH112, D24, the poor quality of diatom preservation and low diatom numbers show that there is no potential for percentage diatom counting. In the top sample, D21, diatom numbers are low and the quality of valve preservation is poor, with low species diversity. The potential for percentage diatom counting of this sample is therefore low.

The basal sample D24 in BH112 at 12.15m (6.5mbOD) appears to be within a glacial deposit (with some reworked marine remains). The sediment sample was collected as a mixed-up bulk sample rather than a core so it was difficult to interpret the sediment. It also had some reworked fossil ostracods and possibly some contamination from the upper levels (Jack Russell *pers. comm.*). These lithological and sampling characteristics are consistent with the very poor quality of preservation and low numbers of diatoms recorded. Small numbers of robust marine (*Podosira stelligera, Paralia sulcata, Rhaphoneis* sp.) and benthic mesohalobous (*Nitzschia navicularis*) are present in D24.

In D23 the well preserved diatom assemblage is dominated by open water, (and some non-planktonic) marine taxa such as Paralia sulcata, Cymatosira belgica, Rhaphoneis minutissima, Campylosira cymbelliformis, Rhaphoneis surirella, Nitzschia panduriformis and Actinptychus undulatus. Benthic, mesohalobous taxa are present but are generally less abundant than the marine component; these taxa include Nitzschia navicularis (common), Diploneis aestuari, Diploneis didyma and Scoliopleura tumida.

In D22 there appears to be a shift from the dominance of polyhalobous diatoms (the planktonic species *Paralia sulcata* and *Podosira stelligera* are present), whilst mesohalobous, benthic diatoms become more common (*Nitzschia navicularis, Nitzschia granulata, Diploneis didyma, Nitzschia punctata, Navicula marina*).

In the top sample D21 the most common species is the planktonic polyhalobous diatom *Paralia sulcata* with *Rhaphoneis amphiceros* also present. The mesohalobous benthic diatoms *Diploneis didyma* and *Nitzschia navicularis* are also present.

The shifts in species composition in D23 and D22, where the diatom assemblages are relatively well preserved, suggest a shift from diatoms of deeper, open water marine conditions (D23) to diatom assemblages more typical (D22) of tidal mudflats for example.

Conclusions

1) Diatoms are present in four samples assessed from BH109 and in the four samples assessed from BH112. The quality of diatom preservation varies from moderately good to very poor. The basal and top samples in BH109 have moderate potential or some potential respectively for percentage diatom counting. The two middle samples in BH112 have good potential for percentage counting. The two middle samples in the sequence from BH109 have low potential for percentage diatom counting. There is little or no potential for percentage diatom counting of the basal and top samples in BH112.

2) Where the diatom assemblages are well enough preserved the evaluation shows that there are shifts between the dominance of open water polyhalobous (marine) diatoms and benthic mesohalobous (brackish or brackish-marine) species. These changes in the source diatom commUnities reflect both changes in salinity and water depth.

3) With the exception of one sample (D18) in BH109, oligohalobous indifferent (freshwater salinity growth optimum) diatoms are absent (and the species concerned has wide salinity tolerance). Planktonic mesohalobous species (e.g. *Cyclotella striata* in D18) occur only rarely in the sequences.

Acknowledgements

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APPENDIX 7: FORAMINIFERA AND OSTRACOD ASSESSMENT

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Introduction
Eight sediment subsamples taken from two boreholes, WA2011_BH109 (at 2.28 to 3.08, 1.08m below OD, 1.34 and 3.42m above OD) and WA2011_BH112 (at 6.35 to 6.65m below OD, 0.92, 1.74 and 3.84m above OD) located on reclaimed farmland adjacent to the Bristol Channel have been assessed for the presence and environmental significance of their microfaunal contents, predominantly ostracods and foraminifera. Sediment from two additional levels within borehole WA2011_BH112 (at 0.78 and 0.75m below OD0) were also assessed due to a hyperabundance of ostracods being noted by eye during the submission of sediments for Optically Stimulated Luminescence (OSL) dating, subsequent to the main assessment. The sampled sediments comprised gravels, sands, silts, clays and peats thought to be predominantly mid-Holocene alluvial and terrestrial sediments associated with the river Parrett and Bristol Channel systems. The peats have been radiocarbon dated yielding Neolithic 3980±35 BP (2580-2340 cal. BC) to 5020±35 BP ; (3950-3700 cal. BC) dates. The sediments above and below the peats have been dated by Optically Stimulated Luminescence (OSL) dating (see Appendix 4). Ostracods and foraminifera occurred in all but three of the samples. Other plant and animal remains were also recovered from the samples a note of which has been made here. Depths are given in metres below OD (Ordnance Datum).

Method
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. Sediment of approximately 2g in weight from the two additional levels from borehole WA2011_BH112 were lightly washed over a 63µm sieve and dried. Microfossils were picked out under 10-60x magnification and transmitted and incident light using a Vickers binocular microscope. Where possible a minimum of one hundred specimens per sample were picked out and kept in card slides. Identification and environmental interpretation of ostracods follows Athersuch *et al*. (1989) and Meisch (2000) and of foraminifera (Murray 1976, 2000).

Results
Abundance of microfaunal remains within the samples is summarised in **Tables 1** and **2.** Abundance of ostracods was varied and where present, the preservation was in general very good. Five of the samples contained ostracods. Foraminifera were present in four of the samples and where present were generally well preserved with variable abundance.

WA2011_BH109

Four levels were assessed, at 2.28 to 3.08, 1.08m below OD, 1.34 and 3.42m above OD). Foraminifera and/or ostracods were present in two of the four samples (**Table 1**).

2.28 to 3.08m below OD. Within this sample a small foraminiferal (well preserved) assemblage was recorded including *Ammonia beccarii*, *Haynesina germanica* and *Jadammina macrescens*. Ostracods were abundant within the sample although were represented by reworked fossilised (?Jurassic) forms. Non fossilised plant remains were also recoded within the sample.

1.08m below OD. Ostracods were not present within this sample. A large and generally well preserved foraminiferal assemblage was recorded including mainly Rotaliid forms dominated by the taxon *Haynesina germanica.* Other species present included *Trochammina inflata*, *Elphidium williamsoni*, *Jadammina macrescens*, and *Ammonia beccarii*. Other emains within the sample included Frequent plant remains and seeds including *Juncus* sp. and radiate diatoms.

1.34m above OD. No foraminifera or ostracods were recovered from this sample although plants including *Juncus* sp. and radiate diatoms were recorded.

3.42m above OD. No foraminifera or ostracods were recovered from this sample although some unidentified plants were recorded.

WA2011_BH112

Six levels were assessed, at 6.35 to 6.65m below OD, 0.78m below OD, 0.75m below OD, 0.92m above OD, 1.74m above OD and 3.84m above OD. Foraminifera and/or ostracods were present in all of the samples except at 1.74m above ODm.

Other remains within these samples included, plant remains, diatoms and fossilised, crustaceans, echinoid and fish were also (**Table 2**).

6.35 to 6.65m below OD. This sample contained a mix of terrestrial elements including moderate amounts of (non fossilised) plants and marine faunal remains including echinoid spines, sponge spicules and fish bones and teeth. These marine faunal remains however are fossilised (from ?Jurassic limestone). Ostracods were rare within the sample however a few stray marine and brackish valves were present including *Cytheropteron* sp. and *Elofsonia* sp..

0.78 and 0.75m below OD. The two small samples with clearly visible ostracod faunas. Contained predominantly *Cyprideis torosa* with occasional *Candona* sp. (and Charophyte oogonia) present at 0.78m below OD. *Cyprideis torosa* was represented by United adult carapaces and instar stages within both samples and hyperabundant at 0.78m below ODm.

0.92m above OD. This sample contained a small fauna of Rotaliid foraminfera (*Elphidium gerthi*, *Elphidium* sp., and *Haynesina germanica*). Ostracods were also present in small number including *Cyprideis torosa* and *Elofsonia baltica.* Other remains noted included radiate diatoms and plant remains.

1.74m above OD. No foraminifera or ostracods were recovered from this sample although plant remains were recorded as were pennate and radiate diatom frustules.

3.84m above OD. No ostracods were recovered from this sample and a small number of foraminifera were present (*Haynesina germanica* and *Elphidium* sp.). Other remains within the sample included seeds, plants and radiate diatoms.

Discussion

WA2011_BH109

The lower two samples (at 2.28 to 3.08m below OD and 1.08m below ODm) within this borehole contained foraminifera indicatice of saltmarsh (*Jadammina macrescens* and *Trocchamina inflata*), brackish/estuarine (*Haynesina germanica*) and estuarine/marine (*Ammonia beccarii*) conditions. The small numbers of very well preserved foraminifera and type of recovered sample at 2.28 to 3.08m below ODm (a plastic tub, not a core sample) suggest the possibility that this small fauna (at 2.28 to 3.08m below OD) is in fact contaminant within the sample. The ostracods recovered were all reworked fossil (?*Ogmoconchella* ?Lower Jurassic) forms. This is not the case at 1.08m below OD where the dominant species, *Haynesina germanica* is indicative of brackish, estuarine and lagoonal environments. It was noted that all of the Rotaliid foraminifera within this sample were of a small size and this restricted growth may well be a response to environmental conditions.

During the waterlogged plant assessment (see **Appendix 8**) a number of well preserved agglutinating taxon *Trochammina inflata* were recovered from a peat deposit in the sample at 0.72 to 0.62m above OD. This record is of great interest as at 0.67m above OD a *Phragmites* reed stem returned a radiocarbon date of (5020±35 3950-3700 cal. BC. (**Appendix 3**). *Trochammina inflata* is known to building its test from detritus rather than secreting a calcareous test as is more common within the order Foraminiferida. Low pH conditions can develop beneath the surface veneer within muddy sediments and it is this that may have caused dissolution of the calacareous foraminiferal tests and ostracod valves which would normally be expected within such sediments. This assemblage indicates that a possible sea level index point (SLIP) can be generated at this level using foeaminifera.

Above this level, within borehole **WA2011_BH109** at 1.44m above OD a *Phragmites* reed stem returned a radiocarbon date of 3980±35 BP (2580-2340 cal. BC).

The upper two samples at 1.34 and 3.42m above OD contained no ostracods or foraminifera and it is possible that soil formation and oxidisation of the sediment at these levels has increased the acidity leading to the dissolution of ostracod valves and foraminiferal tests.

WA2011_BH112
The basal sample at 6.35 to 6.65m below OD contained an unusual mix of environmental remains. The ostracods valves recovered were few in number including singular stray valves of *Cytheropteron* and *Elofsonia* and it is considered likely (as is the case with the foraminifera from the basal sample from borehole WA2011_BH109) that these elements may be contaminant. The other marine faunal remains including fish bones and teeth, sponge spicules and crustacean claws are fossilised remains reworked from (?Jurassic) limestone bedrock. The plant remains within the sample were however well preserved and numerous and are possibly the result of a reworked waterlogged /soil horizon.

The two small sediment samples at 0.78 and 0.75m below OD containing abundant remains of the ostracod *Cyprideis torosa* are very interesting. *Cyprideis torosa* is a euryhaline taxon that can occur in freshwater to hypersaline conditions and it's mass development is usually associated with organic detritus and brackish water (Meisch 2000). The occasional presence of Candoniids and *Charophyte* oogonia at 0.78m below OD are indicative of freshwater input (into a brackish environment) at this level.

Above this at 0.92m above OD the ostracods (*Cyprideis torosa* and *Elofsonia baltica*) and foraminifera (*Haynesina germanica* and *Elphidium* sp.) are inidcative of brackish lagoon and estuarine conditions.

Within borehole WA2011_BH112 at 1.60m above OD a *Phragmites* reed stem returned a date of 4715±35 (3640-3370 cal. BC) and at 1.74m above OD a *Phragmites* reed stem returned a date of 4145±35 (2880-2620 cal. BC).

At 1.74m above OD no foraminifera or ostracods were recorded, due possibly to post depositional dissolution of ostracod and foraminiferal tests, similar to the upper samples assessed in borehole WA2011_BH109.

Recommendations

- Sample for analysis should be directed at the core samples due to the possibility noted here of contamination of the tub samples.
- Foraminifera and ostracods should be analysed from the samples already assessed, where present.
- Additional samples from minerogenic levels (avoiding oxidised sediments) is recommended for both WA2011_BH109 and WA2011_BH112.
- Particular attention should be paid to dated levels (OSL and radiocarbon where practicable), and interstitial samples in order to understand the successive environments. From core samples within borehole WA2011_BH112 further samples are recommended from between c.2m above OD and 1m in below OD borehole WA2011_BH112. From borehole WA2011_ BH109 further samples are recommended from between c.1.5m above OD to 1.5m below OD.

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WA2011_BH109 mbGL	8 to 8.8	6.8	4.38	2.3
maOD	-2.28 to -3.08	-1.08	1.34	3.42
Candona sp.				
Cyprideis torosa				
Cytheropteron sp.				
Elofsonia sp.				
Broken				
Unidentified	x			
Carboniferous fossil ostracods	xxx			
Foraminfera				
Ammonia beccarii	x	x		
Ammonia/Elphidium				
Elphidium gerthi				
*Elphidium*sp.		x		
Elphidium williamsoni		x		
Haynesina germanica	x	xxx		
Jadammina macrescens	x	x		
Rotalids	x			
Trochammina inflata		x		
Unidentified		x		
Animal remains				
crustacean claw				
echinoid pieces				
echinoid spines				
Fish teeth/bones				
Sponge spicules				
Plant remains				
Charophyte oogonium				
Diatom	x	x	x	
Juncus sp.		x	x	
Potomageton				
Plants unidentified	xx	xxxx	xxx	xx
Seed unidentified		x		

Table 1. Abundance of taxa per sample in WA2011_BH109
Abundance:
x – 1-9 specimens
xx – 9-50 specimens
xxx – greater than 50 specimens
xxxx – greater than 100 specimens

WA2011_BH112 mbGL	12 to 12.3	6.43	6.4	4.73	3.91	1.81
maOD	-6.35 to -6.65	-0.78	-0.75	0.92	1.74	3.84
Ostracods						
Candona sp.		x				
Cyprideis torosa	?	xxxx	xxxx	x		
Cytheropteron sp.	x					

Elofsonia sp.	x			x		
Broken				x		
Unidentified				x		
Carboniferous fossil ostracods						
Foraminfera						
Ammonia beccarii						
Ammonia/Elphidium				x		
Elphidium gerthi				x		
Elphidium sp.				x		x
Elphidium williamsoni						
Haynesina germanica				xx		x
Jadammina macrescens						
Rotalids				x		
Trochammina inflata						
Unidentified				x		
Animal remains						
crustacean claw	x					
echinoid pieces	x					
echinoid spines	x					
Fish teeth/bones	xx					
Sponge spicules	xx					
Plant remains						
Charophyte oogonium		x				
Diatom				x		x
Juncus sp.					x	
Potomageton						
Plants unidentified	x		xxxx	xxx	xxx	xx
Seed unidentified						x

Table 2. Abundance of taxa per sample in WA2011_BH112

Abundance:

x – 1-9 specimens

xx – 9-50 specimens

xxx – greater than 50 specimens

xxxx – greater than 100 specimens

APPENDIX 8: WATERLOGGED PLANTS, MOLLUSCS, CHARCOAL AND INSECT INTERIM ASSESSMENT

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Introduction

Four samples were selected from two cores for assessment of the recovery, survival and potential of waterlogged plant remains to inform on past environments. Two came from 0.72 to 0.62 m aOD and 1.42m to 1.52m aOD within BH109. The remaining two came from 1.60 to 1.64m and -0.7 to -0.75m aOD within Borehole BH112. The material from BH109 and that from the upper deposit of BH112 are all likely to be Neolithic in date.

Two sub-samples of around 100 to 250 ml were taken within each borehole (see Tables X.X). The samples were processed for the recovery of mollusca, plant remains, insect remains and other waterlogged material.

Methods

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 were preserved. Nomenclature follows that of Stace (1997). Other material present is also noted within Table 1 with further identifications carried out where possible.

Results

Organic material was present within all of the samples examined from the boreholes, although very little identifiable material was present within that from 1.64m to 1.60m within BH112.

The upper Late Neolithic sample from BH109 at 1.44m aOD had generally indicators of wet freshwater marshland with probably frequent areas of disturbance perhaps caused by flooding events and/or grazing. Most common were small seeds of goosefoots either of the *Pseudoblitum* e.g. for Britain, oak-leaved goosefoot (*C. glaucum*) or red goosefoot (*C. rubrum*) or of the *Degenia*, that in Britain only includes saltmarsh goosefoot (*C. chenopodioides*). While comparison to modern reference material might enable further identification all have relatively similar ecologies growing mainly being found close to the sea, and in the case of saltmarsh goosefoot within rough bare pastures, or for the other two, cultivated and waste ground. Also present were occasional seed of orache (*Atriplex* sp.*) a species associated with* similar disturbed environments, but also potentially associated with saltmarsh. Occasional fragments of water-crowfoot (*Ranunculus* subgenus Batrachium) could not be identified to species and might be associated with brackish or freshwater. Similarly, seeds recovered of bulrush (*Typha* sp.) or may all potentially be associated with fresh water marshes or near estuarine marshes with some saltwater input. The sample also had a possible fragment of seed of bogbean (*Menyanthes trifoliata*). More indicative of freshwater environments were frequent statoblasts of Bryozoan that were most likely related to freshwater Plumetella types. Similarly, occasional eggs of waterflea would indicate standing pools or freshwater.

The lower Early Neolithic sample from this borehole at 0.72-0.62m aOD indicated a somewhat different environment with several seeds of sea blite (*Suaeda maritima*) present, along with seeds of Sea Aster (*Aster tripolium*). It was not possible to identify the seeds of rush, but the cell pattern and sized closely match saltmarsh rush (*Juncus gerardi*), although positive identification could not be carried out and other species, such as compact rush (*Juncus conglomeratus*), that has both a similar cell pattern and similarly sized (0.5-0.7mm) seeds could not be ruled out. The sample also contained a number of seeds of Cyperaceae which had a very distinctive surface texture and while trigonous in shape had a smooth dorsal surface resembling either grey club rush (*Schoenoplectus tabernaemontani*) or saltmarsh flat-sedge (*Blysmus* sp.). A single seed of common nettle (*Urtica dioica*) was also present.

The sample didn't have any statoblasts within it but did have a few tests of the foraminifera. *Trochammina inflata*.

The upper sample from borehole BH112, 1.64-1.60m aOD, dated to the Late Neolithic as stated above had only two tentatively identified fragments of plant remains, these were a possible fragment of bramble (*Rubus* sp.) and a possible fragment of a Brassicaeace capsule perhaps Raphanus, but too fragmented and poorly preserved for identification.

The lower sample from -0.70 to -0.75m aOD is likely to pre-date the Early Neolithic and had high numbers of seeds of red goosefoot (*Chenopodium rubrum*), along with a few seeds of mint (*Mentha* sp.), orache (Atriplex *sp.)* and nightshade (*Solanum* sp.). Also present were two gametes of stonewort (*Chara* sp.). Taken together these elements would all indicate a more likely freshwater environment, with tracts of highly disturbed grassland.

No remains of insects or charcoal were seen within the samples.

SUMMARY

Similar evidence for potential saltmarsh at an unknown date as seen within BH109 at 0.72-0.62m aOD was recovered in a Testpit at 4m aOD within previous work at Steart Point (Wessex Archaeology 2009).

There are some differences between the samples within BH109. The material from the Early Neolithic at 0.72m to 0.62m aOD has more obvious indicators of a more permanent wet saltmarsh, for example sea-blite, sea Aster and possibly saltmarsh rush with little indication of freshwater input. The higher Late Neolithic sample within BH109 at 1.52 to 1.42m aOD shows elements of rough bare, disturbed periodically flooded ground, for example, red/oak-leaved or possible saltmarsh goosefoot, with a much greater indication of freshwater-input in particular seen through the presence of bryozoa. These differences would correspond to the effect of sea-level rise with periods of more permanent wet saltmarsh in the Early Neolithic with disturbed, periodically flooded, esturine/riverine muddy ground with some elements of marsh-grassland within the Late Neolithic.

The deposit from BH112 at -0.70 to -0.75m aOD is likely to date to either the very beginning of the Early Neolithic or more probably the Late Mesolithic in the period just prior to the development of the saltmarsh seen within BH109 at 0.72-0.62m aOD.

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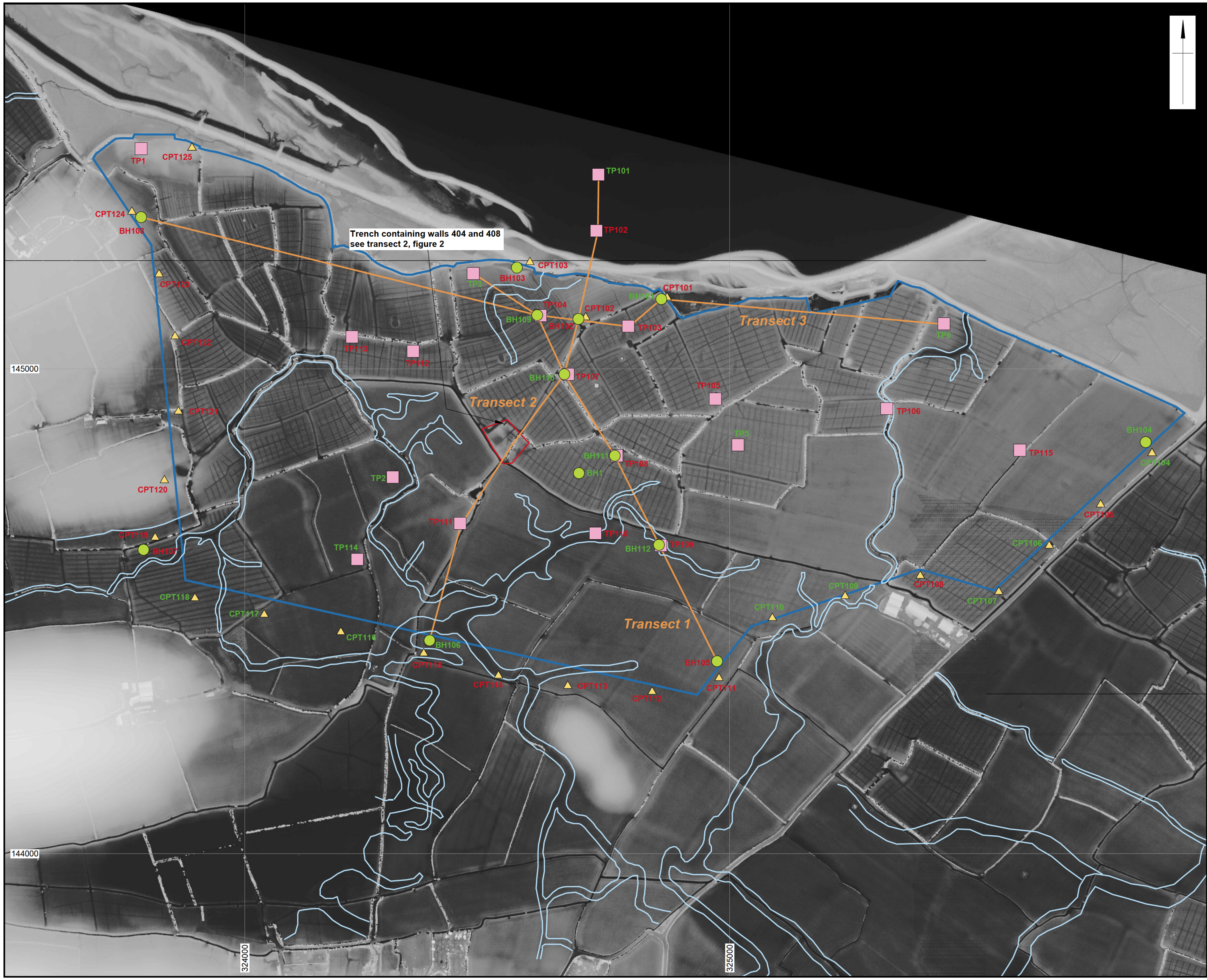
Table X.X. Waterlogged material recovered from boreholes BH109 and BH112

	Borehole	BH109	BH109	BH112	BH112
	Depth m aOD	1.52 to 1.42	0.72 to 0.62	1.64 to 1.60	-0.70 to -0.75
	Depth m	4.20-4.30	5.00 -5.10	4.01-4.05	6.35-6.40
	Date (cal. BC)	2580-2340	3950-3700	3640-3370	>3640-3370
Species	**Common Name**				
Chara (gametes)	stonewort	-	-	-	2
Ranunculus subg. Batrachium	water-crowfoots	+	-	-	-
Ranunculus sceleratus	celery-leaved buttercup	1	-	-	-
Urtica dioica	common nettle		1	-	-
Chenopodium glaucum, rubrum, chenopodioides	goosefoot	++	-	-	++
Suaeda maritima	sea-blite	-	4	-	-
Atriplex sp.	orache	+	1	-	1
Brassicaceae capsule fragment	Prob. Wild/sea radish	-	-	cf.1	-
Rubus sp.	bramble	-	-	cf.1	
Solanum sp.	nightshade	-	-	-	2
Menyanthes trifoliata	bogbean	cf.1	-	-	
Mentha sp.	mint	-	-	-	3
Aster tripolium	Sea Aster	-	3+cf.4	-	-
Potamogeton sp.	pondweeds	-	1	-	-
Juncus sp. ?*J. gerardii/conglomeratus*	rush	-	++	-	-
Poaceae (culm nodes)	Grass/reed stems	-	-	-	3
Schoenoplectus tabernaemontani/Blysmus sp.	grey club-rush	1	5	-	-
Carex sp.	sedge	-	-	-	1
Typha latifolia/angustifolia	bulrush	++	+	-	-
Other	**Common Name**				
Coleoptera remains	insect remains	+	+	-	+
Daphnia sp. *(Ephippium)*	water flea	+	1	-	-
Plumetella type (statoblasts)	freshwater bryozoan	+++	-	-	-
Trochammina inflata	foraminifera	-	x4	-	-



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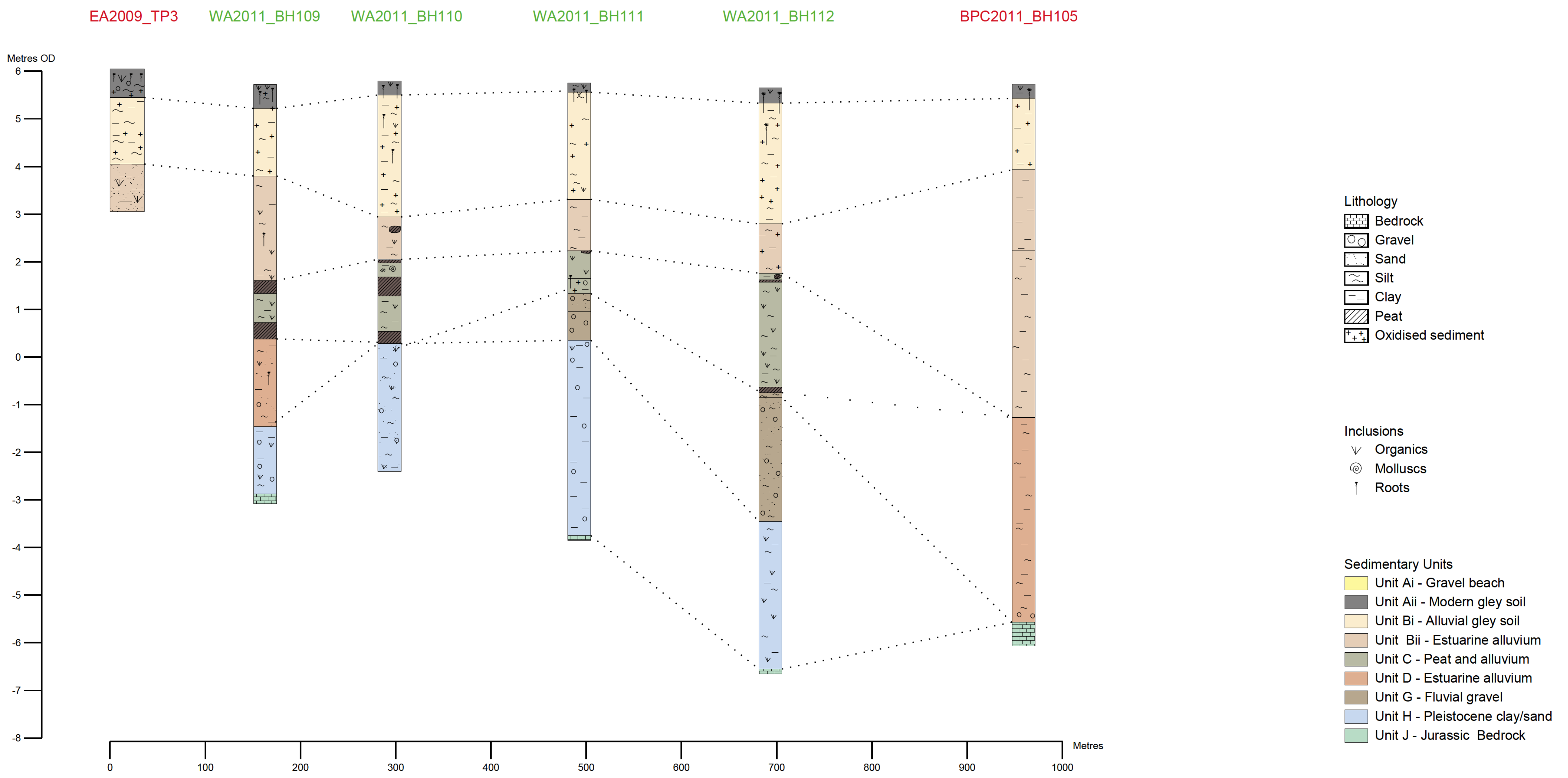
- Scheme outline
- Archaeological evaluation area
- Borehole
- Test pit
- Cone Penetrometer Tests
- Transect
- Palaeochannel
- BH/TP/CPT Contains peat

Revision Number:	0
Illustrator:	LJC
Date:	25/05/11
Scale:	1:8 000 @ A3
Path:	Y:\PROJECTS\70944\D.. O.\Rep..
	\Enviro_borehole\11_05_24\70944_Enviro.dwg

Location of site and geotechnical investigations

Figure 1



Wessex Archaeology

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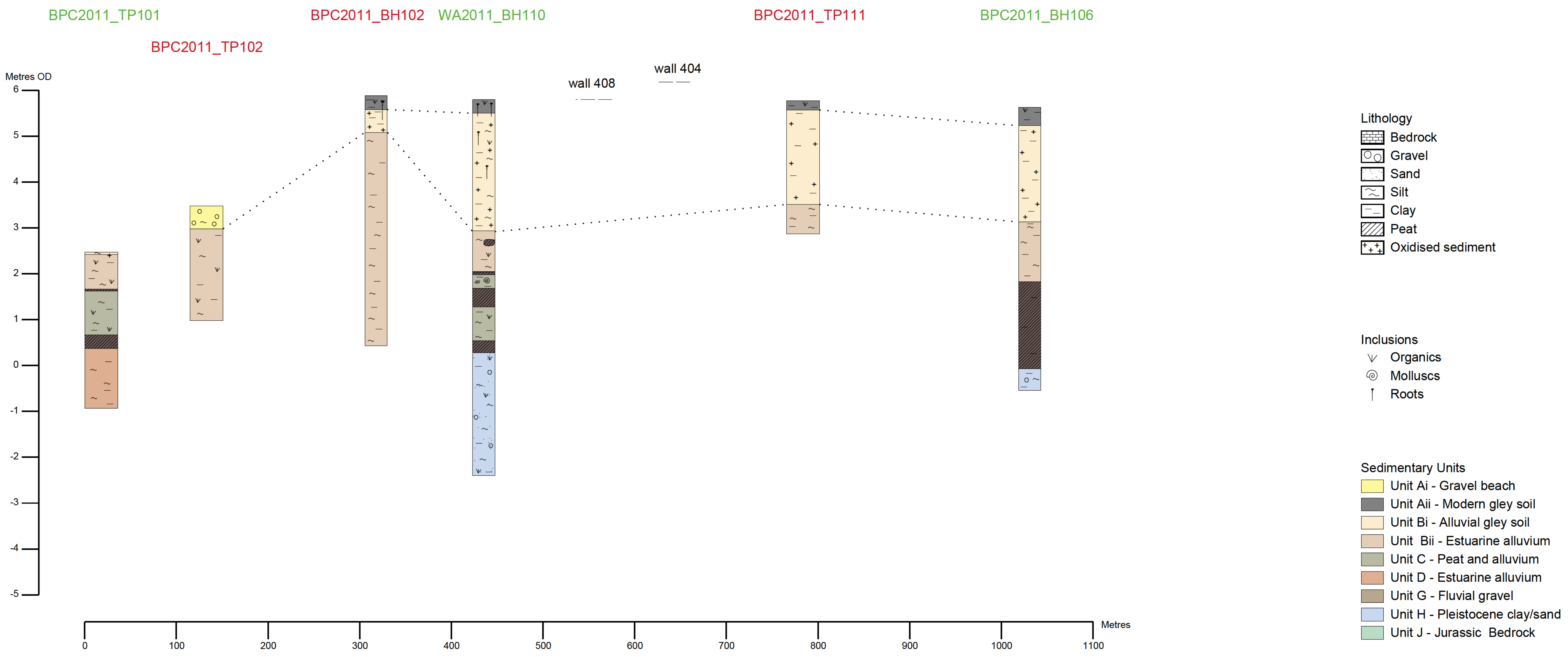
Transect 1

Figure 2



Wessex Archaeology

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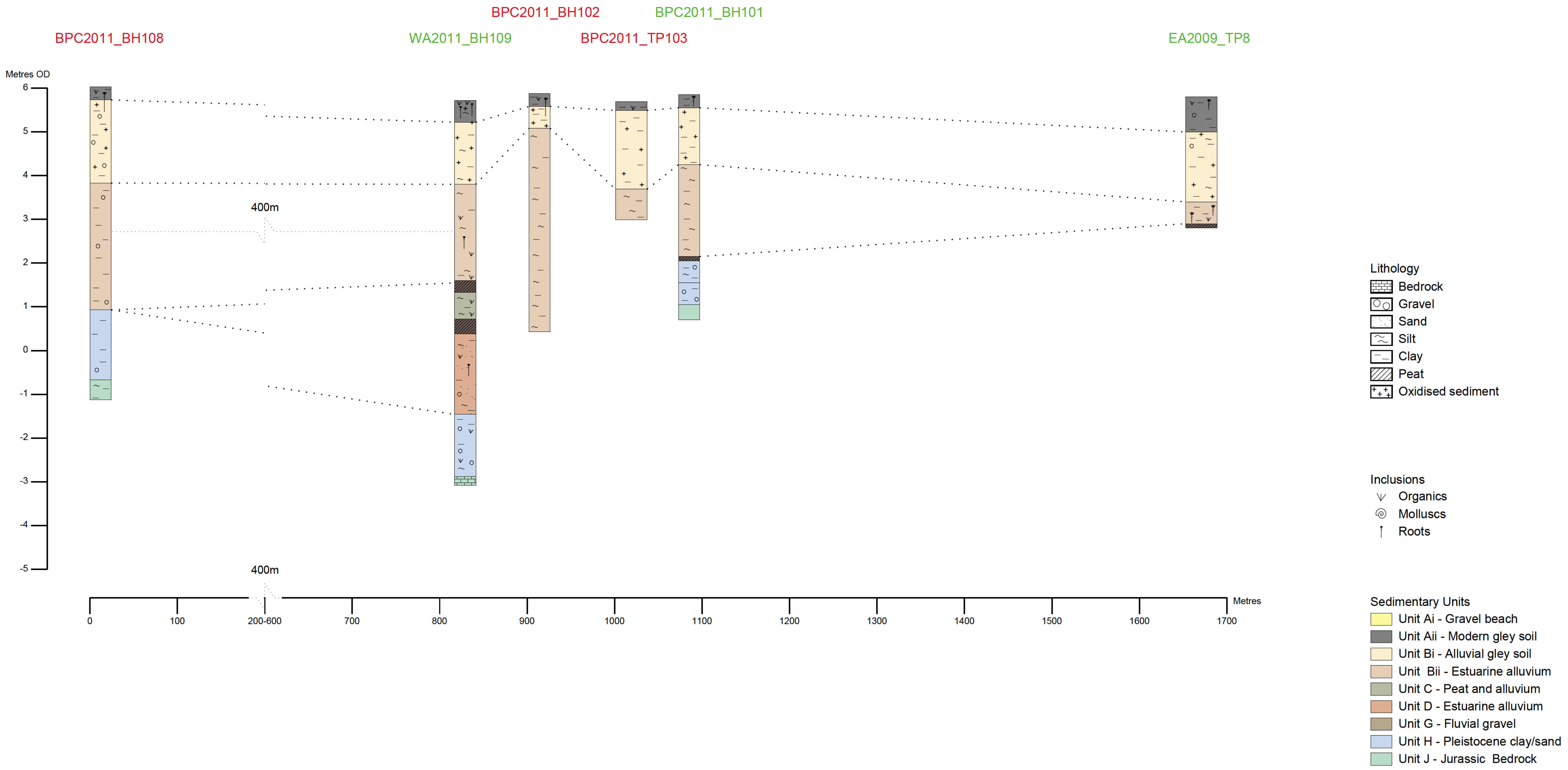
Transect 2

Figure 3



Wessex Archaeology

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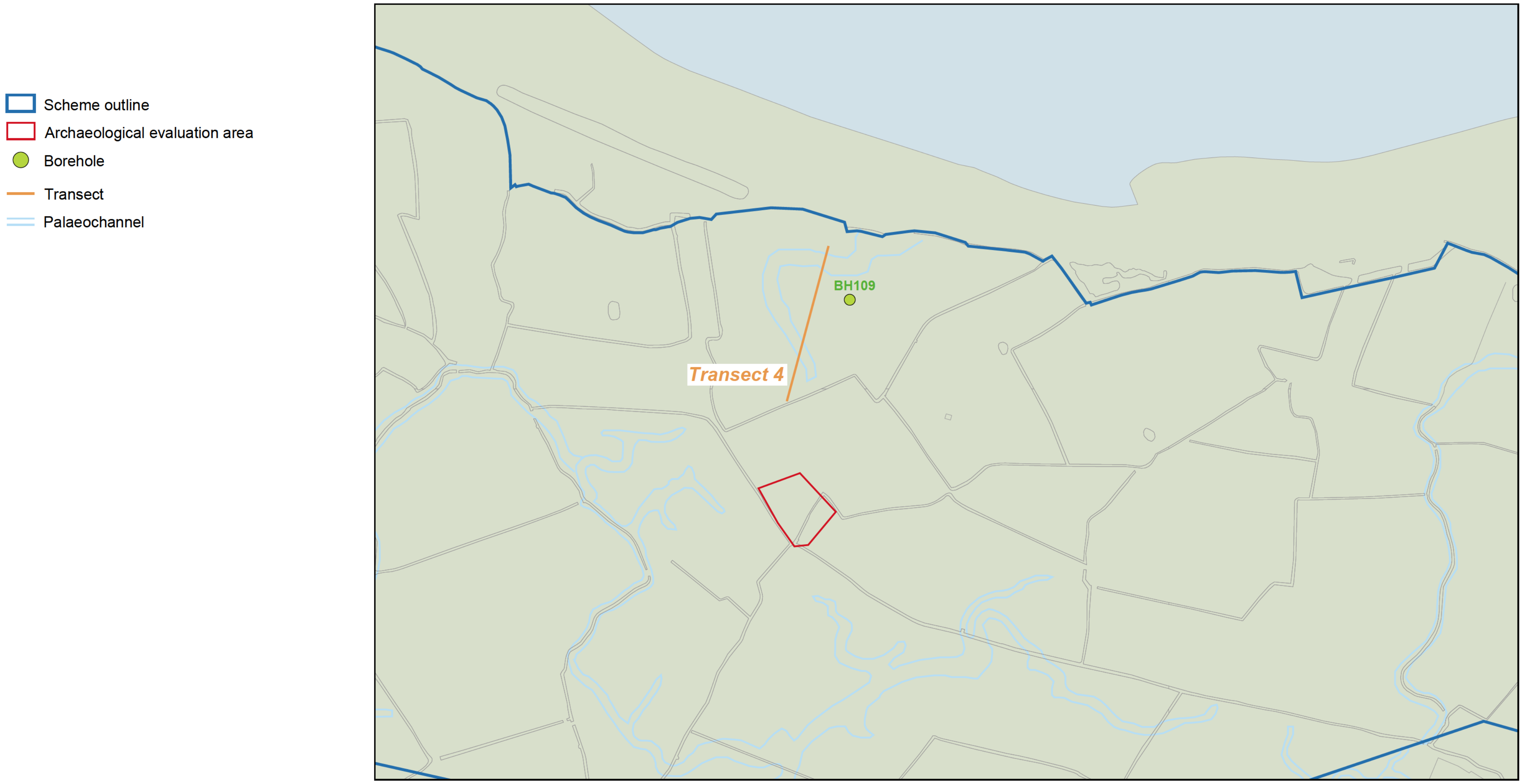
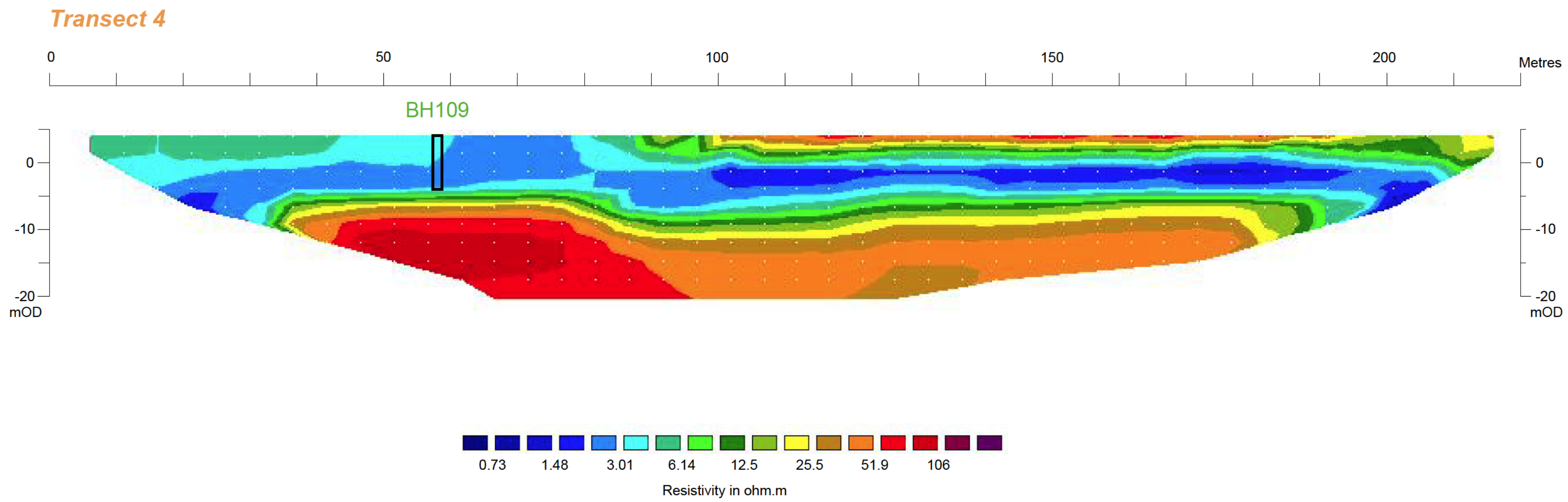
Transect 3

Figure 4





Wessex Archaeology		Date:	26/05/11	Revision Number:	0
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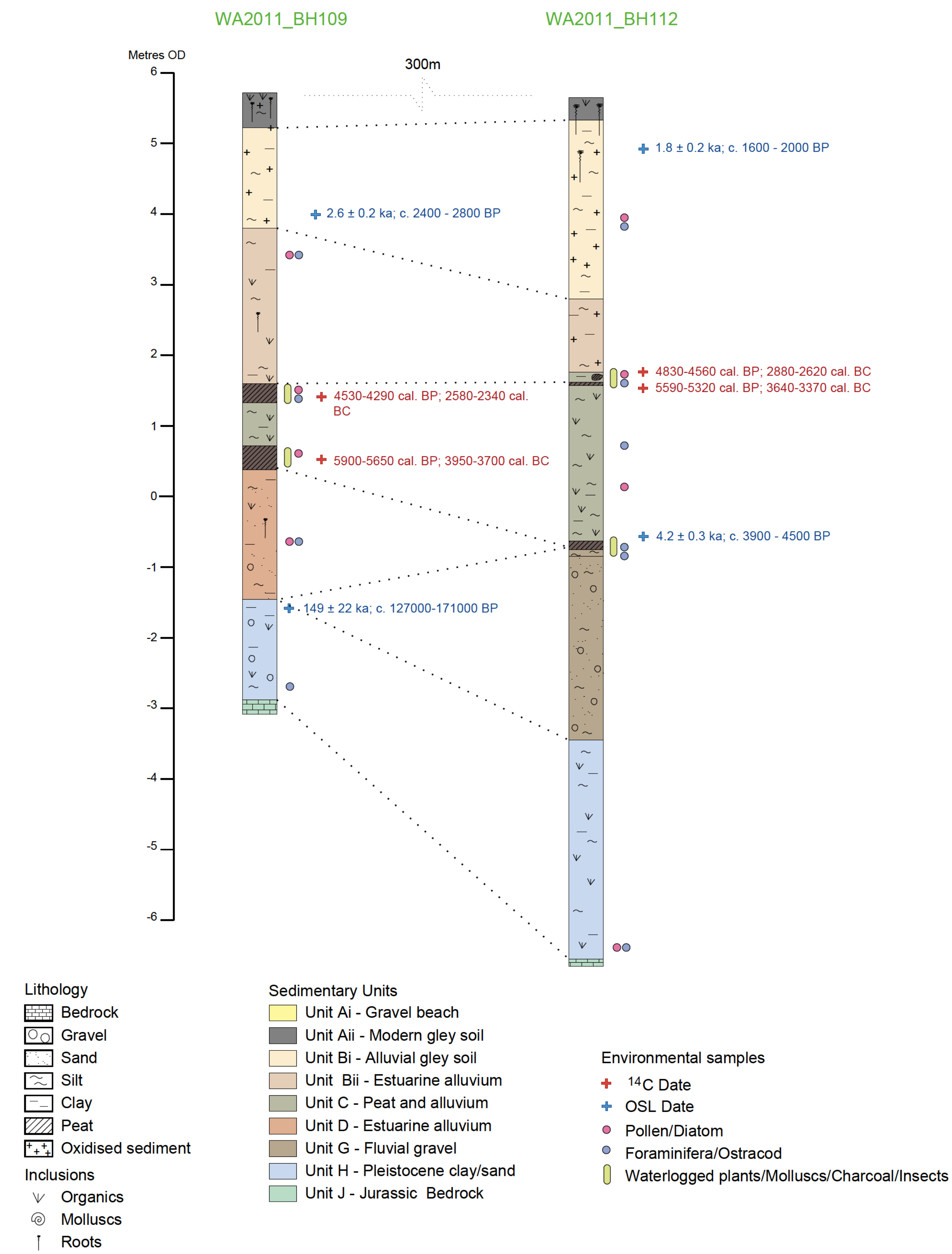
		Path:	Y:\..\70944\D.. O..\Rep..\Enviro_borehole\11_05_24\70944_Enviro_Figs2-6.dwg		

Transect 4, borehole BH109 and Electrical Resistivity Tomography trancsect

Figure 5



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Boreholes WA2011_BH109 and WA2011_BH112, dating and environmental samples

Figure 6

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