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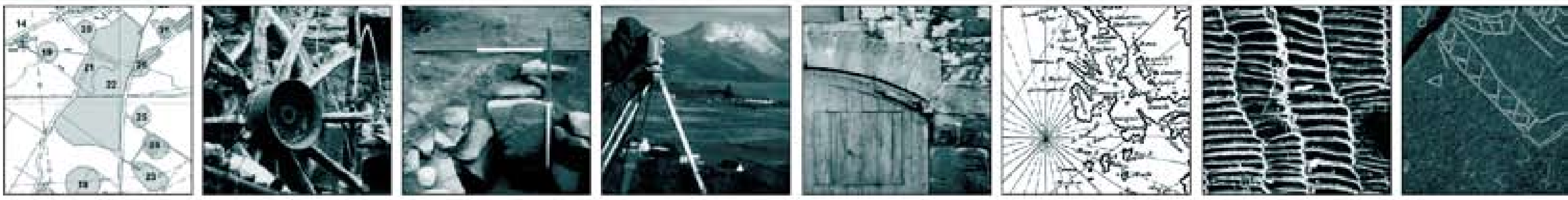

AN INVESTIGATION INTO THE SEDIMENTS AT BUTLIN'S BOGNOR

The Pagham raised beach

for Butlins

BR/106/11/DOC

April 2012

HEADLAND ARCHAEOLOGY Ltd

REGISTERED IfA ORGANISATION

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CONTENTS

1. INTRODUCTION 1

2. BACKGROUND 2

3. METHOD 3

3.1 Stratigraphy 3

3.2 Microfossils 4

3.3 Optically stimulated luminescence dating 4

3.4 Carbon 14 dating 4

4. RESULTS 4

4.1 Stratigraphy 4

4.2 MICROFOSSILS 6

Micro fossils from Test Pit 1 (Table 2) 6

Micro fossils from Test Pit 2 (Table 3) 7

Micro fossils from Test Pit 3 (Table 4) 7

Micro fossils from Test Pit 4 (Table 5, Illus 8) 8

Discussion of the microfossil evidence 8

4.3 Optically stimulated luminescence dating 9

4.4 Carbon 14 dating 11

5. DISCUSSION 11

6. BIBLIOGRAPHY 13

7. APPENDICES 14

Appendix 1 – Detailed recording from the test pits 14

Test pit 1 14

Test pit 2 14

Test pit 3 15

Test pit 4 15

Appendix 2 – Microfossil samples examined 16

Test pit 2 16

Test pit 3 16

Test pit 4 16

Appendix 3 – OSL sample background data 16

Appendix 4 – Radiocarbon dating certificates 17

SUERC-35621 (GU-24591) (31 August 2011) 17

SUERC-35622 (GU-24592) (31 August 2011) 18

SUERC-35623 (GU-24593) (31 August 2011) 19

LIST OF ILLUSTRATIONS

Illus 1 viii
Site location plan for West Sussex Coastal Plain showing position of main sites discussed in text

Illus 2 2
Raised beach staircase of terraces beneath the West Sussex Coastal Plain

Illus 3 4
Site location plan for Bognor area showing main sites containing evidence for marine conditions in the late Pleistocene

Illus 4 5
The Bognor Butlins site showing position of test pits

Illus 5 6
Stratigraphy in test pit 2

Illus 6 6
Stratigraphy in test pit 3

Illus 7 6
Stratigraphy in test pit 4

Illus 8 8
Test pit 4 including sample positions

Illus 9 10
Composite section across the site showing sample locations

Illus 10 10
The relative heights, extent of microfossil preservation and location of OSL dates from selected sites on the south coast

Illus 11 11
Extract from the County survey of Sussex 1778

LIST OF TABLES

Table 1 3
Stratigraphic table for the study area

Table 2 7
Test pit 1 microfossil assemblages

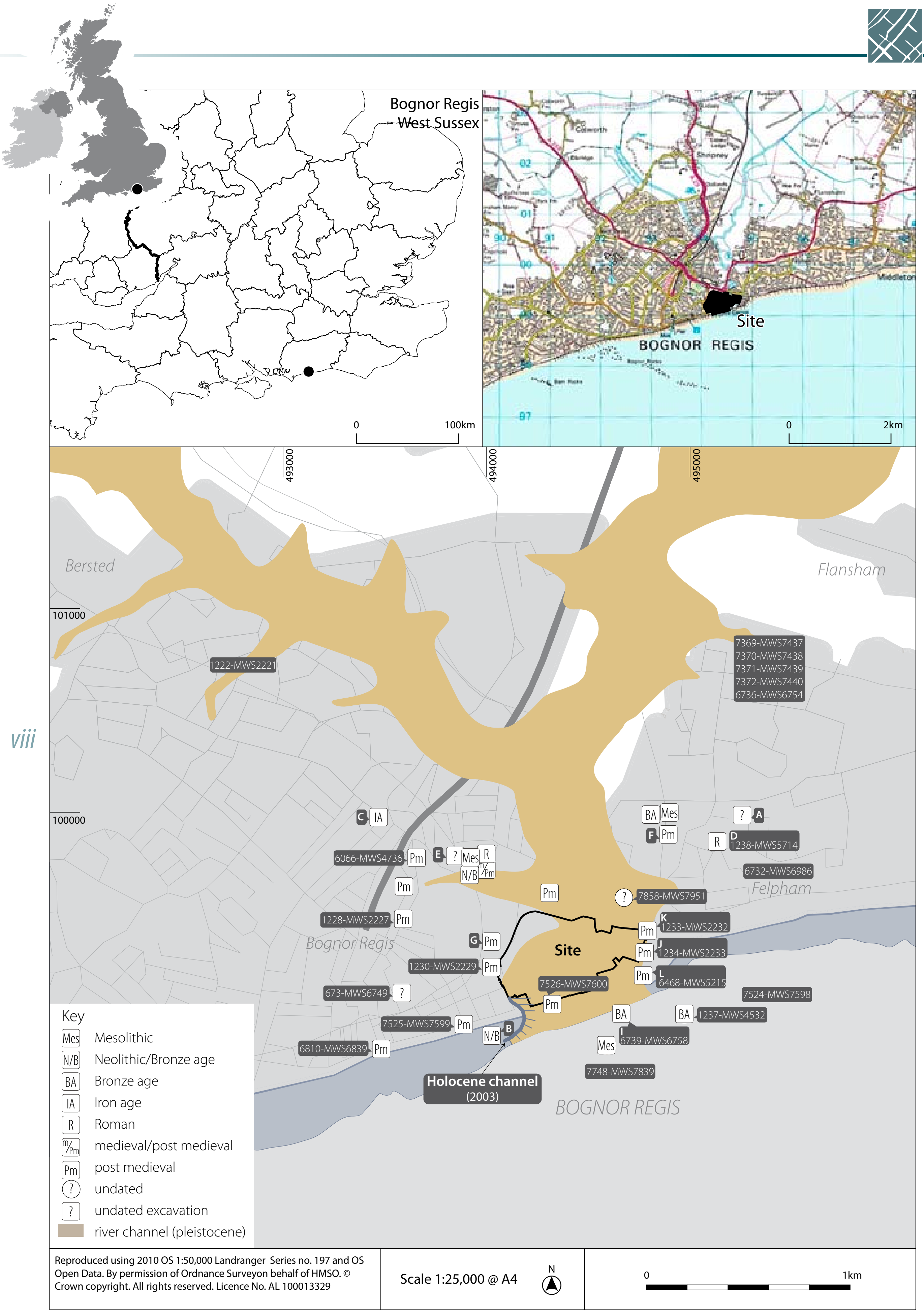
Table 3 7
Test pit 2 microfossil assemblages

Table 4 7
Test pit 3 microfossil assemblages

Table 5 8
Test pit 4 microfossil assemblages

Table 6 9
OSL dates from Pagham raised beach sites including Bognor

Table 7 12
Beach comparison showing the presence of different types of microfossils



Illus 1

Site location plan for West Sussex Coastal Plain showing position of main sites discussed in text

AN INVESTIGATION INTO THE SEDIMENTS AT BUTLIN'S BOGNOR

The Pagham raised beach

An investigation was undertaken into Pleistocene sediments preserved beneath the Butlins site in Bognor. This is the first time that parts of the final phase of marine sedimentation in the interglacial have been recovered with evidence for a regressive sequence (period of sea level fall) through the recovery of the restricted brackish fauna. Cold or cool freshwater faunas, seen elsewhere on the coastal plain but very rarely superimposed on marine sediments, indicate a transition into a cold climate period. However, the relationship between this and the marine regressive elements of the faunal evidence may be simply a result of post depositional mixing of deposits rather than suggesting that regression is occurring under cold climate conditions.

More globally it appears that elements of the true marine faunas found patchily preserved at the base of a number of the test pits indicate a complex reworking history from older, higher raised beaches. The dating of the sediments to Marine Isotope Stage 5e through OSL dating (c. 119,000 years BP) also confirms the cool water nature of the last interglacial assemblages that have previously been made. Carbon dating places upper levels of peat deposition between 1640 and 1800 AD.

1. INTRODUCTION

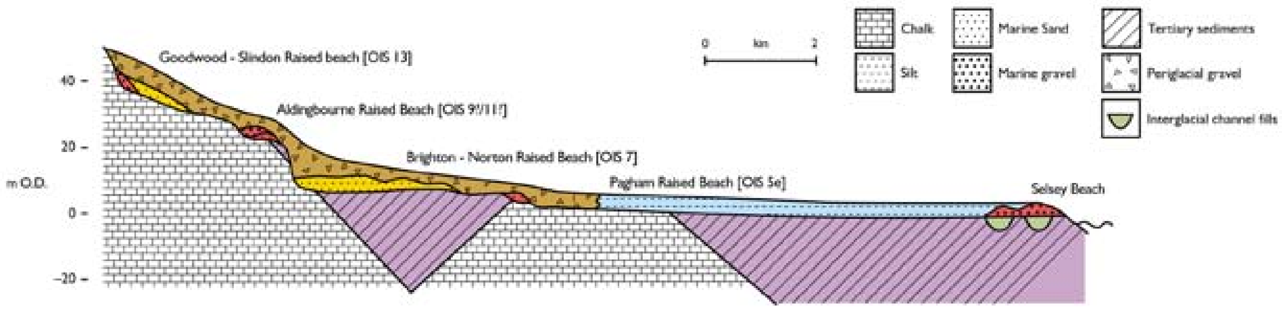
A new Butlins hotel and associated car parks lie to the west of the Holocene Aldingbourne Rife and straddle the edge of an earlier Pleistocene channel. Previous work within the channel has demonstrated that unlike some other water courses along the south coast, the Aldingbourne Rife became a marine environment very early in its life, other channels being fresh water. Desk-based work has identified a focus of past occupation along the edges of the channel including Bronze Age activity immediately to the south of the site of the current proposals.

Investigations recently completed by Headland Archaeology (Brekmoe and Rouse 2011) for Hotel A, targeted what is believed to be the edge of the Pleistocene channel. The work identified the bank edge and a raised beach. The sediment sequence associated with the bank is rare for the south coast as normally only the high energy deposits survive. In addition to this, the preservation of foraminifera is also rare. Samples from the peat showed that pollen was poorly preserved, but plant macrofossils had survived in good condition. The peat overlying the Holocene alluvial deposits that filled the channel may imply the area was a boggy wetland during the medieval or post-medieval period.

The scope of the work for this project was identified following the previous stage of evaluation (*op sit*) on the site which identified a Pleistocene Landscape. In summary the requirements were:

- Submission of samples for radiocarbon dating from the plant macrofossil assemblage, and from the worked wooden stake Find 001 (recovered during the earlier work by Brekmoe and Rouse (2011));
- Submission for radiocarbon dating of a sample from the layer of 'charcoal', located at 7.4m in a bore hole (Brekmoe and Rouse 2011; Section 6);
- Further investigation and recording of the 'Raised Beach' deposits, as recommended at the end of Appendix 2 (*op sit*), involving excavation of five further test pits, before development commenced.
- Off-site – carrying out the necessary analyses, scientific dating, and completion of an overall report on all the findings, for publication and dissemination to the local community.

This report primarily describes the results of the investigation into the sediments preserved at the Butlins



Illus 2

Raised beach staircase of terraces beneath the West Sussex Coastal Plain

site in Bognor (Illus 1). As part of the initial phase of site investigation (*op sit*) conducted at the site five samples were collected from a single test pit for microfossil assessment. This initial investigation indicated that a range of microfossils were preserved at the site within the sands and as a result further sampling and investigation was undertaken in April 2011.

The following text provides detail on the background to the site, the stratigraphy from all the excavated trenches of both phases of investigation, detailed information on the contained microfossils from the recovered samples and documentation of the results of an attempt to date the age of the sands as well as dates on later carbon bearing material. The results of the investigation are then considered in the context of the history of development in the coastal plain.

2. BACKGROUND

The site lies inland of the modern coast at Bognor Regis within an area of low lying ground behind the modern beach on the edge of Aldingbourne Rife (Illus 1). Bedrock geologies consisting of Cretaceous Chalk beneath Tertiary clays and silts (Gallois, 1965) exist within the area.

Quaternary sediments are dominated by marine sediments. These sediments have been partially mapped and can be divided into at least three major groups on the basis of their position in the landscape and elevations above sea level (Illus 2, Table 1) (Bates *et al*, 2010):

- Goodwood/Slindon Raised Beach of the Upper Coastal Plain
- Aldingbourne Raised Beach present at the boundary between the Upper and Lower Coastal Plains
- A composite sequence of marine sands of the Lower Coastal Plain including the Brighton/ Norton and Pagham Raised Beaches

Although a great deal of interest has been generated in the preserved sedimentary sequences and their associated archaeology of the West Sussex Coastal Plain, through the discoveries at Boxgrove (Roberts and Parfitt, 1999), considerable problems in differentiating and contextualising the lowermost marine sediments around the coast between Selsey and Bognor Regis remain (Bates *et al*, 2010).

Of particular importance to this investigation are the composite sequences of sands of the Lower Coastal Plain. Two sequences of marine sediments are now known to occur on the Lower Coastal Plain and are known as the Brighton/Norton Raised Beach and the Pagham Raised Beach (Illus 2, Table 1) (Bates *et al*, 2010). By contrast to the relatively well defined older sequences the sequences associated with the Brighton/Norton and Pagham beaches are more difficult to delimit and define because of their close proximity in elevation. The elevation of the sequences indicates that two broad clusters of platform heights with associated sequences of marine sands exist within the region approximately delimited by the 5m contour. Spatially these sequences also cluster with the majority of the sequences at higher elevations occurring towards the northern margin of the Lower Coastal Plain. They are typically about 2m in thickness except towards the northern end of the coastal plain where up to 4m of sediments have been recorded (*eg* at Norton Farm, Bates *et al* 2000). In many cases the sequences of marine sediments are dominated by horizontally bedded marine sands that are slightly gravelly in places.

Sediments located below 5m OD are restricted to the southern margin of the higher parts of the Lower Coastal Plain at locations such as Warblington and Woodhorn Farm, and in the area to the west and northwest of Bognor Regis (Illus 3). Marine gravels are only exposed at the present time at West Street, Selsey (Illus 1). However, similar sorts of gravels were noted by many authors in the low cliffs along the Sussex coast (*eg* Reid, 1903) before the construction of sea defences resulted in their burial in concrete. Typically, the Pagham sequences comprise sands containing much flint and Chalk debris which

Epoch	Age kBP	MI stage	Traditional stage (Britain)	Marine sediments (Raised Beaches)	Region Palaeogeographic condition	Local Palaeogeographic conditions
Holocene	Present – 10,000	1	Flandrian	–	–	Harboured coastline
Late Pleistocene	25,000	2	Devensian	–	–	–
	50,000	3	Devensian	–	–	–
	70,000	4	Devensian	–	–	–
	110,000	5a–d	Devensian	–	–	–
	125,000	5e	Ipswichian	Selsey Ridge Pagham Formation (Pagham Raised Beach)	Fully open channel. Isle of Wight/ mainland ridge breached by sea, truncated Solent system and modern tidal patterns established	Harboured coastline
Middle Pleistocene	190,000	6	Wolstonian / Saalian complex	–	–	–
	240,000	7	Wolstonian / Saalian complex	Norton Formation (Brighton/ Norton Raised Beach) Aldingbourne Formation (Aldingbourne Raised Beach)	Fully open channel. Major Solent estuary Open channel for part of interglacial. Major Solent estuary	Open coastline Embayed coastline
	300,000	8	Wolstonian / Saalian complex	–	–	–
	340,000	9	Wolstonian / Saalian complex	?	?	Embayed coastline
	380,000	10	Wolstonian / Saalian complex	–	–	–
	425,000	11	Hoxnian	?	?	Embayed coastline
	480,000	12	Anglian	–	Channel ridge breached	–
	620,000	13–16	Cromerian complex & Beestonian glaciation	Slindon Formation (Goodwood/ Slindon Raised Beach)	Channel closed. Major Solent Estuary	Embayed coastline
	780,000	17–19	Cromerian complex & Beestonian glaciation	–	–	–
Early Pleistocene	1,800,000	20–64	–	–	–	–

Table 1

Stratigraphic table for the study area

would seem to indicate active erosion or a high energy environment.

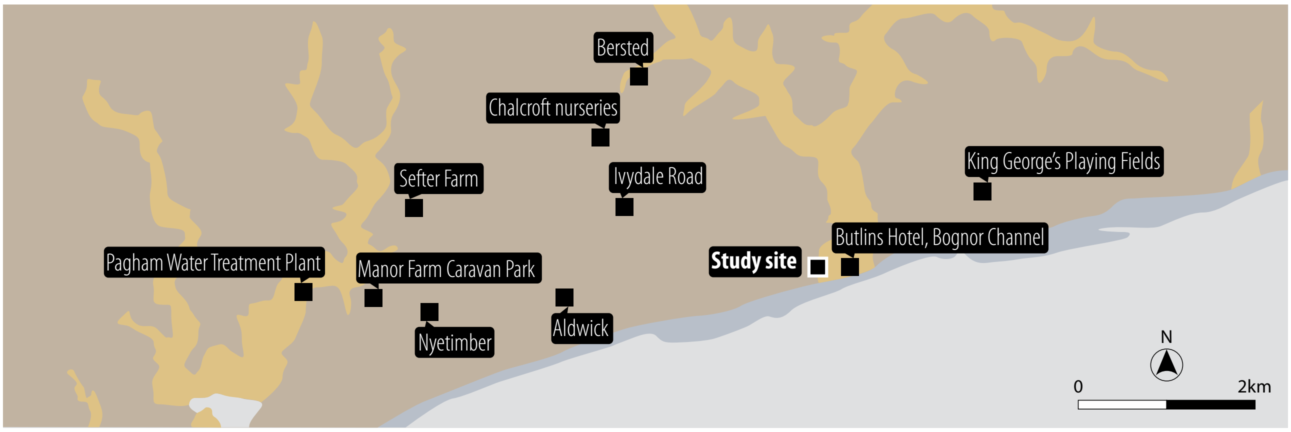
Within the Bognor area (Illus 3) sites such as Pagham Water Treatment Plant, Iveydale Road and Aldwick have produced microfossil assemblages, while other sites such as Sefter Farm probably belong to the same beach but their sequences were decalcified and did not preserve any microfaunas. What is surprising is that the microfaunas contain virtually identical foraminiferal and ostracod assemblages to that of the older Brighton/ Norton Raised Beach (Bates *et al*, 2010) in which the microfossil assemblages often contain cold indicator species. This is surprising in sediments thought to belong to the last interglacial, a period of time in which temperatures probably exceeded those of the current interglacial. Additionally the foraminifera are dominated by large robust *Elphidium clavatum*, *Cassidulian reniformis* and *E. albiumbilicatum*, while *Ammonia batavus* and *E. fichtellianum* are both dwarfed as in the Brighton/Norton Raised Beach. Even the reworking has a similar pattern with a constant input of large robust and ornate *A. batavus* suggesting that drainage was eroding the Aldingbourne Raised Beach exposure at this time.

3. METHOD

3.1 Stratigraphy

It was established that three further test pits needed to be excavated to obtain samples relating to the 'Raised Beach' identified during the earlier evaluation. These are shown in relation to the areas of earlier investigation on Illus 4. Trenches were excavated using a toothless bucket.

Written, photographic and drawn records were made



Illus 3

Site location plan for Bognor area showing main sites containing evidence for marine conditions in the late Pleistocene

alongside a survey of the work using a dGPS. Colour slide and print film were used to record the sections and sample locations and 7.2mp digital camera was used for illustrative purposes. Sections were recorded at 1:20 and *pro forma* record sheets were completed. OSL dating samples were collected by Dr Martin Bates of Lampeter University who also recorded the sediment sequence exposed and obtained further samples for the study of osracods and foraminifera.

3.2 Microfossils

Twenty one samples were investigated from the test pits (see Appendix 2 for details). The samples, many of which were very wet on arrival, were first put in ceramic bowls and thoroughly dried in an oven. Then a small amount of sodium carbonate was added to each (to help remove the clay fraction) and hot water poured over them. They were left to soak. Good breakdown was rapidly achieved by washing through a 75 micron sieve with hot water. Each residue was then decanted back into a bowl and returned to the oven to dry. Samples were stored in labelled plastic bags and analysed by placing each sample into a nest of sieves and examining each of the fractions on a tray under a binocular microscope. The faunas were noted and the microfossils picked out and put into 3” x 1” slides for archive purposes.

3.3 Optically stimulated luminescence dating

The sample was measured in automated Risø luminescence readers (Bøtter-Jensen, 1988, 1997, 2000) using a SAR post-IR blue OSL measurement protocol (Murray and Wintle 2000, Banerjee *et al* 2001, Wintle and Murray 2006). Dose rate calculations are based on the concentration of radioactive elements (potassium, thorium and uranium) derived from elemental analysis by ICP-MS using a fusion sample preparation technique. The final OSL age estimates include an additional 2% systematic error to account for uncertainties in source calibration. Dose rate calculations are based on Aitken (1985). These incorporated beta attenuation factors (Mejdahl 1979), dose rate conversion factors (Adamiec and Aitken 1998) and an absorption coefficient for the water content (Zimmerman 1971). The contribution of cosmic radiation to the total dose rate was calculated as a function of latitude, altitude, burial depth and average over-burden density based on data by Prescott and Hutton (1994).

3.4 Carbon 14 dating

Headland Archaeology (UK) Ltd carefully extracted material from the peat deposit identified in Test Pit 5 of the previous stage of trial trenching (two samples from depths of 85–95cm and 96–105cm). These were submitted to the SUERC laboratory for Carbon 14 dating along with a sample from a wooden stake recovered from Trench C, Find 001 (Brekmoe and Rouse 2011). A carbon deposit recovered from a bore hole on the site at a depth of roughly 7m beneath the surface was identified as being coal-like and therefore not submitted for dating This work was undertaken by Scott Timpany of Headland Archaeology (UK) Ltd.

4. RESULTS

4.1 Stratigraphy

Four test pits were excavated (Illus 4–7) to obtain samples for investigation and to investigate the nature of the sediments present (TP1 was excavated as part of the previous stage of work). These logs and their samples are including in Appendix 1.

Illus 4

The Bognor Butlins site showing position of test pits

Illus 5

Stratigraphy in test pit 2

Illus 6

Stratigraphy in test pit 3

Illus 7

Stratigraphy in test pit 4

The sediments identified can be subdivided into a relatively simple sequence consisting of:

1. Made ground
2. Fine grained clay-silts (brickearths)
3. Angular chalk and flint rubble
4. Sands becoming sandy gravels laterally
5. Bedrock

The sequences attained a maximum thickness of c.2.5m. The bedrock surface where present lay at around +2.0m OD and comprised Tertiary clay. These major units are well illustrated in Illus 8.

The sands present above bedrock in all cases form a thin sheet of sand that laterally varies from pure sand to sand with substantial quantities of rounded flint clasts. The sand body varies from a greenish colour to a reddish brown colour. These qualities are typical of sands from the lower reaches of the coastal plain and similar sediments have been recorded at the Pagham Waste Water Treatment Plant (Illus 3).

The sediments overlying the sands typically consist of fine grained clay-silts which resemble the 'brickearth' that dominates the Lower Coastal Plain (Hodgson, 1964) and has been ascribed to the last cold stage by both Hodgson (1964) and Parks and Rendell (1982). These deposits consist of a mix of wind blown silt and water derived sediments accumulating in shallow bodies of water collecting on the low angle surface of the Lower Coastal Plain. Sandwiched between the marine sediments and the brickearth in one test pit (3) was a mix of chalk and flint rubble that appears to represent a soliflucted sediment derived from cold climate weathering and breakup of chalk bedrock and introduced via slumping and gravity feed down the low angled slopes.

4.2 MICROFOSSILS

The following study comprises the identification and analysis of foraminifera and ostracods that were preserved within the ancient beach deposits found on the site. Foraminifera are effectively represented by their calcium carbonate casings or shells and derive from one of the most common plankton species. Ostrocods are small, bivalved, crustaceans that usually live in the upper part of the sea bed. Both types of microfossil are diagnostic and provide an indication as to the temperature and conditions at the time they colonised the ocean.

The description below first lists the contents of each sample and then discusses the distribution and significance of the foraminifera and ostracods (shown graphically in Tables 2–5).

Micro fossils from Test Pit 1 (Table 2)

The top three samples (TP1.S1 – TP1.S3) were all barren. In particular, samples TP1–S1 and TP1–S2 contained much iron mineral and were apparently weathered and thus decalcified. The bottom two samples, however, did contain foraminifera, but no ostracods or molluscs.

In sample TP1–S4 microfossils were not very common and were only found after a careful and time-consuming examination. They comprised two types of *Ammonia batavus* (a robust and very ornate form and a somewhat flatter and less ornate form), together with *Elphidium crispum* and *Elphidium excavatum*.

Sample TP1.S5 had the best fauna, but it was still rather restricted with only five species of foraminifera present, three of them common (Table 2), with two of them not found in sample TP1–S4.

	TP1–S1	TP1–S2	TP1–S3	TP1–S4	TP1–S5
Ammonia batavus (Type I – robust and ornate)	B	B	B	x	x
Ammonia batavus (Type II – flat with small boss)	A	A	A	x	xx
Elphidium crispum	R	R	R	x	–
Elphidium excavatum	R	R	R	x	xx
Elphidium williamsoni	E	E	E	–	xx
Haynesina germanica	N	N	N	–	x
	sand (weathered)			*gravelly sand*	

x – present (several specimens); xx – common

Table 2

Test pit 1 microfossil assemblages

Micro fossils from Test Pit 2 (Table 3)

Sample TP2–S1 contained chalk and flint debris (with chalk microfossils). The pleistocene component consisted of fragmentary and very eroded barnacle plates, and two forms of foraminifera, *Ammonia batavus* and *Elphidium williamsoni*.

FORAMINIFERA	TP2–S1
Ammonia batavus (Type I – robust and ornate)	x
Ammonia batavus (Type II – flat with small boss)	x
Elphidium williamsoni	x

x – present (several specimens); xx – common

Table 3

Test pit 2 microfossil assemblages

Micro fossils from Test Pit 3 (Table 4)

Sample TP3–S2 (1.3m) was a curious sediment full of chalky agglomerations (with embedded quartz grains) formed around rootlets (rhizolith-like). It contained cold climate freshwater ostracods (*Leucocythere batesi* and *Limnocytherina sanctipatricii*) and shallow marine (?regressive facies) foraminifera (*Ammonia batavus* Type II only) and ostracods (*Cythere lutea*, *Hemicythere villosa* and *Robertsonites tuberculatus*) of Pleistocene date (Table 4).

Sample TP3–S3 (1.6m) contained a sediment identical to that from TP3–S1 and again contained cold/cool freshwater ostracods (the same species as in TP3–S1), and shallow marine foraminifera (this time *Elphidium williamsoni* only, but common) and four species of ostracod (as in TP3–S1, but with the addition of *Leptocythere psammophila*) (Table 4).

Samples TP3–S4 (1.7m), and TP3–S5 (2.0m) both contained a completely barren silty sand.

Sample TP3–S6 (2.4m) contained chalk and flint debris (with Chalk fossils). The Pleistocene component consisted of a few barnacle plate scraps (very eroded) and foraminifera. (*Ammonia batavus* Type I only, *Elphidium crispum*, *Elphidium excavatum* and *Ammonia falsobeccarii*).

	TP3–S2	TP3–S3	TP3–S4	TP3–S5	TP3–S6
FORAMINIFERA	**1.3m**	**1.6m**	**1.7m**	**2.0m**	**2.4m**
Ammonia batavus (Type II – flat with small boss)	x	–	–	–	–
Elphidium williamsoni	xx	xx	–	–	–
Ammonia batavus (Type I – robust and ornate)	–	–	–	–	x
Elphidium crispum	–	–	–	–	x
Elphidium excavatum	–	–	–	–	x
Ammonia falsobeccarii	–	–	–	–	x
	2	**3**	**4**	**5**	**6**
MARINE OSTRACODS	**1.3m**	**1.6m**	**1.7m**	**2.0m**	**2.4m**
Cythere lutea	x	x	–	–	–
Hemicythere villosa	x	x	–	–	–
Robertsonites tuberculatus	x	x	–	–	–
Leptocythere psammophila	–	x	–	–	–
	2	**3**	**4**	**5**	**6**
FRESHWATER OSTRACODS	**1.3m**	**1.6m**	**1.7m**	**2.0m**	**2.4m**
Leucocythere batesi	x	x	–	–	–
Limnocytherina sanctipatricii	x	x	–	–	–

x – present (several specimens)
xx – common
cool/cold indicators

Table 4

Test pit 3 microfossil assemblages

FORAMINIFERA	TP4-S7	TP4-S8	TP4-S9	TP4-S10	TP4-S11	TP4-S12	TP4-S13	TP4-S14	TP4-S15	TP4-S16
Ammonia batavus (Type I – robust and ornate)	–	–	–	–	–	–	–	x	–	–
Ammonia batavus (Type II – flat with small boss)	–	–	–	–	–	–	–	x	–	–
Elphidium crispum	–	–	–	–	–	–	–	x	–	–
Elphidium excavatum	–	–	–	–	–	–	–	x	–	–
Elphidium williamsoni	–	–	–	–	–	–	–	x	–	–

Table 5

Test pit 4 microfossil assemblages

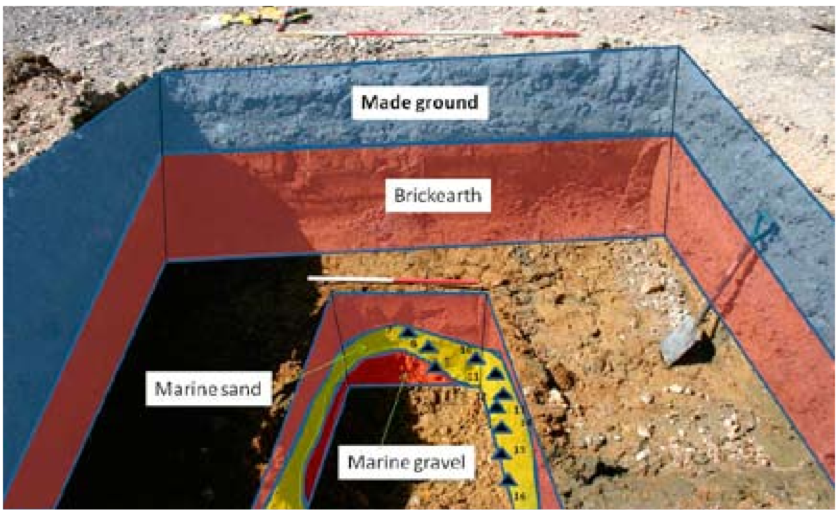
Micro fossils from Test Pit 4 (Table 5, Illus 8)

The most productive sample from this test pit was TP4–S14 (2.0m) which contained flint pebbles and chalk fossils with a Pleistocene component consisting of fragments of barnacle plates, molluscs and quite common foraminifera (two forms of *Ammonia batavus*, *Elphidium crispum*, *E. excavatum* and *E. williamsoni*.

Sample TP4–S7 contained a few fragments of chalk and chalk microfauna (only agglutinating foraminifera) but was otherwise barren.

The following samples were barren with the exception of the points noted:

- TP4–S8 and S15 being a silty sand,
- TP4–S9 containing some iron mineral (goethite),
- TP4–S10 containing chalk and flint debris,
- TP4–S11 containing chalk and flint debris (with Chalk foraminifera),
- TP4–S12 containing chalk and flint debris with Cretaceous macrofauna and microfauna and some possible (?etched) earthworm granules,
- TP4–S13 containing flint pebbles, and
- TP4–S16 containing chalk and flint debris with some iron mineral.



Illus 8

Test pit 4 including sample positions

Discussion of the microfossil evidence

The distribution of the microfossils is very patchy but some meaningful and most interesting conclusions can perhaps still be drawn.

The uppermost two samples from test pit 3 (TP3–S2 (1.3) and TP3–S3 (1.6m)) clearly represent a Devensian cold stage deposit, the likes of which are widely found in the Bognor area and have previously been described by Bates *et al* (2009). The curious chalky rhizolith-rich sediments are the result of the drying out of tundra-like seasonal waterbodies. The importance of freshwater ostracods such as these, as cold indicators, is given in Whittaker & Horne (2009). This unit therefore appears to be a solifluction deposit which has incorporated an older marine component, probably belonging to the Pagham Raised Beach.

The patchy preservation of microfossils in the Pagham raised beach has previously been noted and is a function more often than not of decalcification of the marine sediments. Here, however, the incorporation of the chalky Devensian sediment seems to have buffered it and resulted in a better-than-usual preservation of both the Pagham macro- and microfossils. It is also interesting that the upper parts of test pit 3 contain a very restricted brackish fauna, characterised by the preponderance of the shallow euryhaline foraminifer *Elphidium williamsoni*, accompanied by only a few flat, unornate (and possibly) more brackish forms of *Ammonia batavus* (herein referred to as type II). This may indicate a regressive phase at the end of the Pagham interglacial, something not previously seen in sediments of this supposed age. The ostracods present are shallow marine phytal forms in the main, and quite robust but even these are slightly decalcified and it is suspected that other more delicate ostracods may have been totally destroyed. Robertsonites tuberculatus would not be found living in southern England today. It is considered to be a 'northern form', but species such as these are commonly found in all the (warm) temperate interglacials from the South Coast, and are thus referred to as 'non-analogue' forms.

Most of the rest of the samples are completely barren (and decalcified) which is unfortunately often the case with the Pagham Raised Beach, but the clean silty-sand component does look marine. However, in test pit 4 (TP4–S14), test pit 2 (TP2–S1) and test pit 3 (TP3–S6 (2.4m)) marine Pleistocene microfossils occur again, this time as foraminifera only, and for the most part rather different from those found in test pit 3 (interval 1.3–1.6m; Table 4). Furthermore, these are identical faunas to those found in TP1–S4 and TP1–S5 from test pit 1 at the site (Whittaker, 2011). The main type of *Ammonia batavus* is now Type I (robust, ornate and often large), Type II is either completely missing as in test pit 3 (TP3–S6) or rare as in test pits 2 and 4 (TP2–S1, TP4–S14). It could be argued that the occurrence of the two forms has ecological significance; the very robust Type 1 being indicative of fully marine and high energy environments; whereas Type II is perhaps indicative of a more protected or brackish environment (or both). The also highly ornate Type I is, however, almost certainly indicative of a warm interglacial and could be reworked (*ie* eroded from earlier deposits). Moreover, they are very reminiscent of the type found in the Aldingbourne Raised Beach. This is accompanied by *Ephidium crispum* in both test pits 3 and 4 and even a few specimens of *Ammonia falsobeccarii* in test pit 3 (TP3–S6 (Table 4). This last species is only known in the vicinity from the Boxgrove and Aldingbourne raised beaches, and may indicate that the Aldingbourne Rife was active as a major stream cutting through these older Pleistocene deposits at this time, redepositing their contents at this site. Similar extensive reworking has been found previously in the Pagham Raised Beach, especially, and most spectacularly at Warblington (WAB/09), BH 9, 9A and 11 (Bates *et al*, 2010).

4.3 Optically stimulated luminescence dating

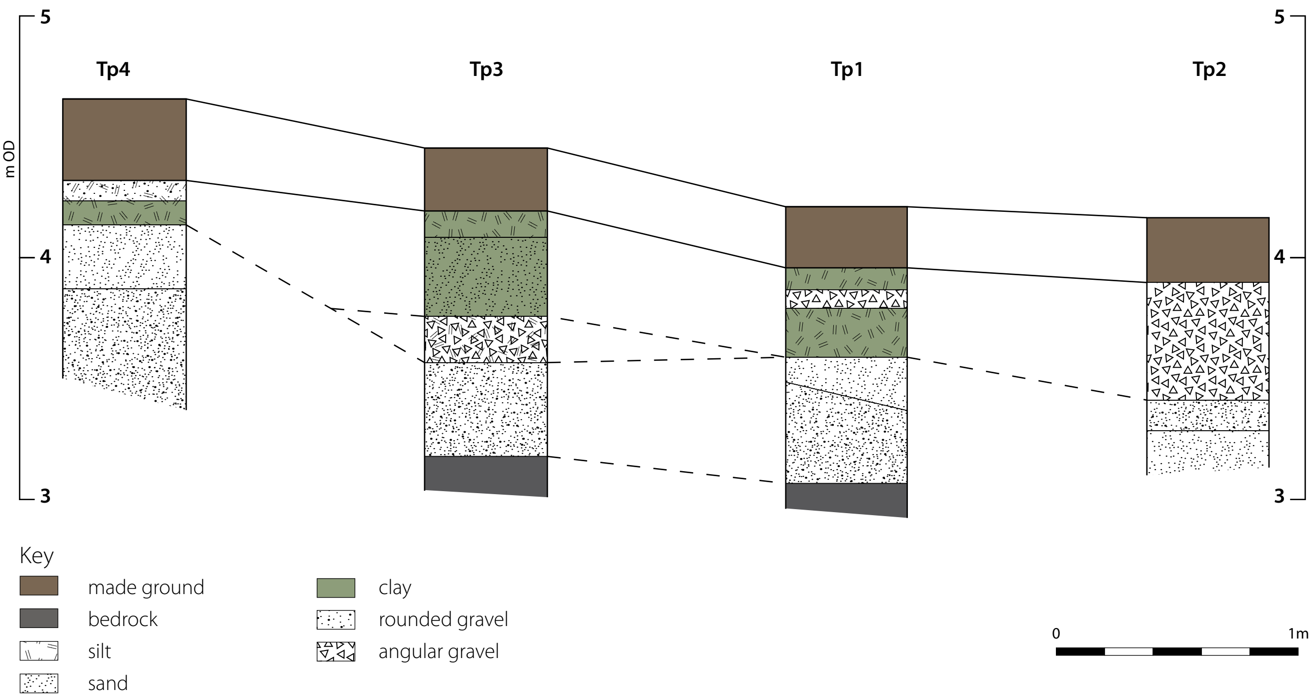
The dating method used here is loosely similar to thermo luminescence dating. The principle is based on the assumption that energy stored in the form of loose electron traps would be completely dissipated whilst a sediment is settling in sun light, the sun's rays clearing the electrons from their traps. Once sealed from the light, bombardment by radiation gradually builds up a store of energy over time. The amount of such energy stored at the time the sample is taken will be proportional to the length of time the sediment has been sealed from light and the level of background radiation. The latter can be estimated (see Method above), and therefore by collecting a sample and releasing the energy stored in the electron traps (in the form of emitted light – luminescence) so can the length of time the deposit has been buried. The result is based on luminescence measurements of sand-sized quartz (180–255µm). Further details for individual samples are presented below in Appendix 3.

Field code	Lab. code	Field moist. (%)	K conc. (%)	Th conc. (%o)	U conc. (%o)	Overburden thickness (m)	Cosmic dose rate (Gy/ka)	Total dose rate (Gy/ka)	Mean D_e (Gy)	Age est. (ka)	MIS
Butlins, Bognor											
BUT–11, OSL 1	X5283	15.3	0.450±0.02	4.5±0.25	1.10±0.6	1.00	0.19±0.06	0.19±0.4	1.04±0.05	119.8±10.6	5e
Selsey West Street											
SEL01–1	X549	10.0	0.05±0.00	0.48±0.04	0.25±0.02	2.60	0.15±0.01	0.28±0.02	39.10±1.1	138.8±11.0	5e-6
SEL01–2	X550	10.0	0.05±0.00	0.34±0.02	0.25±0.01	3.55	0.13±0.01	0.25±0.02	31.60±1.2	126.0±10.1	5d-6
Pagham Water Treatment Plant											
PWT06–01[i]	X2796	3.0	0.61±0.03	4.60±0.23	1.30±0.07	1.15	0.18±0.02	1.35±0.09	167.2±4.3	123.8±8.7	5d-e
PWT06–02[i]	X2797	3.0	0.61±0.03	4.70±0.24	1.30±0.07	1.15	0.18±0.02	1.36±0.09	159.4±7.3	117.4±19.7	5c-6
Warblington											
WAB05 BH1 6.65–6.72m[i]	X2875	18.0	0.93±0.05	5.40±0.27	2.40±0.12	6.68	0.09±0.01	1.57±0.11	207.1±13.5	131.7±12.4	5e-6
Woodhorn Farm											
WHF05 BH1 4.48–4.54m[i]	X2876	22.0	1.35±0.07	4.80±0.24	1.90±0.10	4.50	0.12±0.01	1.70±0.12	210.8±6.6	123.9±9.6	5d-6

Table 6

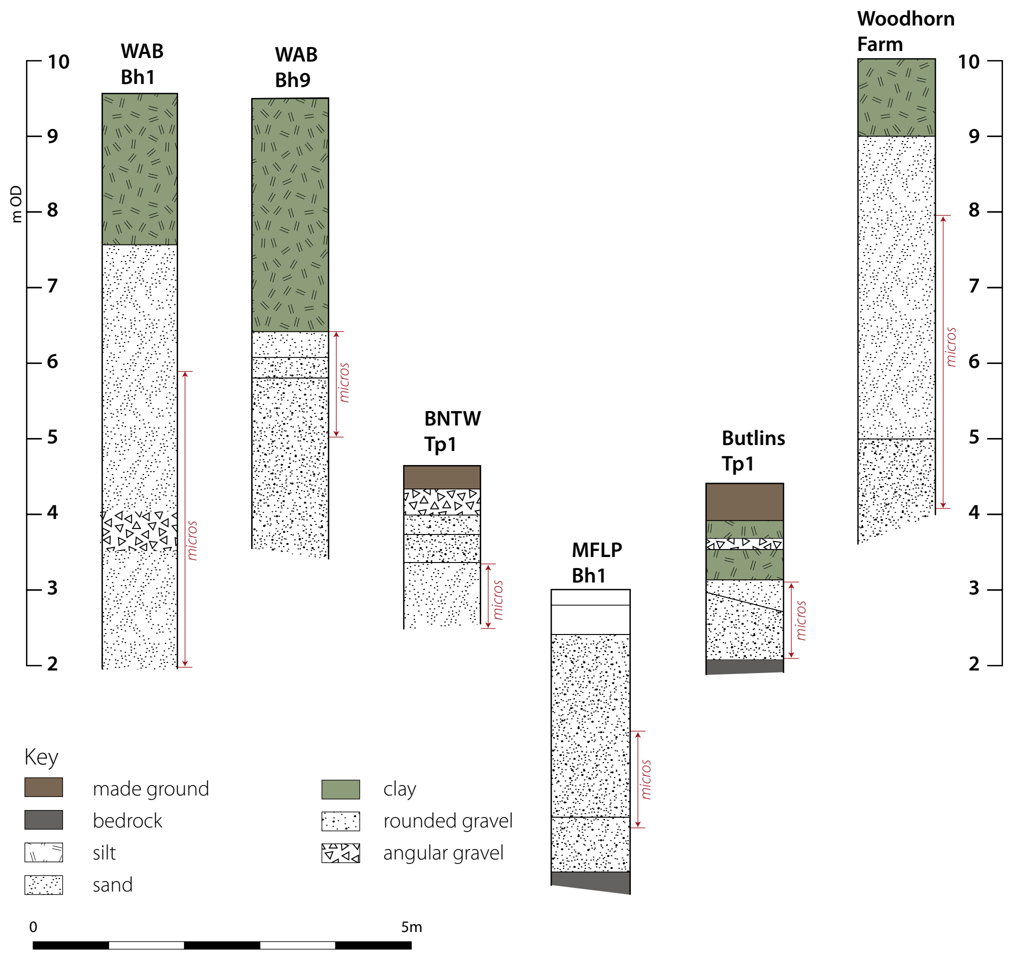
OSL dates from Pagham raised beach sites including Bognor

OSL dosimetry, equivalent dose and age estimates for samples from the Sussex / Hampshire Coastal Corridor. Gy = Grays, ka = thousands of years. Dose rate estimate based on neutron activation analysis (NAA) and gamma spectroscopy where feasible (equipment available, section stable), and NAA(N) or ICP-MS(i) alone elsewhere. Samples denoted 'a' have dose rates based on radioisotope concentrations from associated samples. Age calculated by dividing mean De by total dose rate. Error quoted as one standard error (standard deviation / √n). MIS boundaries are taken from Shackleton et al (1990) and Bassinot et al (1994).



Illus 9

Composite section across the site showing sample locations



Illus 10

The relative heights, extent of microfossil preservation and location of OSL dates from selected sites on the south coast

Illus 11

Extract from the County survey of Sussex 1778
(Yeakell and Gardner)

One date was obtained for a sample from test pit 1 taken in the area of TP1–S1 and TP1–S2 a barren deposit sealing the more foraminifera-rich deposit below (TP1–S4). The date derived for this deposit was 119.8±10.6 thousand years BP.

4.4 Carbon 14 dating

Three samples were submitted for the purpose of dating later, Holocene deposits identified at the top of the stratigraphic sequence. These derived from formations of peat lying between 0.75m and 1m beneath the ground surface. The first sample, part of a wooden (ash tree) stake, proved to be too recent to enable its date to be resolved (GU–24591). However, two Hawthorne fruit stones were successfully dated the results of this are laid out in Appendix 4.

The lower date (GU–24593 from 95–105cm below the surface) proved to be younger than the higher (GU–24592 from 85–95cm below the surface) on the basis of the ^{14}C measurments. This could imply a degree of mixing within the deposit and therefore a combination of the two dates is likely to provide the best indication of the date of deposition for the peat. On this basis the peat would appear to have been laid down sometime between 1640 and 1800 AD.

5. DISCUSSION

The evidence recovered from the investigation of the site has demonstrated that marine sediments belonging to the last interglacial are preserved extensively within the development footprint. Age estimates from the site compared to those from other sites in the Bognor area (Table 6) indicate that last interglacial sediments are present across this part of the coastal plain. Furthermore the microfossil evidence has provided new and hitherto unknown parts of the last interglacial story:

1. For the first time parts of the final phase of marine sedimentation in the interglacial have been recovered with elements of the regressive sequence (period of sea level fall) documented through the recovery of the restricted brackish fauna in test pit 3.

2. The transition into a cold climate period above is documented in test pit 3 by the recovery of elements of the cold/cool freshwater faunas seen elsewhere on the coastal plain (Bates *et al*, 2009) but very rarely superimposed on marine sediments.

3. The relationship between the marine regressive elements of the faunas and the cold stage faunas is unknown at present. The mixing of the faunas is likely to be one of taphonomic relevance rather than suggesting that regression is occurring under cold climate conditions.

4. That elements of the true marine faunas found patchily preserved at the base of a number of the

	YEO	PTS	PORT 1	NORT 1	NORT 2	NORT 3	HAV 1	HAV 3	CHAL 2	CHAL 3	OV	WAB 1	WAB 9A	WAB 9	WAB 11	IVY RD	ALD GR	KING	PWTW	MFCP	BUT
Cassidulina reniformis	x	x	x	x	x	x	x	x	–	–	x	x	x	x	x	x	x	x	x	x	–
Elphidium clavatum	x	x	x	x	x	–	x	x	–	–	x	x	x	x	x	–	–	–	–	–	–
Elphidium albiumbilicatum	x	–	x	x	x	x	x	x	x	–	x	x	x	x	x	–	x	–	x	x	–
Elphidium fichtellianum (Dwarf)	x	–	x	x	x	–	–	x	–	–	–	x	x	–	x	–	x	–	–	x	–
Nonion orbicularis	–	–	–	–	–	–	–	–	–	–	–	–	x	x	x	–	–	–	–	–	–
Ammonia batavus (Dwarf)	x	x	x	x	x		x	x			x	x	x	x	x		x	x		x	
Ammonia batuvus (large/ornate)	x	–	x	x	x	–	–	x	x	x	x	x	x	x	x	x	–	x	x	x	x
Elphidium crispum	x	x	–	–	–	–	–	–	x	x	–	x	x	x	–	x	–	–	x	x	x
Rosalina margareli	–	–	x	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–
Aubignyna perlucida	–	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Elphidium cf complanatum	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Finmarchinella finmarchica	x	x	x	x	x	x	–	–	x	x	–	x	x	x	x	x	x	x	x	–	–
Hemicytherura clathrata	x	–	x	x	–	x	x	x	x	x	–	x	x	x	–	x	x	–	x	–	–
Roundstonia globulifera	–	–	–	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
Sarsicytheridea bradii	–	–	–	–	–	–	–	–	–	–	–	x	x	–	–	–	–	–	x	–	–
Robertsonites tuberculatus	x	x	x	x	x	x	–	–	x	x	–	x	x	–	–	x	x	x	x	x	–
Semicytherura similis	x	–	x	–	–	–	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
Finmarchinella angulata	x	x	x	x	–	–	x	x	x	x	–	x	x	–	x	x	x	–	–	–	–
Semicytherura undata	x	–	x	x	–	–	x	x	–	x	–	–	x	–	–	x	x	–	–	–	–
Semicytherura affinis	–	–	x	–	–	–	–	x	–	–	–	–	x	–	–	–	–	–	–	–	–
cf. Argilloecia conoidea	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pterygocythereis cf. Mucronata	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Elofsonella concinna	–	–	x	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Kangarina sp.	–	–	x	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Roundstonia globulifera	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sarsicytheridea bradii	–	–	x	x	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Aurila convexa	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–	–
Sagmatocytherer variesculpta	x	–	–	x	–	–	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 7

Beach comparison showing the presence of different types of microfossils

test pits indicate a complex reworking history from older, higher raised beaches.

5. The sediments have been dated to the last interglacial (MIS 5e).

6. That this evidence confirms the cool water nature of the last interglacial assemblages that have previously been made.

The investigation of the site has added considerably to our knowledge of the nature and timing of events associated with the last interglacial on the coastal plain. It does however, remain an enigma that sediments deposited in an interglacial that was supposedly of equivalent warmth to today should produce a range of microfossils indicative of cooler or colder conditions.

On the basis of Radiocarbon dates from the upper peat deposit it appears that this was laid down sometime between the mid 17th and end of the 18th century AD. Cartographic evidence from the late 18th century (1778; Illus 11) shows the area of the site lying within what appears to be a quite early intake field system linked to drainage ditches. The land to the east still appears to be salt marsh meadow, however, it would seem likely that the reclamation of the land as fields predates the formation of peaty deposits probably placing this field-system sometime in the late 17th – early 18th century AD.

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7. APPENDICES

Appendix 1 – Detailed recording from the test pits

Test pit 1

Lithology and sampling positions of samples. Sample TP1–S5 taken from adjacent section where sand unit above gravel thickened considerably. Ground level at surface of test pit 4.2m OD.

Depth below ground surface (m)	Lithology	Samples
0.0–0.45	Made ground	–
	---sharp contact---	
0.45–0.6	Reddish-brown sandy clay-silt. Very compact and firm. Structureless.	–
	---graded contact---	
0.6–0.7	Grey sandy clay-silt with occasional sub-angular flint clasts (<5cm). Structureless and massive.	–
	---abrupt contact---	
0.7–1.2	Mid brown to reddish-brown very sandy clay-silt to silty-clay. Pliable and structureless. Many sub-vertical root canals (1–3mm) and occasional small sub-angular flint clasts (<0.5cm).	–
	---sharp contact---	
1.2–1.3/1.45	Yellow brown medium sand with occasional large (>5cm) sub-rounded flint clasts. Apparently structureless.	TP1–S1 (1.25m) TP1–S2 (1.3m) OSL 1
	---sharp/dipping contact---	
1.3/1.45–2.2	Yellow-brown becoming red/yellow sandy flint gravel. Clasts 2–10cm, sub-angular to rounded. Matrix supported with matrix of clayey-sand. Chalk clasts appear towards base of unit. Very loose and unconsolidated.	TP1–S3 (1.5m) TP1–S4 (2.1m)
	---sharp contact---	
2.2–2.4	Red clay	–
	---base of test pit---	

Test pit 2

Lithology and sampling positions of samples. Gound level at surface 4.14m OD.

Depth below ground surface (m)	Lithology	Samples
0.0–0.1	Made ground	–
	---sharp contact---	
0.1–0.5	Grey brown to yellowish brown made ground	–
	---sharp contact---	
0.5–1.5	Reddish brown clay-silt with sand and gravel clasts. Clasts are well rounded to sub-angular in shape. Moderately compact and firm. Occasional clasts of reworked grey clay.	–
	Graded downwards	
1.5–1.7	Yellowish brown sandy gravel with mixed gravel clasts of rounded to sub-angular shape. No structure.	–
	Grades downwards	
1.7–>2.0	Becoming coarser sand with depth	TP2–S1 (1.4m)

Test pit 3

Lithology and sampling positions of samples. Ground level at surface 4.44m OD.

Depth below ground surface (m)	Lithology	Samples
0.0–0.1	Made ground	–
	---sharp contact---	
0.1–0.45	Made ground	–
	---sharp contact---	
0.45–0.65	Dear grey clay-silt. Occasional well rounded flint clasts (<5cm). Dense and compact in patches.	–
	---abrupt contact---	
0.65–1.3	Reddish-brown to yellowish brown clay-silt becoming sandy clay-silt with depth. Sand increase in grain size with depth. Occasional flint cobbles. Firm and compact.	TP3–S2 (1.3m)
	---sharp contact---	
1.3–1.7	Grey brown to yellow sandy silt with chalk and flint fragments.	TP3–S3 (1.6m)
	---abrupt contact---	
1.7–2.45	Mid grey sand and gravel. Very large rounded and rolled gravel clasts in places. Loose and unconsolidated.	TP3–S4 (1.7m) TP3–S5 (2.0m) TP3–S6 (2.4m)
	---abrupt contact---	
2.45 -	Grey brown to yellowish brown clay. Very dense and compact.	–
	---base of test pit 2.50m---	

Test pit 4

Lithology and sampling positions of samples. Ground level at surface 4.66m OD.

Depth below ground surface (m)	Lithology	Samples
0.0–0.1	Made ground	–
	---sharp contact---	
0.1–0.65	Made ground	–
	---sharp contact---	
0.65–0.8	Dark grey to greenish grey sandy silt to silty sand. Dense, compact and firm. Very common rounded and rolled flint clasts (<6cm) occasional broken clasts with sharp edges.	–
	---diffuse contact---	
0.8–0.95	Dark brown clay-silt with some sand. Occasional flint clasts (angular and sharp)	–
	---abrupt contact---	
0.95–1.1	Dark brown sand with some silt.	–
	---sharp contact---	
1.1–1.5	Dark brown sand.	–
	---sharp, dipping contact---	
1.5–>2.0	Sand and gravel	–

Appendix 2 – Microfossil samples examined

Test pit 2

Sample	Weight processed
TP2–S1	55g

Test pit 3

Sample	Weight processed
TP3–S2 [1.3m]	55g
TP3–S3 [1.6m]	60g
TP3–S4 [1.7m]	60g
TP3–S5 [2.0m]	75g
TP3–S6 [2.4m]	50g

Test pit 4

Sample	Weight processed
TP4-S7	65g
TP4-S8	65g
TP4-S9	60g
TP4-S10	65g
TP4-S11	55g
TP4-S12	55g
TP4-S13	60g
TP4-S14 [2.0m]	75g
TP4-S15	60g
TP4-S16 (6)	65g

Appendix 3 – OSL sample background data

Sample Field code **BUT-11 OSL1**

Laboratory code **X5283**

Palaeodose (Gy)	**124.23**
uncertainty	9.48
measured	9.15
Calibration error (2%)	2.48
Grain size	
Min. grain size (mic)	180
Max grain size (mic)	255
Measured concentrations	
standard fractional error	0.050
% K	0.450
error (%K)	0.023
Th (ppm)	4.900
error (ppm)	0.245
U (ppm)	1.100
error (ppm)	0.055
Cosmic dose calculations	
Depth (m)	1.000
error (m)	0.200
Average overburden density (g.cm^3)	1.900
error (g.cm^3)	0.100
Latitude (deg.), north positive	51
Longitude (deg.), east positive	1
Altitude (m above sea-level))	20.00
Geomagnetic latitude	53.6
De (Gy/ka), 55N G.lat, 0 km Alt.	0.184
error	0.039
Cosmic dose rate (Gy/ka)	0.185
error	0.039
Moisture content	
Measured water in OSL sample (% of wet sediment)	15.31
Estimated mean moisture (water / wet sediment)	0.150
error	0.030
Total dose rate, Gy/ka	**1.04**
error	**0.05**
AGE (ka)	**119.76**
error	**10.57**

Appendix 4 – Radiocarbon dating certificates

SUERC-35621 (GU-24591) (31 August 2011)

Laboratory Code	SUERC-35621 (GU-24591)
Submitter	Dr Scott Timpany Headland Archaeology 13 Jane Street Edinburgh EH6 5HE
Site Reference	Butlins, Bognor Regis
Context Reference	worked wood
Sample Reference	BUBR10
Material	Wood : Ash
δ13C relative to VPDB	-25.5 ‰

Fraction Modern Fm	1.2686 ± 0.0046

N.B.

1. The above 14C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.
2. The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal3).
3. Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after the SUERC code. The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or Telephone 01355 270136 direct line.

Conventional age and calibration age ranges calculated by :- Date :-

Checked and signed off by :- Date : –

SUERC-35622 (GU-24592) (31 August 2011)

Laboratory Code	SUERC-35622 (GU-24592)
Submitter	Scott Timpany Headland Archaeology 13 Jane Street Edinburgh EH6 5HE
Site Reference	Butlins, Bognor Regis
Context Reference	85-95cm
Sample Reference	BUBR10
Material	Fruit stone : Hawthorn
δ13C relative to VPDB	-25.5 ‰
Radiocarbon Age BP	275 ± 30

N.B.

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

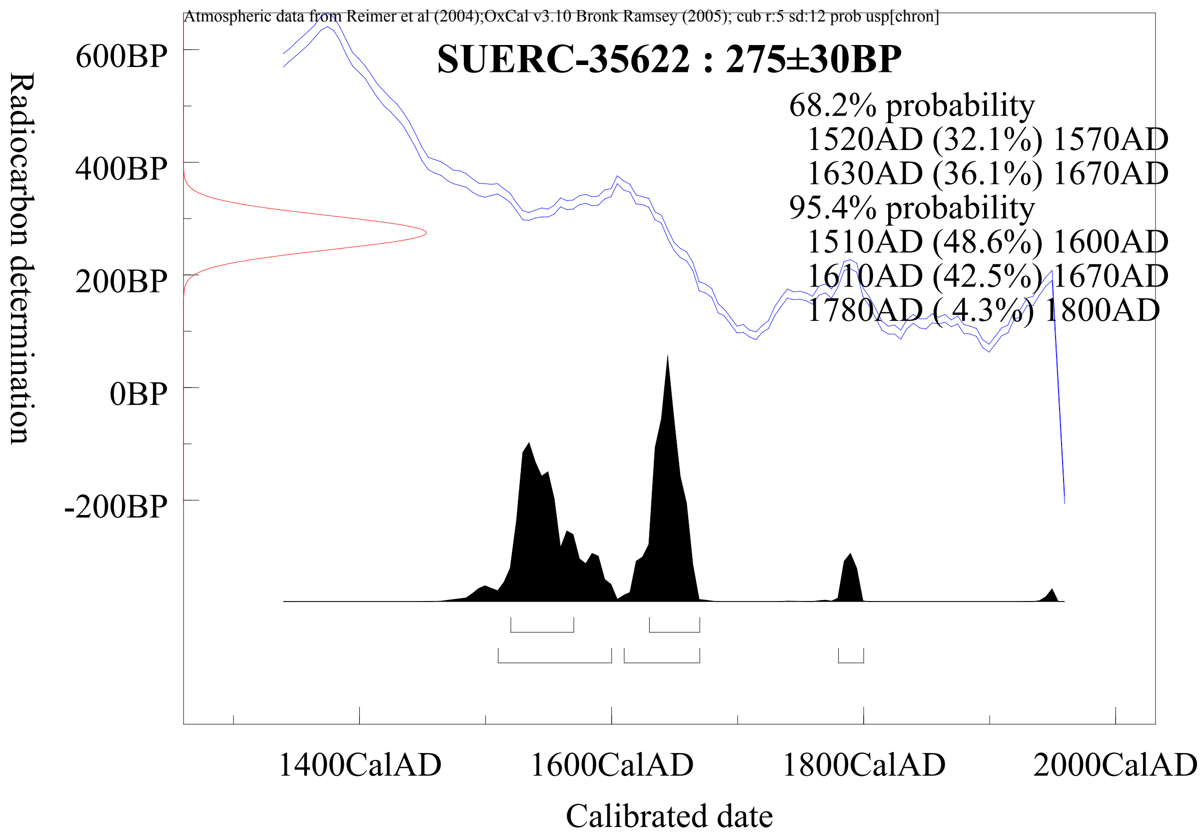
2. The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal3).

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

Conventional age and calibration age ranges calculated by :- Date : –

Checked and signed off by :- Date : –

Calibration Plot



SUERC-35623 (GU-24593) (31 August 2011)

Laboratory Code	SUERC-35623 (GU-24593)
Submitter	Scott Timpany Headland Archaeology 13 Jane Street Edinburgh EH6 5HE
Site Reference	Butlins, Bognor Regis
Context Reference	95-105cm
Sample Reference	BUBR10
Material	Fruit stone : Hawthorn
δ13C relative to VPDB	-25.0 ‰ assumed

Radiocarbon Age BP	200 ± 30

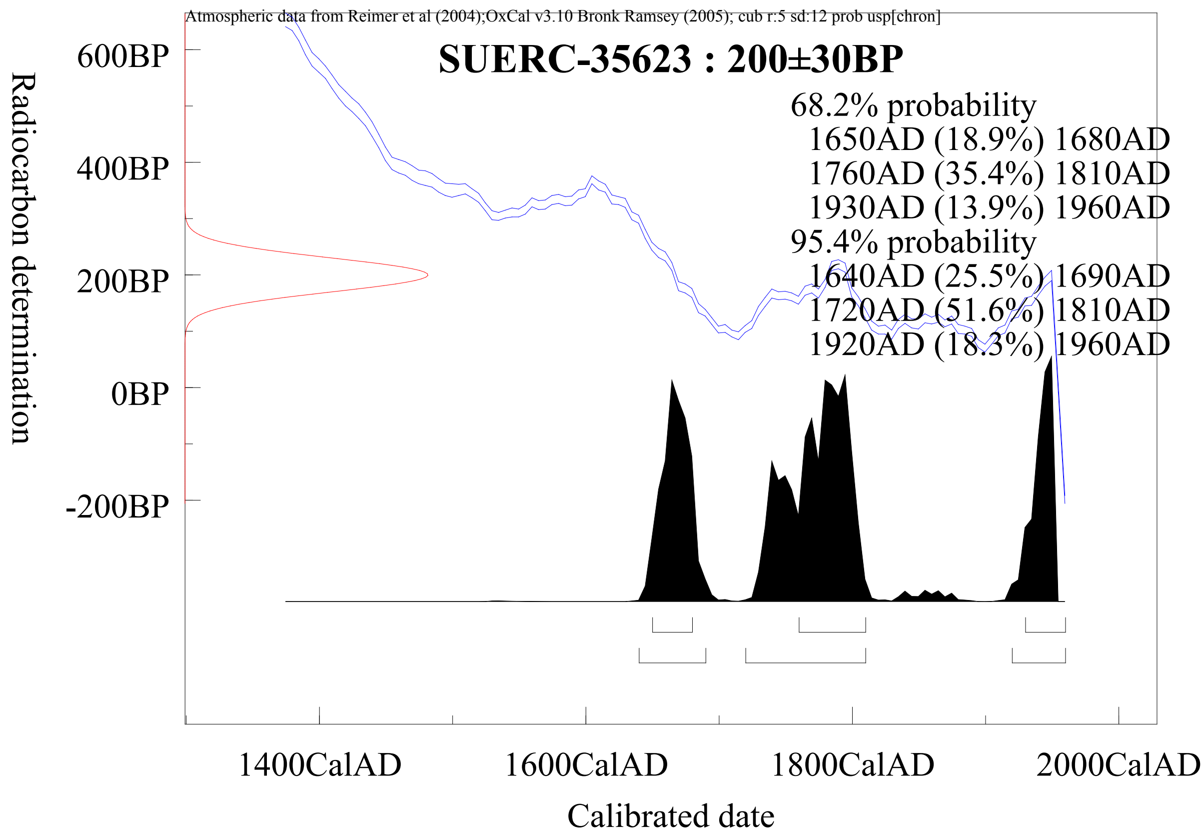
N.B.

1. The above 14C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standard and blank and the random machine error.
2. The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal3).
3. Samples with a SUERC coding are measured at the Scottish Universities Environmental Research Centre AMS Facility and should be quoted as such in any reports within the scientific literature. Any questions directed to the Radiocarbon Laboratory should also quote the GU coding given in parentheses after the SUERC code. The contact details for the laboratory are email g.cook@suerc.gla.ac.uk or Telephone 01355 270136 direct line.

Conventional age and calibration age ranges calculated by :- Date : –

Checked and signed off by :- Date : –

Calibration Plot



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