MANORBIER MEDIEVAL FISHPONDS

GEOARCHAEOLOGICAL SITE INVESTIGATION AND PRELIMINARY LABORATORY ASSESSMENT

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December 2003

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Executive summary

This study was instigated at the request of the Manorbier Medieval Fishponds Restoration Group in August 2003. The objectives of the investigation were to provide information on the nature of the sediments within the supposed area of the Medieval fishponds in order to determine the location and depth of burial of sediments considered likely to relate to these features.

The investigation was undertaken using a small drill rig to recover samples from three boreholes. The recovered cores were cut, recorded and sampled and 2cm thick sub-samples of key units were sent for specialist assessment. The results of the investigation indicate that a complex history of site formation and environmental change is recorded at the site. Presently a series of changes between marine and freshwater situations may be envisaged for the site.

Five different sequences of deposits were identified in borehole 1 (located within the supposed area of the ponds). The lowermost unit (Unit 1) consisted of coarse gravel and probably represents material derived from slope wash processes. A basal peat unit (Unit 2) was subsequently established under alder carr conditions. Plant debris, seeds and insect fragments were recovered from this peat. Sand accumulation (Unit 3) followed and this is likely to have resulted from a marine incursion into the valley either directly via flooding or through a phase of wind blow activity (sand dunes). There is also the suggestion that drying out of the sand surface occurred at times. A further peat unit (Unit 4) and overlying silts (Unit 5) then developed suggesting the initial development of a reed swamp later giving way to minerogenic accumulation. Oospores (fruiting bodies) of charophytes (stonewort), horned pondweed (*Zannichellia palustris*), poorly preserved ostracods and testate amoebae all confirm the freshwater conditions in these deposits. Similar sediments were found in BH 3.

The evidence from BH 2 remains very different to interpret. The sequence present consisted of bedded sands that may be associated with a former marine incursion or as blown sediments possibly as dune sands. The relationship with borehole 1 cannot be established.

Although it has been possible to begin to understand the palaeoenvironments associated with the sediments it is currently impossible to determine the age of the sediments recovered. The age of the sediments within borehole 1 remains equivocal as does the relationship between the deposits in borehole 1 and those in boreholes 2 and 3.

At present it therefore remains somewhat difficult to ascertain whether or not a body of sediment is present that represents material accumulated in a fish pond despite the fact that sediments of Units 2, 4, 5 and 6 (in borehole 3) are all associated with freshwater indicators. Despite the recovery of a range of palaeoenvironmental material from the assessed samples only a single fish bone (eel) was found. At present the possibility exists that the fishponds may actually be represented not by the presence of particular deposits but by the boundary surface between Units 4 and 5 in borehole 1. This remains to be verified.

Introduction

This study was instigated at the request of the Manorbier Medieval Fishponds Restoration Group in August 2003. The objectives of the investigation were to provide geoarchaeological and palaeoenvironmental evidence, in an archaeological context, pertinent to understanding the history of formation of the deposits adjacent to the castle and, in particular, addressing the question of the presence and location of any Medieval fishponds in the area.

Investigation strategy

The geoarchaeological investigation of the sediments adjacent to the castle was undertaken using a small drill rig (Terrier) to recover samples (Plate 1). Three holes were drilled (a fourth borehole was abandoned due to the presence of impenetrable ground):

1. A single borehole (BH 1) was drilled, to maximum depth possible, within the area of the presumed fishponds. This was targeted to enable description and sampling of the stratigraphy associated with this area.

2. A second borehole (BH 2) was drilled, to maximum depth, within the area outside the area of the presumed fishponds and seawards of the pond area. This borehole should record the conditions in the lower valley outside any possible influence of the fishponds.

3. A third borehole (BH 3) was drilled, to maximum depth, within the inland portion of the presumed fishponds.

The drill rig used was a tracked Terrier rig capable of being driven onto site to drill holes to a depth of 7-8m to recover undisturbed 1m sleeved core samples. This equipment is capable of drilling up to 40m in a day to a typical maximum depth of 8m (depending on ground conditions). Fieldwork was supervised by Dr. Martin Bates. Locations and height datums for all boreholes were recorded by representatives of the Manorbier Medieval Fishponds Restoration Group.

Borehole 1 was drilled and logged first. All retained cores were returned to the laboratory for cutting, recording and sampling. Core stratigraphy was recorded using standard geological criteria commonly used in archaeological surveys. All cores are retained for possible future investigation. Each core was photographed and representative illustrations are presented in Plates 2-8.

Two centimetre thick sub-samples of key units were sent to a specialist micropalaeontologist (Dr. John Whittaker, The Natural History Museum) for assessment for contained foraminifera and ostracoda (Appendix I).

Results: stratigraphy

Following drilling and cutting of the cores it was immediately apparent that differential compaction of the cores had occurred during drilling. The degree of compact varied depending on the nature of the sediments (i.e. little compaction was noted in borehole 2 (sands) while considerable compaction was noted in others (borehole 1 was drilled to a maximum depth of 6 metres but only 4.09m of stratigraphy was actually logged). Because of the difficulties in calculating the differential compaction all measurements were made as cumulative measurements downcore, i.e. in borehole 1 for example the top 1m of sediment drilled (recovered in core 0-1m depths) compacted to 0.55m within the core, consequently although the next core was drilled between 1 and 2m this has been recorded as commencing at a depth of 55cm). The alternative approach would be to attempt to stretch the samples within each core out, however this requires considerable knowledge of the differential compaction rates of the sediments and this has not as yet been attempted.

The full stratigraphic sequence present within the cores recovered from the three boreholes is presented in Figures 1 – 3 and all sample positions are also shown, stratigraphic descriptions are presented in Tables 1 – 3.

Seven major stratigraphic units were identified in the boreholes. In all cases these seven units consist of a number of discrete minor beds that have been grouped together because of shared characteristics (usually grain size or organic content). The designation and, particularly the correlation (Figure 4), are tentative as no direct ways of linking units between boreholes is currently available and consequently any correlations may be subject to revision following further work. However, it is clear that:

1. A basal unit was recovered in BH 1 (Unit 1) consisting of coarse angular clasts of bedrock bedded with thin bands of organic matter. A similar gravely deposit was present at the base of BH 3 but was not sampled in the core samples. These deposits clearly represent deposition of locally eroded bedrock. The angularity of the clasts indicate that they have only been subject to minimal reworking by water and it is likely that they are predominantly slope colluvium. However the presence of thin bands of organic matter suggests that local reworking on the river floodplain may have occurred.

2. A dark brown peat (Unit 2) was recovered from BH 1 above the basal gravels. The composition of the peat and the location of the peat immediately above the basal gravels suggests that the sediments may have accumulated under alder carr wetland situations. Many river valleys in the vicinity are known to contain similar sequences of peats. It is possible that the sediments recovered from the base of BH 3 represent the lateral equivalent of those of Unit 2 in BH 1.

3. Sands of Unit 3 occur above the peats and consist of a basal inorganic sand sequence overlain by a series of well bedded organic rich sands. It is possible that the basal part of this sand sequence represents a marine incursion into the valley floor area followed by a period of declining marine influence and greater accumulation of organic detritus in the vicinity. A situation consisting of channels operating in an increasingly freshwater situation may be envisaged for the upper part of this sequence.

4. The peat of Unit 4 appears to represent a different kind of wetland situation to that previously occurring in the valley with the possible establishment of a reed swamp situation prone to inundation periodically by both fresh and brackish waters.

5. The uppermost sediments in borehole 1 consist of minerogenic sediments accumulating under freshwater valley bottom conditions with minimal *in situ* organic accumulation. There is also probable seasonal incursion of moving water and occasional brackish incursions. It is possible that the sediments lying between datums of 0.35 and 1.28m in BH 3 are the lateral equivalents of those seen in BH 1.

6. A third peat unit (Unit 6) is noted in BH 3 at the top of the sequence and this sequence is probably still accumulating today. This situation is dominated by freshwater wetland with reed and tree growth and impeded drainage with seasonal flooding (occasional brackish incursions).

7. The final unit (7) is only seen in BH 2. This sequence of sands appears to be derived from the nearby beach although it is not possible to determine whether the sequence represents a series of aeolian (wind-blown) sediments blown on-shore or sediments accumulating through an initial marine incursion followed higher in the sequence, and later in time, by Aeolian (wind) activity). At present we cannot link this sequence to those seen in BH's 1 and 3.

The evidence from the borehole stratigraphy is typical of stratigraphic sequences accumulating within a marine marginal valley bottom situation in the Middle to Late Holocene. Bell (1997) has illustrated a typical sequence of sediments from such situations and the sequences present at Manorbier only differ in detail from that outlined by Bell.

Results: sample assessment

Twenty-three samples were analysed and are listed in Table 4. Full details of sample processing etc can be found in Appendix I.

Twelve samples were examined from BH 1 and the results are summarised in Table 5. The basal sample (332/334cm, Unit 2) contains plant debris, seeds and insect fragments, but is barren of any calcareous component or any readily discernable environmental indicator, as are the lower parts of the sands (Unit 3) from 260/262cm up to and including 195/197cm. The remainder of the Unit 3, above 175/177cm and the basal part of Unit 4 however, reveal a more interesting story. Three samples between 175/177cm to 134/136cm have a marine component, indicated by foraminifera, ostracods and molluscs, albeit rare, fragmentary, and worn. The foraminifera are represented solely by *Ammonia batavus*, with a few specimens of the marine sediment-dwelling ostracod, *Pontocythere elongata*; both would readily be found washed into beach sand. At the same time no less than four samples, 175/177cm, 134/136cm, 145/147cm and 115/117cm, contain a terrestrial component, evidenced by small (indeterminate) mammal bones, earthworm granules, slug plates, and (? terrestrial) molluscs. The uppermost two samples from Unit 5 (23/25cm – 68/70cm) contains common oospores (fruiting bodies) of charophytes (stonewort) and the distinctive seed of the horned pondweed (*Zannichellia palustris*). Unfortunately, very few ostracods were found (only *Candona neglecta* and *Limnocythere inopinata* in sample 23/25cm) and *C. neglecta* and *Cyclocypris* sp. in 68/70cm). Interestingly both samples contain distinctive testate amoebae, the freshwater relatives of the Foraminifera (protists with filose pseudopodia, rather than reticulose pseudopodia, as in foraminifera), which in this case belong to one or more species of *Difflugia.* They have an elongate, flask-like shell made of agglutinated mineral grains (silica) cemented together with organic cement, and a rounded aperture at one end.

Five samples (all from Unit 7) were also examined from BH 2. The results are shown in Table 6. All sediments from the samples were identical and comprised of shelly sand, containing worn and polished molluscs (for the most part marine) and a few marine foraminifera. The foraminifera comprised of one species, *Ammonia batavus*. The only exception was in sample 133/135cm, which, in addition to the same marine component, contained some terrestrial molluscs and earthworm granules.

Finally six samples were examined from BH 3 (see Table 7). The samples from Unit 5 between 124/126cm and 53/55cm contain charophyte oospores, clodoceran ephippia (egg-cases of water-fleas), testate amoebae (*Difflugia* spp.), molluscs, and rare freshwater ostracods.

Conclusions

The results of the investigation indicate that a complex history of site formation and environmental change is recorded at the site. Presently a series of changes between marine and freshwater situations may be envisaged for the site.

Initial onset of sediment accumulation appears to have begun with the formation of Unit 1. This unit has been considered to represent deposition of locally eroded bedrock. The angularity of the clasts indicate that they have only been subject to minimal reworking by water which indicates that they are likely to be predominantly slope colluvium. However the presence of thin bands of organic matter suggests that local reworking on the river floodplain may have occurred. No samples were assessed from these deposits.

Accumulation of the basal peat unit (Unit 2) is likely to have occurred under alder carr conditions. The basal sample from BH 1 (332/334cm) contains plant debris, seeds and insect fragments and a similar range of material was collected from the basal 2 samples in BH 3. The appearance of these sediments is similar to many basal peats in lowland river valley situations in southern Britain and indeed a peat deposit is known to outcrop at Manorbier on the foreshore at low tides.

A switch to sand accumulation (Unit 3) is noted in BH 1 and this is likely to have resulted from a marine incursion into the valley either directly via flooding or through a phase of wind blow activity. A marine presence is attested to by the presence of a range of foraminifera, ostracods and molluscs within the sands although the presence of terrestrial material (small bones, earthworm granules, slug plates etc.) also suggests drying out of the sand surface at times or major influxes of terrestrial material into the sand complex. The terrestrial and freshwater component remains present into Unit 4 (peats) and Unit 5 (uppermost silts). These two sediment bodies suggest the initial development of a reed swamp later giving way to minerogenic accumulation. The oospores (fruiting bodies) of charophytes (stonewort) and the distinctive seed of the horned pondweed (*Zannichellia palustris*) found in Unit 5 suggests deposition in a freshwater body rich in vegetation (note however that in comparison to the peats organic preservation in Unit 5 is relatively poor). Unfortunately, very few ostracods were found (only *Candona neglecta* and *Limnocythere inopinata* in sample 23/25cm and *C. neglecta* and *Cyclocypris* sp. in 68/70cm). These species can tolerate all manner of (permanent) waterbodies, such as ponds and slow-flowing streams. The presence of the testate amoebae also confirms the freshwater conditions as these organisms live in all manner of moist and freshwater habitats from moss, soil, peat, to standing water (Ogden & Hedley, 1980). What is not obvious at the moment is why the ostracods are so rare (given the apparent high values of carbonate as shown in Figure 1), and the testate amoebae so common. A similar signature can be observed in BH 3.

Unit 7 from BH 2 remains very different to interpret. It is suggested that the sequence represents sands associated with a former marine incursion or as blown sediments possibly as dune sands. The shell content is very diminuted and increasingly worn up-section, perhaps indicating increased distance from the marine connection through time (supported by the addition of a terrestrial component in the penultimate sample, 133/135cm), and/or the affect of wind action on the sands. The foraminifer, *A. batavus*, is found in the stand-line of any beach (it lives on seaweed and sea-grass) and it probably survived as it is the most robust of foraminiferal species and of the same size and shape to the typical sand-grain.

Although it has been possible to begin to understand the palaeoenvironments associated with the sediments it is currently impossible to determine the age of the sediments recovered. Given the similarity of the sequences with those commonly reported from the lower reaches of the river valleys in southern Britain it might be expected that the basal peat (Unit 2) is of possible middle Holocene date (e.g. Heyworth (1978) has suggested that submerged forests from southern England date between 5500 and 600 cal B.C.). The age of the overlying sediments remains equivocal as does the relationship between sediments in the individual boreholes.

At present it therefore remains somewhat difficult to ascertain whether or not a body of sediment is present that represents material accumulated in a fishpond despite the fact that sediments of Units 2, 4, 5 and 6 are all associated with freshwater indicators. Given the alder carr nature of Unit 2 it is unlikely this sequence represents a body of material accumulating in a fishpond and equally both other peaty units (4 and 6) are unlikely to represent such a situation. The potentially brackish nature of Unit 3 appears to rule out this body of material being related to the fishponds and consequently Unit 5 appears the most likely sediment to be associated with such a feature. It should however be noted that the water conditions may have been very sluggish, biological evidence suggests the environment was rich in vegetation and the presence of the silt attests to significant quantities of silt inwash. Additionally it should be noted that despite the recovery of a range of palaeoenvironmental material from the assessed samples only a single fish bone (eel) was found.

It should however be remembered that the fishponds may actually be represented not by the presence of particular deposits but by a boundary surface between deposits. All units sedimentary units observed, by their very nature, are infilling depressions and hollows in the landscape and hence their presence would appear to be the very opposite of the conditions desired in a fishpond. Consequently the evidence for the phase of operation of the fishpond may be a boundary between adjacent sediment units rather than the units themselves. On this basis the most likely position for the fishpond would be the boundary between Units 4 and 5 in borehole 1. Unit 5 may be the subsequent infill of the abandoned fishponds.

Recommendations for future work

The absence of a dating framework is currently the most important missing element to the study. It is impossible to define the position in the core at which the temporal stratigraphy dating to the Medieval period is preserved. Consequently a program of radiocarbon dating of key locations in the stratigraphic sequences is required. Suitable material has been located for dating in BH 1 at depths of 1.1m (Unit 4 top), 1.35m (Unit 4 base), 1.65m (upper part of Unit 3) and 2.5m (Unit 2) and BH 3 at 1.3m (Unit 2). Dating of these samples is strongly recommended in order to construct a robust chronostratigraphic sequence and allow cross correlation between boreholes. Given both the carbonate content of parts of the sequence (evidenced by the presence of shell fragments) as well as the presence of various organic acids and roots throughout the sequence a strategy dating only one or two points in the stratigraphy may well results in anomalous dates and erroneous conclusions.

Further work may also be considered on the plant macrofossils noted in the assessed samples. It is certain that a detailed and informative insight into the conditions in the past may be deduced from the plant macrofossil remains however to undertake this without further refinement of the areas of interest in the stratigraphy would be time consuming and expensive.

Ultimately further drilling or test pitting may be required in order to collect additional samples from the contexts considered most likely to represent the pond bottom and infill sequence. The objective of this exercise would be to collect larger samples with the aim of recovering additional bone material that may provide information on the fish species kept in the pond. Additionally it might be necessary to address the issue of the nature of the barrier at the downstream end of the pond and its possible association with any mill structures in the area. This might initially be addressed using geophysical survey coupled with possible trial pits/trenches (ground water content permitting).

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APPENDIX I.

PRELIMINARY MICROPALAEONTOLOGICAL REPORT ON THREE BOREHOLES DRILLED AT MANORBIER CASTLE, PEMBROKESHIRE

By John E. Whittaker
The Natural History Museum, London

INTRODUCTION

Twenty-three samples, from three boreholes, were submitted for micropalaeontological assessment by Dr Martin Bates (University of Wales, Lampeter) in October 2003. The boreholes (Project MMF/03) were drilled in the valley bottom beneath the medieval Manorbier Castle, Pembs. The site (M. Bates, pers. comm.) supposedly once had fish ponds with a barrier between the ponds and the sea (presently some 300m away). The boreholes consist of two within the fish ponds area (BH 1 and 3) and one seawards of it (BH 2). There is a possibility of an earlier Holocene organic deposit at the base of the sequence with a phase of minerogenic organic sedimentation occurring before a later phase of organic accumulation. So far, no absolute dating has been undertaken. The purpose of this report is to provide a preliminary reconstruction of the palaeoenvironment of the borehole sequences, using the microscopic organic remains, especially the foraminifera, ostracods, etc.

SAMPLES

The samples analysed are listed below, with weight processed (wet) of each:

(Borehole)	(Depth)	(Weight)
BH 1	23/25cm	48g
	68/70cm	66g
	95/97cm	62g
	115/117cm	68g
	134/136cm	72g
	145/147cm	81g
	175/177cm	80g
	195/197cm	93g
	228/230cm	72g
	245/247cm	88g
	260/262cm	53g
	332/334cm	
BH 2	63/65cm	75g
	133/135cm	77g
	156/158cm	79g
	203/205cm	83g
	236/238cm	106g
BH 3	53/55cm	51g
	81/83cm	54g
	100/102cm	57g

124/126cm	48g
175/177cm	62g
192-194cm	56g

Each sample was put in a ceramic bowl and dried in an oven. When dry, hot water was added with a little sodium carbonate to help remove the clay fraction. After soaking for several hours the contents were washed with hot water through a 75 micron (0.075mm) sieve, before the residue was returned to the bowl for final drying. Each dried residue was stored in a plastic bag before being sieved again into >250, >150, and <150 micron components. The contents of these sieves were sprinkled in turn onto a tray and the microfauna (foraminifera, ostracods and any other interesting item) picked out with a fine brush under a binocular microscope. The specimens were placed onto a glued 3”x1” faunal slide, abundance being estimated semi-quantitatively by eye (and experience).

RESULTS

Borehole 1

Borehole 1 is sited in an intermediate position between boreholes 2 and 3, and is also the longest sequence. Twelve samples were submitted from a 3.09m section, their organic contents being listed in Figure 1. The basal sample (332/334cm) contains plant debris, seeds and insect fragments, but is barren of any calcareous component or any readily discernable environmental indicator, as are the sands in the lower part of the borehole from 260/262cm up to and including 195/197cm. The remainder of the sandy sediment, above 175/177cm, however, reveal a more interesting story. Three samples between 175/177cm to 134/136cm have a marine component, indicated by foraminifera, ostracods and molluscs, albeit rare, fragmentary, and worn. The foraminifera, as in Borehole 2, are represented solely by *Ammonia batavus*, with a few specimens of the marine sediment-dwelling ostracod, *Pontocythere elongata*; both would readily be found washed into beach sand. At the same time no less than four samples, 175/177cm, 134/136cm, 145/147cm and 115/117cm, contain a terrestrial component, evidenced by small (indeterminate) mammal bones, earthworm granules, slug plates, and (?terrestrial) molluscs. One suggestion is that the sand (dune) barrier, represented by the sediments of Borehole 3, was breached by a catastrophic storm bringing marine sand as far as the site of Borehole 1, which in time was colonised by land snails, slugs and the like. The organic silts of the uppermost two samples (23/25cm – 68/70cm), on the other hand clearly represent deposition in a fresh waterbody, and with vegetation at that. The oospores (fruiting bodies) of charophytes (stonewort) are common and the distinctive seed of the horned pondweed (*Zannichellia palustris*) is much in evidence. Unfortunately, very few ostracods were found (only *Candona neglecta* and *Limnocythere inopinata* in sample 23/25cm) and *C. neglecta* and *Cyclocypris* sp. in 68/70cm). These species can tolerate all manner of (permanent) waterbodies, such as ponds and slow-flowing streams, and are not very helpful in the present situation. Far more abundant in these two samples are distinctive testate amoebae, the freshwater relatives of the Foraminifera (protists with filose pseudopodia, rather than reticulose pseudopodia, as in foraminifera), which in this case belong to one or more species of *Difflugia.* They have an elongate, flask-like shell made of agglutinated mineral grains (silica) cemented together with organic cement, and a rounded aperture at one end. They live in all manner of moist and freshwater habitats from moss, soil, peat, to standing water (Ogden & Hedley, 1980). What is not obvious at the moment is why the ostracods are so rare, and the testate amoebae so common, unless the pond water was perhaps rather acidic.

Borehole 2
This is the most seaward of the boreholes. Five samples were submitted (see above) from a 1.75m sequence, the deepest being 236/238cm, the uppermost being 63/65cm. The organic contents are shown in Figure 2. All these sediments were identical, comprised of shelly sand, containing worn and polished molluscs (for the most part marine) and a few marine foraminifera. The foraminifera comprised but one species, *Ammonia batavus*. The only exception was in sample 133/135cm, which, in addition to the same marine component, contained some terrestrial molluscs and earthworm granules. It is suggested that the sequence represents sands associated with a former marine embayment (possibly as dune sands). The shell content is very diminuted and increasingly worn up-section, perhaps indicating increased distance from the marine connection through time (supported by the addition of a terrestrial component in the penultimate sample, 133/135cm), and/or the affect of wind action on the sands. The foraminifer, *A. batavus*, is found in the stand-line of any beach (it lives on seaweed and sea-grass) and it probably survived as it is the most robust of foraminiferal species and of the same size and shape to the typical sand-grain.

Borehole 3
Six samples representing a 1.39m section was drilled in this, the most landward of the three boreholes. The sediments between 124/126cm and 53/55cm (the uppermost sample) are all conclusively freshwater, as evidenced variously by charophyte oospores, clodoceran ephippia (egg-cases of water-fleas), by testate amoebae (*Difflugia* spp.), molluscs, and rare freshwater ostracods (Figure 3). Again the pond (or whatever waterbody it was) was clearly well vegetated (the seeds of various pondweeds, including *Zannichellia palustris*, being much in evidence in the samples). If it was indeed a fishpond (see Introduction) then the paucity of fish remains must be commented on. In fact, only one fish bone, and that of an eel vertebra (in sample 81/83cm), was ever found!

ACKNOWLEDGEMENT
I am grateful to Simon Parfitt (The Natural History Museum, London) for commenting on the small mammal and fish bones.

REFERENCE
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3rd November 2003

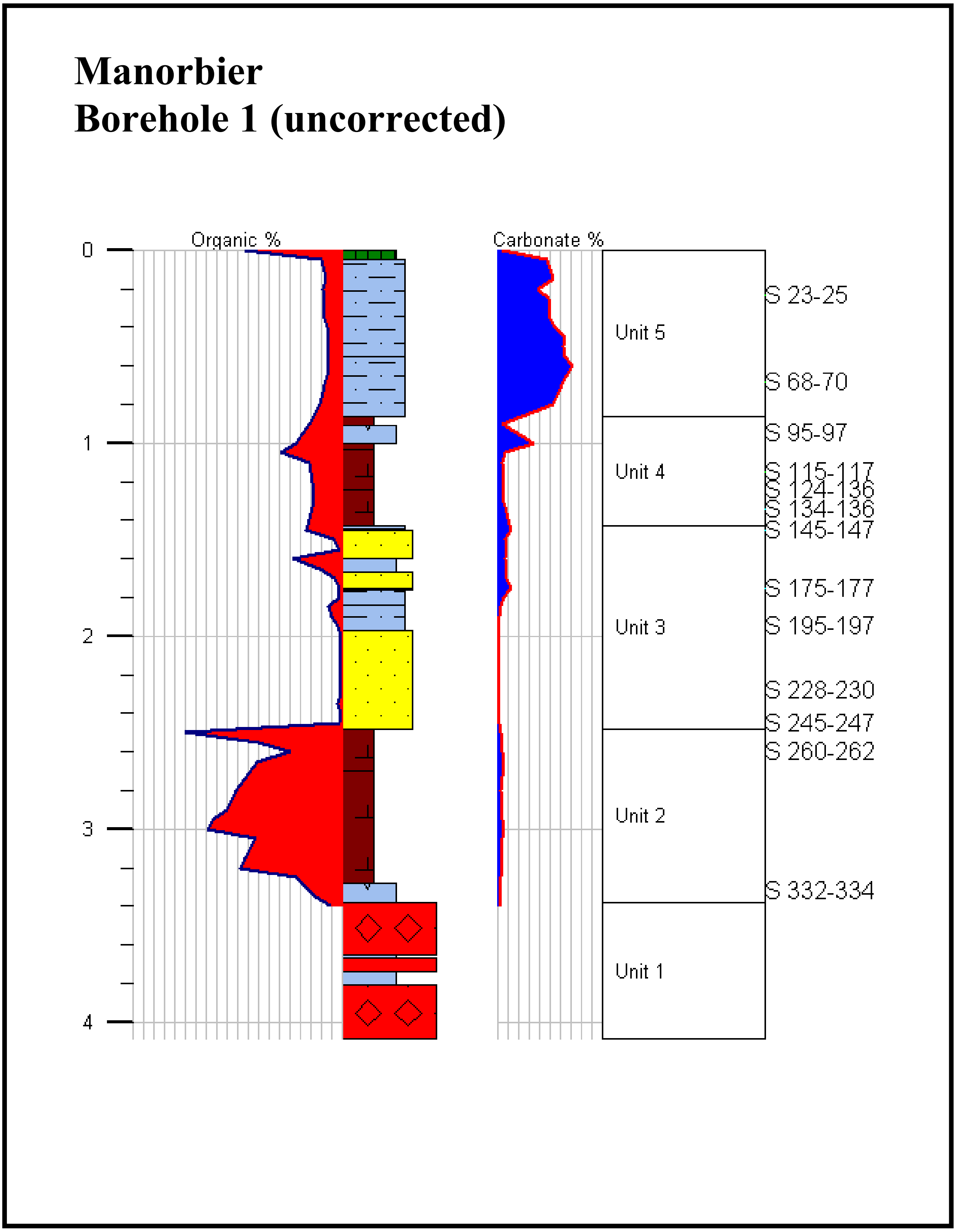

Figure 1. Lithological sequence, percentage organic and carbonate, designated stratigraphic unit and location of assessed samples in Borehole 1 (depths in metres below ground surface).

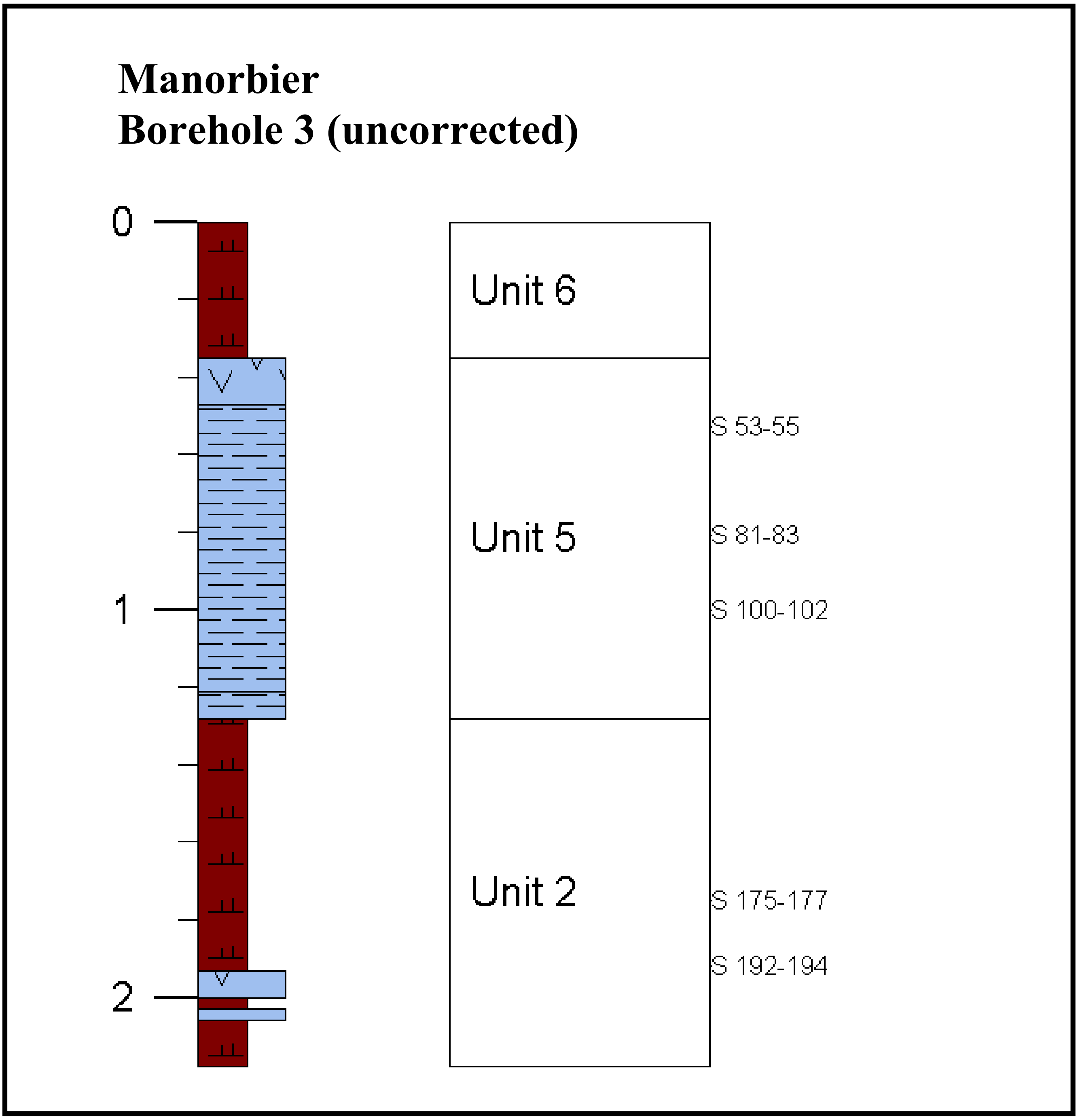

Figure 3. Lithological sequence, designated stratigraphic unit and location of assessed samples in Borehole 3 (depths in metres below ground surface).

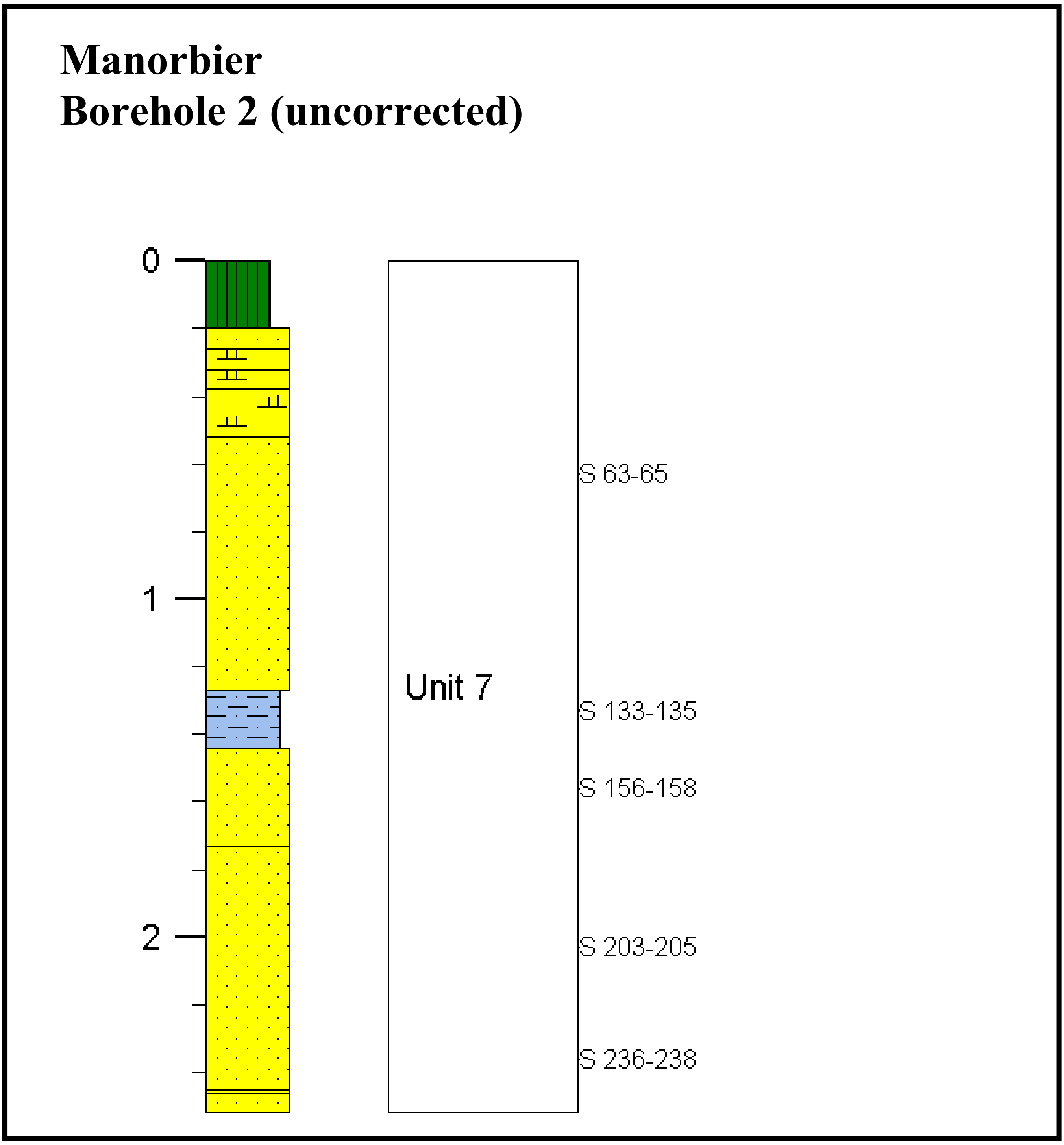

Figure 2. Lithological sequence, designated stratigraphic unit and location of assessed samples in Borehole 2 (depths in metres below ground surface).

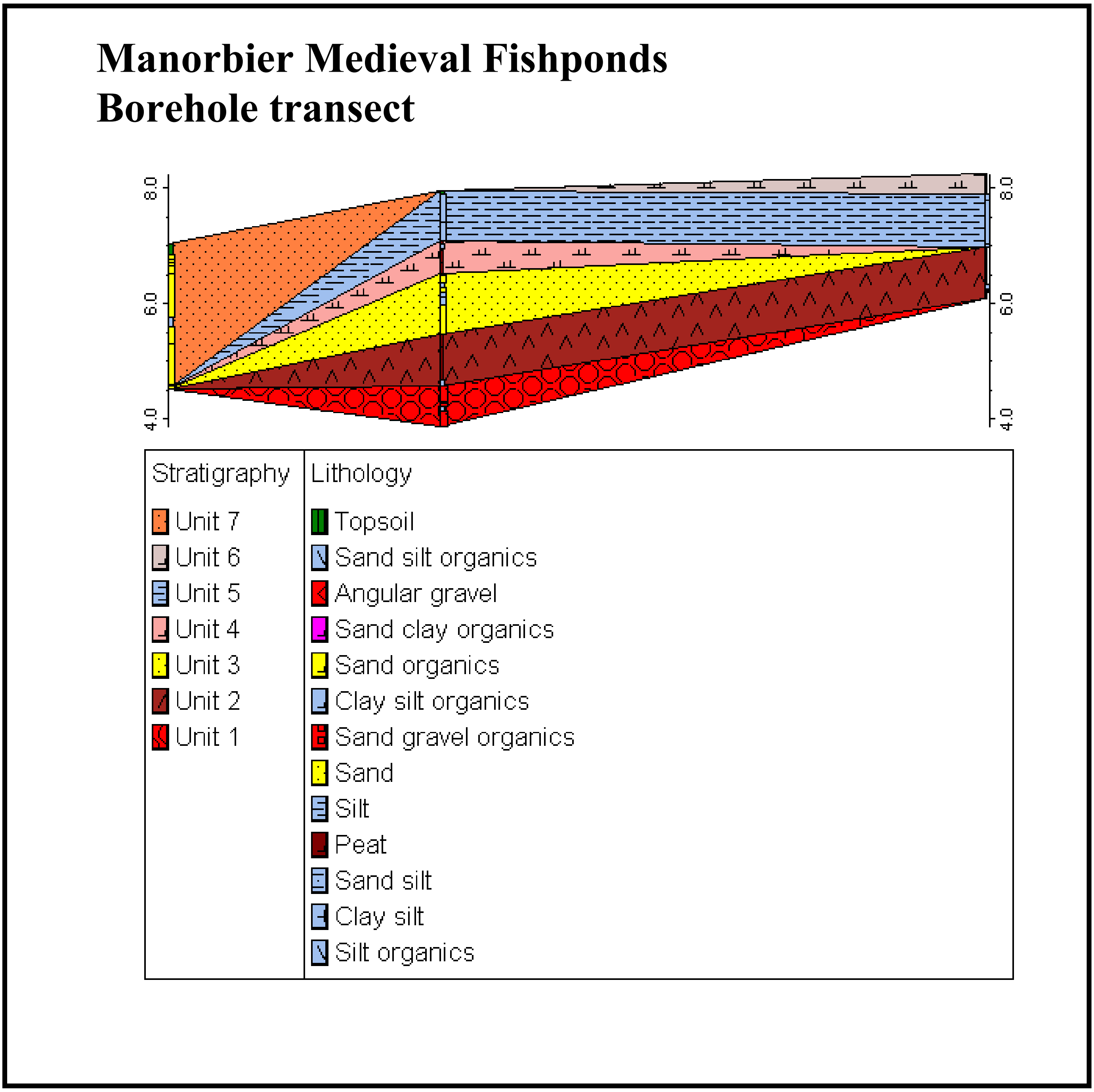

Figure 4. Cross section based on correlated units in boreholes 1-3 (depth in metres O.D. – all depths uncorrected for compaction).

Borehole	Sample depth	Weigh processed
BH 1	23/25cm	48g
	68/70cm	66g
	95/97cm	62g
	115/117cm	68g
	134/136cm	72g
	145/147cm	81g
	175/177cm	80g
	195/197cm	93g
	228/230cm	72g
	245/247cm	88g
	260/262cm	53g
BH 2	63/65cm	75g
	133/135cm	77g
	156/158cm	79g
	203/205cm	83g
	236/238cm	106g
BH 3	53/55cm	51g
	81/83cm	54g
	100/102cm	57g
	124/126cm	48g
	175/177cm	62g
	192-194	56g

Table 4. Samples processed for palaeoenvironmental assessment

Depth (metres) below ground surface as a continuous measurement	**Stratigraphic description**	**Inferred environment of deposition**	**Designated unit**
0 – 0.05	Topsoil.		
0.05 – 0.86	Mid brown sandy-silt to fine sand. Some organic matter becoming darker and more organic towards base	Freshwater valley bottom wetland with minimal *in situ* organic accumulation. Probable seasonal incursion of moving water and occasional brackish incursions.	5
0.86 – 1.43	Dark brown relatively fresh peat. Unit contains beds of dark brown to reddish brown clay silt between 0.91 and 1.00m. Minerogenic content appears to increase towards base and sand grains noted. Shell fragments also seen.	Possible alder carr wetland in valley bottom with periods of fluvial activity resulting in washing in of silts or reed swamp development in slightly brackish conditions.	4
1.43 – 2.48	Dark grey becoming yellow with depth fine to medium sand. Upper part of sequence (to 1.97m) consists of interceded dark and light grey sand beds with variable organic content. Root or stem fragments of reeds (?Phragmites sp.)Present. Shell fragments are noted through much of upper part of sequence. Below 1.97m sediment is yellow and without structure and does not appear to contain any	Possible marine incursion initially resulting in inwash of sands. Gradual transition through time to increasingly marshy conditions and wetland reed growth.	3

	shell fragments.		
2.48 – 3.38	Dark brown peat. Woody towards top of unit. Clearly bedded in places with minerogenic sediment present between 2.52 and 2.58m.	Possible alder carr wetland in valley bottom with periods of fluvial activity resulting in washing in of silts.	2
3.38 – 4.09	Red angular gravel in a clay-silt matrix. Clearly bedded with thin beds of organic silt noted in places.	Possible colluvial sediment reworked in valley bottom by minor fluvial activity. Local presence of organic beds suggest local vegetation and impeded drainage.	1
	Core samples: 0 – 1m 1 – 2m (commences 0.55m) 2 – 3m (commences 1.24m) 3 – 4m (commences 1.97m) 4 – 5m (commences 2.70m) 5 – 6m (commences 3.38m)		

Table 1. Stratigraphic description, inferred environments of deposition and unit designation: Borehole 1.

Depth (metres) below ground surface as a continuous measurement	Stratigraphic description	Inferred environment of deposition	Designated unit
0 – 2.52	Mid brown medium sand varying to dark brown in places. Clearly bedded with beds c.5cm thick. Dark and lighter brown beds in upper 1.27m of sequence indicate variable organic content. Below 1.27m sand is red in colour and becomes coarser with depth. Shell fragments common and occasional patches of darker brown organic sediment are noted.	Basal part of sequence likely to reflect either a marine incursion or sediment blown inland from adjacent beach. Increased terrestriality noted up sequence with higher organic content suggesting possible presence of buried soils.	7
	Core samples: 0 – 1m 1 – 2m (commences 0.93m) 2 – 3m (commences 1.73m)		

Table 2. Stratigraphic description, inferred environments of deposition and unit designation: Borehole 2.

Depth (metres) below ground surface as a continuous measurement	**Stratigraphic description**	**Inferred environment of deposition**	**Designated unit**
0 – 0.35	Dark brown to reddish brown peat. Material is unhumified and clearly contains wood fragments in places.	Freshwater wetland with reed and tree growth and impeded drainage with seasonal flooding (occasional brackish incursions).	6
0.35 – 1.28	Yellow brown silt with variable organic content. Evidence of vertically orientated root or stem material (?Phragmites sp.).	Freshwater valley bottom wetland with minimal *in situ* organic accumulation. Possible moving water.	5
1.28 – 2.18	Dark brown peat. Clearly containing sand throughout. Bedded in places with sandy organic silts noted. Wood fragments seen in places.	Possible alder carr wetland in valley bottom with periods of fluvial activity resulting in washing in of silts.	2
	Core samples: 0 – 1m 1 – 2m (commences 0.60m) 2 – 3m (commences 1.40m)		

Table 3. Stratigraphic description, inferred environments of deposition and unit designation: Borehole 3.

	23/25cm	68/70cm	95/97cm	115/117cm	134/136cm	145/147cm	175/177cm	195/197cm	228/230cm	245/247cm	260/262cm	332/334cm
Plant debris	x	x	x	x	x	x	x	x			x	
Seeds	x	x	x	x	x	x	x					x
Charophyte oospores	x	x										
Cladoceran ephippia	x											
Ostracods (freshwater)	x	x										
Testate amoebae (freshwater)	x	x										
Insects		x			x	x						x
Small mammal bones				x								
Earthworm granules					x	x						
Slug plates					x							
Foraminifera (marine)					x	x	x					
Ostracods (marine)							x					
Molluscs (marine)							x					
Molluscs (?terrestrial)							x					

Table 5. Summary results: assessed samples BH 1.

	63/65cm	133/135cm	156/158cm	203/205cm	236/238cm
Molluscs (marine)	x	x	x	x	x
Foraminifera (marine)	x	x	x	x	x
Molluscs (?terrestrial)		x			
Earthworm granules		x			

Table 6. Summary results: assessed samples BH 2.

	53/55cm	81/83cm	100/102cm	124/126cm	175/177cm	192/194cm
Plant debris	x	x	x	x	x	x
Seeds	x	x	x	x	x	x
Charophyte oospores	x			x		
Cladoceran ephippia	x	x	x			
Testate amoebae (freshwater)	x	x	x	x		
Insects	x	x	x	x	x	x
Ostracods (freshwater)		x				
Fish bones		x				
Molluscs (freshwater/terrestrial)			x			

Table 7. Summary results: assessed samples BH 3.