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ASSESSMENT REPORT
EXCAVATION OF THE CAR DYKE
HELPRINGHAM
LINCOLNSHIRE
(CDP 99)

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ARCHAEOLOGICAL

PROJECT

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ASSESSMENT REPORT
EXCAVATION OF THE CAR DYKE
HELPRINGHAM
LINCOLNSHIRE
(CDP 99)

By
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with contributions by
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Prepared for
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SUMMARY

During July 1999, archaeological investigations were undertaken of the Car Dyke at Helpringham, Lincolnshire. This report provides a formal assessment of these archaeological excavations. Excavation of two trenches and a number of boreholes amassed data which is discussed here with their relevance to potential for further understanding of this monument.

1. INTRODUCTION

1.1 The Car Dyke is a linear watercourse approximately 100km in length and generally believed to be Roman in origin. It extends from Washingborough, east of Lincoln, to Peterborough, although it is not known if this constitutes one single uninterrupted course.

1.2 The Car Dyke has been the subject of previous studies funded by English Heritage (Simmons 1975; Simmons and Cope-Faulkner 1997). The latter work sought to produce a management document for the monument. It became apparent during this course of study that, despite the wealth of data present, the overall understanding of the Car Dyke was limited.

1.3 In order to increase understanding of the Car Dyke and as part of the preparation of a management document, a short length in Helpringham Fen, Lincolnshire (NGR TF 1455 3905), was chosen for further examination. This location has two very well preserved banks and has been afforded Scheduled Monument Status (County No. 274). A trench was excavated at this location in 1971, although no paper archives survive from this investigation.

1.4 In light of this it was proposed to re-excavate a trench through each bank, along the line of the 1971 trench, and to examine the channel by close interval augering. A programme of environmental sampling and dating methods was also employed.

2. AIMS AND OBJECTIVES

2.1 The aims were as follows;

2.1.1 to determine the full dimensions of the Car Dyke including the channel and banks.

2.1.2 to retrieve a full range of environmental data for assessment in order to determine the full sedimentary and environmental history of the site.

2.1.3 to retrieve details on the original construction methods of both the channel and the banks.

2.1.4 to retrieve any details as to the original function.

2.1.5 to retrieve dateable material.

2.1.6 to incorporate this data with data obtained from previous archaeological investigations of the Car Dyke as an aid to formulating appropriate management options for the long-term survival of the monument.

3. METHODOLOGY

3.1 Prior to the excavation the landowners permission was sought and Scheduled Monument Consent was obtained for the excavation (Appendix 1).

3.2 *Excavation of the Banks*

3.2.1 prior to the excavation of the trenches, trench positions were marked out as part of a survey of the field. In addition, a contour survey was undertaken over the part to be affected in order to facilitate restoration of the monument following completion of the work.

3.2.2 excavation of the banks was undertaken by a JCB-type mechanical excavator fitted with a toothless ditching bucket. Machining was terminated at the upper surface of natural deposits.

3.2.3 sides of the trenches were then cleaned and rendered vertical by hand. The base of the trench, representing the uppermost surface of the underlying natural deposits, was also cleaned by hand.

3.2.4 contexts were recorded onto *pro-forma* sheets as used by the Museum of London (MoLAS 1994). All colour was described with reference to Munsell colour charts. Sections were recorded at a scale of 1:10 and a comprehensive photographic record compiled.

3.3 *Examination of the channel*

3.3.1 The channel was investigated by means of close interval augering using an Eijelkamp open sided corer as outlined by Canti and Meddens (1998). This was undertaken by Matthew Canti of the Ancient Monuments Laboratory using AML equipment. Coring was undertaken at 1m intervals.

3.3.2 recording of the cores was undertaken by describing the contexts removed and measuring depths of deposits within the corer. These were then related to Ordnance Datum and plotted using a Geodolite.

3.3 *Sampling for environmental data*

3.3.1 Pollen and soil micromorphology

a) The palaeosol profile was sampled for pollen in monolith tins from the bank and in plastic pipes from the channel sediments. Each was staggered so as to provide a continuous sequence through the sediments encountered.

b) Following the removal of sufficient sediment for pollen assessment and analysis, the remaining sample within the monolith tins was examined by soil micromorphology techniques.

3.3.2 Plant macrofossils, molluscs and foraminifera

a) Sixteen samples for analysis were collected from the core of the channel, following removal of sediment for pollen analysis. Sample size was limited due to the size of the core.

3.4 *Optically stimulated luminescence dating (OSL)*

3.4.1 Near replicate samples were taken from the bank and channel as was *in-situ* dosimetry measurements using a portable gamma spectrometer.

4. FACTUAL DATA

4.1 *Stratigraphic/Structural data*

4.1.1 The excavation produced 169 context sheets derived from the 2 trenches and 13 boreholes excavated at the site. A total of seventeen sections were produced, one for each borehole and for each long side of the trenches. A stratigraphic matrix has been produced and accords well with the known and suspected sedimentary sequence.

4.1.2 Overlying the natural drift geology was a preserved buried soil sealed beneath the banks and continuous along the base of both trenches except where impacted into by some bank deposits.

4.1.3 Banks were well constructed with no visible structural support. They were formed from alluvial sands, gravels and boulder clay upcast derived from the channel.

4.1.4 Channel deposits range from highly organic silts to sands and clays.

4.2 *Artefactual data*

4.2.1 No artefactual material was retrieved from stratified deposits.

4.3 *Macrofossil data*

4.3.1 Sixteen samples were collected from Borehole 9 for plant and animal macrofossil assessment. Samples were limited by the diameter of the core with the largest samples weighing 0.5kg.

4.3.2 For assessment, eight alternate samples were examined. The sample was described, weighed and soaked for several days. The samples were then disaggregated and washed through sieves before examination under suitable magnification.

4.4 *Pollen data*

4.4.1 Twenty five sub-samples were extracted from four monoliths taken from positions beneath the bank. The sub-samples were taken from the deposits deemed to be the buried soil.

4.4.2 Twelve sub-samples were taken from Borehole 9 to determine pollen abundance and preservation. The number of samples was kept to a minimum so as not to incur unnecessary costs.

4.5 *Foraminifera data*

4.5.1 A total of eleven samples for foraminiferal data were taken from Borehole 9. All samples were processed by disaggregation of the sediments and subsequent sieving.

4.6 *Soil Micromorphology data*

4.6.1 The remaining sediment within the four monolith tins was submitted to Dr. C. French. These were quickly scanned to determine their suitability for further analysis.

4.7 *OSL Dating data*

4.7.1 Two near replicate samples were taken from bank deposits and two samples were taken from the base of Borehole 9 at the interface between channel fill and natural boulder clay. The second sample was designed as a back-up to the first in the result of a lack of suitable mineral material.

5. STATEMENT OF POTENTIAL

5.1 *Stratigraphic/Structural data*

5.1.1 The stratigraphic element of the excavation is believed to be consistent and of good quality. The sequence of events in the construction of the Car Dyke banks at Helpringham can now be understood. The channel was investigated by coring and a continuous sequence not seen. Therefore, some surmising of the nature of these deposits will be expected.

5.1.2 Deposition within the channel should contrast or compare well with other excavated portions of the Car Dyke. This may indicate regional similarity or change.

5.1.3 Dimensions of the Car Dyke were established and the presence of a berm, as suggested by the earthworks at Helpringham, can now be dismissed.

5.1.4 A paper archive now exists for archaeological work which will replace the 'lost' archive from the 1971 excavation of a trench at this location.

5.1.5 It is unlikely from this investigation that the original function of the Car Dyke can be determined from the nature of the excavated material.

5.2 *Macrofossil data*

5.2.1 Preservation of the material was good, though densities varied. The basal sample had little biological material possibly indicating primary deposition within the channel. Plant macrofossils, mollusc shells and 2 small fish bones were identified.

5.2.2 Variations in deposit make-up indicate that the channel was subject to a period of faster flowing water replaced by a slower flow.

5.2.3 Plant macrofossils comprise fruits, seeds, monocotyledons, stem and leaf fragments, deciduous leaf fragments and small scraps of wood. Most of these are derived from freshwater aquatic species.

5.2.4 Animal macrofossils comprise mollusc shell, arthropods and fish bones.

5.2.5 The assemblages of macrofossils was generally small. More detailed analysis might increase the numbers of species though a more detailed palaeoecological record is not likely to result.

5.3 *Pollen data*

5.3.1 Sampling over critical horizons of the buried soil had failed to produce suitable pollen assemblages, possibly due to decomposition. Some grasses, dandelion type plants, ferns and fungal hyphae were recorded.

5.3.2 The paucity of pollen indicates that the buried soil remained bioactive for a period after burial by the bank.

5.3.3 The canal sediments produced a wider variety of pollen. Basal sediments contained no pollen although higher in the sequence, pollen from woody plants, aquatic plants, waterside plants and cereals.

5.3.4 The results show that the Car Dyke appears to have been constructed in an open landscape, notably grassland adjacent to the channel. Higher within the sequence, an increase in cereal production was noted that may have lead to heavy accretion of deposits within the channel.

5.4 *Foraminifera data*

5.4.1 Freshwater species were generally recovered with one episode in the middle of the sequence indicating a brackish water incursion.

5.4.2 No further analysis is deemed necessary.

5.5 *Soil Micromorphology data*

5.5.1 Two of the four monoliths taken for soil micromorphology were suitable for further analysis. One of the discarded samples was too poorly preserved and the other appeared to incorporate channel fills.

5.5.2 It is suggested that these two samples be processed and analysed using thin section techniques. These samples represent the first occurrence of buried soil preservation associated with this monument and, therefore, are worthy of full analysis.

5.6 *OSL Dating data*

5.6.1 The sample taken from bank deposits is either insensitive to low and moderate radiation levels or has retained its geological date. As such, no date is likely to be obtained.

5.6.2 A sample taken from the base of the channel appears to be too old to provide a late Holocene date as would be expected for the Car Dyke.

5.7 Radiocarbon Dating data

5.7.1 As no dates could be obtained from OSL methods, macrofossils were examined again for their suitability for radiocarbon dating.

5.7.2 Most macrofossils are aquatic species and are unsuitable for radiocarbon dating techniques.

6. CONCLUSIONS

6.1 The excavation and subsequent environmental analyses achieved certain of the original aims of the project whilst the data were insufficient to elucidate all the required information.

6.2 Aim 2.1.1 in this report (determination of the dimensions) was achieved, as was the retrieval of a range of environmental data. Unfortunately, the generally poor quality of the latter did not provide a full sedimentary and environmental history of the monument through time. Nor did they allow the function of the monument to be deduced or construction methods understood.

6.3 Not enough biological remains were present to date episodes of the infilling of the monument by radiocarbon and attempts at OSL dating also failed.

6.4 On the positive side the project micromorphologist, Charles French, recommends analysis of two of the samples from the paleosol beneath the banks.

6.5 Other than those samples none of the remaining environmental remains have been deemed worthy of further analysis.

6.6 It is recommended that the structural/stratigraphic elements of the site are fully described, along with summaries of the environmental material and a full report on the soil micromorphology, are included in a forthcoming Management document, much of which already exists in draft form.

7. STORAGE AND CURATION

7.1 All primary records are currently kept at:

Archaeological Project Services
The Old School
Cameron Street
Heckington
Sleaford
Lincolnshire, NG34 9RW

7.2 Upon completion of the project, the archive will be deposited in accordance with the document titled *Conditions for the Acceptance of Project Archives* produced by the Lincolnshire City and County Museum.

7.3 The ultimate destination of the project archive is:

Lincolnshire City and County Museum
12 Friars Lane
Lincoln
LN2 1HQ

8. REFERENCES

Canti, M.G. and Meddens, F.M., 1998 'Mechanical Coring as an Aid to Archaeological Projects' *Journal of Field Archaeology*, Vol. **25**, 97-105

MoLAS, 1994 *Archaeology Site Manual* (3rd edition), London

Simmons, B.B., 1975, *The Lincolnshire Fens and Fen edge north of Bourne*

Simmons, B.B. and Cope-Faulkner, P., 1997 *The Lincolnshire Car Dyke; Past Work, Management Options and Future Possibilities*, unpublished APS report **51/97**

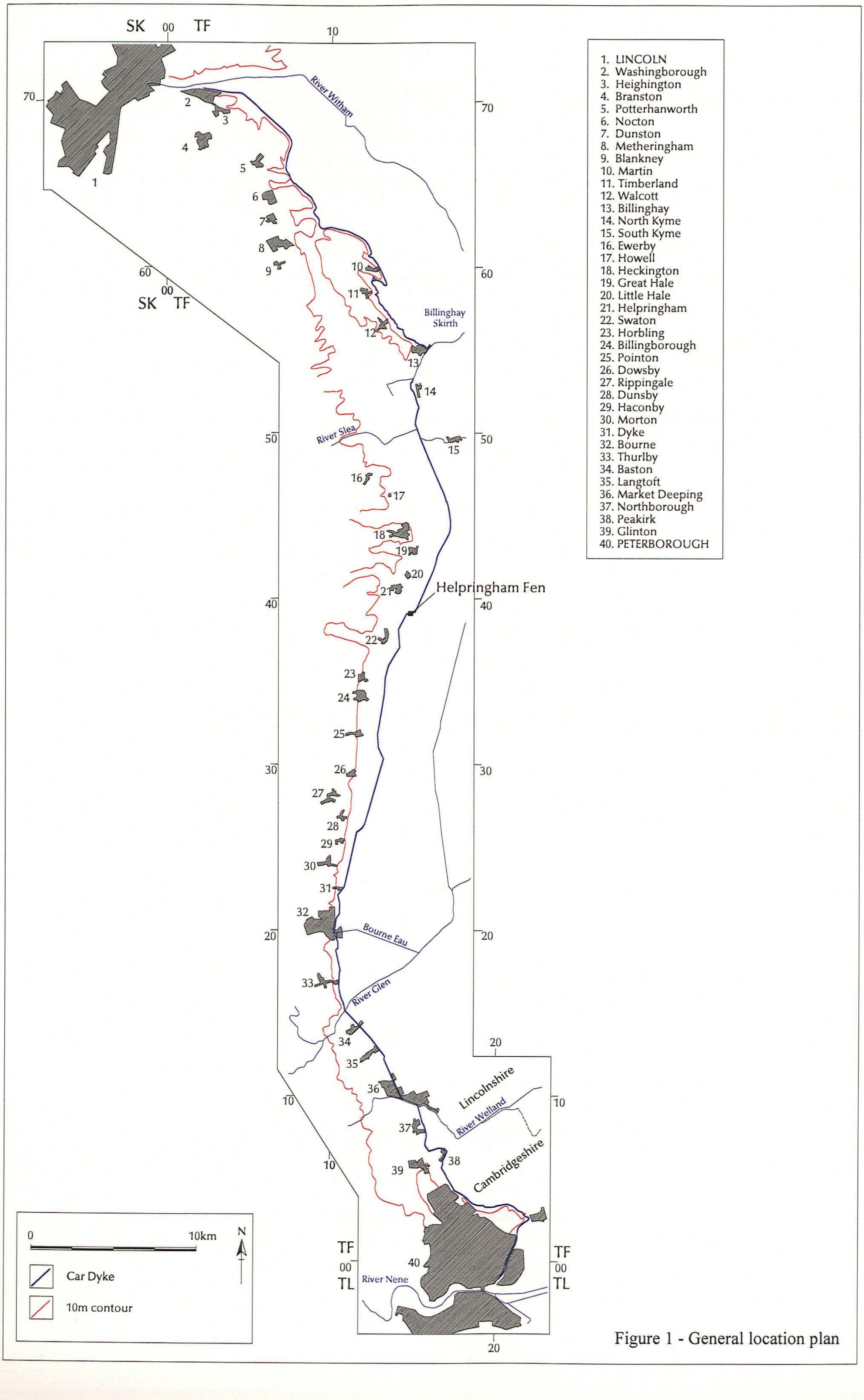

Figure 1 - General location plan

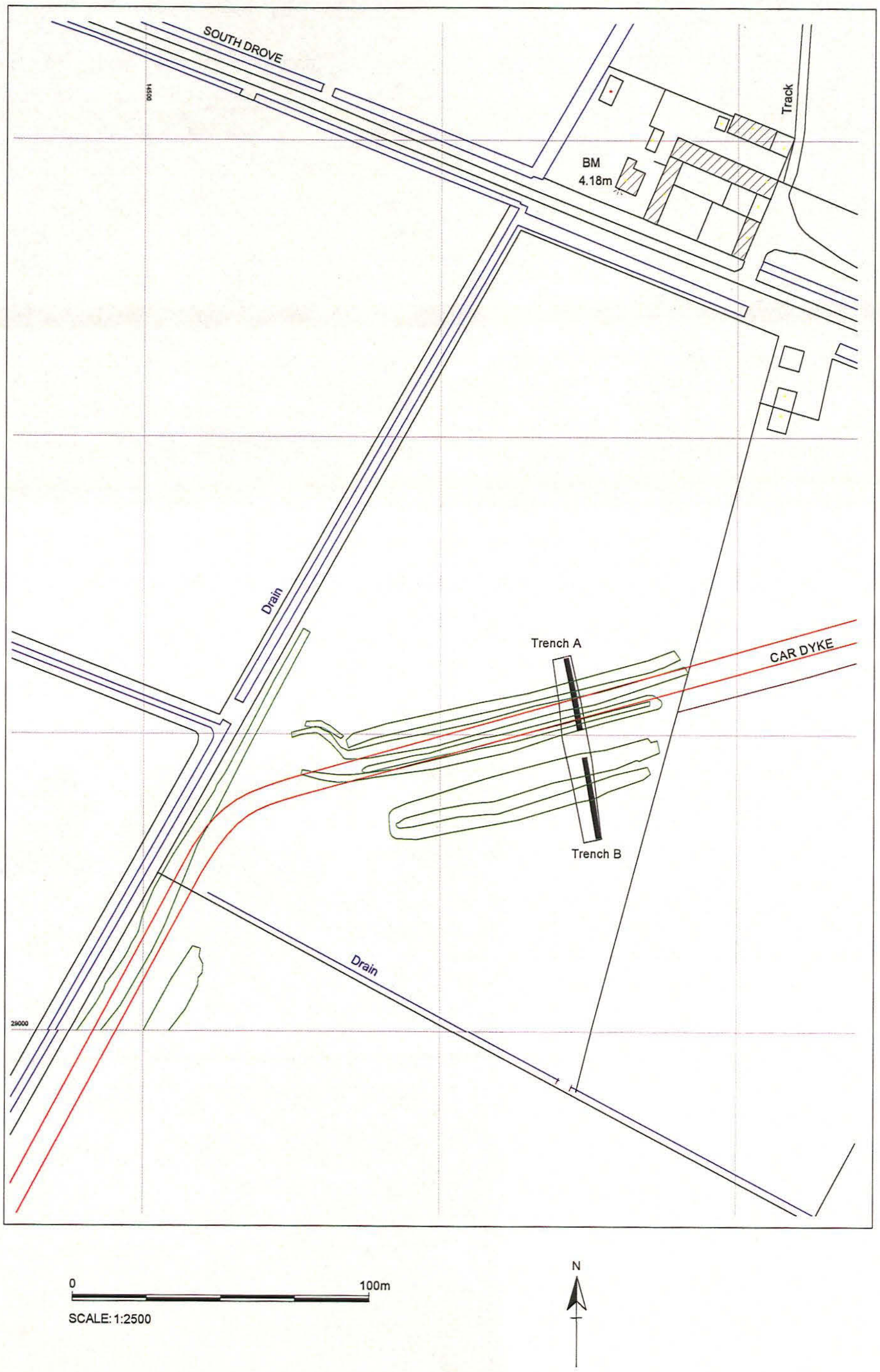

Figure 2 - Trench location plan

Plate 1 - General view across the banks and channel of the Car Dyke during excavation, looking north

Plate 2 - Close view of the southern trench showing the buried soil and bank deposits

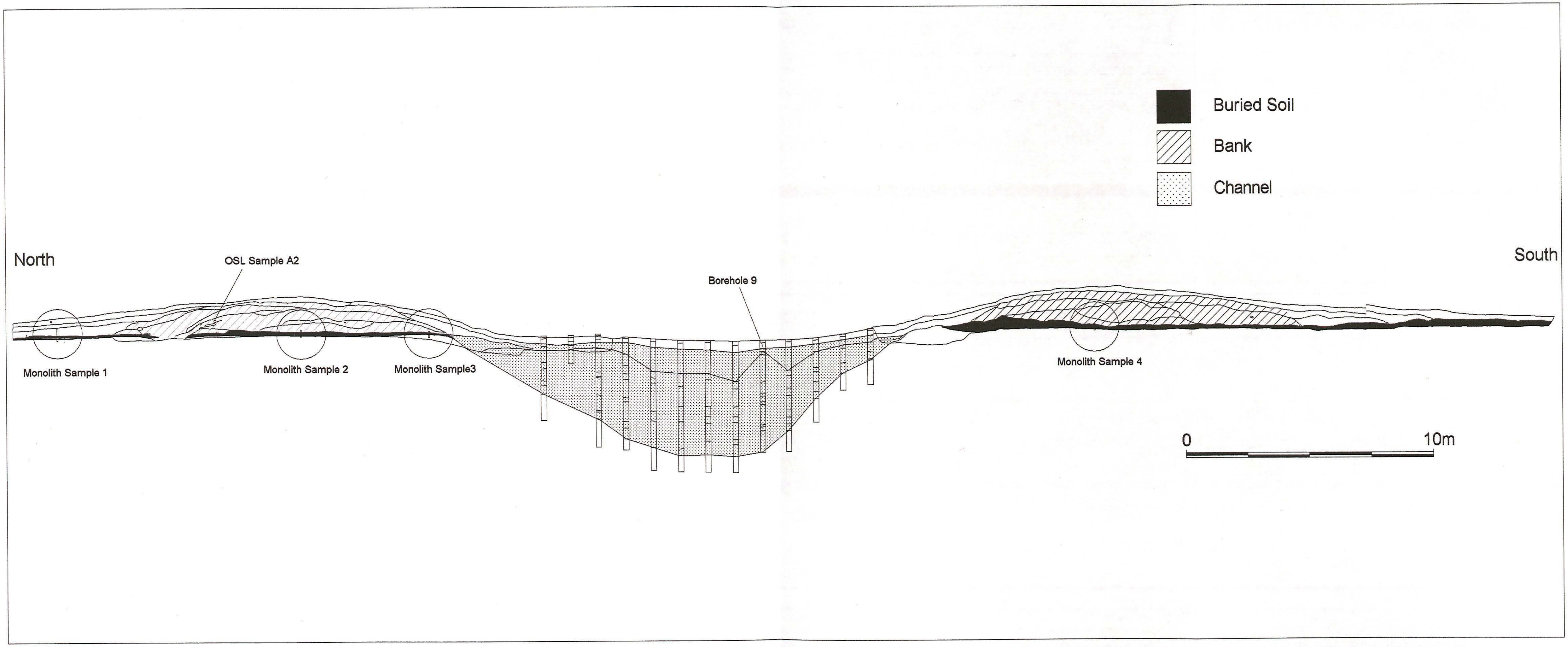

Figure 3 - Section through the Car Dyke

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18 May 1999

Mr T Lane
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Our ref: HSD 9/2/4186 Pt 1

Dear Sir

ANCIENT MONUMENTS AND ARCHAEOLOGICAL AREAS ACT 1979 (AS AMENDED) - SECTION 2
PROPOSED WORKS AT CAR DYKE ROMAN CANAL AT HELPRINGHAM, HELPRINGHAM, NORTH KESTEVEN, LINCOLNSHIRE
COUNTY MONUMENT NO: 274
APPLICATION BY MR T LANE ON BEHALF OF ARCHAEOLOGICAL PROJECT SERVICES

1 I am directed by the Secretary of State for Culture, Media and Sport, to refer to your application for scheduled monument consent dated 25 January 1999, and to the project design extract, aerial photograph and location plans highlighting the areas of proposed works submitted therewith, in respect of proposed works at the above scheduled ancient monument, concerning the re-excavation of a 3 metre wide section of the monument excavated in the 1970s, and associated sampling to inform a management plan for the monument.

2 In accordance with paragraph 3(2) of Schedule 1 to the 1979 Act, the Secretary of State is obliged to afford to the applicant, and to any other person to whom it appears to the Secretary of State expedient to afford it, an opportunity of appearing before and being heard by a person appointed for that purpose. This opportunity has been declined in Mr Trimble's telephone conversation with Mr Paragreen of the Department on 18 May 1999.

3 The Secretary of State is required by the Act to also consult with the Historic Buildings and Monuments Commission for England (English Heritage), before deciding whether or not to grant scheduled monument consent. Having considered the advice of English Heritage, the Secretary of State agrees that the proposed works are an archaeological excavation supported by a full research design, which adequately justifies the controlled destruction of buried archaeological evidence, and its recording and preservation in archive and published form, in order substantially to increase the understanding of the remainder of the monument. The Secretary of State is content for the works to proceed providing the conditions recommended by English Heritage, and set out below, are adhered to. Accordingly the Secretary of State hereby grants scheduled monument consent under section 2 of the 1979 Act, for the proposed works as described and detailed in paragraph 1 above, subject to the following conditions :-

Appendix 2

CAR DYKE, LINCOLNSHIRE (BOREHOLE 9): ASSESSMENT OF PLANT AND ANIMAL MACROFOSSILS

by Peter Murphy

Introduction

Excavations were undertaken at this site under the direction of Paul Cope-Faulkner (Heritage Lincolnshire) for English Heritage. Although sections were cut through the embankments and subjacent palaeosols flanking the Roman canal, it was not possible to section the channel itself. Instead, cores were collected by Dr M. Canti (Centre for Archaeology, EH), to establish the stratigraphy and to obtain samples for palaeoecological assessment.

Factual data

Quantification of material

Sixteen samples were collected from Borehole 9 for plant macrofossil assessment. Sample size was limited by core diameter, but samples of up to 0.5kg were obtained. Samples came from the following depths (cm) below present ground surface: 155-165, 165-175, 175-185, 185-195, 200-210, 210-220, 220-230, 230-240, 250-260, 260-270, 270-280, 280-290, 310-320, 320-330, 330-340, 340-350.

Data collection and method statement

For assessment purposes, eight alternate samples were examined. Macroscopic characteristics of the samples were described, (Table 1), they were weighed, then soaked in water for several days. They were then disaggregated manually, and washed through a sieve bank, with a minimum mesh size of 250 micrometres. Complete disaggregation was not achieved in all cases. Three petri dishes of retent >500 micrometres were scanned under a binocular microscope at low power (x20) and higher magnifications were used as necessary for identification. All identifications were confirmed by comparison with modern reference material.

Statement of potential

Macrofossils noted during scanning are listed in Table 2. Preservation of plant and animal macrofossils was good in most samples, though densities of material varied considerably. The basal sample included very little biological material, and could represent the original base of the cut. Mollusc shell fragments were not present in the topmost sample assessed (155-165cm), perhaps due to decalcification.

The sample from 320-330cm had a high sand content with some small subrounded subangular flints, and seemed to represent a moderately high current velocity. Samples above this included only traces of sand, and larger amounts of fine plant detritus, implying increasingly sluggish flow.

Categories of material present comprised plant macrofossils (fruits, seeds, monocotyledonous stem and leaf fragments, deciduous leaf fragments, small scraps of wood), mollusc shells, arthropods (beetles, caddis larval cases, cladoceran ephippia, fly puparia and ostracods) and fish bones.

The plant macrofossils noted were predominantly of freshwater aquatic species, including *Alismaplantago-aquatica* (water plantain), *Lemna* sp (duckweed), *Myriophyllum spicatum* (spiked water milfoil), *Oenanthe aquatica* (water dropwort) and *Potamogeton spp* (pondweeds). Also present were *Carex* spp (sedges) and *Scirpus* sp, with macrofossils of wetland and terrestrial plants, both grassland species and weeds. Trees and/or shrubs were represented only by scraps of wood and leaves, with a seed of *Solanum dulcamara* (woody nightshade). The molluscs were exclusively freshwater species. The beetle remains, though well-preserved, were few in number, as were other arthropods, with the exception of ostracods in some samples. The sample from 210-220cm included very small fish bones.

The assemblages of macrofossils retrieved were generally small, due to the constraints of sample size, but are quite typical of lowland freshwater habitats with an input of terrigenous material. Although more detailed assessment or analysis would no doubt increase the species lists it seems improbable that palaeoecological information significantly affecting site interpretation would be obtained. Data on the wider landscape and the setting of the canal are better obtained from palynology.

Up-dated Project Design

No further analysis of this material is proposed, but all sievings and unprocessed samples have been retained *pro tem,* in case they may be of use to other specialists.

Anaerobic preservation of plant and animal material is plainly still good in the canal fills. In terms of mitigation, any works which might result in water-table lowering would be undesirable. Dewatering of the sediments would probably preclude future investigations using more advanced techniques, or examining areas of the canal where more informative material might be obtained (e.g. at loading staithes).

Table 1: Descriptions of sediments from Borehole 9

Depth (cm)	Sediment description
155-165	Very dark greyish-brown organic mud
185-195	Very dark greyish-brown organic mud
210-220	Very dark greyish-brown organic mud
230-240	Dark greyish-brown organic mud; shell fragments common
260-270	Dark brown organic mud; shell fragments common.
280-290	Greyish-brown organic mud
320-330	Greyish-brown organic mud
340-350	Grey mud with rare small flints, very firm

Depth (cm)	340-350	320-330	280-290	260-270	230-240	210-220	185-195	155-165
Plant macrofossils								
Alisma plantago-aquatica L.							XX	
Alismataceae indet.			X	X				
Aphanes arvensis/microcarpa		X						
Apiaceae indet.				X	X			
Atriplex sp.						X		
Carex sp.							X	
Chenopodium album L.					X			
Cirsium/Carduus sp.				X				
Epilobium sp.							X	
Lemna sp.						X		
Myriophyllum spicatum L.			X					
Oenanthe aquatica (L) Poiret							X	
Potamogeton spp.			X	XX	X	XX	X	
Prunella vulgaris L.			X					
Scirpus sp.			X					
Solanum dulcamara L.						X		
Deciduous leaf frags					X			
Monocot. Stem/leaf frags.	X	X	X	XX	XX	XXX	X	X
Wood scraps				X	X	X	X	X
Molluscs								
Armiger crista (L.)			X					
Bithynia sp.					X		X	
Bithynia sp (opercula)			X	X	X	X	XX	
Gyraulus albus (Mueller)			X					
Planorbis carinatus (Mueller)							X	
Succineidae indet.			X		X			
Unionidae indet. (small fragments)		X	X	X		X		
Indeterminate shell scraps	X	X	X	XX	XX	X		
Arthropods								
Beetles			X	X	X	X	X	X
Caddis larval cases			X			X		
Cladoceran ephippia				X	X			
Fly puparia				X				
Ostracods		X	X		X	X	X	
Bone								
Fish						X		
Lithology								
Fine plant detritus	X	X	XX	XX	XX	XXX	XXX	XXX
Sand content	X	X						
Subrounded-subangular flints	X(<14mm)	X(<6mm)			X(<3mm)			
Sample weight (kg)	0.24	0.2	0.14	0.18	0.2	0.21	0.4	0.47

Table 2: plant and animal microfossils from Borehole 9

Appendix 3

CAR DYKE, HELPRINGHAM, LINCOLNSHIRE - PALYNOLOGICAL ASSESSMENT OF CHANNEL DEPOSITS AND THE CHANNEL BANK BURIED SOILS

by Patricia E.J. Wiltshire

1. Introduction

A north/south transect of bore holes of the Car Dyke, a relic Roman canal, was made by English Heritage. This revealed the channel-fill to consist of a series of clay, silly clay, and peat deposits. The sediments from Bore Hole 9 reached a depth of more than 3.6 m, and were collected for palynological assessment. Sediment descriptions were lodged in the site archive.

The soils adjacent to the channel had been buried by upcast material during the construction of the canal, and it was decided to carry out both palynological and micromorphological assessments of these palaeosols. Accordingly, monolith samples were obtained from the sections either side of the borehole transect. Samples 1, 2, and 3 were taken from the north side of the channel, with Sample 3 being close to the very edge of the channel itself. Sample 4 was taken from the section on the southern side of the channel.

2. Aims

It was hoped that the buried soils might yield information on the vegetation prevailing at the site before construction of the channel. The four palaeosol profiles were obtained for assessment in order to investigate spatial variation in vegetation and land use in the environs of the site. There was also the prospect that the bore hole sediments would provide temporal information on the history of vegetation and land use subsequent to channel construction.

3. Factual Data

3.1 Buried soils

An attempt was made in the laboratory to identify the position of the interface between the palaeosol and overlying spoil in the 4 monolith samples. In each case, closer subsampling was carried out over the deposits deemed to represent the A horizons of the buried soils. The sampling frequencies are indicated in Table 1. A total of 7 subsamples were assessed for Monolith 1, 5 subsamples for Monolith 2, 6 subsamples for Monolith 3, and 7 subsamples for Monolith 4.

3.2 Channel sediments

In the first instance, it was decided to prepare just 12 subsamples, spread throughout the 3.6m of sediment, to gain information on palynomorph abundance and preservation. This relatively low number of samples was chosen so that, if the sediments proved to be sterile, unnecessary costs would not be incurred. The sampling frequency is indicated in Table 2.

4. Methods

4.1 Processing

Standard preparation procedures were used (Dimbleby 1985). Wet sediment was measured for 2.0cm^3 volume displacement (Bonny 1972). Tablets of *Lycopodium* spores (Stockmarr 1972) were added to each sample to allow estimates of palynomorph concentration (Benninghof 1962). Concentration of exotic was 13,000 cm-3 of sediment. Samples were lightly stained with 0.5% safranine and mounted in glycerol jelly.

4.2 Counting

Pollen counting was carried out with a Zeiss phase contrast microscope at x400 and xl000 magnification. Palynomorphs were relatively poorly-preserved and present in low concentration throughout the profile. Grains too badly corroded for identification were counted and classified as "unidentified'. Every attempt was made to count at least 100 pollen grains or plant spores and, it was found that the concentration of *Lycopodium* spores exceeded that of palynomorphs by a factor of approximately 4. It was decided, therefore, to count all palynomorphs up to a *Lycopodium* count of 400. In this way, the relative palynomorph concentration could be demonstrated. If a count of 400 *Lycopodium* represented a spike of 13000, then a count of 100 palynomorphs represented 3250 grains cm-3.

4.3 Microscopic charcoal

The concentration of microscopic charcoal fragments was estimated subjectively. A single + represents presence, and additional ones represent increased concentration. All particles with a diameter of > 5 pm were included in the subjective assessment of abundance.

4.4 Iron Pyrite Framboids

These were counted in the same way as microscopic charcoal particles

4.5 Fungal and Algal Palynomorphs

Fungal remains (hyphae and spores) were assessed subjectively but counts were made of algae. Percentage values of algae are given in Table 2.

5. Identification and Nomenclature

Identification was aided by examination of modern reference material wherever necessary. Nomenclature follows that of Bennett *et al.* (1994), Moore *et al.* (1991), and Stace (1991). Cereal-type pollen refers to all grains >40.0 mų with annulus diameters >8.0 mų (Anderson 1979; Edwards 1989). It must be remembered, however, that the sweet grasses (Glyceria spp.) produce pollen in the same size range as some cereals, and that they could have been growing in and on the banks of Car Dyke. However, it must be stressed that the cereal-type pollen grains found in the Car Dyke sediments were exceedingly large, and it is fairly safe to assume that it was derived from cereals rather than wild grasses.

6. Expression of Palynomorph Data

Percentage data were expressed on the basis of total pollen and spores (TLP/S), excluding obligate aquatics. Aquatics and algae were expressed as percentage of self plus TLP/S. All values of <1.0% are shown as "+" in the results.

7. Results

The palaeosol results are shown in Table 1 and those from the channel sediments are shown in Table 2.

7.1 Palaeosols

The results on Table 1 show that in spite of high sampling resolution over what appeared, in the field, to be critical horizons, the palaeosols had lost their palynomorph assemblages, probably through decomposition. The palaeosol samples represent the soils prevailing near to the banks of the Dyke when the canal was constructed. The only palynomorphs found were those of Poaceae (grasses), Lactuceae (dandelion-type plants), and the ferns, *Polypodium* (polypody fern), and some fern which produced monolete spores but which could not be identified accurately. Fragments of fungal hyphae were also found sporadically.

The results probably indicate that the soils remained bioactive for some time after burial so that palynomorphs were decomposed by the resident microflora. The palynomorphs found represent taxa which are considered to be very resistant to breakdown. The data do not lend themselves to meaningful interpretation.

7.2 Channel sediments

The data in Table 2 are divided into two local pollen assemblage zones which are designated CD1 (from 340cm up to 160 cm) and CD2 (from 135 cm up to 72 cm).

7.2.1 Zone CD1: The sediments in this basal zone consisted of clays, silty clays, and intercalated peaty deposits. The basal clays (samples at 340 cm and 330 cm) were sterile of palynomorphs and probably represent deep, weathered sediments into which the canal had been cut. The samples at 300 cm contained relatively abundant palynomorphs and iron pyrite framboids were very frequent. Eroded Pinaceae (pine family) grains were quite frequent but from their state of preservation, it is likely that these had been derived from re-worked Tertiary sediments. Algal remains were sparse and wet conditions in the channel are indicated by aquatics such as

Myriophyllum spicatum (spiked water-milfoil), *M. verticillatum* (whorled water-milfoil), and *Sparganium-type* (e.g. bur-reed). Both *Myriophyllum* species are found in mesotrophic to eutrophic canals and dykes where water flow is sluggish and slow and of high alkalinity; *M. spicatum* can tolerate slightly turbid water while *M. verticillatum* can tolerate slightly brackish conditions. The high values for Cyperaceae (sedges) probably indicates the wet conditions along the edges and banks of the canal. The plants growing in and around the dyke indicate that the water was relatively shallow, might have been turbid or even slightly brackish, and was flowing very slowly or was even still.

The very high levels of iron pyrite framboids indicate that the basal sediments were intensely anaerobic and that they probably contained fermenting organic debris (see Wiltshire *et al.,* 1994). Indeed, most of the samples for the assessment in this zone were taken from the peaty sediments where organic content was relatively high. The low redox potential at the waterlsediment interface (as evidenced by the framboids) might further suggest the sluggish nature of the water flow.

The local landscape appears to have been very open and dominated by weedy grassland, possibly pasture. Arable agriculture was also important and cereal-type pollen reached a percentage of 12.7% at 300 cm. The only woody taxa recorded in the catchment were *Alnus* (alder), Corylus-type (probably hazel), and *Quercus* (oak). In spite of the high nutrient status of the flowing water, there must have been some degree of acidification of the local soils since pollen from ericaceous plants (heather and allies) and spores of *Pteridium* (bracken) were recorded. Both thrive best on acidic, oligotrophic (nutrient-poor) soils, and bracken is also intolerant of waterlogging so must have been growing in drier areas.

The sample at 265 cm was sterile of palynomorphs other than some pre-Quaternary spores, fungal remains, and iron pyrite. It is possible that sedimentation was very rapid over this part of the profile so that any pollen or spores present are too diluted to be recorded in this assessment.

The rest of the zone (from 210cm-160cm) shows a continuing similar picture for the surrounding landscape. Open water is indicated by the presence of *Lemna* (duckweed) and *Batrachium*-type *Ranunculus* (e.g. water crowfoot). However, the edges of the channel appear to have become colonised by *Apium*-type (e.g. water celery), and *Sparganium-type* (bur-reed), with Cyperaceae (sedges) and *Filipendula* (meadowsweet) also being abundant. *Typha latifolia* (greater reedmace) and *Thelypteris* (marsh fern) were also recorded. These all indicate that the water was still or very slow-flowing and that immediately adjacent soils were probably waterlogged. However, dry and acidic soils were still available locally, as evidenced by *Pteridium* (bracken) and *Calluna* (heather).

The local landscape appears to be very similar to before, being dominated by herb-rich grassland/pasture and arable agriculture. *Alnus* (alder), Corylus-type (hazel), and *Quercus* (oak) were all growing in the catchment, along with *Betula* (birch) and some *Carpinus* (hornbeam).

7.2.2. Zone CD2: Between 160 cm and 135 cm there appears to have been some marked change in the nature of the canal. The sediment changed from peaty and silty clays to a mottled clay. Microscopic charcoal was more abundant and iron pyrite was virtually absent. The lack of iron pyrite formation might be explained in terms of the reduced amounts of organic debris being incorporated into the sediment. There is little doubt that the canal still contained standing water since algae were abundant and aquatics such as *Alisma* (water plantain), *Batrachium*-type (e.g. water crowfoot), Apium-type (water celery), *Myriophyllum altemiflorum* (alternate-flowered water-milfoil), and *Sparganium*-type (e.g. bur-reed) were frequent in the sequence. Wet soils are also indicated by relatively abundant Cyperaceae (sedges), although *Filipendula* (meadowsweet) was no longer recorded. Most of the algae shown on Table 2 might be considered to be "weed" species which respond to eutrophication and periodic drying out. This could be related to an influx of nutrient-rich sediment into the canal and possible increasingly swampy conditions, at least seasonally.

Land use in the area seems to have continued in a similar way as in the earlier history of the canal, but there appears to have been more emphasis on cereals than before. Along with increased values for cereal pollen, there was the appearance and rise of taxa which might represent weeds of cultivation and disturbed ground. These include *Anthemis*-type (e.g. mayweed), Apiaceae (Many plants in the hogweed family), *Sinapis*-type (e.g. charlock), Lactuceae (dandelion-type plants), Caryophyllaceae (e.g. chickweeds), and Chenopodiaceae (goosefoot family).

Alnus, Quercus, and *Coryus*-type seem to continue to be the most important woody plants in the catchment but *Betula,* and *Pinus* were also recorded. The pollen assemblage in the sample at 110 cm seems to be a little distorted by virtue of very low concentrations of palynomorphs. It is possible that sediment/soil influx resulted in dilution of palynomorphs, although the possibility of material being brought in by short-term enhanced flow in the canal cannot be discounted.

There is a hint that the local soils were becoming increasingly acidified since *Pteridium* was more frequent and *Calluna* achieved a higher percentage at 100 cm. The presence of *Myriophyllum altemiflorum* might also suggest that the canal itself was less base-rich than previously.

8. Discussion

The chronology of the environmental changes shown in this assessment cannot be ascertained by palynological analysis alone and, in the absence of more detailed data, all interpretation here must be viewed with caution. Nevertheless, this relatively brief assessment of the canal sediments has thrown some light on the nature of the landscape after the canal was constructed as well as the variation in conditions within the canal itself.

The counts make it clear that the canal sediments do not contain sufficiently high concentrations of palynomorphs to warrant further analysis. Furthermore, the palaeosols were virtually sterile of palynomorphs, and it is possible that the soil at the site during Romano-British times was particularly nutrient-rich and bioactive; its pollen and spore load could have decomposed before any compaction by overburden (and thus reduction of free oxygen) could prevent it. The plants recorded within the canal itself certainly point to the canal water being eutrophic and alkaline for most of the period of sediment accumulation, and these conditions are certainly not conducive to preservation of biological remains.

The canal was constructed in a very open landscape dominated by mixed agriculture. Trees and shrubs were either present as isolated individuals, or were growing some distance away from the pollen site. Alder, birch, hazel, and oak were the most frequent woody plants, although there was some heather growing in the catchment, possibly invading grassland as local soils became acidified. The area surrounding the pollen site adjacent to the canal seems to have supported herb-rich grassland/pasture for the period represented by the canal sediments, although arable agriculture was being practised locally.

The nature of the canal itself changed quite noticeably between 160 cm and 135 cm and the peaty sediments gave way to mottled clays. Accompanying this pattern of sedimentation, there seems to have been slightly more intensive activity locally with microscopic charcoal being more frequent and cereal growing seeming to be more important. There might also have been some acidification of local soils. It is possible that these changes in land use were responsible for soil erosion and run-off into the canal. This would have accelerated the build-up of sediment and impeded the functionality of the water course.

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Car Dyke

Depth (cm)	72	86	100	110	135	160	170	210	265	300	330	340
Deposit-type												
mottled clay	+	+	+	+	+							
Peat						+			+	+		
Silty clay							+					
Clay											+	+
Prequaternary spores									+			
Eroded Pinaceae, possibly pre-Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1		
Ceratophyllum leaf spines	0.0	0.0	0.0	0.0	0.0	0.0	+	0.0		0.0		
Algae/Cyanabacteria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Mougeotia	0.0	+	1.3	0.0	1.1	0.0	0.0	0.0	0.0	+		
Spirogyra	0.0	0.0	+	3.8	1.6	0.0	3.1	4.3	0.0	0.0		
Botryococcus	6.5	4.5	2.5	7.7	1.6	0.0	0.0	0.0	0.0	+		
Other algae	0.0	1.3	1,9	0.0	1.6	0.0	0.0	0.0	0.0	0.0		
Trees & Shrubs												
Alnus	0.0	2.7	2.0	0.0	+	2.7	3.3	5.4		1.0		
Betula	0.0	0.0	1.4	0.0	0.0	1.8	1.6	5.4		0.0		
Carpinus	0.0	0.0	0.0	0.0	0.0	0.0	+	0.0		0.0		
Corylus-type	4.7	3.4	6.8	0.0	4.6	7.1	8.2	4.5		4.9		
Pinus	0.0	0.0	0.0	2.2	0.0	0.0	0.0	0.0		0.0		
Quercus	0.0	1.4	2.7	0.0	3.5	4.4	4.9	2.7		1.0		
Fagus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0		
Dwarf Shrub	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0		
Calluna	0.0	0.0	1.4	0.0	0.0	+	+	+		0.0		
Ericaceae indet.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.0		
Crop Plants	0.0	0.0	0.0	0.0	0.0	0.0	0.0	010		0.0		
Cereal-type	9.3	12.9	3.4	6.5	6.4	2.7	4.9	3.6		12.7		
Herbs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0		
Anthemis-type	0.0	3.4	2.0	2.2	1.7	0.0	0.0	0.0		0.0		
Apiaceae	2.3	2.7	9.5	2.2	5.8	13.3	5.7	+		2.0		
Artemisia	0.0	0.0	+	0.0	0.0	0.0	0.0	+		0.0		
Aster/Bellis-type	2.3	0.0	+	0.0	0.0	0.0	0.0	+		0.0		
Brassicaceae (Sinapis-type)	2.3	4.8	1.4	0.0	0.0	0.0	+	0.0		0.0		
Brassicaceae (Capsella-type)	0.0	+	0.0	2.2	0.0	0.0	0.0	1.8		1.0		
caryophyllaceae (Cerastium-type	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0		1.0		
Caryophyllaceae	2.3	6.1	0.0	2.2	+	0.0	0.0	0.0		0.0		
Centaurea nigra-type	0.0	0.0	0.0	0.0	0.0	+	2.5	+		0.0		
Chenopodiaceae	0.0	+	0.0	2.2	1.2	0.0	0.0	+		0.0		
Cirsium	0.0	0.0	0.0	0.0	0.0	+	+	+		0.0		
Fabaceae	0.0	+	+	0.0	0.0	0.0	+	0.0		0.0		
Galium-type	0.0	0.0	0.0	0.0	1.2	0.0	+	0.0		0.0		
Persicaria	0.0	0.0	+	0.0	0.0	0.0	0.0	0.0		0.0		
Lactuceac	11.6	2.0	6.1	10.9	4.6	+	+	0.0		8.8		
Plantago lanceolata	2.3	+	5.4	2.2	4.0	4.4	4.9	8.1		9.8		
Plantago major	0.0	0.0	0.0	0.0	1.2	0.0	0.0	+		0.0		
Plantago media	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.0		
Poaceae	20.9	21.1	23.1	34.8	19.1	30.1	27.9	35.1		30.4		
Polygonum aviculare-type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.0		
Ranunculus-type	0.0	0.0	0.0	0.0	+	0.0	+	0.0		2.9		
Rosaceae	0.0	+	0.0	0.0	0.0	0.0	0.0	0.0		0.0		
Rumex acetosa-type	0.0	0.0	0.0	0.0	0.0	0.0	+	0.0		0.0		
Rumex obtusifolius	0.0	0.0	0.0	0 -c	0.0	0.0	0.0	0.0		1.0		
Spergula-type	0.0	0.0	0.0	0.0	+	0.0	0.0	0.0		0.0		
Ferns and Allies	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0		
Equisetum	0.0	0.0	+	0.0	0.0	0.0	0.0	0.0		0.0		
Pteropsida (monolete) indet.	7.0	+	2.7	2.2	1.2	+	+	+		2.9		
Polypodium	0.0	0.0	+	0.0	0.0	0.0	0.0	0.0		0.0		
Pteridium	2.3	0.0	+	4.3	0.0	+	+	+		4.9		
Thelypteris	0.0	0.0	0.0	0.0	0.0	0.0	+	0.0		0.0		
Aquatics and Plants of Wet Soil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0		
Alisma	0.0	1.4	0.0	0.0	+	0.0	0.0	0.0		0.0		
Apiaceae (Apium-type)	0.0	0.0	0.0	0.0	+	+	+	0.0		0.0		
Cyperaceae	20.9	12.9	6.1	10.9	12.7	6.2	4.9	+		9.8		
Filipendula	0.0	0.0	0.0	0.0	0.0	1.8	1.6	3.6		0.0		
Lemna	0.0	0.0	0.0	0.0	0.0	0.0	0.0	+		0.0		
Myriophyllum alterniflorum	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0		
myriophyllum spicatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.0		
myriophyllum verticillatum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.0		
Ranunculus (Batrachiurn-type)	2.3	4.1	2.0	0.0	0.0	0.0	0.0	+		0.0		
Sparganium-type		2.3	13.6	19.0	13.0	27.2	18.6	13.9	14.4		1.0	
Typha latifolia-type	0.0	0.0	0.0	0.0	0.0	+	0.0	0.0		0.0		
Unidentified	0.0	2.0	0.0	2.2	2.3	0.0	4.9	3.6		0.0		
Pollen/spore count(excl. fungi,	43	147	147	46	173	113	122	111	0	102		

Car Dyke

Palaeosol Sample	Depth (cm)	
Sample 1	10	15 16 17 20 30 40
Sample 2	2	3 9 13 22
Sample 3	6	10 23 25 26 20
Sample 4	2	4 6 8 13 18 22

Only an occasional broken grain of Poaceae or Lac found in any of the samples. Some contained amorp organic matter and occasional fragments of hyhae. Polypodium and monolete spores were also found.

Appendix 4

PALAEOENVIRONMENTAL ANALYSIS OF MATERIAL FROM THE CAR DYKE NEAR HELPRINGHAM

by Mike Godwin

Introduction

The material examined here was extracted from the fill of the Car Dyke (Helpringham section) in auger hole 9. Samples were taken at 325-350, 300-310, 230-240, 210-220, 180-190, 140-150, 120-130, 100-110, 80-90, 60-70, and 45-55 cms from the ground surface. The sediments were treated with hydrogen peroxide (4% solution) for 24 hours to break up the material. They were then sieved through a 125 micron mesh with warm water and dried in an oven. The residues were then examined under a binocular microscope for microfauna and mineral grains.

No microfossils of indisputably Holocene age were detected throughout the section, which is thought to be entirely freshwater in character apart from one possible brackish episode which may just represent an exceptional marine flood. There was no sedimentological or mineralogical evidence for any tidal influence during the period of deposition. It was noted that fresh water molluscs were common towards the base of the sequence where they coincide with black anoxic muds.

Sediment Descriptions

The sequence of sediments here can be divided into 5 separate layers. At the base (3.58m) the material is typical of the chalky tills of Eastern England (North Sea Drift possibly). This consists of sand and gravel with chalk fragments in a fine grained matrix and is of Pleistocene age. The dyke was cut into this material, which would have also formed part of the banks.

The second layer of fill in the feature consists of a dark black organic mud with fragile freshwater molluscan shell debris. Between 325 and 350 cms some very poorly preserved foraminifera were recovered. These included some *Cibicides-like* forms and more numerous Cretaceous planktonics (cf *Hedbergelia)* which were no doubt transported to the site from the North Sea and later reworked into the deposit probably by falling from the banks of the dyke.

Around 230 cms the sediment contained abundant plant debris and numerous small anhydrite crystals with rarer gypsum also present. Some poorly preserved foraminifera were also recovered. These appeared to be specimens of *Ammonia beccarii* and *Haynesina (Protoelphidium)* and represent a typical brackish water fauna. However, it would also be possible to interpret this assemblage as a warm water Pleistocene fauna reworked into the dyke. The preservation is too poor to make specific identification possible. One interpretation of this deposit is that a marine flood introduced brackish water into the site and for a brief time a sparse foraminiferal population flourished. Subsequently the waters dried out leaving the layer of salt crystals. However, there is no evidence that the feature became completely desiccated at any point as no hard crusts appeared to have formed.

At around 2.06m there is a transition to the third layer - a dark brown, organic-rich mud with abundant fresh water molluscs including the gastropods *Planorbis and Acroloxus lacusfis.* Plant material is also abundant in this strata which continues up to 1.5m. The facies is entirely freshwater in character.

Above 1.5m there is a further transition (the boundary was obscured by the auger corer) to the fourth layer which consists of a blue/grey mud with organic streaks and iron staining. This deposit grades into the soil profile at around 33cm. The sand content of this sediment is characterised by angular, unrounded grains which have seen little transport. They are undoubtedly reworked from adjacent Pleistocene sources. The sediment also appeared to be unlaminated which suggests a lack of tidal influence. With one exception this stratum is unfossiliferous. At about 1 metre some poorly preserved *Ammomia beccarii* were encountered. These were probably derived from adjacent Pleistocene sands. Unlike the lower layers of the sequence plant debris was not abundant here which might suggest more freely flowing water in the dyke.

Conclusions

The palaeoenvironments in the dyke are in the main freshwater apart from one possible brackish flooding episode. The most distinctive feature of the sequence is a transition from anoxic black muds through dysoxic brown sediments to oxic blue/grey material. This appears to parallel a decrease in the overall organic content of the sediments and a possible increase in current velocity. These trends may be reflecting overall climate changes which occurred during the Roman Period.

Appendix 5

CAR DYKE, LINCOLNSHIRE, 1999 (CDP/99) : ASSESSMENT OF THE BURIED SOIL

by C.A.I. French

Introduction

Four series of samples were taken in monolith tins for soil micromorphological assessment, as follows (Fig 1) :

Sample monolith 1 was taken from the west facing section of the north bank. It comprised soil build-up against the bank (context 111) beneath which was a silty clay loam with irregular blocky structure buried soil profile (contexts 112 and 113) developed on the boulder clay and gravels natural. Unfortunately, this sample profile did not sample well and is quite disturbed.

Sample monolith 2 was taken from the buried soil beneath the north bank. It comprised the base of the bank (context 129) overlying the buried soil (context 122) which is a dark greyish brown, fine sandy/silty clay loam with occasional flint gravel pebbles about 16.5 to 18cm thick, developed on the boulder clay and gravels subsoil.

Sample monolith 3 was taken from the edge of the Car Dyke channel. It comprised a silty clay with gravel and chalk fragments (context 129) overlying a greyish brown sandy/silty clay loam with fine chalk fragments and gravel pebbles (context 113), accumulated on the boulder clay subsoil.

Sample monolith 4 was taken from the buried soil beneath the south bank. It comprised bank material overlying a buried soil profile (context 142 and 141) about 15cm thick which is similar to that observed in sample series 2 (above).

Preservation and importance

Sample monolith 1 is too poorly preserved to deserve processing and sample monolith 3 appears to be ditch edge-effect and fill material, and therefore also should not be processed.

In contrast, the buried soil profiles sampled in monoliths 2 and 4 appear to be similar and well sealed by bank material. In my experience of examining other section lengths through the Car Dyke in the Peterborough and Cambridge regions, this is the first occurrence of buried soil preservation associated with this monument to have been discovered and sampled. For this reason alone, it is worthy of full analysis because of this good preservation.

In addition, soil development and land-use on the fen-edge of Lincolnshire have rarely been studied for the pre-Roman/early Roman period, with most sites already investigated tending to be either of earlier or later periods (ie. Deeping St Nicholas site 28 (French 1994) and Parsons Drove (French 2001).

Recommendations

It is suggested that sample profiles 2 and 4 be processed and analysed using thin section techniques (after Murphy 1986 and Courty *et al* 1989). This should provide evidence of the pre-Car Dyke soil type, whether there is any associated soil truncation, and possibly some ideas on pre-Car Dyke land-use on this part of the Lincolnshire fen-edge.

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Appendix 6

THE LINCOLNSHIRE CAR DYKE PHASE 1: ASSESSMENT OF THE POTENTIAL FOR LUMINESCENCE DATING OF AN ANCIENT WATERCOURSE

Dr. J.-L. Schwenninger

Introduction

This report presents the initial test results associated with Phase 1 of the luminescence dating programme of the Helpringham section of the Car Dyke as outlined in Section 8.6.3 of the Project Design elaborated by Archaeological Project Services (APS) and following consultation and approval by English Heritage.

The assessment of the potential for optically stimulated luminescence dating (OSL) reveals that the sample collected from the bank of the dyke appears to have retained its geological age and is not suitable for determining the construction date of this ancient watercourse. However, mineral grains extracted from the basal part of the alluvial fill seem to have been sufficiently exposed to daylight during their transport and consequently, may be dated by OSL.

Optical Dating: An introductory note

Luminescence dating is based on the measurement of signals that accumulate in minerals as a result of natural ionising radiation (Huntley *et al.* 1985). The signals grow as a function of time and environmental radiation, and therefore can be used to estimate the time elapsed since the mineral grew or underwent an event of signal resetting. Quartz is an excellent natural dosimeter (Huntley *et al.* 1985; Aitken 1990, 1998; Rhodes 1990), which can be reset by light and does not undergo decay over time. In recent years, it has been extensively used for dating aeolian, alluvial, glacial and archaeological sediments (Gilbertson *et al.* 1999).

In order to obtain luminescence age estimates one needs to determine the accumulated radiation dose or palaeodose to which a sample has been exposed since the event that is being dated, and the rate at which it has been exposed to radiation during this time, also referred to as the annual radiation dose at the sampling location. The latter may be calculated from *in situ* gamma spectrometer measurements or the concentrations of uranium, thorium and potassium as determined by Instrumental Neutron Activation Analysis (INAA) of a sub-sample. Dividing the first value by the latter gives the age of the sample. Attenuation factors associated with the water content and the depth of burial of the sediment must also be considered. Further information regarding luminescence dating techniques may be found in Aitken (1985, 1990, 1998) and recent general reviews of the use of luminescence dating in archaeology have been given by Feathers (1997) and Roberts (1997).

Sample collection and sampling strategy

The fieldwork took place on the 13th and 22d of July 1999♦. In addition to collecting samples, *in-situ* dosimetry measurements were taken using a portable gamma spectrometer at accessible sampling locations within the trenches of the northern and southern banks.

In accordance with the proposed sampling strategy, near replicate samples were collected from the dyke's bank (samples A1 and A2) as well as the alluvial sequence of the channel (samples B1 and B2). For research purposes, additional samples (C1 to C8) were retained. These were not directly related to the brief of this project, which was primarily concerned with the direct dating of the construction of the Car Dyke. Instead, this supplementary series of samples were considered to be of purely scientific interest within the wider context of the local archaeology and the application of OSL to the dating of man-made features.

A list of all samples and details regarding their appropriate codes, lithostratigraphic origins and archaeological contexts is given in Table 1. The precise location of each sample is further indicated in Figure 1.

♦ A further day of fieldwork became necessary due to equipment failure of the engine powered percussion gouge during the first site visit.

Lab. code	Field code	Location	Depth cm	Context	Sample type	Lithology	Moisture content %
A1	A1	North Trench	70-75	120	Large OSL	Sand lens within bank	undetermined
A2	**A2**	**North Trench**	**95-100**	**120**	**Large OSL**	**Sand lens within bank**	**6**
B1	**B9-6**	**Borehole 9**	**390-394**	**107?**	**Small OSL**	**Silty sand**	**29**
B2	B9-5	Borehole 9	377-380	107?	Small OSL	Silty sand	
C1	C1	North Trench	100-105	?	Large OSL	Sand below buried soil	undetermined
C2	A3	South Trench	130-135	152	Large OSL	Sand lens above buried soil	undetermined
C3	B9-1	Borehole 9	87-97	099	Medium OSL	Clay	undetermined
C4	B9-2	Borehole 9	282-292	104	Small OSL	Organic clay	undetermined
C5	B9-8	Borehole 9	318-320	105	Wood for ^{14}C	Organic clay	undetermined
C6	B9-7	Borehole 9	340-345	107?	Small OSL	Sandy silty clay	undetermined
C7	B9-3	Borehole 9	350-355	107?	Small OSL	Sandy silty clay	undetermined
C8	B9-4	Borehole 9	355-360	107?	Small OSL	Sandy silty clay	34

Table 1 List of samples and corresponding details. Samples highlighted in bold characters were processed and measured for OSL during this phase 1 investigation.

The two samples which were considered to be most suitable for OSL dating were samples A2 and B1, with near replicates A1 and B2, being kept as back-ups in the case of paucity of suitable mineral material for dating and to safeguard against any inadvertent exposure and failures that may occur during subsequent transport, storage and laboratory treatment.

Samples A1 and A2 were collected in large OSL sampling tubes from the excavated northern bank of the dyke. They were intentionally located in one of several sedimentary units containing higher proportions of sand in order to maximise the amounts of quartz mineral material required for coarse grain dating (e.g. 90-180 microns). Furthermore, it was expected that if any daylight 'bleaching' (e.g. resetting or zeroing of the OSL clock) had occurred during the building process, then the chances of this happening would be highest with loose and coarse textured sediments such as sand rather than silts and clays which tend to aggregate and form lumps during excavation. With the exception of the mineral grains located on the outside of such lumps, the majority of them would have escaped exposure to daylight and hence, would have retained their original geological or depositional age.

Samples B1 and B2 are derived from a thin silty sand unit at the very base of the alluvial fill and originate from one of four replicate boreholes located in the central part of the channel (borehole 9). They were directly sub-sampled in the field from a narrow open sided gouge using small OSL tubes. With a diameter of only 5 cm, the latter offered substantially less sampling material than could have been obtained from the use of the anticipated 10 cm wide gouge. The very small quantity of mineral material (*circa* 10-15cm^3) implied extreme caution in sample preparation and imposed restrictions on the amount of aliquots that could be prepared for OSL measurements.

Sample preparation and measurement procedure

Samples were air-dried and their water content was determined in order to account for appropriate attenuation factors. The 125-180 µm size fraction was treated with dilute 10% hydrochloric acid for 5 minutes in order to remove any calcium carbonate. This was followed by treatment with concentrated hydrofluoric acid for 40 minutes to eliminate organic material and plagioclase. This acid treatment also served to remove the alpha-irradiated outer 20 µm layer of quartz grains. The material was then briefly treated with diluted 10% hydrochloric acid to remove potentially neo-formed fluorite crystals and thoroughly rinsed in distilled water. The separation of quartz grains from feldspars and heavy minerals was achieved by heavy liquid separation using sodium polytungstate at specific gravities of 2.62 g cm^{-3} and 2.68 g cm^{-3} at a room temperature of 20 °C. These steps were followed by renewed multiple washing in distilled water and a final rinse with acetone. For measurement, the grains were deposited in dry form as a monolayer on aluminium discs (10 mm diameter, 0.5 mm thick) using viscous silicone oil.

Measurements were carried out at the Luminescence Laboratory of the Department of Geography at Royal Holloway, using an automated OSL/TL RisoØ unit equipped with a calibrated ^{90}SR β-radiation source and fitted with a combined blue light and infrared OSL excitation attachment operating at a current of 18 mA (BØtter-Jensen and Duller 1992, BØtter-Jensen 1997). The stimulation spectrum emitted from the filtered array of 30 blue diodes (type Nichia NSPB500S, filtered through 3 mm SCHOTT GG420 and operated at a current of 18 mA) was 470 nm and the power delivered to 1 cm^2 was 15 mW at 20 mA. A detection emission filter pack consisting of 7.5 mm of HOYA U-340 was placed in front of the photomultiplier tube to suppress the scattered excitation light. The emitted wavelength of the infrared diodes (TSHA6203) was 875 nm, providing a nominal power of 21 mA per 1 cm^2 at a maximum current of 100mA. To prevent internal heating and wavelength shift, the current to the IR-diodes was pre-adjusted to 30 mA.

The procedure adopted in this initial assessment stage was based on a standard multiple aliquot and additive dose procedure using both, short shine natural light and dose normalisation techniques. The OSL intensity measurements were integrated over the full 25 second time span of the blue light stimulation period. Final age determinations scheduled for Phase 2 should be based upon a single aliquot regeneration protocol (Murray and Wintle *in press*), in which all the measurements necessary for palaeodose determination are made on a single sub-sample, following initial laboratory tests and estimates of the age of the sample. This latter method offers the significant advantage of the small amount of sample that is required, the increased precision associated with the lack of a requirement for normalisation between aliquots and the use of an improved linear as opposed to exponential fitting procedure.

Prior to the OSL measurement, each sample was checked for feldspar contamination in the form of single grains or mineral inclusions during a 25 second stimulation period with infrared light.

Results and discussion

No unusual levels of infrared counts were detected above normal background noise for any of the measured aliquots. This confirms adequate sample pre-treatment and enables to dismiss any risk of undesired luminescence contribution from potential feldspar contaminants. The results for samples A2 and B1 are presented in Figures 2 to 5. For both samples, the non-normalised and natural normalised data is provided in the form of scatter plots.

In the case of sample A2, there appears to be no significant increase in OSL intensity with added dose (Figures 2 and 3). This suggests that the sample is either extremely insensitive to low and moderate radiation levels (1 to 20 Gy) and consequently, may not be suitable for dating young sedimentary events or more likely, that the trapped charge population has become saturated as a result of its 'old' age and/or its exposure to exceptionally high ambiental radiation levels. The most likely explanation seems to be that the sample has retained its geological age and almost certainly, does not appear to have been reset within the late prehistoric or early historic periods.

The failure to obtain a luminescence date from this particular sample collected from the bank of the dyke should not discourage future attempts at dating similar types of disturbed sediments from man made features. The requirements for successful OSL dating imply a brief exposure of several seconds to natural daylight. Depending on factors such as the nature of the substrate, the time of the day as well as the excavation and construction techniques employed at the time, the chances for adequate bleaching of displaced earth may vary considerably. Furthermore, for such types of deposit, a great deal of intra-site variability in the degree of bleaching may also be expected, even over very short distances.

Certain pockets of sediments related to former single scoops, spade loads or bucket contents may display OSL characteristics associated with fully bleached, partially bleached or unbleached mineral material. Although in theory, the sampling of a sandy sedimentary unit should have favoured the chances of successful bleaching, there can be no guarantee that this would have been the case. It is possible that the measurement of multiple samples across the bank could reveal at least one suitably bleached sample capable of providing a date for the construction of the dyke.

Sample B1 collected from the base of the alluvial clay sequence shows increasing luminescence intensity following incremental exposure to artificial beta irradiation (Figures 4 and 5). The growth curve characteristics of the normalised OSL data indicates a palaeodose in the region of 10 Gy (Figure 5). A reliable age determination will have to await the determination of the annual dose rate by neutron activation analysis of a sediment sub-sample during phase 2 of the luminescence project. However, the extrapolated palaeodose appears much too high to provide a late Holocene date as may be expected in the case of a construction date contemporary with the Iron Age, Roman or Medieval periods.

The initial assessment of sample B1 thus seems to indicate that the base of the channel is likely to be of early Holocene age. This prompts the suggestion that the construction of the dyke may have involved the modification of a pre-existing natural watercourse.

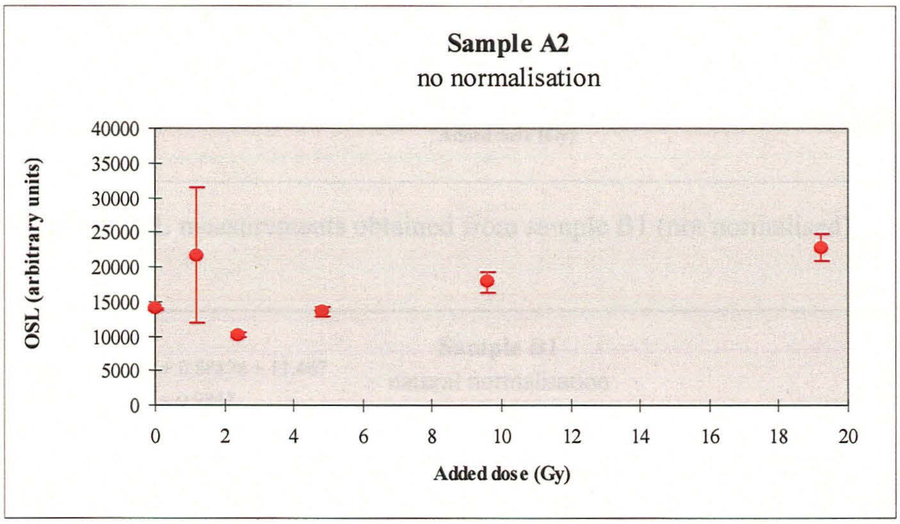

Figure 2 OSL measurements obtained from sample A2 (not normalised).

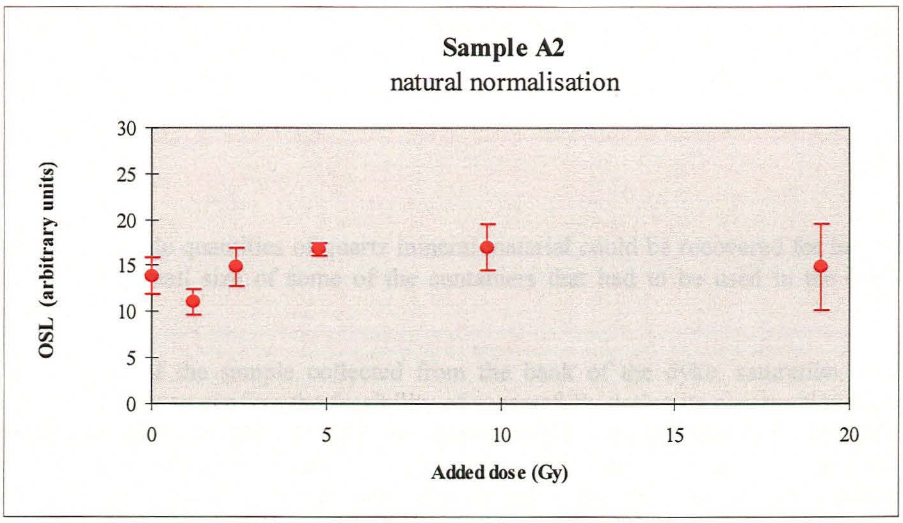

Figure 3 Normalised OSL measurements obtained from sample A2.

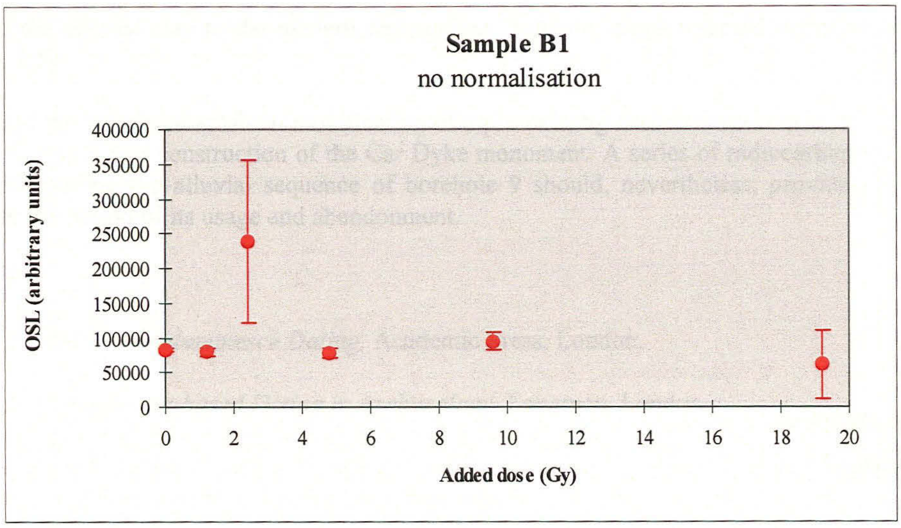

Figure 4 OSL measurements obtained from sample B1 (not normalised).

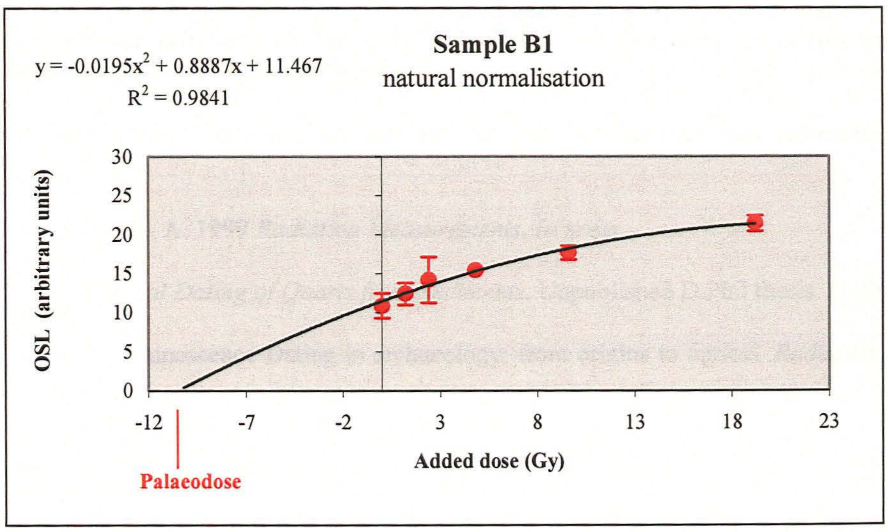

Figure 5 Normalised OSL measurements obtained from sample B1.

Conclusion

For both samples, suitable quantities of quartz mineral material could be recovered for luminescence dating and this, despite the very small size of some of the containers that had to be used in the sub-sampling from the percussion gouge.

However, in the case of the sample collected from the bank of the dyke, saturation of the trapped charge population did not enable to confirm the feasibility of successfully dating its construction by optically stimulated luminescence. Although the preparation of more samples could in theory, lead to the identification of a suitably bleached pocket of material, the practical and economic implications seem too exhaustive to justify further investigations in this direction. This may best be achieved in the wider context of a future research oriented project centered on the application of OSL dating to artificially disturbed sediments, man made features and monuments.

The final age determination of sample B1 from the basal fill could be of interest. However, it will almost certainly not provide a construction date for the dyke but instead, an early date of natural alluviation within the channel. Some comfort may be found in the knowledge that despite initial fears regarding the potential paucity of material for radiocarbon dating and hence, the justification of OSL as a 'back-up' dating technique, the sedimentary sequence from borehole 9 revealed a series of peat and organic clay horizons extending almost from the base of the alluvial clay to the modern day surface. Suitable samples should therefore be available for ^{14}C dating (e.g. C5).

Again, due to the stipulated artificial modification of a pre-existing natural watercourse, it may prove difficult to accurately fix the actual construction of the Car Dyke monument. A series of radiocarbon dates and/or OSL age determinations along the alluvial sequence of borehole 9 should, nevertheless, provide a good chronological control over the period of its usage and abandonment.

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