Environmental Archaeology

Appendix 1 – Case Studies

Summary

This document is part of a suite of documents about environmental archaeology practice. It is an appendix to the main text: Environmental Archaeology: A Guide to the Theory and Practice of Methods, from Sampling and Recovery to Post-excavation (third edition), and should be read in conjunction with that document. It contains nine case studies which provide additional detail and context to the advice given in the main text. Additional methodological detail and technical advice is provided in Appendix 2 – Commonly studied biological remains: preservation, recovery and significance.

This guidance note has been prepared by Don O'Meara (Historic England), Gill Campbell (Historic England) and Lisa Moffett (Historic England).
This edition published by Historic England December 2025.

Please refer to this document as:
Historic England **2025** *Environmental Archaeology. Appendix 1 - Case Studies*. (Historic England, Swindon).

HistoricEngland.org.uk/

Front cover: Flower heads of knapweed from within the Pewsey hoard

Contents

Case Study 1

Environmental sampling on archaeological watching briefs

Don O'Meara (Historic England) and David Jackson (Wardell Armstrong Archaeology)

During an archaeological watching brief for the installation of a utilities pipe north-east of Carlisle, Cumbria, a series of pits and a larger structure were observed. These were archaeologically cleaned and prepared for recording. The presence of fired daub suggested the larger structure might be a corn-drying oven or kiln (Figure 1). The archaeological investigation included the collection of flotation samples from the features. The presence of Roman pottery and the proximity of Hadrian's Wall to the north initially suggested this was a Roman structure.

Figure 1: Fired clay showing wattle impressions from the structure of the corn drying oven.
© Wardell Armstrong Archaeology

Sixteen samples were taken comprising 265 litres of sediment, with the samples ranging from 5 to 40 litres, and all the sampled sediment was processed to ensure maximum recovery of charred plant remains. The samples produced low numbers of wheat, rye and barley grains, as well as over 2,000 oat grains (mainly from what was now evidently a corn drying oven). Although the identified artefacts were all Roman, an archaeobotanical assemblage of this nature would more typically be found in a medieval context in this region. A radiocarbon date from the oat grains was sought, and produced a date of AD 1033–1207. The results of this investigation were later published in a local archaeological journal (Jackson et al. 2015).

The environmental samples from this project:

- confirmed the use of the structure as a corn-drying oven;
- suggested an alternative date to the one suggested by the initial artefactual evidence;
- provided the material for the radiocarbon date to confirm the medieval date for the remains.

It was important for this project that the client was briefed about the possibility that environmental samples could be taken as part of the fieldwork, and an agreement on the costs of analysis and possible radiocarbon dates was clear. Publication in a local journal also meant that the results of the project were disseminated as an open-access article, ensuring they can inform future projects and research.

Further reading

Jackson, D., O'Meara, D., and Stoakley, M. 2015 'Land at Low Crosby, Cumbria: results of an archaeological watching brief', *Transactions of the Cumberland and Westmoreland Antiquarian and Archaeological Society*, 15, 29–44. https://doi.org/10.5284/1084819.

Case Study 2

Creating project-specific written schemes of investigation

Don O'Meara (Historic England) and Jim MacQueen (BWB Consulting)

Iron Age sites in the lowlands of North East England are characterised by concentrations of circular ring-gully features, often surrounded by deeper enclosure ditches and shallow linear features. The nature of these remains means research is often best advanced by stripping large areas of ground, an activity that in North East England is commonly associated with house building or surface mining. The study of these sites was greatly advanced by the advent of Planning Policy Guidance 16: Archaeology and Planning (PPG16) in 1990, and by later iterations of local government planning.

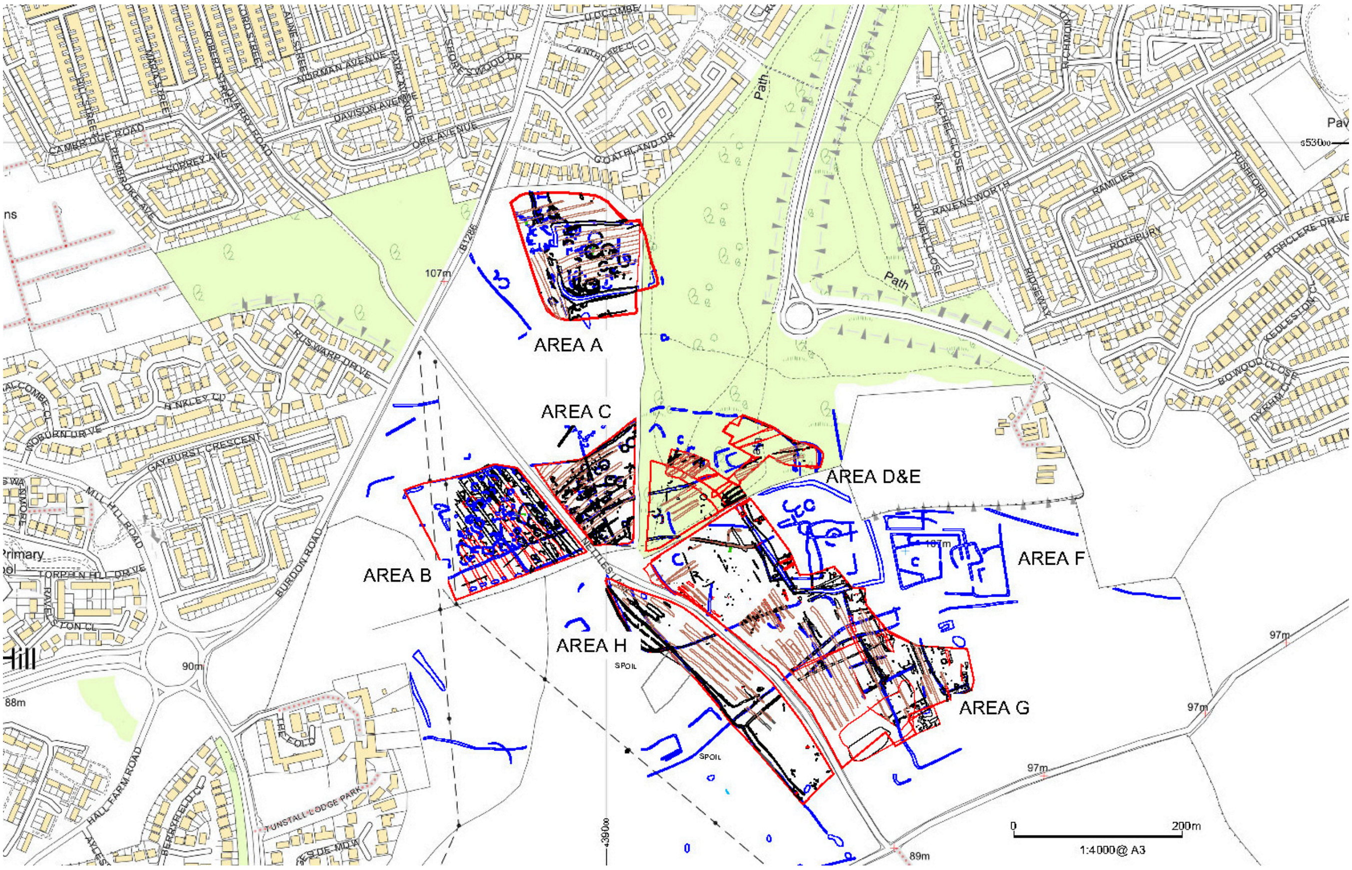


Figure 2: Interpretation of the geophysical survey showing a typical Iron Age settlement of the Northumberland coastal plain. © BWB Consulting

An understanding of the chronological phasing of these sites was developed through the 1990s, and then by archaeological work in advance of mining and house-building activity north of Newcastle from 2002 to 2008 (Hodgson et al. 2012; as well as subsequent publications, particularly in the local journal *Archaeologia Aeliana*). However, although an understanding of the nature and form of these settlements has been developed from the 1990s, the sites are typically artefact poor. Pottery assemblages tend to be small, and of a type that is poorly diagnostic, and metalwork of any kind is rare. The evidence from environmental archaeology also tends to be comparatively poor, with low densities of charred plant remains and poor bone survival, the latter as a result of the acidic, free-draining soils.

In 2017 archaeological remains were revealed by geophysical survey during the preconstruction work for a housing development at Burdon Lane, Ryhope, Tyne and Wear (Figure 2). The form of the features revealed them to be typical of the Iron Age in North East England. Discussions between the archaeological consultant for the developer, the local authority archaeologist from Tyne and Wear Archaeology, and the Historic England Science Advisor, focused on creating a site-specific written scheme of investigation (WSI) to address the regional research framework for this site type and also acknowledge the limitations of sites of this nature based on the experience of other projects.

In 2020, during the preparation of the WSI, the stakeholders had access to a geophysical survey and an evaluation report. Using these documents and a broader knowledge of comparable sites, the premise of the WSI was:

- deposits were expected to be well drained and acidic in nature;
- the types of biological remains and artefacts present would be similar to other comparable sites in the region;
- material suitable for radiocarbon dating would not be present in all contexts;
- the broad pattern of settlement seen in comparable sites (with a distinct settlement morphology between the early, middle and late Iron Age) would be applicable.

On this basis the WSI focused on:

- accepting that bone preservation would likely be poor and mainly restricted to loose teeth;
- preservation of plant material would largely be in the form of charred remains;
- the dating of the site needed to be placed within a Bayesian framework, and should not be wholly reliant on radiocarbon dating of charred plant remains.

The WSI did not focus on sampling every context with a 40–60 litre flotation sample, as enough data was available from other sites in the region to show this was not productive. Instead, the sampling and recovery strategy focused on:

- sampling the termini of ring gullies, pits and hearths associated with the roundhouses, and primary fills of enclosure ditch termini;
- taking optically stimulated luminescence (OSL) samples from all enclosure ditches and retaining these for consideration at the post-excavation stage, when an updated project design would be prepared;
- committing to the utilisation of stable isotope analysis for the charred cereal grains and organic residue analysis for the pottery with the aim of advancing regional agendas for the Iron Age.

This sampling and recovery strategy focused resources on areas of the site that were thought likely to be the most productive based on past experience of directly comparable sites in the region. At the same time, it used techniques that would develop understanding of this site type overall. It was flexible enough to allow for unexpected scenarios (such as the presence of waterlogged preservation at the base of deeper ditches, unexpected preservation of deposits of animal bone, or human burials from any period), but also created an agreed hierarchy of sampling for typical contexts.

Regionally the project aimed to build upon previous work and to encourage the use of novel approaches and techniques. Importantly, it was appreciated that this form of prehistoric settlement is relatively commonly encountered in the region, and that future projects would be able to further refine and adapt the approach taken at Burdon Lane.

Further reading

Hodgson, N., McKelvey, J., and Muncaster, W. 2012 *The Iron Age of the Northumberland Coastal Plain*. Tyne and Wear Archives and Museums Archaeological Monograph.

Case Study 3

Environmental archaeology and metal finds: the Pewsey hoard

Ruth Pelling (Historic England)

A late Roman copper alloy vessel hoard found by metal detectorists in the Vale of Pewsey, Wiltshire, contained exceptionally well-preserved plant remains, enabling the reconstruction of the packing and burial history of the hoard. The hoard consisted of a series of stacked and covered bowls and cauldrons, with four pan scales in the interior. Leaves, stems and flower heads were clearly visible within the interior of the hoard. The sediment within and between the vessels was sieved and sorted for macroscopic plant remains, and samples were carefully scraped from the corrosion salts on the surfaces of the various vessels for the analysis of microscopic remains (pollen and fern spores).

Metal corrosion salts can impregnate organic material in contact with corroding metal and act as a natural biocide inhibiting attack by micro-organisms and fungi in the soil. While textile or plant fibres are often seen within surface corrosion on copper alloy or iron objects, a void within the interior of the Pewsey hoard resulted in the preservation of loose plant material. Flowers, seeds, stem and leaf fragments were completely desiccated, some of which were encrusted with green, blue-grey or grey to white metallic deposits (Figure 3). X-ray fluorescence (XRF) examination detected both lead and copper. Enough carbon was preserved in one flower head and some stems to enable radiocarbon determinations.

Pollen, spores and macrofossils from the interior of the hoard indicated that it was most likely packed in mid-late summer, using bracken and grassland vegetation to wrap the pan scales, and buried by early autumn. The grassland exploited was likely to have been long-established, with betony (*Betonica officinalis*), devil's bit scabious (*Succisa pratensis*; represented only by pollen) and vetches (*Vicia* species) present. Knapweed (*Centaurea* species) and bracken (*Pteridium* species) were the best represented of the larger plant items, but only occurred in low proportions in the pollen/spore samples. The plant remains recovered from the vessels represented a mixture of habitats, with plants indicative of calcareous grassland, arable fields, woodland edge and heath, the latter possibly representing more acidic soils. Modern, uncharred cereal remains in the outer vessel, a cauldron, are likely intrusive material from the contemporary arable environment from which the hoard was recovered.

Figure 3: Flower heads of knapweed (*Centaurea nigra*), from within the Pewsey hoard.

While the preservation of flower heads and bracken fronds was exceptional, it was the combination of archaeological methods, including pollen analysis and macrofossil analysis, and radiocarbon dating, that enabled such a detail reconstruction. Importantly, no treatment or cleaning of the vessel had been conducted prior to its submission to the Portable Antiquities Scheme, and the scientists involved were able to sample the vessels and accompanying sediment together (Henry et al. 2019).

Further reading

Henry, R., Roberts, D., Grant, M., Pelling, R., and Marshall, P. 2019 'A contextual analysis of the late Roman Pewsey and Wilcot vessel hoards, Wiltshire', *Britannia*, 50, 149–84. https://doi.org/10.1017/S0068113X19000266.

Case Study 4

Sampling for charred plant remains: the importance of considering context type and the archaeological period being investigated

Gill Campbell (Historic England)

The size of sample needed to ensure the recovery of sufficient numbers of plant remains for meaningful interpretation is a subject of considerable importance from the point of view of science and for resource allocation.

Table 1 shows the average and range of number of items per litre in samples analysed for charred plant remains other than charcoal in southern England, broken down by broad chronological period. It is based on research undertaken in 2001. It is immediately apparent that the concentration of plant remains in Neolithic, Bronze Age and early medieval contexts is very low.

The high concentration of plant remains reflected in the maximum of the ranges given in Table 1 is largely attributable to deposits of pure burned grain or crop processing debris found as primary deposits, such as in corn drying ovens and deep pits. This is not typical of the kinds of remains recovered from most sites. These large deposits of grain, which are easily spotted during excavation, were also the only samples examined in the early days of archaeobotany before sieving and sampling programmes became established techniques.

Table 1: Concentration of charred plant remains in samples from southern England, comprising results from the following counties: Kent, East Sussex, West Sussex, Surrey, Berkshire, Oxfordshire, Hampshire and the Isle of Wight, Wiltshire, Dorset, Somerset, Devon, Cornwall and the Isles of Scilly

Concentration of charred plant remains in samples expressed as items per litre from sites of different periods		
	mean average	**range**
Neolithic to Early Bronze Age	0.7	0.1–23
Middle Bronze Age	8.89	0.07–1751.6
Iron Age	502.96	0.03–11580
Roman	765.04	0.03–5475.2
early medieval	8.95	0.1–51.27
medieval	73.07	0.03–756

Using the figures given in Table 1, where the mean average concentration of charred plant remains is just under nine items per litre for Middle Bronze Age and early medieval sites, a 40-litre sample will recover between 200 and 360 items and a 60-litre sample between 300 and 540 items, assuming an even distribution of remains (see Figure 5 in the core text of this guidance). About 400–540 items are needed to undertake statistical analysis of the remains, while 200 items might be sufficient to characterise an assemblage where the diversity is low (Veen 1985). Thus, if the aim of the analysis is to understand the crop processing activities that are taking place on site, samples of 50–60 litres will be needed. Alternatively, if the aim of the project is to obtain an understanding of the crops used at a site during different periods of occupation, then smaller samples of 40 litres may suffice.

The figures given in Table 1 to do take account of regional variation, for instance the number of plant remains recovered from sites in northern England are typically lower. Differences in geology as well as the depth and type of feature excavated, and the rate of burial will all contribute to the survival or loss of charred plant remains.

Context type can have considerable effect both on the types of plant remains recovered and on the concentration and preservation of the material. In southern England contexts associated with Bronze Age houses would appear to be especially important as a source of Middle and Late Bronze Age charred plant remains. At some sites the postholes of these buildings have produced the greatest concentration of material, as for example at Potterne, Wiltshire (Straker 2000) and at Grange Road, Gosport, Hampshire (Letts 1995). Furthermore, assemblages from postholes have provided evidence that contrasts with evidence derived from other features. At Rowden, the postholes provided the only evidence for the cultivation of wheat at the site (Carruthers 1991), while at Weir Bank Stud Farm, Bray, Berkshire, postholes associated with a round house contained large numbers of flax seeds (Clapham 1995). There was only a single seed recovered from the other features sampled at this site. Therefore, while the taphonomy of material recovered from postholes makes interpretation difficult, it provides an important source of evidence (Vilsteren 1984). Pits from settlements of Middle Bronze Age date at Rowden, Dorset and Black Patch have also produced large assemblages. However, at both these sites the pits were located inside buildings (Hinton 1982).

The fills of Iron Age storage pits have proved a rich source of material. For example, a sample from a pit at Hascombe, Surrey did not require flotation because it consisted of almost pure charred plant remains, and produced more than 9,000 identifiable charred plant items per litre of soil. The large assemblages recovered from Iron Age pits in some areas might have resulted in a tendency to concentrate sampling efforts on these features, especially where funds and or time is limited. However, the evidence recovered from pits may be very different from that recovered from other features. For example, at Tollard Royal, Wiltshire the pits produced mostly wheat, while the ‘granary’ postholes contained mainly barley (Evans and Bowman 1968). This emphasises how essential it is to sample the range of contexts at a site in order to address questions concerning crop husbandry and plant use.

Further reading

Carruthers W.J. 1991 The carbonised plant remains from Rowden, in Woodward, P.J. The South Dorset Ridgeway Survey and Excavations 1977–84. *Dorset Nat Hist Archaeol Soc Monograph 8*, 106–11.

Clapham, A.J. 1995 Plant remains, in Barnes, I., Boisnier, W.A., Cleal, R.M.J., Fitzpatrick, A.P. and Roberts, M.R. *Early Settlement in Berkshire: Mesolithic–Roman Occupation Sites in the Thames and Kennet Valleys*. Wessex Archaeology Reports 6, 35–45.

Evans, A.M. and Bowman, A. 1968 Appendix II: Report on the carbonised grains from Tollard Royal, Berwick Downs, Wiltshire, in Wainwright, G.J. et al. The excavation of a Durotrigian farmstead near Tollard Royal in Cranborne Chase, Southern England. *Proceedings of the Prehistoric Society* 34, 102–47.

Hinton, P. 1982 Carbonised seeds, in Drewitt, P. Later Bronze Age downland economy and excavations at Black Patch, East Sussex. *Proceedings of the Prehistoric Society* 48, 321–400; 382–90

Letts, J.B. 1995 Carbonised plant remains, in Hall, M. and Ford, S., Archaeological excavations at Grange Road, Gosport, Proc Hampsh Field Club Archaeol Soc, 50, 30–1

Straker, V 2000 'Charred plant macrofossils', in Lawson, A J (ed) Potterne 1982–5: Animal Husbandry in Prehistoric Wiltshire. Wessex Archaeology Reports 17, 84–91

Veen, M van der 1985 'Carbonised seeds, sample size and on-site sampling', in Fieller, N.R.J., Gilbertson, D.D., and Ralph, N.G.A. (eds) Palaeoenvironmental Investigations: Research Design, Methods and Data Analysis . BAR, Int Ser 258, Oxford, 165–78

Vilsteren, V.T. van 1984 The medieval village of Dommelen: a case study for the interpretation of charred plant remains from postholes, in van Zeist , W. and Casparie, W.A. (eds) *Plants and Ancient Man*. Rotterdam, A.A. Balkema, 227–36

Case Study 5

Consequences of not assessing all the samples taken for the recovery of charred plant remains

Jacqui Huntley (independent researcher, retired Historic England Science Advisor)

The following case study demonstrates the importance of assessing all of the samples taken and the different interpretation made when only about a quarter, in this case, was initially assessed. Excavations along the Walshford to Dishforth section of the A1 in North Yorkshire were undertaken by Northern Archaeological Associates in advance of road widening. A series of pits, mostly shallow and irregular, was present over much of the area excavated and contained considerable quantities of Neolithic pottery with various types recorded. 110 samples were collected from these pits, ranging in volume from 6 to 28 litres. It was known from the outset that full analysis of processed material would be undertaken.

The excavators chose 30 samples for initial assessment. Consultation with the author made it possible to estimate the approximate time and cost for full analysis. It became clear that cereal grains, both barley (*Hordeum* sp.) and wheat (*Triticum* sp.), were present in six of them. Wild fruits, nuts and tubers were more common, being recorded as present in 21 samples, although, with one exception, not in huge numbers. The exception had been selected by the excavators because it had obvious and abundant charred material in it – later determined as apple or pear (*Malus/Pyrus*) pips and fruit, and hazel (*Corylus*) nutshell. The other samples were typical 'brown silty fills with occasional flecks of charcoal', and had been selected from across the total area of excavation. Even at this stage, it was clear that the charred plant remains constituted a significant assemblage of Neolithic material for the north of England. The case, therefore, was made to process all of the remaining material.

Full processing and analysis of all 110 samples were therefore undertaken and this produced some rich assemblages that were not recognised (i.e. visible) during excavation. One of these contained more than a thousand grains of barley (*Hordeum* sp.) and was interpreted as a storage pit. Discussion of spatial patterning of the remains was also possible. This suggested that the cereals were more common in the central area and that wild fruits and, especially tubers, were more evident in the northern end. Radiocarbon dating of material was recommended to see if this reflected different periods of activity.

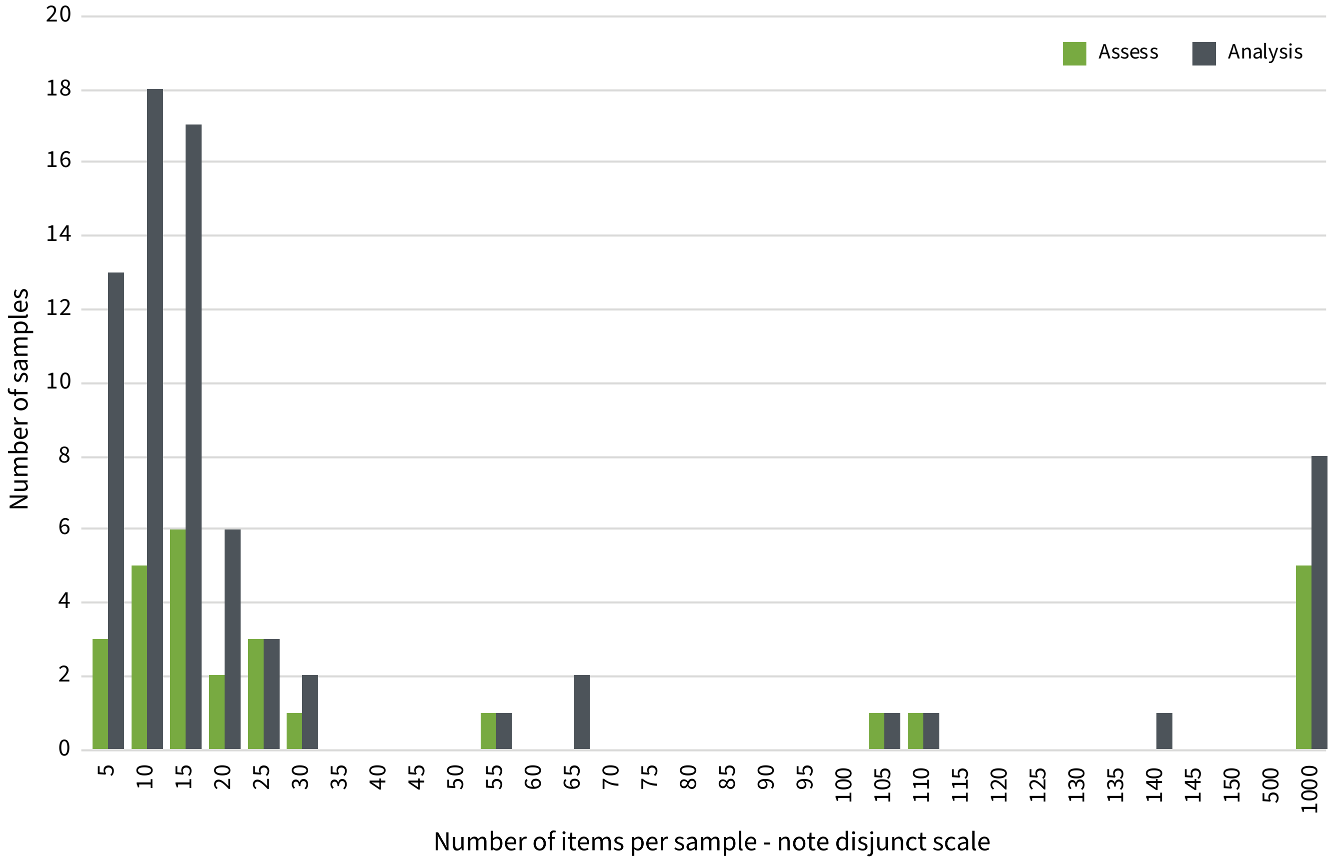


Figure 4: Comparison of samples chosen for assessment with the total dataset.

In terms of effectiveness, the choice of samples for assessment moderately reflected the range of concentrations present in the total dataset, although, importantly, this choice missed some of the samples with the richest assemblages (Figure 4). This selectiveness was not an issue in the current situation, as it was known that full analysis would go ahead. It would, however, have been more problematic if this had not been the case, as the overall interpretation would have been that a few samples contained the occasional cereal grain or chaff fragments with no indication that storage of grain was a distinct possibility for the site as a whole. The conclusion could have been that emmer wheat (*Triticum dicoccum*) and barley were in use on the site, but that cereal cultivation was only a minor component of the economy.

The situation with regard to hazel nutshell and apple remains is slightly different in that the one pit was clearly full of something when excavated and therefore it was chosen for assessment. Four other samples contained large numbers of one or other of these remains, but the majority produced up to 10 fragments, thus probably representing nothing more than casual disposal. Onion couch tubers (*Arrhenatherum elatius*), interestingly, were principally recovered from the initial assessment samples with only one occurrence in the 'only analysed' group. Other fruit remains were scattered across the samples in low numbers – 31 items in total. Spatial patterning could not have been discussed in this case.

The other taxa, from weeds and grassland plants predominantly, were considerably more common in the ‘only analysed’ samples, although never especially abundant (total = 98). They certainly gave some indication of local habitats, which would have been impossible from the assessment samples, from which only three items were present (one *Bromus* and two indeterminate seeds).

Thus for this site, where hindsight is possible, it is clear that only a small part of the picture emerged when about a quarter of the samples taken were assessed. In addition, the recommendations resulting from this assessment may well have been for no further work. The case for analysis would have been difficult to justify. This would have resulted in almost three quarters of the samples being discarded without any appraisal, which begs the question, why had they been collected in the first place.

Case Study 6

Multidisciplinary sampling in the intertidal zone at Goldcliff East, Gwent Levels, Severn Estuary

Vanessa Straker (retired Historic England Science Advisor)

The potential of the Severn Estuary for research into Mesolithic environment and archaeology was recognised during multi-period research at Goldcliff. This was followed by a NERC-funded research project entitled 'Mesolithic to Neolithic Coastal Environmental Change 6500–3500 cal BC' and associated excavation funded by Cadw. This research, with associated PhD projects, was led by Professor Martin Bell, Dr Petra Dark, Professor Stuart Manning and Professor John Allen, with a team of specialists.

Figure 5: Excavating, recording and taking large specialist samples from the block samples supported in wooden frames. © E Sacre

The Goldcliff East sites lay around the edge of a former bedrock island. The project has shown the complexity of the coastal environment used by later Mesolithic groups. The forest surrounding the sites was replaced by a dynamic wetland comprising episodes of reed swamp, fen woodland, and saltmarsh and mudflats, which were covered at high tide. The sampling strategy was designed to maximise the opportunity to address archaeological research questions defined in the project research design. Eight of these are listed here:

- Did hunter-gatherers burn woodland or other vegetation in a coastal setting?
- Did human activity and economy change as the Holocene transgression progressed from fen woodland to reed swamp and then to saltmarsh and mudflats?
- What was the nature and economy of Mesolithic activity at Goldcliff East?
- Is there evidence of seasonality of occupation and environmental disturbance?
- What were the main species of animals, birds and fishes present and exploited, as indicated by footprint, track and bone evidence?
- What fishing techniques were employed in the Mesolithic?
- What was the contribution of plants to the Mesolithic diet?
- Do artefact and ecofact distributions point to specific activity areas? What are the implications of this for the duration and nature of settlement?

To address these questions, palaeoenvironmental analyses concentrated on pollen, plant macrofossils, charcoal, insects, and mammal, bird and fish bones, and included a programme of radiocarbon dating.

An integrated sampling strategy was designed to ensure appropriate comparisons among the results of the palaeoenvironmental analyses. The following sequences were sampled:

Site A, a buried land surface on the slope of Goldcliff island;
Site B, associated with the lower submerged forest;
Site J, a concentration of Mesolithic activity below the upper submerged forest;
Site D, ‘off-site’ contexts closely associated with Site B.

These sites comprise an environmental transect of c. 740m, running eastwards from the dryland edge of Goldcliff island into the surrounding wetland. There was also recording and excavation of human and other animal footprint and tracks at sites C and E. Specialist chapters give detailed accounts of all the studies undertaken, including the tree-ring and radiocarbon wiggle-match dating of the submerged forests.

Sampling the peats and silty clays was focussed on drawn sections where the deposits sampled could clearly be related to the archaeological stratigraphy. Samples for different analyses were taken adjacent to each other. Monolith tins were taken from vertical sections and where possible the same monolith tin was used for extraction of pollen, plant macrofossil and radiocarbon samples. As larger samples are required for insect analysis, these were taken adjacent to the botanical samples.

Fish bones were recovered from blocks of sediment, which were lifted intact and subsampled off-site for excavation and recording, followed by water sieving. Block-lifting was achieved by dividing each $1m^3$ into 16 $250mm^3$ blocks, which were collected in metal four-sided tins. These were wrapped on site and reassembled within $1m^3$ wooden frames for excavation, recording and wet sieving. Mesh sizes were 2mm for residues and 500 μm for flots. Plant macrofossils and charcoal were also recovered from these samples, as well as from the monolith tins (Figure 5).

Sampling in the intertidal zone, the area only exposed between high and low tides, is challenging, as the sites may only be exposed for a few daylight hours and are covered with mud and water between exposures. Getting to the sites can be treacherous and transport of sampling kit and samples is difficult. At Sites A and B, it was possible to transport the samples to dry land using a quadbike and trailer; elsewhere in the estuary, however, where the mud is deeper, this was not possible.

The specialist chapters and concluding summary for the Goldcliff East sites present detailed discussions of the data recovered. Many of the research questions were successfully addressed, but perhaps the most enigmatic issue remains that of season or frequency of occupation.

In a wide-ranging discussion of the multidisciplinary evidence used to address this issue, Bell concludes that long-term sedentary occupation at Goldcliff East is not supported by the evidence, and that shorter visits were made at various times of year, but predominantly in late summer and autumn. Footprint tracks show that the same area was visited at least annually.

Further reading

Bell, M.G., Caseldine, A.E. and Neumann, H. 2000 (eds) *Prehistoric Intertidal Archaeology in the Welsh Severn Estuary*. York, CBA Res Rep 120.

Bell, M.G., Allen, J.R.L, Buckley, S., Dark, S.P. and Haslett, S.K. 2002 Mesolithic to Neolithic Coastal Environmental Change, Excavation at Goldcliff East 2002, *Archaeology in the Severn Estuary* 13, 1-29.

Bell, M. 2007 'The Mesolithic site at Goldcliff East: introduction to the site, the sequence and methodology', in Bell, M., *Prehistoric Coastal Communities: the Mesolithic in Western Britain*. York, CBA Res Rep 149, 19–35.

Case Study 7

The Norfolk Projects: embedding environmental archaeology in submerged landscape assessments for offshore wind farms

Claire Mellett and Victoria Boothby (Royal HaskoningDHV)

Site and background

The offshore wind farms Norfolk Boreas, Norfolk Vanguard East and Norfolk Vanguard West (collectively the Norfolk Projects) are located in the southern North Sea, approximately 50km off the coast of Norfolk. The export cables connecting the offshore array to the national grid make landfall at Happisburgh, one of the earliest and best preserved Lower Palaeolithic sites in Britain.

The identification and investigation of prehistoric archaeology offshore can be challenging. Within the offshore boundaries of the Norfolk Projects, water depths reach up to 50m and the subsurface geology is buried beneath sand waves up to 5m high in places. The approach to environmental archaeology in these inaccessible contexts requires an almost entirely different approach. It is not simply a case of translating strategies used onshore into the marine environment.

The following case study demonstrates how, through cross-discipline collaboration, an approach has been developed that embeds environmental archaeology objectives within submerged landscape assessments for offshore wind farms.

Offshore survey

Marine geophysical survey data underpins submerged landscape assessments and is used to identify and map landscape features such as palaeochannels and palaeoshorelines on the seabed and in the subsurface. Bathymetric data from the Norfolk Boreas Project provided the first hint that palaeochannel features were present (Figure 6). Upon assessment of sub-bottom profiler data, an extensive palaeochannel network was revealed, indicating a high potential for preservation of alluvial or floodplain deposits, including peat.

Geomorphological assessment of the marine geophysical survey data provided the palaeogeographic context to understand the extent and preservation potential of submerged prehistoric landscapes across the Norfolk Projects. However, it was through marine

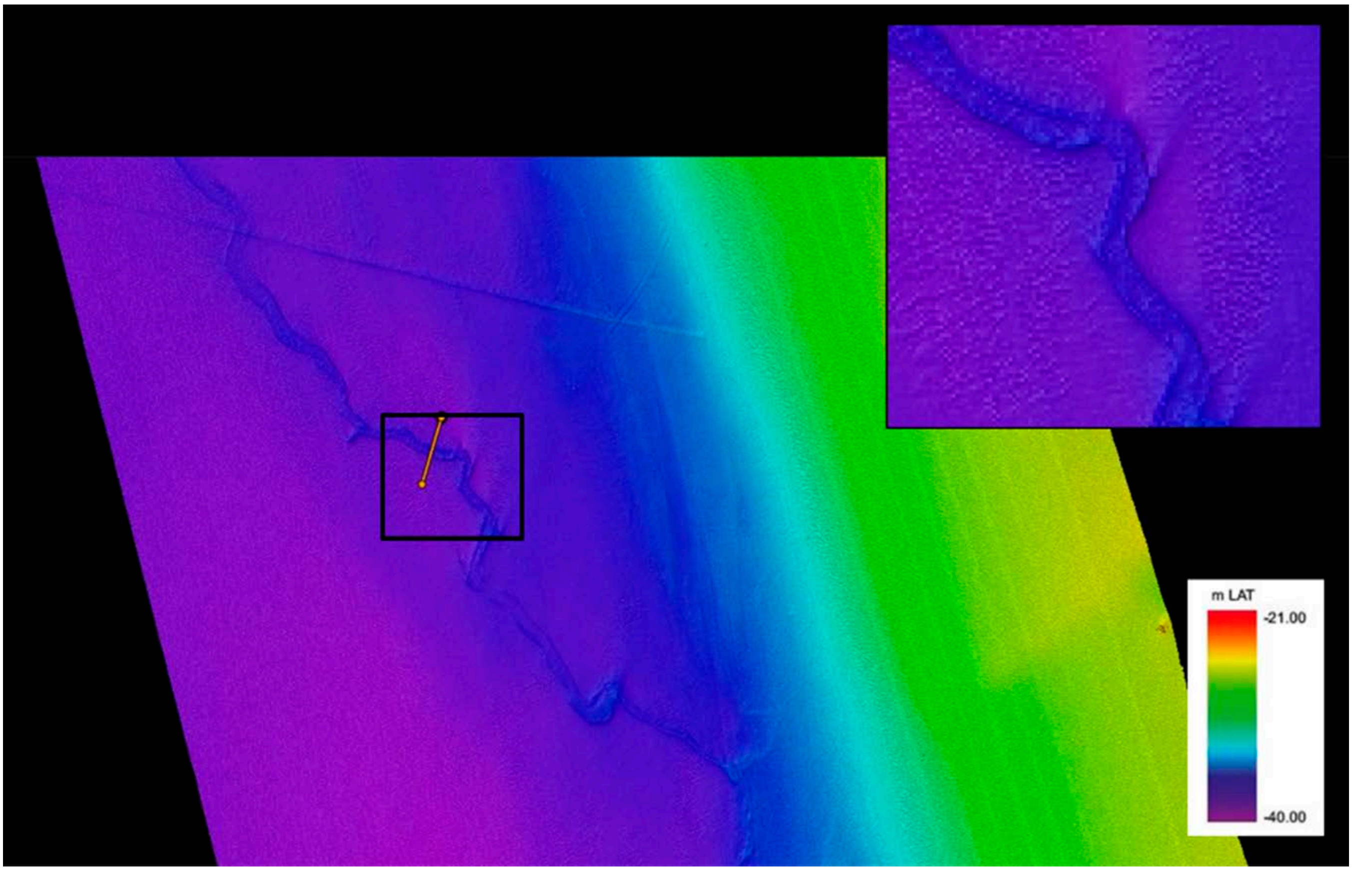


Figure 6: Bathymetry indicating a palaeochannel preserved on the seabed. © Royal HaskoningDHV

geotechnical surveys that sediment samples from contexts of archaeological interest were recovered to ground truth these geophysical interpretations and provide the physical material that could be assessed for environmental remains.

Considering the high costs of marine survey vessels, particularly those large enough to undertake geotechnical surveys, it is not sustainable to undertake separate geotechnical surveys for geoarchaeological purposes on offshore wind farm projects. Therefore, collaboration between geotechnical engineers and marine geoarchaeologists is vital to ensure that archaeological objectives are embedded in the geotechnical survey programme from the very early stages of a project. The archaeological assessment is conducted as part of the development processes and is not an afterthought. This approach speeds up the delivery of both the archaeological and engineering objectives.

Assessment strategy

Once core samples had been acquired for the Norfolk Projects, a full suite of multiproxy palaeoenvironmental and dating techniques was applied to subsamples from peat and minerogenic deposits. An assessment of macroscopic plant, pollen, foraminifera, ostracod and diatom remains was undertaken. Preservation and concentrations were sufficient to undertake a full analysis of all the remains, except for diatoms, which were poorly preserved, most likely as a result of post-depositional processes. In total, nine new palaeoenvironmental records were produced from two key periods: the transition from the Late Palaeolithic to Early Mesolithic, and the Middle to Upper Palaeolithic. The palaeoenvironmental analysis was supported by radiocarbon and luminescence dating.

Research questions

It is typical to define research objectives and questions prior to undertaking any palaeoenvironmental assessment, building on previous work undertaken locally or in similar contexts, and drawing on regional or period-specific research agendas. There were no known archaeological or palaeoenvironmental records from the area of seabed covered by the Norfolk Projects. Therefore, during the early stages of the geoarchaeological assessment, the research objective was very broad: identify submerged landscape features and develop a stratigraphic framework to understand archaeological potential. By the final stages of the project, however, the research questions were significantly refined towards understanding landscape evolution, vegetation history, palaeogeography, and the timing and nature of landscape inundation.

This was achieved through an iterative process. Each time a new geotechnical survey was undertaken, the logs were reviewed, samples from deposits of archaeological interest were retained, and the stratigraphy/deposit model was updated. The approach to palaeoenvironmental investigations was staged and included an initial assessment of the suitability of a range of multiproxy techniques and the development of a skeleton chronological framework. This was supplemented by full, high-resolution analyses of the proxies, with additional dating to provide a robust Bayesian chronology. At each of these stages, the research questions were revisited and refined to narrow uncertainty and allow any future work to be targeted. This made the processes manageable and sustainable, considering the temporal and spatial scale of the investigations, and provided a degree of flexibility to maximise the outcomes of the assessment.

Correlating geoarchaeology onshore and offshore

Typically, geoarchaeological assessments for the onshore and offshore portions of offshore wind farm cable routes are undertaken independently because of the different planning requirements. However, given the archaeological significance of the deposits preserved at Happisburgh, a more integrated approach was adopted for the Norfolk Projects.

Terrestrial and marine geoarchaeologists worked collaboratively to ensure the investigations being undertaken in the nearshore and coastal zone were complementary. This included reviewing and correlating stratigraphy across the land–ocean interface to create a seamless deposit model. Crucially, the same palaeoenvironmental techniques (and specialists) were used for marine and terrestrial assessments to ensure consistency in methodologies and reporting.

Engagement with academic researchers was also a priority to maximise the research outputs from the project. Researchers at the University of Southampton provided input into the nearshore geotechnical survey design, and provisions were made to share samples recovered for academic research. This was all facilitated by the developer (Vattenfall), who supported collaborative working between different elements within the Norfolk Project teams, but also with the wider academic community.

Highlights and next steps

The geoarchaeological and palaeoenvironmental assessments undertaken to support the Norfolk Projects identified an area of prehistoric peat/wetland covering up to 85km^2 of the seabed. This is arguably one of the most extensive, intact palaeolandscapes identified to date in UK waters. The palaeoenvironmental investigation has provided 14 new luminescence dates and 15 new radiocarbon dates, almost doubling the number of dates available from offshore contexts in the southern North Sea. It also provided four new pollen sequences, bridging the gap between British and continental pollen datasets for the Early Holocene. A new sea-level index point was produced, improving understanding of the timing and nature of inundation of the North Sea. Publication of the assessment reports as open access as part of the planning process ensured outputs were timely and transparent. Ongoing assessment will address outstanding research questions, culminating with publication in peer-reviewed academic journals.

Across the full extent of the Norfolk Projects, nearly one million years of human history has been investigated, from the earliest record of human activity in Britain at the landfall near Happisburgh, to final inundation of the North Sea during the Early Mesolithic. The sustainable, collaborative, iterative and flexible approaches outlined here have maximised the geoarchaeological and palaeoenvironmental outcomes from the Norfolk Projects, providing a new baseline and archaeological context to inform submerged landscape research in the southern North Sea.

Further reading

Walker, J., Gaffney, V., Harding, R., Fraser, A.I., Fitch, S. and Boothby, V. 2024 Winds of Change: Urgent Challenges and Emerging Opportunities in Submerged Prehistory, a Perspective from the North Sea, Heritage 7(4), 1947-1968, https://doi.org/10.3390/heritage7040093

Case Study 8

A sampling strategy fit for purpose: a fishy tale from Chester that matches aims, methods and site

Sue Stallibrass (independent researcher, retired Historic England Science Advisor)

The site and background

The site was a prime location in Chester city centre, in the heart of the Roman legionary fortress and the later medieval town. Much of Chester's historic core was redeveloped after the Second World War with little regard to environmental archaeology. This site was one of the few remaining areas with intact Roman, medieval and post-medieval deposits, and material preservation was predicted to be good.

National, regional and local research questions

England has little evidence for the exploitation of fish during the Roman period, possibly owing to poor recovery methods, as relatively few Roman deposits have been sieved. Chester is well placed to exploit fish from the river and its estuary, and from inshore and deep-sea waters. As a regional administrative and military centre it could also have received long-distance trade in fish products from elsewhere in the Roman Empire. Did people in Roman Chester exploit local habitats for fish and/or did they import processed products? Barrett et al (2004) have highlighted the UK-wide increased exploitation of larger, offshore fish in the medieval period, but evidence often comes from size-biased, hand-recovered assemblages. Did Chester see a similar rise in the exploitation of deep-sea fish and, if so, did these supplement or replace any earlier patterns of fish exploitation?

Evaluation objectives and results

A detailed brief was prepared by Chester's archaeological curators. Only restricted areas of the development were to go deep enough to destroy Roman levels. Objectives included an assessment of preservation conditions, the presence or absence of fish bones and their potential to address the research questions. Trial trenching included deep areas and a targeted sampling strategy. Processed samples proved that fish bones did survive, in all phases, in various states of preservation.

Excavation objectives and results

Well-stratified deposits were to be sampled for the recovery of (inter alia) fish bones. The same strategy and methodology was to be used throughout the excavation, so that valid comparisons could be made between contexts and phases. Samples were processed through a flotation machine on site, using a 1mm mesh to catch the residues. Volumes ranged from to 5-100 litres, the smaller samples being constrained by the amount of sediment in the context. Both flots and residues were examined for fish bone.

The processed samples produced forty times more identifiable fish bones (sieved N = 3638) than the whole of the rest of the site put together (hand-recovered N = 90). Twice as many types of fish were identified (23 species from sieved material and 11 from hand-recovered material) (Table 2).

Table 2: Identified specimens of fish for all periods at 25 Bridge Street, Chester; their absolute numbers and relative proportions.

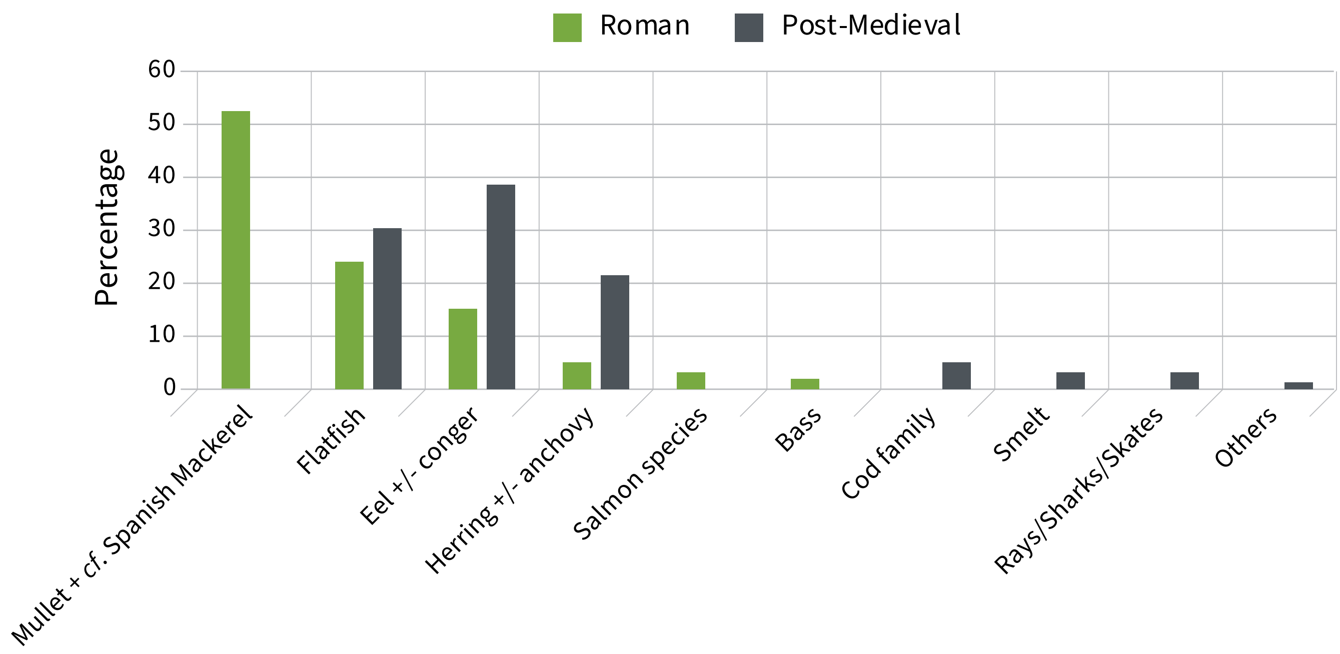
	Hand-recovered		Sieved through 1mm	
	Number of species/types: 11		Number of species/types: 23	
Taxa	number of identified bones		number of identified bones	
Herring	3	3%	876	24%
Salmon/trout	5	6%	24	<1%
Smelt	-	-	180	5%
Eel	1	1%	937	26%
Cod	20	22%	15	<1%
Other cod family	11	12%	74	2%
Small flatfish	40	44%	1252	34%
Others	10	11%	280	8%
Total Identified fish bones	90		3638	

Roman results

Fish bone densities were variable: five (n = 11) samples produced fish bones. One yielded 56 bones from 72 litres of processed sediment, while another sample of 72 litres and five very small samples (8–18 litres) produced no fish bone at all (Table 2). The others (24–72 litres) produced less tha n 10 each. Identified species were eel, herring, flatfishes, salmon, sea bass, mullet and *cf*. Spanish mackerel, suggesting the exploitation of local estuarine and inshore waters, plus some Mediterranean products. The *cf*. Spanish mackerel bones are vertebrae from a restricted portion of the spine, and almost certainly arrived at Chester as processed, salted fish, packed in an amphora imported from the Mediterranean.

Table 3: Relative frequencies of identified fish bones from Roman and early post-medieval sieved samples at 25 Bridge Street, Chester.

Taxa	Roman	Post-Medieval
Mullet + cf. Spanish mackerel	52	0
Flatfish	24	30
Eel +/- conger	15	38
Herring +/- anchovy	5	21
Salmon species	3	0
Bass	2	0
Cod family	0	5
Smelt	0	3
Rays/Sharks/Skates	0	3
Others	0	1



Post-medieval results, Table 3, compares the identified fish bones from sieved samples from the Roman and early post-medieval periods (the latter mostly from 16th-century cess pits). The absence of mullet and *cf*. Spanish mackerel are notable in the later material and cannot be ascribed to sample size (n=69) for the Roman period; n = 1551 for the post-medieval period). While large sea fish bones were recovered from most phases at Chester from the medieval period onward (not shown in Table 3), the smaller, more local, fish types still predominated in the 16th century.

Were the aims and objectives met by the sampling strategy? Yes. Questions at the national, regional and local level could be addressed using the evidence recovered by using this sampling strategy.

Was the sampling strategy fit for purpose? Yes. Processed samples were essential at evaluation stage (to assess the site's potential) and at excavation stage (to recover relevant material). Large samples were necessary to obtain adequate quantities. Comprehensive sampling was required because the productivity of different deposits could not be predicted. The consistent and systematic strategy was crucial for inter-period comparisons.

Further reading

Barrett, J H, Locker, A M and Roberts, C M 2004 'Dark Age Economics revisited: the English fish bone evidence AD 600–1600' . Antiquity 78, 618–36]

Jacques, D., Hall, A., Kenward, H., and Carrott, J. 2008 'Plant, invertebrate and fish remains', in Garner, D. 2008 *Excavations at Chester. 25 Bridge Street 2001:Two Thousand Years of Urban Life in Microcosm*, Archaeol Serv Excav and Survey Rep 14. Chester: Chester City Council.

Case Study 9

The empty 'grave-shaped feature' – how can we tell if it once contained a body?

Simon Mays (Historic England)

Introduction

When excavating an archaeological site, features may be encountered whose morphology suggests that they may be graves, but which appear to be devoid of human remains. Most usually, this occurs where the soils or sediments are highly acidic and/or free draining, and so are hostile to the survival of skeletal remains. Such burial conditions are prevalent in parts of East Anglia, south-western England, and over large areas of northern England.

Sometimes, a soil-stain may betray the former position of a body. At Tranmer House, Bromeswell, Suffolk, body stains were present in all 19 Anglo-Saxon graves devoid of bone (Fern, 2015). At Mucking, Essex, 48 of 63 graves (76%) lacking bone in Anglo-Saxon Cemetery 1 showed body stains (Hirst & Clarke, 2009). On the other hand, partial body stains were only occasionally observed at Anglo-Saxon Boss Hall cemetery, Ipswich (Scull, 2009); eight body marks were seen among about 130 Anglo-Saxon inhumations at Springfield Lyons, Essex (Tyler & Major, 2005); and among 16 Roman graves at Low Boroughbridge, Cumbria, none showed body stains (Hair et al., 1996).

In the absence of a body stain, it may still be fairly clear whether a feature is a grave even if it was not part of an organised cemetery area - for example, because it may have features, such as a stone lining, that place it within a recognisable burial tradition (Figure 7). But this may not always be the case. The purpose of this note is to provide advice regarding field procedures, and associated laboratory methods, that might potentially help in resolving these unclear cases. In broad terms, the approach is firstly for efforts to be made to retrieve from the potential grave any surviving human remains whose existence may not have been obvious. If this fails, efforts can be made to trace biomolecular signatures of a decomposed body in the grave soil. The methods discussed have only been sporadically applied to this problem, so no single case study demonstrates them all. This note therefore draws upon a range of different archaeological examples. In terms of biomolecular analyses, it does not attempt to be comprehensive, but concentrates on techniques that currently appear most likely to produce useful results.

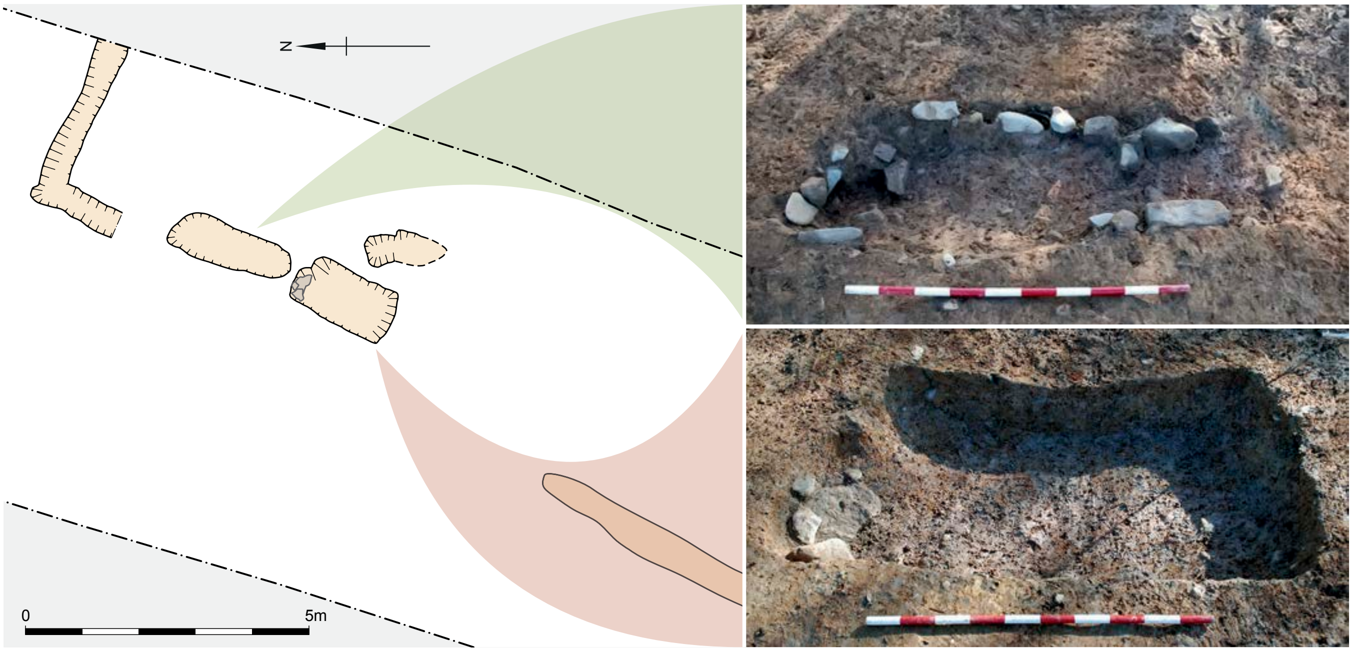


Figure 7: Two features, identified as late Roman graves, at Birdoswald, Cumbria. Both were devoid of human remains, as is usual in the region, due to soil conditions. They were positioned across a gap in an enclosure ditch of a Roman period cemetery containing cremation burials. The more northerly of the two (the one toward the left in the plan) had a cobblestone lining resembling that seen in some other late Roman burials in northern England; its shape is suggestive of a single inhumation. The other appears to have pillow stones at one end, again a consistent with its function as a grave. Its morphology is suggestive of a double inhumation (Source: Wilmott, in press). Drawing: J Vallender Photographs: T Wilmott © Historic England

The degree to which the methods described might be employed in individual cases depends upon technical factors pertinent to the particular site under investigation, and upon the importance placed upon identifying whether a particular feature was indeed a grave (and hence the resource it is appropriate to direct toward addressing this problem). This latter is likely to depend upon factors including the relevance of that question to establishing the significance of the site, for example as part of a field evaluation, or its pertinence in addressing site-specific or broader research aims identified for a fieldwork project.

On-site recovery of bone and tooth fragments

Sieving of grave soil to recover small pieces of bones and teeth should be routine in cemetery excavations, and should, of course, be undertaken to recover any remains from apparently empty 'graves'. Skeletal remains may sometimes survive in the microenvironments adjacent to metallic objects, so particular attention should also be paid to these. For example, at the Tranmer House site, fragments of bone and dental remains were found preserved adjacent to copper alloy shield bosses in graves otherwise devoid of skeletal material (Anderson, 2015).

The most resistant human tissue to dissolution in soils is dental enamel, the least is bone, with tooth dentine occupying an intermediate position (Mays, 2021: 26). In some instances, dental enamel crowns may be the only tissue that survives. In an apparently empty stone cist at St Martin’s, Isles of Scilly, soil samples yielded a number of human dental enamel crowns and enamel fragments (Johns & Taylor, 2016).

Although every effort should be made to recover small fragments of bones and teeth, care is needed with regard to security of context. In the soil samples from the St Martin's cist, in addition to the dental remains, a small bone fragment was also recovered. However, radiocarbon dating showed it to be intrusive (Johns & Taylor, 2016). Context is more secure when multiple dental elements or bone fragments are retrieved in close association. Recovering basal grave fills as spatially discrete samples will be helpful in determining this.

Laboratory Methods

Identification of fragments of bones and teeth

When fragments of bones and teeth are very small, it may be difficult to determine whether they are human on morphological grounds. Under such circumstances, biomolecular techniques can be useful. The amino-acid sequence in collagen differs between species, allowing human bone or dentine fragments to be identified, providing the molecule is preserved. Usually, analysis is via a technique known as zooarchaeology by mass spectrometry (ZooMS) (Hendy, 2021). Dental enamel fragments contain trace amounts of amelogenin proteins. These differ in their amino-acid sequence across different animal species, allowing human dental enamel to be distinguished (Hendy, 2021). Enamel peptides (protein remnants) are very resistant to degradation in the burial environment (Welker et al., 2020).

ZooMS and dental enamel peptide analyses ideally require ca. 20mg of bone or dental enamel, although successful results have been achieved with less. Skeletal remains vary in density, depending, *inter alia*, upon the extent of degradation in the soil, so the size of fragment this corresponds to will vary. Examples of dental enamel and bone fragments together with their weights are shown in Figure 8 in order to help decision-making with regard to mesh sizes for recovery. It is difficult to make precise recommendations, but given the propensity for dental enamel to fracture into small slivers, using mesh down to 2mm or less would appear prudent to recover remains.

Chemical traces of a decomposed body

A decomposed corpse may leave evidence of its location in the form of biomarkers from hard or soft tissue or from gut contents. Using these to infer the former presence of a body involves analysis of soil from the grave together with suitable control samples.

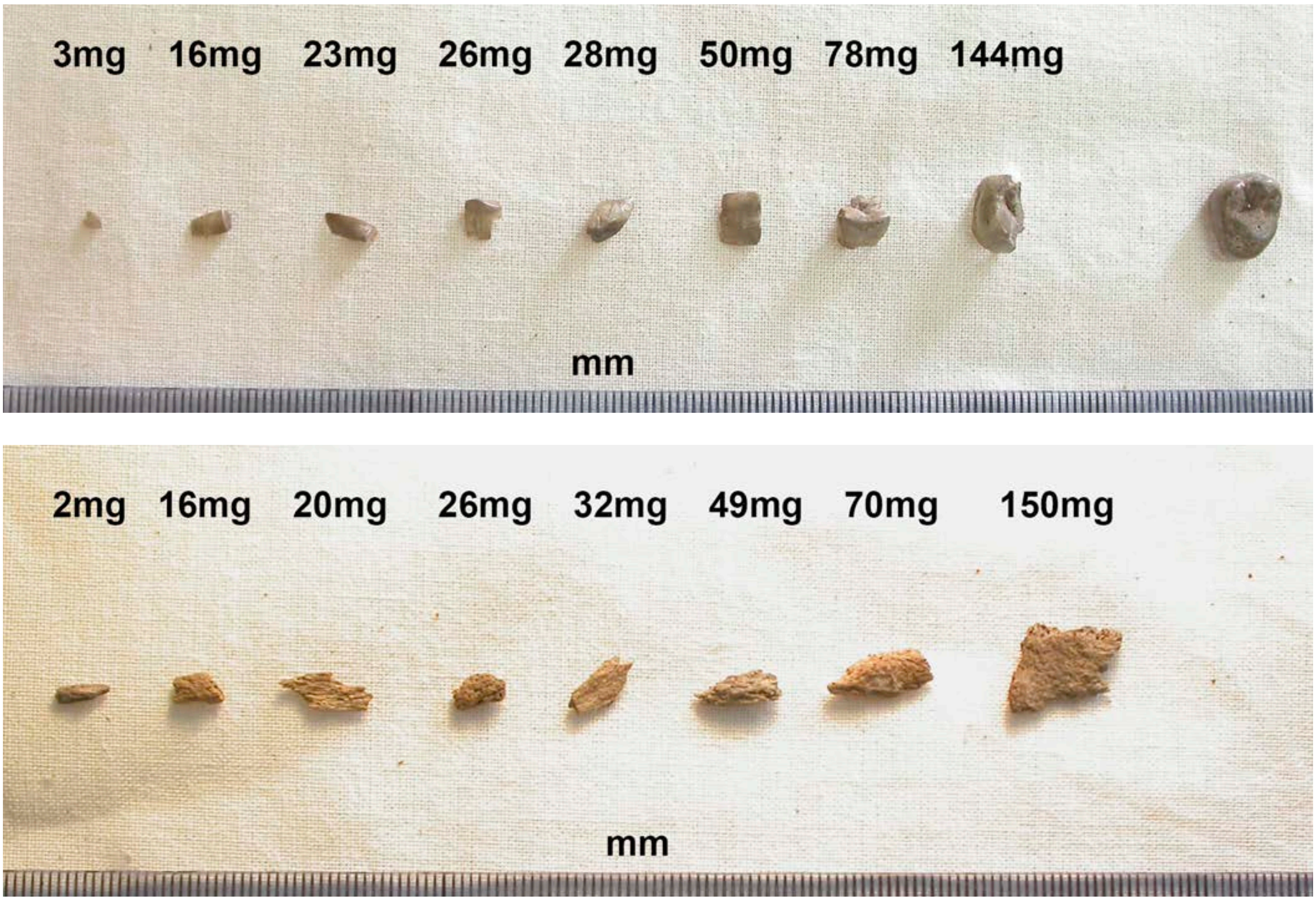


Figure 8: Example dental enamel (a) and bone (b) fragments with weights. Normally c. 20mg is used for enamel peptide or bone zooarchaeology by mass spectrometry (ZooMS) analyses. For the enamel chart, a complete enamel maxillary molar crown is shown on the right for comparison. All enamel pieces lack dentine. Bone samples are generally eroded fragments of cortical bone. They vary in thickness, and in density, much more than is the case for the enamel fragments, both for anatomical and for taphonomic reasons, hence the link between size, as seen in the illustration, and weight is less obvious. Material is from a cist grave at Hillside Farm, Bryher, Isles of Scilly (1st century AD). Both dental enamel peptide and bone collagen survived for analysis (Mays et al. 2023).
© S Stark, S Mays

The mineral part of the skeleton is composed principally of calcium and phosphate ions. Phosphate, being fairly resistant to leaching in the soil, has been the traditional focus when looking for traces of vanished burials. Enrichment in phosphate was interpreted as evidence for an interment in the famous Anglo-Saxon ship burial excavated just before World War II at Sutton Hoo, Suffolk (Bethell, 1989). Enriched levels of phosphate have been found in body stains in Anglo-Saxon graves from Mucking, Essex, Boss Hall, Ipswich (Biek et al., 2009; Barham et al., 2009), and in a Viking Age grave at Hesby, Norway (Viklund et al., 2013). Among graves lacking a body stain, elevated phosphate was found at a Viking Age grave at Fregeslev, Denmark (Sulas et al., 2022), but this was not consistently so at Anglo-Saxon Spong Hill, Norfolk (Hughes, 1984; Keeley, 1984) and was not the case at the historic Anderson Site, Arkansas, USA (Beard et al., 2000). Localised concentrations of phosphate might be expected to be clearest when there is also preservation of a body stain, but this is not a prerequisite for successful analysis. Soils also differ in their propensity to preserve phosphate signals. For example, sandy, well-drained soils are not only hostile to bone survival but also have low phosphate retention (Crowther, 2002).

Phosphate is clearly not specific to human hard tissue so it could not distinguish human from faunal remains. Fecal biomarkers, particularly 5β-Stanols, present in the gut, are fairly stable, and a human fecal source can potentially be distinguished from those of most domestic species (Herrault et al., 2019; Lerch et al., 2022). In modern forensic cases, lipid residues from decomposed adipose tissue survive in soil (Bull et al., 2009), and they may be very persistent in the burial environment (Schroeter et al., 2020). Although the lipids involved are not specific to humans, it appears possible to distinguish inputs from human adipose tissue using stable isotope analyses (Bull et al., 2009). Given the above, it might be thought that these biomarkers are potential indicators of the former presence of human bodies in archaeological features. However, few studies have been done, and the results are inconsistent. Fecal biomarkers showed elevated levels in the gut region of a burial from Anglo-Scandinavian York (Pickering et al., 2018) and in some burials from a 11th century mass grave from Dorset (Pickering et al., 2014). The York burial also showed increased levels of biomarkers associated with decomposed adipose tissue. These were not ‘empty graves’, skeletal remains survived. Body fat signatures were not identified in the grave soil in two 10th-13th century burials from Hofstaðir, Iceland (skeletal remains were present), a fact attributed to the free-draining nature of the soils at the site (Burns et al., 2022). No trace of human fecal biomarkers was retrieved from the grave devoid of human remains at Fregerslev, despite other indications that a body had been present (Sulas et al., 2022).

When attempting to identify chemical traces of a body, and to integrate this work with sampling that may be carried out for purposes unassociated with identification of human remains, multiple sampling, and coordination between specialists, and between specialists and site staff, is important. In the large grave pit at Fregerslev, in addition to sieving of grave fills, a multiscale sampling programme was instigated from basal parts of the grave and other features, plus appropriate control samples, for geochemistry, macrobotanical remains, phytoliths, pollen, non-pollen palynomorphs and fecal lipid biomarkers (Sulas et al., 2022). This necessitated close collaboration among field- and laboratory-based members of the project team.

Summary

The likelihood of bone destruction/survival at a site should be evident at an early stage in a fieldwork project (desk-based assessment, evaluation). This, together with general nature of the archaeology, can suggest the potential need for some of the approaches outlined here, and can also allow estimation of cost implications. On site, advice should be sought at an early stage on optimal approaches. Sampling, including relevant control samples, should be undertaken by the relevant specialist(s) or else by site staff following their instruction. A flow chart to aid decision-making regarding possible analyses is presented in Figure 9.

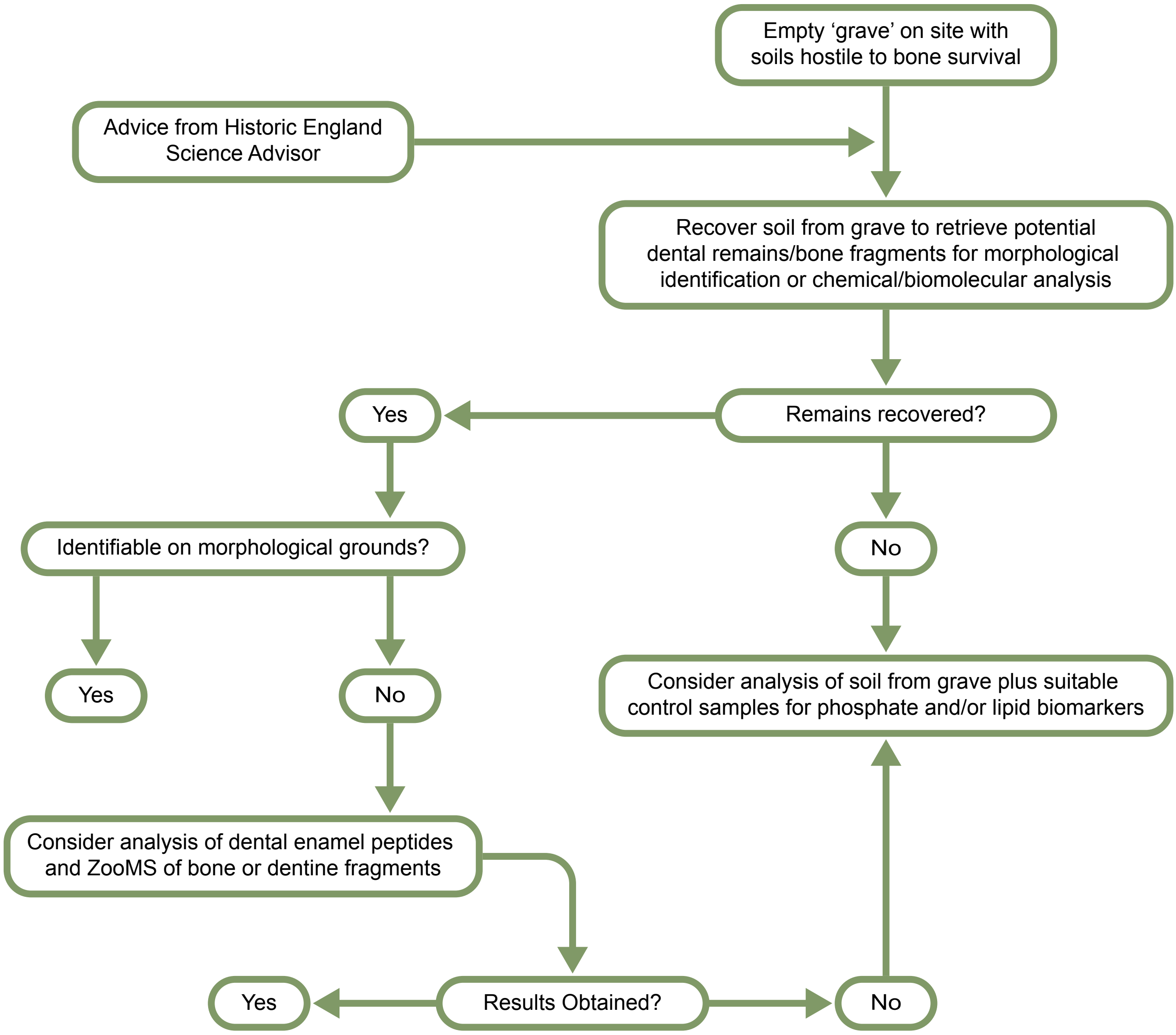


Figure 9: . Flowchart to assist decision-making in identification of potential graves lacking visible human remains.

Acknowledgements

The author is grateful to the following for their comments on an earlier draft of this note: Matt Canti (Historic England), Andy Hammon (Historic England), Jessica Hendy (University of York), Sam Rowe (Historic England), Sarah Stark (Historic England), Gordon Turner-Walker (National Yunlin University of Science and Technology), Anne de Vareilles (Historic England), Michael Wallace (Headland Archaeology), Jim Williams (Historic England).

Further reading

Anderson, S. 2015 'Human remains from the inhumation burials', in Fern, C. J. R., ed. *Before Sutton Hoo: The Prehistoric Remains and Early Anglo-Saxon Cemetery at Tranmer House, Bromeswell, Suffolk*. East Anglian Archaeology Report No. 155. Bury St Edmunds: Suffolk County Council, 147–8. https://eaareports.org.uk/publication/report155/ (accessed November 2024).

Barham, A., Bloomfield, C., Canti, M. G., Porter, A., and Williamson, V. 2009 'Soil chemistry: phosphate', in Scull, C., ed. *Early Medieval (Late 5th–Early 8th Centuries AD) Cemeteries at Boss Hall and Buttermarket, Ipswich, Suffolk*. The Society for Medieval Archaeology Monograph 27. Leeds: Society for Medieval Archaeology, 63.

Beard, L., Hilliard, J., and Akridge G. 2000 'Historical and chemical traces of an Ozark cemetery for enslaved African-Americans: a study of silhouette burials in Benton County, Arkansas', *North American Archaeologist*, 21, 323–49.

Bethell, P. 1989 'Chemical analysis of shadow burials', in Roberts, C. A., Lee, F., and Bintliff, J., eds. *Burial Archaeology. Current Research, Methods and Developments*. British Archaeological Reports British Series 211. Oxford: BAR, 205–14.

Biek, L., Bayley, J., and Hirst, S. 2009 'The soil silhouettes', in Hirst, S., and Clark, D., eds. *Excavations at Mucking. Volume 3. The Anglo-Saxon Cemeteries*. London: Museum of London Archaeology, 12–18.

Bull, I.D., Berstan, R., Vass, A., and Evershed, R. P. 2009 'Identification of a disinterred grave by molecular and stable isotope analysis', *Science and Justice*, 49, 142–9.

Burns, A., Pickering, M. D., Green, K. A., Pinder, A. P., Gestedóttir, H., Usai, M.-R., Brothwell, D. R., and Keely, B. J. 2017 'Micromorphological and chemical investigation of late-Viking grave fills of Hofstaðir, Iceland', *Geoderma*, 306, 183–94. https://doi.org/10.1016/j.geoderma.2017.06.021.

Crowther, J. 2002 'The experimental earthwork at Wareham, Dorset after 33 years: retention and leaching of phosphate released in the decomposition of buried bone', *Journal of Archaeological Science*, 29, 405–11.

Fern, C. J. R. 2015 *Before Sutton Hoo: The Prehistoric Remains and Early Anglo-Saxon Cemetery at Tranmer House, Bromeswell, Suffolk*. East Anglian Archaeology Report No. 155. Bury St Edmunds: Suffolk County Council. https://eaareports.org.uk/publication/report155/ (accessed November 2024).

Hair, N., Howard-Davis, C., Newman, R., and Oliver, T. 1996 *Transect Through Time. The Archaeological Landscape of the Shell North Western Ethylene Pipeline*. Lancaster: Lancaster Imprints 1. Lancaster University Archaeological Unit.

Hendy, J. 2021 'Ancient protein analysis in archaeology', *Science Advances*, 7, eabb9314. https://www.science.org/doi/10.1126/sciadv.abb9314.

Herrault, L., Milek, K., Jardé, E., Jeanneau, L., Derrien, M., and Anderson, D. G. 2019 'Faecal biomarkers can distinguish specific mammalian species in modern and past environments', PLoS ONE, 14(2), e0211119. https://doi.org/10.1371/journal.pone.0211119.

Hirst, S., and Clark, D. 2009 *Excavations at Mucking. Volume 3. The Anglo-Saxon Cemeteries*. London: Museum of London Archaeology.

Hughes, M. J. 1984 'Analysis of soil samples from inhumation 31 for phosphate', in Hills, C., Penn, K., and Rickett, R., eds. *The Anglo-Saxon Cemetery at Spong Hill, North Elmham. Part II: Catalogue of Inhumations.* East Anglian Archaeological Report No. 21. Gressenhall, Norfolk Archaeological Unit, 32–3. https://eaareports.org.uk/publication/report6/ (accessed November 2024).

Keeley, H. C. M. 1984 'Trace element analysis of soil samples from inhumations 40 and 42', in Hills, C., Penn, K., and Rickett, R., eds. *The Anglo-Saxon Cemetery at Spong Hill, North Elmham. Part II: Catalogue of Inhumations*. East Anglian Archaeological Report No. 21. Gressenhall: Norfolk Archaeological Unit, 34–6. https://eaareports.org.uk/publication/report6/ (accessed November 2024).

Johns, C., and Taylor, S. R. 2016 'Excavation of a Porthcressa-type cist grave at Churchtown Farm, St Martin's, Isles of Scilly, 2013', *Cornish Archaeology*, 55, 163–79. https://cornisharchaeology.org.uk/2022/08/19/volume-55-2016/ (accessed November 2024).

Lerch, M., Bromm, T., Geitner, C., Haas, J. N., Schäfer, D., Glaser, B., and Zech, M. 2022 'Human and livestock faecal biomarkers at the prehistorical encampment site of Ullafelsen in the Fotsch Valley, Stubai Alps, Austria: potential and limitations', *Biogeosciences*, 19, 1135–50. https://doi.org/10.5194/bg-19-1135-2022.

Mays, S. 2021 *The Archaeology of Human Bones*, 3rd edn. London: Routledge.

Mays, S., Parker, G., Johns, C., Stark, S., Young, A. J., Reich, D., Buikstra, J., Sawyer, K., and Hale, K. 2023 'Sex identification of a Late Iron Age sword and mirror cist burial from Hillside Farm Bryher, Isles of Scilly, England', *Journal of Archaeological Science Reports*, 52, 104099. https://doi.org/10.1016/j.jasrep.2023.104099.

Pickering, M. D., Ghislandi, S., Usai, M.-R., Wilson, C., Connelly, P., Brothwell, D. R., and Keely, B. J. 2018 'Signatures of degraded body tissues and environmental conditions in grave soils from a Roman and an Anglo-Scandinavian age burial from Hungate, York', *Journal of Archaeological Science*, 99, 87–98. https://doi.org/10.1016/j.jas.2018.08.007.

Pickering, M., Lang, C., Usai, M.-R., Keeley, B., and Brothwell, D. R. 2014 'Appendix 1: Organic residue analysis of soils', in Loe, L., Boyle, A., Webb, H., and Score, D., eds. *'Given to the Ground' A Viking Mass Grave on Ridgeway Hill, Weymouth*. Dorset Natural History Society Monograph Series: No. 22. Dorchester / Oxford: Dorset Natural History and Archaeological Society and Oxford Archaeology, 237–45. https://eprints.oxfordarchaeology.com/5870/ (accessed November 2024).

Schroeter, N., Lauterbach, S., Kalanke, J., Mingram, J., Yildiz, C., Schouten, S., and Gleixner, G. 2020 'Biomolecular evidence of early human occupation of a high-altitude site in western Central Asia during the Holocene', *Frontiers in Earth Science*, 8, a20. https://doi.org/10.3389/feart.2020.00020.

Scull, C. 2009 *Early Medieval (Late 5th–Early 8th Centuries AD) Cemeteries at Boss Hall and Buttermarket, Ipswich, Suffolk.* The Society for Medieval Archaeology Monograph 27. Leeds: Society for Medieval Archaeology.

Sulas, F., Bagge, M. S., Enevold, R., Harrault, L., Kristiansen, S. M. et al. 2022 'Revealing the invisible dead: integrated bio-geoarchaeological profiling exposes human and animal remains in seemingly 'empty' Viking-Age burial', *Journal of Archaeological Science*, 141, 105589. https://doi.org/10.1016/j.jas.2022.105589.

Tyler, S., and Major, H. 2009 *The Early Anglo-Saxon Cemetery and Later Saxon Settlement at Springfield Lyons, Essex*. East Anglian Archaeology Report No. 111. Chelmsford: Essex County Council. https://eaareports.org.uk/publication/report111/ (accessed November 2024).

Viklund, K., Linderholm, J., and Macphail, R. I. 2013 'Integrated palaeoenvironmental study: micro- and macrofossil analysis and geoarchaeology (soil chemistry, magnetic susceptibility and micromorphology)', in Gjerpe, L. E., ed. *E18-prosjektet. Gulli-Langåker. Bind 3: Oppsummering og arkeometriske analyser*. Bergen: Fag bokforlag, 25–84.

Welker, F., Ramos-Madrigal, J., Gutenbrunner, P., Mackie, M., Tiwari, S., Rakownikow, R. et al. 2020 'The dental proteome of *Homo antecessor*', *Nature*, 580, 235–8. https://doi.org/10.1038/s41586-020-2153-8.

Wilmott, T. (in press) *The cemetery of the Hadrian's Wall fort of Birdoswald,* Cumberland and Westmorland Antiquarian and Archaeological Research Series. Lancaster, Cumberland and Westmorland Antiquarian and Archaeological Society.

Contact Historic England

East of England
Brooklands
24 Brooklands Avenue
Cambridge CB2 8BU

Tel: 01223 582749
Email: eastofengland@
HistoricEngland.org.uk

Fort Cumberland
Fort Cumberland Road
Eastney
Portsmouth PO4 9LD

Tel: 023 9285 6704
Email: fort.cumberland@
HistoricEngland.org.uk

London and South East
4th Floor
Cannon Bridge House
25 Dowgate Hill
London EC4R 2YA

Tel: 020 7973 3700
Email: londonseast@HistoricEngland.org.uk

Midlands
The Foundry 82 Granville Street,
Birmingham B1 2LH,

Tel: 0121 625 6888
Email: midlands@HistoricEngland.org.uk

North East and Yorkshire
Bessie Surtees House
41-44 Sandhill
Newcastle Upon Tyne NE1 3JF

Tel: 0191 403 1635
Email: northeast@HistoricEngland.org.uk

37 Tanner Row
York YO1 6WP

Tel: 01904 601948
Email: yorkshire@HistoricEngland.org.uk

North West
3rd Floor, Canada House
3 Chepstow Street
Manchester M1 5FW

Tel: 0161 242 1416
Email: northwest@HistoricEngland.org.uk

South West
Fermentation North (1st Floor)
Finzels Reach
Hawkins Lane
Bristol BS1 6JQ

Tel: 0117 975 1308
Email: southwest@HistoricEngland.org.uk

Swindon
The Engine House
Fire Fly Avenue
Swindon SN2 2EH

Tel: 01793 445050
Email: swindon@HistoricEngland.org.uk

Historic England

We are the public body that helps people care for, enjoy and celebrate England's spectacular historic environment.

Please contact guidance@HistoricEngland.org.uk with any questions about this document.

HistoricEngland.org.uk

If you would like this document in a different format, please contact our customer services department on:

Tel: 0370 333 0607
Email: customers@HistoricEngland.org.uk

All information and weblinks accurate at the time of publication.

Please consider the environment before printing this document

HEAG327b
Publication date: December 2025 © Historic England
Design: Historic England