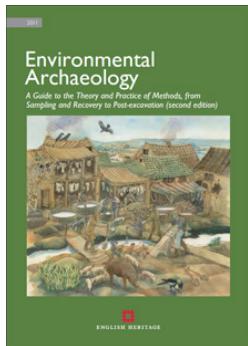




Historic England

## Environmental Archaeology



On 1st April 2015 the Historic Buildings and Monuments Commission for England changed its common name from English Heritage to Historic England. We are now re-branding all our documents.

Although this document refers to English Heritage, it is still the Commission's current advice and guidance and will in due course be re-branded as Historic England.

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2011

# Environmental Archaeology

*A Guide to the Theory and Practice of Methods, from Sampling and Recovery to Post-excavation (second edition)*



ENGLISH HERITAGE

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## Preface

This document provides guidance for good practice in environmental archaeology. It gives practical advice on the applications and methods of environmental archaeology within archaeological projects. It should not replace advice given by specialists on specific projects, nor is it intended that these guidelines should inhibit future development of methodologies or recommended procedures.

Many archaeological projects will be undertaken as a requirement of the planning process. For these projects, Planning Policy Statement (PPS) 5: *Planning for the Historic Environment*, and its accompanying *Historic Environment Planning Practice Guide* (Department for Culture Media and Sport / Department for Communities and Local Government 2010), set out planning policies on the conservation of the historic environment in England. These documents give clarification for all those involved with the planning process on how to assess the significance of heritage assets and mitigate impacts of development on the historic environment. They are a material consideration for local authorities when preparing development plans and determining planning applications. They are also material to the preparation and consideration of Strategic Environmental Assessments (*European Directive 2001/42/EC, The Environmental Assessment of Plans and Programmes Regulations 2004 (Statutory Instrument 2004 No 1633)*) and Environmental Impact Assessments (*Town and Country Planning Regulations*, Department of the Environment, Transport and Regions 1999). PPS5 is consistent with obligations undertaken when the UK became a signatory to Council of Europe conventions, including *The European Convention on the Protection of the Archaeological Heritage* (the ‘Valletta Convention’ 1992) and *The European Landscape Convention* (the ‘Florence Convention’ 2000).

Consideration of the impact of development on the historic environment will include assessing the significance of, and impacts of development on, the biological remains preserved on archaeological sites and the palaeoenvironmental resource.

These guidelines are intended to provide guidance to:

- curators who advise local planning authorities and issue briefs;
- field project managers writing specifications or written schemes of investigation;
- those working on development-led or research projects;
- other practitioners.

The guidelines should be used with reference to areas with a north-west European or temperate climate. Other climates will give rise to different preservation conditions, which lie outside the scope of this document.

These guidelines have been produced by English Heritage in consultation with field archaeologists, curators and environmental specialists.

## What the guidelines cover

- an introduction to environmental archaeology;
- good practice for environmental archaeology from project planning to publication;
- an introduction to sampling strategies;
- the circumstances under which environmental evidence survives;
- a guide to types of environmental samples;
- taking and storing samples;
- a summary of the most common types of environmental evidence;
- a glossary of terms;
- where to get advice;

## I Introduction

Environmental archaeology is the study of past human economy and environment using earth and life sciences. It tells us about ecological, cultural, economic, and climate change.

Archaeological sites are created by human activity involving material culture (acquisition, manufacture, use, deposition). Archaeological sites and landscapes are altered by a combination of natural and cultural processes. Natural processes include geological and biological activity, such as erosion, sedimentation, frost heave, reworking by plants and animals, plant growth, deposition of dead plants and animals, and degradation by living ones. Cultural processes include subsistence and ritual activities, building, discarding or loss of material, manufacturing and the creation of manufacturing waste, recycling, deliberate destruction and resource utilisation.

Examples of the types of questions that environmental archaeology seeks to answer are:

- What was the environment of the area like at the time of occupation and how did it change over time?
- How did people procure food?
- How did people prepare food?
- What did they throw away and where?
- What did people exchange, buy or sell?
- Is it possible to identify social status?
- How were plants and animals used in rituals?
- How did people use or interact with their environment?
- Was this site occupied seasonally or all year round?
- Were these fields/houses flooded by fresh or saltwater?

## 2 Practice

This section provides a guide to good practice for the environmental archaeology component of projects. It is not intended to be a ‘methods manual’ for all the various types of environmental material, but rather a set of practical guidelines to help with project planning and implementation.

Specific guidelines are available for waterlogged wood (Bunning and Watson 2010), waterlogged leather, (English Heritage 1995), human bone (Mays *et al* 2004; Mays 2005; McKinley and Roberts 1993), geoarchaeology (English Heritage 2007) and dendrochronology (Hillam 1998). An up-to-date list of

English Heritage guidance is available on HELM ([www.helm.org.uk/](http://www.helm.org.uk/)). The Institute for Archaeologists' (IfA) *Standards and Guidance for collection, documentation, conservation and research of archaeological materials* (2008e) provides general guidance for all finds work.

These guidelines are applicable to all archaeological projects, but are aimed primarily at projects following the management principles set out in MoRPHE and MoRPHE PPN3 (Lee 2006; Kerr and Stabler 2008). These principles are designed to ensure the efficient execution of archaeological projects within set time and cost constraints, from fieldwork to publication, including the creation of a project archive.

Government guidance set out in Planning Policy Statement 1 (PPS 1) (Office of the Deputy Prime Minister 2005) urges applicants and planning authorities to engage in early pre-application discussions in order to ensure that wherever possible planning applications are determined swiftly. This is particularly relevant to investigations of heritage assets, which can take several months to complete. Where projects are commissioned to inform the planning process, PPS 5 (Policy HE 6) and the accompanying EH guidance document (paragraph 68) make it clear that the information sought should be proportionate to the significance of the heritage asset and to the potential impacts of the proposed development. Assessments of heritage assets in advance of determination of planning applications should therefore be sufficient to provide an understanding of the significance of



**Fig 1** Sampling prehistoric deposits for lithics (green lids) and biological remains (blue lids) at Stainton West, near Carlisle. (photo by J P Huntley).

heritage assets and their settings affected either directly or indirectly by the development proposals. Project designs and briefs should clearly set out the timetable for the project, ensuring that information required for the assessment of significance is available in good time to inform the planning process.

Where initial assessment of collected material shows that it warrants analysis, it is not acceptable to discard samples or material even where analysis is not required to establish the significance of a heritage asset. Such samples and materials should be fully analysed, recorded, and, where appropriate, the results published. This ensures that potentially important archaeological information is not lost or destroyed as a consequence of the planning process. Project designs and briefs should

therefore make provision for necessary analysis, recording, storage and publication.

Definitions of briefs, specifications and project designs can be found in the Association of County Archaeological Officers' (1993) *Model Briefs and Specifications for Archaeological Assessments and Field Evaluations* and the IfA's Standard and guidance series (2008a, 2008b, 2008c, 2008d, 2008e, 2009, 2010). The document *Archaeological Science at PPG16 Interventions: Best Practice Guidance for Curators and Commissioning Archaeologists* (English Heritage 2003) gives clauses that can be appropriately modified and incorporated into documents. These clauses can also be used as guidance for how environmental archaeology should be considered in the formal planning process. Curators will need to seek advice on the appropriateness of certain methods or types of investigation; however, independent non-commercial advice for curators can be sought from English Heritage through the Regional Science Advisors (see the end of this document). Where advice is obtained from a commercial contractor, it is the responsibility of the commissioning body to ensure that vested interests are openly declared and that subsequent competition is fair (IfA 2010).

Full use should be made of all available sources of information on environmental potential when planning archaeological projects. Environmental evidence is present in some form on all archaeological sites and therefore the sampling and study of such material should form an integrated part of the initial project specification. It should not be tacked on as a contingency (Table 1, Fig 1).

**Table 1** Stages of project planning for environmental archaeology under MoRPHE (Lee 2006) with examples of activities at each stage

start-up	Consider the main purpose and drivers for the project. How will environmental archaeology contribute to project aims and objectives? What types of material need to be recovered? What types of material are likely to survive? Consult specialists for advice.
initiation	Design specifics of sampling strategy, including sample type, sample size, sample density, general types of context to be sampled. Clearly define how sampling meets aims and objectives of the project. Clearly state what products will result (eg reports, databases, tables, illustrations).
execution	Collect samples, review sampling strategy, adapt sampling strategy in consultation with specialist(s). Process samples for assessment. Assess samples and report results. Update project design. Undertake analysis. Produce report(s) and any other dissemination products. Deposit material and archive reports, databases etc with site archive. <i>NB There may several iterations of this stage in more complex projects.</i>
closure	Review achievements and lessons learned.

## Desk-based assessment

The purpose, definition and standards for desk-based assessment are given in IfA (2008a).

The following information in a desk-based assessment can be relevant to environmental archaeology:

- topography;
- solid geology;
- drift geology;
- soil type;
- aerial photographs;
- lidar survey;
- geophysical survey;
- borehole survey and geotechnical test pits;
- local water table;
- current land use and surface conditions;
- the nature of any previous ground disturbances;
- other local archaeology, including environmental archaeology;
- the nature and extent of any proposed ground disturbance if known.

Useful sources of information are geology and soil maps, previous surveys, other

local archaeological reports, the National Monuments Record (NMR), the Historic Environment Records (HERs) and the *Environmental Archaeology Bibliography* (EAB) found through the Archaeology Data Service (ADS) website (<http://ads.ahds.ac.uk/>).

Once information from the desk-based study is available, the potential for the survival of environmental materials should be discussed with suitable experts. Specialists appropriate to the type of materials considered likely to be encountered should join the project team to advise on the formulation of the project design. Experienced expert advice is essential at this stage to avoid wasteful or misdirected outlay of resources, or missed opportunities. Predicting the survival of environmental remains in archaeological deposits is not an exact science (Table 2, Fig 2). Any written scheme of investigation or project design drawn up after an evaluation should allow sufficient flexibility to review arrangements once full fieldwork begins.

Recording methods for environmental materials should be agreed before fieldwork begins and an understanding reached on

any materials and equipment needed. For larger projects, arrangements should be made for specialists to pay site visits once the fieldwork begins, and for them to stay in touch during fieldwork so that any issues can be dealt with promptly.

## Watching briefs

The purpose, definition and standard for watching briefs is given in IfA (2008d). Whether sampling can be done during watching briefs depends on many factors. Good practice would allow for the sampling of interpretable and datable archaeological deposits and provision should be made for this.

## Field evaluation

The purpose, definition and standard for evaluations are given in IfA (2009). Evaluation seeks to understand the nature of the archaeological resource in order to inform decisions on planning and mitigation. In some cases an evaluation might be the only excavation undertaken.

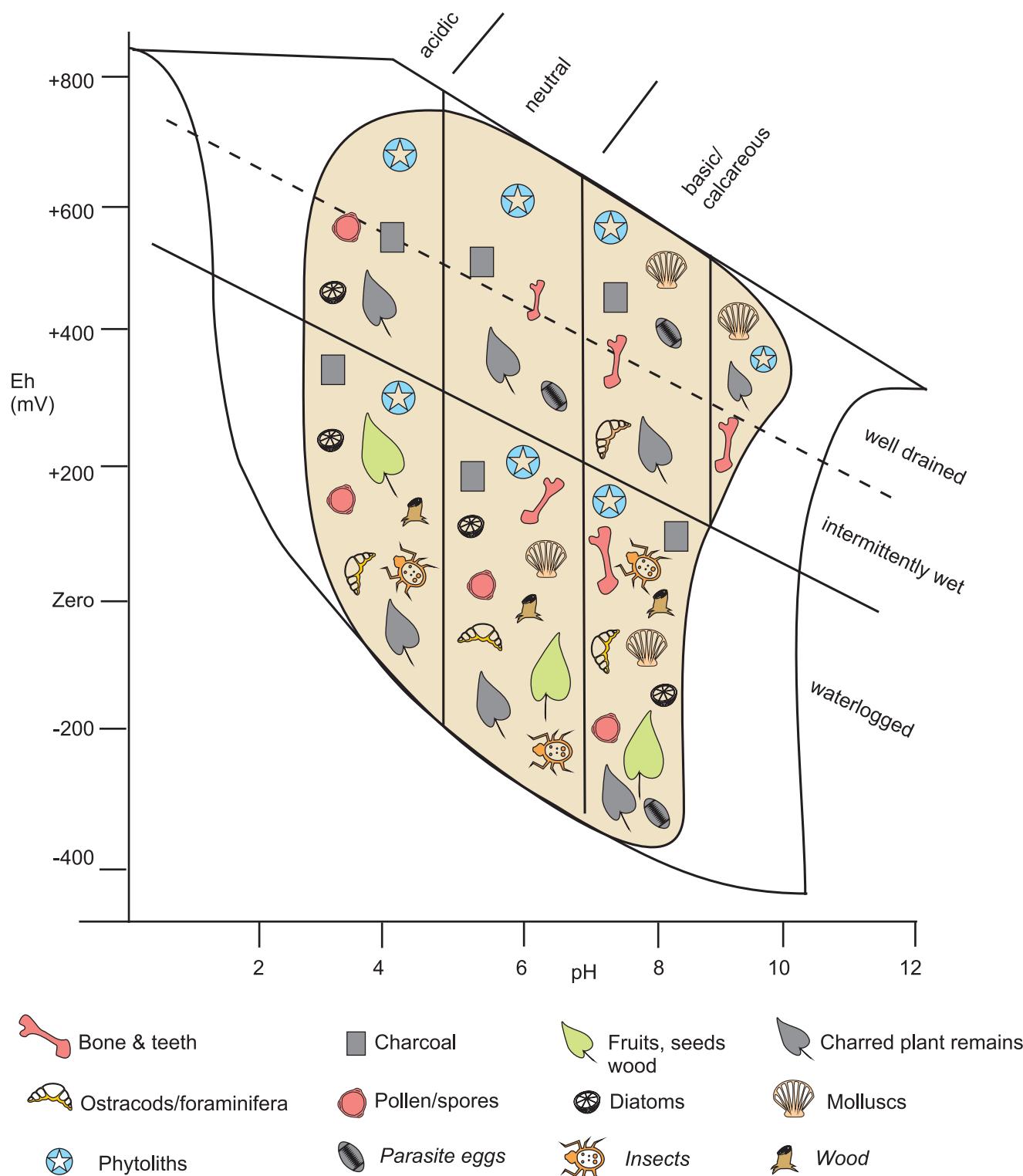
Evaluation trenching will provide a much more reliable indication of the potential of the environmental archaeology

**Table 2** Preservation conditions (adapted from Evans and O'Connor 1999)

burial environment	main soil and sediment types	some typical situations	environmental remains
acid, pH usually <5.5, oxic	podzols and other leached soils	heathlands upland moors some river gravels	charcoal and other charred plant macrofossils pollen and spores phytoliths diatoms
basic, pH usually >7.0, oxic	rendzinas (but can be acid in the topsoil) lake marls tufa alluvium shell-sand	chalk and limestone areas valley bottoms karst machair	charcoal and other charred plant macrofossils mineral-replaced plant and insect remains! molluscs bones ostracods foraminifera parasite eggs! pollen and spores (rarely)
neutral to acid, pH 5.5–7, oxic	brown earths and gleys river gravels alluvium	clay vales and other lowland plains	charcoal and other charred plant macrofossils mineral-replaced plant and insect remains! bones molluscs parasite eggs! pollen and spores
acid to basic, anoxic (anoxic conditions can be patchy and unpredictable)	peats and organic deposits, eg lake sediments and alluvium gleys	some well sealed stratigraphy, including organic urban deposits wetlands river floodplains wells wet ditches upland moors	charcoal and other charred plant macrofossils waterlogged plant remains insects mineral-replaced plant and insect remains! molluscs bones ostracods foraminifera pollen and spores diatoms wood parasite eggs!

<sup>1</sup> Parasite eggs and mineral-replaced plant and animal remains survive in a range of very local conditions that are difficult to predict.

**Fig 2** Schematic representation of environmental conditions and types of material typically preserved.



Schematic representation indicating under which depositional environments specific categories of environmental remain can be expected to survive and hence be recovered using appropriate sampling techniques.

Filled area = envelope into which most naturally derived sediments fit. Material outside these limits tends to reflect human activity, eg. basic slag and other industrial deposits.

Modified from Retallack, 1984

resource than can be predicted from a desk-based assessment. Sampling in evaluation should be fit for purpose – that is, to contribute to an understanding of the potential and significance of the archaeological resource. The sampling strategy should be included in the project design and the objectives encompass:

- types of biological remains present;
- preservation;
- concentration;
- distribution;
- significance in a local, regional and national context.

Where appropriate, specialists should be asked to make site visits as for full excavation (*see below*). For geoarchaeological input into evaluations see geoarchaeology guidelines (English Heritage 2007, 25)

Assessment of environmental remains from evaluations should be done to the same standards as for excavation. The results of these assessments should, with the rest of the archaeological record, inform any further planning decisions. Assessments resulting from field evaluations are often carried out within tight time constraints. They should clearly set out the limitations of the information presented and the potential of this information to alter assessments of significance as a result of further investigation.

In some cases an evaluation might be the only type of excavation undertaken. Where assessment has demonstrated that material has considerable potential to add to the body of archaeological knowledge, it should be analysed and published as part of the evaluation project (English Heritage 2003).

## Excavation

The purpose, definition and standard for excavations are given in IfA (2008b). The sampling strategy should be fit for purpose; and designed to meet aims and objectives as stated in the project design. It should be agreed by the project team, which includes the specialists (project experts), and will take into account the results of any evaluation.

It is the project manager's responsibility to ensure that the specialists are kept informed about developments during excavation, including important finds and factors affecting the environmental sampling. Significant changes or alterations in strategy should be recorded and should be agreed by the project team, including the relevant specialists. An issues log can be a useful way of recording these

changes for future reference. Site visits by specialists should form part of the communications plan. Some specialists will need to take their own samples (*see section 3*). It is helpful to have a trained environmental officer on site as part of the project team to co-ordinate and monitor sampling, to identify when there is a need to call in other specialists and to integrate different methodologies. This person needs to be skilled in excavation and recording methods and to understand the potential of a wide range of environmental remains.

All flotation and coarse-sieved samples (*see section 3*) should be processed as part of the data collection and recovery stage of a project, so that the specialist can clearly see the full range of material and judge its potential to meet project aims and objectives.

For sites on heavy clay soils, sample processing is resource intensive. Therefore, difficult decisions may have to be taken about how and what to sample to best meet the project aims and objectives. The reasons for adopting a particular approach need to be stated in the project design. Any changes that occur during the course of the project should be recorded, communicated to and agreed by the project team.

For complex or long-term projects it can be useful to write an archive report that documents discoveries and issues resulting in a change to the way the project was implemented in the field. It can also include information on the location of the samples, ie whether they are with the specialists or at the unit, and a brief summary of what was found (Kerr and Stabler 2008, Appendix 1).

## Assessment

The purpose of an assessment is to establish the significance of the material, its potential to address project aims and its potential to enhance understanding of the past. An assessment should include or take account of the results of previous interventions and should make recommendations for the type and scope of further analysis, which should feed into the updated project design. To be cost-effective these decisions should be made in the light of best academic knowledge, and therefore need to be carried out by specialist staff who are highly experienced in studying the type of material being assessed. For example, they need to be able to recognise the significance of interesting or unusual taxa, which may not always occur in the richest samples.

Assessment methodology should be fit for purpose and will vary according to the type of remains. The distribution and

occurrence of biological remains cannot be determined without examining what is present in the samples. As these samples will have been collected according to a strategy designed to meet project aims, this will normally mean that every flot from flotation samples and the material recovered from all coarse-sieved samples should be assessed unless determined to be unstratified or unacceptably contaminated (*see also Case Study 1 and section 3 Sampling strategies*). Assessments of animal bone assemblages require counts of identifiable, ageable and measurable fragments of each of the more common taxa (eg cattle) or broad taxonomic group (eg wild birds) taking into account chronology, area and feature type (Payne 1991).

Specialist samples require different approaches, which should be discussed with the appropriate specialists as part of project planning and during fieldwork.

Information the specialist requires to carry out an assessment:

- brief account of the nature and history of the site;
- aims and objectives of the project;
- summary of archaeological results;
- context types and stratigraphic relationships;
- phase and dating information;
- sample locations;
- preservation conditions;
- residuosity / contamination;
- other relevant contextual information;
- list of samples;
- some indication of quantity (number of boxes, flots, etc);
- contact details of other project team members.

The assessment report should include:

- specialist aims and objectives relevant to the project design;
- summary description of soil, sediments and stratigraphy, where relevant;
- sampling and processing methods, including mesh sizes;
- assessment methodology;
- any known biases in recovery;
- any known problems of contamination or residuosity;
- quantity of material (how many samples? what was the sample size?);
- statement on abundance, diversity and state of preservation of the material;
- statement of potential to contribute to the project aims;
- statement of potential to contribute to research issues of wider significance;

- recommendations for material suitable for scientific dating, when this has been requested;
- recommendations for future work (analysis and publication);
- resources required for further work.

### Analysis and reporting

The type and level of analysis required will be clear from the assessment report and updated project design, as agreed by the project team. The report should state aims in relation to the project design, methods, results and conclusions. Reports need to include clear statements of methodology, with the results of scientific analysis clearly distinguished from their interpretation. Non-technical summaries of results should be included, and the full data from the analysis presented. Access to data from other aspects of the project will allow the production of an integrated report.

Reports should include the following sections:

- Introduction
- Aims and objectives
- Methods
- Results – including the full data set
- Discussion
- Conclusion

Overviews and syntheses of the environmental results will generally be written by one of the environmental specialists involved in the project. In order to avoid misinterpretation or technical inaccuracy, any integrated discussion incorporating specialists' results should be seen by the specialists who undertook the work. This should be considered when estimating project costs.

### Publication and archiving Historic Environment Record (HER)

It is essential that a report on any archaeological intervention, even if it goes no further than an evaluation, should be lodged with the local HER as promptly as possible. This is necessary to inform future interventions and guide the local planning authority on future decisions. Environmental information should form part of this report, including any information on deposits and the preservation of biological remains.

Environmental archaeology data can now be recorded on Historic Environment Records. Guidance is available on the HELM website ([www.helm.org.uk/](http://www.helm.org.uk/); *Guidelines for the Addition of Archaeological Science Data to the Historic Environment Records*).

### Publication

The publication of the full data in association with their interpretation should be encouraged in the main body of reports. At the minimum, publication needs to include the aims and objectives of the study, a basic description of the material, methods of analysis, interpretation of results and sufficient data to support the conclusions drawn. The location of the environmental archive should also be included, as should the scope and limitations of the study, as well as relevance to other work and any recommendations for future work. Non-standard methodologies should be described and justified.

There is often a conflict in communicating the results of any analyses to specialist and general readerships. The publication needs to address both. The interpretation and conclusions of the study should be aimed at a general archaeological readership. Information of interest to specialists within the particular field of study, including illustrations of unusual or important material should also be published.

### Archiving

Environmental material, associated data and related documentation are all likely to be incorporated into the overall project archive, which will be deposited with the appropriate repository. All archive material should be stable and accessible, in line with published guidelines (Brown 2007; Walker 1990). The digital archive component should contain all born digital (material that was created by digital means as opposed to on paper) material and some secondary digitised material, including codes, electronic files of data and metadata, and text files, diagrams, photos, etc, and be fully documented and indexed (Brown 2007, 18; Archaeology Data Service 1997). Human remains form a special case and reference should be made to existing standards (DCMS 2005; McKinley and Roberts 1993) <http://www.justice.gov.uk/about/burials.htm>). Decisions on what to include for archiving should be made in consultation with the specialist, the project manager and the archive repository.

It is sometimes desirable for material to be retained by specialists for future study. This should only take place with the permission of the project manager and the owner of the material. Such material is also part of the project archive. A description of the material and its location should be entered in the project archive.

A summary of the archived data should include a sufficient description of what is in the archive, to enable future researchers to

decide whether or not the data are relevant to their concerns. The existence of data in an archive and its location should also be lodged in the HER.

Individual museums usually have their own standards for archive deposition, but overall guidance can be found in Brown (2007), in Longworth and Wood (2000) and in Museum and Galleries Commission (1992).

Standards for digital archiving are available from the Archaeology Data Service. The publication *Digital Archives from Excavation and Fieldwork: Guide to Good Practice* (1 and 2 edns) can be obtained from their website: <http://ads.ahds.ac.uk>.

## 3 Sampling

This section covers:

- what a good sampling strategy should include;
- asking the right questions;
- examples of possible methodologies;
- which types of samples to take;
- what to consider when taking samples;
- how to store samples.

### Sampling strategies

The most important element in developing a sampling strategy is to understand how the information gained from the site or area of interest will enhance knowledge of the period and issues in question (the aims). Asking key questions, or targeting types of information (objectives) that will contribute to the greater understanding of the past, clarifies what needs to be done to achieve these aims. It is impossible to make decisions about the most effective way to sample, how best to deploy resources or how to modify the approach in response to issues arising if the aims and objectives of the project are not clear. Flexibility in response to new information or changing circumstances is an important part of project planning and management. This makes it possible to modify the aims and objectives as a project progresses (Fig 3).

The need for sampling and a consideration of what types of samples will best address project aims should be considered at the start of a project (see Table 1). Advice should be sought from appropriate specialists to ensure that the sampling will meet the project's needs and be cost-effective. The project design must demonstrate that the sampling strategy is fit for purpose (Case Study 2). A well-constructed sampling strategy addresses the aims and objectives of the project and



**Fig 3** Flotation tank in use on the site of a Roman town along the A46. Practical constraints meant that a recycling system was developed for the on-site processing of whole earth samples. This made it possible to give rapid feedback to the excavation team (photo by J P Huntley).



**Fig 4** Plank-lined springhead and launder excavated at Town Farm Quarry, Burlescombe, Devon. The launder did not survive to the left of the springhead, where conditions were not permanently wet. Dating evidence suggests that construction took place shortly after AD 629, the felling date obtained on one of the timbers (Best and Gent 2007; photo by V Straker).

research questions identified in regional and national research agendas. These aims and objectives will determine the types of sample taken (Table 3), types of context sampled, density of sampling and sample size, all of which should be described at least in outline in a sampling strategy.

Archaeological sites can be simple or complex in terms of features, chronology, the chemical and physical properties of the deposits, and the site formation processes. These factors will influence the survival of different types of biological remains. Therefore, preservation will partly determine the objectives that can be set.

The environmental material recovered from a site will depend on the geology and depositional environment of that site, as well as on the nature of the archaeology itself. While the survival of different types of environmental evidence can be predicted to a certain extent, this is not an exact science. Table 2 provides a summary of

where various types of remains are most likely to occur, but local conditions can vary (Fig 4).

Excavators often tend to sample from layers expected to be productive. It is essential, however, to collect samples from all types of deposit that are relevant to the aims of the sampling strategy. Many classes of environmental material are not visible to the naked eye, for example chaff fragments and small weed seeds. Appearances can also be deceptive. Black deposits, for example, might not contain any charred material, or might be rich in wood charcoal, but poor in seeds.

Environmental remains are not necessarily homogenously distributed through a given deposit, and this needs to be considered when taking samples (Fig 5). The best way of obtaining a representative sample of the material within a context is to take the sample from several different areas within the context (scatter sampling).

A single sample of equivalent size from a single area in a context will be less representative of the context as a whole (Orton 2000, 153–4; Lennstrom and Hastorf 1992).

If the objective is to explore variation within a context, multiple samples from different locations within the context will be required. For example: using a grid to sample an occupation layer.

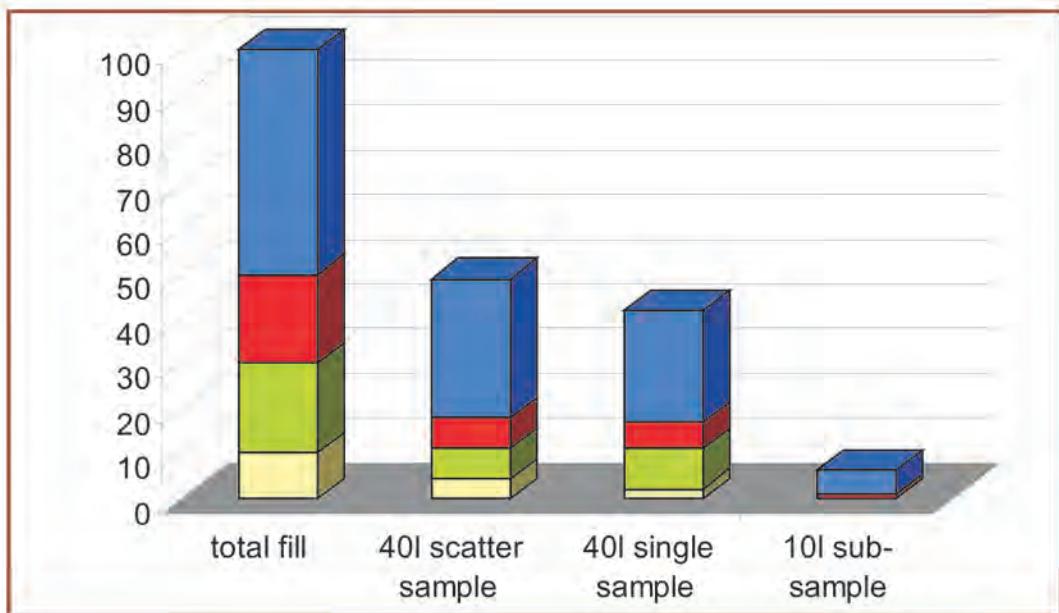
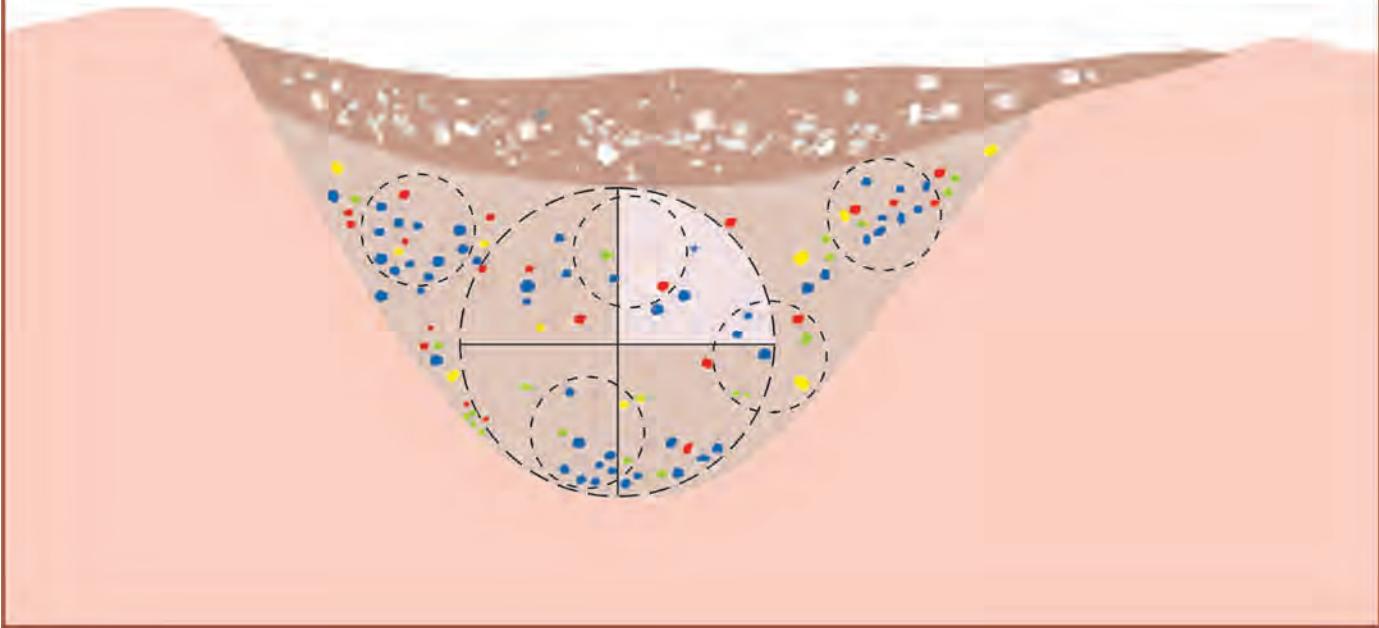
Co-ordinated sampling for different environmental materials from the same deposits is often desirable and will provide a more enhanced interpretation than relying on a single line of evidence. Environmental sampling can also be integrated with sampling for various types of artefactual and technological evidence, eg the recovery of technological waste such as hammerscale (see Case Studies 2 and 6).

Sampling should not concentrate only on features that can be dated or phased in the field, but should also consider features

**Table 3** Examples of sample types appropriate to particular materials

	coarse-sieved	flotation	specialist
vertebrate (bone also recovered by hand on site)	✓	✓ (small bones in residue from flotation)	✓
molluscs	✓ (large, mainly marine)	—	✓
insects, arachnids, etc	—	—	✓
parasite ova	—	—	✓
plant macrofossils	✓ (large fruit stones etc)	✓ (charred and mineral-replaced)	✓ (waterlogged and mineral-replaced)
wood	—	—	✓
charcoal	—	✓	✓ (radiocarbon dating)
pollen and spores	—	—	✓
phytoliths	—	—	✓
foraminifera	—	—	✓
ostracods	—	—	✓
diatoms	—	—	✓
soils and sediments	—	—	✓

**Fig 5** Sampling the fill of a pit to recover biological remains.



**Fig 5** The figure shows a hypothetical pit fill, which appears to the naked eye to be a homogenous fill showing no differentiation. However, within the fill are biological remains, not visible to the naked eye, which are unevenly distributed. This is a common occurrence. The small circles represent a 40 litre sample (scatter sample, section 3) taken from different areas within the pit and with a bit from each circle put into each sample tub. The large circle represents a 40 litre sample taken out of a single area of the pit, each quarter of the circle representing one sample tub. The light-coloured quarter represents a 10 litre sub-sample of this sample.

There are 10 yellow items. The 40 litre single sample recovers 2 of these, whereas the 10 litre sub-sample of this sample recovers none. The 40 litre scatter sample recovers 4 yellow items.

There are 20 green items. The 40 litre single sample recovers 9 of these, whereas the 10 litre sub-sample of this sample recovers none. The 40 litre scatter sample recovers 7 green items.

There are 20 red items. The 40 litre single sample recovers 6 of these, whereas the 10 litre sub-sample of this sample recovers only 1. The 40 litre scatter sample recovers 7 red items.

**Table 4** Sampling methodologies

sampling method	description	advantages	disadvantages
random	contexts to be sampled are selected in a statistically random manner	mathematically rigorous	could miss all important deposits if used on its own
judgement	samples are taken from obviously 'rich' deposits	cost-effective since the 'good' contexts only are targeted	highly subjective; 'good' contexts are not always apparent to the excavator
systematic	samples are taken to an agreed strategy	ensures that the whole site is considered; can be easily re-evaluated during excavation	can miss the unusual contexts, or sample inappropriate contexts if poorly planned

that are undated during excavation. Recovered environmental evidence can provide the material needed to date these features and, by ignoring them, some types of activity, or periods of activity, might be entirely overlooked.

Sampling can be achieved using several different methodologies. The choice is primarily between random, judgement and systematic sampling. Common practice is a combination of judgement and systematic sampling (Table 4). See Veen (1985) for a discussion on random and judgement sampling specifically in relation to charred plant remains.

Heritage assets can also include deposits or features that preserve evidence of human environment, land use, landscape and climate change. Examples of such assets include buried peats, bogs, lakes, palaeochannels, alluvium and colluvium. There is widespread recognition that such deposits preserve important information about our past. This is recognised in the revised European Convention on the Protection of the Archaeological Heritage (1992) (the Valetta Convention) and the European Landscape Convention – ELC (2000) (the Florence Convention). The UK is a signatory to both these conventions.



**Fig 6** Using a modified Livingstone piston corer in kettle hole deposits on the A66 at Stainmore, County Durham (photo by J P Huntley).

The ELC defines landscape as an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors.

To examine environmental change over time, long sequences of deposits are usually needed. These are recovered from locations with substantial accumulations of sediments, for example river channels, lakes, bogs, mires and glacial depressions, or ditch sections and ponds. Sampling a long sedimentary sequence will provide information both on the site and on the wider ecological history of the area (Dark 1996). Analyses need to date a sufficient number of subsamples to link processes and events to human history (Gearey *et al* 2009; Case Study 3). If a continuous sequence is not available, it is possible to sample from succeeding phases or contexts. Sequences from one or more locations may be sampled. Multiple samples of the same sequence from slightly different locations will give a more accurate picture than a single sequence, which may be biased by local factors (for an example see Whittle *et al* 1993).

Samples are often taken using coring equipment – ranging from hand augers to commercial drilling rigs – in order to recover sedimentary sequences that can be used for a variety of different analyses (Fig 6). Machine or hand-dug trenches can also be cut, where the sampling site is suitable. Some sampling locations might be covered by legislation. For example, permission from Natural England is needed to sample within a Site of Special Scientific Interest (SSSI).

#### Sample types

The archaeological context is important when deciding what types of samples should be collected. The likely presence of particular environmental remains will be related to preservation conditions (see Table 2), to human activities and to depositional processes. For example, samples for charred plant remains are collected routinely from dry feature fills such as pits and postholes, while samples for the recovery of both plant and invertebrate remains can be taken from waterlogged

deposits. Exposures of peats and clays in river valley or coastal sequences would require a range of samples for the recovery of different types of evidence.

The terminology applied to different sample types is varied and confusing. In part this reflects the wide range of materials for which samples are taken and the different processing methods used for them. These guidelines classify sample types primarily by how they are dealt with on site. The use of the term 'bulk sample' has deliberately been avoided, as this term is used differently by different people and fosters a lack of clarity about the purpose for which the samples were taken.

Samples can be classified into three basic types: coarse-sieved samples, flotation samples and specialist samples.

#### Coarse-sieved samples

Coarse-sieved samples can be wet or dry sieved depending on the soil conditions, and are usually processed on site. Collected for the retrieval of small bones, bone fragments, larger (mainly marine) molluscs (such as oysters, mussels, limpets, etc) and smaller finds, they are best taken with the advice of the appropriate specialist. Other materials that could be collected include wood charcoal, large plant remains (charred, waterlogged and mineral-replaced) and waterlogged wood, but coarse-sieved samples are not suitable as the sole means of retrieving these materials. Samples should be 'whole earth' with nothing removed unless the way in which the sample is processed would have a detrimental effect on fragile material (eg metal objects). Where material is removed, this should be noted on the record and the information passed on to the relevant specialists.

Coarse-sieved samples are usually sieved on a minimum mesh size of 2mm. Research has shown that sieving down to 2mm will provide a good indication of the fish and small mammal species present in a context. However, full recovery of fish and small mammal bones requires a 0.5mm or 1mm mesh size. The residues from flotation samples are

often used for this purpose (Barrett *et al* 2004). See Case Study 2 for an example of sampling designed to recover fish remains as part of an integrated sampling strategy combining flotation and coarse-sieving.

Hand recovery of animal bones is always biased in favour of larger elements and will tend to over-represent the importance of, for example cattle over sheep, or long bones over foot bones. Sieving onto a 4mm mesh ensures good recovery of small artefacts and the bones of the principal domesticated animals (sheep, goat, pig, and cattle). Samples of around 100 litres or more are usually necessary to recover representative assemblages (Payne 1975), but specialist advice should be sought on sample size, mesh size and suitability of the context.

#### Flotation samples

These are taken from well-drained deposits for the recovery of charred plant remains from the floating fraction (the flot), and for charcoal fragments, small mammal and fish bones, mineral-replaced plant remains, industrial residues such as hammerscale and smaller finds from the residues. They are usually collected by the excavation team and should preferably be processed on site where facilities (water, adequate drainage, silt disposal and drying space) are available. Molluscs can also be retrieved from flotation samples, but specialists should advise on whether these samples are suitable or whether other types of sample would be more appropriate or needed in addition.



**Fig 7** Material sorted from residues: small to medium fraction (photo by J P Huntley).

Sample size will normally be of the order of 40–60 litres or 100% of smaller features (see Case Studies 1 and 4). The flot is usually collected on a sieve with a mesh size of 250–300µm (microns). Residues are usually collected on a sieve size of 0.5mm (500µm)–1mm and are sorted for the recovery of the small items mentioned above. Mesh size for flotation samples might need to vary from site to site according to the practicalities of processing different soil types. The advice of a specialist should be sought for the most appropriate sample size and mesh sizes for a given site. Specialist advice on mesh sizes will be needed particularly for sites on iron-rich clay soils, where charred plant remains are often partly coated or impregnated with iron salts, and where conditions are suitable for mineral-replacement by calcium phosphate or calcium carbonate (see below Macroscopic plant remains). This material often fails to float, remaining in the residue. In order to ensure full recovery of mineral replaced remains the residue mesh should 0.5mm.

For the recovery of finds (eg beads, flint, glass, pot), residue fractions larger than c 2mm can be sorted by non-specialists with the naked eye, although this should be done under appropriate supervision (Fig 7). Small residue fractions (approximately 2mm or less) need to be scanned or sorted under a microscope by the appropriate specialist(s). Biological remains within the smaller fractions are too small (and sometimes too unfamiliar) to be recovered adequately by non-

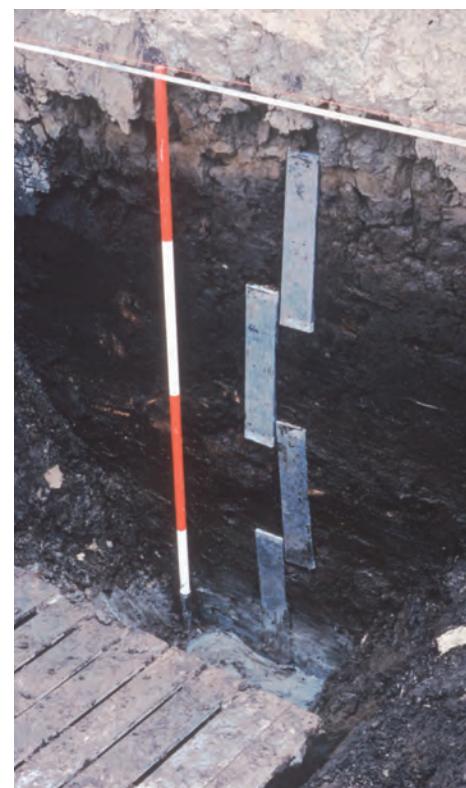
specialists. Large volumes of residue can be subsampled under specialist guidance. It should be noted that flotation machines are not always highly effective at recovering charred plant remains (Moulins 1996), and that it is necessary to check residues to note the quality of recovery.

#### Specialist samples

These samples are usually collected by specialists and processed in the laboratory. In some cases, they can be subsampled to provide material for a number of different specialists. Specialist samples include:

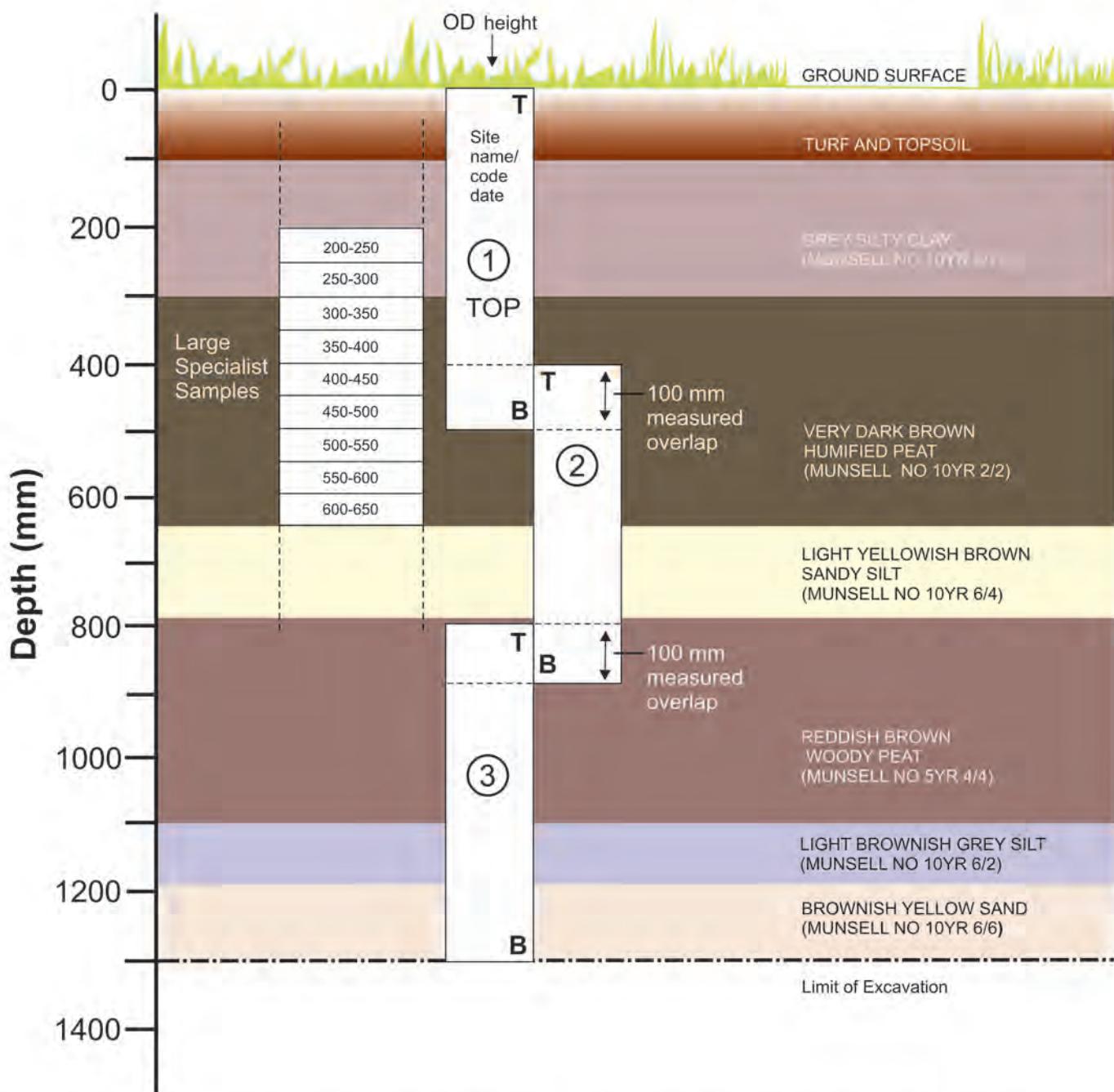
##### 1 Large samples

These are often collected from waterlogged/anoxic deposits for plant and invertebrate remains. The sample size is normally of the order of 20 litres. They can be taken from individual contexts or from vertical sections. In some circumstances larger samples will be needed, for example for the recovery of small vertebrates (small rodents, reptiles, etc) and for smaller marine molluscs. Generally, samples for land and freshwater molluscs, of the order of 2 litres, are collected from dry or wet deposits. Mesh sizes used in processing large specialist samples will vary according to the material to be recovered.



**Fig 8** Glastonbury Relief Road: monolith tins in peat deposits overlying estuarine silty clays. Note the overlapping tins, which enable researchers to take samples from undisturbed positions throughout the length of the sequence. The monoliths were sampled for pollen and diatoms. Additional specialist samples from the same deposits were analysed for insects, macroscopic plant remains and foraminifera (photo by V Straker).

# EXAMPLE OF SAMPLING FOR SEDIMENTARY AND BIOSTRATIGRAPHIC ANALYSES



*Radiocarbon samples - no thicker than 10mm. Samples for dating can also be taken from vertical monolith or monolith tin placed horizontally. These are sub-sampled in the laboratory as required. Tins in drawing are 500x100x100mm*

*Specialists will carry out more detailed sediment description in the lab when sub-sampling for analysis.*

T - Top of tin

B - Base of tin

*Position of samples should be marked on site section drawings. Large specialist samples - for waterlogged macroscopic plant remains, foraminifera, molluscs and insects. Number of samples, sample sizes and sample intervals should be advised by specialists.*

Fig 9 Schematic diagram for sampling.

## 2 Monolith samples

These are collected from vertical sections in monolith tins, square plastic guttering or Kubiena boxes. Samples taken in monolith tins and guttering can be subsampled in the laboratory for a range of analyses such as pollen, spores, diatoms and foraminifera (see section 4 Common types of environmental evidence). Kubiena boxes are usually made of aluminium or stainless steel, with lids on the front and back, and are specifically designed for collecting samples for the preparation of thin sections. Monoliths should be taken at a size suitable for the types of material being recovered. The sections from which they are taken can be drawn, photographed and described (Figs 8 and 9). For these reasons it is preferable to sample from sections.

## 3 Cores

Cores can be taken where it is not possible or desirable to collect monolith and specialist samples from sections. For further details on coring refer to the English Heritage Geoarchaeology Guidelines (2007). The size, type of core and coring method used should be carefully considered at the project design stage. Cores are most useful for the recovery of microfossils such as pollen, diatoms and testate amoebae (see section 4 Common types of environmental evidence).

## 4 Small samples

These can be collected separately from discrete contexts for certain items, such as ostracods (10–50g), and for geoarchaeological analyses, such as particle size determination. Small samples, usually 10–20 mm<sup>3</sup>, can also be taken for pollen and spores.

Certain types of material, such as larger bones and shells, will be mainly collected by hand during excavation and recorded through the finds system. The hand-recovered material needs to be assessed, analysed and considered along with that retrieved from samples.

### Recovering human remains

If human remains exposed on site are to be recovered, rather than left *in situ*, then the entire skeleton, or at least all of it that lies within the excavated area, should be recovered. After lifting the bones, the fill remaining on the floor of the grave should be recovered as three subsamples from the head, torso and leg/foot areas, and processed for the recovery of small bones and grave goods. Advice should be sought from a bone specialist before cleaning

and lifting whole skeletons and groups of articulated bones (whether human or non-human). Bones in articulation should be treated as a separate context, bagged and dealt with separately. Jaws with teeth should also be bagged as a unit, although preferably kept together with the other bones from the same context. Bagging as a unit will ensure that teeth, which might fall out during post excavation, in transport, etc, can be re-associated with their specific jaw.

All cremation deposits should be 100% sampled. Generally cremations should be half sectioned or dug in quadrants and excavated in spits, with each spit retained as a separate sample. Vessels from any urn burials should be block-lifted and x-rayed before being excavated and sampled. Larger crematory deposits, such as *busta* or pyre sites, should be excavated as multiple discrete samples. Any fragments of charcoal greater than 100mm should be recovered as individual samples and 3D recorded. Flotation samples can be used to recover plant remains and charcoal used in the cremation rite and associated rituals. Careful processing is required to minimise fragmentation of any cremated bone. Samples can be gently dry sieved over an 8mm or 4mm mesh to recover the large bone fragments and finds prior to flotation. For further guidance on the sampling of cremation burials and related deposits see McKinley and Roberts (1993) and Case Study 5.

### Taking samples

Samples should be taken from individual contexts, unless they are monolith samples that intentionally cross stratigraphic boundaries. Sometimes it is appropriate to sample thick contexts in spits of, for example, 50–100mm. Each sample must come from a cleaned surface, be collected with clean tools and be placed in clean containers.

It is essential that all samples are adequately recorded and labelled. A register of all samples should be kept. Sample records should provide information on sample type, reason for sampling, size, context and sample numbers, spatial location, date of sampling, as well as a context description and interpretation (eg grey-brown silt, primary pit fill, ?late Roman). The approximate percentage of the context sampled should be recorded where known.

Labelling must be legible, consistent and permanent. It is best to use plastic or plasticised labels and permanent markers. Samples in plastic tubs should be labelled twice on the inside and once on the

outside. Samples in polythene bags should be double-bagged, and labels placed inside both bags and on the outside of the outer bags. Bags should be tied securely with synthetic string. Specialist samples with an orientation, such as cores, monoliths and Kubiena boxes need to have the top and bottom marked, the depth within the sequence of the deposit, and the height above and below Ordnance Datum recorded. Overlapping samples must have their relationship noted. The position of samples should be marked on all relevant site plans and section drawings. Specialists might also wish to make sketches and take separate notes. Photographic records of sampling taking place can be extremely useful in providing a complete record of sample position and orientation (Fig 9).

All sample processing should be recorded on sample records whose format is agreed by the project manager, the specialists and the on-site environmental supervisor. Processing records should include sample volume (for coarse-sieved samples and flotation samples), context and sample number, mesh sizes used, the date processed and any other comments or observations that might be needed when the flots and residues are assessed or analysed.

### Sampling in difficult conditions

Sampling in the intertidal zone presents particular challenges, for example The Stumble, Blackwater Estuary (Murphy 1989). An example is also given in Case Study 6. Sampling is possible on underwater sites, for example by using very large monolith tins, which are raised to the surface and subsequently excavated, for example as at Bouldner Cliff (Momber 2004). Cores can also be taken as in the Arun palaeovalley project (Gupta *et al* 2007).

At some terrestrial sites where physical access is difficult (eg some cave and coastal sites) the volume of whole earth samples can be reduced by very coarse dry sieving or by hand-removal of larger stones, as at Tintagel (Straker 2007). Sample size is recorded on collection and again when the stones have been removed.

### Storing samples

Key points for storage are:

- 1 Keep samples cool; exclude light and air.
- 2 All relevant records need to be safe and accessible.
- 3 Avoid long-term storage.

Samples for laboratory processing should be collected by, or sent to, specialists as soon as possible. Once excavated, organic material becomes more vulnerable to decay

by micro-organisms such as bacteria, algae and fungi; it is not possible to prevent this completely, but the rate of deterioration can be minimised. The general rule is to maintain samples in conditions as close as possible to those in the ground (in which they were found): they should be kept chilled and dark, and, as far as possible, in airtight containers. This will slow bacterial and algal growth, although dark conditions might encourage the growth of fungi.

The growth of fungal hyphae (threads) through the sample can lead to redistribution of carbon. Light, however, will encourage the growth of algae and perhaps other green plants, which will (through photosynthesis) incorporate modern carbon into the samples. Both of these can affect the accuracy of radiocarbon dating (Wohlfarth *et al* 1998). These biological processes can also cause substantial damage to charred plant remains and even to bone. Therefore, samples should be processed as soon as possible.

It is not usually cost-effective to store unprocessed flotation or large specialist samples from dry deposits, as they take up a large amount of space. These should be processed as part of the data collection stage, but if there is no alternative, then they should be kept as described above.

Ideally samples should be kept in a cold store. A refrigerator is fine for small samples. For large samples an adequate substitute is a cellar or similar storage space. It should be as cool and dark as possible and not subject to fluctuating temperatures. Waterlogged samples should be well sealed to prevent drying out. If a waterlogged sample does accidentally dry out it should not be re-wetted, but left dry and a note put in the sample record stating that the sample had accidentally dried in storage.

Freezing samples can destroy or obscure sediment structure and should not be used where soil or sedimentological analyses are envisaged. However, freezing is preferable to storage in warm conditions, except for short periods, for highly organic deposits. Pre-treating highly compacted organic sediments by freezing prior to sieving has been shown to improve recovery and causes least damage to the delicate remains when compared with other techniques (Vandorpe and Jacomet 2007).

Guidance on the curation of waterlogged plant macrofossils and invertebrate remains is given in D Robinson (2008). Waterlogged wood should only be stored for short periods of time before it is recorded, as the longer it is kept in storage the worse its condition will become (Brunning and Watson 2010).

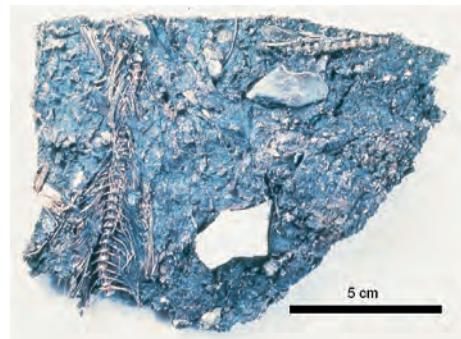
## 4 Common types of environmental evidence

The sections below describe the classes of material most often considered within environmental archaeology and when and where such material will be encountered. It summarises the potential information that analysis of these materials can provide. Identification of biological material should always be by comparison with modern reference specimens, although books and illustrations can sometimes be a useful aid.

### Vertebrate remains, excluding humans

The bodies of vertebrates are composed of various hard and soft tissues. Remains usually include bones, teeth, hair, eggshell and other such materials. Usually, it is only the hard tissues (bones, teeth, horncores and antlers) that survive (Figs 10, 11 and 12). The hard tissues are mixtures of organic and inorganic compounds. Inorganic mineral crystals of calcium phosphate are laid down in a lattice of organic protein (collagen). Although the collagen (which contains DNA; *see below Biomolecules*) is biodegradable, it is given some protection by the mineral component. Generally, skeletal elements with a high ratio of mineral-to-organic content, eg tooth enamel, survive better than those with a lower ratio, such as the bones of newborn animals. Calcium phosphate is more soluble under acidic conditions, so bones tend to survive best in alkaline to neutral deposits. Local microenvironments, such as shell middens, that raise the pH can enhance preservation at sites where most of the sediments are acidic. If bone is heated to  $\approx 600^{\circ}\text{C}$  or more (when it becomes white or ‘calcined’) the minerals recrystallise into a very stable structure. Calcined bone can be found at many sites where even tooth enamel has decomposed, although severe fragmentation often impedes identification.

Soft tissues usually only survive in extreme conditions, where bacterial activity is restricted, for example by freezing or by desiccation. In north-west Europe, the most common place for soft tissue preservation to occur is in acidic peat bogs, where waterlogging is accompanied by the effects of tannic acids. Keratinous tissues such as hair, hoof and horn can survive, as well as skin and, occasionally, internal organs and other soft tissues. All of these may become unstable when their burial environment is disturbed, and it is important that a conservator is consulted when soft tissue preservation is predicted or discovered. Leather (which is skin that



**Fig 10** Articulated fish skeletons, including herring (*Clupea harengus*) from early medieval waterfront deposits at St Martin Palace Plain, Norwich. Bones of herring, cod, eel and other fish are extremely abundant in refuse and latrine deposits at city sites, attesting to the importance of fish in the urban medieval diet. They are rarely found articulated, as here; usually disarticulated bones occur dispersed through the matrix of the deposit. Wet-sieving is necessary for effective retrieval (photo by M Sharp; © Norfolk Museums Service).



**Fig 11** Lower jaw of a water vole from a Bronze Age cairn at Hardendale, Shap, Cumbria. This was one of  $\approx 40,000$  bones recovered from wet-sieved, large specialist samples. Species included mice, voles, frogs and toads, birds and fish, and were probably deposited in owl pellets. The material was used to interpret the landscape around the cairn; scale = 10 x 1 mm (photo by T Woods).



**Fig 12** Late Neolithic antler pick from Marden Henge, Wiltshire. Scorch marks are visible (top right) where the antler has been heated to effect breakage at this point (photo by F Worley).

has been deliberately treated to enhance its preservation) often survives in waterlogged deposits. Its recovery, treatment and handling are covered by *Guidelines for the Care of Waterlogged Archaeological Leather* (English Heritage 1995).

Larger vertebrate remains, such as the larger bones of domesticated animals, are usually visible, along with artefacts, during excavation. To avoid collecting biased assemblages (Payne 1975), small bones (fish, small mammals, small birds, immature and small elements of larger animals), loose teeth and fragments of all

species need to be recovered from coarse-sieved or flotation samples (*see above* Sample types).

Animal bones are used in a very wide variety of studies (O'Connor 2000), most of which investigate how the presence of animal bones at an archaeological site relates to past human activities, beliefs and environment. Small vertebrate faunas have been used to characterise local habitats. At the Pleistocene site of Boxgrove the evolutionary stage of the remains of water voles was used as a proxy dating tool (M Roberts and Parfitt 1999). Other wild species, such as birds and fish, can demonstrate the range of habitats exploited, the season of exploitation, and the tools, equipment and techniques needed for their capture. This can be as important for urban developments (Coy 1989) as it is for hunter-gatherer sites (Mellars and Wilkinson 1980) or rural settlements (Nicholson 1998).

The development of domestic forms of livestock, and their relationships with their wild progenitors are still uncertain. Current research is developing the use of DNA techniques to address these questions, but DNA does not always survive well in archaeological material, and very specific questions are needed to justify the expense. More traditional studies, using analyses of skeletal size and shape, are beginning to show that regional and modern forms of domestic cattle and sheep developed much earlier than has been suggested by most of the documentary evidence (S Davis and Beckett 1999) (Fig 13).

Age and sex profiles are used in interpretations of how people looked after and utilised their domestic animals (Halstead 1998; McCormick 1998). When material from several related sites is available, complex investigations can be undertaken into people's access to, and treatment of, animal resources. Bond and O'Connor (1999) studied variations in economic and social status within a single town, while Maltby (1994) made comparisons between rural and urban settlements.

Hard skeletal tissues (bone, antler and ivory) have often been used as raw materials for craft working (MacGregor *et al* 1999). Other industries using animal products include horn working, tanning and parchment making (Serjeantson and Waldron 1989).

Although animals and their remains can be used in very utilitarian ways, they can also be a focus for ritual and religious beliefs and practices. Their remains have been found in special deposits at sites of various dates, including Romano-British temples (Legge *et al* 2000) and Iron Age settlement sites (Hill 1995). Also, they are often included in cremation rites and in burials (McKinley and Bond 2001; Worley 2009).

Animals were also used for social display. At Launceston Castle the social and economic fortunes of the castle and its inhabitants were reflected in their food waste. Other studies have shown how social status was communicated through food and through differential access to animals and animal parts (Albarella and Davis 1996;

Albarella and Thomas 2002; Sykes 2006).

Bird eggshell is preserved best where conditions are alkaline. It is surprisingly robust, although normally recovered in a fragmented state. Species identification is made through measurement and by description of internal structures and sculpturing in comparison with modern reference material (Sidell 1993). Large fragments of eggshell are not necessary, as all identification requires Scanning Electron Microscopy. Recently, research has shown that fossil eggshell is a particularly rich source of ancient DNA, which could be used to identify species and thus shed light on environmental changes, ancient diets and biodiversity (Oskam *et al* 2010).

Determining whether eggs were hatched can indicate the presence of a breeding population. As many species are selective about breeding grounds, eggshell analysis can assist in ecological reconstruction. It is also possible to examine the history of breeding patterns over time, by tracking the breeding grounds of individual species. The results from the Late Norse middens at Freswick Links, Caithness, Scotland, demonstrate the potential of eggshell analysis to answer these questions (Sidell 1995).

#### Human remains

Excavated human remains should always be treated with respect and decency. If an excavation is expected to disturb human remains, legal permission should be sought in advance from the Ministry of Justice. If human remains are encountered unexpectedly, prompt application should be made to the Ministry of Justice for permission to remove them. The coroner need not be informed of the discovery of human remains if they are properly interred in a recognised burial ground or if there is reason to suppose they are more than 100 years old.

On land currently under Church of England jurisdiction, ecclesiastical law applies in addition to the relevant secular statutes. This means that in most such cases permission to remove human remains needs to be sought both from the Ministry of Justice and from the relevant church authorities. Ecclesiastical permission is normally administered via the Faculty system (this applies to churches that have not been declared redundant, churchyards in current use and parts of municipal cemeteries). Some Church of England places of worship, such as cathedrals, and chapels at royal residences, lie outside the Faculty system and permission needs to be sought directly from the relevant authorities

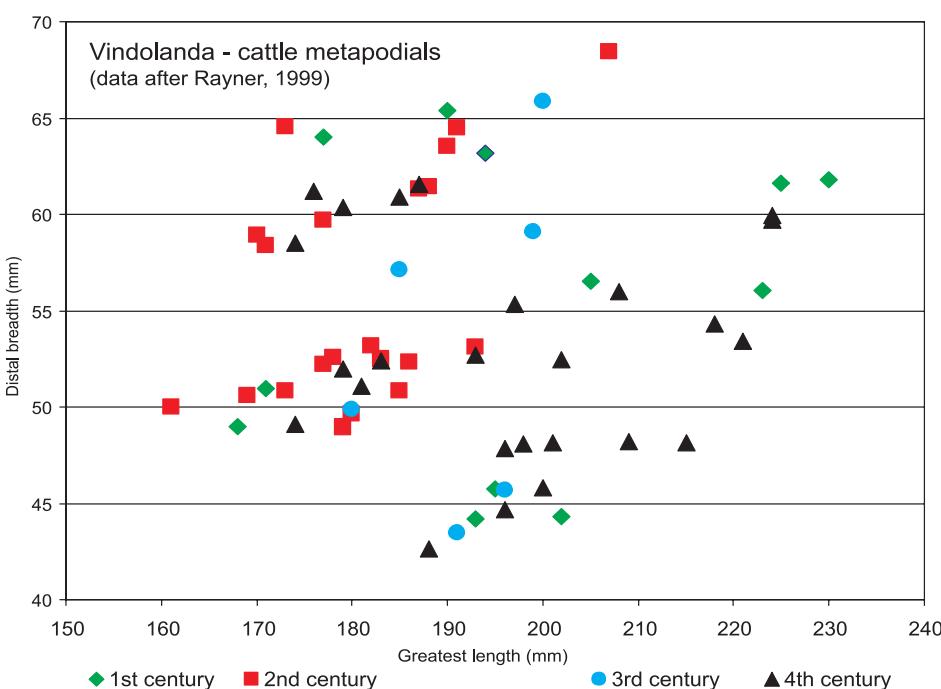


Fig 13 Measurement of animal bones can demonstrate changes in livestock through time, as here at Vindolanda on Hadrian's Wall, where larger animals are more common during the 4th century; while this might reflect local breeding programmes or the import of larger stock, changes in proportions of the sexes cannot be ruled out.

(the Dean and Chapter in the case of cathedrals). Ecclesiastical Law does not apply to monastic burial grounds, nor to most disused churchyards. The secular and ecclesiastical law surrounding the removal of burials is summarised in Mays (2005, 17–22), although note that since 2007 there has been a reinterpretation of secular law regarding burials by the Ministry of Justice, and the burial laws and their application to archaeology are currently under review (Tucker 2009; also <http://www.justice.gov.uk/guidance/burials.htm>).

Human skeletal remains normally pose no special health and safety risks. Where soft tissue is preserved, gloves should be worn. In dusty situations, it is sensible to wear a suitable filter mask covering nose and mouth; this applies particularly in crypts (Mays 2005, 45).

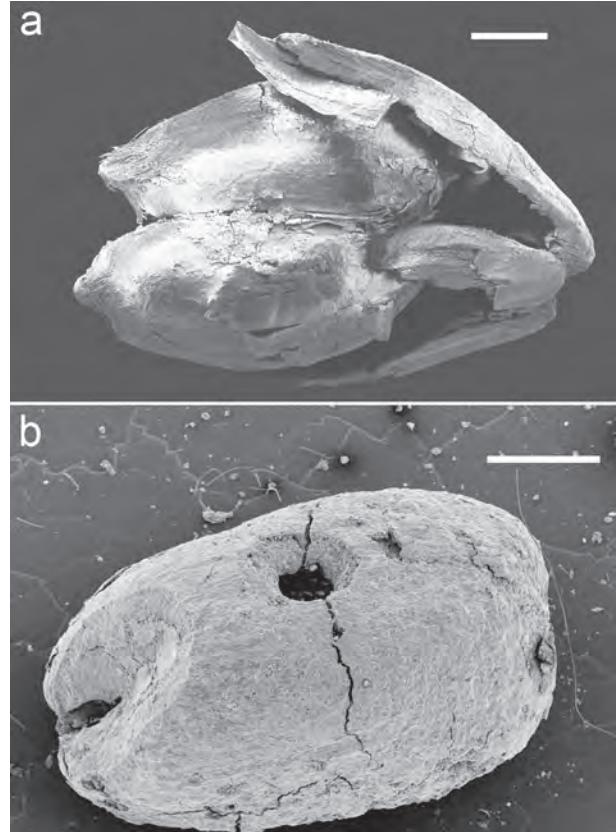
As with animal bones, soil acidity is an important determinant of human bone survival, with greater preservation being found in neutral or alkaline conditions. It is worth noting, however, that even in regions where natural soils are hostile to bone preservation, skeletal material often survives well in urban contexts, presumably because human activity has altered the character of the soils and sediments. As noted in Vertebrate remains (*above*), cremated bone tends to be more resistant to destruction than does unburned bone, so that it may survive well even in highly acidic soils where all traces of inhumed bone have vanished (*see Case Study 5*).

Scientific examination of human skeletons can provide information on the demography, diet, health and disease, growth, physical appearance, genetic relationships, activity patterns and funerary practices of our forebears (Cox and Mays 2000; Mays 2010; C Roberts 2009). To a lesser extent cremated bone can also tell us about some of these aspects, particularly funerary practices in relation to pyre technology.

The study of mortuary practices and ritual has been particularly important for our understanding of the prehistoric and early historic periods (Fig 14). Issues of ethnicity and migrations of peoples are also enjoying renewed interest. The larger assemblages available from the historic periods lend themselves to ‘population’-based studies. Important areas of enquiry include the rise of urbanism, the nature of monastic life, and the ways in which demography, health and disease changed over time as lifestyles altered in response to social, environmental and technological change. The study of human remains can also help us to understand the antiquity of some diseases.

Work on human remains increasingly involves stable isotope and DNA analyses (*see below Biomolecules*). Analyses of stable isotopes of carbon and nitrogen are shedding new light on early diets. Study of stable isotopes of strontium, oxygen or lead may help us investigate population movements in the past.

For reasons that are poorly understood, survival of DNA in buried bone is variable. Nevertheless analysis of DNA extracted from ancient human skeletal remains is beginning to improve our diagnosis of certain infectious diseases. It can also sometimes be of value in kinship studies, for studying relationships between populations and for sex determination where osteological indicators are missing or ambiguous.



**Fig 15** Cereal remains from the Danebury Environs Roman programme; scale bar = 1 mm. (a) charred spelt wheat spikelet from the floor of a 4th century corn drying oven; (b) spelt wheat grain showing evidence of insect attack by the grain weevil (*Sitophilus granarius*) (photos by G V Campbell).

#### Macroscopic plant remains

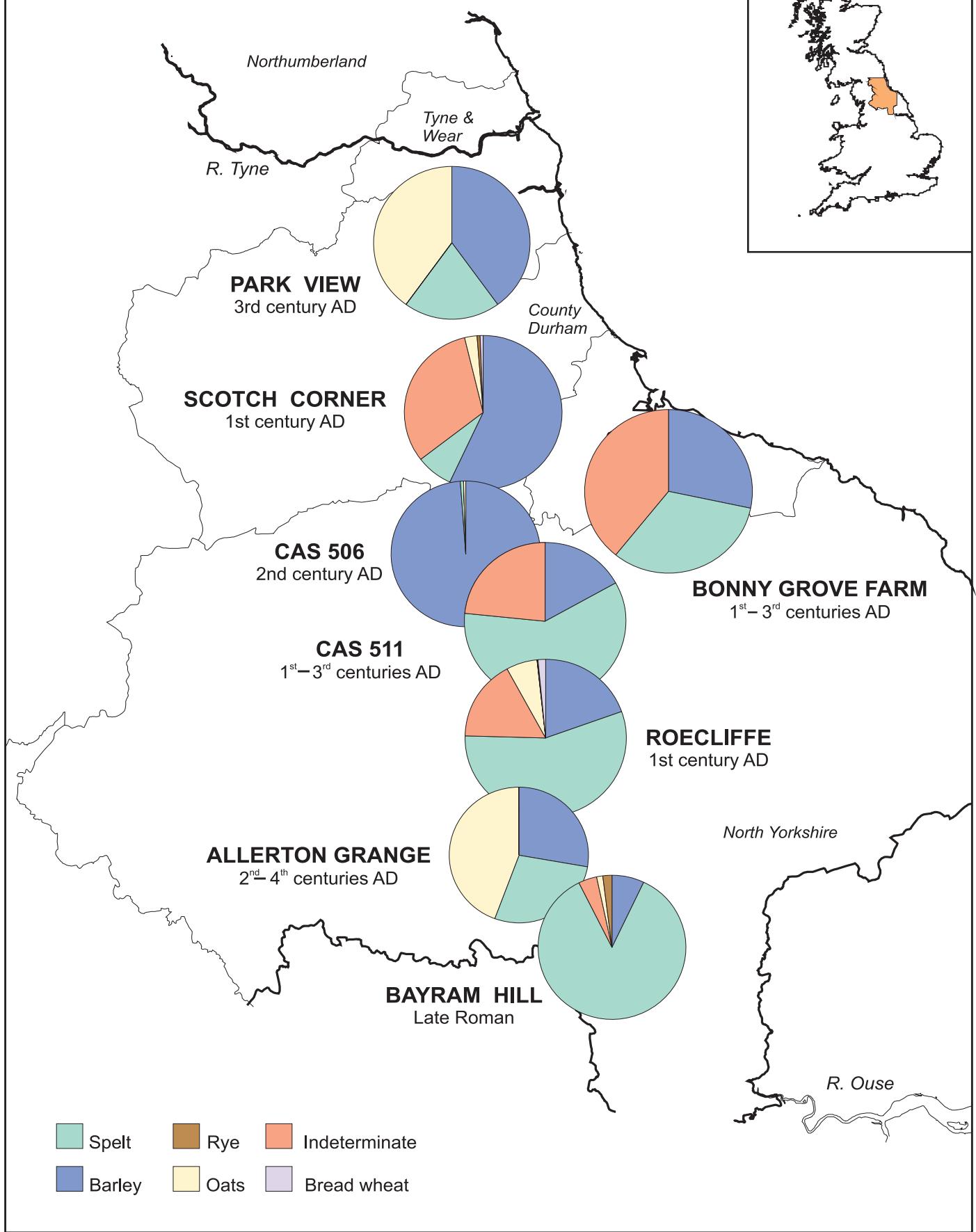
The remains of fruits, seeds, flowers, leaves, stems, wood and roots have all been found in archaeological deposits. Wood and charcoal are discussed separately, below. In Britain and the rest of north-west Europe macroscopic plant remains are most commonly preserved by charring, anoxic conditions (such as waterlogging), or by mineralisation (mineral preservation or mineral replacement). In buildings, preservation can also occur through desiccation, and by smoke blackening (eg in smoke blackened thatch; Letts 1999).

Charred plant remains are found on most archaeological sites. Preservation occurs when plant material is burned under reducing conditions. This leaves a skeleton, primarily of carbon, but sometimes also including residual starches, lipids and DNA. The carbon skeleton is resistant to chemical and biological attack, although vulnerable to mechanical damage. High temperature fires with a good air supply can result in loss of carbon, leaving only silica. Macroscopic silica remains of plants have been retrieved from ashy deposits at some sites (M A Robinson and Straker 1991). The majority of charred macroscopic plant remains are present as a result of human action. In most cases they provide information

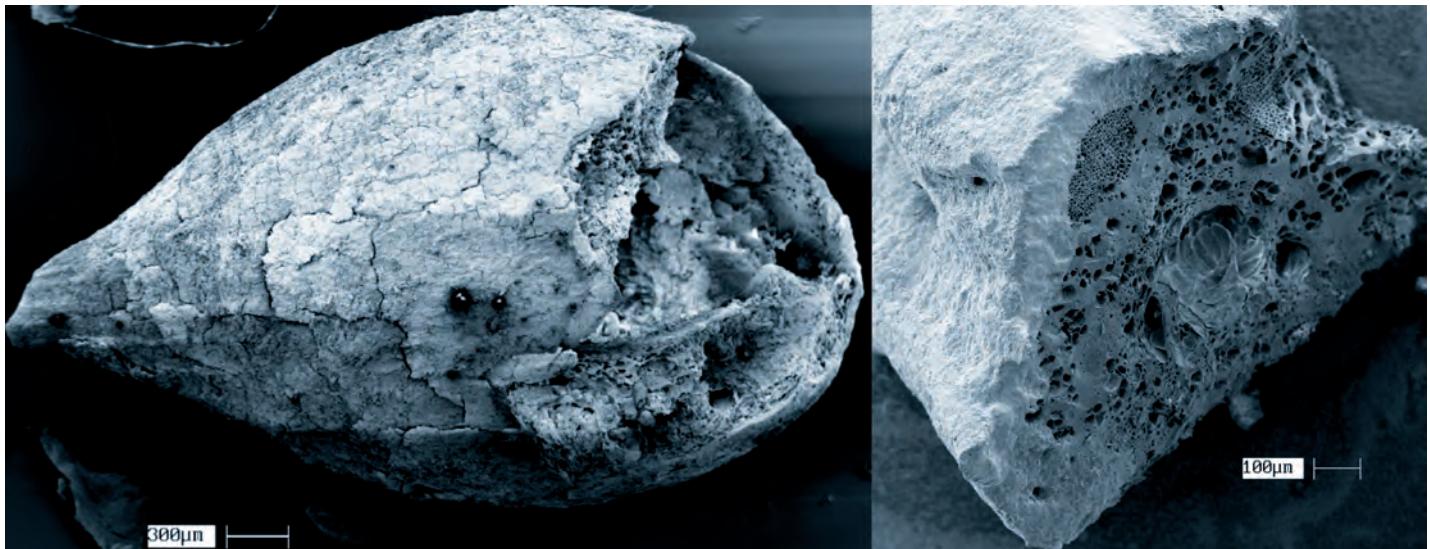


**Fig 14** Three burials found in a 3rd century AD pit at Stanwick, Northamptonshire (photo by S Andrews).

## NORTH EAST ENGLAND. ROMAN PERIOD: PERCENTAGE CEREAL GRAINS



**Fig 16** Charred plant assemblages can demonstrate both temporal and spatial patterns. In the north of England, during the Roman period spelt wheat is more common in the southern part of the region and barley in the north. There is also a suggestion that oats are more important at later sites.



**Fig 17** Charred tubers/roots from Iron Age deposits at Stanwick, North Yorkshire: left low-power, showing general shape: internal structure lost during charring process; right segment of swollen stem of a dicotyledon. This transverse section shows a concentration of xylem vessels, external to which are fibres, and, internally, a glassy area, which would have been the phloem. The collapsed central area would have been the pith (photos by D de Moulins).

reflecting the intensity of human activity involving fire. Therefore, scarcity of charred plant remains can, in itself, be useful information (Figs 15, 16 and 17).

Waterlogged plant remains are found in places where the water-table has remained high enough to inhibit destruction by decay-causing organisms. They can also occur in certain deposits above the water table if conditions are anoxic and highly organic, such as in the fills of pits lined with stone, dug into heavy clay, or sealed by overlying stratigraphy (Figs 18 and 19). Replacement of plant tissues with soluble phosphates and carbonates commonly occurs in cesspits (Green 1979; McCobb *et al* 2001), but can occur wherever these minerals are present and there is sufficient moisture to transport them into plant tissues. Close proximity to metal corrosion products can also preserve plant remains. Additionally, the roofs of late medieval and

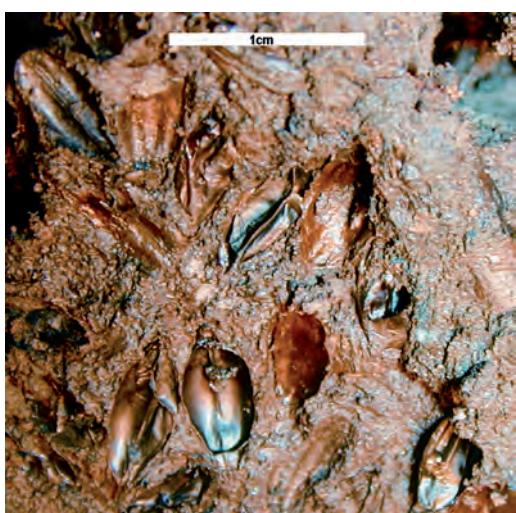
post-medieval buildings sometimes include the original thatch preserved by smoke blackening (Letts 1999).

Plant remains provide information on diet (Dickson and Dickson 1988; Greig 1983), social aspects of food (Veen 2003; Veen *et al* 2008), arable husbandry practices (Hillman 1981; Veen 1992), foddering of livestock (Karg 1998), the introduction of various non-indigenous plants (Greig 1996) and the reconstruction of local environments (Hall and Kenward 1990). They can also reveal details of landscape use, such as hedgerows (Greig 1994), and provide evidence for gardens and garden plants (Dickson 1995; Murphy and Scaife 1991). The use of plants in medicine,

in textile working, and in the fabric and furnishing of dwellings can also be detected. Sometimes specific activities can be identified, such as dyeing (Tomlinson 1985) or malting (Hillman 1982). Where documentary evidence exists, comparison with the archaeobotanical evidence can enhance interpretation (Foxhall 1998; Greig 1996). Distribution patterns of plant remains on sites are important to determine where different activities, especially refuse disposal, took place (*see Case Study 1*).

#### Wood and charcoal

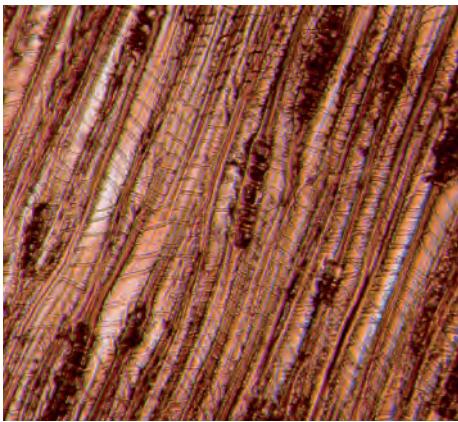
Wood is preserved by the same processes that preserve macroscopic plant remains (*see above*). Waterlogged wood can be little



**Fig 18** Cereal grains are most often preserved through being charred, but, under exceptional conditions, their waterlogged remains can survive. This is typical of deposits at Vindolanda on Hadrian's Wall (photo by J P Huntley).



**Fig 19** Moss fragments from the upper organic mound, Silbury Hill, Wiltshire dating to the late Neolithic (© English Heritage).



**Fig 20** *Taxus* (yew): tangential longitudinal section showing spiral thickening. This sample is from Roman deposits at The Lanes, Carlisle, where good evidence for craft woodworking was revealed (photo by J Jones).

more than a lignin skeleton supported by water, and de-watering in such cases results in rapid deterioration.

Recording wood, especially structures and objects, calls for close collaboration between a wide range of researchers: field archaeologists, environmental archaeologists, conservators, wood technologists, dendrochronologists, scientists concerned with radiocarbon dating, and museum curators.

Archaeologists involved with projects having the potential for waterlogged wood remains are advised to consult *Waterlogged Wood: Guidelines on the Recording, Sampling, Conservation and Curation of Waterlogged Wood* (Brunning and Watson 2010).

Studies of wood, both converted timber and roundwood, provide information on the management of woodlands and hedgerows. Such studies also give details of fuel sources, supplies of raw material for basketry and hurdles (Murphy 1995), wood use in buildings and boats (McGrail

1979), and information on trade and status (Cutler 1983). Worked wood can help us understand selection processes, preferences and woodworking techniques (Brunning and O'Sullivan 1997) (Figs 20 and 21).

Dated tree-ring chronologies for the UK extending back to the Neolithic have been produced from living trees, standing buildings, archaeological structures, bog oaks and 'submerged forests' (Hillam 1998), while wood from 'submerged forests' and river sediments provides independent data on the composition and structure of former woodlands (Lageard *et al* 1995; T J Wilkinson and Murphy 1995).

Charcoal is formed from the incomplete burning of wood. Depending on the temperature of burning and the supply of air, the charcoal can retain enough of its original physical structure and shape to be identified. If not subjected to physical stresses, charcoal (and other charred plant material) is durable and survives well in the archaeological record. However, this durability means that it can be re-worked and re-deposited within contexts. An understanding of the taphonomy of the charcoal in an assemblage is therefore essential.

Charcoal assemblages from hearth deposits or on industrial sites can provide information regarding use of particular species for fuel. This can, but does not necessarily, reflect the composition of local woodlands. The study of mean random reflectance of charcoal can be used to distinguish between low- and high-temperature processes (McParland *et al* 2009).

The widespread use of ash and oak for industrial processes, such as iron smelting, has been demonstrated by Gale

(1991). The examination of charcoal from cremation-related deposits shows that a restricted range of wood was used. This might have been based on practical considerations, but also might well have involved a ritual element (Gale 1997; Thompson 1999).

Microscopic charcoal should be routinely quantified from pollen slides. Very fine charcoal particles can be transported some distance from the scene of the fire. These can become incorporated into deposits in a similar way to pollen, and will survive the chemical processes of typical pollen sample preparation techniques. Concentrations of charcoal particles in pollen samples can therefore provide useful information on local burning of woodland and vegetation, and hence, possibly, human clearance (Simmons 1996).

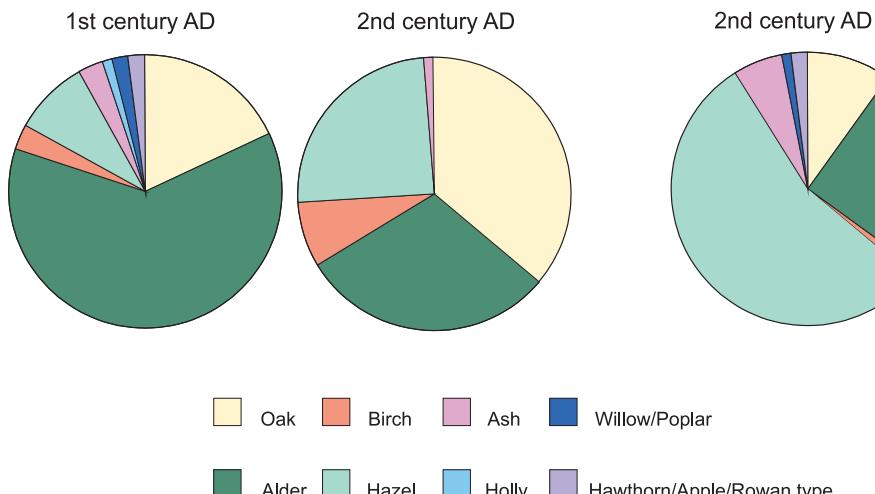
#### Pollen and spores

Higher plants produce pollen, while fungi and lower plants (eg ferns and mosses) produce spores. The ecological information gained from an assemblage depends on two things. One is the level to which pollen can be identified, and the other is how specific the taxa are in their environmental requirements.

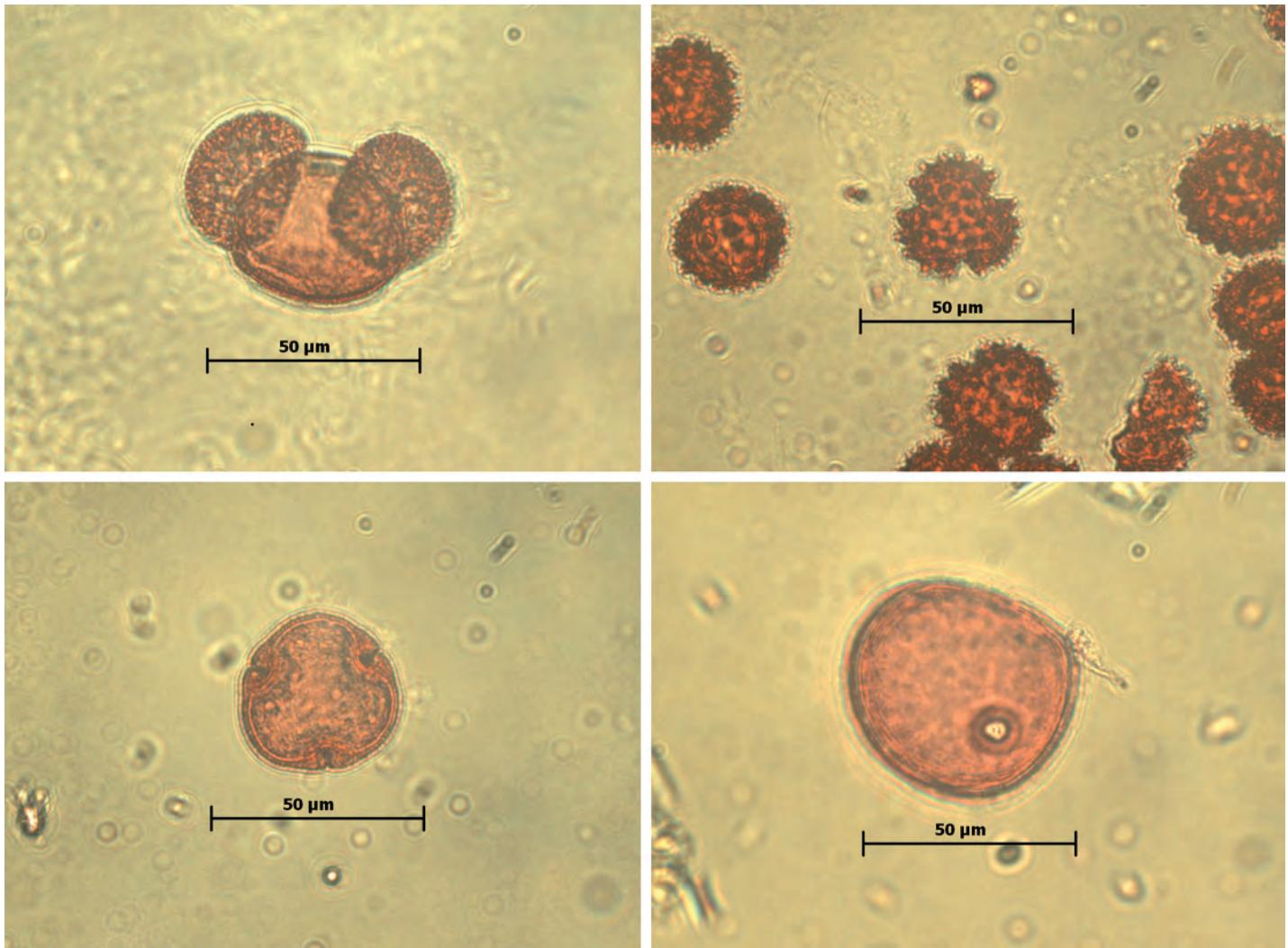
Examination of a number of features such as the size, shape, surface texture and number and type of apertures, facilitates identification of pollen grains (Fig 22). A number of keys exist for the identification of pollen and spores (eg Moore *et al* 1991) and further techniques have been developed for the separation of archaeologically and ecologically important taxa such as cereals and dwarf/silver birch (eg Andersen 1979; Clegg *et al* 2005). A reference collection is vital for checking difficult identifications and it is sometimes necessary to use higher magnification (x1000) to see fine details. Identification of moss or fungal spores is rarely attempted, mainly because of a lack of systematic study and the unavailability of reference material. However, Dr Bas van Geel and colleagues at the University of Utrecht have catalogued a wide range of non-pollen objects found in pollen preparations (Hoeve and Hendrikse 1998) so identification of these may become more commonplace in future.

Pollen grains are typically 25–120 µm in diameter, although the smallest (*Myosotis* species – forget-me-nots) are only 6 µm across. Pollen and spores survive best in acidic and anoxic conditions, such as peat bogs, some lake sediments, and waterlogged ditch and pit fills. Grains are not necessarily destroyed under

#### CARLISLE: ANNETWELL STREET



**Fig 21** Proportions of tree species in 1st and 2nd century Carlisle and 2nd century Ribchester (Lune Valley) derived from studies of waterlogged wood. Simple plots such as these can demonstrate differences that may be related to the natures of local woodland and/or woodland management practices.



**Fig 22** Pollen grains showing a variety of apertures and textures: (a) *Pinus sylvestris* (pine), (b) *Tilia platyphyllos* (lime), (c) *Aster tripolium* (sea aster), (d) *Triticum spelta* (spelt wheat). Pine pollen is dispersed over long distances due to the air sacs forming part of the structure. Large, heavy grains such as those of cereals are only dispersed over short distances (photos by Z Hazell).

other preservation conditions, but when analysing samples from less favourable environments it is important to consider the impact of differential preservation on the assemblage (see Hovinga 1984). Robust pollen grains tend to be overrepresented, while fragile types can be lost completely; it is useful to tally the levels and types of degradation to aid interpretation.

Owing to their small size, pollen and spores are widely disseminated by wind, rain and water, and they can be found at considerable distances from the parent plant. This causes challenges for interpretation, especially when considering the influence of vegetation from the wider landscape, as opposed to that of the immediate archaeological site or context. Comparison with the evidence from macroscopic plant remains can help to clarify matters.

Pollen from naturally accumulating sites such as bogs and lakes can be used to establish the nature of the landscape within which people lived and to identify human impact upon vegetation. The pollen assemblage accrued is affected by the size

and type of sampling site, the presence or absence of inflowing water, the nature of the surrounding terrain and the vegetation itself (Bunting *et al* 2008; Jacobson and Bradshaw 1981; Prentice 1988; Sugita 1994; Tauber 1967). In general, large sites within an open landscape are more likely to accumulate pollen representative of the regional vegetation, while smaller, enclosed sites will accumulate a local pollen record with a small regional component. Pollen from small archaeological features is also most likely to reflect local vegetation. It is therefore essential to choose sampling locations appropriate to the questions being asked.

In addition to considering pollen accumulation, interpretation also takes account of differential pollen production and dispersal mechanisms (Fig 22). Other factors include the non-linear relationship between the amount of pollen reaching the sampling point and how far the plant is from it. The patchiness of the vegetation within the landscape is also important. The combination of these factors makes interpretation of pollen diagrams challenging.

There have been various attempts to transform pollen data mathematically to make them more representative of the 'real' vegetation (M B Davis 1963; Prentice 1988; Sugita 2007a and 2007b). A slightly different approach uses simulated landscapes to produce hypothetical pollen data for comparison with actual palynological assemblages (Bunting *et al* 2008). Both approaches use modern analogues to estimate the pollen productivity and 'fall speed' of grains from various species. Modelling and simulation methods are a useful tool for interpretation, but are not a replacement for critical examination of the data; and there is almost always more than one viable interpretation based on the assemblage. The analysis of multiple profiles to better understand differences in pollen assemblages over short distances can overcome some of the problems inherent in interpreting pollen diagrams (Mighall and Chambers 1997).

Others aspects of pollen taphonomy should be also considered when interpreting pollen assemblages from archaeological deposits such as waterlogged

ditches, buried soils and pits. Ditches often silt up after the associated site has been abandoned, so pollen might not provide information about the life of the site. Soil processes (Tipping *et al* 1999) will affect pollen within buried soil profiles preserved under, for example, earthworks, or under naturally deposited alluvium or colluvium. Pits are quite likely to contain material from a variety of sources (Greig 1982), including rubbish and other material deposited by people. Copper salts from artefact corrosion can also preserve pollen by inhibiting decay (Greig 1989).

Some of the more unusual archaeological contexts from which pollen has been recovered include a Neanderthal ‘burial’ in Shanidar Cave, Iraq, where palynological evidence was used to infer the laying of brightly coloured flowers on the body (Solecki 1971), and the intestines of the Iceman, from which pollen was used to identify the environments in which his last few meals were eaten (Oeggl *et al* 2007).

In the past, pollen diagrams were frequently assigned dates on the basis of correlation with nearby dated sequences, but the variability of assemblages between and even within sites means that a programme of sampling for radiocarbon or other scientific dating will be necessary in order to interpret pollen data fully. The number of dates required depends on many factors, including peat/sediment accumulation rates, depth of sediment and the project objectives (*see* Case Study 3).

Depending on preparation techniques, other materials (eg charcoal particles, diatoms, parasite ova and tephra shards) might also be seen on the microscope slides used for pollen counts. These could

provide evidence complementary to the interpretation derived from the pollen spectra. If possible, pollen data should be compared with other environmental proxy evidence in order to gain a comprehensive understanding of deposits (Wiltshire and Murphy 1998). Changes in environment and stratigraphy are not always synchronous, underlining the importance of sampling below, at and above stratigraphic boundaries (Hosfield *et al* 2008, 44).

### Insects

Insects belong to the phylum Arthropoda, which are invertebrates with an exoskeleton and jointed limbs. Insects and certain other arthropods, such as arachnids, have exoskeletons of chitin, which are readily preserved under anoxic conditions. Examples of insects and arachnids found archaeologically include beetles, true bugs, mites, flies, fleas (Fig 23), caddis flies and chironomids. Beetles are the most commonly found and studied.

Disarticulated remains (eg heads, wing cases, thorax coverings, mouthparts and genitalia) can survive in most waterlogged sediments. These include fen and bog peat, lake sediments, palaeochannel alluvium, flood deposits, and the fills of pits, ditches and wells. Fly puparia, along with body segments of two other groups of arthropods, woodlice and millipedes, are sometimes preserved by calcium phosphate mineral replacement in latrines, for example at the Roman shrine at Uley, Gloucestershire (Girling and Straker 1993).

Insects live in most terrestrial, freshwater aquatic and maritime intertidal habitats. There are more species in the class Insecta than in all the rest of the animal

kingdom, and some have very narrow environmental requirements – for example feeding on a single plant species. Insects are particularly good indicators of climate change, as they respond rapidly to sudden changes in temperature. On Post Glacial (Holocene) sites they are useful for general palaeoenvironmental reconstruction, for providing details of past hygiene (eg lice and fleas) and living conditions, and for providing evidence of crop infestation. In rural situations, they are particularly useful for showing the character of woodland, the quality of water and the occurrence of domestic animals (M A Robinson 1991). In urban situations with deep organic stratigraphy very detailed reconstructions can be made of human environment and living conditions, as at Coppergate, York (Kenward and Hall 1995). Chironomids (non-biting midges) are particularly sensitive to changes in water temperature. Analysis of their larvae in waterlogged sediments provides a proxy-record of climate change (Sadler and Jones 1997).

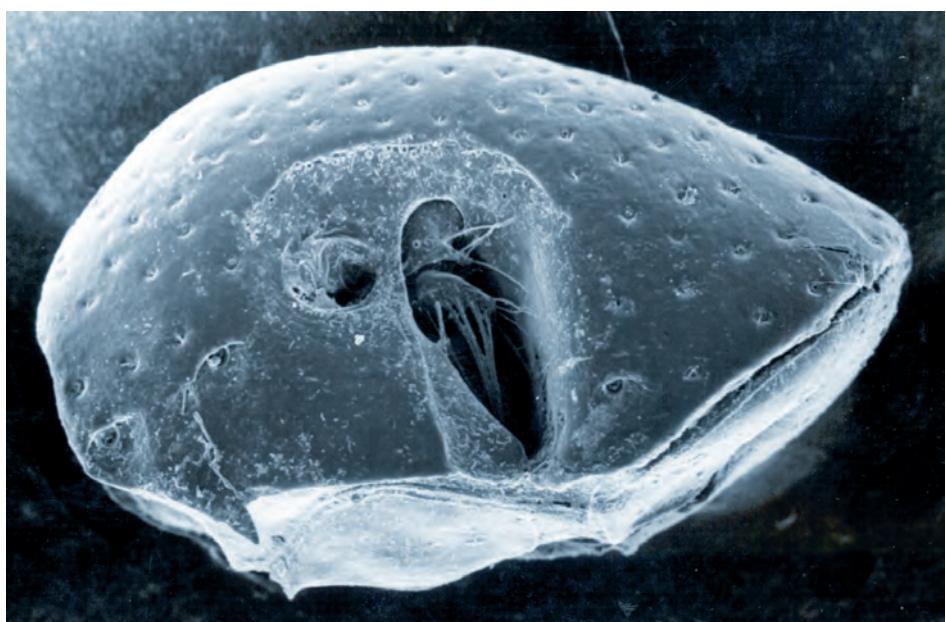
Reviews of all types of study are given by Buckland and Coope (1991), Kenward (2009) and by M A Robinson (2001).

### Molluscs (snails and shellfish)

Most molluscs build straight or coiled shells (gastropods) or paired shells (bivalves), and live in a wide range of conditions in water (fresh, brackish and salt) and on land. Each part of the land and coast usually has a characteristic range of snail species, and some species live only in specific conditions (such as damp woodland, short-turfed grassland, and brackish channels).

Mollusc shells provide an excellent means to reconstruct past environments and use of the land and coast, and to trace changes in these over time. Shells normally survive well enough for analysis in regions where the underlying rock produces neutral or alkaline soils (regions where pollen remains are usually less well preserved), but also in more acidic soil regions if the deposits were rendered neutral or alkaline by calcareous additions (sometimes by the shells themselves). Understanding the various mollusc species’ ecological requirements and factors determining their distribution is fundamental (Davies 2008), while processes affecting re-distribution following death and preservation after burial should always be carefully considered (Claassen 1998).

Mollusc studies for reconstructing land use and environmental change usually require specialist samples taken in vertical columns (see section 3 Samples, subsection

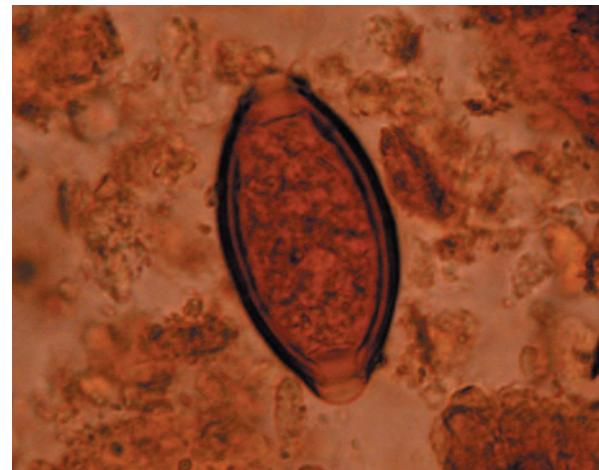


**Fig 23** Head of the human flea (*Pulex irritans*), a species characteristically recorded from floor deposits in Anglo-Scandinavian York (photo by H Kenward).



**Fig 24** (left) Dog-whelks from Le Yaudet, Brittany, showing the characteristic breakage pattern for extracting the gland for producing the dye, Tyrian purple. Whole, unbroken shells are pictured on the left (photo by G E Campbell).

**Fig 25** Egg of the parasitic nematode *Trichuris* recovered from an 11th-century deposit at Viborg, Denmark (photo by A Roeprstorff, originally published in Roeprstorff and Pearman 2006).



Specialist samples). Molluscs from alluvial sequences give important information on floodplain development and regional land use change (Davies 2008). Periglacial and tufa deposits are particularly useful in understanding environmental change during the Palaeolithic and Mesolithic periods. Mollusc studies can also trace the change in balance between woodland, ploughland and pasture in the Neolithic period, and the nature of the landscape in which Neolithic and later sites and monuments were set. For example, molluscan analysis (with other environmental evidence) showed that the Neolithic Easton Down long barrow in Wiltshire was sited at the transition between woodland and grassland. As molluscs reflect local vegetation, samples taken were from several locations (spatial sampling). The monument's setting would not have been detected from a single column of samples (Whittle *et al* 1993; Davies 2008).

The larger marine molluscs have been part of the human diet for millennia. Their study shows not only the sources of shellfish used for food in the past, but also the methods used to manage those resources and the impact of consumption upon wild populations (Winder 1992). Several English coasts have mounds of harvested shells (middens) from many periods, but few have been investigated in detail. Changes over time within a midden or site in the proportions and age structures of the harvested shellfish can reflect human exploitation (Mannino and Thomas 2001). Isotope studies on harvested shells have been used to reconstruct sea conditions (such as temperature and local salinity), showing the season of harvest and past climate (Mannino *et al* 2003). Harvested shells should be recovered at least in part by sieving sizable whole-earth samples, since hand-recovery is greatly biased towards the larger and more complete shells. Marine shells have been used for a range of other purposes, especially as personal adornments (beads, mother-of-

pearl). Clipped dog-whelks (like those from Morwenstow, Cornwall) show they were used to make purple dye (Light 1995) (Fig 24). Shells are also roasted to make lime for mortar, or incidentally imported (in seaweed and hay for fodder, in clay for daub and bricks, in marine gravel for construction), and their identification can source these materials (Murphy 2001).

#### Parasite eggs and cysts

The parasite eggs most commonly studied are those from intestinal nematode worms. As their reproductive cycle requires transport from the faeces of one host to the intestines of another, the eggs of some species are robust and resistant to decay. Some tapeworms produce resistant cysts as part of the resting stage in their life cycle. These survive well in archaeological deposits (A K G Jones 1982) (Fig 25).

Parasite eggs are small, up to c 60 $\mu$ m in length. They are often recovered from pit and ditch fills, but are also present in occupation spreads and general dumps. Most often they survive in wet deposits, but can sometimes survive in dry ones. Although parasites are often host-specific, in many cases the eggs themselves are not necessarily identifiable to species, limiting their interpretation.

Parasite eggs and cysts are used to provide indications of the health of individuals, if discrete coprolites are present (A K G Jones 1983), or of populations, if only amorphous faecal deposits survive (Huntley 2000). Their presence is also useful in identifying contamination by human and animal faecal waste.

#### Phytoliths

Phytoliths are microscopic bodies produced by many plants through the deposition of dissolved silica within or between plant cells and range in size from c 5–100 $\mu$ m. They are found mainly in the above-ground parts of plants and

are released when the plant tissues break down. The silica matrix confers resistance to decay and mechanical breakage, so phytoliths may survive where other plant remains do not. Only a high pH (>9) is detrimental to survival and can lead to differential preservation. A very good understanding of context formation is also required, as phytoliths occur naturally in the environment, although human activities can generate concentrations.

Phytoliths can be used to differentiate between broad groups (Tribes) of grasses (including cereals), and some wood taxa (Hodson 2002), but it is the identification of phytolith suites that has proved most useful. Examples using modern analogues include the identification of cattle and sheep dung and peat in the Outer Hebridean middens at Baleshare and Hornish Point; and differentiation between roof and floor deposits in Hebridean blackhouses (Powers 1994). Phytoliths have also been used to identify ancient agricultural fields in the Outer Hebrides (Smith 1996). Current research is investigating the potential of phytoliths for stable isotope reconstruction of past climates and arable practices (eg Hodson *et al* 2008).

#### Starch granules

Plants store energy within their cells as semicrystalline starch granules (polysaccharides). Edible storage tissues such as seeds, roots and tubers are especially rich in these microscopic granules, which have genus-specific morphology. Research has tended to focus on situations where little or no other evidence survives. Multidisciplinary studies of stone tool surfaces (eg Aranguren *et al* 2007) and dental calculus (Hardy *et al* 2009) can enable identification of processing activities and foods that may lack macrofossil evidence. Further research is required on how different granule types are affected by cooking and burial conditions.

**Table 5** Use of biological remains in reconstructing past wet environments

	temperature	salinity	nutrient status	water availability and/or depth	oxygen concentration	substrate	acidification
testate amoebae	—	✓	✓	✓	—	—	✓
diatoms	✓	✓	✓	✓	✓	—	✓
ostracods	✓	✓	—	✓	✓	✓	—
foraminifera	—	✓	—	—	—	✓	—
cladocerans	—	✓	—	✓	—	—	✓
chironomid larvae	✓	—	—	✓	—	—	—



**Fig 26** The diatom *Brachysira serians* showing four together in sets of two. This species can be used to help establish degree of acidification (photo by E Forster).



**Fig 27** Test of the foraminiferan *Globigerina bulloides* (380 µm spiral view). Foraminifera occur in marine and brackish water sediments and can provide information on the relationship of coastal sites to their contemporary shoreline, besides giving data on salinity levels, current velocities and marine flooding events (© Department of Earth Sciences, UCL, <http://www.ucl.ac.uk/GeoSci/micropal/welcome.html>).



**Fig 28** Burnham-on-Sea, Severn Estuary showing two peat shelves exposed after a gale. Sampling for both microfossils (such as pollen and foraminifera) and for plant macrofossils below, at and above the stratigraphic boundary showed that changes occurred to the environment before it was evident from the stratigraphy (Druce 1998) (photo by V Straker).

### Diatoms

Diatoms are freshwater and marine algae that have a resilient, silica frustule or chamber consisting of two valves. They are typically c 5–80 µm in size, though they can be larger. The silica frustules survive well in most depositional environments and can usually be identified to species level owing to their distinctive shapes and surface sculpturing (Fig 26). Shape and size are also distinguishing factors, but size ranges may be large. There are thousands of species of diatoms and reference material is not widely available, so most identifications are carried out with the use of keys featuring line drawings or photographs (eg Hartley 1996; Krammer and Lange-Bertalot 1991). Diatoms are usually counted using phase contrast and oil immersion at ×1000 magnification.

Species are habitat-specific and provide indications of water quality and depositional environment, such as temperature and salinity, nutrient and

mineral levels, acidity and degree of oxygenation, and whether the site was periodically dried out. Archaeologists use diatoms to address a range of questions (Juggins and Cameron 1999) (Table 5). They are perhaps most valuable in the investigation of coastal and estuarine sites, providing data on the extent of marine influence and phases of sea-level change. This is demonstrated by work on the central London Thames (Cameron in Sidell *et al* 2000) and on the North Somerset Levels (Cameron and Dobinson 2000).

### Foraminifera

Foraminifera are marine protists found in habitats ranging from salt marshes to the deep oceans. They secrete a shell called a test, which is the part that survives. This is composed of organic matter and minerals such as calcite or aragonite, or is agglutinated from a mixture of materials. Foraminifera survive best in non-acidic conditions. Ideally they should be analysed

in conjunction with diatoms, but this is not always possible. Foraminifera are particularly useful for the information they can provide concerning marine habitats such as levels and type of salt marsh present.

Oxygen isotope ratios obtained from foraminiferal tests in muds from deep ocean cores have provided data on global climate change (Wilson *et al* 2000).



**Fig 29** The ostracod *Limnocythere sanctipatricii* (female left valve, length 850 µm). This is a freshwater species associated with oxygen rich, nutrient-poor, cold, deep lakes (© Department of Earth Sciences, UCL, <http://www.ucl.ac.uk/GeoSci/micropal/welcome.html>).

More locally, the known habitat requirements of foraminifera can be used to reconstruct salinity changes. They are therefore particularly valuable at coastal sites, where changes in freshwater and marine influence are important. Foraminifera have been used in studies attempting to identify coastal reclamation, as, for example, at middle Saxon Fenland sites (Murphy 2000), and in the Severn Estuary Levels (Haslett *et al* 2000) (Fig 28). At a broader scale the study of foraminifera has made an important contribution towards the understanding of sea-level change (Haslett *et al* 1997).

#### Ostracods and cladocerans

Ostracods are small (normally <2mm), bivalve crustaceans with calcareous shells that grow by ecdysis – shedding their old shell and secreting a new one approximately twice the size. Ostracods inhabit nearly all types of aquatic environment from freshwater to marine. The robustness of their shells means that they survive in almost any non-acidic, water-lain deposit. Like foraminifera and molluscs, the shells of most species have unique shapes and sculpturings, making them readily identifiable (Fig 29). It is also possible to distinguish between male and female individuals within a species. Griffiths (Griffiths *et al* 1993), provides a useful summary of sampling, preparation and identification techniques.

Because of their size and the fact that samples of only 10–50g are required for analysis, ostracod analyses reveal subtle changes in environments, which might otherwise have gone unrecorded. However, the ecology of ostracod species is, in general, less well understood than that of molluscs and therefore, when possible, an integrated approach using these two groups should be employed.

Many physical and chemical factors influence the distribution of ostracod species, including salinity, temperature, water depth, pH, oxygen concentration, substrate and food supply (Griffiths and Holmes 2000). Application of this knowledge to Holocene and Pleistocene fossil faunal records has enabled researchers to reconstruct a broad range of palaeoenvironments (eg E Robinson and Straker 2004).

Ostracod analysis should be considered as a useful technique to complement mollusc, diatom and foraminiferan analyses where water-lain deposits are identified during archaeological investigations (eg ditches, moats, fishponds), or as part of general palaeoenvironmental

reconstruction (eg coastal evolution, relative sea-level changes, general water resource issues).

Ostracods studies from the Roman fortress ditch in Exeter, Devon, suggested periods of standing water, but with somewhat polluted conditions, resulting in a restricted fauna (E Robinson 1984). They were also used for environmental reconstruction in the Fenland Management Project (Godwin in Crowson *et al* 2000).

Cladocerans, a group of small freshwater crustaceans, are often found on archaeological sites and are also occasionally used in reconstruction of freshwater environments. They are useful in determining whether contexts held water (Kenward 2009; Polcyn 1996).

#### Testate amoebae

Testate amoebae are microscopic (15–300µm) protists (Protozoa: Rhizopoda) composed of a single cell protected by an outer shell or ‘test’. The tests are either self-made (secreted smooth or plated forms) or formed from particles incorporated from the substrate (eg diatoms, pollen or sand grains). The tests are readily preserved in organic sediments and are identifiable to species or species-group level (Fig 30). The preparation technique used for studying testate amoebae is relatively simple, particularly when compared with other microfossil methods (Charman *et al* 2000).

Testate amoebae inhabit wet environments and commonly live in the water film around soil particles. Many species have specific environmental

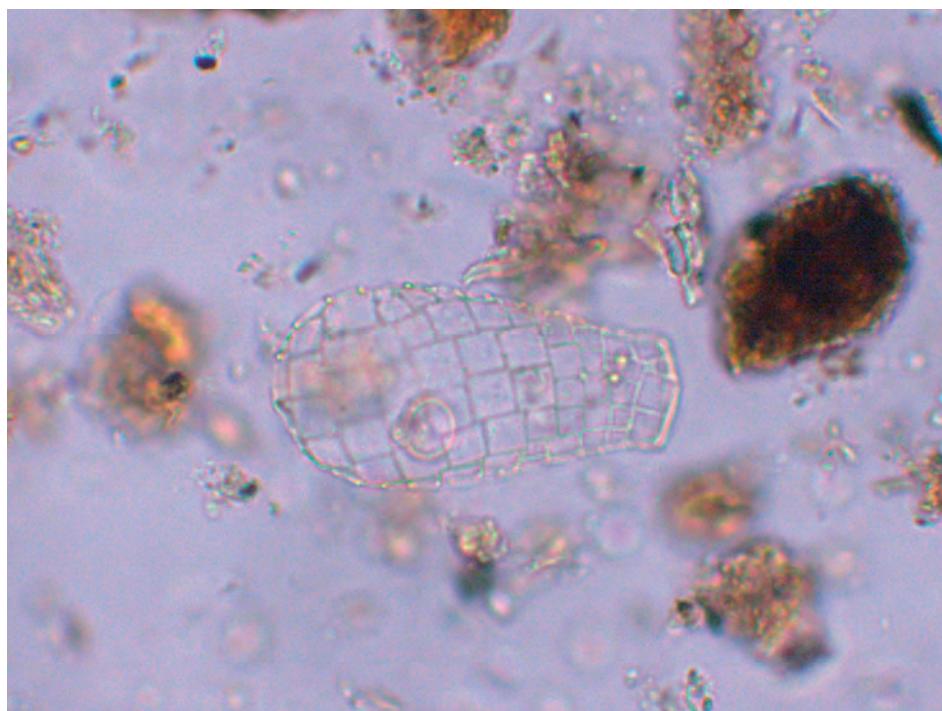
tolerances, and are particularly sensitive to water availability (often expressed as ‘percentage moisture content’ or ‘depth to water-table’), but also respond to other variables, including pH and nutrient status (Tolonen *et al* 1994). Some research has also focussed on the potential of testate amoebae as sea-level indicators (Blundell and Barber 2005; Mauquoy and Barber 1999).

Interpretive studies involve measuring the environmental variables of modern testate amoebae habitats, from which a mathematical model (‘training set’) is created. This data is then used to derive a ‘transfer function’ – a model used to quantitatively reconstruct a specified palaeo-variable, based on the assemblages of subfossil testate amoebae preserved within the stratigraphy (Charman *et al* 2007; Woodland *et al* 1998;). For peatlands, the most commonly reconstructed variable is one of moisture availability and this can sometimes be used to infer palaeoclimatic conditions too.

In an archaeological context, reconstructed moisture values can be used to investigate the effect of hydrology on human activities and vice versa. For example, palaeomisture records are useful for exploring causes of changes in settlement patterns, such as site abandonment owing to waterlogging (Amesbury *et al* 2008).

#### Isotopes

The use of isotope analysis for the reconstruction of past human diets (Lee-Thorp 2008) and population movement



**Fig 30** The testate amoeba *Quadrilella symmetrica*. This species is an indicator of wet and nutrient enriched conditions (photo by Z Hazell).

(Montgomery *et al* 2007) is becoming increasingly prevalent. Chemical elements often come in different forms, or isotopes. Some of these are stable while others, like radiocarbon ( $^{14}\text{C}$ ), are unstable and decay with time. Quantification of isotopes is usually expressed as a ratio and is often expressed as a delta ( $\delta$ ) value in comparison to an international standard such as atmospheric nitrogen (Sealy 2005). Ratios of some pairs of stable isotopes relate to factors such as ambient temperature, local geology, drinking water or food. Fractionation of isotopes occurs through processes such as photosynthesis (carbon), evaporation (oxygen) and ingestion (strontium, oxygen, carbon and nitrogen).

Living tissues such as bones, seeds and wood contain carbon and thus can provide samples for radiocarbon dating. The basis for this is that when an organism is alive it absorbs carbon from the atmosphere and from food and water, but no further carbon is absorbed after death. The ratio of unstable carbon fourteen ( $^{14}\text{C}$ ) to stable carbon twelve ( $^{12}\text{C}$ ) in the deceased organism changes over time as the  $^{14}\text{C}$  decays, and because the rate at which  $^{14}\text{C}$  decays is known, the ratio of  $^{14}\text{C}$  to  $^{12}\text{C}$  provides a measure of the length of time since the organism died. Burned remains can be used since the carbon isotope ratios are not altered by heat, but care must be taken if animals ingested marine resources.

Seas are repositories of ancient carbon (often referred to as the ‘marine reservoir’) and marine organisms such as fish incorporate this into their bodies. Radiocarbon ratios from individuals who have eaten a significant proportion of marine-based foods will be biased by this old carbon and compensatory algorithms need to be applied. The routine measurement of carbon and nitrogen stable isotope ratios when dating human bone should be undertaken to quantify potential offsets due to diet (Bayliss *et al* 2004).

The advantage of carbon and nitrogen stable isotope analysis for human dietary studies is that it reflects the foods actually consumed by individuals over the time of tissue formation. Food chains can include several stages of fractionation (eg a plant photosynthesises sugar using sunlight, a herbivore then eats the plant, then a carnivore eats the herbivore). Some organisms (such as fish) can have very long food chains. Carbon ratios differ between foods from certain environments such as plants with different photosynthetic pathways (C3 and C4 plants) or between terrestrial and marine ecosystems (Schwarz and

Schoeninger 1991). Values for  $\delta^{15}\text{N}$  increase systematically up a food chain and therefore provide an indicator of plant versus animal protein in the diet, but they cannot distinguish between meat and dairy products from the same animals (Ambrose 1993). Studies investigate the relative proportions of plant and animal proteins, and potential sources of food such as C3 (most terrestrial species) or C4 plants (some tropical and desert plants, including maize), marine or coastal resources. These may vary according to sex, age and status (Richards *et al* 1998). Investigations should include control samples in order to provide local standards for comparison with the human isotope ratios. Controls should include animals with known diets such as ‘pure’ herbivores and ‘pure’ carnivores. Once incorporated into an organism’s tissues, stable isotope ratios become fixed, indicating conditions that existed when the individual was alive or when those particular tissues formed. The most stable and reliable materials used for analysis are bone collagen, tooth enamel and dentine. Bone apatite can be used but there is a large risk of post-depositional changes due to the fluid nature of the apatite structure, and consequently a risk of misinterpretation of the signatures. Tooth enamel and dentine are far less soluble than bone apatite and the isotopic composition changes little through life or during deposition (Mays 2000). Work with plant tissues is still under review. Burning does affect the ratio between carbon and nitrogen in tissues. Therefore studies can be undertaken on inhumations and unburnt animal bones but not on cremated bone.

The use of carbon and nitrogen stable isotope ratios in bone collagen to reconstruct human diet has been used, for example, for individuals dating from the Upper Palaeolithic (Richards *et al* 2000), Iron Age (Jay and Richards 2006), and Anglo-Saxon–post-medieval periods (Müldner and Richards 2007). It has also been applied to investigate the diet of animals in the medieval Royal menagerie at the Tower of London (O’Regan *et al* 2005) and to the role of salt-marsh and coastal exploitation by farming communities (Britton *et al* 2008).

Oxygen ( $^{18}\text{O}$  and  $^{16}\text{O}$ ) and strontium ( $^{87}\text{Sr}$  and  $^{86}\text{Sr}$ ) isotopes (sometimes with lead, sulphur or hydrogen) have been studied less often than carbon and nitrogen, but their use is increasing. They are used to investigate geographical origins and mobility of humans and animals. Strontium ratios are dependent on geology,

and hence geographical area, while oxygen typically reflects the isotopic composition of drinking water. By combining oxygen isotope data on climate zones with strontium isotope data it is possible to place constraints on the geographical origins of individuals and reconstruct journeys they made during their lifetimes (Evans *et al* 2006). Teeth are particularly important, not only because the enamel preserves an isotopic ‘signature’ typical of the place of residence in childhood, but also because enamel is for the most part resistant to post-depositional decay. Bone tissues continually remodel throughout life and may reflect an average of isotopes relating to the last years of life. This enables a comparison to be made between where an individual was born (teeth) and where they spent the end of their life (bones) (Evans *et al* 2006; Schroeder *et al* 2009). It is easier to demonstrate that a person is, or is not indigenous, to where their skeletal remains are found, than to demonstrate where they came from (if they are not local). This is because geological strata can be widespread, and climatic zones can also be rather large. The other isotopes are usually brought into a study at a later stage (if necessary) to try to narrow down the range of geographical possibilities.

Oxygen isotopes can be used on their own in palaeoclimatic studies using animal remains such as bones, shell and microfossils. Ratios of oxygen isotopes ( $^{16}\text{O}$  and  $^{18}\text{O}$ ) in bone or shell relate to the water they ingest and to the mean annual temperature. Early oxygen isotope studies investigated long-term climate changes recorded in the shells of minute marine organisms found in deep-sea sediments or in ice cores, as frozen water contains oxygen. In the oceans, evaporation of water preferentially removes the lighter isotope of oxygen ( $^{16}\text{O}$ ). The isotopic signature of oxygen found in shells of sea creatures therefore reflects the temperature conditions at the time of tissue formation. Carbonate-rich lake sediments provide similar deposits, but usually cover shorter (mainly Holocene) time spans. Oxygen studies are now being applied to skeletal tissues of terrestrial animals and are particularly relevant to climatic reconstructions for the Pleistocene and early Holocene (R T Jones *et al* 2002; Stephan 2000).

## Biomolecules

The development of highly sensitive analytical techniques has enabled small quantities of biomolecules, preserved in archaeological remains, to be extracted and characterised. Biomolecules include:



**Fig 31** Deep peat sections at Wells Road, Glastonbury: monolith and specialist samples being taken for biological analyses (photo by R Brunning).

- lipids (oils, waxes and fats);
- proteins (eg blood and milk);
- DNA (deoxyribonucleic acid).

Factors influencing the preservation or decay of biomolecules in ancient materials are complex. The best preservation conditions are stable, cool, dry environments with a neutral pH. Lipids tend to survive best, followed by proteins and then DNA.

Lipids and proteins can be absorbed into the fabric of an object, and lipid residues are thus often used in the characterisation of organic matter associated with artefacts such as pottery vessels. Lipids and proteins therefore provide information about food products (such as plant oils and waxes, and animal fats) and raw commodities used in antiquity. Lipids in anthropogenic soils, sediments, human, animal and plant remains can also be analysed (Copley *et al* 2003; Evershed *et al* 2001; Stern *et al* 2003).

The identification of blood proteins on stone artefacts is a controversial issue in archaeology, with different techniques producing inconsistent results, or results that conflict with other archaeological evidence (Downs and Lowenstein 1995; Fiedel 1996). While protein radioimmunoassay techniques are improving they have yet to be applied to ancient blood residues (Reuter *et al* 2006). Work on casein, a milk protein, has been more successful. It has been possible to detect the presence of milk residues in pottery (Craig *et al* 2000).

DNA encodes the genetic information of an organism, so ancient DNA is an important source of palaeogenetic information. It has been used to examine human evolution, migration and the social organisation of past communities (Stone 2008), to identify disease organisms (Donoghue 2008), and to investigate the origins and evolution of domesticated animals and plants (Larson *et al* 2007, Li *et al* 2010).

Before undertaking any work on biomolecules it is necessary to take specialist advice. While protocols are being developed (eg for lipid analysis Heron *et al* 2005) researchers need to consider potential contamination, the likelihood of preservation of suitable compounds and the potential contribution of the proposed study to archaeological knowledge.

It should be emphasised that, for skeletal remains, no bone samples for biomolecular work should be taken before the remains in question have been recorded by an osteologist. In particular, and contrary to popular belief, problems with contamination do *not* dictate removal of bone for DNA analysis as soon as remains are uncovered in the field. Although handling will contaminate bone surfaces with modern DNA, most of those who work with DNA circumvent this problem in the laboratory, principally by taking samples from the internal parts of bones or, more especially, teeth. This enables successful studies to be made on specimens that have been handled (*see* section 4 Common types of environmental evidence, subsection Human remains).

## Geoarchaeology

For more details see *Geoarchaeology Guidelines* (English Heritage 2007).

Geoarchaeological studies can significantly enhance archaeological interpretations by making it possible for archaeologists to determine the effects of earth surface processes on the evidence for human activity at various different scales, and by providing evidence on soil resources for food production. Thus, the aims of most geoarchaeological work are the understanding of both site formation processes and landscape changes. The focus can range from the microscopic examination of a junction between two contexts, to sediment logging or soil survey across a whole landscape (Cloutman 1988; K N Wilkinson *et al* 2000).

Geoarchaeology typically examines both soils and sediments, so the distinction between these two material types needs to be clear from the outset:

**1** Soils are bodies of sediment or the upper part of solid rocks that have been altered by surface processes such as weathering, and by bioturbation, including both root growth of plants and disturbance and digestion by animals. Buried soils are generally only found beneath earthworks or peat, or under rapidly accumulating sediments such as alluvium, where they represent former ground surfaces. In some circumstances, they can provide information about past environments and land use, while in others, they help in understanding the overlying remains; for example, was the area of a barrow deturfed before construction?

**2** Sediment is a broader term covering all material that has been transported by one or more processes, for example flooding, colluviation and wind. People are also agents of deposition through such activities as terracing, building earthworks or levelling uneven surfaces.

Studying soils and sediments can also inform archaeologists on other processes that modify stratigraphy, such as erosion, burning and cultivation. Such studies are thus integral to both the formation and the alteration of the site, underpinning stratigraphic interpretation in any archaeological project.

## Stratigraphic and landscape studies

Examination of stratified deposits on site is the single most important method for studying site formation processes, with laboratory techniques only necessary

in some cases. A full knowledge of sedimentation processes, weathering effects, soil formation, bioturbation and taphonomy has to be interwoven with the available cultural information to provide an integrated understanding of how the site formed. This understanding also forms the basis for sampling designs involving other geoarchaeological and palaeoenvironmental techniques. It is essential, therefore, that there is close agreement between the geoarchaeologist and the site director on the detail of interpretation.

Fully understanding site formation processes and soil resources should involve studying the relationship between a site and its surrounding landscape. How, for example, is sediment being delivered to an alluvial site, and what pattern does this show over time? Various forms of geomorphological survey, soil survey and sedimentary mapping have been valuable adjuncts to site studies in some cases (Howard *et al* 2001). Geoarchaeology might also involve studying the resources that would have been available to people in the past. For example, where were the best agricultural soils in relation to the site (Barker and Webley 1978) and what would people have been able to grow?

#### Chemical and physical analyses

The survey of various topsoil chemical characteristics over all or part of an excavation is a fairly widespread geoarchaeological technique. Chemical analysis can be used to provide quick multi-element maps of sites for prospection purposes (James 1999), while other analyses concentrate on particular groupings, such as heavy metals in alluvium near centres of mining (Hudson-Edwards *et al* 1996). The most popular chemical surveys are those measuring phosphate levels. The relative immobility

of phosphates in the soil means that current levels can reflect the sum of past biological and fertiliser inputs to the soil system and lateral redistribution caused by deposition of human or animal wastes. Hotspots can be located by grid surveys and inferences can be made by comparing archaeological fills with blank areas.

A number of laboratory analyses can be applied to soil and sediment samples to answer questions relating to stratigraphic or taphonomic processes (Reynolds and Catt 1987). The most common examples are determination of calcium carbonate, pH and percentage organic carbon content. Recently, biochemical residues of biological materials in the soil have also received attention (Simpson *et al* 1999a), but this last approach is still at the research stage.

#### Soil micromorphology

This is the term applied to the microscopy of whole blocks of soil or stratified deposits. Various methodologies make possible detailed examination of accumulations, rearrangements, contacts and residual materials in what amounts to a microscopic analogy for normal stratigraphic interpretation (Davidson and Simpson 2001; Milek 1997). The most common of these methods is the thin section viewed in two forms of polarised light – a system that provides an intact view of the microstratigraphy with recognition of many soil constituents, including fragments and residues of materials resulting from or influenced by human activity. The technique offers potential for examination of detailed issues, such as individual depositional events (Matthews *et al* 1997) and use of domestic space (Simpson *et al* 1999b). The necessarily small sample size means

that the method is only really effective when dealing with clear questions refined from the larger-scale stratigraphic problems (French and Whitelaw 1999).

#### Mineralogy

The sand and silt fractions of soils and sediments are made up of a number of different minerals, dominated, in much of the British Isles, by quartz and calcium carbonate, but also including uncommon minerals such as zircon and tourmaline, which are resistant to weathering. These rarer minerals can be identified, depending on size and concentration, by heavy mineral analysis or by X-ray diffraction. Some might be significant to site development insofar as the differences can reflect different sediment sources (Catt 1999). Whole rock fragments can also be identified, which can also assist in sediment sourcing work.

As well as these primary minerals, secondary minerals (those formed *in situ*) and biominerals (those produced by organisms) are starting to play a part in the interpretation of stratigraphic and taphonomic issues at some sites (Canti 2000).

#### Particle size analysis

Particle size analysis is a technique that produces quantitative data on the proportions of different grain sizes in a soil or sediment, where ‘finger-texturing’ only gives approximations. The more exact values are not needed for the majority of interpretative uses. Particle size analysis is valuable, however, where processes that changed the soil texture are suspected to have occurred, where sediments have been used for construction (Davidson 1973), or where sediment sourcing affects our understanding of formation process (Canti 1999). Particle size analysis also provides a definitive record for future comparative purposes.

# Case Study I Consequences of not assessing all the samples taken for the recovery of charred plant remains Jacqui Huntley

The following case study demonstrates the importance of assessing all of the samples taken and the different interpretation offered 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. The site lies quite close to the major henges at Thornborough: 110 samples were collected from these pits, ranging in volume from 6 to 28 litres. It was known from the outset that full analysis 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

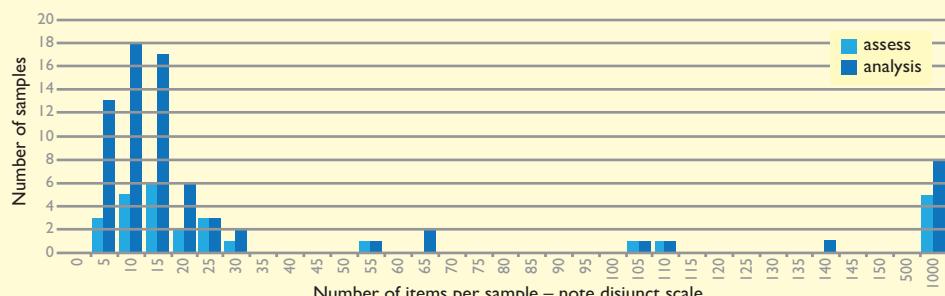


Fig CS1.1 Comparison of samples chosen for assessment with the total dataset.

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 (ie 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.

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 (Fig CS1.1). 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 (Table CS1.1). 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).

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.

Table CS1.1 Full data counts from the analysis phase for samples with cereal remains. Samples are split into those that were initially assessed then analysed and those that were just analysed. Initial assessment was done on a subjective abundance scale for each type of charred plant remain.

## Assessed then analysed samples

context	6205	6207	6618	6650	6655	6667	6634	6634	6634	6634
sample	–	–	–	–	–	–	1	4	5	6
Cerealia indeterminate	2	3	–	1	–	–	–	–	–	–
<i>Hordeum</i> undiff	–	–	1	1	1	1	–	–	1	1
<i>Triticum dicoccum</i>	1	–	–	–	1	5	3	4	–	–
<i>Triticum</i> sp.	–	8	–	–	–	8	–	–	–	–
<i>Triticum</i> sp. spikelet fork	–	–	–	–	–	–	1	–	–	–

## Analysed samples

context	6535	6582	6598	6604	6610	6624	6661	6750	6771	6776	9119	9130
Cerealia indeterminate	–	4	1	–	–	–	1	1	–	–	5	1
<i>Hordeum</i> hulled and naked	–	–	–	–	–	–	–	–	>1000	–	–	–
<i>Hordeum</i> undiff	–	–	–	–	–	–	–	–	1	2	–	–
<i>Triticum dicoccum</i>	1	–	–	1	–	–	–	–	–	ca.200	4	–
<i>Triticum dicoccum</i> spikelet fork	–	–	–	–	–	–	–	–	–	7	–	–
<i>Triticum</i> sp. spikelet fork	–	–	–	–	–	9	6	–	–	–	–	–

# Case Study 2 Fit for purpose: a fishy tale from Chester that matches aims, methods and site

Sue Stallibrass

## The site and background

A prime commercial location in Chester city centre, in the heart of the Roman legionary fortress a medieval town.

Much of Chester's historic core was redeveloped after World War II 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

The UK 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

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.

## Evaluation results

Processed samples proved that fish bones did survive, in all phases, in various states of preservation.

## Objectives of the excavation

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.

## Method

Samples were processed through a flotation machine on site, using a 1mm mesh to catch the residues. Volumes ranged from 5 to 100 litres, the smaller samples being constrained by the amount of sediment in the context. Both flots and residues were examined for fish bone.

## Results

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 CS2.1).

**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 (Fig CS2.1). The others (24–72 litres) produced less than 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 CS2.1** Identified specimens of fish for all periods at 25 Bridge Street, Chester; their absolute numbers and relative proportions

taxa	hand-recovered number of species/types: 11	sieved through 1mm number of species/types: 23		
	number of identified bones	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%
<i>total identified fish bones</i>	<b>90</b>		<b>3638</b>	



**Fig CS2.1** Some of the 56 fish bones recovered from a 72 litre Roman sediment sample at 25 Bridge Street, Chester (photo by Ian Smith, Chester Archaeology).

**Post-medieval results** Fig CS2.2 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 collection 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 CS2.1), 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.

#### Sources

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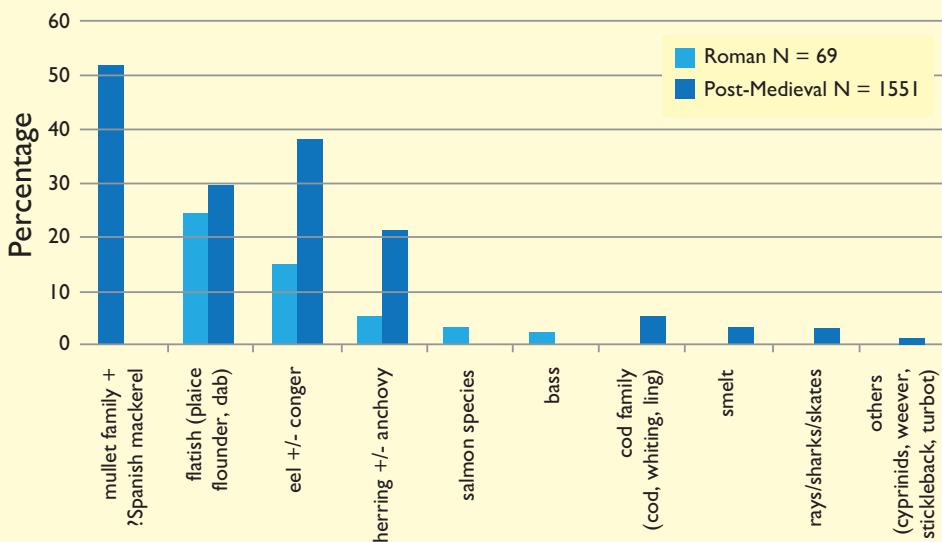


Fig CS2.2 Relative frequencies of identified fish bones from Roman and early post-medieval sieved samples at 25 Bridge Street, Chester.

	Period I Roman %	Period VI late 15th - mid 17th C %
mullet family + ?Spanish mackerel	52	0
flatfish (plaice, flounder, dab)	24	30
eel +/- conger	15	38
herring +/- anchovy	5	21
salmon species	3	0
bass	2	0
cod family (cod, whiting, ling)	0	5
smelt	0	3
rays/sharks/skates	0	3
others (cyprinids, weever, stickleback, turbot)	0	1
total number identified	69	1551

## Case Study 3 Palaeoenvironmental reconstruction: building better age-depth models John Meadows

### Background

Excavation in advance of a housing development at Market Lavington, Wiltshire exposed a Romano-British building and a small early-mid Saxon settlement and burial ground. A palaeoenvironmental sequence, obtained from the Easterton Brook palaeochannel, a peat and silt filled watercourse next to the site, provides a detailed record of agricultural activities and human impact on local vegetation during these periods.

The pollen sequence was dated using 10 AMS radiocarbon measurements of plant macrofossils. The results showed age increasing with depth, and a Bayesian chronological model was built, in which the calibrated radiocarbon dates were constrained by the stratigraphic sequence. An age versus depth model was then created, by linear regression between

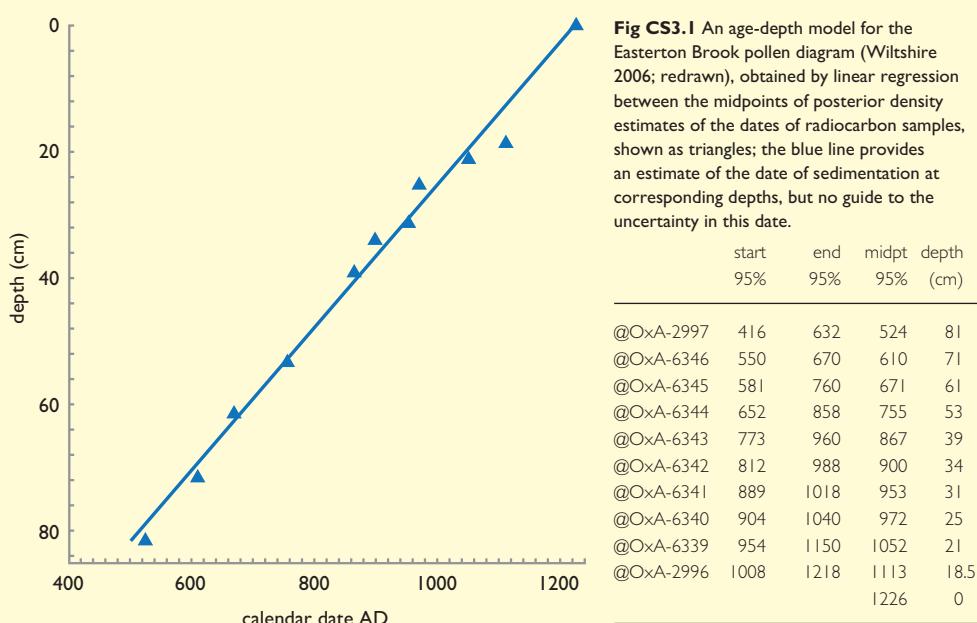


Fig CS3.1 An age-depth model for the Easterton Brook pollen diagram (Wiltshire 2006; redrawn), obtained by linear regression between the midpoints of posterior density estimates of the dates of radiocarbon samples, shown as triangles; the blue line provides an estimate of the date of sedimentation at corresponding depths, but no guide to the uncertainty in this date.

the sample depths and the midpoints of the model's posterior density estimates of the sample dates (Fig CS3.1).

### Research questions

Age versus depth models are used to construct a chronology for palaeoenvironmental sequences from off-site sediments, such as peat. Traditionally, estimates for the dates of changes in the palaeoenvironmental record not directly dated have been achieved by interpolating between dates of adjacent radiocarbon samples, assuming that the sedimentation rate was constant between each pair of samples. Such an approach will produce point-estimates of the dates of sedimentation throughout the sequence, but does not provide a measure of the uncertainty in these dates.

### Recent developments

Various programs designed to build more realistic age-depth models have been developed in recent years. OxCal

v4 includes two models: a uniform (*U\_Sequence*) model that assumes a constant deposition rate and a random (*P\_Sequence*) model that takes into account some variation in the rate of deposition (Bronk Ramsey 2008).

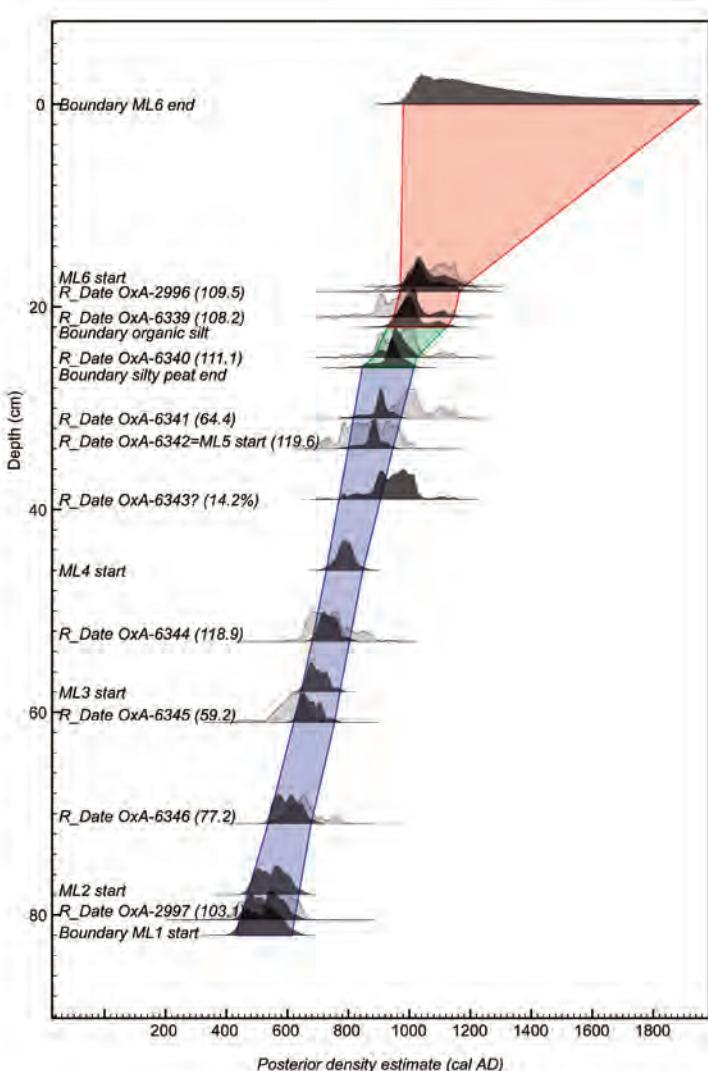
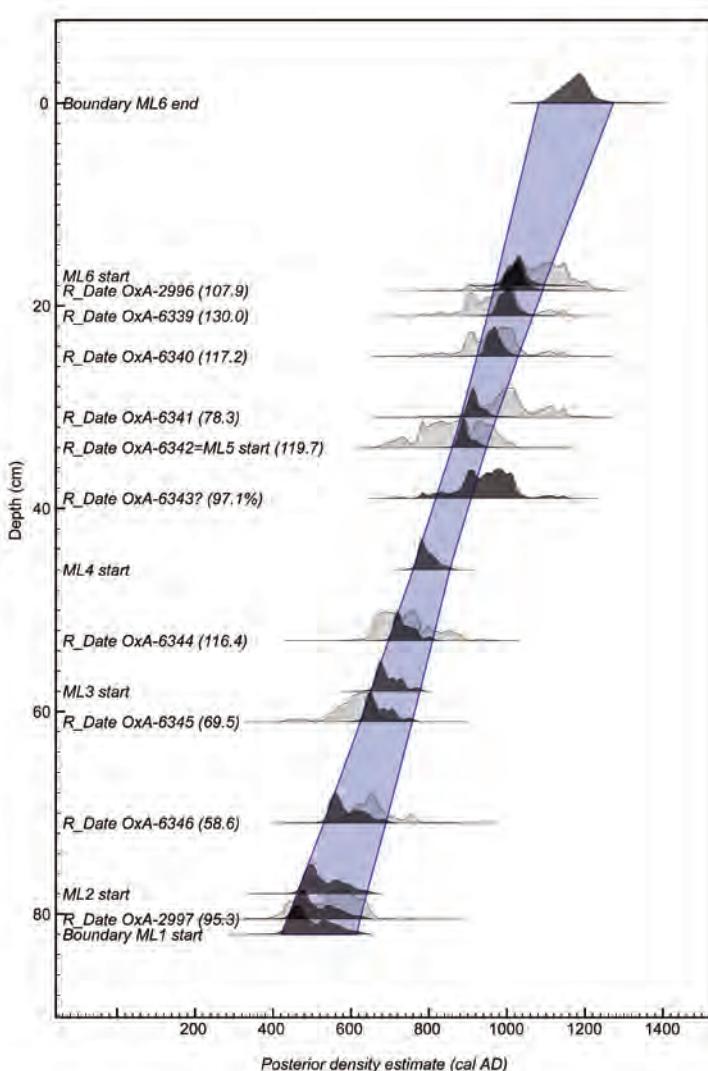
Both models give an index of agreement,  $A_{model}$ , which indicates how well the radiocarbon dates agree with the 'prior information' in the age-depth model (ie the vertical sequence and spacing between samples); poor agreement means that either one or more radiocarbon dates is inconsistent with the sample's date of deposition, or that the sedimentary sequence is more discontinuous than it appears.

### Easterton Brook revisited

The Market Lavington radiocarbon data can be reinterpreted using both *P\_Sequence* and *U\_Sequence* models. There are no obvious 'age reversals', but one sample, OxA-6343, appears slightly too recent for its depth, as its inclusion produces

poor overall agreement ( $A_{model} < 60$ ) in *U\_Sequence*, and also in *P\_Sequence*. This was not apparent in the original model (Wiltshire 2006, fig 57), which considers only the stratigraphic sequence, not the vertical spacing of samples.

A *U\_Sequence* model ( $A_{model} = 66.7$ ; Fig CS3.2), which excludes OxA-6343, suggests that deposition ended c cal AD 1080–1280 (95% probability; ML6 end, Fig CS3.2), or that the deposit was truncated at this level. A *P\_Sequence* model with 'boundaries' (changes in the deposition rate) at the transitions from silty peat to organic silt between 220mm and 250mm also has good overall agreement ( $A_{model} = 60.3$ ; Fig CS3.3). Both models produce posterior density estimates of the dates of important transitions in the pollen record, which in this case are very similar (Fig CS3.4). These estimates can be compared directly to the dates of archaeological events, to see whether the latter are reflected in changes in the



**Fig CS3.2** A deposition model for Easterton Brook, created using *U\_Sequence* (Bronk Ramsey 2008), which assumes a constant rate of sedimentation; OxA-6343 has been omitted, as it appears to be too recent to date sedimentation at 390mm. The blue band shows the posterior density estimate (95% probability) within which sedimentation took place at the corresponding level, according to the model. Black probability distributions are posterior density estimates of the dates of radiocarbon samples and of events in the pollen record.

**Fig CS3.3** A deposition model for Easterton Brook, created using *P\_Sequence* (Bronk Ramsey 2008;  $k=10\text{cm}^{-1}$ ); OxA-6343 has again been omitted. The format is the same as that of Fig 3.2, but the addition of lithostratigraphic divisions at 220mm and 250mm is reflected in the blue, green and red bands, showing the posterior density estimate (95% probability) for sedimentation at corresponding levels.

palaeoenvironmental record. An increase in cereal pollen from the later 7th century AD at Market Lavington can be linked to finds of lava quern fragments on the site. The dating of the top of the sequence made it possible to suggest that viticulture was continuous from c AD 900 to after the Norman Conquest.

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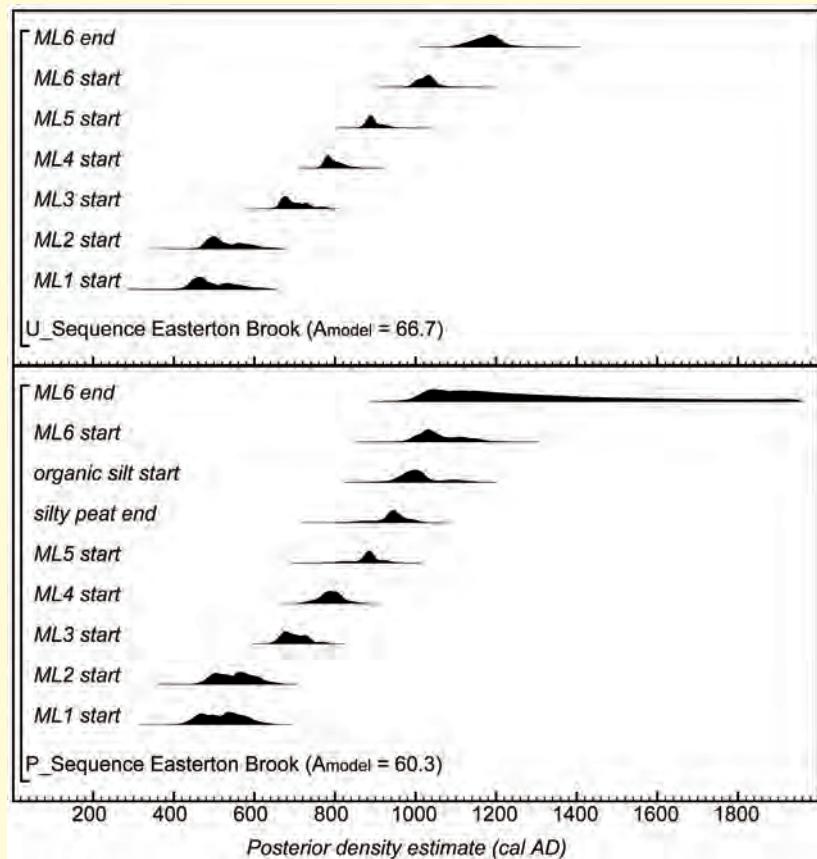
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**Fig CS3.4** Probability distributions for the dates of events in the pollen record at Easterton Brook, derived from the models shown in Fig 3.2 (top) and Fig 3.3 (bottom).

## Case Study 4 Sampling for charred plant remains: the importance of considering context type and the archaeological period being investigated **Gill Campbell**

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 CS4.1 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 CS4.1 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 (Fig CS4.1). This is not typical of the kinds of remains recovered from most sites. These

**Table CS4.1** 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

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.



**Fig CS4.1** Sampling a primary deposit from the floor of a burnt down corn-drying oven at Grateley South, Hampshire (© Oxford University).

Using the figures given in Table CS4.1, 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 Fig 5). 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. 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.

There is some debate about whether concentrations of charred plant remains are lower in northern England, where samples often recover very few plant remains, than in southern England. However, the figures given above do not take account of regional variation and the nature of the archaeology encountered at different sites. 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 and at Grange Road, Gosport, Hampshire. 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, while at Weir Bank Stud Farm, Bray, Berkshire, postholes associated with a round house contained large numbers of flax seeds. 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. 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.

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 of agricultural practice and economy.

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## Case Study 5 Romano-British cremation burials and related deposits at Ryknield Street, Wall, Staffordshire Jacqueline I McKinley

### Site

Archaeological investigations undertaken by Oxford Wessex Archaeology in 2000–3 in advance of construction of the M6 Toll Road confirmed the position of Ryknield Street, long known to have run to the east of the Roman town of *Letocetum* (the present village of Wall). The site straddled the north–south road c 200m to the south of its junction with the east–west orientated Watling Street. A small, multi-rite cemetery was found to lie to either side of the road. In addition to the 42 cremation and 15 (possibly 21) inhumation graves excavated, this included a variety of other

mortuary features mostly associated with the cremation rite. Owing to the acidic burial environment (free-draining sands and gravels) no unburned bone survived; only the cremation-related deposits are discussed here.

### Methods and objectives

The osteoarchaeologist visited the site and was in regular contact with the excavators. The excavation strategy generally followed standard methods with some minor adaptations to suit site-specific conditions. All the cremation-related deposits were fully excavated and subject to whole-earth

recovery to ensure the retrieval of all the surviving archaeological components.

The remains of intact or almost intact urned burials were lifted whole for more detailed excavation under laboratory conditions (Fig CS5.1). The vessels were wrapped in crepe bandages (slightly elasticated and therefore flexible) to support the urns during lifting and subsequent excavation of the fills. Laboratory excavation was undertaken in 20mm spits, by post-excavation assistants, to enable details of the burial formation process to be analysed. It should be noted that where carried out by the



**Fig CS5.1** An urned burial being excavated in the laboratory (photo by Karla Graham).

ostearchaeologist, such excavation would normally take the form of quadranted spits accompanied by annotated scale drawings. In several cases grave cuts for urned burials could not be distinguished because of small grave size and the similarity between the fill and the surrounding deposits. Where this was the case, features had to be excavated by first cutting a box section.

Where it was possible to distinguish the remains of the burial (urned or unurned) from the subsequent grave backfill these two contexts were recovered separately, but in some cases disturbance and truncation due to ploughing and machine stripping meant that the two were visually indistinguishable. Some deposits were recovered as single ‘samples’ and others in halves or quadrants to provide information on the distribution of the cremated bone, fuel ash (pyre debris) and other archaeological inclusions. As noted above, however, excavation in quadrants is the advised procedure.

All the fills were floated and then wet sieved using a series of sieve sizes ranging from 1mm to 10mm. The bone in the larger sieve fractions (10mm and 5mm) was sorted from the residues by post-excavation assistants. The residues from the 1mm and 2mm fractions were retained for scanning by the osteologist.

All the archaeological components from each cremation-related deposit were recorded and analysed by the appropriate specialist. A catalogue of the finds from each mortuary-related feature was included

in the publication report, together with the specialist reports on each material type: cremated human and animal bone, artefacts, charcoal (pyre debris) and charred plant remains.

### Results

Cremated bone was recovered from 168 contexts, which included the remains of 34 urned burials, 2 combination burials (urned and unurned), 3 burials of uncertain form, four redeposited burials, 5 deposits that may represent the remains of unurned burials with redeposited pyre debris or just redeposited pyre debris, and 15 formal or incidental deposits of pyre debris. Interpretation of deposit types relies on the combined assessment of the data recovered during the study of the cremated remains themselves, eg the condition of the bone and the age and sex of the individual, and the context data particularly the levels of disturbance/truncation, the form of the deposit (eg urned/unurned), and the distribution of the archaeological components (especially of the cremated bone).

In general bone preservation at Ryknield Street was fairly good and, by maximising recovery of the archaeological components, in most cases it was possible to deduce the deposit type with confidence, but a combination of heavy disturbance and insufficient detail on distribution in a few cases rendered some deposits of uncertain form.

The demographic data recovered was relatively detailed, with all those

identified (MNI 48) being allocated to at least a broad demographic group (73.1% adult; 17.3% immature) and 38.7% of individuals were sexed (23% female; 13.7% male – varying confidence levels). These data made it possible to compare among the four temporal phases within the cemetery (indicating stability in population structure through time) and with other contemporaneous cemeteries. Few pathological lesions were recorded, but did include a healed rib fracture; such evidence for trauma is rarely found in archaeological cremated remains.

Data pertaining to pyre technology and cremation rituals were recovered, enabling intra- and inter-site comparisons on treatment. There is some evidence for the rare preferential exclusion of skull elements from one intact grave; an unusually high proportion of the cremations appear to have included animal remains as pyre goods (recovered from 80% of urned burials), possibly a local variation; and the spatial distribution of pits containing redeposited pyre debris in the western half of the cemetery suggests the possible location of the pyre sites/ *ustrina* adjacent to the road. Details of the burial formation process could be deduced in some cases where excavation in sufficient detail had been undertaken. The data demonstrated that the vessels functioning as urns were not used to full capacity, despite the undoubtedly presence of sufficient cremated bone to more than fill them. It also showed that there was in general no ordered deposition (by skeletal element) of remains, which may indicate how the bone was recovered from the pyre site for burial or suggest temporary storage in a different receptacle before burial.

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# Case Study 6 Multidisciplinary sampling in the intertidal zone at Goldcliff East, Gwent Levels, Severn Estuary

Vanessa Straker

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.

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 12

archaeological research questions defined in the project research design. Eight of these are listed here:

- 1 Did hunter-gatherers burn woodland or other vegetation in a coastal setting?
- 2 Did human activity and economy change as the Holocene transgression progressed from fen woodland to reed swamp and then to saltmarsh and mudflats?
- 3 What was the nature and economy of Mesolithic activity at Goldcliff East?
- 4 Is there evidence of seasonality of occupation and environmental disturbance?
- 5 What were the main species of animals, birds and fishes present and exploited, as indicated by footprint, track and bone evidence?
- 6 What fishing techniques were employed in the Mesolithic?
- 7 What was the contribution of plant materials to the Mesolithic diet?
- 8 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.



Fig CS6.1 Excavating, recording and taking large specialist samples from the block samples supported in wooden frames (photo by E Sacre).

These sites comprise an environmental transect of c 740m, running eastwards from the dryland edge of Goldcliff island into the surrounding wetland.

There were 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 (Fig CS 6.1). 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<sup>3</sup> into 16 250mm<sup>3</sup> blocks, which were collected in metal four-sided tins. These were wrapped on site and reassembled within 1m<sup>3</sup> wooden frames for excavation, recording and wet sieving. Mesh sizes were 2mm for residues and 500µm for flots. Plant macrofossils and charcoal were also recovered from these samples, as well as from monolith tins.

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.

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## Glossary

**agglutinated** consisting of particles cemented together

**alluvium** waterlain sediment; not marine or estuarine

**analogue** an equivalent organism or environment – modern analogues are used to interpret past situations or species

**anaerobic** oxygen-depleted, the term anoxic is usually preferred

**anoxic** oxygen-depleted

**apatite** a mineral form of calcium phosphate. Hydroxylapatite forms the main mineral component of bone

**arachnids** spiders, mites and various other eight-legged arthropods

**aragonite** one of the crystalline forms of calcium carbonate

**Arthropoda** phylum including approximately 80% of all animals, among which are insects, spiders, centipedes and crabs

**biogenic** formed by living organisms

**biomolecules** biological molecules such as lipids, proteins and DNA

**bioturbation** soil or sediment disturbance caused by living organisms

**brown earth** a soil type with a dark topsoil over a deep brown subsoil developed on well drained circumneutral parent materials

**bulk samples** a non-preferred term for

any number of different types of sample, including flotation, coarse-sieved and sediment samples

**C3 plant** a plant that produces phosphoglyceric acid, which contains three carbon atoms, as the first step in photosynthesis. Most temperate plants are C3 plants

**C4 plant** a plant that produces oxyaloacetic acid, which contains four carbon atoms, as the first step in photosynthesis. C4 plants can photosynthesize at higher light levels and lower carbon-dioxide levels than C3 plants. Many desert plants and some tropical plants are C4 plants

**calcareous** containing or characteristic of calcium carbonate

**calcined** burned grey-white

**calcite** the most commonly occurring crystalline form of calcium carbonate

**chironomids** non-biting midges

**chitin** skeletal material found in certain invertebrates, especially arthropods; it is a polysaccharide, containing nitrogen and is also found in fungi and lichens

**cladocerans** a group of freshwater crustaceans; ephippia ('egg cases') of *Daphnia* spp, the water flea, are the most commonly encountered on archaeological sites

**collagen** fibrous protein, one of the key skeletal substances

**colluvium** sediment transported by slope processes

**coprolites** mineral-preserved faeces

**crustaceans** class of Arthropoda including crabs and water fleas with an outer shell or cuticle

**demography** the numerical study of human populations

**dendrochronology** tree-ring dating

**desiccation** extreme drying out (used to describe a form of preservation)

**diagenesis** the changes that occur following deposition of a sediment and its contents

**diatoms** unicellular aquatic algae

**DNA** Deoxyribonucleic acid, which contains the genetic information of an organism

**ecdysis** moultling (in the case of ostracods and other crustacea – shedding their old shell and secreting a new one approximately twice the size)

**ecology** the study of the relationship of plants and animals to each other and to their surroundings

**exoskeleton** skeleton covering outside of the body, or in the skin

**foraminifera** mainly marine protozoa with shells or tests; generally microscopic

**fractionation** a change in the ratio of two isotopes of a chemical element caused by the preferential loss or retention of one

of them. Caused by a process such as photosynthesis, ingestion and metabolism, or evaporation	<b>metadata</b> data about data eg resolution of an image, file type, percentages derived from original counts of items	<b>rendzina</b> dark soil that develops below grasslands in limestone or chalk areas
<b>frustule</b> diatom cell consisting of two valves	<b>microfossil</b> biological remains that require a high power microscope for identification, typically $>100\text{--}200\mu\text{m}$ (eg pollen, diatoms)	<b>silica</b> an inert compound forming part or all of many minerals, such as quartz, but deposited by some plants within their tissues
<b>gley</b> a soil strongly affected by waterlogging	<b>micron</b> a unit of measurement: thousandths of a millimetre ( $\mu\text{m}$ )	<b>stable isotope</b> an isotope that does not undergo radioactive decay
<b>Holocene</b> the present warm period that began c 11,700 years ago (10,000 radiocarbon years) following the last glacial period	<b>nematode worms</b> unsegmented worms, typically parasitic on plants or animals	<b>spheroidal carbonaceous particles (SCPs)</b> roughly spherical, $>5\mu\text{m}$ , soot particles produced from the incomplete combustion of fossil fuels. Used as an indicator of industrialisation; SCPs can also be used as a proxy dating tool
<b>interstadial</b> short warm phase within a glacial period	<b>ombrotrophic</b> plant or substrate receiving all its nutrients and water from rain (rain fed)	<b>taphonomy</b> study of the routes and processes whereby material becomes part of the archaeological (fossil) record
<b>invertebrate</b> collective term for all animals without backbones	<b>ostracods</b> subclass of crustaceans with a two-valved shell, generally a few millimetres in length	<b>taxa</b> (singular taxon) a named taxonomic group of any rank (eg order, genus, species)
<b>isotope</b> one of two or more forms of the same element differing from each other in the number of neutrons present	<b>otoliths</b> (ear stones) calcareous structures found in the inner ear of fish	<b>tephra</b> fine, often microscopic, volcanic ash
<b>karst</b> montane hard limestone landscapes	<b>peat</b> deposit comprising mainly decayed or partially decayed vegetable matter	<b>test</b> type of shell (typically in foraminifera)
<b>Kubiena box (or tin)</b> sampling box used for soil micromorphology, open-sided with lids that can be fitted to these sides	<b>pH</b> a measure of acidity/alkalinity	<b>testate amoebae</b> single-celled organisms (amoebae) that are partially enclosed in external shells, or tests
<b>lignin</b> complex carbohydrate polymer found in the cell walls of many plants, giving strength and forming up to 30% of the wood of trees	<b>phylum</b> major group in the classification of living things	<b>thorax</b> the section behind the head in insects bearing legs and wings
<b>lipid</b> fat	<b>phytoliths</b> microscopic silica bodies produced by many plants	<b>tufa</b> a calcareous precipitated sediment often found in springs, rivers and lakes
<b>loess</b> wind-blown sediment, usually of silt	<b>podzol</b> an acidic soil that forms on coarse parent materials in moist climates	<b>vertebrate</b> animals that have a skull, spinal column and skeleton of cartilage or bone
<b>machair</b> fixed dune pasture/grassland of shell sand	<b>polarised light</b> light vibrating in a single plane	<b>vivianite</b> hydrated iron phosphate; it produces a bright blue deposit, typically in waterlogged anoxic conditions; darkens rapidly upon oxidation
<b>macrofossil</b> small biological remains; a term usually applied to plant parts such as seeds, nut shells, fruit stones and stem parts, but the term is also appropriate to any remains visible to the naked eye. Macroscopic remains is normally preferred	<b>polysaccharide</b> complex carbohydrate of large, often fibrous molecules – important structural material	
<b>marl</b> a precipitated sediment found in lake bottoms	<b>posterior density estimate</b> a function that describes the likelihood of a date occurring at a particular point (time)	
	<b>protists</b> single-celled and multi-cellular simple organisms	
	<b>puparia</b> the cases in which some insects develop from larvae into adults	
	<b>pyrite</b> iron sulphide mineral	

## Where to get advice

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## Regional research frameworks

Regional research Frameworks comprising a resource assessment, research agenda and research strategy (Olivier 1996) are an essential tool for setting aims and objectives for archaeological projects. They give an overview of current knowledge and understanding with in each region and identify priorities for future work. A number are now published and available on line. Please visit: <http://www.algao.org.uk/Association/England/Regions/ResFwks.htm> [accessed October 2010]

## Period research frameworks

The following research frameworks have been published at the time of going into press:

Champion, T C, Haselgrave, C, Armit, I, Creighton, J and Gwilt, A 2001

*Understanding the British Iron Age: An Agenda for Action: A Report for the Iron Age Research Seminar and the Council of the Prehistoric Society.* Salisbury: Trust Wessex Archaeol

Gamble, C (ed) 1999 *Research Frameworks for the Palaeolithic and Mesolithic of Britain and Ireland.* Salisbury: Prehist Soc

James, S and Millet, M, 2001 (eds) *Britons and Romans: Advancing an Archaeological Agenda.* York: CBA Res Rep 125

Pettitt, P, Gamble, C and Last, J, 2008  
*Research and Conservation Framework for the British Palaeolithic.* Prehist Soc and English Heritage, <http://www.english-heritage.org.uk/publications/research-and-conservation-framework-for-british-palaeolithic/> [accessed March 2011]

## Regional reviews of environmental archaeology

English Heritage is undertaking, either directly or through external commissioning, a series of regional reviews covering the different types of environmental evidence from archaeological sites and palaeoenvironmental deposits (SHAPE subprogramme 11172.110 Supporting Research Frameworks: National, regional, local, diachronic and thematic frameworks).

The purpose of these reviews is to determine the extent of our knowledge of the past as gained from the study of biological remains, sediments and soils in England. They seek to identify gaps in our current understanding and highlight priorities and directions for future research at a local, regional and national level. As such the reviews provide essential research in support of the development of regional and national research frameworks. Sixteen reviews have been produced to date covering different biological remains and geoarchaeology in southern England, northern England and the midland counties. They are published as English Heritage Research Department Reports and are available to download from the English Heritage website: <http://www.english-heritage.org.uk/publications/research-reports/> [accessed October 2010]

These guidelines are a revised and updated edition of guidelines published in 2002.

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## Cover Images

*front:* A reconstruction of late medieval life on the urban fringe (by Judith Dobie).

*back:* Britain's island status is the result of Holocene sea level rise. The intertidal zone around coasts and estuaries preserves fragile and eroding historic assets, including a wealth of environmental data. This photograph shows the drowned landscape of the Isles of Scilly (photo by V Straker).

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