Centre for Archaeology Guidelines

Environmental Archaeology

A guide to the theory and practice of methods, from sampling and recovery to post-excavation
Preface

These guidelines aim to establish standards of good practice in environmental archaeology. They provide practical advice on the applications and methods of environmental archaeology within archaeological projects. They should not replace advice given by specialists on specific projects. It is not intended that these guidelines should in any way inhibit further development of methodologies or recommended procedures.

Planning Policy Guidance Notes PPG 15 (Department of the Environment 1994) and PPG 16 (Department of the Environment 1990) state government policy on planning issues in archaeology and provide guidance to local authorities and others in the planning system. Local authorities must take account of the PPG guidance notes when preparing development plans and making planning decisions. The archaeological component of some developments is provided for as part of Environmental Impact Assessment under Town and Country Planning Regulations (Department of the Environment, Transport and Regions 1999). The current document is intended to provide guidance to curators who advise on planning decisions and issue briefs. They are also intended for field project directors writing specifications or written schemes of investigation, for those working on development-led or research projects, and for other field archaeologists. Some of the information might also be useful in cases of in situ preservation and other archaeological investigations.

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 these guidelines cover

- an introduction to environmental archaeology
- a summary of the most common types of environmental evidence
- the circumstances under which environmental evidence survives
- a brief summary of the potential information that analysis can provide
- an introduction to sampling strategies
- a guide to types of environmental samples, taking samples, and storing samples
- a guide to good practice for environmental archaeology from project planning to publication
- case studies of good practice
Britain’s island status is the result of Holocene sea level rise. The intertidal zone around coasts and estuaries preserves fragile and eroding archaeological remains including a wealth of environmental data.

The photograph shows the drowned landscape of the Isles of Scilly (Photograph by V Slocie)
Contents
Preface ................................... 3
What these guidelines cover ........... 3
List of figures .......................... 5
List of tables .......................... 5
1 Introduction ........................ 6
2 Common types of environmental evidence ...................... 6
   Animal bones
   Human remains
   Eggshell
   Insects
   Ostracods
   Foraminifera
   Molluscs
   Parasite eggs and cysts
   Plant macrofossils (other than wood/charcoal)
   Wood
   Charcoal
   Pollen and spores
   Phytoliths
   Diatoms
   Biomolecules
   Geoarchaeology
      Stratigraphic and landscape studies
      Chemical and physical analyses
      Soil micromorphology
      Mineralogy
      Particle size analysis
3 Sampling ........................... 17
   Sampling strategies
   Sample types
   Taking samples
   Storing samples
4 Practice ........................... 23
   Desk-based assessment
   Watching briefs
   Evaluation
   Excavation
   Assessment
   Analysis and reporting
   Dissemination and archiving
   Sites and Monuments Record
      Publication
      Archiving
Appendix case studies .................. 26
   Preparing project designs
   Watching brief
   Evaluation
   Excavation
List of figures
   Figure 1 Schematic representation of environmental conditions.
   Figure 2 Cattle horn cores from 1st-century Carlisle.
   Figure 3 Lower jaw of a watervole from a Bronze Age cairn at Hardendale, Shap, Cumbria.
   Figure 4 Articulated fish skeletons from early medieval St Martin-at-Place Plain, Norwich.
   Figure 5 Animal bone measurements demonstrating changes in livestock through time.
   Figure 6 Blank bone-handle plate from Denaby Main, South Yorkshire, and archaeological blank and completed fork handle.
   Figure 7 Three skeletons from Stanwick.
   Figure 8 Section through egg shell of chicken.
   Figure 9 Head of human louse, *Pulex irritans*.
   Figure 10 Test of the foraminiferan *Elphidium excavatum*.
   Figure 11 Mollusc shells from fluvial sands at Hogg's Drove, Marham, Norfolk.
   Figure 12 Egg of the parasitic nematode *Trichuris*.
   Figure 13 Partially mineral-replaced coprolite from Dryslwyn Castle.
   Figure 14 Charred naked barley and emmer wheat from Bronze Age Irby on The Wirral.
   Figure 15 Waterlogged cereal grains from Vindolanda on Hadrian's Wall.
   Figure 16 Stones from *Prunus* spp., Roman deposits at Annetwell St., Carlisle.
   Figure 17 Charred seed assemblages can demonstrate temporal and spatial patterns.
   Figure 18 Proportions of tree species, 1st- and 2nd-century Carlisle and 2nd-century Ribchester.
   Figure 19 Roman basketry from Annetwell St, Carlisle.
   Figure 20 *Taxus* (yew): tangential longitudinal section showing spiral thickening.
   Figure 21 Charred tubers/roots from Iron Age Stanwick, North Yorkshire.
   Figure 22 *Quercus* (oak) and Poaceae (grass) pollen, showing apertures and textures.
   Figure 23 The marine diatom, *Raphoneis amphiceros*.
   Figure 24 Deep peat sections at Wells Road, Glastonbury.
   Figure 25 Segment of Livingstone core, split to show stratigraphic changes.
   Figure 26 Using a modified Livingstone piston corer.
   Figure 27 Flotation tank on site.
   Figure 28 Typical laboratory set-up for sorting plant remains.
   Figure 29 Glastonbury Relief Road: monolith tins in peat deposits overlying estuarine silty clays.
   Figure 30 Extruding a core of continuous sediment from a modified Livingstone piston corer.
   Figure 31 Schematic diagram for sampling.
List of tables
   Table 1 Preservation conditions
   Table 2 Sampling methodologies
   Table 3 Examples of sample types appropriate to particular materials
   Table 4 Environmental Archaeology: Guidance for project planning
Glossary ............................. 29
Where to get advice ................ 30
References .......................... 31
Acknowledgements ................... 35
1 Introduction

Within this document, environmental archaeology includes all earth science and biological studies undertaken to investigate the environments in which past human societies lived and ecological changes through the period of human history.

The main issues in environmental archaeology concern ecological, social and economic reconstruction. These themes can be examined in relation to changes through time, evidence of specific activities or events, and interaction with the contemporaneous landscape. The particular contribution of each type of material is discussed in Section 2.

Archaeological sites are created by human behaviour involving material remains (acquisition, manufacture, use, deposition). Archaeological sites 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 many living organisms. Cultural processes include subsistence activities, building, discard or loss of material, manufacture and manufacture waste, recycling, deliberate destruction and resource utilisation.

2 Common types of environmental evidence

At a broad level, 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 the different types of environmental evidence can be predicted to a certain extent, this is not an exact science. Small-scale, local variations become critical and it is thus essential to allow time for rapid-response discussion between excavators and specialists during excavation.

Table 1 provides a brief summary of where various types of remains are most likely to occur, but, as noted above, local conditions might vary.

The sections below describe the classes of material most often considered within environmental archaeology, when and where such material will be encountered, and briefly discuss 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.

Animal bones

The bodies of vertebrates are composed of various hard and soft tissues. Usually, it is only the hard tissues (bones, teeth, horncores and antlers) that survive. 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 bones of newborn animals. Calcium phosphate is soluble in acidic water, so bones tend to survive best in alkaline to neutral deposits. Local microenvironments that raise the pH, such as shell middens, can enhance preservation at sites where most of the sediments are acidic. If bone is heated to approximately 600°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.
Soft tissues usually only survive in extreme conditions, where bacterial activity is restricted, for instance by freezing or desiccation. In North West Europe, the most common place in which soft tissues are preserved is in 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 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 bones of domesticated animals, are usually visible during excavation and can be collected together with artefacts. To avoid collecting biased assemblages (Payne 1975), small bones such as those of fish, small mammals, small birds, immature elements of larger animals and fragments need to be recovered from coarse-sieved samples (see Section 3, Sample types).

Animal bones are used in a very wide variety of types of study (O’Connor 2000), most of which investigate how the presence of animal bones at an archaeological site relate to past human activities, beliefs and environment. Small vertebrate faunas have been used to characterise local habitats. At the Pleistocene site of Boxgrove (Roberts and Parfitt 1999) the evolutionary stage of the remains of water voles recovered has been used as a proxy dating device. Other wild species, such as birds and fish, can demonstrate the range of habitats exploited for provisioning, 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 is 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 (Davis and Beckett 1999). Age and sex profiles are used in interpretations of how people looked after and utilised their domestic animals; and these interpretations can be quite controversial (Halstead 1998; McCormick 1998).

When material from several related sites is available, complex enquiries can be undertaken regarding 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 relating to animals include hornworking, tanning and parchment-making (Serjeantson 1989).

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

Human remains
Excavated human remains should always be treated with respect and decency. If an excavation is expected to disturb human remains, a Section 25 Licence should be sought in advance from the Home Office. If human remains are encountered unexpectedly, prompt application should be made to the Home Office for a licence. This can be done by telephone. The discovery of

Human remains
Excavated human remains should always be treated with respect and decency. If an excavation is expected to disturb human remains, a Section 25 Licence should be sought in advance from the Home Office. If human remains are encountered unexpectedly, prompt application should be made to the Home Office for a licence. This can be done by telephone. The discovery of
previously unknown human remains should also be reported to the police. For further details on legislation relevant to the excavation of human remains see Garratt-Frost (1992), and Pugh-Smith and Samuels (1996).

Remains from land that is currently consecrated by the Church of England come under ecclesiastical jurisdiction, and their removal requires that a faculty be obtained from the Consistory Court. This is normally in addition to, and not a substitute for, a Section 25 Licence. Cathedrals, and certain other places such as Westminster Abbey and chapels at the Royal residences, are outside faculty jurisdiction. Removal of remains from these places requires permission of the governing bodies of the institutions concerned.

In most instances, excavated human remains pose no special health and safety risks. An exception would be burials that preserve substantial soft tissue, as may occur on occasion with interments from crypts, as a result of desiccation (Baxter et al. 1988; Reeve and Adams 1993).

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 Animal bones (above), cremated bone tends to be more resistant to destruction than unburnt bone, so that it may survive well even in highly acid soils where all traces of inhumed bone have vanished.

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 (Mays 1998; Cox and Mays 2000). To a lesser extent cremated bone can also tell us about some of these aspects, particularly funerary practices in relation to pyre technology (McKinley 2000).

The study of human remains can contribute to a number of important themes in British archaeology. The study of mortuary practices and ritual has been a significant focus, particularly for the prehistoric and early historic periods. 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 and technological change. The study of human remains can also contribute to medical history by helping us to understand the antiquity of some diseases.

Work on human remains is an area where a number of important new techniques have made their presence felt, in particular stable isotope and DNA analyses (see below, Biomolecules). Analyses of stable isotopes of carbon and nitrogen are beginning to shed new light on early diets (Sealy 2001). Study of stable isotopes of strontium, oxygen or lead may help us investigate population movements in the past. For reasons that are at present poorly understood, survival of DNA in burried bone is rather variable. Nevertheless analysis of DNA extracted from ancient human skeletal remains is beginning to contribute significantly to a number of areas of research. It is helping to improve our diagnosis of certain infectious diseases, and it might also be of some value in kinship studies and for sex determination where osteological indicators are missing or ambiguous.

Eggshell

Bird eggshell is mainly composed of calcite with an organic outer coating of protein, fat and polysaccharides, with two proteinaceous inner membranes. Some variation is found in eggshells of sea birds where vaterite is the predominant component. Shell preserves best in alkaline situations; it is surprisingly robust, although it will normally be recovered in a very fragmented state. Species identification is made through measurement and 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.

Figure 7 Three skeletons from Stanwick. (Photograph by S Mays)

Figure 8 Section through egg shell of chicken. (SEM photograph by J Sidell)
Although not at present commonly studied, eggshell is often recovered from archaeological sites. This is generally in the residues of coarse-sieved or floatation samples (Section 3, Sample types), although occasionally whole eggs or eggshell layers are recovered.

Analysis of eggshell can address several research areas. Identification indicates which species were consumed. Depending on the species, it might be possible to consider questions relating to seasonality. 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 address these topics (Sidell 1995).

**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, 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 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 lates, for example at the Roman shrine at Uley, Gloucestershire (Girling and Straker 1993).

Insects live in most terrestrial, freshwater aquatic or marine intertidal habitats. There are more species in the class Insecta than in the remainder of the animal kingdom put together and some have very narrow environmental requirements, for example feeding on only a single plant species. Their remains have proved particularly sensitive climatic indicators for the Pleistocene, responding promptly to the sudden climatic amelioration of interstadials. On Post Glacial (Holocene) sites they are useful both for general palaeoenvironmental reconstruction and for providing details of past hygiene (eg lice and fleas) and living conditions. Reviews of all types of study are given by Buckland and Coope (1991) and by Robinson (2001a). In rural situations, they are particularly useful for showing the character of woodland, the quality of water and the occurrence of domestic animals (Robinson 1991).

Grain beetles can provide evidence of stored products (Kenward and Williams 1979). In urban situations with deep organic stratigraphy very detailed reconstructions can be made of human activity, as at Coppergate, York (Kenward and Hall 1995).

**Ostracods**

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 natural aquatic environment from freshwater to marine. The robustness of their shells means that they survive in almost any non-acidic, waterlain deposit. Like foraminifera and molluscs, the shells of most species have unique shapes and sculpturings making them readily identifiable. It is also usual to be able to tell male and female individuals apart within species. Griffiths et al (1993) provide a useful summary of sampling, preparation and identification techniques.

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.

Ostracod analysis should be considered as a useful technique to complement molluscs, diatom and foraminiferan analyses where waterlain 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). Cladocerans, a group of small freshwater crustaceans, are also occasionally used in reconstruction of fresh water environments and are often found on archaeological sites. Because of their size and the fact that samples of only 10–50g are required for analysis, quite good resolution can be obtained from ostracod analyses, enabling subtle changes in environments to be revealed, 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.

To date, few attempts have been made to study ostracods in archaeological investigations. One example comes from the Roman fortress ditch in Exeter, Devon (Robinson 1984), where the ostracods suggested periods of standing water, but somewhat polluted conditions resulting in a restricted fauna. They were also used for environmental reconstruction in the Fenland Management Project (Godwin in Crowson et al 2000).

---

Figure 9: Head of human louse, Pulicris, a species characteristically recorded from floor deposits in Anglo-Scandinavian York. (SEM photograph by H K Kenward)
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. Foraminifera survive best in non-acidic conditions.

Oxygen isotope ratios in foraminiferal tests in muds from deep ocean cores have provided data on global climate change (Wilson et al. 2000). More locally, the known habitat requirements of foraminifera can be used to reconstruct salinity changes. These protists 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 in Crowson et al. 2000), and in the Severn Estuary Levels (Haslett et al. 2000). At a broader scale the study of foraminifera has made an important contribution towards the understanding of sea-level change (Haslett et al. 1997).

Molluscs

Snails and bivalves live in a wide range of habitats on land, and in fresh, brackish and marine water. Individual species inhabit very specific environments, such as damp woodland, short-turfed grassland and brackish river channels.

The shells of snails and marine and freshwater bivalved molluscs occur in a range of sediments (alluvium, tufa, lake sediments, colluvial deposits, loess, blown sand and intertidal mud), in buried soils and in the fills of archaeological features.

In base-rich deposits survival of shell is normally adequate for analysis, but preservation can be variable and unpredictable. Calcareous deposits in which shells survive sometimes occur over acid bedrock.

Shell assemblages of land, freshwater and brackish-water/marine molluscs provide palaeoecological data, but taphonomy and preservational factors must always be considered carefully (Bell and Johnson 1996). Work on the calcareous regions of Britain, where pollen is often poorly preserved, has provided a long-term picture of natural and anthropogenic habitat change (Evans 1972). More recently, greater attention has been paid to molluscs from freshwater wetlands and coastal habitats (Wilkinson and Murphy 1995). In general, molluscs provide site-specific information on local environmental changes, though regional models can be devised by integrating data from several sites.

The larger marine species of molluscs have been a food resource since at least the Mesolithic period. Prehistoric shell middens occur on some English coastlines. It is also possible to investigate sources of shellfish and their management in later periods (Winder 1992). In addition, shells have been used for ornaments, artefacts and for lime production. Shells have also been imported to sites within clays (used for daub and bricks), seaweed and hay, and their identification can be used to suggest sources for 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. Cysts are the calcified resting stage of some tapeworms (Jones 1982).

Parasite eggs are small, up to about 60 microns in size. They are often recovered from pit and ditch fills but are also present in spreads and general dumps. Most often they survive in wet deposits or in deposits including mineral concretions but can sometimes survive in dry ones.
Although the species 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 (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.

**Plant macrofossils (other than wood/charcoal)**

Plant macrofossils in Britain and the rest of North West Europe are most commonly preserved by charring, by anoxic conditions (such as waterlogging), or by mineral replacement. Preservation can also occur through desiccation, although in Britain this normally occurs only in standing buildings.

Charred plant remains are found on most archaeological sites. Preservation occurs when the 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. For example, macroscopic silica remains of plants have been retrieved from ashy deposits at some sites (Robinson and Straker 1991).

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 they

---

**Figure 12** Egg of the parasitic nematode *Trichuris*. Total length c. 75 microns. Presence of polar plugs at each end enables measurements and comparison for specific identification, in this case probably *T. ovis*, characteristic of ruminants. (Photograph by J R G Daniell)

**Figure 13** Partially mineral-replaced coprolite from medieval deposits in Dryslwyn Castle; probably originally from a dog given the moderate sized fragments of bone surviving in the specimen. Plant remains can also survive in such material, although none are present in this specific example. (Photograph by J R G Daniell)

**Figure 14** Cereal grains provide evidence for use of specific crops, but the chaff (ear and stem fragments) can help in the investigation of the stages of crop processing represented. The two glume bases (centre top) are from emmer wheat while the barley rachis node (centre bottom) is from a 6-row variety. The grains on the left show the characteristic longitudinal wrinkles and rounded triangular shape of naked barley. Those on the right have the high dorsal ridge and twisted lateral groove often found on emmer. (Photograph by J P Huntley)

**Figure 15** 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. Scale bar = 1 cm. (Photograph by J P Huntley)
are anoxic and highly organic, such as in the fills of pits lined with stone, dug into heavy clay, or sealed by overlying stratigraphy. 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. 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 aspects of diet (Dickson and Dickson 1988, Greig 1983), arable husbandry practices (Hillman 1981; van der 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). Plant remains can also reveal details of landscape use, such as hedgerows (Greig 1994), and provide evidence for gardens and garden plants (Murphy and Scaife 1991; Dickson 1995). 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). Archaeobotanical information can be integrated with documentary evidence to give an enhanced picture (Greig 1996; Foxhall 1998). Patterns of distribution of plants on sites are important to determine where different activities took place.

Plant remains can also reveal details of landscape use, such as hedgerows (Greig 1994), and provide evidence for gardens and garden plants (Murphy and Scaife 1991; Dickson 1995). 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). Archaeobotanical information can be integrated with documentary evidence to give an enhanced picture (Greig 1996; Foxhall 1998). Patterns of distribution of plants on sites are important to determine where different activities took place.
Wood

Wood is preserved in waterlogged anoxic deposits, by charring (see charcoal, below), or by mineral replacement (with compounds from metal corrosion products, biogenic phosphate, by microbially induced pyrite deposition, or by calcite replacement in mortared walls). Waterlogged wood can be little more than a lignin ‘skeleton’ supported by water, and de-watering in such cases results in rapid deterioration.

Standing buildings and ancient living trees contribute to information regarding tree-ring chronologies (Hillam 1998), while wood from ‘submerged forests’ and river sediments provides independent data on the composition and structure of woodlands (Lageard et al 1995; Wilkinson and Murphy 1995).

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), timber for buildings and boats (McGrail 1979), trade, and status, where scarce material has been used (Cutler 1983).

Recording wood, especially structures and objects, calls for close collaboration between a wide range of workers: 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 1995).

Charcoal

Much charcoal represents the burning of wood, but it is also produced when other plant material is incompletely burnt. Depending upon 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 easily reworked.

The larger pieces of charcoal, such as might occur in hearth deposits or on industrial sites, can provide information regarding use of particular species. This can, but does not necessarily, reflect the composition of local woodlands. 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).

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 preparation. Concentrations of charcoal particles in pollen samples can therefore provide useful information on local burning of woodland/vegetation and hence, possibly, human clearance (Simmons 1996). Microscopic charcoal should be routinely quantified alongside pollen.

Pollen and spores

Higher plants produce pollen, while lower plants (such as ferns and mosses) and fungi produce spores. A combination of size, surface texture, and number and type of apertures (among other features) enables these microscopic structures to be identified to a greater or lesser taxonomic level (Moore et al 1991). Ribwort plantain (Plantago lanceolata) pollen, for example, can be identified to the species level, but many species in the daisy family (Asteraceae) cannot be separated from each other. Identification of moss or fungal spores is rarely attempted, mainly because of a lack of systematic study or availability of reference material. Recent advances have been made, however. Dr Bas van Geel and colleagues at the University of Utrecht have catalogued a wide range of types of non-pollen palynomorphs (van Hoeve and Hendriks 1998).

Pollen and spores are typically 25–120 microns in diameter. Being small, they are widely disseminated by wind, rain and water, which means that individual grains can be found at considerable distances from the parent organism. Thus, caution is required during interpretation, especially when considering the relative importance of the wider landscape as opposed to that of the immediate archaeological site or context.

Pollen and spores survive best in acidic and anoxic conditions, such as peat bogs, some lake sediments, and waterlogged ditch and pit fills. Copper salts from artefacts can also preserve pollen (Greig 1989). Pollen and spores are not, however, necessarily destroyed under other preservation conditions and tallying the levels and types of degradation can aid interpretation considerably.

Both pollen and spores are used to provide information about the vegetation of an area. In naturally accumulated deposits, the character of a pollen assemblage (the taxa recorded and the proportions of each type of pollen present in any given sample),
will provide an integrated picture of the vegetation for some distance around the site (Prentice 1988). This distance can be from a few hundred metres to some tens of kilometres, depending upon the nature of the area from which the sample was taken. The size of the coring area, and whether the landscape around it was wooded or treeless at any particular time, are the most important factors to consider when interpreting a pollen diagram (Jacobson and Bradshaw 1981). Clearly, the area represented by a sequence of pollen assemblages can change with time, as natural vegetation succession occurs. Thus, it is important to choose sampling locations appropriate to the questions being asked. The analysis of multiple profiles can overcome some of the problems of interpreting pollen diagrams (Mighall and Chambers 1997). Current work on pollen from small archaeological features indicates that the assemblages recovered might be giving a very local picture.

Pollen taphonomy is extremely important and caution is needed especially in interpretation of pollen assemblages from archaeological deposits such as waterlogged ditches, buried soils and pits. Ditches often silt up after the associated site has been abandoned; thus, 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 naturally deposited alluvium or colluvium. Pits are quite likely to have material in them from a variety of sources (Greig 1982), including rubbish and other material deposited by people.

Pollen data should, where possible, be compared with other environmental results in order to interpret deposits (Wiltshire and Murphy 1998). Currently, advances are being made regarding the interpretation of pollen data by using modern analogues (Gaillard et al 1994). Pollen assemblages will not usually date a sediment with any precision, and thus independent dating techniques will need to be applied. 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 will depend on many factors, including peat accumulation rates, depth of sediment and the project objectives.

Depending upon preparation techniques used on the sediment, other materials (e.g., charcoal particles, diatoms, parasite ova and tephra shards) might also be seen on the microscope slides used for pollen counts. These could provide evidence that complements the interpretation derived from the pollen spectra.

**Phytoliths**

Phytoliths are microscopic bodies produced by many plants via the deposition of dissolved silica within or between plant cells. 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 and 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.

Phytoliths range in size from about 5–100 microns. In Britain they rarely have a species- or family-specific size and shape, but it is the identification of phytolith suites which has proved most useful (Powers 1994). Interpretation relies on the use of modern analogue source material, thus limiting the present application of the technique. 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). They have also been used to identify ancient agricultural fields in the Outer Hebrides (Smith 1996).

**Diatoms**

Diatoms are freshwater and marine algae that have a silica frustule or chamber made up of two valves, and it is this that survives. They are typically about 5–80 microns in size, though they can be larger. They are identified by their morphology, mainly the shape and surface texture.

![Figure 23](Image)

**Figure 23** The diatom, *Raphoneis amphiceros*, (total length c. 70 microns); this is a species characteristic of marine conditions. (Photograph by J. Sidell)

Species are habitat-specific and provide indications of water quality and depositional environment, such as temperature and salinity, nutrient/mineral levels, acidity and degree of oxygenation, and whether the site was periodically exposed to air. Diatoms are used by archaeologists to address a range of questions (Juggins and Cameron 1999). 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 recent work on the central London Thames (Cameron in Sidell et al. 2000), on the North Somerset Levels (Cameron and Dobinson 2000) and on Fenland sites (Cameron in Crowson et al. 2000).

**Biomolecules**

Biomolecular archaeology refers to the study of biological molecules retrieved from archaeological specimens. The development of highly sensitive analytical techniques has enabled small quantities of these molecules, preserved in archaeological remains, to be extracted and characterised. Biomolecules include:

- lipids (Evershed et al. 2001)
- blood and milk proteins (Cattaneo et al. 1993; Craig et al 2000)
- collagen (Mays 2000, Katzenberg 2000)
- DNA (deoxyribonucleic acid) (Brown 2000; Stone 2000)

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 pottery, and lipid residues are thus often used in the characterisation of organic matter associated with artefacts such as pottery vessels. Lipids and proteins thus provide information about food products (such as plant oils and waxes, and animal fats) and raw commodities used in antiquity. However, analysis of the lipid component of human, animal and plant remains, anthropogenic soils and sediments is also undertaken.

The identification of blood proteins on stone artefacts is a controversial issue in archaeology. Recent work on casein, a milk protein, has made possible the identification of cow milk residues in pottery.

The main protein of bone, collagen, is the most common target for stable isotope analyses, although work has also been done on lipids, hair, dental enamel and bone mineral. Stable isotope ratios may vary with climate (eg oxygen), with food source (eg carbon and nitrogen) or with local geology (eg strontium). In human remains, stable isotopes have been used to study aspects such as diet, infant feeding practices, climate and population movements.

DNA encodes the genetic information of an organism, so ancient DNA is an important source of palaeo-genetic information. It has been used to examine human evolution, migration and the social organisation of past communities, to identify disease organisms, and to investigate the origins and evolution of domesticated animals and plants.

Before undertaking any work on biomolecules it is necessary to take specialist advice about potential contamination, the likelihood of preservation of suitable compounds and the potential contribution of the material to archaeological knowledge. It should be emphasised, however, 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 on-site. 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.

**Geoarchaeology**

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; 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:

- 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/digestion by animals. Buried soils are generally only found beneath earthworks or under rapidly accumulating sediments such as alluvium and peat, 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 instance, was the area of a barrow de-turfed before construction?
- 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. They 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.

Off-site work might also be needed in some cases. 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). Off-site geoarchaeology might also involve studying the resources that would have been available to people in the past. 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 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 commonest examples are determination of calcium carbonate, pH, percentage organic carbon content and magnetic susceptibility. 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 (Milek 1997). The commonest of these methods is the thin section viewed in two forms of polarised light – a system that allows 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 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 interpretational 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.

3 Sampling
This section covers:
- why sampling strategies are needed
- examples of possible methodologies
- which types of samples to take
- what to consider when taking samples
- storing samples

Figure 24 Deep peat sections at Wells Road, Glastonbury: monolith and specialist samples being taken for biological analyses. (Photograph by R Bruning)
Sampling strategies

The main issues in environmental archaeology concern ecological, social and economic reconstruction. These themes can be examined by studying changes over time, changes in activities across sites, evidence of specific activities or events, and interaction with the contemporaneous landscape. Sampling is part of the process of recovering archaeological materials and information from a site. The excavation is itself a sample, often a relatively small one, of the whole archaeological site. Achieving effective environmental sampling of the excavation sample requires a well-constructed sampling strategy. This is one of the most difficult, but fundamental, areas of environmental archaeology.

The decisions in formulating sampling strategies depend on two factors:

- the identified research aims (as defined in the project design)
- the likely presence of particular environmental remains

The first consideration is: what are the questions being asked? Examples could include:

- What agricultural activities were taking place on the site?
- What was the environmental setting of this settlement and how has it changed over time?
- Were these fields/houses inundated by freshwater or marine flooding?
- Was this site occupied seasonally or all year round?
- Is there evidence for differentiation of food preparation and rubbish disposal?
- Is it possible to identify social status?

This will affect what types of samples are taken (see Table 3) and their sizes. 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 preservation or loss of different materials, thus leading to different considerations for sampling.

Sampling should not only concentrate on features that can be dated in the field, but should also consider features that are undated during excavation. The 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.
To examine environmental change over time, long sequences of deposits are usually needed. These are recovered from locations with substantial accumulations of sediments, for instance river channels, lakes, bogs, mires and glacial depressions, or ditch sections and ponds. Sampling a long sedimentary sequence near to an archaeological site, for example, will provide information both on the site and on the wider ecological history of the area (Dark 1996). If long single sequences are unavailable, it is possible to sample from succeeding phases or archaeological contexts. Well dated pit fills or ditches, for example, can give information on vegetational change through time (Hunn and Rackham forthcoming). Co-ordinated sampling for different materials from the same deposits is often desirable and will provide a more enhanced interpretation than a single line of evidence. A more detailed discussion of sampling for environmental materials can be found in Orton (2000, chapter 6). When planning a coherent sampling strategy it is necessary to involve the relevant specialists at the earliest possible opportunity and to:

- Have clear objectives. For example, a typical objective is to examine the species richness and diversity of the subfossil assemblages by considering the proportions of various species across a site. Other objectives will concern the nature of human activity and ecological reconstruction.
- Use all available current knowledge to inform decisions. Information from comparable sites can support predictions about the likely survival and density of material in different features. It can sometimes also provide an indication of the likely level of spatial homogeneity.
- Be clear about which contexts are to be sampled. Many classes of environmental material are not visible to the naked eye and appearances can be deceptive. Black deposits, for example, might not contain any charred material, or might be rich in wood charcoal but poor in seeds. Commonly excavators tend to sample from layers expected to be productive. It is essential, however, to collect samples from all types of deposit. The exceptions are unstratified deposits, make-up layers or contexts with a high degree of residual or intrusive artefacts that are not generally useful, except when specific questions are posed.
- Allow for the fact that environmental remains are not necessarily homogeneously distributed through a given deposit. In some instances, several samples from the same context can be preferable to a single one. Multiple samples can always be combined later, if appropriate, but a single sample cannot be divided meaningfully to represent environmental variation within that context.
- Have a flexible sampling strategy that can be re-evaluated as the excavation proceeds.
- Realise the potential of integrating environmental sampling with that for other types of artefactual evidence, e.g. the recovery of technological waste such as hammer scale.
- Ensure compatibility between the environmental sampling strategies and the recovery of other classes of information to meet the project objectives.
- Consider the logistics of collecting, processing and transporting sampled material.

Samples can be collected on- or off-site depending on the aims of the project and the presence of suitable deposits.

On-site sampling
The term ‘on-site’ refers to an excavated archaeological area. On-site sampling collects data from the range of contexts and phases encountered on archaeological sites and can be achieved using several different methodologies. In selecting an on-site sampling strategy the choice is primarily between random, judgement and systematic sampling, as summarised below. Common practice is a combination of judgement and systematic sampling. (See van der Veen (1985) for a discussion on random and judgement sampling specifically in relation to charred plant remains.)

Off-site sampling
The term ‘off-site’ refers to any area that lies beyond an excavation, but which can still be sampled for archaeological purposes. Off-site deposits might preserve evidence of human environment, land use and landscape change. Examples of such deposits include buried peats, bogs, lakes, alluvial and colluvial deposits. There is now a more widespread recognition that such deposits preserve important archaeological information, and should be construed as part of the archaeological heritage as defined by the revised European Convention on the Protection of the Archaeological Heritage (1992) (the Valetta Convention).

Off-site sampling generally involves targeting one or several locations for the collection of samples. Samples are usually 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.

<table>
<thead>
<tr>
<th>Table 2 Sampling methodologies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sampling method</strong></td>
</tr>
<tr>
<td>random</td>
</tr>
<tr>
<td>judgement</td>
</tr>
<tr>
<td>systematic</td>
</tr>
</tbody>
</table>

![Figure 26 Using a modified Livingstone piston corer in kettle hole deposits on the A66 at Stainmore, County Durham. (Photograph by J P Huntley)](image)
Machine- or hand-dug trenches can also be cut, where the sampling site is suitable. Some off-site sampling locations might be covered by legislation: for example, permission from English Nature 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 (Table 1), human activities and depositional processes. For example, samples for charred plant remains are routinely collected from dry feature fills such as pits and postholes, while samples for the recovery of both plant and invertebrate macrofossils can be taken from waterlogged deposits. Exposures of peats and clays in river valley or coastal sequences would require a range of samples for 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 since this term is used differently by different people and can lead to confusion.

Samples can be classified into three basic types:

Coarse-sieved samples. These are collected by the excavation staff for the retrieval of small bones, bone fragments, larger (mainly marine) molluscs (such as oysters, mussels, limpets, etc) and smaller finds. Other materials that could be collected include wood charcoal, large plant remains (charred, waterlogged and mineralised) 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. Sample size is normally on the order of 100 or more litres, and the samples are usually sieved on a minimum mesh size of 2mm. The samples may be wet or dry sieved depending on the soil conditions and are usually processed on site. Coarse-sieved samples are often collected from deposits that are unusually rich in bone or shell and are best taken with the advice of the appropriate specialist.

Figure 27 Flotation tank on-site at St. Giles by Brompton Bridge, North Yorkshire. (Photograph by S. Stallibrass)

Flotation samples. These are taken from well drained deposits for the recovery of charred plant remains from the ‘flot’, and for charcoal fragments, small bones, mineralised plant remains, industrial residues such as hammerscale, and smaller finds from the residues. They are usually collected by the excavation team and should generally be processed on site where facilities (water, adequate drainage, silt disposal, drying space) are available. Molluscs could also be recovered in flotation samples, but generally should be recovered in ‘specialist’ samples (see below).

Sample size will normally be of the order of 40–60 litres or 100% of smaller features. The floating material (the flot) is usually collected on a sieve with a mesh size of 250–300 microns. Residues are usually collected on a sieve size of 0.5mm (500 microns)–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 mineral-replaced or at least mineral-coated.

The plant material often fails to float, remaining in the residue. In such cases, residue mesh size must equal flot mesh size in order to not lose valuable material.

The smaller fractions of residues from flotation samples (generally residue fractions smaller than 4mm) need to be sorted under a microscope by the appropriate specialist(s), as biological remains within the smaller fractions are too small (and sometimes too unfamiliar) to be recovered adequately by non-specialists. Larger fractions can sometimes be sorted by non-specialists for the recovery of larger finds with the naked eye, though this should be done under appropriate supervision. In many cases where no bone or industrial material is present, the specialist will probably only need to scan the residues to check the effectiveness of the flotation. It should be noted that flotation machines are not always highly effective at recovering charred plant remains (de Moulins 1996) and that checking residues to note the quality of recovery is necessary.

Flotation samples are also taken for cremated human remains. Residue mesh sizes are usually 2mm and 4mm with flot mesh sizes as above. The whole of each deposit should be sampled. Specialist advice should be sought before processing, as on-site processing is not always suitable.

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 macrofossils. The sample size is normally of the order of 20 litres. These can be taken from individual contexts or from vertical sections. In some circumstances larger samples will be needed, for instance for the recovery of small vertebrates (small rodents, reptiles, etc). Samples for snails are generally smaller, of the order of 2 litres, and are collected from dry or wet deposits where snails are present. Mesh sizes for large specialist samples will vary according to the material to be recovered.

2. Monolith samples. These are collected from vertical sections in monolith tins, squares 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. Kubiena boxes are usually made of aluminium, with lids on the front and back, and are specifically made for micromorphology sampling.

3. Cores. Cores can be taken for a similar range of materials to monolith samples and smaller samples (below).

4. Small samples can be collected separately from discrete contexts for certain items, such as ostracods (10–50g), and for geoarchaeological analyses, such as particle size determination (0.5 litre). Small samples, usually 1–2 cm³, 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.

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. 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 and bagged and dealt with separately. Jaws with teeth should also be bagged as a unit, although preferably then 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 transport etc, can, nonetheless, be re-associated with their specific mandible.

<table>
<thead>
<tr>
<th>Table 3 Examples of sample types appropriate to particular materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>coarse-sieved</td>
</tr>
<tr>
<td>vertebrate (bone also recovered by hand on site)</td>
</tr>
<tr>
<td>molluscs</td>
</tr>
<tr>
<td>insects, arachnids, etc</td>
</tr>
<tr>
<td>parasite ova</td>
</tr>
<tr>
<td>plant macrofossils</td>
</tr>
<tr>
<td>wood</td>
</tr>
<tr>
<td>charcoal</td>
</tr>
<tr>
<td>pollen and spores</td>
</tr>
<tr>
<td>phytoliths</td>
</tr>
<tr>
<td>foraminifera</td>
</tr>
<tr>
<td>ostracods</td>
</tr>
<tr>
<td>diatoms</td>
</tr>
<tr>
<td>soils and sediments</td>
</tr>
</tbody>
</table>
Taking samples

Samples should be from individual contexts, unless they are monolith samples that cross stratigraphic boundaries. Sometimes it is appropriate to sample thick contexts in spits of, for example, 5–10cm. The samples must come from cleaned surfaces, 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 record sheets should provide information on sample type, reason for sampling, size, context and sample numbers, spatial location, date of sampling, and 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 poly 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 and the depth within the sequence of the deposit recorded; overlapping samples must have their relationship recorded. The position of samples should be marked on all relevant site plans and section drawings. Specialists might also wish to make sketches and take notes. Photographic records of sampling taking place can be extremely useful in providing a complete record of sample position and orientation.

All sample processing must be recorded on sample record forms whose format is agreed by the project director, 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.

Storing samples

Key points for storage are:

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

Ideally, samples for laboratory processing should be collected by, or sent to, specialists as soon as possible. It might be necessary for excavators to store samples in some circumstances. Once excavated, however, organic material becomes more vulnerable to decay by microorganisms 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: they should be kept chilled and dark, and, as far as possible, in airtight containers. This will slow bacterial and algal growth, though dark conditions might encourage the growth of fungi.

The growth of fungal hyphae (threads) through the sample can lead to redistribution of carbon. This could conceivably affect radiocarbon dating. Light, however, will encourage the growth of algae and perhaps other green plants, which will (through photosynthesis) incorporate modern carbon into the deposits. This is very likely to affect the accuracy of radiocarbon dating.

These biological processes can also affect samples from ‘dry’ deposits and can cause substantial damage to charred plant remains and even to bone. 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. Ideally these should be processed on site during excavation, but if there is no alternative, then they should be kept as described above.

Refrigerating small samples such as those for pollen and diatoms presents few problems. Monoliths and individual samples may be kept well wrapped in a domestic refrigerator. Field archaeologists will not, however, usually have access to cold stores, in which larger samples from waterlogged deposits should ideally be kept, and many specialists do not

Figure 31 Schematic diagram for sampling.
have such expensive facilities either. 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. The containers should be well sealed to prevent drying out of waterlogged samples. 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 to the effect that the sample had accidentally dried in storage.

Freezing samples can destroy or obscure sediment structure and damage organic material, but is preferable to storage in warm conditions except for short periods.

4 Practice

This section proposes a guide to good practice for environmental archaeology sampling in fieldwork, including evaluations and full excavations. It aims to address the requirements for project planning, sampling, recording and storage, and to summarise some important current issues. 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 the project director plan and manage effectively. There are other more detailed sampling manuals available for environmental archaeology, such as those produced by the Association for Environmental Archaeology (1995) and Murphy and Wiltshire (1994). Specific guidelines for particular types of material are available for waterlogged wood (Brunning 1995), waterlogged leather, (English Heritage 1995), human bone (McKinley and Roberts 1993) and dendrochronology (Hillam 1998). It is hoped that specific guidelines on other aspects of archaeological science will be forthcoming.

The Institute of Field Archaeologists’ (IFA) Standard and guidance for archaeological materials (2001) provides general guidance for all finds work.

The present guidelines are aimed primarily at projects following the management principles set out in ‘MAP 2’ (English Heritage 1991). It is intended that they should be applicable to all archaeological projects, as these procedures are designed for the efficient execution of archaeological projects within set time and cost constraints, from fieldwork to publication, including the creation of a site archive.

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 (1996, 1999a; 1999b; 1999c; 1999d). The document Model Clauses on Archaeological Science for Briefs and Specifications (English Heritage forthcoming) 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 Advisors for Archaeological Science (listed at 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 1990).

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 4).

Desk-based assessment

The purpose, definition and standard for desk-based assessment are given in IFA (1999a).

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

- topography
- solid geology
- drift geology
- soil type
- aerial photographs
- 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

Useful sources of information are geology and soil maps, previous surveys, other local archaeological reports, the sites and monuments records (SMR), the Environmental Archaeology Bibliography (EAB) (http://www.eng-h.gov.uk/eab/) and the Archaeology Data Service (ADS) (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 appropriate experienced specialists. 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. It should be appreciated that, as remarked elsewhere in this document, predicting the survival of environmental remains in archaeological deposits is not an exact science (Table 1). Any schemes 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. Arrangements should be made for specialists to pay site visits once the fieldwork begins, and to stay in touch during fieldwork so that any difficulties can be dealt with promptly.

Watching briefs

The purpose, definition and standard for watching briefs is given in IFA (1999b). Whether sampling is done during watching briefs depends on many factors. Best practice would allow for the sampling of interpretable and datable archaeological deposits and provision should be made for this.

Evaluation

The purpose, definition and standard for evaluations is given in IFA (1999c). In some cases an evaluation might be the only excavation undertaken.

Evaluation trenching will provide a much more reliable indication of the potential for environmental archaeology than can be predicted from a desk-based assessment. Sampling in evaluations is normally less intensive than during full excavation. It should be directed to a representative range of context types from each phase, and examine:

- survival of material
- key archaeological contexts

Where possible, specialists should be asked to make site visits as for full excavation (see below, Excavation).

The results of assessments of environmental
material should, with the rest of the archaeological record, inform any further planning decisions.

Situations might arise where no further archaeological intervention is proposed following evaluation, yet significant scientific material has been retrieved and taken to assessment level only. Significant material should be analysed and published as part of the evaluation project (English Heritage, forthcoming).

Excavation

The purpose, definition and standard for excavations is given in IFA (1999d). A comprehensive sampling strategy should be agreed in the project design. Specialists will need to take their own samples as part of the evaluation project (English Heritage, forthcoming).

It is the project director’s responsibility to ensure that the specialists are kept informed about developments during excavation, including important finds, problems affecting the environmental sampling, and any significant alterations in strategy from what was agreed in the project design. Specialists should visit the site at appropriate times as arranged with the project director. 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 excavation team to co-ordinate and monitor sampling, 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 materials.

All flotation and coarse-sieved samples (see Section 3, Sample types) should be fully processed, preferably at the fieldwork stage:

**Assessment**

Once the material has been collected and processed it will need to be assessed. Every flot and coarse-sieved sample should be assessed unless determined to be unstratified or unacceptably contaminated. An assessment should give consideration to the potential contribution the material could make to archaeological knowledge. The assessment should also make recommendations for the type and scope of further analysis, and should feed into the updated project design for post-excavation. To be cost-effective these decisions must 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.

Information the specialist requires from the project director to carry out an assessment:

- a 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
- sampling and processing methods
- sample locations
- preservation conditions
- residuality/contamination
- other relevant contextual information
- list of samples and other material with an indication of quantity to be assessed

The assessment report should include:

- specialist aims and objectives relevant to the project research design
- sampling and processing methods
- assessment methods
- any known biases in recovery
- any known problems of contamination or residuality
- quantity of material assessed (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
- any agreed selection of organic materials

<p>| Table 4 Environmental archaeology: guidance for project planning |
|----------------------|------------------|-----------------|-----------------|-----------------|
|                      | Pre-excavation   | Excavation including evaluation | Post-excavation | Analysis and dissemination |
| MAP2 stage           | Project planning | Fieldwork       | Assessment      |                               |
| all categories       | • input into costed project design, eg background information from similar sites if relevant | • site visit(s) | • assessment of potential for full analysis, taking into account quality and quantity of data, state of preservation, and its potential contribution to the project aims (and in some cases beyond?) | • full analysis as agreed |
|                      | • agree possible sampling strategies and number of site visits needed | • implementation and revision of sampling strategies | • production of an assessment report | • project meeting to discuss results |
|                      | • liaison over proposed project timetable | • collection of specialist samples by specialists | • detailed recommendations should be made concerning whether detailed analysis is justified, and if so what should be done, how long it will take and how the costs are likely to be. | • production of a final report for publication, and if necessary an archive report for data that will not be published; transfer of report plus data to SMR, ADS, etc, with the rest of the site archive |
|                      | • planning for deposition of archive | • update on costs for assessment | • review of assessment phase/project meeting | • production of illustrations for publication |
|                      | additional/different requirements | • discussion of new or revised project aims arising during fieldwork | • input to updated project design | • preparation of material for archiving and transfer to archival body |
| animal bone          | as above          | additional/different requirements | • update on costs for full analysis, which should include any technical help that will be needed | • project meeting(s) |
|                      | collection and sieving of coarse-sieved samples hand collection during excavation | additional/different requirements |                               |                               |
|                      | estimate of costs for analysis of DNA, stable isotopes, etc | additional/different requirements |                               |                               |
|                      | analysis of DNA, stable isotopes, etc; this should only be done once osteological analysis has been completed | additional/different requirements |                               |                               |</p>
<table>
<thead>
<tr>
<th>MAP2 stage</th>
<th>Pre-excavation</th>
<th>Excavation including evaluation</th>
<th>Post-excavation</th>
</tr>
</thead>
<tbody>
<tr>
<td>human remains</td>
<td>as above</td>
<td>on-site presence of specialist washing of bone marking of bone wet-sieving soil samples sorting of residues from sieved soil samples</td>
<td>assessment of potential of assemblage for analysis in terms of site-specific and more general questions estimate of costs for analysis of DNA, stable isotopes, etc</td>
</tr>
<tr>
<td>insects, etc</td>
<td>as above</td>
<td>sampling</td>
<td>paraffin flotation</td>
</tr>
<tr>
<td>egg shell</td>
<td>as above</td>
<td>site visit not essential sieving of samples as specified by specialist</td>
<td>sample preparation</td>
</tr>
<tr>
<td>molluscs</td>
<td>as above</td>
<td>sampling</td>
<td>sample preparation</td>
</tr>
<tr>
<td>ostracods</td>
<td>as above</td>
<td>sampling</td>
<td>sub-sampling, if necessary, from specialist samples or monolith column sample preparation</td>
</tr>
<tr>
<td>foraminifera</td>
<td>as above</td>
<td>sampling</td>
<td>sub-sampling, if necessary, from specialist samples or monolith column sample preparation</td>
</tr>
<tr>
<td>parasite ova</td>
<td>as above</td>
<td>sampling</td>
<td>sample preparation</td>
</tr>
<tr>
<td>plant macrofossils (charred and mineral-replaced)</td>
<td>as above</td>
<td>sampling flotation of all flotation samples sorting of dry residues</td>
<td>assessment of all flots and proportion of residues</td>
</tr>
<tr>
<td>plant macrofossils (waterlogged)</td>
<td>as above</td>
<td>sampling</td>
<td>sample processing for waterlogged sediments</td>
</tr>
<tr>
<td>wood</td>
<td>as above</td>
<td>sampling cleaning if necessary recording of tool marks storage in suitable conditions</td>
<td>sorting of flots</td>
</tr>
<tr>
<td>charcoal</td>
<td>as above</td>
<td>sampling flotation/sieving of samples extraction of charcoal from dry residues</td>
<td></td>
</tr>
<tr>
<td>pollen and spores</td>
<td>as above</td>
<td>sampling</td>
<td>sediment description and sub-sampling in the laboratory pollen preparations</td>
</tr>
<tr>
<td>phytoliths and diatoms</td>
<td>as above</td>
<td>sampling</td>
<td>sub-sampling sample preparation</td>
</tr>
<tr>
<td>biomolecules</td>
<td>as above</td>
<td>seek specialist advice</td>
<td>seek specialist advice</td>
</tr>
</tbody>
</table>
| geoarchaeology | exploratory coring exercise and report if required | sampling coring (sometimes as an extension to excavation) site visit report if geoarchaeological involvement goes no further | full description of soils and sediments (In some cases some thin sections and some analytical tests might be needed as a guide to what will be required in the analysis phase,)
| dating | costs to be included in project design | selection and submission may take place at the fieldwork, assessment or analysis stages | |

* During evaluations, human bones are usually left undisturbed.
for radiocarbon dating, or recommendations of suitable material for dating

- recommendations for future work, including full analysis
- standard description of soils and sediments
- time required and costings for future work

**Analysis and reporting**

The type and level of analysis needed should be clear from the assessment report and agreed between project director and specialist. The report should state aims in relation to the project research design, methods, results and conclusions. Reports should include clear statements of methodology. The results from scientific analysis should be clearly distinguished from their interpretation. Non-technical summaries of results should be included. The full data from the analysis should be presented. Access to data from other aspects of the site will allow the production of an integrated report.

Reports should include:

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

**Dissemination and archiving**

**Sites and Monuments Record**

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 SMR 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 preservation of biological remains.

**Publication**

The publication of the full data in association with their interpretation should be encouraged, in the text of printed reports or in the main body of reports disseminated by electronic means. At the minimum, publication needs to include 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 must 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 particular interest to specialists within the particular field of study, including illustrations of unusual or important material should also be included.

**Archiving**

The environmental archive is made up of the environmental material itself and the associated data. These are both part of the site archive and should be deposited with it in the receiving museum. Both the data and the materials should be accessible.

Preparation of the archives for long-term storage should be undertaken with reference to the guidelines for long-term storage given by Walker (1990). Decisions on discard policies should be made in consultation between the specialist, the project director and the receiving museum. Human remains form a special case and reference should be made to McKinley and Roberts (1993).

The data archive should contain the full data set, including codes, electronic files of data and metadata, and text files, diagrams, photos, etc.

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

The publication Standards in the Museum Care of Archaeological Collections (Museum and Galleries Commission 1992) gives standards for archive deposition in receiving museums.

Standards for digital archiving are available from the Archaeology Data Service. The publication Digital Archives from Excavation and Fieldwork: Guide to Good Practice (1st and 2nd editions) can be obtained from their website: http://ads.ahds.ac.uk/project/goodguides/g2gp.html

**Appendix: case studies**

To develop and implement an appropriate and cost-effective sampling strategy, careful thought is needed at all stages of the archaeological process. The following case studies provide some examples of good practice.

**Preparing project designs:**

Resources for palaeoenvironmental sampling are always limited. The most informative results will be obtained where a sampling programme targeted towards answering specific questions can be developed. Plainly, contingencies are necessary to allow for the unpredictable, but in general a focused and interrogative approach is best, to avoid dissipating resources in the production of redundant and repetitive data. The questions to be addressed will relate to Regional Research Frameworks, but frequently there will also be a need to define a more local framework. Data from Desk-based assessment, field evaluation and sometimes (as below) some additional analysis will feed into this. Close collaboration between curators, consultants, developers, field units, archaeological scientists and advisers helps to ensure a successful outcome.

Ivel Farm, Bedfordshire

A planning application was submitted for mineral extraction in a 24 hectare site at Ivel Farm, on the floodplain of the River Ivel, Bedfordshire. The developer, now RMC Aggregates (Eastern Counties) Ltd, was advised by the Archaeological Conservation Officer (ACO), Bedfordshire County Council, that, before determination of the application, information would be needed on the archaeological impact. A specification and project design was agreed with the ACO, and the Bedfordshire County Archaeology Service (now Albion Archaeology) was commissioned by The Guildhouse Consultancy, on behalf of the developer, to undertake evaluation.

The evaluation demonstrated extensive Mesolithic–Bronze Age and Roman activity, partly sealed by alluvium, as well as several palaeochannels, including waterlogged sediment sequences.

It was plain that Archaeological Science aspects of the site would form a significant part of the project design for excavation, and also a major cost component. It was necessary to develop a well defined strategy for Archaeological Science to maximise the information yield from the resources available and to avoid an open-ended financial commitment on the developer’s part.

Following meetings involving the ACO, Consultant, Field Unit and English Heritage
Adviser, however, it became clear that developing a strategy was hampered by the fact that earlier archaeological investigations in the Ivel Valley had not progressed beyond assessment, and were only published in outline. It was impossible to define a local research framework. Dr Mark Robinson was therefore commissioned to undertake analysis of plant macrofossils, insects and molluscs from selected samples from earlier excavations at a comparable site nearby – Warren Villas. A targeted programme of radiocarbon dating was also carried out. From this, Dr Robinson was able to present a model for changing land use and hydrology for the Middle Ivel Valley (Robinson 2001b). Sampling during excavation at Ivel Farm will be directed towards verifying this model and detecting any spatial variability in environmental conditions and land use in the valley. The ACO's Brief and Project Design incorporate this approach.

Thanks are due to RMC Aggregates (Eastern Counties) Ltd for their enlightened approach to this project.

Watching brief
Results from evaluation may indicate that no more than a watching brief is required, at least for parts of sites. There is always the potential for unexpected significant finds, however, as illustrated in this case study. Always, but especially in this situation, good communication and close collaboration between all those involved in the project are the key to its successful application.

Swalecliffe, Kent (RPS Consultants 2000)
Evaluation at this site related to the construction of a wastewater improvement scheme at Swalecliffe Wastewater Treatment Works, Swalecliffe, near Whitstable, Kent. The specifications were written by Kent County Council (KCC) archaeologists in March 2000 and the investigation carried out by RPS Consultants, archaeological consultants to Southern Water. Several other evaluations and watching briefs around the site had shown the presence of late prehistoric cut features and a sequence of Pleistocene deposits including remains of woolly rhinoceros and mammoth. The new evaluation was specifically aimed at investigating the latter deposits further.

Although the Pleistocene deposits were relocated during the evaluation, no diagnostic palaeoenvironmental remains were found and the results proved less productive than anticipated. During a watching brief, however, a slab of concrete outside the immediate evaluation area under observation was moved, revealing a waterlogged Late Bronze Age pit complex. On the insistence of the KCC, all seventeen pits, which included well preserved organic remains and wooden artefacts, were excavated and recorded by the RPS Consultants field staff. RPS were aided by Archaeoscope (Royal Holloway College), who had been commissioned to carry out the environmental work for the evaluation. Experts operating in the south-east visited at short notice to advise on the sampling, dating, lifting and treatment of worked wood and other organic materials.

Following meetings to consider funding, Southern Water supported the costs of post-extraction work as estimated by the consultants. RPS Consultants provided the funds for the five radiocarbon dates and a significant contribution for the dendrochronology, as well as additional staff time. Help in kind was provided by English Heritage to cover part of the cost of dendrochronology.

A dendrochronological report (Tyers 2001) and environmental reports by Archaeoscope have been produced and a publication is planned for the beginning of 2002. Although more radiocarbon dates could be obtained and, it is hoped, will be, results are at the moment quite substantial. Data on the functions of these features were obtained from analysis of pollen, plant macrofossils, insects, molluscs and animal bones. It was concluded that they were wells, cut and recut at intervals of possibly 30–50 years, and used continuously over a 500–year period (Masefield et al forthcoming).

Evaluation
The environmental archaeology component of evaluation involves, first, an assessment of preservation conditions for biological remains, soils and sediments. The potential of these sources of data to provide pertinent results for site interpretation, or to contribute to a wider understanding of landscape development, must also be considered. Where preservation (in situ) is the preferred option, appraisal of likely impacts of the development on the archaeological deposits is needed. Commonly, samples and other material will be obtained from evaluation trenches, but deeply stratified sites present special problems, as outlined below.

Barnwood Court, Silvertown, East London
A geoarchaeological evaluation was carried out in advance of housing development under an archaeological condition on the planning consent, advised under PPG16. The evaluation was designed to characterise the sedimentary history of the site, particularly with reference to the changing history of the Thames and to establish whether any archaeological remains might have been present. Using the previously existing geotechnical data, the seven boreholes were sited in order to gain maximum data collection across the site; the consultant and contractor together undertook this process. Drilling took place using a rig hired specifically for the archaeological project, and monitored throughout by a geoarchaeologist.

Following fieldwork, the assessment stage consisted of lithological examination (description, X-ray, magnetic susceptibility and loss-on-ignition) with assessment of the pollen and diatom content in order to examine adequately the river regime and vegetation dynamics. A chronological framework was constructed with two radiocarbon dates per borehole. The assessment indicated no evidence of on-site human presence, while making it clear that borehole evaluations are very much a first-stage evaluation tool and that trench evaluation should supplement the use of boreholes wherever possible. No further fieldwork was undertaken, as the chances of any archaeological remains occurring were thought to be low and the depth to intact stratigraphy would have made trench investigation difficult. Nevertheless, the palaeoenvironmental aspects were deemed sufficiently important as a background to the regional archaeology to persuade the developer to fund the analysis of the sequence data. The analysis examined the issues of site formation processes, vegetational history and relative sea-level change more fully, and has since been published (Wilkinson et al 2000). The report has been used by other fieldwork projects in the area as important information on regional vegetation types.

Excavation
Two case studies of palaeoenvironmental sampling undertaken within well defined research frameworks are given here – one urban, one rural. The desirability of having an ‘environmentalist’ present on site, and the absolute need for frequent site visits by specialist archaeological scientists are highlighted. Large-scale sampling can present logistical problems: coarse-sieving and flotation should be seen as part of the excavation process, and where possible, undertaken concurrently with it. An approach to fieldwork, assessment and analysis consistent with MAP2 provides scope for definition of new research objectives, not apparent at the outset.

Number One Poultry, City of London
The excavations carried out at Number One Poultry were among the largest undertaken in this country. Approximately 9000 m² of Iron
Age to post-medieval archaeology was excavated by hand. Initially, consent for work was given before PPG16 was issued, but the project was deferred until 1994 when the initial consent was revised, in consultation with the developer and City of London archaeologist. The project was then run along PPG16 and MAP2 lines.

The environmental strategy was discussed significantly before evaluation with an environmental project design and then a sampling strategy was prepared using local knowledge and incorporating data from the evaluation. A minimum of one environmentalist was present throughout all the fieldwork, to oversee and modify the sampling strategy where and when necessary, to facilitate the work of the other environmental specialists visiting and sampling, and to assist and monitor the sample processing, which was carried out in a dedicated facility on-site. A little more than one thousand samples for coarse-sieving and flotation were collected, both waterlogged and dry, as well as several hundred inhumations and several tons of timber, animal bone and shell.

The sample processing was completed a few weeks after excavation with the exception of subsamples, which were retained for specialist analysis. The project moved straight on to assessment with the completion of the stratigraphic archive, also undertaken during fieldwork. The assessment revealed an enormous diversity of biological material as well as good potential for using the geoarchaeological samples to reconstruct site formation processes and hydrological regimes. The assessment targeted how to proceed with reference to the original research questions, additionally highlighted a number of new research objectives based on the material recovered.

A review occurred on completion of the assessment, and the analyses of pollen, insects, wood, dendrochronology, geoarchaeology, bones, molluscs, diatoms, ostracods, parasites, eggshell and plant macrofossils went ahead. The full monographs are not yet published, but a popular book, Heart of the City (Rowsome 2000) has been published, incorporating information from the biological remains.

The Arrow Valley (Palmer 2000)
Archaeological investigations took place in the Arrow Valley, Warwickshire, during 1993–4, in advance of road construction. The river Arrow is a major tributary of the Warwickshire Avon. Several sites within a few kilometres of each other, spanning in date the Neolithic to Saxon periods, were excavated along the line of the road. A previous excavation related to the same road scheme had been undertaken at a nearby medieval settlement at Boteler’s Castle (Jones et al 1997). A major research aim of the project was the consideration of changes in human activity and landscape use through time. The investigations were funded by the Highways Agency and carried out by the Warwickshire Museum.

Samples for charred plant remains were taken following a strategy agreed between the project director and the charred plant remains specialist, and reviewed during site visits by the specialist. The strategy was intended to recover evidence from every feature type and also to sample a number of similar features from each phase in order to compare like with like. This was done for each phase of each site and thus the sampling was quite extensive. Bone preservation was reasonably good, but the actual amount present was fairly limited; thus, only hand collection of bone was undertaken, with the exception of a Bronze Age cremation pyre, where the pyre contexts were recovered in their entirety and wet-sieved to 1mm. The single waterlogged feature encountered, a Roman ditch, was sampled collectively by the specialists for beetles, plant macrofossils and pollen.

Individual specialists undertook assessment of the material. Cremated human remains, waterlogged plant remains, beetles and pollen were all recommended for full analysis. The animal bone specialist concluded that, given the limited size of the assemblage, no further analysis was needed on the animal bones, but the results of the assessment were included in the final report.

All of the samples for charred plant macrofossils were assessed and selected samples were recommended for further analysis according to the specialist’s judgement of their potential to contribute to the project research aims. The charred plant remains assessment identified which samples had abundant wood charcoal. These data provided a sufficient basis for the charcoal specialist and project director to discuss and agree which samples should be analysed for wood charcoal, without the charcoal specialist having to look at all the flotation.

The integrated results of the environmental evidence, especially when considered within the whole picture for each site, show very clearly a changing story of human landscape use. From possible ritual use in the Neolithic, probably within a landscape of still-abundant woodland resources, there emerged definite ritual use in the Bronze Age, with a small amount of evidence for managed woodland. The sparse Iron Age evidence appears to suggest a domestic settlement with some arable activity. There is clear evidence that by the late Roman period there was a very open, managed landscape with a mixed arable and pastoral economy. The greater amount of evidence from the Roman period enabled more detailed work to be done, which defined some of the possible human activities that had been taking place. There was also possibly an economic change in the use of the area from the early to later Roman periods. In the Saxon period there was a change in domestic activities related to the use of plant resources.

The results of this study have contributed greatly to the current understanding of settlement and landscape change in southern Warwickshire, and have provided wider research implications for other archaeological studies in the Avon drainage system.
Glossary

agglutinated consisting of particles cemented together
alluvial waterlain sediment; not marine or estuarine
analogue an equivalent organism or environment – modern analogues are used to interpret past situations or species
anoxic oxygen-depleted
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
calcareous containing or characteristic of calcium carbonate
calcined burnt white
calcite the commonest crystalline form of calcium carbonate
chironomids non-biting midges
chitin skeletal material found in certain invertebrates, especially arthropods; it is a carbohydrate, containing nitrogen
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)
diatoms unicellular aquatic algae
DNA Deoxyribonucleic Acid, which contains the genetic information of an organism
ecdysis moulting (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 their surroundings
exoskeleton skeleton covering outside of body, or in the skin
foraminifera mainly marine protozoa with shells or tests, generally microscopic
frustule diatom cell consisting of two valves
gley a soil strongly affected by waterlogging
interstadial short warm phase within glacial periods
invertebrate collective term for all animals without backbones
karst montane hard limestone
Kubiena box sampling box used for soil micromorphology, open-sided with lids on both sides
lignin complex carbohydrate polymer found in cell walls of many plants, giving strength and forming up to 30% of the wood of trees
lipid fat
loess wind-blown sediment, usually of silt
machair fixed dune pasture/grassland of shell sand
macrofossil small biological remains; term is usually applied to plant parts such as seeds, nut shells, fruit stones and stem parts but is also appropriate to any remains visible to the naked eye
marl a precipitated sediment found in lake bottoms
metadata data calculated from primary data, eg percentages derived from original counts of items; often used in syntheses
micron a measurement: thousandths of a millimetre
nematode worm unsegmented worms, typically parasitic on plants or animals
ostracods sub-class of crustaceans with two-valved shell, generally a few mm in length
pH a measure of acidity/alkalinity
phylum major group in classification of animals
phytoliths microscopic silica bodies produced by many plants
podzol an infertile acidic soil that forms in cool moist climates
polarised light light vibrating in certain narrow planes
polysaccharide complex carbohydrate of large, often fibrous molecules – important structural material
protists single-celled organisms with a nucleus
puparia the case in which some insects develop from larva to adult
pyrite iron sulphide mineral
rendzina dark soil that develops below grasslands in limestone or chalk areas
silica an inert compound forming part or all of many minerals such as quartz, but deposited by some plants within their tissues
stable isotope slightly different forms (different masses) of an element that behave in the same way chemically
taphonomy study of post-depositional processes
tephra fine, often microscopic, volcanic ash

test type of shell (typically in foraminifera)
thorax the section behind the head in insects bearing legs and wings
tufa a calcareous precipitated sediment often found in springs, rivers and lakes
vaterite a rare crystalline form of calcium carbonate
vertebrate animals which have a skull, spinal column and skeleton of cartilage or bone
Where to get advice

The first point of contact should be your local English Heritage advisor for archaeological science. The nine regional advisors for archaeological science are available to provide independent non-commercial advice on environmental archaeology and other aspects of archaeological science. They are based in universities or in the English Heritage regional offices. Please contact regional advisors currently based in universities at their university addresses, using the regional office address as a further contact point when necessary.

**East of England** (Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Norfolk, Suffolk)

Mr Peter Murphy
Centre of East Anglian Studies
University of East Anglia
Norwich
NR4 7TJ
Tel: 01603–592662
Fax: 01603 592660
E-mail: p.l.murphy@uea.ac.uk

English Heritage Regional Office
67–74 Burleigh Street
Cambridge
CB1 1DJ
Tel: 01223 582700

**East Midlands** (Derbyshire, Leicestershire, Rutland, Lincolnshire, Nottinghamshire, Northamptonshire)

Dr Jim Williams
English Heritage regional office
44 Derngate
Northampton
NN1 1UH
Tel: 01604 735400
E-mail: Jim.Williams@english-heritage.org.uk

**North East** (Northumberland, Durham (including former Cleveland), Tyne & Wear, all of Hadrian’s Wall)

Mrs Jacqui Huntley
Department of Archaeology
University of Durham
Science Laboratories
Durham
DH1 3LE
Tel and fax: 0191 374 3643
E-mail: JPHuntley@durham.ac.uk

English Heritage Regional Office
Bessie Surtees House
41–44 Sandhill,
Newcastle upon Tyne
NE1 3JF
Tel: 0191 269 1585

**North West** (Cheshire, former Greater Manchester, former Merseyside, Lancashire, Cumbria (excluding Hadrian’s Wall: see North East))

Dr Sue Stallibrass
University of Liverpool
School of Archaeology, Classics and Oriental Studies (SACOS)
William Hartley Building
Brownlow Street
Liverpool L69 3GS
Tel: 0151 794 5046
Fax: 0151 794 5057
E-mail: Sue.Stallibrass@liv.ac.uk

English Heritage Regional Office
Canada House
3 Chepstow Street
Manchester
M1 5FW
Tel: 0161 242 1400

**South East** (Kent, Surrey, Sussex (East and West), Berkshire, Buckinghamshire, Oxfordshire, Hampshire, Isle of Wight)

Dr Dominique de Moulins
University College London
Institute of Archaeology
Room 204A
31–34 Gordon Square
London WC1H OPY
Tel: 0207 679 1539
Fax: 0207 383 2572
E-mail: d.moulins@ucl.ac.uk

English Heritage Regional Office
Eastgate Court
195–205 High Street
Guildford
GU1 3EH
Tel: 01483 252000

**South West** (Cornwall, Isles of Scilly, Devon, Somerset, Dorset, Wiltshire, Gloucestershire, Bath and NE Somerset, Bristol, South Gloucestershire, North Somerset)

Ms Vanessa Straker
School of Geographical Sciences
Bristol University
University Road
Bristol
BS8 1SS
Tel: 0117 928 7961
Fax: 0117 928 7878
E-mail: V.Straker@bristol.ac.uk

English Heritage Regional Office
29 Queen Square
Bristol
BS1 4ND
0117 975 0700

**West Midlands** (Herefordshire, Worcestershire, Shropshire, Staffordshire, the former county of ‘West Midlands’, Warwickshire)

Ms Lisa Moffett
Department of Ancient History and Archaeology
University of Birmingham
Edgbaston
Birmingham
B15 2TT
Tel: 0121 414 5493
Fax: 0121 414 3595
E-mail: l.c.moffett@bham.ac.uk

English Heritage Regional Office
112 Colemore Row
Birmingham
B3 3AG
Tel: 0121 625 6820

**Yorkshire Region** (North Yorkshire, former South and West Yorkshire and Humberside (East Riding of Yorkshire, Kingston-upon-Hull, North Lincolnshire and North East Lincolnshire))

Mr Ian Panter
English Heritage
37 Tanner Row
York
YO1 6WP
Tel: 01904 601983
Fax: 01904 601997
Mobile: 07967 706869
E-mail: Ian.Panter@english-heritage.org.uk
Plant macrofossils
Gill Campbell: 02392 856780; Gill.Campbell@english-heritage.org.uk

Pollen
David Robinson: 02392 856776; David.Robinson@english-heritage.org.uk

Geoarchaeology
Matthew Canti: 02392 856775; Matt.Canti@english-heritage.org.uk

Animal bones
Polydora Baker: 02392 856774; Polydora.Baker@english-heritage.org.uk

Human bones
Simon Mays: 02392 856779; Simon.Mays@english-heritage.org.uk

References

Archaeology Data Service. Digital Archives from Excavation and Fieldwork: guide to good practice (1st and 2nd eds). http://ads.ahds.ac.uk/project/goodguides/g2gp.html (Accessed December 2001)

Association for Environmental Archaeology
1995 Environmental Archaeology and Archaeological Evaluations: recommendations concerning the environmental archaeology component of archaeological evaluations in England. Working Papers of the Association for Environmental Archaeology Number 2 (also available online via http://www.envarch.net/)

Association of County Archaeological Officers
1993 Model Briefs and Specifications for Archaeological Assessments and Field Evaluations. Assoc County Archaeol Officers


Buckland, P C, and Coope, G R 1991 A Bibliography and Literature Review of Quaternary Entomology. Univ Sheffield: J Collis Pult


Davidson, D A 1973 ‘Particle size and phosphate analysis – evidence for the evolution of a tell’. Archaeometry 15, 143–52


de Moulins, D 1996 ‘Sieving experiment: the controlled recovery of charred plant remains from modern and archaeological samples’. Vegetation Hist Archaeobot 5, 153–6


Dickson, C 1995 ‘Macroscopic fossils of garden plants from British Roman and medieval deposits’, in Moe, D, Dickson, J H, and Jorgensen, P M (eds), Garden History: garden plants, species forms and varieties from Pompeii to 1800. PACT 42, 47–72. Rixensart

Dickson, C, and Dickson, J 1988 ‘The diet of the Roman army in deforested central Scotland’. Plants Today 1, 121–6


English Heritage forthcoming Model clauses on Archaeological Science for Briefs and Specifications

Environmental Archaeology Bibliography (EAB) http://www.eng-h.gov.uk/eab/ (accessed December 2001)


Evans, J. and O’Connor, T 1999 Environmental Archaeology: principles and methods. Stroud, Glos: Sutton


Foxhall, L 1998 ‘Snapping up the unconsidered trifles: the use of agricultural residues in ancient Greek and Roman farming’. Environmental Archaeol 1, 35–40

French, C A I, and Whitelaw, T M 1999 ‘Soil erosion, agricultural terracing and site formation processes at Markiani, Amorgos, Greece: the micromorphological perspective’. Gerasarcheol 14, 151–89

Gaillard, M-J, Hicks, S, and Ritchie, J (eds) 1994 ‘Modern pollen rain and fossil pollen spectra’. Rev Palaeobot Palynol 82 (special issue)


Green, F J 1979 ‘Phosphatic mineralization of seeds from archaeological sites’. J Archaeol Sci 6, 279–84


— 1994 ‘A possible hedgerow of Iron Age date from Alcester, Warwickshire’. Circaea 11, 7–16

— 1996 ‘Archaeobotanical and historical records compared – a new look at the taphonomy of edible and other useful plants form 11th to the 18th centuries AD’. Circaea 12, 211–47

Griffiths, H I, Rouse, A, and Evans, J G 1993. ‘Processing freshwater ostracods from archaeological deposits, with a key to the valves of the major British genera’. Circaea 10, 53–62


Institute of Field Archaeologists 1990. Code of Conduct. Reading

— 1999a Standard and Guidance for Archaeological Desk-based Assessment. Reading
—1999b Standard and Guidance for Archaeological/Watching Brief. Reading

—1999c Standard and Guidance for Archaeological Field Evaluation. Reading

— 1999d Standard and Guidance for Archaeological Excavation. Reading

— 1996 Standard and Guidance for Archaeological Investigation and Recording of Standing Buildings or Structures. Reading


Jacobson, G L, and R H W Bradshaw 1981
‘The selection of sites for palaeoecological studies’. Quat Res 16, 80–96

James, P 1999 ‘Soil variability in the area of an archaeological site near Sparta, Greece’. J Archaeol Sci 26, 1273–88


Kenward, H K, and Williams, D 1979 ‘Biological evidence from the Roman warehouses in Coney Street’. The Archaeology of York 14/2, 45–100. London: CBA


Murphy, P 1995 ‘Anglo-Saxon hurdles and basketry; Collins Creek, Blackwater Estuary, Essex’. Anc Mon Lab Rep S95. London: English Heritage


— 1992 Crop Husbandry Regimes: an Archaeobotanical Study of Farming in Northern England (Sheffield Archaeological Monographs 3), Sheffield: J R Collis Publ

van Hoeve, M L, and Hendrikse, M (eds) 1998 A Study of Non-pollen Objects in Pollen Slides: the types as described by Dr Bas van Geel and colleagues. Utrecht: Univ Utrecht


Acknowledgments

These Guidelines were written by English Heritage Environmental Archaeologists and have benefited greatly from the comments and suggestions made by colleagues. These include Curators, Contractors, Specialists and other English Heritage staff, to all of whom we are extremely grateful. A special thanks to Allan Hall who kindly proofread and edited the final draft.

The following people have contributed text or provided comments:


The following people contributed illustrations:


Reconstruction for front cover: Judith Dobie
Written and compiled by the English Heritage regional advisors for archaeological science and the staff of the Environmental Studies Branch, English Heritage Centre for Archaeology.

English Heritage is the Government’s statutory adviser on the historic environment. English Heritage provides expert advice to the Government about all matters relating to the historic environment and its conservation.

For further information (and copies of this leaflet, quoting the Product Code, please contact:

English Heritage
Customer Services Department
PO Box 569
Swindon
SN2 2YP

Telephone: 0870 333 1181
Fax: 01793 414926
E-mail: customers@english-heritage.org.uk

Published March 2002

Copyright © English Heritage 2002
Edited and brought to press by David M Jones,
English Heritage Publications
Designed by Simon Borrough
Produced by English Heritage Publications
Printed by Empress Litho

Product Code 50691