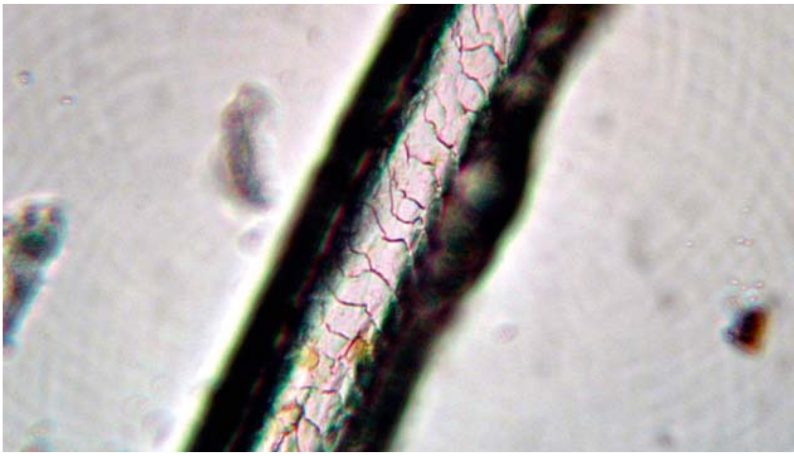
2012

Waterlogged Organic Artefacts

Guidelines on their Recovery, Analysis and Conservation



ENGLISH HERITAGE

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Preface

The preservation of waterlogged organic materials has transformed our understanding of the historic environment. Their study involves the collaboration of many different disciplines from within the heritage sector. These guidelines are aimed at anyone planning for or working with waterlogged organic artefacts, including archaeological curators, archaeologists and specialists (finds, environmental archaeologists and conservators).

The 1995 English Heritage Guidelines on the care of waterlogged archaeological leather (Edwards and Mould 1995) have been reviewed in the light of new developments in conservation treatments and changes in the planning system for the heritage environment. Other waterlogged organic materials are included in these new guidelines, as they present a similar range of issues and require a comparable approach for their recovery, storage and conservation.

This guideline covers waterlogged organic artefacts, but not waterlogged environmental remains such as pollen and insects (ecofacts), or unworked organic materials such as human or animal bone. Ecofacts do not merit conservation in the same way as artefacts. Ecofacts should be sampled and curated following the *Environmental Archaeology* guideline (English Heritage 2011) and *Guidelines for the Curation of Waterlogged Macroscopic Plant and Invertebrate Remains* (English Heritage 2008a). Composite objects made of organic and inorganic components form a special case and are also not discussed in this guideline.

The discovery of waterlogged organic materials can in certain circumstances be expected and planned for. In other situations their discovery is unexpected and this can lead to subsequent problems in the post-excavation stage or with regards to funding and archiving. These guidelines provide information for both situations and guidance throughout all project stages.

- **Section 1** outlines the aim of these guidelines and an introduction to why waterlogged organic artefacts are important and require special care.
- **Section 2** focuses on project planning and points out the responsibilities of the project members and how they contribute to the project.
- **Section 3** deals with soil conditions that preserve waterlogged organic artefacts and commonly encountered materials. A brief introduction is given to each material, together with the typical decay patterns.
- **Section 4** gives on-site advice, which covers lifting, handling and storage on-site.
- **Section 5** focuses on analytical techniques useful for the examination of waterlogged materials.
- **Section 6** describes commonly used conservation techniques. It is equally useful for the archaeologist, who would like to find out about conservation options, and for the conservator, who may be less familiar with waterlogged organic materials.
- **Section 7** concludes with recommendations for storage and display.

Points of contact for further help and information as well as a glossary can be found before the list of references. Specialists' views are presented throughout these guidelines, outlining why waterlogged organic materials are important to archaeological research.

These guidelines should be used in conjunction with other English Heritage guidelines, as some of the principles outlined in those publications are also relevant to waterlogged organic materials – eg *Guidelines on the X-radiography of Archaeological Metalwork* (Fell *et al* 2006), *Investigative Conservation* (English Heritage 2008b), *Waterlogged Wood* (English Heritage 2010a) and *Environmental Archaeology* (English Heritage 2011).

1 Introduction

1.1 Aim of these guidelines

These guidelines cover waterlogged organic artefacts, which range from minute fibre remains to complete items such as shoes, garments or containers. Waterlogged environmental remains (ecofacts such as pollen, plant remains and insects, and unworked organic materials such as human or animal bone) are not included in these guidelines as they do not merit conservation in the same way as artefacts. Environmental remains should be sampled and curated following the *Environmental Archaeology* guideline (English Heritage 2011) and *Guidelines for the Curation of Waterlogged Macroscopic Plant and Invertebrate Remains* (English Heritage 2008a).

These guidelines are written for anyone working with archaeological waterlogged organic artefacts and cover all stages from project planning and initiation to archive deposition and curation. They are intended to make people aware of the wide variety of waterlogged organic artefacts that may be encountered during archaeological investigations. The overall aim is to ensure that the significance of waterlogged organic artefacts is appreciated, that their research potential is fully realised and that they are integrated during the excavation and post-excavation phases of an investigation. An overview of most waterlogged organic materials is given and good practice for the care of such artefacts is outlined. Small wood artefacts are included in this guideline, but not structural wood, which is already covered in the *Waterlogged Wood* guidelines (English Heritage 2010a). A reference list and points of contact are provided for those who require more detailed information.

1.2 What can waterlogged organic artefacts tell us?

Waterlogged organic artefacts can provide a wide range of important information and their study can shed light on many aspects of life in the past. Extracting this information will often require the work of a number of different specialists and the integration of other types of environmental data, for example from pollen, plant remains and insects (English Heritage 2011).

1.3 Why special care is needed for waterlogged organic materials

Organic materials were exploited from the earliest times. Their survival, however, is often poor, so that our understanding of their use in the past is limited. They can be preserved in wet or waterlogged (anoxic) sites. This includes seas, rivers, lakes and marshes, and excavations that reach down below the water table. Low-lying urban sites are often particularly rich in organic remains.

Waterlogged organic artefacts are unstable when found and sensitive to rapid changes in environmental conditions, which, if not carefully controlled, can lead to the deterioration of artefacts upon excavation. Uncontrolled drying of organic materials and outbreaks of mould on them can lead to the loss of archaeological evidence. To prevent this, some simple steps need to be taken (*see* section 4). Correct packaging and storage and a swift workflow will not only benefit the preservation of organic materials after excavation, but will also ensure that costs are minimised.

2 Project planning stages

For field evaluation and investigations initiated through the planning process, work is undertaken in the context of Planning Policy Statement for the

Fig 1 Wooden tankard, *Mary Rose* (© Mary Rose Trust).

Fig 2 Stave lantern, *Mary Rose* (© Mary Rose Trust).

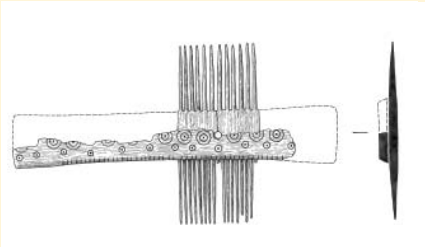


Fig 3 Illustration of a bone comb, Fishbourne Beach (© Isle of Wight County Archaeology and Historic Environment Service).

Exploitation of the natural environment
The choice of raw materials provides evidence of the exploitation of natural resources. The degree of repair, reuse and recycling give insights into the availability of raw materials. Such information contributes to the reconstruction of past climates, vegetation, diet and husbandry (Fig 1).

Technology and crafts
Evidence of craft techniques is preserved in organic finds so that the development of, and changes in, technology can be traced. This supplements the evidence provided by surviving tools and, later, by written and pictorial sources (Fig 2).

Provenance
Technological, stylistic and material characteristics can be used to provenance finds (Fig 3).

Trade
Trade patterns can be studied when looking at non-indigenous materials and artefacts (Fig 4).

Dating
Waterlogged organic materials can be used to date assemblages. They can provide the material for carbon dating (^{14}C). For some periods, particular categories of objects, such as garments, textiles, shoes and scabbards, can be closely dated, in certain circumstances more so than pottery (Fig 5).

Carrier of written or graphic information
Waterlogged organic materials can be carriers of graphic or written information, as in the case of writing tablets or birch-bark letters (Fig 6).

Social status and wellbeing
Personal items such as clothing and footwear can give an insight into the social status or wellbeing of an individual (*see* Case Study 1) (Fig 7).

Fig 4 Walrus ivory gaming pieces, York (© York Archaeological Trust).

Fig 5 Medieval leather knife sheath, Thames Street, London (© Museum of London).

Fig 6 Roman writing tablet; Silchester, Hampshire.

Fig 7 Silk hat (© York Archaeological Trust).

Specialist's view: the environmental archaeologist

Gill Campbell

Anoxic deposits often contain a wealth of delicate biological remains, including invertebrates such as beetles and fleas, and also the remains of plants – everything from fruit-stones to moss and fern frond fragments. They provide evidence for diet (Fig 8), economy, trade, health and living conditions, as well as the nature of the surrounding environment or the types of environment being exploited. Recovery of the full range of remains within such deposits is achieved by taking samples: the type and size of sample will vary, depending on the remains being targeted and on the aims and objectives of the project. Following analysis, these remains should form part of the research archive. Curation of macroscopic biological remains is covered in separate guidelines (English Heritage 2008b).

Sometimes the biological remains preserved in these deposits are of such a rare and unusual nature that they are treated as objects worthy of conservation for museum display or storage. For example bog bodies and associated materials such as the true tinder fungus (*Fomes fomentarius*) found among the Ice Man's Ötzi's possessions, whole stone pine cones (*Pinus pinea*) imported for use in Roman ritual practices or a rosary made of Job's tears (*Coix lacryma-jobi*)

Fig 8 Grape remains from the wreck of the *Stirling Castle* on the Goodwin Sands, off Kent provide dietary information.

Specialist's view: the artefact researcher

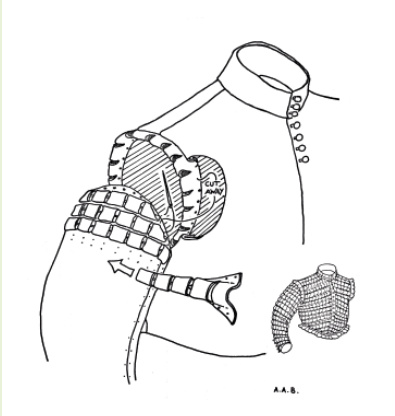
Penelope Walton Rogers

In waterlogged deposits, textiles often occur in large numbers and can be arranged in dated sequences, revealing technical changes over time (Figs 9 and 10). They can be compared with dated sequences of textile tools and written sources to reconstruct the history of the textile industry.

Trade links can be identified from the presence of exotic materials and techniques, such as silk or unusual weaves.

Sometimes garment details are preserved (or, in the case of the Viking-Age sock from Coppergate, York, a whole garment). These reflect changes in fashion.

Social issues can be addressed by comparing the fabric types at sites of differing status (eg ecclesiastical, domestic, quayside, urban, rural).



Figs 9 and 10 Decorative slashing of garments was a fashion of the 1540s onwards. These applied slashed strips were cut from soft-finished wool twill. They were excavated in the castle ditch, Newcastle upon Tyne (Walton 1981) (© The Anglo-Saxon Laboratory, drawing by Anthony Barton).

Case Study 1 Leather from the *Mary Rose*

A range of leather clothing was recovered from the wreck of the *Mary Rose*, the Tudor warship that sank in the Solent close to Portsmouth Harbour in 1545. The clothing, which included jerkins, shoes and boots, mittens and belts, had been worn by the men on board or stored in chests and bags below deck. The shoe styles, decoration and degree of wear all provided information about those on board, while the condition of a number of shoes suggested that the wearers had foot problems.

A large hole worn in a shoe upper above the great toe joint suggested that the wearer suffered from a bunion (*hallux valgus*). Another shoe vamp with a secondary, horizontal slash in a similar position indicated that the wearer had cut their shoe in order to relieve the pressure on a painful joint caused by the same condition (Fig 12). Injuries to the feet were also implied. One shoe had much of the vamp crudely cut away to accommodate a foot injury and would have to had been tied on to the foot. One might speculate whether the shoe had been adapted to cope with a recent injury or whether the condition of the shoe implies that the owner walked with difficulty as a result of a long-standing injury, as those with a temporarily painful foot might prefer to go barefoot until the trouble eventually healed, rather than ruin the shoe. If the adaption of the shoe was necessary to accommodate a permanent, serious injury to the foot, then the wearer would have been unable to perform many of the physical activities required by an ordinary member of crew, suggesting that he had held another, less energetic, role on board the ship (Evans and Mould 2005, 92).

While fractures and bunions could also be seen on the foot bones recovered from the wreck, in this instance the shoe leather was able to provide an insight into another, more elusive, aspect of the wearer.

Fig 12 A slash above the big toe suggests that the wearer suffered from a foot complaint such as bunion (© Mary Rose Trust).

Specialist's view: the leather specialist

Quita Mould

The nature of vegetable-tanned leather, making it soft and flexible or extremely hard and durable, depending on how it is processed, resulted in its use for making a wide range of items, including clothing, coverings, cases, watertight containers, armour and even seafaring crafts. In turn, this variety means that much valuable information can be gained from its study.

Styles of individual leather items, technological aspects of their construction and decoration all reflect those who made them and those who used or wore them, and can be seen as cultural indicators.

One well-studied object type, footwear, is able to provide information on the wearer's gender, age, social status (Fig 11) and occasionally their painful foot complaints (*see* Case Study 1) – a degree of personal knowledge seldom gained from the study of other finds.

Fig 11 Medieval leather shoe, Newport Ship, Newport, South Wales (© Newport Museum and Heritage Service).

Historic Environment (PPS5). *The English Heritage Historic Environment Planning Practice Guide* (English Heritage 2010b) supports the implementation of PPS5.

The Management of Research Projects in the Historic Environment (MoRPHE) is a system developed to promote an integrated programme of research for English Heritage funded projects. A typical project will often proceed through a number of stages (Lee 2006; Kerr *et al* 2008) and the role of conservation and finds specialists is described broadly in relation to these.

2.1 Project initiation

All team members should be involved from the start of a project to achieve the best possible outcome in terms of realising the research potential, creating a stable archive and establishing costs.

A geoarchaeological survey should be considered and costed early in a project (English Heritage 2004a). Boreholes can be used to assess the nature of the ground conditions and sediments and the potential for waterlogged deposits.

Any excavation that may result in the removal of archaeological artefacts should involve a conservator and finds specialist, as they will be able to provide valuable assistance throughout the various project stages of excavation (English Heritage 2008b; Brown 2007, 6; IfA 2008a, 2; IfA 2009; Watkinson and Neal 2001, 1). Furthermore they can help define research questions and the aims and objectives of a project.

If waterlogged organic artefacts are preserved, other types of environmental evidence (pollen, seeds etc) will also be preserved and an appropriately qualified environmental archaeology specialist should be consulted and provision made for the sampling and analysis of these remains (English Heritage 2011).

Before embarking on an archaeological investigation it is important to acquire as much information and knowledge about the area of investigation as possible. This will help in the planning and preparation and can avoid unnecessary problems at a later stage. Even though unexpected finds or unusual preservation conditions can always occur, the consultation of the following documents and sources can help during the initial planning stage:

- historic, documentary evidence
- Historic Environment Record (HER)
- regional research frameworks
- literature review of the results of previous work in the area
- field walking

The results of this work are normally summarised in a desk-based assessment (DBA) and will help to formulate research questions to address the aims and objectives of a project.

The basis on which an archaeological investigation is to be carried out is normally laid down in a document called a written scheme of investigation (WSI) or project design (PD) (Lee 2006, 44; IfA 2008b, 4; English Heritage 2010b). All parties involved should be informed of the WSI or PD and agree to it before any fieldwork is undertaken.

When large amounts of waterlogged organic artefacts are expected (*see* section 3.1), sampling, retention and disposal policies and strategies should be agreed and included in the WSI or PD. It is also advisable to consider the long-term outputs of the project, including research areas, archive deposition and display. Contact should be established with the archive repository at an early stage in order to comply with individual collection policies and standards (Museums and Galleries Commission 1992, 13; Brown 2007).

2.2 Project execution

2.2.1 Fieldwork: data gathering

Depending on the nature of the site, waterlogged organic artefacts can be found in abundance or as the occasional chance find. The quantity of artefacts recovered and individual recording systems will result in material being recorded as bulk finds or as small or registered finds.

Most excavations are unable to employ a full-time conservator. A finds processor is, however, present in most cases and everyone should have access to conservation advice through the English Heritage Science Advisors and the Institute of Conservation (ICON) Conservation Register (*see* section 7). The following tasks give some examples of where the involvement of a conservator and finds specialist will benefit the project. A visit by the conservator should be scheduled in advance.

preparation A conservator can provide information on materials and equipment essential for the recovery, lifting and storage of waterlogged organic artefacts and provide time and cost estimates.

lifting The lifting of fragile wet material often requires the skills and expertise of a conservator. This knowledge will ensure the survival of material during and after excavation, and before conservation. A finds specialist can give valuable information on what to look out for in the ground.

spot dating A finds specialist can provide spot dating by brief examination during the excavation.

storage Waterlogged organic materials are most sensitive

immediately after excavation. A conservator can give advice on how to correctly store waterlogged organic material to prevent deterioration.

transport The correct packaging before transportation from the site to the conservation laboratory is essential to avoid damage to waterlogged artefacts.

If waterlogged organic material is discovered unexpectedly, a deviation from the WSI or PD is likely and the budget has to be reviewed. Depending on the project, either the local authority curator or Inspector of Ancient Monuments should be contacted, as well as the developer and English Heritage Science Advisor. The finds specialist, conservator, environmental specialist and repository should also be informed as soon as possible when such finds are made.

When faced with overwhelming quantities of waterlogged organic materials, it can be difficult to know how best to deal with the assemblage, so contact with the relevant specialists and local authority curator is crucial to review the approach (sampling, retention and disposal) and costs (*see* Case Study 2). In certain circumstances extra funding from outside bodies may be obtainable. The local English Heritage Inspector or Science Advisors can provide support and further information.

Case Study 2 Excavation at 2nd Wood Street, Nantwich, Cheshire

The site on Second Wood Street, Nantwich, Cheshire was granted planning permission for a small housing development in 2003, subject to the completion of a programme of archaeological excavation. An earlier pre-determination evaluation of the site by Earthworks Archaeological Services, who also carried out the subsequent programme of investigation (Dodd forthcoming), produced evidence of medieval and post-medieval archaeological deposits, including well-preserved timbers and artefacts.

The project design for the excavation was well informed and prepared for the preservation of organic remains, including timber structures. Relevant specialists were involved from the start. The excavation confirmed the presence of extensive and substantial areas of *in situ* timber structural remains consisting of plank floors, base plates and uprights, wattling etc. Small organic artefacts were also found, and included wooden mallets, turned wooden bowls (Fig 27) numerous leather shoes (Figs 40 and 41), two fragments of textile and a salt storage basket.

Unexpectedly though, eight 14th-century barrels (*see* back cover figure) and a 7.6m long 13th-century salt 'ship' (a hollowed-out tree trunk used for the storage of brine) were found intact and *in situ*. At this stage of the developer-funded excavation, it was not possible to make major alterations to the timing and budget. Decisions had to be made quickly, and this was possible owing to the original set-up that involved conservators, dendrochronologists and finds specialists, the local museum, the archaeological curators and the English Heritage Science Adviser. This facilitated a successful bid for HLF funding to lift, conserve and display the salt ship, aided by its temporary reburial on site through cooperative developers.

Good communication and strong collaboration between all parties, including the on-site contractors and the developer, was the key. The specialists were able to visit and train people on site with regard to excavation, handling and sampling. This made it much easier to extend from the predicted into the unpredicted situation.

Where possible, structural timbers remained *in situ*. The assessment involved all stakeholders and considered factors such as conservation, storage and display costs and options, future use and the value of artefacts. Non-structural and portable artefacts were conserved. This included large amounts of leather waste as well as the salt ship.

Even though the intervention at Nantwich was well planned, unpredictable quantities of organic artefacts were discovered. Using established archaeological techniques, standards and guidance, coupled with good communication, specialist's advice, and on-site improvisation meant that maximum information could be retrieved within the constraints and realities of contract archaeology. Operating within agreed budgets and timescales ensured that both the planners and the developers remained happy and supportive.

2.2.2 Fieldwork: assessment of potential

The potential of the recovered artefacts to meet the project aims and objectives, and to enhance understanding is assessed after the excavation. The finds and conservation assessment has to be carried out by an appropriately qualified person, who has previously been named in the project design. The assessment should include the following points (Goodburn Brown 2001; English Heritage 2008b; Kerr *et al* 2008):

- quantity and condition of material
- work required for identification
- advice on sampling prior to treatment (for materials provenance, scientific dating and manufacturing evidence)
- research potential
- conservation proposal
- methodology
- work required for archive transfer
- time and cost estimates

It is important that waterlogged organic artefacts are assessed as soon as possible after excavation. Prolonged and inappropriate storage conditions can lead to the loss of information. Extra work may then be required to make the assemblage fit for assessment, such as removing microbiological infestation or the removal of inappropriate packaging material. These extra steps will not only hinder the progress of the project but will also increase the overall costs.

Funding for conservation should be earmarked during the project planning stage and the budget reviewed during the assessment phase, when the range and condition of the material is known. Lack of funding for conservation can result in delayed archive deposition, the creation of backlog material and storage problems. Delays in the study of such material can incur the unacceptable loss of valuable information. Such material may not be studied and valuable information unacceptably lost.

The assessment should plan and resource the archive compilation stage (the ordering, indexing and packing of the archive). Conserved waterlogged organic artefacts may require specific packaging and storage conditions. The retention and disposal policy may have to be reviewed by the finds specialist, conservator and archive repository at this point in light of a better understanding of the quantity, quality and research value of the material in question. The results of the assessment should then be summarised in an updated project design (UPD) and agreed by the project team.

Fig 13 A typical waterlogged deposit, Richborough Roman fort.

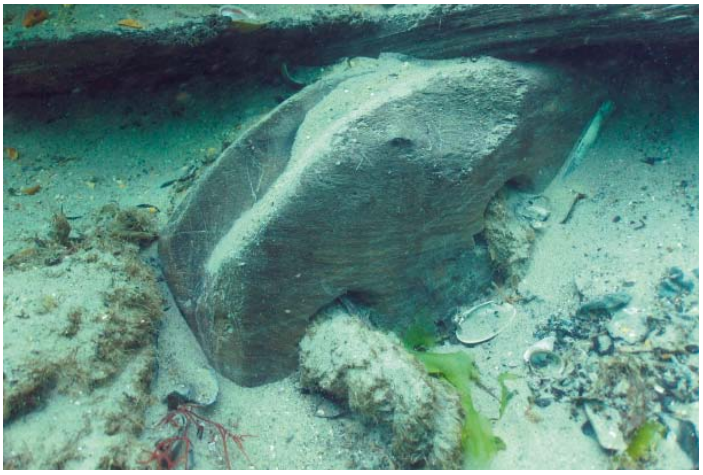


Fig 14 A typical marine environment: a deadeye with remains of rope from the *Swash Channel* wreck.

Fig 15 A medieval barrel at Nantwich containing a multitude of organic artefacts (© Earthworks Archaeology).

2.2.3 Analysis

All work proposed and agreed in the UPD should be carried out by appropriately qualified personnel. In the case of waterlogged material this will normally include stabilisation by a conservator so that the artefacts can be safely studied and deposited with a museum (Brown 2007, 25–26; Ganiaris and Starling 1996, 56).

It is the project manager's responsibility to ensure that appropriate advice has been taken about sampling or scientific dating requirements, and that any constraints on conservation are fully discussed, and allowed for, in advance of treatment.

2.2.4 Archive deposition

The archive has to be in a complete, stable, ordered and accessible state before it can be deposited. All data generated and information gathered during fieldwork, assessment and analysis have to be incorporated into the archive. More information on archive deposition standards can be obtained from Walker 1990, Museums and Galleries Commission 1992, Brown 2007 and IfA 2009.

2.2.5 Dissemination

The results of the project work should be made available in a report or subsequent publication. Specialist work should be incorporated and authorship clearly identified. The reporting of conservation, analyses or other specialist work on finds can take various forms, including a contribution to the main text or a publication in its own right. As there may be a significant delay before the final publication, it is good practice to produce the specialist report on completion of the practical phase. Where used, completed specialist's reports should be noted in the OASIS system for a project (www.oasis.ac.uk). The report should include:

- names of individuals involved
- site location (including National Grid Reference) and excavation date
- aims and objectives of specialist work for the project
- types of material examined
- methodology and results
- analysis with full data included
- discussions and recommendations
- references

A record of archaeological science, including conservation, can be entered onto the Historic Environment Record Science-based information following the *Guidelines for the addition of Archaeological Science data to Historic Environment Records* (English Heritage 2006).

2.3 Project closure

A closure report at the end of the project can be a valuable opportunity to reflect on the project's outcome, to flag up issues encountered along the way, to improve practice in future projects by sharing lessons learned and to point out future work.

3 Condition of waterlogged organic materials

3.1 Environments that preserve waterlogged organic materials

The deterioration of objects in the ground is the result of a complex interaction between the burial environment and the artefact itself. Artefacts are prone to biological, physical and chemical decay. Temperature, pH and the presence of oxygen, water and microorganisms are the main factors influencing decay.

Organic materials in the UK are commonly encountered in anoxic waterlogged environments, the formation of which are dependent upon the local geology, topography, sediment characteristics, impeded drainage and a supply of water (Holden *et al* 2006, 2009). Organic materials are preserved in a range of sediments such as alluvial silts, clays and peats, and in a variety of site types, including low-lying urban sites, perched water tables, wetlands, river floodplains, lakes and marine environments (Figs 13–15; English Heritage 2004a). Waterlogged conditions that may also preserve organic deposits can sometimes be found on dry sites in isolated features such as wells, pits, post holes, ditches and graves.

preserving waterlogged soil types (pH)	*material*
neutral (or weak acid/alkali) to alkaline	bone
acid to neutral	horn
acid to alkaline	leather
acid	animal fibres: silk, wool
alkaline	plant fibres: flax, hemp
acid to alkaline	wood

Table 1 Materials and the waterlogged burial environments in which they are preserved (based on Watkinson and Neal 2001)

Figs 16 and **17** A piece of leather that has split into two layers.

Organic materials survive mainly due to two factors: the abundance of static water and the chemical balance of this water (pH and oxidation-reduction potential [Eh]), *see* Table 1. Water that excludes air creates reduced oxygen levels and prevents most microorganisms from flourishing. In conditions like these, organic materials become saturated with water, so their shape is largely preserved (*see* Fig 27). Nevertheless, some level of decomposition will take place in an anoxic environment: anaerobic microorganisms such as sulphur-reducing bacteria can survive and form microscopic iron sulphides within wood and to a lesser degree in leather. On exposure to air, the iron sulphides can oxidise to form sulphuric acid, which can cause the further deterioration of artefacts in wet storage or after conservation (Fors and Sandstrom 2006).

Specialist's view: the archaeologist

Nicola Hembrey

Organic materials are of tremendous interest to archaeologists due in no small part to their scarcity. The unusual deposition conditions required to preserve such remains as part of the archaeological record means that these artefacts represent rare survivals of what in the past would have been common and everyday objects – leather bags, shoes or flasks, wooden plates, bowls, writing tablets or jewellery, fabric from clothing and blankets. As a finds specialist I spend my working life looking at objects, but it is extremely rare that I see an iron tool with more than a trace of its wooden handle, or a copper-alloy brooch with more than a thread of the fabric it held. An archaeologist may dig up thousands of ceramic sherds, but never a wooden plate fragment. The importance of organics lies in their rarity, and the preservation and study of these objects is a way of redressing this imbalance; this is our only window into the history of these objects and provides direct links with their owners.

3.2 Leather and other skin products

Leather is a material made from the skin of any vertebrate animal by any process that renders it non-putrescible under warm, moist conditions. True leather retains this property after repeated wetting and drying (Kite and Thomson 2006, 1). Skin is converted into leather by the introduction of chemical bonds, which are resistant to biochemical attack between the skin protein (collagen) and the various tanning materials (Cronyn 1990, 265). This prevents microbiological decay. Skins can be temporarily preserved by drying or by the application of salt. This is known as curing.

From the earliest times, skins, with or without the hair attached, were preserved by treatment with fatty materials and manipulation to ensure thorough impregnation, followed by controlled drying and sometimes aided by exposure to a smoky environment. In some cases, the fats were chemically inert and acted simply as waterproofing agents. These products are best described as pseudo-leathers. In others, chemically reactive materials such as brains, marrows and fish oils were employed, which had a tanning action resulting in oil-tanned leathers.

Later, in Britain during the Roman Empire and, again, from the Later Saxon period onward, vegetable tanning in which the skins were treated with extracts of barks, roots, woods, fruit, etc became common.

Since the end of the 19th century, there has been an increase in the production of chrome-tanned leather and from the mid-20th century, the great majority of leather objects will have been made from this material. Chrome-tanned leather is likely to be stable in most burial conditions and increasing quantities will be recovered from more recent contexts.

Other skin products include animal pelts (*see* section 3.3.2), rawhide, parchment and vellum, which are not tanned and are therefore not leather.

In archaeological contexts, of all skin products, vegetable-tanned leather is the most stable, particularly in waterlogged environments where the usual microbiological decay is inhibited. Some leaching of the tannins will, however, occur even under these conditions, resulting in soft and weakened leather. This is especially true at higher pH levels, when alkaline hydrolysis takes place. Preservation of leather is more favourable in, but not restricted to, mild acidic environments (Huisman *et al* 2009, 65). Untanned skins and pseudo-leathers only survive burial in exceptional circumstances. Bog bodies, for example, are believed to have been preserved by naturally occurring compounds in the peat (Huisman *et al* 2009, 59). Skin-based materials can also be preserved by metallic (particularly copper) salts leached from adjacent artefacts.

Hardening and blackening can take place due to the formation of iron-tannin compounds. Splitting into two layers is also common, causing the leather to appear to comprise two separate pieces (Figs 16 and 17). This may be due to incomplete penetration of the tanning materials into the skin. In later stages of decay, the fibre network can become disintegrated and make the leather very friable.

3.3 Fibrous materials

3.3.1 Textiles

The raw materials of textiles divide into three categories:

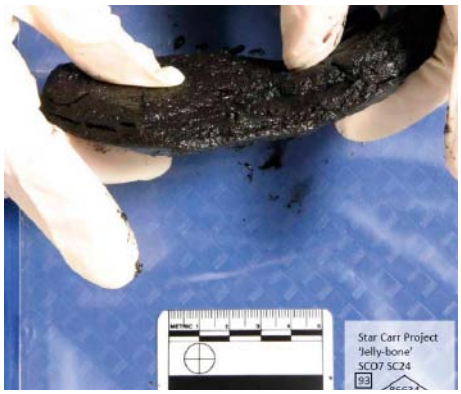
- protein-based animal fibres
- cellulose-based plant fibres
- metal filaments

Animal fibres include coat fibres, such as sheep's wool and goat hair; and silk from the cocoon of the silk moth, *Bombyx mori* L. Plant fibres mostly prove to be derived from stems of flax, *Linum usitatissimum* L., or hemp, *Cannabis sativa* L., although fibres from the common stinging nettle, *Urtica dioica* L. and bast from trees (from the layer beneath the bark) are also sometimes encountered. These were joined in the late

Fig 18 A three-strand plait worked from bundles of hair moss (© York Archaeological Trust).

Figs 19 and **20** Acidic soil conditions at Star Carr, an early Mesolithic site near Scarborough, North Yorkshire, caused severe degradation in antler. This resulted in flattening (the antler on the left is lifted on a pedestal of soil) and flaking of the outer surface (right) (© York University).

Fig 25 Horn found in peat land, showing signs of delamination and opaqueness (© Tameside Archaeological Society).



Figs 21 and **22** Bone that has become extremely soft due to the acidic soil at Star Carr (note: the pictures depict the same bone being flexed) (© York University).

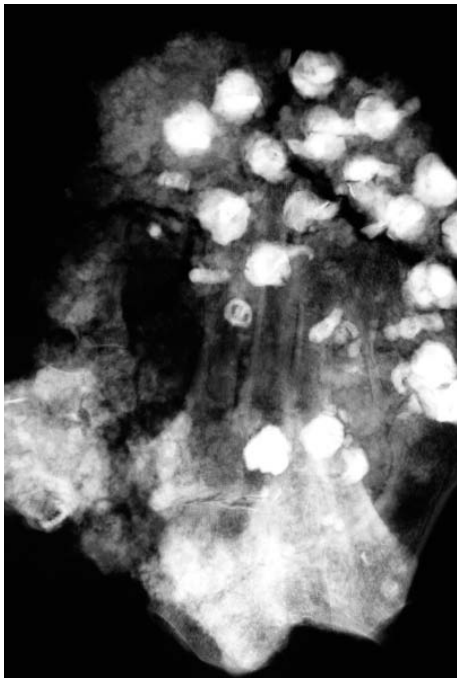
Fig 26 Fragment of baleen, Perth, Horse Cross, Scotland (© York Archaeological Trust).

medieval period in Britain by imported cotton from the seed boll of *Gossypium* sp.

Metal filaments can be made of gold, silver, silver-gilt or gilded copper; or they may be 'membrane threads', which are made from gold leaf or gilded silver mounted on a skin, gut or paper substrate (Barker 1980). The filament is usually a flat strip, which can be used as it is, or spun around a core thread.

Once buried in waterlogged conditions, the three groups interact with the burial environment in different ways (Jakes and Sibley 1983; Sibley and Jakes 1984; Florian 1987; Timár-Balázsy 1989; Cooke 1990; Peacock 1996). Animal fibres survive well because aerobic bacteria are excluded. The mildly acidic conditions of most waterlogged sites also reduce microbiological damage, as does the salinity of sea water. The exclusion of air also protects plant fibres from the most common cause of above-ground deterioration: fungal attack. Acidic conditions (low pH) promote hydrolysis of the cellulose and can lead to dissolution of the fibre. In alkaline conditions (high pH) plant fibres survive in moderately good condition, but wool and silk are damaged by alkaline hydrolysis and tend to be preserved only in a weak and damaged form. Charred plant fibres seem more resistant to decay than non-charred ones, and often emerge as black and brittle representatives of the original fabrics.

High-carat gold filament will survive in most conditions, although any organic material on which it has been mounted will often decay. Silver and copper on the other hand will corrode and the corrosion products of copper in particular can act as a biocide (Janaway 1989) and preserve organic materials in the immediate vicinity of the metal thread.



Figs 23 and **24** Foot bones with degraded leather and iron hobnails, block-lifted from a Roman burial at Healam Beck, North Yorkshire and associated X-radiograph (© Highways Agency).

3.3.2 Animal pelts

Animal pelts, that is, animal skins with the hair, fur or wool still intact, were used extensively in the past for clothing and household furnishings. They might be derived from domestic animals such as sheep, cattle and goat, or from local wild species such as squirrel, fox, hare and deer; or they could be imported pelts such as lynx and bear. They usually survive in waterlogged levels as only tufts of fibre (the skin part invariably decays), which often look as if they have been singed at one end. This is due to the ginger colour of the fibre

Fig 27 Wooden bowl *in situ*; Nantwich (© Earthworks Archaeology).

Figs 28 and **29** Barrel stave fragment, which appears intact (right), but is severely damaged by marine wood borers, as seen on the X-radiograph (left).

Fig 30 Cork bung from the Newport Ship, Newport, South Wales (© Newport Museum and Heritage Service).

Fig 31 Basket being block lifted, London (© Museum of London).

root and the black specks of decayed skin adhering to it. The fibre tufts, or 'staples', survive in the same circumstances as wool textiles, that is, primarily in waterlogged, mildly acidic conditions.

3.3.3 Cordage and basketry

Cordage was usually made from locally available material and the identification of the fibre is therefore especially significant when dealing with evidence from ports or shipwrecks, because it enables trade routes and overseas connections to be identified. Imported fibres can include goat hair (Nordic), palm fibre (Mediterranean), sisal (originally Central American) and coir (coconut fibre from Sri Lanka or India). British-sourced fibres include whole flax stems, hemp, heather, grasses, hair-moss (*Polytrichum commune* Hedw.; Fig 18) and withies (twisted young woody stems from species such as willow or hazel).

Basketry is comparatively rare in the archaeological record, which may reflect the brittle nature of the raw material when it is old and dry, and the ease with which it can be broken up and burned. It was used for baskets, bags, mats and outer clothing and examples made from willow, sedge, grass, heather and hair-moss have been recorded. Wickerwork (constructed in the basketry technique), is discussed below.

The fibres of cordage and basketry respond to the burial environment in much the same way as other plant fibres do, although the coarser woody fibres can be both more robust and more brittle.

3.4 Keratinous and skeletal materials

3.4.1 Bone, antler and ivory

Skeletal materials, such as bone, antler and ivory, consist both of an organic protein (chiefly collagen) and an inorganic mineral (hydroxyapatite – a form of calcium phosphate). Although soil-dwelling microorganisms, particularly bacteria, attack the collagen, rendering archaeological skeletal materials fragile, the most important factor controlling the survival of buried skeletal materials is the chemical dissolution of the inorganic component (Turner-Walker 2008).

Deposits that are acidic and/or free draining increase the loss of the inorganic component through leaching, and are thus hostile to the survival of skeletal material (Figs 19–22). Neutral or alkaline environments with low water flow are more likely to lead to good survival. Therefore waterlogged deposits, provided that they are not acidic, often result in good survival of skeletal materials.

On rare occasions human remains may be found fused to archaeological artefacts: for example foot bones inside leather shoes (Fig 23 and 24).

3.4.2 Horn and baleen

Materials such as horn, hoof or baleen represent non-living tissue, mainly consisting of keratin, a complex protein. They are formed as a growth either from the skull, digits or, in the case of baleen, from the upper jaws of certain whales.

The amount of sulphur in the keratin determines stability, flexibility and chemical reactivity. Keratin-based materials are prone to decay in alkaline conditions.

Fig 32 Direct lifting (left) and passive lifting (right) of a textile fragment.

Fig 33 Excavation of antler picks, Marden Henge.

Fig 34 Lifting of antler (**Fig 33**).

They are rare in an archaeological context. Water is the main agent of decay, which results in hydrolysis of keratin. They become opaque on burial and start to laminate (Fig 25 and 26). They can be extremely soft and easily damaged.

3.5 Wood

3.5.1 Wooden artefacts

Wood is mainly composed of cellulose, lignin and water. In a waterlogged anoxic burial environment, the hydrolysis of cellulose is slowed down but does not completely stop, gradually leading to a weakening of the wood structure, and an increase in its water content (Fig 27).

The most common agents of decay in waterlogged wood are soft-rot fungi and erosion bacteria (Blanchette *et al* 1990; M Jones and Eaton 2006). Bacteria can withstand lower oxygen levels than fungi and their activity is elevated in areas with high water circulation. In both cases cell wall material is removed by enzymatic action, resulting in cavities in the wood cell structure. These voids are filled with a mixture of water and decay products.

In a marine environment, wood is also prone to damage by boring organisms such as *Teredo navalis* (shipworm) and *Limnoria limnorium* (gribble) (Figs 28 and 29). Such damage can be severe.

Case Study 3 Freeze lifting

The recovery of waterlogged archaeological artefacts can take place in challenging environments. Adverse weather conditions, stormy seas or incoming tides often require fast action. Freeze lifting using solid carbon dioxide (CO_2) is a method that is ideally suited for the recovery of wet artefacts.

Freeze lifting has successfully been used on a Neolithic wooden hurdle that was excavated on the beach at Seaton Carew in County Durham (J Jones 1996) The team only had a seven-hour window to reveal, record and lift the hurdle. A section of approximately 1m x 1m was lifted using solid pellets of carbon dioxide (CO2) (Figs 35–38).

advantages

- no disturbance of the surrounding stratigraphy or stratigraphy within the block
- minimal preparation time on site prior to freezing
- X-radiography possible in the frozen state

disadvantages

- sufficient insulation required to avoid freeze drying during frozen storage
- can be costly
- soil block can be heavy

Fig 35 Neolithic hurdle *in situ*, Seaton Carew

Fig 36 The hurdle is isolated and CO_2 pellets are being applied. Thermocouples are inserted around the hurdle.

Fig 37 The frozen block is being levered from the ground.

Fig 38 The frozen block in the laboratory.

Decay always starts from the outside and moves towards the inside. Artefacts therefore often consist of a well preserved inner core surrounded by a decayed soft outer layer. Degraded waterlogged wooden artefacts may be much more fragile than they first appear. Indeed, if of any size, they are unlikely to be able to bear their own weight once removed from the ground. Loss of water from the most degraded outer surface begins as soon as the wood is exposed during excavation. This is where most useful information (such as tool marks or decoration) will be preserved and it is important not to let the surface be damaged by drying out or rough handling. Material that is uncovered is susceptible to abrasion and physical breakdown. Desiccation leads to irreparable damage as water evaporates from the degraded cells, causing cell wall collapse and irreversible cross-linking of the cellulose, resulting in cracking, shrinkage and gross distortion of the object.

3.5.2 Woody materials such as cork

Cork, harvested from the outer bark of the cork oak tree, is sometimes encountered as a component of archaeological artefacts, particularly in footwear. Cork's composition and decomposition mirrors that of wood. The waxy component – suberin – makes cork impermeable to water. It can survive waterlogged conditions very well and is often encountered in a maritime context (Fig 30). Cork will be soft and prone to mechanical damage upon excavation.

3.5.3 Wickerwork

Wickerwork can be encountered from the Neolithic period onwards. Willow and hazel are most commonly used to produce baskets, fish traps, linings of wells and pits or hurdles.

These artefacts behave much like wood, with the addition that decay can cause loss of integrity or collapse of the overall structure (Fig 31).

4 Lifting, handling and processing on site

Archaeological materials are most at risk when they are removed from the soil that preserved and protected them and before they reach a conservation laboratory. The following section outlines a few steps to reduce this risk. More detailed information on these subjects can be found in Bowens 2009, Daley and Murdock 1992, Gillis and Nosch 2007, Leskard 1987, Robinson 1998, and Watkinson and Neal 2001. The recommended materials in Tables 2 and 4 can be obtained from a variety of stockists, including garden centres (capillary matting), hardware stores, conservation suppliers (Correx®, Plastazote®, Tyvek®), art suppliers (plaster of paris bandages) or supermarkets (cling film, bandages).

Before finds are lifted, handled and processed, thought must be given to the potential requirements for analysis, in particular biomolecular analysis and dating where certain lifting and packaging materials could preclude future analysis (*see* section 5). Seek advice from the intended specialist for these analyses for information on any protocols that should be followed.

4.1 Lifting

Waterlogged organic materials may look more stable in the ground than they actually are. The soil matrix gives support to these fragile materials, which is lost as soon as lifting is attempted. It is advisable to adopt a passive lifting system; that is *not* to lift the artefacts directly, but do so with the aid of a board or similar support, so that the artefacts do not have to bear their own weight and the weight of water and soil within them (Fig 32). This approach can be applied on land and under water and should be used especially for large, flat and thin items, such as fibrous materials, wooden writing tablets or baskets. Lifting with the surrounding soil in place (Figs 33–34) or freeze lifting is also possible; *see* Case Study 3 (J Jones and Clogg 1993; J Jones 1996, J Jones 2007).

Special care has to be taken that the lifting materials selected can withstand constant contact with water. Generally it is best to make use of durable, water-resistant and non-corrosive materials (*see* Table 2). Use what is easily obtainable or even naturally available to support an object or soil block or, to fill empty spaces in a box (eg sand or soil). To avoid contamination of the archaeology place a separating layer (such as cling film) between the artefact and any material introduced, and ensure that materials only recommended for short-term use are removed after lifting. It is advisable to make a record of the artefact before lifting, of the materials used to lift the artefact and of the actual lifting process (*see* section 5.1).

4.2 Handling on site

Once lifted out of the soil, limit or avoid handling the artefacts and opening the bags and boxes. Due to their toxicity, the use of biocides is no longer recommended.

The soil surrounding an artefact can contain valuable information associated with the artefact itself. The remains of stitching, stuffing and quilting materials or seeds, pollen and insects may be lost during washing (Fell 1996; Madsen 1994, 107; Goodburn Brown 2001; Skals 1996, 163). Components of one object can also become disassociated from one another (Fig 39). The finds specialist, conservator and project manager should discuss whether washing is carried out on site and to what degree (Table 3).

On agreement with the finds specialist, environmental archaeologist and the conservator more robust materials can probably withstand gentle cleaning with running water and soft brushes or sponges, but only if conservation takes place soon after excavation (Figs 40 and 41). The cleaning of fibrous materials such as textile and basketry should only be carried out by a conservator under laboratory conditions. The conservator should also retain a wet sample of basketry for later analysis. For textiles, evidence of insect infestation and associated remains can be recorded at this stage. There is a general consensus that artefacts stored wet with the surrounding soil survive better during storage.

4.3 Storage post-excavation

All too often the temporary storage of waterlogged organic materials turns into long-term storage for a variety of reasons. This will lead to the deterioration of material and can result in artefacts becoming unfit for conservation or study. This in turn will not only impede the overall progress of a project, but can also push up costs or present a health hazard if mould forms (Figs 42 and 43). It cannot be repeated often enough that a swift workflow is not only beneficial for budget control, but also for the survival of the material.

What constitutes temporary and long-term storage depends on a number of factors, including material type, condition, storage environment and even on seasonality (depending on whether the object can be placed in a fridge or not). If an artefact is in a good condition and it is kept in a fridge, six months could constitute temporary storage. For an artefact in a poor condition or less than ideal conditions, then a week may be temporary, for example, if it does not fit in a fridge or cold store and must be kept in a cool room. The key issue is that procedures must be in place both to routinely monitor the condition of the artefacts and to respond appropriately if the artefacts actively start to deteriorate.

A few steps to ensure the best storage conditions for waterlogged organic materials are outlined below.

Fig 39 The stitching in this 15th-century ankleshoe from Westgate, Wakefield has decayed and the individual pieces have become disassociated from one another (© Birmingham Archaeology).

Fig 40 Leather shoe just lifted out of the ground, Nantwich (© Earthworks Archaeology).

Fig 41 Leather shoe (**Fig 40**) after washing on-site (© Earthworks Archaeology).

Fig 42 Incorrect storage has caused this wooden mallet to dry out and as a result split and develop mould, which is visible as a white bloom.

Fig 43 Leather sole that has developed mould during storage for more than 20 years (© Museum of London).

application	*materials*	
	recommended	*use with caution; short term* only*
wrapping around artefacts	• cling film: Polyethylene (PU) film not the Polyvinyl Chloride (PVC) type • gauze • Netlon tubing (Polyethylene netting) • Scotchcast® (fibreglass fabric impregnated with polyurethane) • capillary matting (cotton / polyester material with a water holding capacity) • nylon string	• fabric • string • rope • bubble wrap • fabric bandages (medical / veterinary)
embedding of artefacts / soil blocks	• plaster of Paris bandages • foam (eg Plastazote®) • naturally / readily available soil or sand (with separating layer) • Scotchcast® • X-Lite® (thermoplastic copolymer over cotton mesh)	• Polyurethane (PU) foam • other foam material
support, crates	• Correx®(corrugated polypropylene sheet)	• MDF (medium density fibreboard) boards • metal sheets
waterproof labelling	• Tyvek® labels (spun-bonded polyethylene) • plastic cards • Livestock tags • Dymo® • waterproof pen • pencil	
** short term: recommended six weeks maximum*		

Table 2 Materials useful for the lifting of waterlogged organic materials

	advantages	*disadvantages*
washing on site	• artefact can be assessed and identified • reduced time and costs when conservator or finds specialist takes over	• accidental loss of associated material • artefacts more prone to physical damage, desiccation and mould
not washing on site	• more favourable conditions for artefacts during storage	• increased time and costs when conservator or finds specialist takes over • no identification, spot dating or initial condition assessment possible

Table 3 Overview of the advantages and disadvantages of washing waterlogged organic materials on site

application	*materials*	
	recommended	*use with caution; short term* only*
wrapping	• cling film: Polyethylene (PU) film not the Polyvinyl Chloride (PVC) type • Netlon tubing (Polyethylene netting) • Tarpuline	• bubble wrap
bags, containers	• zip lock bags • bags (heat sealed to close) • PE boxes with lids	
padding and keeping wet	• PE-foam • capillary matting	• fabrics • natural materials (sawdust, moss, seaweed – careful: mould growth possible)
to close boxes and bags	• clips • stapler gun (stainless steel staples) • copper tags • heat sealer	• rope
** short term: recommended six weeks maximum*		

Table 4 Materials useful for the storage of waterlogged organic materials post-excavation

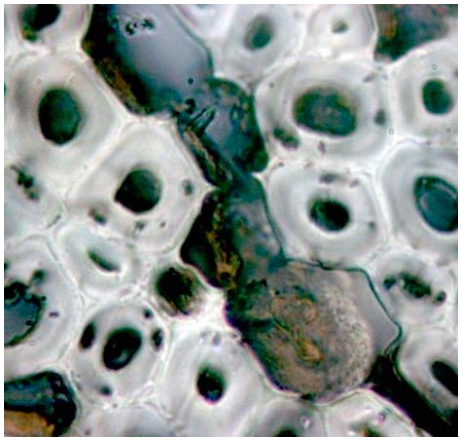


Fig 44 SEM image of elm wood cells showing cavities distinctive of soft rot fungal attack, developed during prolonged storage in tap water (magnification x1000) (© Mary Rose Trust).

KEEP IT WET ➡ Waterlogged organic material must not be allowed to dry out. Irreversible loss will occur that may render the artefact worthless for future study.

KEEP IT DARK ➡ Reduced light levels or, ideally, dark storage will hinder microbiological growth and keep temperatures down.

KEEP IT COOL ➡ Reduced temperatures will slow decay rates down and hinder microbiological growth. Fridges, cool boxes or cooling porta-cabins are suitable. Freezing is only recommended as a last resort and in consultation with a conservator. Artefacts will suffer physical damage if they are not stored correctly and subjected to uncontrolled freeze-thaw cycles.

MONITOR IT ➡ Routinely monitor the condition of the artefacts, packaging and the water levels. Establish procedures to respond if the condition deteriorates, including informing the project manager, conservator and finds specialist.

The use of tap water for storage is sufficient. Marine finds can be stored in seawater if no tap water is available. This should then be changed to tap water as soon as possible.

The degraded and soft surfaces of waterlogged organic materials are prone to abrasion and indentation. Make sure that materials directly in contact with the artefacts are not too tight and do not leave an impression (for example, netlon tubing or bubble wrap where the bubble side is facing inwards next to the surface rather then facing outwards). Some materials (such as bubble wrap) are only suitable for short term application (maximum six weeks). Do not wrap material spirally around the object: the rotation of the object when it is unwrapped may cause harm.

Double bag artefacts if possible and exclude as much air as possible from the bags. Too much water in a bag or container can cause damage when the artefact moves around. Due to the water in and around artefacts and additional packing material, containers can become very heavy; therefore take care when lifting.

Decay will continue, even when the best packing and storage practice is applied (Fig 44). If microbiological growth occurs during storage, rinse the finds and change the water. If storage is likely to go beyond six months, it is better to submerge the objects, as this is easier to maintain long term. In this case, assess the condition regularly and discuss with the finds specialist and project manager.

Mould

Mould can present a health hazard to staff and there is a risk of spreading it to other, previously uninfected artefacts. If mould has developed on wet artefacts or following conservation, a risk assessment should be carried out before any further work can be undertaken.

If mould is discovered, the infested artefacts should be isolated by appropriate packing to prevent the mould from spreading and if possible by moving the infested items to a separate location. Labels should also be applied to boxes and bags, warning colleagues of the infestation.

The removal of mould depends on the artefacts and their condition. Strict precautions should be taken by wearing appropriate protective equipment and by making full use of fume cupboards, equipped with the correct filters.

Further information on mould can be obtained from the Health and Safety representative of an organisation, Health and Safety Executive (HSE) or can be found in Florian 1997 and Florian 2002

5 Documentation, examination and analysis

This section draws attention to common and more advanced methods of analysis for waterlogged organic artefacts, most of which will be carried out by specialists in the relevant fields. A brief introduction to each method, combined with examples or case studies, will demonstrate how it can be used to address the research potential of the artefacts.

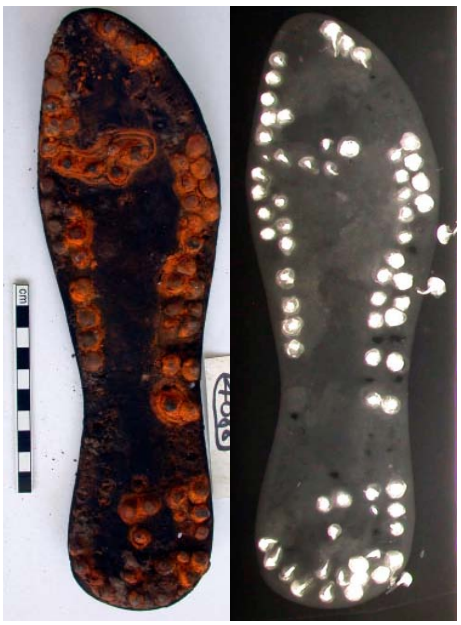
An assessment will identify the most appropriate analytical method to achieve the desired outcome and meet the aims and objectives of the project. The strategy for sampling and analysis, costs and timetabling should be agreed between the project manager and all the relevant project specialists (conservator, finds specialist and environmental specialist). Sometimes a combination of two or more analytical methods is required to address research questions. It is recommended to start with the least intrusive methods, such a visual examination under the microscope, and then moving on to more advanced methods if still required.

5.1 Documentation and recording

Artefacts may be recorded *in situ* before removal and before and after conservation work. The level and type of recording will be determined by the quantity, quality and research potential of the artefacts.

Recording normally takes the form of text descriptions, photographs, sketches and drawings. Section 5.2 covers some more advanced imaging techniques such as laser scanning.

During conservation, conservators will create a record of the condition and treatment for each artefact for inclusion in the site archive. This information can be drawn upon by other specialists and inform curators who need to manage long-term storage requirements. A basic record of the



Figs 45 and **46** Roman hobnailed sole (Carlisle) and associated X-radiograph to record nailing pattern and condition.

artefact is made following examination by a finds specialist (RFG & FRG 1993). No further work will be necessary for the vast majority of artefacts. Selected artefacts may be illustrated and for a small number more detailed analysis may be required.

5.1.1 Description

The purpose is to record basic information on material composition, type of artefact, dimensions, condition and evidence of construction, working and use. Some of this information can be recorded on-site but recording some of this information might only be possible post-excavation, once the soil has been removed or revealed through detailed examination or imaging techniques (*see* sections 5.2 and 5.3). Artefact description may take the form of a tabulated or free text description.

5.1.2 Record keeping of conservation and analysis

Conservation records should identify the nature of conservation treatments, and chemicals used, so that artefacts later retrieved from the archive can be assessed for their potential contribution to future programmes. Where analysis has been undertaken it is important to include the equipment specification and settings. A detailed report is sent to the Historic Environment Record (HER) and recipient museum as part of the archive. Archaeological science data can also be recorded as an 'Event' onto the HER using archaeological science fields and terms developed by the English Heritage Science Advisors (English Heritage 2006).

5.1.3 Digital imaging (photography)

Photography is a fundamental component to any project and must be planned carefully. The quantity, quality and research potential will determine whether artefacts are photographed or not, when they are photographed (*in situ* before lifting and before, during and after conservation) and whether they are photographed individually in detail or batch photographed.

Compact and Digital SLR cameras will vary in both the type and quality of lens and digital capture sensor (pixel number and dynamic range), equivalent to film in analogue cameras. A recording project should use scale bars and colour charts (Kodak) to ensure consistent size and colour calibration (Dorrell 1994). Projects should also consider the type of lighting used, the minimum image resolution, acceptable file formats (eg JPEG, TIFF or RAW) and numbering conventions. Guidance on planning a photography project can be found on the JISC (Joint Information Systems Committee) Digital Media website (www.jiscdigitalmedia.ac.uk) and general advice on creating digital resources on the Archaeology Data Service (ADS) website (www.ads.ahds.ac.uk).

Consideration should also be given to the potential use of any photographs for publication: and the advice of individual publishing bodies should be sought. For good quality publication, high-resolution (usually a minimum of 300–350dpi) is required, and TIFF formatted files are the most stable.

5.1.4 Illustration

Drawings or sketches of an object are undertaken by a variety of specialists and annotated to record observations (to accompany text descriptions, *see* 5.1.1) and to indicate where measurements or samples were taken. Drawings should reference standards for the illustration of archaeological artefacts (Adkins and Adkins 1989; Griffiths *et al* 1990) or specific materials (Allen 1994; Goubitz 1984). Only certain artefacts may be selected for illustration by a specialist archaeological illustrator. Preliminary sketches and drawings should be made available to help inform the formal illustration of the artefacts.

Case Study 4 Wood recording project

The *Stirling Castle* Wood Recording Project employed laser scanning and polynomial texture mapping (PTM) to track how fine surface details on archaeological wood change during conservation (Karsten and Earl 2010). An area displaying tool marks on a barrel fragment was chosen for this study (Fig 47).

Both techniques can be used as a visualisation tool, but also contain an analytical element making it possible for the user to establish how surface morphology changes.

Laser scanning creates an accurate 3D image of the object (Fig 48). PTM exploits a similar approach to raking light photography and gives the possibility of viewing the object virtually under different lighting conditions, which makes the visualisation of fine surface details easy and convenient, without having to handle the original artefact (Fig 49).

In this study laser scanning and PTM were also used as monitoring tools to record surface changes following conservation. The results show that surface changes do take place during conservation, such as flattening of edges. And even though a detailed study of fine surface details is not impossible after conservation, better results will probably be achieved when examining the wet timber before conservation.

Fig 47 Area of interest on wooden barrel fragment showing distinct tool marks.

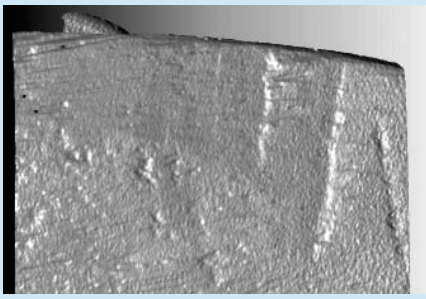


Fig 48 Laser scan of area of interest.

Fig 49 Area of interest viewed under different lighting conditions: *left*, specular enhancement, centre and *right*, differently angled light.

Fig 50 Cattle hide from a Bronze Age cist at Langwell Farm, Strath Oykel, Scotland, excavated by GUARD on behalf of Historic Scotland (© The Anglo Saxon Laboratory).

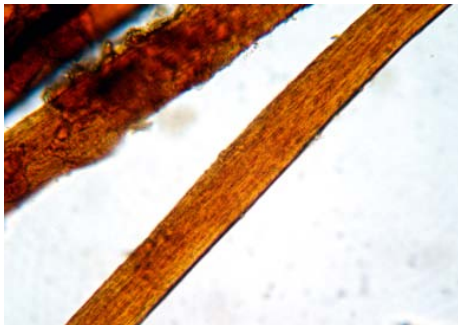


Fig 51 Whole mount of cattle fibre (**Fig 50**) showing moderate pigmentation (brown) (fibre diameter 30–65microns) (© The Anglo Saxon Laboratory).

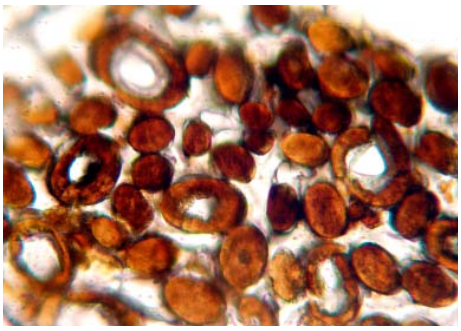


Fig 52 Cross section of cattle fibre (**Fig 50**) as a diagnostic feature to aid identification (© The Anglo Saxon Laboratory).

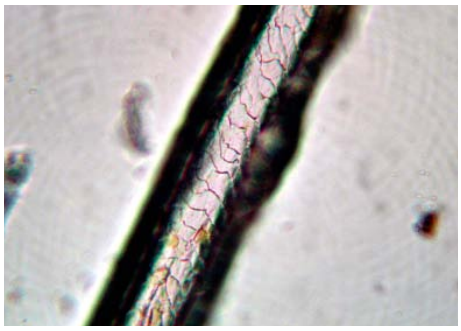


Fig 53 Cast of scale pattern (**Fig 50**) mid-shank of fibre (© The Anglo Saxon Laboratory).

Digital photographs or scans of such drawings being considered for publication also require minimum standards. Resolution should be a minimum of 1200dpi, and, as with object photographs, TIFF formatted files are best, while EPS files are also acceptable.

5.2 Imaging techniques

5.2.1 X-radiography

X-radiography is a rapid and non-interventive imaging technique for studying metal artefacts and some other materials and composites (Fell *et al* 2006; Lang and Middleton 2005; O'Connor and Brooks 2007). The response of materials to X-radiography depends upon their thickness, density and chemical nature.

Although not commonly applied to organic artefacts, X-radiography can be a very useful tool for:

- recording composite artefacts (Peacock 2007)
- recording the content and construction of baskets, especially when block lifted
- recording constructional features of wooden artefacts
- investigating arrangements of metal threads on archaeological textile
- recording hobnailed sole patterns (*see* Figs 45 and 46)
- recording stitching in leather and thin wooden artefacts which are obscured by soil; the stitches are often more X-ray opaque due to the accumulation of iron minerals
- investigating damage caused by marine boring organisms in artefacts and modern wooden test blocks placed in marine environments to monitor type and rates of damage (Palma 2004) (*see* Fig 29)

5.2.2 Laser scanning and polynomial texture mapping (PTM)

Lately three-dimensional (3D) recording and visualisation techniques have become more accessible and their application in archaeology is being explored (English Heritage 2007; Lobb *et al* 2010; Moulden 2009) (*see* Case Study 4). These techniques use laser, photographic or a combination of the two technologies to map the surface morphology and to visually record the texture of artefacts. The results can be used in various ways:

- as a visualisation tool (display artefacts in 3D)
- as a monitoring tool (track surface changes over a period of time)
- as a recording tool (creating an accurate 3D record of an artefact)
- for replica making
- for 3D models, animations and illustrations

For laser scanning the accuracy, data resolution, output types (points, mesh, line work or complete 3D model) and later archiving requirements all need careful consideration prior to justifying its application within a project. Image based approaches, such as PTM and photogrammetry, provide additional, lower-cost ways to record and analyse the surface texture and morphology of artefacts. However, it should be noted that the associated costs and required expertise for some of these techniques might restrict them from being used as routine recording tools.

5.3 Visual examination

5.3.1 Optical light microscopy (OLM)

In one form of optical light microscopy, artefacts are examined with the aid of a low-powered stereo microscope (x2.5 to x50 magnification) and two angled light sources either side of the object. This enables the operator to see details that would not immediately be noticeable to the naked eye, such as the stitching in layers of leather or the weave in textiles. It is possible to identify many materials at this magnification, or at least to see if enough of the structure survives to be worth attempting more detailed work.

Access to modern comparative collections is essential for identification, as well as a thorough knowledge of the material or remains being studied; and often collaboration across the disciplines is essential. It may be necessary to consult a wood specialist, zoo-archaeologist or an archaeobotanist for the identification of raw materials. For example, the identification of the raw materials of cordage and basketry is best done by an experienced archaeobotanist, after consultation with the finds specialist on the selection of samples.

This form of optical light microscopy (OLM) is particularly useful, as it can enable the specialist to:

- identify basic construction
- identify material composition; for example, recognise the structural differences between bone and antler, or between leather and fungus (Wills and Mould 2008)
- identify weave structure and yarn type in textiles (Walton and Eastwood 1989)
- identify animal species of leather (Haines 2006)
- observe evidence of manufacture (tool marks), use and damage
- observe deposits such as pigments and coatings
- observe deposits from use or the burial environment

Another form of OLM, transmitted light microscopy (TLM), involves the focussing of a narrow beam of light through the sample mounted on a glass slide into the objectives lens and eyepiece. A polarised light transmission microscope is useful for plant fibres (Bergfjord and Holst 2010).

Using TLM the specialist can:

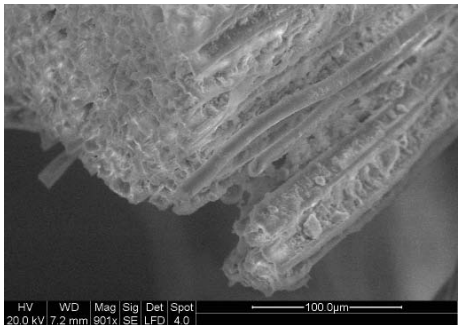


Fig 54 SEM image (x901 magnification) of baleen sample showing tubular fibres in keratin matrix (© Sonia O'Connor, Bradford University).

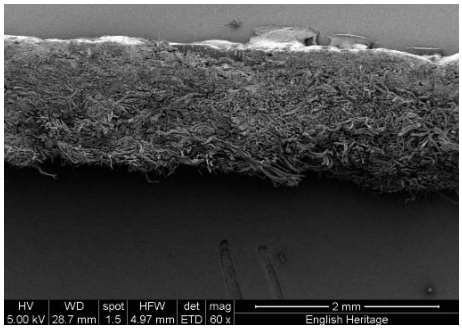


Fig 55 SEM image (x60 magnification) of leather cross section after conservation. The fibre structure is intact and cohesive.

- identify wood species (Schweingruber 1978; Hather 2000)
- identify fibres to species level at magnifications of x400 to x600 (*see* Figs 51 and 52)
- identify pigmentation in wool at x400 to x600 magnifications (*see* Fig 51)
- study wear and damage in textile fibres (Cooke and Lomas 1989).

The identification of animal pelts is a highly specialised task (Appleyard 1978). The identification is based on the shape of the staple (Fig 50) and the individual fibre morphology. Samples are prepared for microscopy as whole mounts (Fig 51), as cross-sections (Fig 52) and as casts (Fig 53). A comparative collection of specimens of known origin is essential.

5.3.2 Scanning electron microscopy (SEM)

Scanning electron microscopy is high resolution, capable of a magnification range in the region of x15 up to tens of thousands, although most analysis is done at 2,000x magnification or lower. Usually the examination takes place under vacuum and is therefore only suitable for dry materials. Sampling may be required due to the size of the chamber and requirement to prepare the sample (coating with a conductive material). For the study of wet specimens, SEMs with a variable pressure and/or environmental stage can be used.

Unlike optical microscopy, SEM produces a greyscale image of the topographical structure of the surface of the sample. The advantages of using this type of microscopy are the very high magnification and the very good depth of field.

This technique is particularly useful for:

- examining small samples in order to identify organic materials such as wood, bone, antler, ivory and horn (*see* Fig 54)
- detailed study of tool marks, wear and damage; this can be destructive, as sampling is required if the artefact cannot be fitted in the chamber. Alternatively, it may be possible to make a silicone mould of an area of interest, which can then be studied in the SEM
- detailed study of an artefact's structure following conservation (*see* Fig 55)
- examination of fibres, after drying or when using environmental or variable pressure settings

5.3.3 Infrared and ultraviolet light

Excavated artefacts made from organic materials such as wood, leather and textiles can be hard to distinguish from one another, and even after conservation all seem to have a fairly uniform brown colour. This means that details such as writing or coloured decoration are barely visible to the naked eye. In these situations photography using an infrared filter or examination under ultraviolet light can enhance the residual detail. For example, ink writing on wooden writing tablets becomes more visible through an infrared filter and can be further clarified with digital processing (English Heritage 2008b, 9). Under ultraviolet light some pigments and resins fluoresce, so that they can be identified or enable suitable areas for sampling to be located (Caple 2006).

aim of analysis		*type of analysis*
identify structure and materials		• microscopy (optical and transmitted light) • scanning electron microscopy (SEM) • Fourier transform infrared (FTIR) and • near-infrared spectroscopy (FTNIR)
identify composition of coatings and deposits	pigments	• X-Ray diffraction (XRD) analysis
	organic residues	• Fourier transform infrared (FTIR) and near-infrared spectroscopy (FTNIR)
	non-organic residues	• X-Ray fluorescence (XRF) analysis • X-Ray diffraction (XRD) analysis
identify dyes		• absorption spectrophotometry • thin-layer chromatography (TLC) • high-performance liquid chromatography (HPLC)
identify construction, tool marks, wear and damage		• microscopy • scanning electron microscopy (SEM) • X-radiography • laser scanning • polynomial texture mapping (PTM)
assess condition		• microscopy • X-radiography • scanning electron microscopy (SEM) • Fourier transform infrared (FTIR) and • near-infrared spectroscopy (FTNIR)
scientific dating		• dendrochronology • radiocarbon dating

Table 5 Example research questions and types of analysis

5.4 Analytical techniques

A wide range of analytical techniques are now available for the investigation of artefacts and their associated remains. Analysis should only be undertaken to answer specific questions about an artefact rather than applied as a matter of course (*see* Table 5 for examples). The handling and processing of an artefact may compromise some forms of analysis such as dating (*see* section 5.4.4) and biomolecular analysis (*see* section 5.4.6), and should therefore be considered soon after the recovery of material. Advice should be sought from the relevant specialist regarding handling, sampling and storage protocols for samples.

5.4.1 Fourier transform infrared and near-infrared spectroscopy (FTIR, FTNIR)

Fourier transform infrared (FTIR) and Fourier transform near-infrared

spectroscopy (FTNIR) are chemically specific analysis techniques and are used for the qualitative and quantitative analysis of chemical compounds. These techniques can be non-destructive when the item is placed directly onto the spectrometer and analysed by reflectance. Where this is not possible a small sample can be analysed. The resulting spectra are compared with reference spectra of known materials.

These techniques are particularly useful for:

- identifying polymers and resins used in historical times as well as past conservation treatments
- identifying naturally occurring materials (Garside and Wyeth, 2006; Carr *et al*, 2008)
- recording the state of preservation for wood and leather (Godfrey and Kasi, 2005)

5.4.2 X-Ray diffraction (XRD) analysis

X-Ray diffraction (XRD) analysis determines the chemical compounds of crystalline material associated with organic artefacts including pigments, minerals, efflorescent salts, chemical residues and corrosion products. A small sample is required and powdered for analysis. The resulting spectra are compared with reference spectra of known materials.

5.4.3 X-Ray fluorescence (XRF) analysis

X-Ray fluorescence (XRF) analysis is commonly used to identify the elemental composition of metal alloys, inlays and coatings. XRF can be useful for the examination of organic materials where there is a non-organic component or deposit.

5.4.4 Scientific dating

Artefactual material may need to be used for dating, placing constraints on conservation measures that may result in contamination. Even if conservation treatments such as Polyethylene glycol (*see* section 6.1) can in theory be washed out successfully, it is impossible to know in practice that this has been done completely. Archaeological material submitted for radiocarbon dating (14C) should therefore be unprocessed and not treated. Ideally such material should be placed in an acetate box or plastic bag and kept in the dark, and preferably in cold storage. The sample should be clearly labelled for dating to avoid accidental contamination or further processing. Records of what treatments have been applied should be kept.

Detailed guidance on the dating of wood using dendrochronology is found in the relevant English Heritage guideline (English Heritage 2004b and 2010a) and the English Heritage Science Advisors should be able to advise on specialists to contact.

5.4.5 Dye analysis

Dyes in textiles and leather from waterlogged sites are often masked by staining from the soil and their analysis follows a different procedure from that used for visibly coloured textiles (Walton and Taylor 1991). Any colorants present are extracted into a series of solvent systems and the resulting extracts are examined by absorption spectrophotometry (visible spectrum) followed by thin-layer chromatography (TLC), high-performance liquid chromatography (HPLC). Mould, algae and solvents can interfere with the results.

5.4.6 Biomolecular analysis

Ancient biomolecules include lipids (fats, waxes and oils), protein (blood and milk) and DNA (deoxyribonucleic acid). Lipids and proteins may have been absorbed into the fabric of an artefact or comprise residues associated with an artefact. Their sampling for analysis must be undertaken following specialist advice (Heron *et al* 2005; English Heritage 2011). The analysis of animal bone DNA for the identification of species and the analysis of stable isotopes for the origin of sheep's wool represent new techniques, still at the development stage (Hedges *et al* 2005; Capellini *et al* 2010; Hollemeyer *et al* 2008). The requirements for biomolecular analysis should be considered early on in the project before processing or conservation treatment that could compromise analysis (Eklund and Thomas 2010).

6 Conservation

Due to their waterlogged state, wet organic artefacts are generally unstable. All conservation methods have one aim in common; which is to convert the artefact from an unstable to a stable condition. This is achieved by the careful removal of the supporting water while at the same time controlling and limiting the damaging effects of drying on the weakened cell and fibre structure. This process is referred to as remedial conservation and often involves 'interventive' conservation treatments.

Some archaeological investigations and the post-excavation processes can go on for many years. Due to their unstable nature, the prolonged storage of waterlogged organic artefacts can become time consuming, and if possible, it is better to fast track the conservation of these materials.

Specialist's view: the conservator
Jennifer Jones

Working with waterlogged organic artefacts requires the use of a different set of conservation skills to investigate and stabilise artefacts with a wide and non-standard variety of forms and textures, and to interpret the information that such artefacts can hold.

Because of their rarity, organic artefacts have an important place in the archaeological record. Archaeologists appreciate that a large part of the material culture of the past is not available for study because it was organic and has not survived. The discovery of organic artefacts and materials can provide us with clues to the breadth and variety of that resource.

Organic artefacts are also more likely to represent personal possessions, shaped through wear and use by the owner, thus adding richness and detail to our view of the past, which is more usually formed from formally manufactured metal or ceramic artefacts.

Conservation of waterlogged organic artefacts can be challenging, as artefacts may sometimes respond in an unexpected way to well-tried conservation techniques. But the information contained in successfully stabilised organic artefacts makes them a highly informative resource for study, and the presentation of personal possessions from the past has the potential to make an engaging and powerful display.

6.1 Conservation options

The conservation of waterlogged organic materials normally consists of three phases: cleaning, impregnation and drying. The specific detail of these phases will vary according to the type of organic material and this is outlined in sections 6.2 to 6.5.

It is advisable to consult a conservator if fragile, unusual or composite artefacts are found. Composite artefacts such as a leather shoe with a cork sole, or leather with a textile lining are rare, and the different materials will react

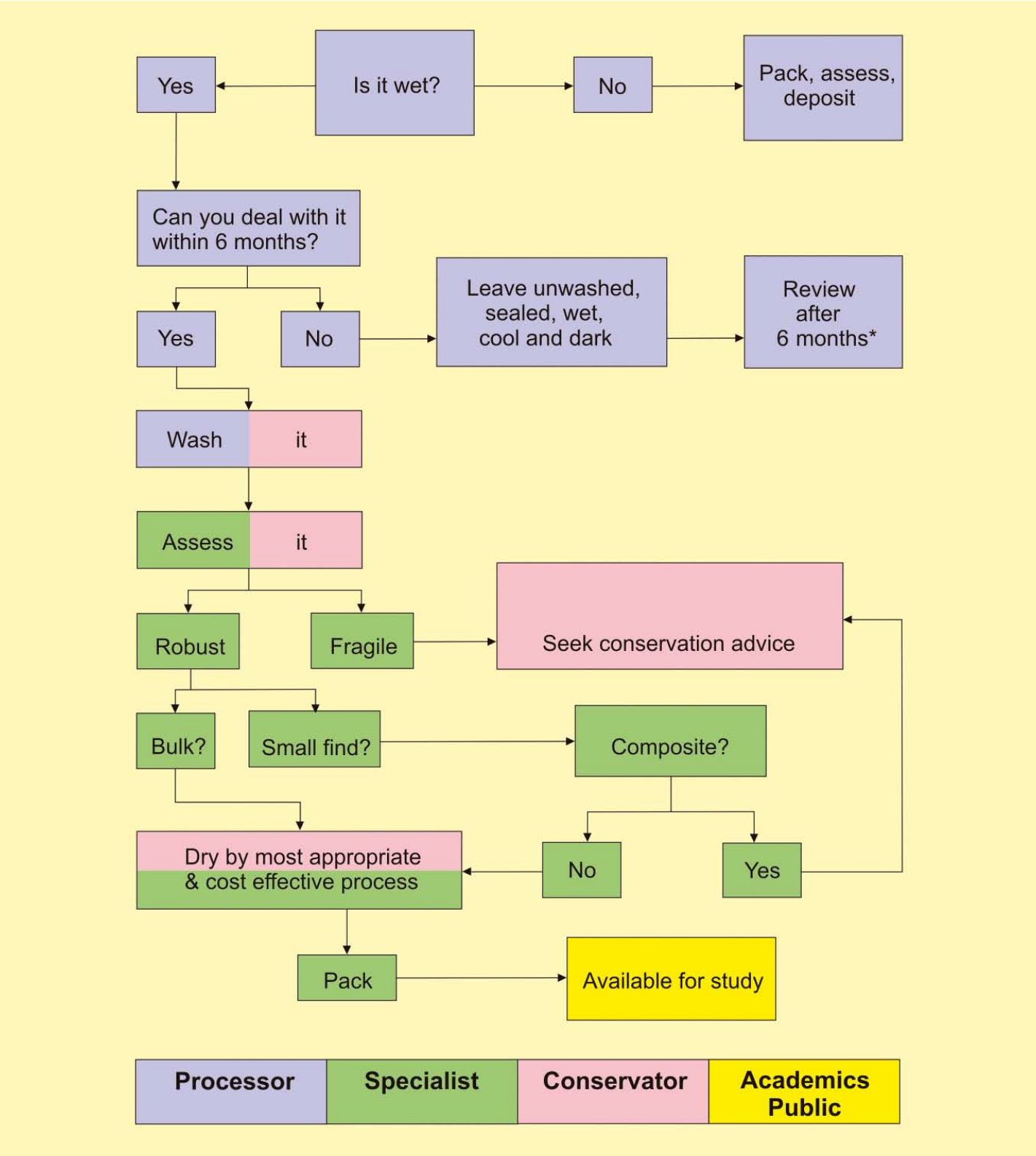


Fig 60 Decision making flow chart (designed by working group on leather, see Acknowledgements). *Review the condition of the leather, resources and time table.

differently during the drying process. A conservation treatment has to be found to cater for all materials present on the one artefact (*see* Case Study 6).

The conservation assessment report (*see* section 2.2.2) should outline a conservation proposal. The method of choice depends on a variety of parameters such as:

- the type, condition and volume of the material
- the finds research potential and the overall significance of the site or assemblage
- the future of the artefact: whether it is intended for museum display or storage
- consideration of the health and safety implications of treatments through the assessment of risks according to the Control of Substances Hazardous to Health (COSHH) regulations (Health and Safety Executive 2005)
- environmental considerations (disposal of waste chemicals)
- costs and staffing levels
- time constraints

In some cases, the conservation assessment may recommend that the waterlogged artefacts can be dried successfully from the wet state through air drying at ambient conditions. It is more common, though, to impregnate them with a bulking agent

before drying is attempted. Polyethylene glycol (PEG) and glycerol have been used successfully for many years on most organic artefacts. They replace the excess water and add support to the degraded structure following conservation. The glycerol or PEG remains in the organic material, acting as a humectant to draw in water from the air. For marine artefacts, seawater and salts should be removed before impregnation through prolonged washing in tap water.

The mineral content of organic materials (in particular wood and leather) is sometimes considered a problem, which can result in iron staining and brittleness (Ganiaris *et al* 1982; Hovmand and Jones 2001). Chelating agents to reduce mineral content before impregnation should only be used selectively following a condition assessment and recommendation by a conservator. If used, this should be followed by copious rinsing in tap water.

Drying can be carried out using specialist equipment such as a 'vacuum freeze drying' chamber (Fig 56). Freeze drying is successful because it eliminates drying stress, and because large quantities of material can be stabilised relatively quickly. The initial high purchase costs or access to such specialist equipment can mean that other drying methods may be a necessary and real alternative (*see* Case Study 5). Freeze drying can also be carried out without the vacuum in a domestic chest freezer ('non-vacuum freeze drying') (Fig 57). Chemicals (such as saturated salt solutions) or specialist equipment can be used to create and maintain a certain environment (relative humidity) during drying; this is called 'controlled air drying' (Fig 58). For certain artefacts, 'solvent drying' is the only realistic alternative (*see* section 6.5.1). Disposal and safety concerns about quantities of solvents mean that this technique is rarely used other than where absolutely necessary. After an assessment, some artefacts may be suitable for careful 'air drying' (Fig 59).

Some materials, especially wood, react best to vacuum freeze drying and this is often the only option.

Figure 60 presents an example flow chart to aid decision making about conservation options. It is derived from the Leather drying trial (*see* Case Study 5).

6.2 Leather and other skin products

Wet excavated leather is first washed using soft brushes or sponges while supported on a water-permeable, net-covered frame to catch loose fragments. Recording by methods most appropriate for the object or group of artefacts should be done at this stage.

The leather is immersed for several days in a water-based solution, usually containing either glycerol or low molecular weight PEG. Freeze drying has been a largely successful conservation treatment for more than 30 years, and is still the most commonly used method of stabilisation for wet archaeological leather.

Other untanned animal skin products, such as parchment, vellum, rawhide or pelts (where the skin survives), are comparatively rare finds. If present, they are likely to be fragmentary, highly degraded and barely recognisable. The conservation methods described above for more robust, tanned leathers are not suitable, and the chosen method of preservation will need to be individually tailored to the condition and type of material. Conservation for untanned material is likely to be based on careful cleaning and the highly controlled removal of supporting water from the object's structure, possibly followed by the introduction of a consolidant or humectant of suitable strength and plasticity.

6.3 Fibrous materials

The conservator's first task is to remove any obscuring soil and reveal the nature and extent of the fabric or cordage. Danger of disintegration may be a problem when cleaning archaeological fibres. The structure of both protein – and cellulose-based fibres may have been weakened by hydrolysis, even in a well-sealed anoxic deposit, and individual fibres can be easily broken and lost. This is a particular problem with cordage, which may be made from fibres that are only loosely twisted, not spun.

Washing should be done with the textile or cordage supported on a netted frame or sieve, and a slow gentle flow of water to avoid flushing loose fibres away (Fig 63). If the artefact is particularly fragile, it can be washed inside a loose-weave, non-abrasive net bag to further discourage fibre loss. Fingers, very soft brushes or natural sponge and a mild, non-ionic detergent are best for dislodging dirt from between the spun or twisted fibres. During washing, the textile can be carefully unfolded if necessary – under water for extra support of very damaged fibres. Ultrasonic tanks can be useful for cleaning soil from more robust specimens.

The flexibility of fragile textiles can be improved by the addition of a humectant such as glycerol or low molecular weight PEG to the final wash water.

Fig 56 Vacuum freeze drying chamber.

Fig 57 Non-vacuum freeze drying in a domestic chest freezer.

Fig 58 Controlled air drying using saturated salt solutions.

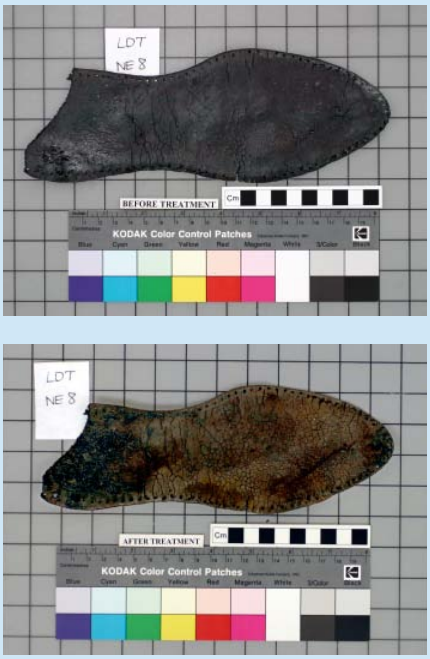
Fig 59 Slow air drying at ambient conditions.

Case Study 5 Leather drying trial

The aim of this study (Graham and Karsten 2009, 26–29; Karsten *et al* forthcoming) was to compare different treatment and drying methods using parameters such as shrinkage, flexibility, appearance, time, effort and equipment.

During the first part of this study treatments included 20% glycerol, 20% PEG and no impregnation. Half the samples in each treatment category were pre-treated using 5% Na_2EDTA. The leather was dried using vacuum freeze drying, non-vacuum freeze drying, air drying and controlled air drying (Figs 61 and 62). In the second part of this study the leather was treated using 20% glycerol followed by vacuum freeze drying, non-vacuum freeze drying or air drying. The drying methods were separated into best practice and real-life scenarios typical for bulk treatment.

The study made clear that a routine pre-treatment with Na_2EDTA is not required, but that the use of either PEG or glycerol will produce better results. A careful assessment by a conservator and/or a leather specialist can divide leather into groups that could be controlled air dried, and individual finds that would have better results with vacuum or non-vacuum freeze drying. It was shown that vacuum freeze drying is the most effective drying method. Aesthetically the best results were achieved following freeze drying with or without the vacuum. Air drying requires time, laying-out space, a well-ventilated area and vigilance to watch for mould growth and damage due to rapid drying. Although a vacuum freeze dryer requires a large initial outlay, in person time this method is much more cost-effective than the other methods discussed here.



Figs 61 and **62** Leather sole: *above*, before and, *below*, after treatment (20%PEG 400 followed by non-vacuum freeze drying).

More degraded textiles or cordage with a greater tendency to fibre loss can be strengthened by the addition of a little hydroxypropyl cellulose (Klucel G) to the wash water. These should only be applied if essential to the survival of the artefact.

After the washing, careful examination, recording and, in some cases, impregnation of the textile; it may be dried under controlled conditions (Fig 64) or by freeze drying.

Where pelts consist of hair only, controlled air drying may be suitable. Where the skin survives, it can be treated as an untanned skin product (*see* section 6.2).

Basketry is made of plant materials and the same range of conservation methods as for rope or textile is applicable. Differences come from the original flexibility of such artefacts and their resulting fragility when removed from the burial environment. Again, as with textiles, disintegration may be the major conservation problem and it may be necessary to sacrifice flexibility in order to preserve an artefact's integrity. Details of the proposed conservation strategy will be dictated by the precise form, size and material of each individual piece of fragile basketry.

It may prove impossible to maintain the integrity of very degraded textile, cordage or basketry without the aid of a stronger, solvent-based consolidant. This can be used as part of the conservation process – after replacement of the water in the textile with a solvent – or applied later to the dried textile or cordage to improve fibre cohesion (Figs 65 and 66). Solvent-based consolidants result in the loss of much of the flexibility and natural feel of the textile or cordage, and prohibit some types of analytical work, but this should be balanced against the possibility of total disintegration without their use.

6.4 Keratinous and skeletal materials

Bone and antler artefacts that are judged to be reasonably robust may require no more conservation than careful, controlled drying after surface cleaning. While drying, examine the artefact frequently to check for cracking or lamination of the surface; and the conservator should be ready to take immediate steps to re-hydrate the artefact and re-think the conservation strategy. Solvent drying can be used as an alternative to air drying. Again, carry out the process with caution and a readiness to halt and reverse the treatment if necessary.

Fig 63 Washing of textile supported on a sieve.

Fig 64 These textile fragments from Saveock were carefully air dried, which preserved the weave and colour (© Jacqui Wood).

Figs 65 and **66** Roman plant-fibre cordage before (left) and after (right) conservation; Carlisle Millennium excavation (photo by J Jones, Durham University). The rope was conserved by immersion in Primal WS24, PEG 400 and Glycerol followed by freeze drying. This resulted in a good colour but poor cohesion. An application of Primal WS24 to the dry rope improved fibre cohesion.

Case Study 6 Conservation of silk-lined purse, York

This draw-string purse was excavated in 1992 and is medieval in date. It is a composite object of silk, animal skin (probably tawed) and iron (Walton unpublished) (Fig 67).

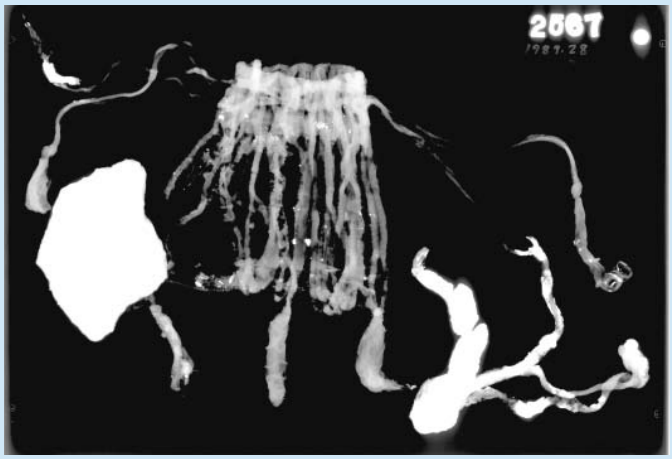
The object was lifted on site by the excavators and kept wet before initial examination. The purse was cleaned of soil in gentle running water using soft brushes, then laid out on a plastic mesh and immersed in distilled water to remove further ingrained residues. The remains of skin, which originally made up the main body of the purse, were recorded inside the piped trimmings. The textile itself appeared to be in good condition, although one corner was obscured by a large, very hard organic concretion. This was attached to the silk itself and the weight of it had torn the corner badly. A second metallic concretion was attached to one of the drawstrings.

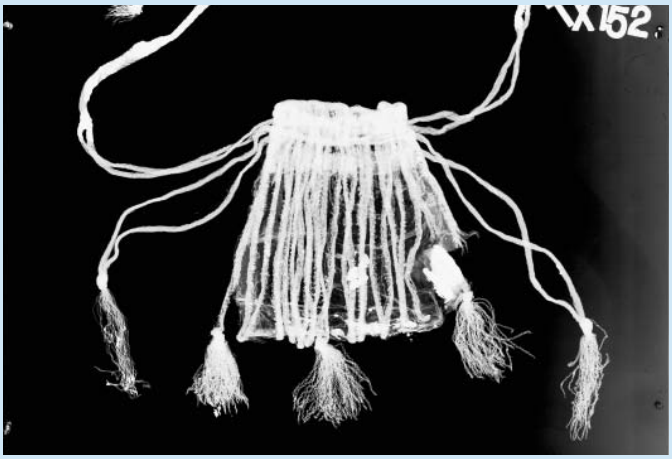
The purse was X-rayed before conservation to investigate the content and to explore the nature of the metallic concretion (Fig 69). The X-ray revealed this to be a chain with surface plating.

The purse was slowly air dried between paper towelling and glass sheets. The towelling was changed as soon as it appeared damp. After one week the towelling remained dry and both it and the glass sheets were removed to allow the purse to equilibrate (Fig 68). Once dry the organic concretion was removed using a scalpel and pin vice under the microscope. Although it had softened somewhat during drying, it was difficult to remove. The corner of the purse has been stained and torn by it. X-radiography after conservation proved to be useful. It showed that the purse contained seeds (Fig 70), and that details of the fabric are better visible after the careful removal of the water (O'Connor and Brooks 2007, 48).

A mount was made to enable it to be viewed from both sides while remaining physically protected.

Figs 67 and **68** Silk-lined purse before (left) and after (right) conservation (© York Archaeological Trust).





Figs 69 and **70** X-radiographs of the purse before (left) and after (right) conservation (© Sonia O'Connor, University of Bradford, reproduced by permission York Archaeological Trust).

If necessary osseous materials can be pre-treated with PEG and freeze dried. Commonly used consolidants to control surface lamination include Primal WS24, before drying, or Paraloid B72 after drying.

Materials like ivory, horn and baleen are conserved using the same methods, while taking account of the artefact's extreme fragility.

6.5 Wood

Before beginning water removal, careful surface cleaning of the wet wood should be carried out, using water and fingers, soft brushes or natural sponge, with the object well supported to avoid collapse. The wood surface may be very soft, and it is important not to obliterate surface details and possible tool marks during cleaning.

Mineral salts of iron and sulphur are readily absorbed from the burial environment into the wood structure. Acids produced by the oxygenation of these iron sulphide compounds after conservation result in the continuing degradation of the artefacts in oxygen-rich environments. Ideally, the iron and sulphur should be removed from the wood structure before stabilisation, either

Case Study 7 Conservation of a Roman writing tablet

This wooden writing tablet was found in a well in Silchester and has been dated to *c* AD 200. It is made of maple (*Acer* sp.) (Watson 2008).

Even though dirt obscured the surface (Fig 72), fine lines could be seen on closer examination (Fig 71). These lines could have held the wax and a sample was taken for FTIR analysis.

FTIR analysis as well as examination using UV light proved inconclusive.

The tablet was conserved using 10% PEG 400 and 15% PEG 4000 followed by vacuum freeze drying (Fig 73).

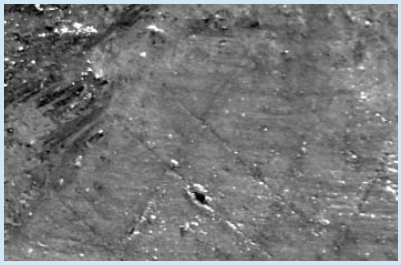


Fig 71 Detail of the writing tablet showing cross hatching.

Figs 72 and **73** Roman writing tablet before (top) and after (bottom) conservation.

by prolonged washing or by chemical treatment with chelating agents.

Conservation methods using impregnants and bulking agents are suitable for artefacts of all sizes, with PEG probably the most common impregnant (*see* Case Study 7). Small, thin wooden artefacts may be suitable for solvent drying. This method has been successfully used for the conservation of delicate Roman ink writing tablets (Blackshaw 1974). In this case PEG treatment was not appropriate as the PEG would have dissolved the ink. Given the size of the objects, only small amounts of solvents were needed.

Although of woody origin, cork can react unpredictably to conventional wood conservation treatments. Critical point drying, if available, has been used successfully for cork conservation (Kaye *et al* 2000). The same range of conservation options as for wood are applicable for wickerwork. Maintaining the integrity of basket elements and the overall structure will be the main challenge. Conservation on the soil block is one way of preventing disintegration (*see* Case Study 8).

6.6 Storage and display

After waterlogged organic artefacts have been conserved they should be stored, handled and displayed in the same controlled environment recommended for dry organic materials. They are still vulnerable to biological, physical and chemical decay. Preventive conservation aims to reduce these decay processes through the control of environmental conditions (temperature, relative humidity, light levels and pollutants) and the choice of packaging materials or display cases to protect against pollutants (including dirt and dust) (Fig 79), and buffer against temperature and relative humidity changes in the wider environment.

6.6.1 Environmental conditions

At the time of writing, a new specification for environmental control for cultural collections in the UK is in preparation. The British Standards Institute (BSI) is developing a Publicly Available Specification for environmental conditions: PAS198 will set out the requirements for temperature, relative humidity, light and pollution for a range of materials applicable to all types of cultural collections in storage, on display and loan (British Standards Institution forthcoming).

In the museum and archives sectors, there is ongoing discussion regarding the narrow environmental conditions outlined in many standards. There is a move towards standards that are based on scientific evidence (Erhardt *et al* 2007) and are sustainable in terms of their energy requirements. Specific recommendations should be determined according to the material type, construction and conservation treatment.

In general, rapid environmental fluctuations over a short period (day–night cycles) should be avoided and a consistent long-term storage environment aimed for. A range of 45–55% RH is

Fig 79 Organic artefacts on display in the Museum of London (© Museum of London).

suitable for most organic artefacts. Relative humidity greater than 65% should be avoided as this will encourage the development of mould.

6.6.2 Materials for storage and display

Depending on the size and fragility of an object, bespoke packaging systems may be required with mounts or adequate padding to support the artefacts (Figs 80 and 81). All packaging materials should allow for some air exchange during storage, as ventilation will help to prevent mould formation. To avoid any unnecessary handling the artefacts should be clearly labelled, recorded and packed, ie the artefact is visible without the need to remove it from the packaging or box.

All materials used with artefacts, both in storage and on display, should be evaluated for their suitability

Figs 80 and **81** Bespoke packaging for textiles (©York Archaeological Trust).

Case Study 8
Conservation of baskets

The basket fragments from Anslow's Cottages, Berkshire were lifted on soil blocks. These elements probably constituted part of a fish trap and are dated to 1060 ±80 BP (OxA-2126) (Butterworth and Lobb 1992). The basket is made in a close plain weave, using split hazel for the warp and the weft components (Watson 1991).

The basket fragments were encased on one side in X-Lite® to maintain their integrity, and conserved on the soil blocks (Figs 74 and 75) by either immersion or spraying with 40% PEG 400 followed by 40% PEG 4000. All parts were freeze dried without vacuum in a domestic chest freezer.

A 17th-century wicker basket was found in London and block lifted (*see* Fig 31). In the laboratory, adhering soil was removed from the outside of the basket. A 25mm lining of soil was left on the inside to support the basket during impregnation (20% PEG 200, 20% PEG 4000 applied by spraying) (Fig 76). Following vacuum freeze drying the interior soil lining was removed using spherical glass beads in a micro sandblaster (air abrasive). The exterior was cleaned partly with compressed air and partly mechanically (Fig 77). During cleaning the wicker was periodically consolidated with Butvar B98 in IMS (industrial methylated spirit) (Fig 78).

Figs 74 and **75** Two basket fragments before conservation.

Fig 76 Basket after PEG treatment.

Fig 77 Basket in the process of being cleaned on the exterior (left: clean, right unclean).

Fig 78 Basket after conservation (**Figs 76–78**) (© Museum of London).

to ensure that they will not cause harm to the artefact, such as through the emission of gases (Thickett and Lee 2004; Strlič *et al* 2010).

6.6.3 Housekeeping

Organic artefacts are a food source for micro – and macro-organisms even after conservation. Good housekeeping (the cleaning of storage or display places), monitoring and controlling the environmental conditions and an Integrated Pest Management (IPM) system will help to deter insect pests and identify a problem early before it becomes an infestation. An IPM will include the setting up of pest traps, their regular inspection, the identification of any pests found in them and an appropriate, agreed strategy in response to pests. Details of the major pests found in historic houses and museums are given in the English Heritage pest poster (English Heritage 2009). It may also be advisable to undertake regular condition surveys to monitor the condition of conserved organic artefacts (Suenson-Taylor and Sully 1997) both in storage and on display (Ganiaris *et al* 2005).

7 Where to get advice

Advice on the excavation, analysis, conservation and preservation *in situ* of waterlogged archaeological remains is available from the English Heritage staff listed below.

1 English Heritage Science Advisors
The English Heritage Science Advisors are available to provide independent, non-commercial advice on all aspects of archaeological science. They are based in the English Heritage regional offices. For contact details visit the English Heritage website at: http://www.english-heritage.org.uk/, select the 'Professionals' tab, then the 'Advice' menu, 'Advice by Topic' and finally 'Heritage Science'. For further details of the work with which the SAs are involved see the SA page hosted on the University of Durham website: http://www.dur.ac.uk/eh.rsa/index.html

2 English Heritage Archaeological Science teams

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3 The Conservation Register of the Institute of Conservation. This is a register of privately practising conservators who are accredited by the Institute of Conservation and are required to work to professional standards set out by the Institute. The register is free to use and it is possible to search for a conservator by location and specialism:

www.conservationregister.com
e-mail: info@conservationregister.org.uk

8 Glossary

acidic soil soil that has a pH of less than 7

aerobic organism an organism that requires air to survive and thrive

air drying drying of wet objects at ambient conditions

alkaline soil soil that has a pH of higher than 7

alum potassium aluminium sulphate; a mineral salt used from antiquity as a mordant for dyes and in the **tawing** process

anaerobic micro organisms mainly bacterial, that can live in **anoxic environments**; they do not depend on oxygen for energy metabolism, but use other sources such as sulphates

anoxic environment (archaeology) levels from which air has become excluded

basketry twined, coiled and plaited techniques worked in semi-flexible materials (Adovasio 1977)

baleen the filtering structure in the mouth of some species of whales, which is made up of the protein **keratin**; synonym – whalebone

biocide chemical substance used to kill organisms such as fungi or bacteria

bulk find finds that are not given individual finds numbers but are registered in bulk; eg one number is assigned to a group of objects, made of the same material from one archaeological context – for example, leather off-cuts can be registered as bulk, as opposed to a complete shoe, which is registered as a **small find** with an individual number

bulking agent a material (eg **PEG** or **glycerol**) used during conservation of wet organic artefacts that bulks out the fibre or cell structure of organic materials (eg wood or leather) to provide support

chelating agent a chemical substance that forms soluble bonds with certain metal ions; synonyms – chelant, sequestering agent; for example, oxalic acid, the disodium salt of ethylene diamine tetra acetic acid (Na_2EDTA) or Triethanolamine (TEA)

chrome tanning a method of **tanning** using chromium based chemicals developed in the later 19th century and in common use from the 20th century onward

consolidant a material that is applied during conservation to provide support or consolidation to fragile or flaking objects

controlled air drying a drying technique that controls the environmental conditions by using saturated salt solutions or electronic equipment; the temperature and humidity can be set at certain levels to limit or prevent drying damage

cross-link part of the polymer molecule where at least four chains emanate (Hedges 2010) – a cross-link forms when one polymer chain bonds to another. After cross-linking, polymer chains loose their ability to move about freely. In the case of uncontrolled drying of wood and leather this results in stiffening or splitting of the material.

critical point drying a drying technique that takes advantage of the fact that certain substances can exist in more than one state under certain conditions – for example, water is solid (ice), liquid (water) and gas (vapour) at the same time at 0˚C and 6.1mbar. This is called the critical point. If the water in a material is replaced with liquid CO_2, and the temperature is then raised above the critical point, CO_2 changes from liquid to vapour without surface tension and without altering the cell structure of materials.

freeze drying a drying technique carried out in a vacuum freeze drying chamber. This technique works by **sublimation** of the frozen water in the artefact thereby eliminating surface tension, which normally damages cell and fibre structure when water evaporates.

glycerol a water soluble **bulking agent**; synonyms – glycerin, glycerine, 1,2,3 propanetriol

humectant a **hygroscopic** substance, such as **glycerol**, that has a strong affinity to form bonds with water owing to its hydrophilic chemical molecular groups

hydrolysis decomposition of chemical compounds by reaction with water

hygroscopic a material capable of absorbing water from the environment and releasing water to the environment

impregnation process during conservation when water in the organic artefact is exchanged for a **bulking agent**

inorganic a compound of mineral origin; compare **organic** below

investigative conservation processes used to examine and record artefacts, by non-invasive means, by removing accretions, or by sampling for analysis

keratin / keratinous a material made up of proteins to form hair, nails, skin, hoofs and horns; synonym – horny

non-ionic detergent a detergent that is polar but does not ionize in aqueous solutions

non-putrescible a material that is not readily broken down by bacteria

non-vacuum freeze drying a drying technique similar to **freeze drying**, but without the vacuum; it normally takes place inside a chest freezer, but also works outdoors; the same principle of **sublimation** of water applies

organic once part of a living organism – for example, bone, antler, wood, skin and horn – but excluding those transformed by geological processes such as jet, shale and amber

osseous a material consisting of bone or resembling bone; synonym – bony

pelt term used in these guidelines in its original sense of an animal skin with hair, fur or wool still intact. Within the modern leatherworking industry it has acquired the meaning of skin from which the hair, fur or wool has been removed before tanning.

polyethylene glycol (PEG) a water-soluble **bulking agent**; synonym – carbowax

pseudo-leather a material produced by impregnating a skin, with or without its hair removed, with inert fatty materials and allowing it to dry slowly. The waterproofing prevents the skin fibres from becoming wet enough for bacterial attack to take place.

qualitative analysis the determination of the different chemical species or elements in a sample

quantitative analysis the determination of how much of a given component is present in a sample

remedial conservation treatments used to stabilise an object for handling and storage; this includes the drying of wet and waterlogged materials or the repair and consolidation of broken and fragile objects

skin products skin and materials produced from it; these include skin and hides, parchment and vellum, **pseudo-leathers**, alum-tawed skins, leathers and fur skins. Furs are the skins treated to retain the hair or wool.

small find an archaeological find allocated an individual finds number when registered

solvent drying process in which the wet object is immersed in successive baths of a water-solvent mix of increasing solvent strength, so replacing water in the object's structure with a solvent that has a lower surface tension, and which will evaporate with less cell disruption during the controlled drying that follows

sorbitol a sugar substitute, used as a water-soluble **bulking agent**

suberin the waxy and water-impermeable substance that is the main constituent of cork

sublimation process when water transfers from the frozen directly to the gas phase without the intermediate liquid phase

surface tension a measure of the cohesion of molecules within a liquid. A liquid with a higher surface tension (such as water) requires more energy to be removed than a liquid with a lower surface tension (such as a solvent). When a liquid such as water evaporates from an artefact the cohesion of molecules can be so strong that they cause cell-wall damage to the artefact.

tanning the conversion of the skin of any vertebrate animal, by any process, into a material that is **non-putrescible** (does not rot) under warm, moist conditions. A true leather retains this property after repeated wetting and drying.

tawing process by which animal skin is treated with a mixture of alum, salt, a fatty material (often egg yolk) and an inert carrier (traditionally flour) and then dried to produce a soft, white leather-like material, which is durable if kept dry, but degrades rapidly in contact with water

vegetable tanning process by which animal skin is soaked in a tannin-rich liquid, dried and further worked into leather. In the past, oak bark has been widely used in Britain.

waterlogged term for an artefact that is saturated with water, ie all cavities and cells are filled with free water

wickerwork rigid constructions such as baskets, chairs, hurdles and scaffolding made in basketry techniques

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Front cover images: (top left) A deadeye with remains of rope from the *Swash Channel* Wreck; (top right) A basket being block lifted, London (© Museum of London); (centre left) Washing of textile supported on a sieve; (centre right) A cast of scale pattern on cattle fibre, mid-shank (© The Anglo Saxon Laboratory); (bottom left) Leather shoes from the *Mary Rose*; a slash above the big toe suggests the wearer suffered from a foot complaint such as bunion (© Mary Rose Trust); (bottom right) Walrus ivory gaming pieces, York (© York Archaeological Trust). Back cover image: A medieval barrel *in-situ*, Nantwich (© Earthworks Archaeology).

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