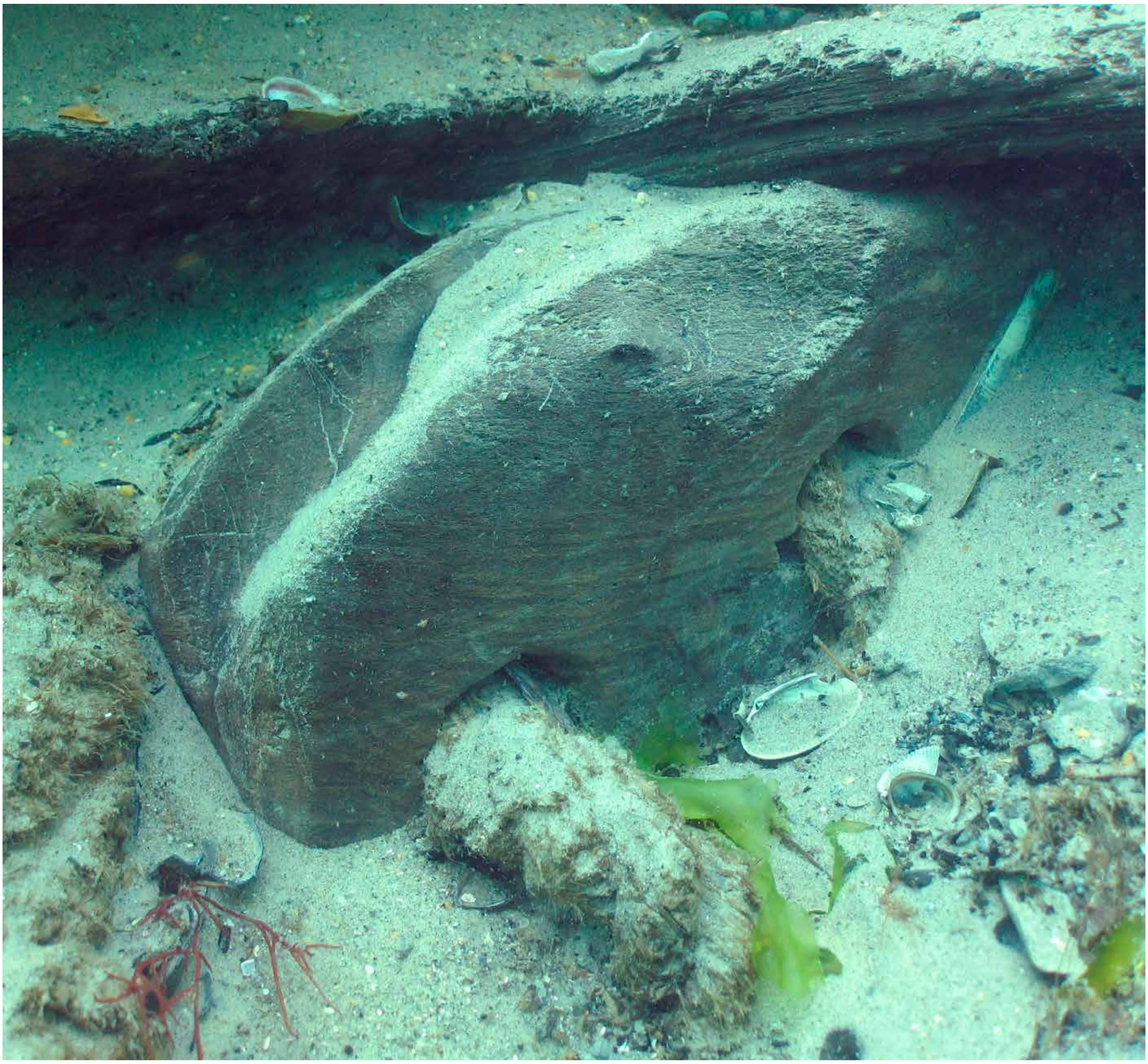
Historic England

Waterlogged Organic Artefacts

Guidelines on their Recovery, Analysis and Conservation



Summary

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. This guidance is aimed at anyone planning for or working with waterlogged organic artefacts, including archaeological curators, archaeologists and specialists (finds specialists, environmental archaeologists and conservators). This guidance will help the reader appreciate the information and research potential waterlogged organic artefacts can offer. It will briefly describe material conditions and commonly applied conservation techniques, in order for people less familiar with these situations to make the right decisions when commissioning work. For practitioners in the field, it contains useful advice on lifting, storage and packaging. The chapter on analytical techniques highlights areas for further research. Case studies and specialist views are provided to illustrate the principles with real-life scenarios.

This guidance should be used in conjunction with other Historic England publications, as some of their content is 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* (Historic England 2018b) and *Environmental Archaeology* (English Heritage 2011). This is the second revised version to reflect organisational changes.

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Front cover:
A deadeye with remains of rope from the *Swash Channel* wreck, Poole Bay, off Dorset.

Contents

Introduction

Aims of this guidance

This guidance covers 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 this guidance as they do not merit conservation in the same way as artefacts. Environmental remains should be sampled and curated following the guidance in *Environmental Archaeology* (English Heritage 2011) and *Guidelines for the Curation of Waterlogged Macroscopic Plant and Invertebrate Remains* (English Heritage 2008a).

This guidance is written for anyone working with archaeological waterlogged organic artefacts and covers 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, their research potential is fully realised and they are integrated during the excavation and post-excavation phases. 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 guidance, but not structural wood, which is covered in *Waterlogged Wood* (Historic England 2018b). The reference list and points of contact (*see* sections 6 and 7) are provided for those who require more detailed information.

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, eg from pollen, plant remains and insects (English Heritage 2011).

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. This contributes to the reconstruction of past climates, vegetation, diet and husbandry (Figure 1).

Figure 1
Wooden tankard, *Mary Rose,* the Solent, Hampshire.

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 (Figure 2).

Figure 2
Stave lantern, *Mary Rose*, the Solent, Hampshire.

Provenance

Technological, stylistic and material characteristics can be used to provenance finds (Figure 3) (*see* section 4.4.6 Biomolecular analysis).

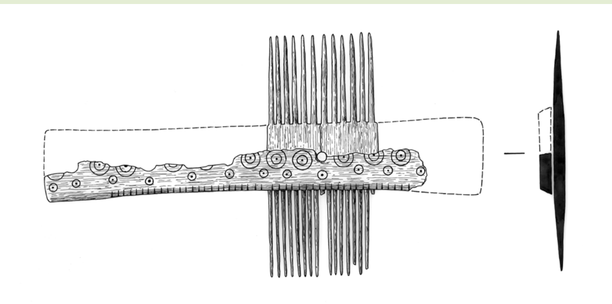

Figure 3
Illustration of a bone comb, Fishbourne Beach, Isle of Wight.

Trade

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

Figure 4
Walrus ivory gaming pieces, York.

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 object, such as garments, textiles, shoes and scabbards, can be closely dated, in certain circumstances more so than pottery (Figure 5).

Figure 5
Medieval leather knife sheath, Thames Street, London.

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 (Figure 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) (Figure 7).

Figure 6
Roman writing tablet, Silchester, Hampshire.

Figure 7
Silk hat, York.

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 (Figure 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. Examples include bog bodies and associated materials, such as the true tinder fungus found amongst the Ice Man Ötzi's possessions, whole stone pine cones imported for use in Roman ritual practices, or a rosary made of Job's tears (*see* Appendix for Latin names).

Figure 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 (Figures 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).

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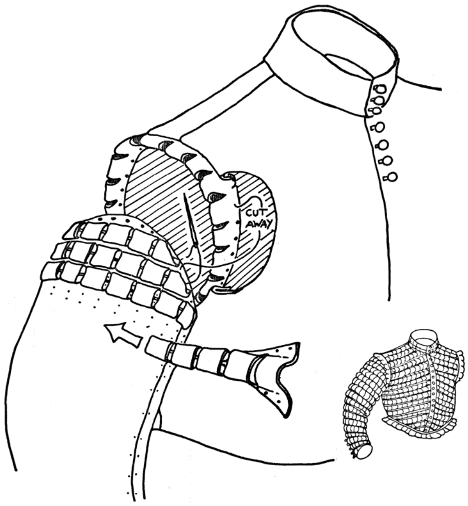

Figures 9–10
Decorative slashing of garments was a fashion of the 1540s onwards. These applied slashed strips were cut from soft-finished wool twill. They were excavated in the castle ditch, Newcastle upon Tyne, Tyne and Wear (Walton 1981).

Specialist's view: the leather specialist

Quita Mould

The nature of vegetable-tanned leather, allowing it to be 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 (Figure 11) and occasionally their painful foot complaints (*see* Case Study 1) – a degree of personal knowledge seldom gained from the study of other finds.

Figure 11
Medieval leather shoe, the Newport Ship, Newport, South Wales.

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. These include 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 can lead to the total loss of archaeological evidence. To prevent this, some simple steps need to be taken (*see* section 3). 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.

1 Project Planning Stages

For field evaluations and investigations initiated through the planning process, work is undertaken in the context of the National Planning Policy Framework (NPPF). Planning advice can be found on the Historic England web page: HistoricEngland.org.uk/advice/planning/planning-system/.

The Management of Research Projects in the Historic Environment (MoRPHE) is a system developed to promote an integrated programme of research for Historic England-funded projects. A typical project will often proceed through a number of stages (Historic England 2015c; Kerr *et al* 2008) and the role of conservation and finds specialists is described broadly in relation to these.

1.1 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 (Historic England 2015b). 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 (Brown 2007, 6; CIfA 2014b, 3; CIfA 2014c; English Heritage 2008b; 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 study area 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, 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) (CIfA 2014a, 7; Historic England 2015c, 30). 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 2.1), sampling, retention and disposal strategies should be raised 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 (Brown 2007; Museums and Galleries Commission 1992, 13).

1.2 Project execution

1.2.1 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 Historic England Science Advisors and the Institute of Conservation (ICON) Conservation Register (*see* section 6). The following tasks give some examples of where the involvement of a conservator and finds specialist will benefit the project.

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. A conservator can 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 store waterlogged organic material correctly to prevent deterioration.

Transport
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 Historic England Science Advisor. The finds specialist, conservator, environmental specialist and repository should also be informed as soon as possible when such discoveries 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 Historic England Inspector or Science Advisor can provide support and further information.

1.2.2 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 PD. The assessment should include the following points (English Heritage 2008b; Goodburn Brown 2001; 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 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 are 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.

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.

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 a direct link with their owners.

1.2.3 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.

1.2.4 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 Brown (2007), CIfA (2014c) Museums and Galleries Commission (1992) and Walker (1990).

1.2.5 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 reports should be noted in the Online AccesS to the Index of archaeological investigationS (OASIS) system for the project (www.oasis.ac.uk). The report should include:

- names of individuals involved
- site location (including a 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 into the HER science-based information following the *Guidelines for the Addition of Archaeological Science Data to Historic Environment Records* (English Heritage nd).

1.3 Project closure

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

2 Material Conditions

2.1 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 wide variety of site types including low-lying urban sites, perched water tables, wetlands, river floodplains, lakes and marine environments (Figures 12–14) (Historic England 2015b). Waterlogged conditions that may preserve organic deposits can sometimes be found on dry sites in isolated features such as wells, pits, post holes, ditches and graves.

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Figure 12
A typical waterlogged deposit, Richborough Roman fort, Kent.

Figure 13
A typical marine environment: a deadeye with remains of rope from the *Swash Channel* wreck, Poole Bay, off Dorset.

Figure 14
A medieval barrel at Nantwich, Cheshire, containing a multitude of organic artefacts.

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	Vegetable 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).

Organic materials survive mainly as a result of two factors: the abundance of static water and the chemical balance of this water (pH and oxidation–reduction potential [Eh]) (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* Figure 26). 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 Sandström 2006).

2.2 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 that 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 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 brain, bone marrow and fish oil 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 onwards, 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 in this way. 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 2.3.2), 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 as a result of the formation of iron–tannin compounds. Splitting into two layers is also common, resulting in the leather appearing to comprise two separate pieces (Figures 15 and 16). This may be because of incomplete penetration of the tanning materials into the skin. In later stages of decay, the fibre network can disintegrate and the leather becomes very friable.

2.3 Fibrous materials

2.3.1 Textiles

The raw materials of textiles can be divided into three categories:

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

Animal fibres include coat fibres, such as sheep wool and goat hair, and silk from the cocoon of the silk moth. Plant fibres are mostly derived from stems of flax or hemp, although fibres from the common stinging nettle and bast from trees (from the layer beneath the bark) are also sometimes encountered. These species were joined in the late medieval period in Britain by imported cotton made from the seed boll of the cotton plant.

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 an organic core.

Once buried in waterlogged conditions, the three fibre groups interact with the burial environment in different ways (Cooke 1990; Florian 1987; Jakes

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Figures 15–16
A piece of leather that has split into two layers.

and Sibley 1983; Peacock 1996; Sibley and Jakes 1984; Timár-Balázsy 1989). 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 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 complete 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.

2.3.2 Animal pelts

Animal pelts, ie 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 of, for example, lynx and bear. They usually survive in waterlogged levels only as tufts of fibre (the skin part invariably decays) that often look as if they have been singed at one end. This is because of the ginger colour of the fibre root and the black specks of decayed skin adhering to it. The fibre tufts, or 'staples', survive in the same circumstances as wool textiles, ie primarily in waterlogged, mildly acidic conditions.

2.3.3 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 (Figure 17) 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 further in section 2.5.3.

The fibres of cordage and basketry will 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.

Figure 17
A three-strand plait worked from bundles of hair-moss.

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Figures 18–19
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 in Figure 18 is lifted on a pedestal of soil) and flaking of the outer surface (Figure 19).

2.4 Keratinous and skeletal materials

2.4.1 Bone, antler and ivory

Skeletal materials, such as bone, antler and ivory, consist of organic protein (chiefly collagen) and inorganic mineral (hydroxyapatite, a form of calcium phosphate) components. 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 (Figures 18–21). Neutral or alkaline environments with low water flow are more likely to lead to good survival. Therefore waterlogged deposits, provided that they are not highly acidic, often result in good survival of skeletal materials.

On rare occasions human remains may be found fused to archaeological artefacts, eg foot bones inside leather shoes (Figures 22 and 23).

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Figures 20–21
Bone that has become extremely soft because of the acidic soil at Star Carr, North Yorkshire (note: Figures 20 and 21 depict the same bone being flexed).

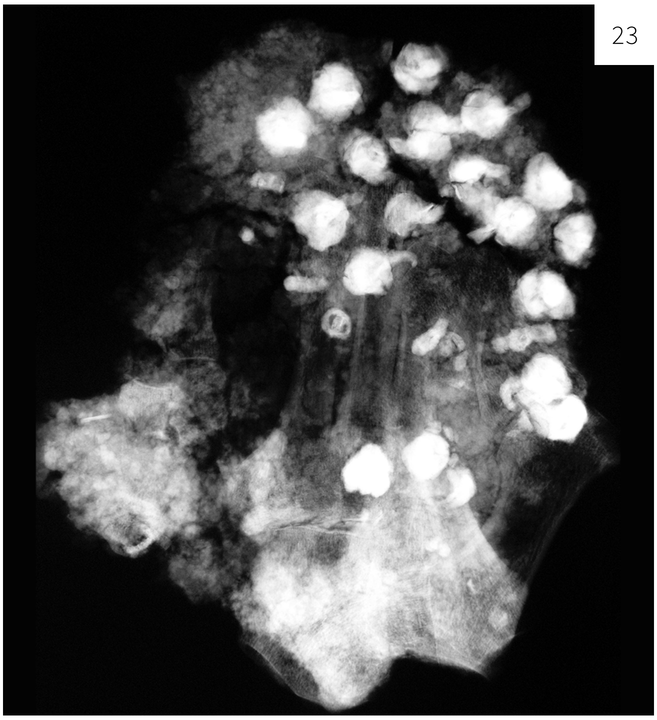

Figure 24
Horn found in peat land, showing signs of delamination and opaqueness.

2.4.2 Horn and baleen

Materials such as horn, hoof or baleen represent non-living tissue consisting mainly 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.

Survival of keratin materials is rare in an archaeological context. Water is the main agent of decay, which results in hydrolysis of keratin. The material becomes opaque on burial and starts to laminate (Figures 24 and 25). Keratin material can be extremely soft and easily damaged.

Figures 22–23
Foot bones with degraded leather and iron hobnails (Figure 22), block-lifted from a Roman burial at Healam Beck, North Yorkshire, and associated X-radiograph (Figure 23).

Figure 25
Fragment of baleen, Horsecross, Perth, Perthshire, Scotland.

2.5 Wood

2.5.1 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 (Figure 26).

The most common agents of decay in waterlogged wood are soft-rot fungi and erosion bacteria (Blanchette *et al* 1990; 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 shipworm and gribble (Figures 27 and 28). Such damage can be severe.

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, 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 become 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.

Figure 26
Wooden bowl *in-situ*, Nantwich, Cheshire.

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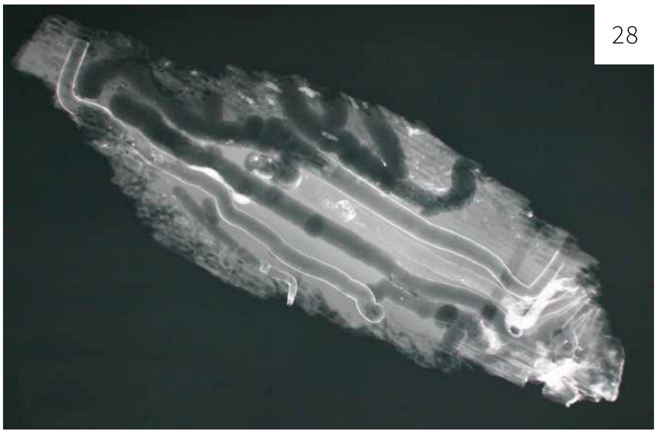

Figures 27–28
Barrel stave fragment, which appears intact (Figure 27) but is severely damaged by marine wood borers, as seen in the X-radiograph (Figure 28).

Figure 29
Cork bung from the Newport Ship, Newport, South Wales.

Figure 30
Basket being block lifted, London.

2.5.2 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. Its 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 (Figure 29). Cork will be soft and prone to mechanical damage upon excavation.

2.5.3 Wickerwork

The earliest evidence for wickerwork occurs in the Neolithic period. 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 (Figure 30).

3 Lifting, Handling and Processing

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 will outline a few steps to reduce this risk. More detailed information 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 3 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 4). Seek advice from the intended specialist for these analyses for information on any protocols that should be followed.

3.1 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: not to lift the artefacts directly but to lift 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 (Figure 31). 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 (Figures 32–33) or freeze lifting is also possible; *see* Case Study 3 (Jones 1996, 2007; Jones and Clogg 1993).

Special care has to be taken that the lifting materials selected can withstand constant contact with water. Generally it is best to use durable, water-resistant and non-corrosive materials (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 the actual lifting process (*see* section 4.1).

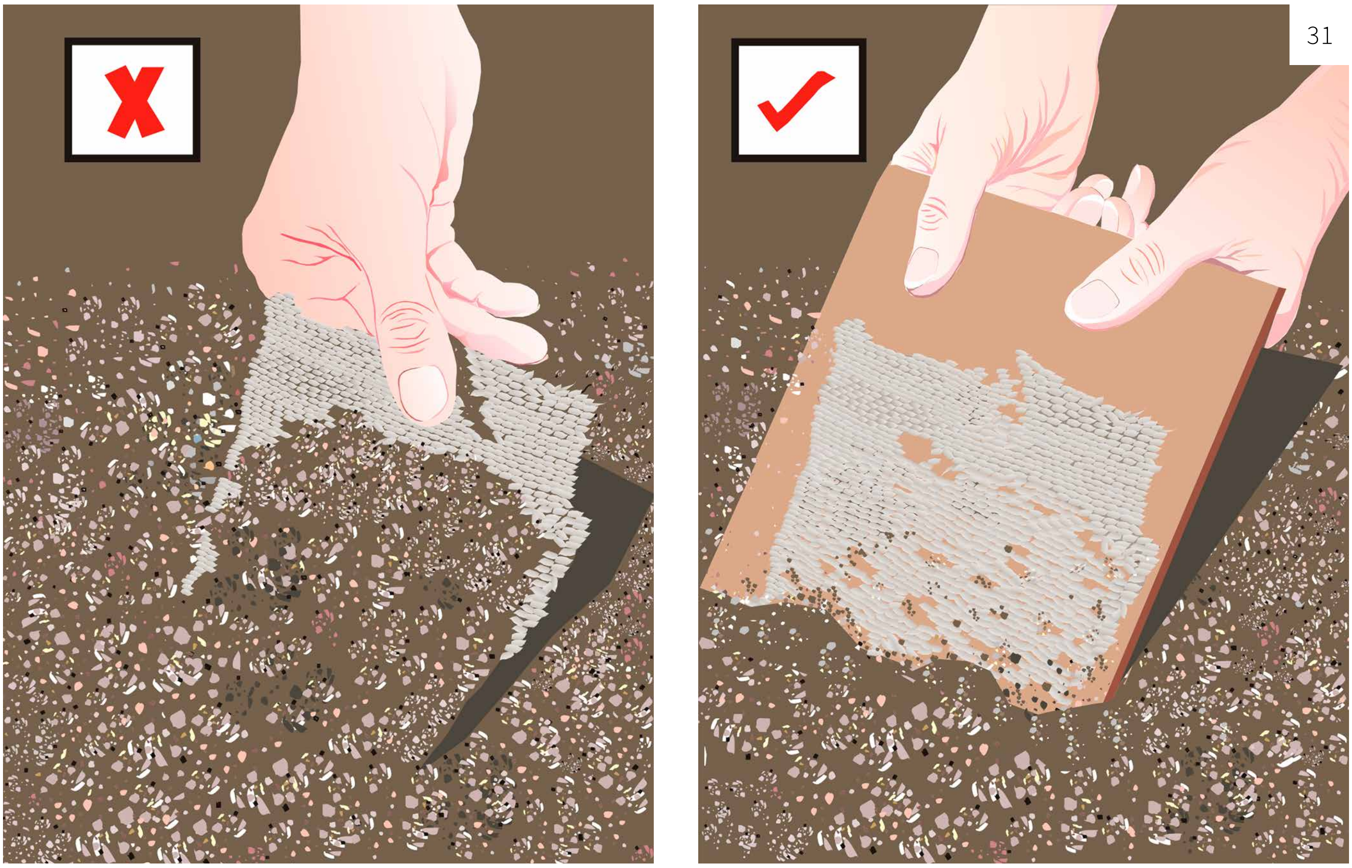

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Figure 31
Direct lifting (left) and passive lifting (right) of a textile fragment.

Figure 32
Excavation of antler picks, Marden Henge, Wiltshire.

Figure 33
Lifting of antler, Marden Henge, Wiltshire (the same antler as in Figure 32).

Application	Materials	
	Recommended	Use with caution; short-term* only
Wrapping around artefacts	■ Cling film: polyethylene (PE) film [not the polyvinyl chloride (PVC) type] ■ Gauze ■ Netlon® mesh (polyethylene netting) ■ Scotchcast® (fibreglass fabric impregnated with polyurethane) ■ Capillary matting (cotton/polyester material with a water-holding capacity) ■ Nylon string	■ Fabric ■ String ■ Rope ■ Bubble wrapping ■ 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) ■ Metal sheets	■ MDF (medium density fibreboard) boards
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.

Application	Materials	
	Recommended	Use with caution; short-term* only
Wrapping	■ Cling film: polyethylene (PE) film [not the polyvinyl chloride (PVC) type] ■ Gauze ■ Netlon® mesh (polyethylene netting) ■ Tarpaulin	■ Bubble wrapping
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, but be careful as 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 3
Materials useful for the storage of waterlogged organic materials post-excavation.

	Advantages	Disadvantages
Washing on-site	■ Artefacts 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 4
Overview of the advantages and disadvantages of washing waterlogged organic materials on-site.

3.2 Handling on-site

Once lifted out of the soil, limit or avoid handling artefacts and opening bags and boxes. Because of 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; Goodburn Brown 2001; Madsen 1994, 107; Skals 1996, 163). Components of one object can also become disassociated from another (Figure 34). The finds specialist, conservator and project manager should discuss whether washing is carried out on-site and to what degree (Table 4).

On agreement with the finds specialist, environmental archaeologist and 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 (Figures 35 and 36). The cleaning of fibrous materials such as textile and basketry should be carried out by a conservator under laboratory conditions. The conservator should 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.

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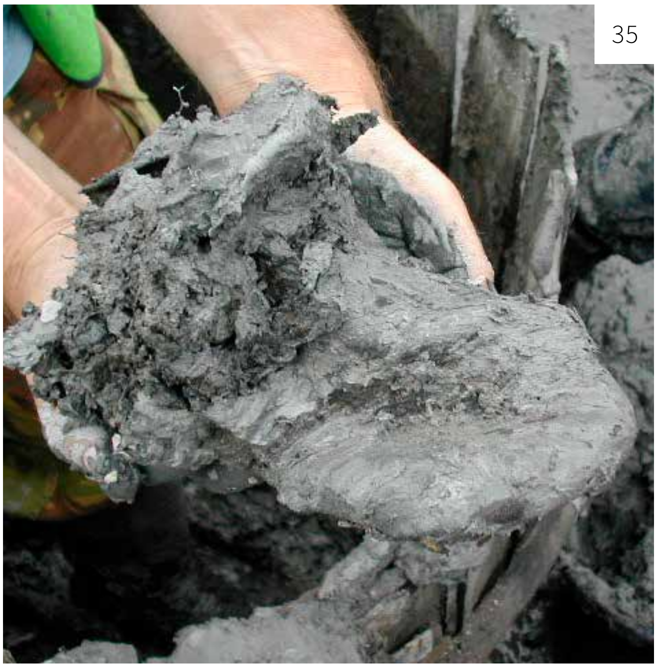

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Figure 34
The stitching in this 15th century ankleshoe from Westgate, Wakefield, West Yorkshire, has decayed and the individual pieces have become disassociated from one another.

Figure 35
Leather shoe just lifted out of the ground, Nantwich, Cheshire.

Figure 36
Leather shoe (the same as Figure 35) after washing on-site.

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Figure 37
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.

Figure 38
Leather sole that has developed mould during storage for more than 20 years.

3.3 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 push up costs or present a health hazard if mould forms (Figures 37 and 38). It cannot be stated 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 seasonality (depending on whether the object can be placed in a fridge or not). If an artefact is in a good condition and is kept in a fridge, six months could constitute temporary storage. For a highly degraded artefact in less than ideal conditions, a week may be temporary, eg 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 monitor routinely the condition of the artefacts and respond appropriately if the artefacts start to deteriorate actively.

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 packaging and, if possible, moved to a separate location, to prevent the mould spreading. Labels should 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 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 or the Health and Safety Executive (HSE), or can be found in Florian (1997, 2002).

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

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 and hinder microbiological growth. Fridges, cool boxes or cooling portable buildings 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 over the winter.

Monitor it
Routinely monitor the condition of artefacts, their packaging and 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 sea water 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 (eg rubber bands, mesh tubing, or bubble plastic wrapping where the bubble side is facing inwards next to the surface rather than facing outwards). Some materials (such as bubble wrapping) 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. Because of the water in and around artefacts and additional packing material, containers can become very heavy: care must therefore be taken when lifting.

Decay will continue even when the best packing and storage practice is applied (Figure 39). 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.

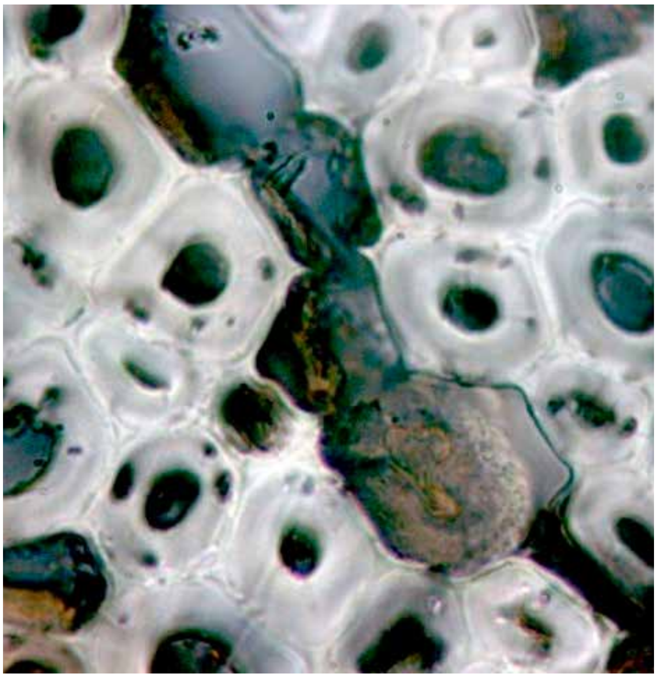

Figure 39
Scanning electron microscopy (SEM) image of elm wood cells showing cavities distinctive of soft-rot fungal attack, developed during prolonged storage in tap water (magnification ×1,000).

4 Documentation, Examination and Analysis

This section draws attention to 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 each 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 as visual examination under a microscope, and then move on to more advanced methods if still required.

4.1 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 4.2 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 artefact is made following examination by a finds specialist (RFG and FRG 1993). No further work will be necessary for the vast majority of artefacts. Selected artefacts may be illustrated.

4.1.1 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 may be recorded on-site but for other information recording may only be possible post-excavation once the soil has been removed or the artefact revealed through detailed examination or using imaging techniques (*see* sections 4.2 and 4.3). Artefact description may be tabulated or free text.

4.1.2 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 HER and recipient museum as part of the archive. Archaeological science data can also be recorded as an 'event' into the HER using archaeological science fields and terms developed by the Historic England Science Advisors (English Heritage nd).

4.1.3 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* prior to lifting and before, during and after conservation) and whether they are photographed individually in detail or batch photographed.

Compact and digital single lens reflex (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 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. General advice on creating digital resources can be found on the Archaeology Data Service (ADS) website (www.ads.ahds.ac.uk). Historic England also provides relevant guidance (Historic England 2015a).

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

4.1.4 Illustration

Drawings or sketches of an object are undertaken by a variety of specialists and annotated to record observations (to accompany text descriptions, *see* section 4.1.1) 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.

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

4.2 Imaging techniques

4.2.1 X-radiography

X-radiography (X-ray) 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-ray depends upon their thickness, density and chemical nature.

Although not commonly applied to organic artefacts, X-ray 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 textiles
- recording hobnailed sole patterns (Figures 40 and 41)
- recording stitching in leather and thin wooden artefacts that is obscured by soil (the stitches are often more X-ray opaque because of 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* Figure 28).

4.2.2 Laser scanning, polynomial texture mapping and photogrammetry

Three-dimensional (3D) recording and visualisation techniques have become more accessible, and their application in archaeology has become more common (Historic England 2017, 2018a; 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 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 (create an accurate 3D record of an artefact)
- for replica making
- for 3D models, animations and illustrations.

Figures 40–41
Roman hobnailed sole (Carlisle, Cumbria) and associated X-radiograph to record nailing pattern and condition.

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 (Historic England 2018a). Image-based approaches, such as polynomial texture mapping (PTM) and photogrammetry, provide additional methods for recording and analysing the surface texture and morphology of artefacts (English Heritage 2013; Historic England 2017). 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.

4.3 Visual examination

4.3.1 Optical light microscopy

In one form of optical light microscopy (OLM), artefacts are examined with the aid of a low-powered stereo microscope (×2.5 to ×50 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, and 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 disciplines is essential. It may be necessary to consult a wood specialist, a zooarchaeologist or an archaeobotanist for the identification of raw materials. For example, 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 OLM (using a low-powered stereo microscope and two angled light sources) is particularly useful as it can enable the specialist to:

- identify basic construction
- identify material composition, eg recognise the structural differences between bone and antler, or 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 focusing of a narrow beam of light through the sample mounted on a glass slide into the objective lens and eyepiece. A polarised light transmission microscope is useful for examining plant fibres (Bergfjord and Holst 2010).

Using TLM, the specialist can:

- identify wood type (Hather 2000; Schweingruber 1978)
- identify fibres at magnifications of ×400 to ×600 (Figures 43 and 44)
- identify pigmentation in wool at ×400 to ×600 magnifications (Figure 43)
- study wear and damage in textile fibres (Cooke and Lomas 1990).

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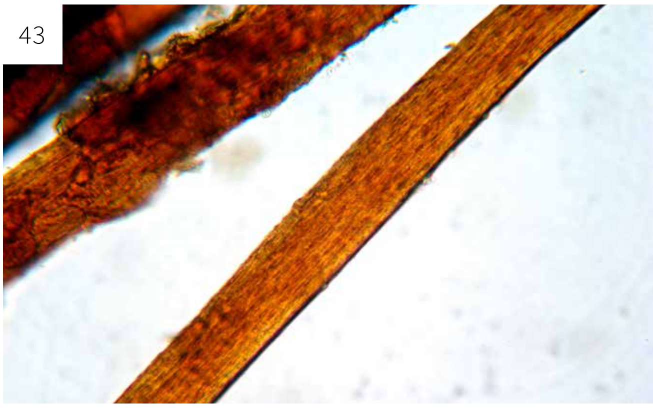

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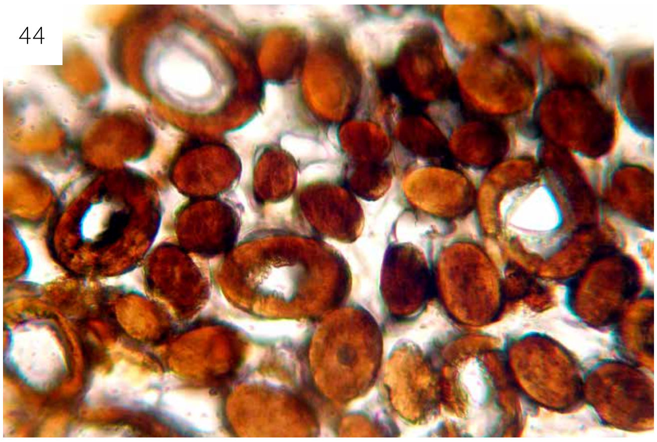

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The identification of animal pelts is a highly specialised task (Appleyard 1978). The identification is based on the shape of the staple (Figure 42) and the individual fibre morphology. Samples are prepared for microscopy as whole mounts (Figure 43), cross-sections (Figure 44) and casts (Figure 45). A comparative collection of specimens of known origin is essential.

4.3.2 Scanning electron microscopy

Scanning electron microscopy (SEM) is a high-resolution technique, capable of magnifying by tens of thousands of times. For dry materials the examination takes place under vacuum. Sampling may be required because of the size of the chamber and the need to prepare the sample (by 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 grey-scale image of the topographical surface of the sample. The advantages of using this type of microscopy are the very high magnification and the very good depth of field. It may be possible to undertake chemical analysis of inorganic components at the same time, as many SEMs are fitted with X-ray spectrometer systems.

Figure 42
Cattle hide from a Bronze Age cist at Langwell Farm, Strath Oykel, Easter Ross, Scotland, excavated by GUARD on behalf of Historic Scotland.

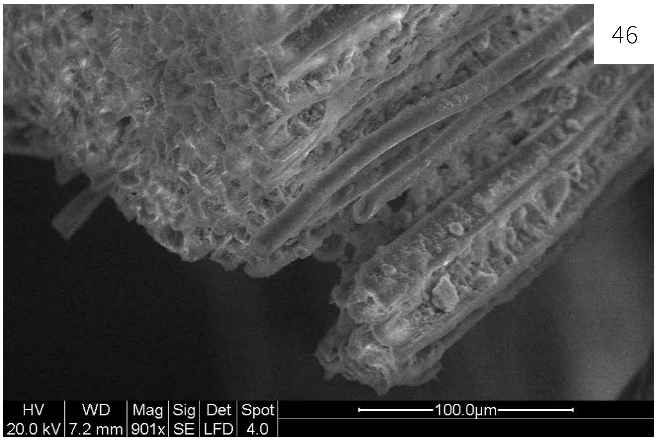
Figure 43
Whole mount of cattle fibre (the same as Figure 42) showing moderate pigmentation (brown) (fibre diameter 30–65microns).

Figure 44
Cross-section of cattle fibre (the same as Figure 42) as a diagnostic feature to aid identification.

Figure 45
Cast of scale pattern (Figure 42) of mid-shank of fibre.

This technique is particularly useful for:

- examining small samples in order to identify organic materials such as wood, bone, antler, ivory and horn (Figure 46)
- detailed study of tool marks, wear and damage (a silicone mould of an area of interest may be made, which can then be studied in the SEM)
- detailed study of an artefact's structure following conservation (Figure 47)
- examination of fibres.



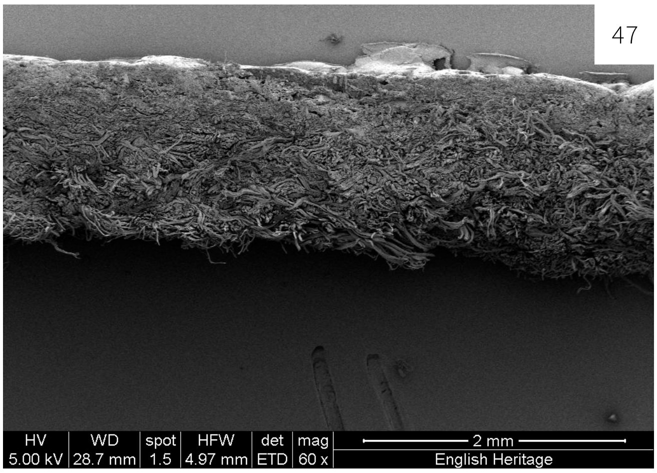


Figure 46
Scanning electron microscopy (SEM) image (×901 magnification) of baleen sample showing tubular fibres in keratin matrix.

Figure 47
Scanning electron microscopy (SEM) image (×60 magnification) of leather cross-section after conservation. The fibre structure is intact and cohesive.

4.3.3 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; they can then be identified or suitable areas for sampling located (Caple 2006).

4.4 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 4.4.4) and biomolecular analysis (*see* section 4.4.6) 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.

4.4.1 Fourier-transform infrared and near infrared spectroscopy

Fourier-transform infrared (FTIR) and Fourier-transform near infrared (FTNIR) spectroscopy 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 (Carr *et al* 2008; Garside and Wyeth 2006)
- recording the state of preservation for wood and leather (Godfrey and Kasi 2005).

4.4.2 X-ray diffraction

X-ray diffraction (XRD) analysis identifies crystalline materials associated with organic artefacts, including pigments, minerals, efflorescent salts, chemical residues and corrosion products. A small sample is required and powdered for analysis. The results are compared with reference patterns of known materials.

Aim of analysis		Type of analysis
Identify structure and materials		■ Microscopy (optical and transmitted light) ■ Scanning electron microscopy (SEM) ■ Fourier-transform infrared (FTIR) spectroscopy ■ Fourier-transform near infrared (FTNIR) spectroscopy
Identify composition of coatings and deposits	Pigments	■ X-radiography diffraction (XRD) analysis
	Organic residues	■ Fourier-transform infrared (FTIR) spectroscopy ■ Fourier-transform near infrared (FTNIR) spectroscopy
	Non-organic residues	■ X-radiography fluorescence (XRF) analysis ■ X-radiography 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 (X-ray) ■ Laser scanning ■ Polynomial texture mapping (PTM)
Assess condition		■ Microscopy ■ X-radiography (X-ray) ■ Scanning electron microscopy (SEM) ■ Fourier-transform infrared (FTIR) spectroscopy ■ Fourier-transform near infrared (FTNIR) spectroscopy
Scientific dating		■ Dendrochronology ■ Radiocarbon dating

Table 5
Example research questions and types of analysis.

4.4.3 X-ray fluorescence

X-ray fluorescence (XRF) analysis is used to determine chemical composition. This technique is useful because it is rapid and no sample is needed, provided that the object fits into the XRF chamber. Alternatively, portable machines (pXRF) can be used for very large objects, or can be used in the field on material that is still *in-situ*. XRF can be useful for examining organic materials where there is a non-organic component or deposit, such as identifying metal alloys, inlays, coatings corrosion products, pigments, etc.

4.4.4 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 (PEG; *see* section 5.1) can in theory be washed out, it is impossible to know in practice that this has been done completely. Archaeological material submitted for radiocarbon dating (^{14}C) 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 Historic England guidance (English Heritage 2004; Historic England 2018b) and the Historic England Science Advisors should be able to advise on specialists to contact.

4.4.5 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) and high-performance liquid chromatography (HPLC). Mould, algae and solvents can interfere with the results.

4.4.6 Biomolecular analysis

Ancient biomolecules include lipids (fats, waxes and oils), protein (collagen, keratin, blood and milk) and deoxyribonucleic acid (DNA). Lipids and proteins may be absorbed into the fabric of an artefact or comprise residues associated with an artefact. Their sampling for analysis must be undertaken following specialist advice (English Heritage 2011; Heron *et al* 2005). The analysis of animal bone DNA or collagen for the identification of species, and the analysis of stable isotopes for the origin of sheep's wool, represent new areas of research that are given increasingly more consideration (Buckley 2018; Buckley *et al* 2009; Capellini *et al* 2010; Hedges *et al* 2005; Hollemeyer *et al* 2008; von Holstein *et al* 2016; Korsow-Richter *et al* 2011). 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).

5 Conservation

Because of their waterlogged state, wet organic artefacts are generally unstable. All conservation methods have one aim in common: to convert the artefact from an unstable to a stable condition. This is achieved by careful removal of the supporting water whilst 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 process can go on for many years. Because of 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, 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.

5.1 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, as outlined in sections 5.2–5.5.

It is advisable to consult a conservator if fragile, unusual or composite artefacts are found. Composite artefacts such as a leather shoe with cork sole or leather with textile lining are rare, and the different materials will react 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 5).

The conservation assessment report (*see* section 1.2.2) will 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 2013)
- 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, however, to impregnate them with a bulking agent before drying is attempted. 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, sea water and salts should be removed before impregnation through prolonged washing in tap or distilled water.

The mineral content of organic materials (in particular wood and leather) is sometimes considered a problem that 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 (Figure 48). Freeze drying is successful because it eliminates drying stress and large quantities of material can be stabilised relatively quickly. The initial high purchase costs or lack of access to such specialist equipment can mean that other drying methods may be a necessary (*see* Case Study 6). Freeze drying can also be carried out without the vacuum in a domestic chest freezer (non-vacuum freeze drying) (Figure 49). 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 (Figure 50). For certain artefacts, solvent drying is the only realistic alternative (*see* section 5.6.1). Disposal and safety concerns about quantities of solvents mean that this technique is rarely used, ie only when absolutely necessary. After an assessment some artefacts may be suitable for careful air drying (Figure 51).

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

Figure 52 presents an example flow chart to aid decision making. It is derived from a leather drying trial (*see* Case Study 6).

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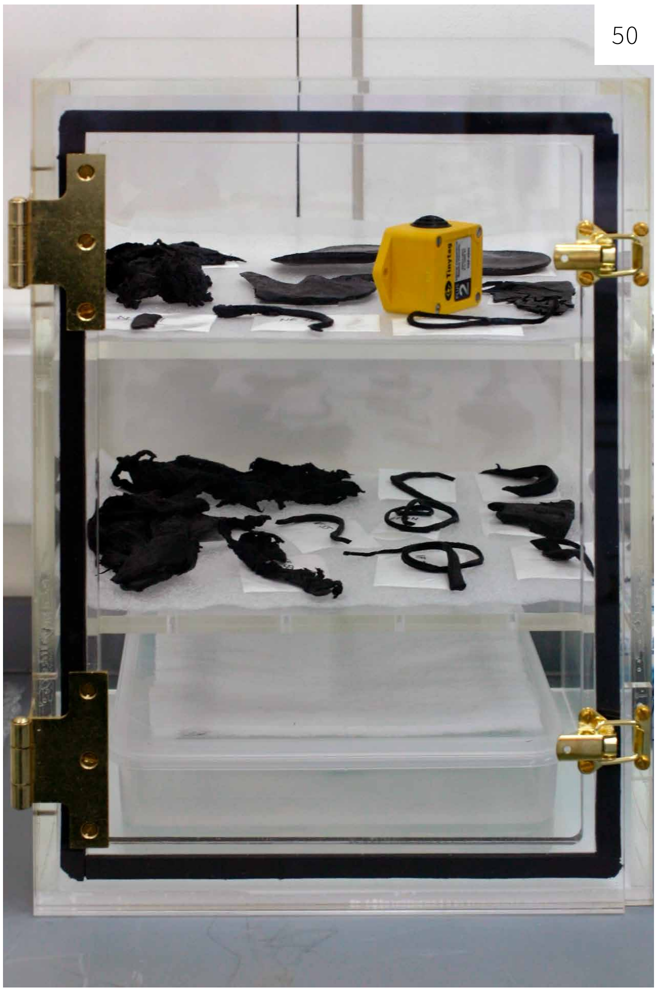

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Figure 48
Vacuum freeze-drying equipment.

Figure 49
Non-vacuum freeze drying in a domestic chest freezer.

Figure 50
Controlled air drying using saturated salt solutions.

Figure 51
Slow air drying at ambient conditions.

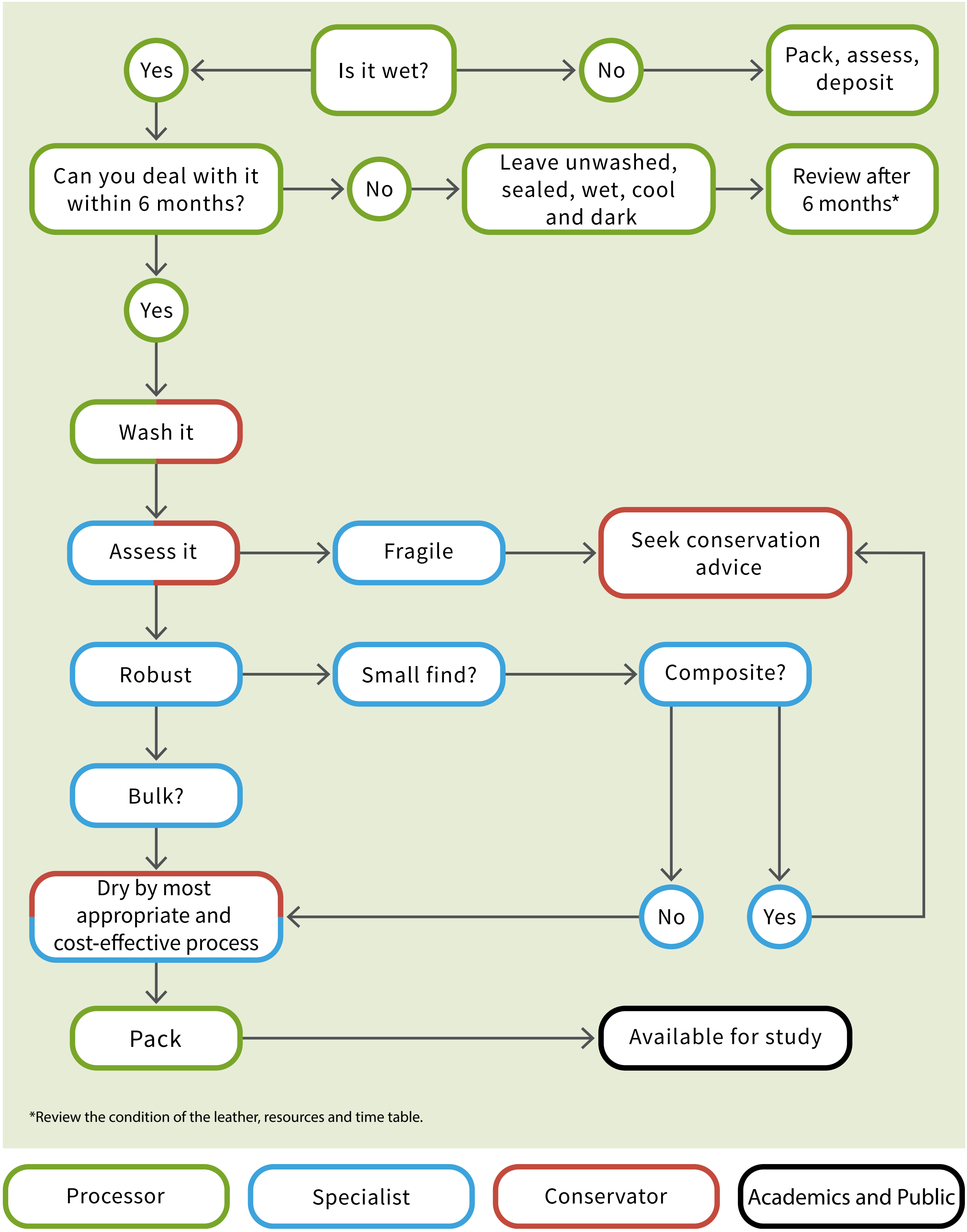

Figure 52
Decision-making flow chart.

5.2 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 then 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.

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.

5.3 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 (Figure 53). If the artefact is particularly fragile, it can be washed inside a loose-weave, non-abrasive net bag to discourage further fibre loss. Fingers, very soft brushes or natural sponges 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.

Figure 53
Washing of textile supported on a sieve.

Figure 54
These textile fragments from Saveock, Cornwall, were carefully air dried, which preserved the weave and colour.

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. More degraded textiles or cordage with a greater tendency to fibre loss can be strengthened with 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 washing, careful examination, recording and, in some cases, impregnation of the textile, it may be dried under controlled conditions (Figure 54) 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 leather (*see* section 5.2).

Basketry is made of plant materials and the same range of conservation methods as for rope or textile is applicable. Differences arise 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 (Figures 55 and 56). 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.

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Figures 55–56
Roman plant-fibre cordage before (Figure 55) and after (Figure 56) conservation; Carlisle Millennium excavation, Cumbria. 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.

5.4 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, the artefact should be examined frequently to check for cracking or lamination of the surface; the conservator should be ready to take immediate steps to rehydrate the artefact and rethink the conservation strategy if necessary. Solvent drying can be used as an alternative to air drying. Again, the process should be carried out with caution and the treatment halted and reversed if required.

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.

5.5 Wood

Before beginning water removal, careful surface cleaning of the wet wood should be carried out, using water and fingers, soft brushes or natural sponges, 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 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, can be 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).

5.6 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, pollutants and pests), and the choice of packaging materials or display cases to protect against pollutants (including dirt and dust) (Figure 57) and buffer against temperature and relative humidity changes in the wider environment.

5.6.1 Environmental conditions

The British Standards Institution (BSI) has developed a Publicly Available Specification (PAS) for environmental conditions: PAS 198:2012 sets 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 2012).

Figure 57
Organic artefacts on display in the Museum of London.

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

5.6.2 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 (Figures 58 and 59). 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 should be 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 to ensure that they will not cause harm to the artefact, such as through the emission of gases (Strlič *et al* 2010; Thickett and Lee 2004).

5.6.3 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) and guide (Pinniger and Lauder 2018). It may also be advisable to undertake regular surveys to monitor the condition of conserved organic artefacts (Suenson-Taylor and Sully 1997), both in storage and on display (Ganiaris *et al* 2005).

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Figures 58–59
Bespoke packaging for textiles.

Case Studies

Case study 1: Leather from the *Mary Rose*

Quita Mould

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, Hampshire, 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.

Figure CS1.1
A slash above the big toe suggests the wearer suffered from a foot complaint such as a bunion.

A large hole worn in a shoe upper above the great toe joint suggested 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 the shoe in order to relieve the pressure on a painful joint caused by the same condition (Figure CS1.1). Injuries to the feet were also implied. One shoe had much of the vamp crudely cut away to accommodate a foot injury and may have 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 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.

References

Evans, N and Mould, Q 2005 'Footwear', *in* Gardiner, J with Allen, M J (eds) *Before the Mast. Life and Death aboard the Mary Rose*. The Archaeology of the Mary Rose **4**. Portsmouth: The Mary Rose Trust, 59–94

Case study 2: Excavation at Second Wood Street, Nantwich, Cheshire

Leigh Dodd

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 2014), 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 (*see* Figure 26), numerous leather shoes (*see* Figures 35 and 36), two fragments of textile and a salt storage basket.

Unexpectedly, however, eight 14th-century barrels (Figure CS2.1) 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 Science Advisor. This facilitated a successful bid to the Heritage Lottery Fund (HLF) for funding to lift, conserve and display the salt ship, aided by its temporary reburial on-site by cooperative developers.

Good communication and strong collaboration between all parties, including the on-site contractors and the developer, was key to a successful outcome. 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 to 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 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.

References

Dodd, L 2014 'IV: Second Wood Street, Nantwich, 2003/4: Excavation of a medieval and early post-medieval salt works'. *J Chester Archaeol Soc* **84**, 39–110

Figure CS2.1
A medieval barrel *in-situ*, Nantwich, Cheshire.

Case study 3: Freeze lifting

Jennifer Jones

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 been used successfully on a Neolithic wooden hurdle that was excavated on the beach at Seaton Carew, County Durham (Jones 1996). The team only had a seven-hour window to reveal, record and lift the hurdle. A section of approximately 1m × 1m was lifted using solid pellets of CO_2 (Figures CS3.1–CS3.4).

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

References

Jones, J 1996 'Freeze-lifting a Neolithic wooden hurdle', *in* Hoffman, P, Grant, T, Spriggs, J A and Dalye, T (eds) *Proceedings of the 6th ICOM group on Wet Organic Archaeological Materials Conference, York 1996*. Bremerhaven: International Council of Museums (ICOM), 25–32

Figure CS3.1
Neolithic hurdle *in-situ*, Seaton Carew, County Durham.

Figure CS3.2
The hurdle is isolated and CO_2 pellets are applied. Thermocouples are inserted around the hurdle.

Figure CS3.3
The frozen block is levered from the ground.

Figure CS3.4
The frozen block in the laboratory.

Case study 4: Wood recording project

Angela Karsten

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 (Figure CS4.1).

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 three-dimensional (3D) image of the object (Figure CS4.2). PTM uses raking light photography and enables 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 (Figure CS4.3).

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

References

Karsten, A and Earl, G P 2010 *The Stirling Castle Wood Recording Project: A Pilot Project to Compare and Evaluate Traditional and Innovative Recording Techniques for Waterlogged Wood*. Res Depart Res Rep **65/2010**. Swindon: English Heritage

4.1

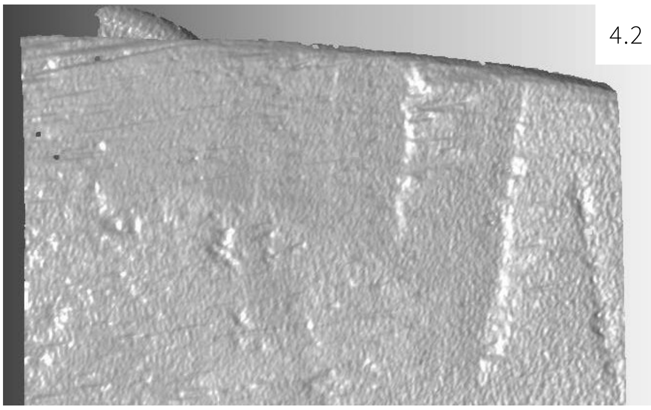

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Figure CS4.1
Area of interest on wooden barrel fragment showing distinct tool marks.

Figure CS4.2
Laser scan of area of interest.

Figure CS4.3
Area of interest viewed under different lighting conditions (left, specular enhancement; centre and right, differently angled light).

Case study 5: Conservation of silk-lined purse, York

Mags Felter

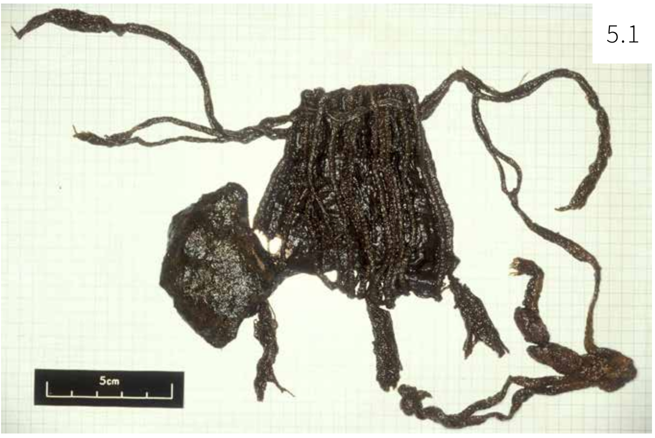
The draw-string purse was excavated in 1992 and is medieval in date. It is a composite object of silk, animal skin (probably tawed) and iron (P Walton unpublished) (Figure CS5.1).

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 iron concretion (Figure CS5.3). 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 (Figure CS5.2).

5.1



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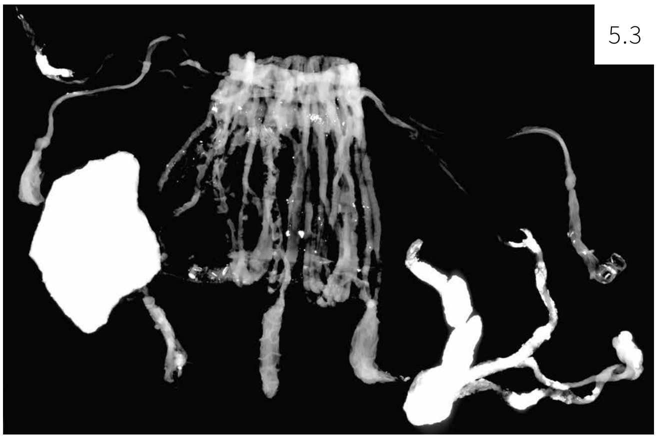

5.2

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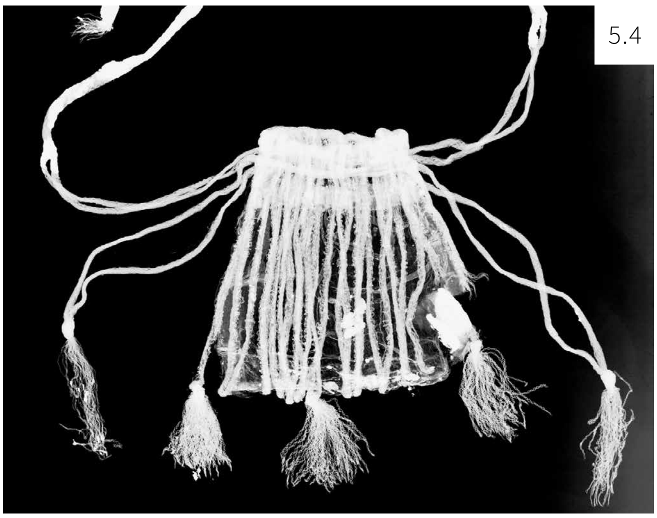


Figures CS5.1–CS5.2
Silk-lined purse before (Figure CS5.1) and after (Figure CS5.2) conservation.

Figures CS5.3–CS5.4
X-radiographs of the purse before (Figure CS5.3) and after (Figure CS5.4) conservation.

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-ray after conservation proved to be useful. It showed that the purse contained seeds (Figure CS5.4), and that details of the fabric were more 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 whilst remaining physically protected.

References

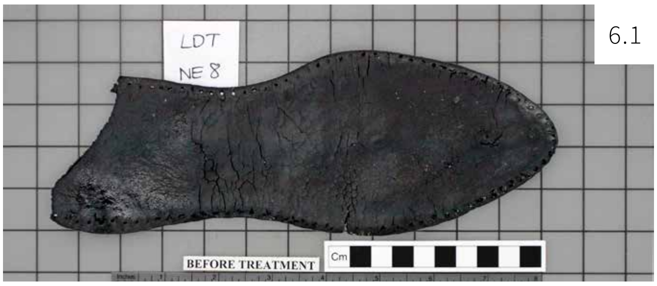
O'Connor, S and Brooks, M M 2007 *X-Radiography of Textiles, Dress and Related Objects*. London: Butterworth-Heinemann

Case study 6: Leather drying trial

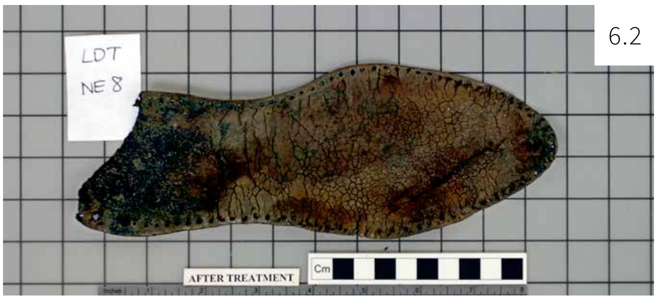
Angela Karsten

The aim of this study (Karsten and Graham 2011; Karsten *et al* 2012) was to compare different treatment and drying methods using parameters such as shrinkage, flexibility, appearance, time, effort and equipment.

During the first part of the study, treatments included 20% glycerol, 20% PEG and no impregnation. Half the samples in each treatment category were pre-treated using 5% Na_2EDTA (disodium salt of ethylene diamine tetra acetic acid). The leather was dried using vacuum freeze drying, non-vacuum freeze drying, air drying and controlled air drying (Figures CS6.1 and CS6.2). In the second part of the 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.



6.1



6.2

The study made it clear that a routine pre-treatment with Na_2EDTA is not required but the use of either PEG or glycerol will produce better results. Careful assessment by a conservator and/or leather specialist can divide leather into groups that can be controlled air dried, and individual finds that would achieve 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 by 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 caused by 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.

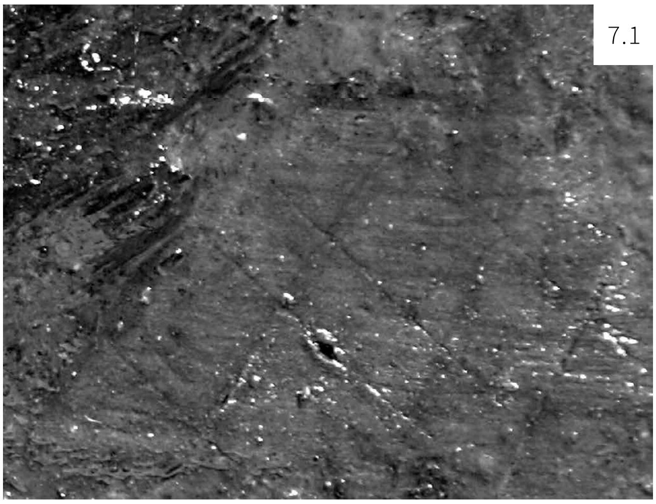
References

Karsten, A and Graham, K 2011 *Leather Drying Trial: A Comparative Study to Evaluate Different Treatment and Drying Techniques for Wet, Archaeological Leather*. Res Depart Res Rep **70/2011**. Swindon: English Heritage

Karsten, A, Graham, K, Goodman, L, Ganiaris, H and Domoney, K 2012 'A comparative study of various impregnation and drying methods for waterlogged archaeological leather', *in* Straetkvern, K and Williams, E (eds) *Proceedings of the 11th ICOM-CC Group on Wet Organic Archaeological Materials Conference. Greenville 2010*. USA: International Council of Museums (ICOM), 595–610. Available at: https://www.lulu.com/

Figures CS6.1–CS6.2
Leather sole before (Figure CS6.1) and after (Figure CS6.2) treatment (20% PEG 400 followed by non-vacuum freeze drying).

7.1



7.2

7.3

Case study 7: Conservation of a Roman writing tablet

Angela Karsten

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

Even though dirt obscured the surface (Figure CS7.2), fine lines could be seen on closer examination (Figure CS7.1). These lines could have held the wax and a sample was taken for FTIR analysis.

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

The tablet was conserved using 10% PEG 400 and 15% PEG 4000 followed by vacuum freeze drying (Figure CS7.3).

References

Watson, J 2008 Silchester. *Conservation of a Wooden Writing Tablet*. Res Depart Res Rep **54/2008**. Portsmouth: English Heritage

Figure CS7.1
Detail of the writing tablet showing cross hatching.

Figures CS7.2–CS7.3
Roman writing tablet before (Figure CS7.2) and after (Figure CS7.3) conservation.

Case study 8: Conservation of baskets

Angela Karsten and Liz Goodman

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 (Figure CS8.1) 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* Figure 30; Barnard *et al* 2012). 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) (Figure CS8.2). Following vacuum freeze drying, the interior soil lining was removed using spherical glass beads in a micro sandblaster (air abrasive). The exterior as cleaned with compressed air or mechanically (Figure CS8.3). During cleaning the wicker was periodically consolidated with ButvarÒ B-98 in industrial methylated spirit (IMS) (Figure CS8.4).

References

Barnard, J, Goodman, L, Shippen, N 2012 'Excavation and stabilization of a 17th century wicker basket: New application of a known method', *in* Straetkvern, K and Williams, E (eds) *Proceedings of the 11th ICOM-CC Group on Wet Organic Archaeological Materials. Greenville 2010.* USA: International Council of Museums (ICOM), 647–650. Available at: https://www.lulu.com

Butterworth, C A and Lobb, S 1992 *Excavations in the Burghfield Area, Berkshire. Developments in the Bronze Age and Saxon Landscapes*. Wessex Archaeol Rep **1**. Salisbury: Wessex Archaeology

Watson, J 1991 *Basketry from Anslow's Cottages, Berkshire (AM Lab No 886119)*. Res Depart Res Rep **30/91**. Portsmouth: English Heritage

8.1

8.2

8.3

Figure CS8.1
Two basket fragments before conservation.

Figure CS8.2
Basket after PEG treatment.

Figure CS8.3
Basket in the process of being cleaned on the exterior (left, clean; right, unclean).

Figure CS8.4
Basket after conservation (same basket in Figures CS8.2–8.4).

6 Where to Get Advice

Advice on the excavation, analysis, conservation and preservation *in-situ* of waterlogged archaeological remains is available from the web pages listed below.

6.1 Historic England

Historic England provides independent, non-commercial advice on all aspects of archaeological science. For contact details visit:

Science Advisors

https://historicengland.org.uk/advice/technical-advice/archaeological-science/science-advisors/

Archaeological Conservation

https://historicengland.org.uk/research/methods/archaeology/archaeological-conservation/

Scientific Dating

https://historicengland.org.uk/research/methods/archaeology/scientific-dating/

Environmental Archaeology

https://historicengland.org.uk/research/methods/archaeology/environmental-archaeology/

6.2 The English Heritage Trust

Advice on collections care is available from:

http://www.english-heritage.org.uk/learn/conservation/collections-advice-and-guidance/

6.3 The Conservation Register of the Institute of Conservation

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

www.conservationregister.com

7 References

Adkins, L and Adkins, RA 1989 *Archaeological Illustration*. Cambridge: Cambridge U P

Adovasio, J M 1977 *Basketry Technology: A Guide to Identification and Analysis*. Chicago: Aldine

Allen, S J 1994 *The Illustration of Wooden Artefacts: An Introduction and Guide to the Depiction of Wooden Objects*. Technical Pap **11**. York: Assoc Archaeol Illustrators and Surveyors

Appleyard, H M 1978 *Guide to the Identification of Animal Fibres*. Leeds: Wool Industries Research Association (WIRA)

Barker, A D 1980 'Gold lace and embroidery northern'. *Soc Costume and Textiles* **1**. Altrincham: Northern Society of Costume and Textiles (NSCT)

Bergfjord, C and Holst, B 2010 'A procedure for identifying textile bast fibres using microscopy: Flax, nettle/ramie, hemp and jute'. *Ultramicroscopy* **110**, 1192–7

Blackshaw, S 1974 'Conservation of wooden writing tablets from Vindolanda'. *Stud Conserv* **19**, 244–6

Blanchette, RA, Nilsson, T, Daniel, G and Abad, A 1990 'Biological degradation of wood', *in* Rowell, R M and Barbour, R J (eds) *Archaeological Wood: Properties, Chemistry and Preservation*. Washington DC: The American Chemical Society, 141–74

Bowens, A 2009 'Archaeological conservation and first-aid for finds', *in* Bowens, A (ed) *Underwater Archaeology. The NAS Guide to Principles and Practice*, 2 edn. Chichester: Wiley-Blackwell Publishing, 148–62

British Standards Institution 2012 *PAS 198:2012 Specification for Managing Environmental Conditions for Cultural Collections*. Available at: https://shop.bsigroup.com/ProductDetail/?pid=000000000030219669 [accessed 5 April 2018]

Brown, D H 2007 *Archaeological Archives: A Guide to Best Practice in Creation, Compilation, Transfer and Curation*. London: Institute of Field Archaeologists on behalf of the Archaeological Archives Forum

Buckley, M 2018 'Zooarchaeology by Mass Spectrometry (ZooMS) collagen fingerprinting for the species identification of archaeological bone fragments', *in* Giovas, C and LeFebvre, C M (eds) *Zooarchaeology in Practice: Case Studies in Methodology and Interpretation in Archaeofaunal Analysis*. Cham: Springer, 227–50

Buckley, M, Collins, M, Thomas-Oates, J and Wilson, J C 2009 'Species identification by analysis of bone collagen using matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry'. *Rapid Commun Mass Spectrom* **23**(23), 3843–54

Capellini, E, Gilbert, T, Geuna, F, Fiorentino, G, Hall, A, Thomas-Oates, J, Asthon, P, Ashford, D, Arthur, P, Campos, P, Kool, J, Willerslev, E and Collins, M 2010 'A multidisciplinary study of archaeological grape seeds'. *Naturwissenschaften* **97**, 205–17

Caple, C 2006 *Objects: Reluctant Witnesses to the Past*. London: Routledge

Carr, D, Cruthers, N, Smith, C and Myers, T 2008 'Identification of selected vegetable textile fibres'. *Rev Conserv* **9**, 75–88

CIfA 2014a *Standard and Guidance for Archaeological Excavation*. Reading: Chartered Institute for Archaeologists

CIfA 2014b *Standard and Guidance for the Collection, Documentation, Conservation and Research of Archaeological Materials*. Reading: Chartered Institute for Archaeologists

CIfA 2014c *Standard and Guidance for the Creation, Compilation, Transfer and Deposition of Archaeological Archives*. Reading: Chartered Institute for Archaeologists

Cooke, B 1990 'Fibre damage in archaeological textiles'. Archaeol Textiles: *UKIC Occas Pap* **10**, 5–13

Cooke, B and Lomas, B 1990 'The evidence of wear and damage in ancient textiles', *in* Walton, P and Wild, J P (eds) *NESAT III: Textiles in Northern Archaeology (Textile Symposium in York)*. London: Archetype, 215–26

Cronyn, J 1990 *The Elements of Archaeological Conservation*. London: Routledge

Daley, T W and Murdock, L D 1992 'Excavating and raising artifacts from a marine environment', *in* Payton R (ed) *Retrieval of Objects from Archaeological Sites*. London: Archetype, 133–45

Dorrell, P 1994 *Photography in Archaeology and Conservation*. Cambridge: Cambridge U P

Eklund, J A and Thomas, M G 2010 'Assessing the effects of conservation treatments on short-sequences of DNA in vitro'. *J Archaeol Sci* **37**, 2831–41

English Heritage 2004 *Dendrochronology. Guidelines on Producing and Interpreting Dendrochronological Dates*. Swindon: English Heritage. https://historicengland.org.uk/images-books/publications/dendrochronology-guidelines/

English Heritage 2008a *Guidelines for the Curation of Waterlogged Macroscopic Plant and Invertebrate Remains*. Swindon: English Heritage. https://www.historicengland.org.uk/images-books/publications/curation-of-waterlogged-macroscopic-plant-and-invertebrate-remains/

English Heritage 2008b *Investigative Conservation. Guidelines on How the Detailed Examination of Artefacts from Archaeological Sites can Shed Light on their Manufacture and Use*. Swindon: English Heritage. https://historicengland.org.uk/images-books/publications/investigative-conservation/

English Heritage 2009 *Insect Pests Found in Historic Houses and Museums Poster*. Swindon: English Heritage, https://www.historicengland.org.uk/images-books/publications/insect-pests-historic-houses-poster/

English Heritage 2011 *Environmental Archaeology: A Guide to the Theory and Practice of Methods, from Sampling and Recovery to Post-Excavation*, 2 edn. Swindon: English Heritage. https://www.historicengland.org.uk/images-books/publications/environmental-archaeology-2nd/

English Heritage 2013 *Multi-Light Imaging for Heritage Applications*. Swindon: English Heritage. https://historicengland.org.uk/images-books/publications/multi-light-imaging-heritage-applications/

English Heritage nd 'Guidelines for the addition of archaeological science data to Historic Environment Records'. Draft report. Swindon: English Heritage

Erhardt, D, Tumosa, C S and Mecklenburg, M F 2007 'Applying science to the question of museum climate', *in* Padfield, T and Borchersen, K (eds) *Museum Microclimates. Contributions to the Copenhagen Conference 19–23 November 2007*. Copenhagen: The National Museum of Denmark, 11–18. Available at: http://www.conservationphysics.org/mm/musmic/musmic150.pdf [accessed 5 April 2018]

Fell, V 1996 'Washing away the evidence', *in* Roy, A and Smith, P (eds) *Archaeological Conservation and its Consequences. Preprints IIC Copenhagen Congress 1996*. London: Internat Instit Conserv, 48–51

Fell, V, Mould, Q and White, R 2006 *Guidelines on the X-Radiography of Archaeological Metalwork*. Swindon: English Heritage. https://historicengland.org.uk/images-books/publications/x-radiography-of-archaeological-metalwork/

Florian, M-L E 1987 'Deterioration of organic materials other than wood', *in* Pearson, C (ed) *Conservation of Marine Archaeological Objects*. London: Butterworth and Co. (Publishers) Ltd, 21–54

Florian, M-L E 1997 *Heritage Eaters: Insects and Fungi in Heritage Collections*. London: James and James

Florian, M-L E 2002 *Fungal Facts: Solving Fungal Problems in Heritage Collections*. London: Archetype

Fors, Y and Sandström, M 2006 'Sulfur and iron in shipwrecks cause conservation concerns'. *Chemical Soc Rev* **35**, 399–415

Ganiaris, H and Starling, K 1996 'Up to standard: Planning the needs of an archaeological archive', *in* Roy, A and Smith, P (eds) *Archaeological Conservation and its Consequences. Preprints IIC Copenhagen Congress 1996*. London: Internat Instit Conserv, 55–8

Ganiaris, H, Goodman, L, Chaplin, T, Clark, R J H and Smith, G D 2005 'Wood on display: An unexpected effect of display conditions on a freeze-dried wooden object', *in* Sourbès-Verger, I (ed) *ICOM-CC Pre-Prints of the 14th Triennial Meeting, The Hague, 12–16 September 2005*. London: James and James, 1064–7

Ganiaris, H, Keene, S and Starling K, 1982 'A comparison of some treatments for excavated leather'. *The Conservator* **6**, 12–23

Garside, P and Wyeth, P 2006 'Identification of cellulosic fibres by FTIR spectroscopy: Differentiation of flax and hemp by polarized ATR FTIR'. *Stud Conserv* **51**, 205–211

Gillis, C and Nosch, M-L B 2007 *First Aid for the Excavation of Archaeological Textiles*. Oxford: Oxbow Books

Godfrey, I M and Kasi, K 2005 'The analysis and treatment of waterlogged leather II: Application of Fourier transform infrared spectroscopy and artificial neural networks', *in* Hoffmann, P, Straetkvern, K, Spriggs, J and Gregory, D (eds) *Proceedings of the 9th ICOM Group on Wet Organic Archaeological Materials Conference. Copenhagen 2004*. Bremerhaven: International Council of Museums (ICOM), 533–44

Goodburn Brown, D 2001 *Excavated Artefacts and Conservation*. London: United Kingdom Institute of Conservation (UKIC)

Goubitz, O 1984 'The drawing and registration of archaeological footwear'. *Stud Conserv* **29**, 187–96

Griffiths, N, Jenner, A and Wilson, C 1990 *Drawing Archaeological Finds: A Handbook*. London: Archetype

Haines, B M 2006 'The fibre structure of leather', *in* Kite, M and Thomson, R (eds) *Conservation of Leather and Related Materials*. Oxford: Butterworth-Heinemann, 11–21

Hather, J 2000 *The Identification of North European Woods: A Guide for Archaeologists and Conservators*. London: Archetype

Health and Safety Executive 2013 *Control of Substances Hazardous to Health, L5 (Sixth Edition). The Control of Substances Hazardous to Health Regulations 2002 (As Amended). Approved Code of Practice and Guidance*. Norwich: HSE Books. Available at: http://www.hse.gov.uk/pubns/priced/l5.pdf [accessed 5 April 2018]

Hedges, R E, Thompson, J M and Hull, B D 2005 'Stable isotope variation in wool as a means to establish Turkish carpet provenance'. *Rapid Commun Mass Spectrom* **19**, 3187–91

Heron, C, Rompou, M and Stern, B 2005 *Sampling Protocol*. Bradford: Dep Archaeol Sci, U Bradford. Available at: http://www.brad.ac.uk/staff/bstern/molecular/Sampling%20protocol.html [accessed 5 April 2018]

Historic England 2015a *Digital Image Capture and File Storage: Guidelines for Best Practice*. Swindon: Historic England. https://historicengland.org.uk/images-books/publications/digital-image-capture-and-file-storage/

Historic England 2015b *Geoarchaeology. Using Earth Sciences to Understand the Archaeological Record*. Swindon: Historic England. https://historicengland.org.uk/images-books/publications/geoarchaeology-earth-sciences-to-understand-archaeological-record/

Historic England 2015c *Management of Research Projects in the Historic Environment. The MoRPHE Project Managers' Guide*. Swindon: Historic England. https://historicengland.org.uk/images-books/publications/morphe-project-managers-guide/

Historic England 2017 *Photogrammetric Applications for Cultural Heritage: Guidance for Good Practice*. Swindon: Historic England. https://historicengland.org.uk/images-books/publications/photogrammetric-applications-for-cultural-heritage/

Historic England 2018a *3D Laser Scanning for Heritage: Advice and Guidance on the Use of Laser Scanning in Archaeology and Architecture*. Swindon: Historic England. https://historicengland.org.uk/images-books/publications/3d-laser-scanning-heritage/

Historic England 2018b *Waterlogged Wood. Guidelines on the Recording, Sampling, Conservation and Curation of Waterlogged Wood*. Swindon: Historic England. https://www.historicengland.org.uk/images-books/publications/waterlogged-wood/

Holden, J, Howard, A J, West, L J, Maxfield, E, Panter, I and Oxley, J 2009 'A critical review of hydrological data collection for assessing preservation risk for urban waterlogged archaeology: A case study from the City of York, UK'. *J Environ Manage* **90**, 3197–204

Holden, J, West, L J, Howard, A J, Maxfield, E, Panter, I and Oxley, J 2006 'Hydrological controls on *in situ* preservation of archaeological deposits'. *Earth Sci Rev* **78**, 59–83

Hollemeyer, K, Altmeyer, W, Heinzle, E and Pitra, C 2008 'Species identification of Oetzi's clothing with matrix-assisted laser desorption/ionization time-of-flight mass spectrometry based on peptide pattern similarities of hair digests'. *Rapid Commun Mass Spectrom* **22**, 2751–67

von Holstein, I C, Walton Rogers, P, Craig, O E, Penkman, K E H, Newton, J and Collins, M J 2016 'Provenancing archaeological wool textiles from medieval northern Europe by light stable isotope analysis (δ13C, δ15N, δ2H)'. *PLoS ONE* 11(10): e0162330. doi:10.1371/journal.pone.0162330

Hovmand, I and Jones, J 2001 'Experimental work on the mineral content of archaeological leather', *in* Wills, B (ed) *Leather Wet and Dry. Current Treatments in the Conservation of Waterlogged and Desiccated Archaeological Leather*. London: Archetype, 27–36

Huisman, D J, van Os, B J H, Nientker, J and Megens, L 2009 'Leather', *in* Huisman, D J (ed) *Degradation of Archaeological Remains*. Sdu Uitgevers: Den Haag, 55–68

Jakes, K A and Sibley, L R 1983 'Survival of cellulosic fibres in the archaeological context'. *Sci Archaeol* **25**, 31–8

Janaway, R C 1989 'Corrosion preserved textile evidence: Mechanism, bias and interpretation', *in* Janaway, R C (ed) *Evidence Preserved in Corrosion Products: New Fields in Artefact Studies*. Occas Pap **8**. London: United Kingdom Institute of Conservation (UKIC), 21–9

Jones, J 1996 'Freeze-lifting a Neolithic wooden hurdle'. *in* Hoffman, P, Grant, T, Spriggs, J A and Dalye, T (eds) *Proceedings of the 6th ICOM group on Wet Organic Archaeological Materials Conference, York 1996*. Bremerhaven: International Council of Museums (ICOM), 25–32

Jones, J 2007 'Freeze-lifting, conservation, and analysis of grave goods from burial 2245', *in* Brown, F, Howard-Davis, C, Brennand, M, Boyle, A, Evans, T, O'Connor, S, Spence, A, Heawood, R and Lupton, A (eds) *The Archaeology of the A1 (M) Darrington to Dishforth DBFO Road Scheme*. Lancaster Imprints **12**. Lancaster: Oxford Archaeol North, 589–94

Jones, J and Clogg, P 1993 *Ground-Freezing on Archaeological Excavations: Lifting a Medieval Chalice from St Giles Hospital, Brough*. Res Depart Res Rep **99/1993**. Swindon: English Heritage

Jones, M and Eaton, R 2006 'Conservation of ancient timbers from the sea', *in* May, E and Jones, M (eds) *Conservation Science. Heritage Materials*. Cambridge: Roy Soc Chem, 266–308

Kaye, B, Cole-Hamilton, D J and Morphet, K 2000 'Supercritical drying: A new method for conserving waterlogged archaeological materials'. *Stud Conserv* **45**, 233–52

Kerr, B, Sloane, B and Stabler, K 2008 *Management of Research Projects in the Historic Environment, PPN 3: Archaeological Excavation*. Swindon: English Heritage. Available at: https://www.historicengland.org.uk/images-books/publications/morphe-project-planning-note-3/ [accessed 5 April 2018]

Kite, M and Thomson R (eds) 2006 *Conservation of Leather and Related Materials*. Oxford: Butterworth-Heinemann

Korsow-Richter, K , Wilson, J, Jones, A K G, Buckley, M, van Doorn, N, Collins, M J 2011 'Fish'n chips: ZooMS peptide mass fingerprinting in a 96 well plate format to identify fish bone fragments'. *J Archaeol Sci* **38**, 1502–10

Lang, J and Middleton, A (eds) 2005 *Radiography of Cultural Material*. Oxford: Elsevier Butterworth-Heinemann

Leskard, M 1987 'The packing and transporting of marine archaeological objects', *in* Pearson, C (ed) *Conservation of Marine Archaeological Objects*. London: Butterworth, 117–21

Lobb, M, Krawiec, K, Howard, A, Gearey, B and Chapman, H 2010 'A new approach to recording and monitoring wet-preserved archaeological wood using three-dimensional laser scanning'. *J Arch Sci* **37**, 2995–9

Madsen, H B 1994 *Handbook of Field Conservation*. Copenhagen: Roy Danish Acad Fine Arts, Sch Conserv

Moulden, H 2009 'The past in three dimensions'. *The Archaeol* **71**, 22–3

Museums and Galleries Commission 1992 *Standards in the Museum Care of Archaeological Collections*. London: Museum and Galleries Commission

O'Connor, S and Brooks, M M 2007 *X-Radiography of Textiles, Dress and Related Objects*. London: Butterworth-Heinemann

Palma, P 2004 'Final report for the monitoring theme of the MoSS project', *in* Cederlund, C O (ed) *MoSS Final Report. Monitoring, Safeguarding and Visualizing North-European Shipwreck Sites: Common European Cultural Heritage – Challenges for Cultural Resource Management*. Helsinki: The National Board of Antiquities, 8–37. Available at: http://moss.nba.fi/download/final_report.pdf [accessed April 2018]

Peacock, E E 1996 'Characterization and simulation of water-degraded archaeological textiles: A review'. *Internat Biodeterioration Biodegradation* **38**, 35–47

Peacock, E 2007 'The contribution of X-radiography to the conservation and study of textile/leather composite archaeological footwear recovered from the Norwegian Arctic', *in* O'Connor, S and Brooks, M M (eds) *X-Radiography of Textiles, Dress and Related Objects*. London: Butterworth-Heinemann, 293–324

Pinniger, D and Lauder, D 2018 *Pests in Houses Great & Small: Identification, Prevention, Eradication*. Tewkesbury: September Publishing

RFG and FRG 1993 *Guidelines for the Preparation of Site Archives and Assessments for all Finds Other Than Fired Clay Vessels*. Roman Finds Group and Finds Research Group AD700–1700

Robinson, W 1998 *First Aid for Underwater Finds*. London: Archetype, and Portsmouth: Nautical Archaeol Soc

Schweingruber, F 1978 *Microscopic Wood Anatomy*. Zurich: F Fluck-Wurth

Sibley, L R and Jakes, K A 1984 'Survival of protein fibres in archaeological contexts', *Sci Archaeol* **26**, 17–27

Skals, I 1996 'From grave to showcase: Modern care for ancient textiles', *in* Roy, A and Smith, P (eds) *Archaeological Conservation and its Consequences. Preprints IIC Copenhagen Congress 1996*. London: Internat Institute for Conservation, 162–5

Strlič, M, Cigić, I K, Možir, A, Thickett, D, de Bruin, G, Kolar, J and Cassar, M 2010 'Test for compatibility with organic heritage materials: A proposed procedure'. *E-Preserv J* **7**, 78–86. Available at: http://www.morana-rtd.com/e-preservationscience/2010/Strlic-15-05-2010.pdf [accessed 5 April 2018]

Suenson-Taylor, K and Sully, D 1997 'The use of condition score to determine glycerol concentration in the treatment of waterlogged archaeological leather: An experimental solution', *in* Hoffmann P, Grant T, Spriggs J A and Daley, T (eds) *Proceedings of the 6th ICOM Group on Wet Organic Archaeological Materials Conference, York 1996*. Bremerhaven: International Council of Museums (ICOM), 157–72

Thickett, D and Lee, L R 2004 *The Selection of Materials for the Storage or Display of Museum Objects*. London: The British Museum

Timár-Balázsy, A 1989 'Deterioration process of fibers in different chemical actions', *in* Járó, M (ed) *Conservation of Metals: Problems in the Treatment of Metal-Organic and Metal-Inorganic Composite Objects*. Hungary: Veszprém, 77–82

Turner-Walker, G 2008 'The chemical and microbial degradation of bone and teeth', *in* Pinhasi, R and Mays, S (eds) *Advances in Human Palaeopathology*. Chichester: Wiley, 3–29

Walker, K 1990 *Guidelines for the Preparation of Excavation Archives for Long-Term Storage*. London: United Kingdom Institute of Conservation (UKIC) Archaeology Section

Walton, P 1981 'The textiles', *in* Harbottle, B and Ellison, M 'An excavation in the Castle ditch, Newcastle upon Tyne, 1974–76'. *Archaeologia Aeliana*, 5 Ser **9**, 190–228

Walton, P and Eastwood, G 1989 *A Brief Guide to the Cataloguing of Archaeological Textiles*, 4 edn. London: Institute of Archaeology Publications

Walton, P and Taylor, G W 1991 'The characterisation of dyes in textiles from archaeological excavations'. *Chromatogr Anal* **17**, 5–7

Watkinson, D and Neal, V 2001 *First Aid for Finds*. London: Rescue/United Kingdom Institute of Conservation (UKIC) Archaeology Section

Wills, B and Mould, Q 2008 'Iron Age fungus', *in* Evans, C and Knight, M *Further Investigations at Arbury Camp, Cambridgeshire: The Eastern Entrance - A Monumental Architecture*. Proc Camb Antiq Soc **XCVII**. Cambridge: Cam Antiq Soc, 17–19

8 Glossary

Acidic soil Soil that has a pH value 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 value higher than 7

Alum Potassium aluminium sulphate, a mineral salt used from antiquity as a mordant for dyes and in the tawing process

Anaerobic microorganisms Mainly bacterial organisms 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 that is made of the protein keratin (synonym: whalebone)

Biocide A chemical substance used to kill micro-organisms such as fungi and bacteria

Bulk finds Finds that are not given individual find numbers but are registered in bulk, ie one number is assigned to a group of objects made of the same material from one archaeological context, eg leather off-cuts, 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 before drying

Chelating agent A chemical substance that forms soluble bonds with certain metal ions (synonyms: chelant, sequestering agent), eg 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 onwards

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 A cross-link forms when one polymer chain bonds to another; after cross-linking, polymer chains lose 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, eg water can be solid (ice), liquid (water) and gas (vapour) at the same time at 0°C and 6.1mbar. This is the critical point for water. If the water in a material is replaced with liquid CO_2, and the temperature is then raised above the critical point, the CO_2 changes from liquid to vapour without surface tension and without altering the cell structure of materials

Freeze drying A drying technique that is 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, because of its hydrophilic groups, has a strong affinity to form bonds with water

Hydrolysis The 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 A process during conservation when water in the organic artefact is exchanged for a bulking agent

Inorganic A compound of mineral origin; cf organic

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 that is 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 ionise 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, and the same principle of sublimation of water applies

Organic (archaeological) Once part of a living organism, eg bone, antler, wood, skin and horn, but excluding those transformed by geological processes, eg jet, shale and amber

Osseous A material consisting of bone or resembling bone (synonym: bony)

Pelt As in its original sense, 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 prior to 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 Determination of the different chemical species or elements in a sample

Quantitative analysis 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, including 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, including skin and hides, parchment and vellum, pseudo-leathers, alum-tawed skins, leathers, and fur skins. Furs are skins treated to retain the hair or wool

Small find An archaeological find that is allocated an individual finds number when registered

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

Sorbitol A sugar substitute that is used as a water-soluble bulking agent

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

Sublimation The 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 remove 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 under warm, moist conditions; a true leather retains this property after repeated wetting and drying

Tawing The process by which an 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 that is very durable if kept dry but degrades rapidly in contact with water

Vegetable tanning The process by which animal skin is soaked in a tannin-rich liquid, dried and further worked into leather; in the past, oak bark was widely used in Britain

Waterlogged An artefact that is saturated with water, ie all cavities and cells are filled with free water

Wickerwork Rigid constructions such as baskets, chairs, hurdle and scaffolding made with basketry techniques

9 Appendix

9.1 Scientific names for species mentioned in the text

Common name	Scientific name	Scientific kingdom
Baleen whale	Mysticeti	Animal
Bear	*Ursus* spp.	Animal
Cattle	*Bos* spp.	Animal
Coir	*Cocos nucifera*	Plant
Cork oak	*Quercus suber*	Plant
Cotton	*Gossypium* spp.	Plant
Deer	Cervids	Animal
Elm	*Ulmus* spp.	Plant
Flax	*Linum usitatissimum*	Plant
Fox	*Vulpes vulpes*	Animal
Goat	*Capra* spp.	Animal
Grasses	Poaceae	Plant
Gribble	*Limnoria limnorium*	Animal
Hair-moss	*Polytrichum commune*	Plant
Hare	*Lepus* spp.	Animal
Hazel	*Corylus* spp.	Plant
Heather	*Calluna vulgaris*	Plant
Hemp	*Cannabis sativa*	Plant
Job’s tears	*Coix lacryma-jobi*	Plant
Lynx	*Lynx lynx*	Animal
Maple	*Acer* spp.	Plant
Oak	*Quercus* spp.	Plant
Palm	Arecaceae	Plant
Sedge	Cyperaceae	Plant
Sheep	*Ovis* spp.	Animal
Shipworm	*Teredo navalis*	Animal
Silk moth	*Bombyx mori*	Animal
Sisal	*Agave sisalana*	Plant
Squirrel	*Sciurus* spp.	Animal
Stinging nettle	*Urtica dioica*	Plant
Stone pine	*Pinus pinea*	Plant
True tinder fungus	*Fomes fomentarius*	Fungus
Willow	*Salix* spp.	Plant

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Images

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