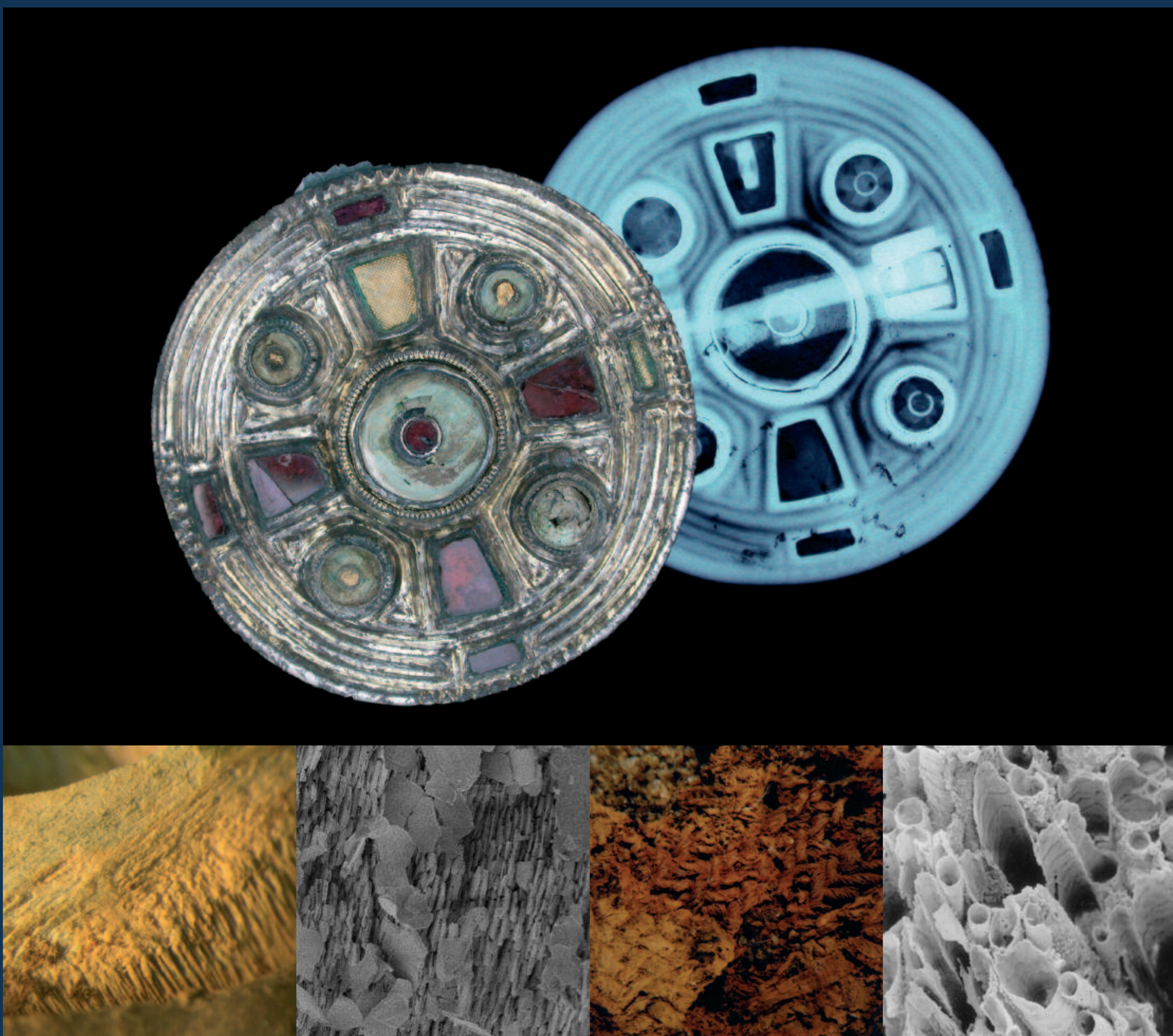
2008

Investigative Conservation

Guidelines on how the detailed examination of artefacts from archaeological sites can shed light on their manufacture and use



ENGLISH HERITAGE

Preface

These guidelines are aimed at archaeologists, finds specialists and museum curators who are involved in the planning and publication of archaeological projects with an expected finds assemblage, as well as finds liaison officers and other museum staff advising metal detectorists. They illustrate the range of assistance that investigative conservation can bring to many projects and how these conservation processes can be incorporated into a project design. They also provide a guide to aspects of good conservation practice and indicate what project managers should expect from conservation practitioners. They do not provide detailed practical conservation advice for fieldwork, and should be viewed as a companion to other texts such as *First Aid for Finds* (Watkinson and Neal 2001).

Archaeological conservation is concerned with the preservation of materials, how they survive in various burial environments and how they can best be stabilised for future study and display. Investigative conservation goes one stage further in that it adopts scientific techniques to enhance the recording and interpretation of the artefacts. By combining these two conservation approaches it is possible to use small groups of excavated material to answer a large number of research questions, and these guidelines will illustrate some of the possibilities.

The value of investigative conservation is widely recognised in the study of pagan cemeteries, where the retrieval and interpretation of trace evidence can be used to build up a detailed picture of burial practice, costume and the construction of various artefacts included in the grave. The same approach can also reveal a great deal of information about artefacts found on other types of site that will contribute to the dating of the site, identifying trade items, manufacture and use.

Conservators can be asked for advice on a wide range of materials from metalwork and organic materials to inorganic materials, and these can come from early prehistoric levels to modern deposits. Also they could be dealing with just one object or a large assemblage from an urban site. Because the work that can be expected of the conservator may be wide-ranging, it is important to concentrate on a clearly defined programme of conservation and analysis to address the specific aims and objectives of the project. The remainder of the archive can be placed into suitable storage environments so that it is available for further study later, if required.

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This selective programming of work is both encouraged and accommodated within current guidance for project planning (English Heritage 1991; Lee 2006).

These guidelines cover:

- a guide to good practice for investigative conservation from project planning to publication;
- examples of the potential information that can be obtained from archaeological finds and the techniques used to achieve this;
- where to get help.

1 What is investigative conservation?

Conservation as a discipline developed out of the need to clean, stabilise and restore archaeological finds in an attempt to preserve them for posterity. The possibility that residual evidence for an artefact's manufacture and history can remain within the microstructure and corrosion layers of an archaeological object, was first highlighted by Leo Biek (1963). He also pointed out that this residual evidence could be used like forensic science to reconstruct the history of objects and add a further dimension to archaeological study. In the 1970s X-radiography was frequently used to examine corroded ironwork, to obtain an image of the object underneath the soil and corrosion products as well as any non-ferrous metal plating and inlays that might be present. In addition conservators were using low-powered microscopes as an aid to cleaning objects, which also revealed traces of organic materials trapped in the corrosion layers (Edwards 1989). The recognition, identification and interpretation of residual evidence on artefacts are the processes that make up investigative conservation, and are essential for the full recording of artefacts, as opposed to their long-term preservation or cleaning and restoration for display.

Five levels of conservation are recognised by conservators (Spriggs and Panter forthcoming), and any or even all might be appropriate for an artefact or the finds assemblage from a large project. These are:

- *First aid conservation* – to ensure the safety of an artefact from its discovery until it undergoes some further conservation process
- *Preventive conservation* – any non-interventive conservation process that slows down or halts the progress of deterioration, such as appropriate packaging and storage in a controlled environment
- *Investigative conservation* – processes used to examine and record artefacts, by non-invasive means, by removing accretions, or by sampling for analysis
- *Remedial conservation* – treatments used to stabilize an object for handling and storage; this includes the drying of wet and waterlogged materials or the repair and consolidation of broken and fragile objects
- *Display conservation* – any further work that is required to display the object

Although these guidelines concentrate on investigative conservation, sometimes the requirements of other conservation levels, such as display, will affect how much analytical investigation can be done, or is even desirable when large samples are required.

2 How conservation fits in with the project planning process

Archaeological field projects should proceed through a series of managed stages, as set out in the project design. Conservators should ensure that they are involved either as project team specialists, providing day-to-day expertise, or at least as stakeholders, consulted at key points during the progress of the project and kept informed in a timely fashion of any conservation issues that arise. This information should be documented in the project design (English Heritage 1991; Lee 2006). To maximise the project's research value conservation should be represented at all stages – *see* Table 1.

2.1 Project initiation

The conservator named in the project design should be involved as early as possible in the planning process. To ensure availability and the smooth running of the project, the conservator must know its start date and anticipated duration.

The costs for conservation at all stages (both assessment and analysis) may need to be included in the initial project design, even though at this stage it may only be a rough estimate. If the scope of the intervention is unknown, planning must allow for the curation, assessment and possible investigative conservation of important unexpected assemblages.

The research potential of the project will be considered by the archaeological team at the planning stage, with reference to existing regional research frameworks. The conservator, as a member of this team, will be able to give advice on the suitability of the site for inclusion in other on-going national level research.

2.2 Project execution: fieldwork

It is important and valuable for the conservator to have an initial meeting with finds staff at the start of the excavation, to advise on packing, storage, transfer of finds from site to laboratory and the handling of more vulnerable materials. This can often be combined with a visit to the site, as it is also important for the conservator to assess the burial environment and the archaeology directly.

Table 1 Conservation and the project planning process.

Project phase	*Tasks and products*
1. Initiation phase	• Project Manager identifies core team members and principal contacts • Project Manager, finds specialist and conservator identify research aims • liaise over proposed timetable and the costed project design • determine archiving arrangements • determine how the results are to be disseminated
2. Project execution: fieldwork	• site visits • conservator gives advice on temporary storage and packaging for the various types of material • advice on lifting and first aid for finds • block-lifting of complex assemblages • X-radiography of metalwork • update on costs for assessment • liaise over new or revised project aims arising from the fieldwork
3. Project execution:	An assessment report outlining the potential of the retrieved artefacts is produced by the finds specialist and conservator, containing the following elements: • conservation objectives and how these can be achieved in liaison with the project team • proposed analysis and method statement • costs for analysis, including any technical assistance that will be needed • if the assessment report indicates that an analysis phase is not required, transfer the site archive
4 Project execution: analysis	• undertake work outlined in the assessment report • interpretation of results • conservation report detailing the examination and analysis done • transfer site archive
5 Project delivery: dissemination	• contribute to site publication • advocacy of project through other agreed media

While the excavation is in progress, conservation assistance may be required to block-lift artefacts. Site staff should seek the advice of the project conservator when deciding whether a site visit is necessary, or whether the lift can be accomplished by experienced site personnel. Knowing when to ask for help is important, and may make the difference between a successful outcome and the loss of important information. The project design should document how conservation expertise will be accessed during fieldwork (Fig 2.2).

Block-lifting can be beneficial for:

- fragile objects – such as fractured ceramics, organic objects not able to support their own weight, or totally corroded metalwork;
- complex or composite objects – wet wooden and metal objects, ceramic or wooden vessels plus contents;
- areas of degraded organics – dark soil stains surrounding artefacts or mineralised organic materials, particularly when associated with grave goods.

Many types of material need care when removed from the ground if they are to survive intact, and correct and careful curation immediately following excavation is essential to preserve all the evidence that the object may contain. The field team should be familiar with the care and storage requirements of the different materials encountered during excavation, and there are several useful publications available for guidance, including *First Aid for Finds* (Watkinson and Neal 2001). Large-scale lifting projects such as kilns, mosaics and other heavy items like lead and stone coffins may require the assistance of other specialists, such as civil engineers.

2.3 Project execution: assessment

The conservation assessment should outline the potential of the assemblage to answer the research objectives of the project, and the conservator should look at all the recorded finds with this in mind. However, groups of unstratified materials and even nails from disturbed contexts may not be worth full assessment at this stage – this is an issue to be discussed and agreed between the archaeologists and the conservators.

The artefacts' state of preservation will be very important in determining the level of information that can be retrieved, and poor preservation may preclude the pursuit of some planned research objectives.

Alternatively, unexpected findings may alter or expand research objectives at the assessment stage. For example the discovery of extensive mineralised organic remains on a grave group assemblage may provide the opportunity for research into clothing, or the identification of usually ephemeral components of metal artefacts, such as knife or tool handles. Such findings can impact both on the project's research objectives and also on the time required for subsequent investigative conservation (Figs 2.3.1 and 2.3.2).

Object selection

The choice of artefacts for investigative conservation will be shaped by the project's archaeological objectives. The object selection process should draw on the knowledge and expertise of all parties involved – conservator, finds specialists and any other members of the archaeological team who are involved with the finds – to fully realise the potential of the assemblage. The conservator's recommendations will be based on the information that an object might hold, and/or concerns for its long-term stability. Though the project's archaeological objectives should be the primary consideration, the national or regional importance of an object or assemblage will inevitably influence recommendations for further investigation.

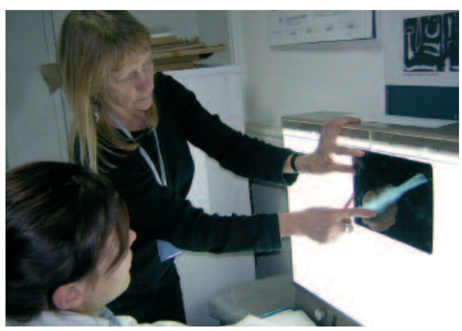
The conservation assessment report, that forms part of the project design and is updated during the planning stages, should include:

- a summary of the type, quantity and condition of artefacts recovered;
- a statement of their potential to address the aims and objectives of the project, and how that might be achieved;
- the costs of undertaking such a programme of work;
- work required to make the assemblage suitable for archive deposition.

Conservation strategy

Preparation of a workable post-excavation timetable for the project must involve the input of the project conservator, as the flow of artefacts from the site through assessment and on to the analysis phase can be complicated. Some finds specialists may wish to study particular artefacts both before and after conservation.

In some cases all the information required to publish the artefacts may have been achieved during the assessment phase, with no need for further analytical work. In this case, the artefacts, documents and other media will be prepared for transfer to the archive.



2.4 Project execution: analysis

The work outlined in the assessment is completed during the analysis stage, using the most cost-effective means to answer the project's updated research objectives. Each project is different and it is important to balance the level of intervention and analysis undertaken against the value of that information, for example:

- Conservation costs are very dependant of the condition of the material. For example, it is possible to clean about 20 well preserved coins in one day, but it can take a whole day to reveal the detail on a very corroded coin.
- Some analytical techniques can produce quick results. For example, X-ray fluorescence analysis can accomplish many scans in few hours, whereas preparing the samples for other techniques, such as X-ray diffraction analysis, metallurgy and lipid analysis, can take a few days before producing any results.
- Identification of organic materials is often possible with the aid of a low-powered microscope, and this is a quick way to scan through a large group of samples, as well as to check if the preservation of these materials will support further in-depth study.

The condition of certain categories of material can dictate conservation priorities, and groups of material left for long periods in inappropriate conditions can become worthless for analytical based research. Some assemblages will therefore have to be dealt with soon after excavation:

- Waterlogged materials deteriorate very rapidly after exposure to air and there is a need to organise the assessment and analysis phases quickly. Working on these assemblages can be hampered by the scale and quantity of the objects involved, which could include large structures, such as bridges or boats (Brunning 1996; English Heritage 1995).
- Lifted blocks of soil with a high clay content will set like concrete if they are left to dry out completely. These will then take much longer to excavate and the artefacts within them will probably be damaged in the process (Fig 2.4).

2.5 Project delivery: dissemination

Publication

A conservation report, at least in a summary form, should be included in the site publication. As there can be a significant delay between the conservation of the finds and the final publication, it is always good practice to produce a conservation report on completion of the practical phase. This should include:

- names of individuals involved;
- site and excavation dates;
- aims and objectives of investigative conservation for the project;
- types of material examined;
- methodology and results;
- analysis, with full data included;
- discussion and recommendations.

In some instances the conservation work may merit a more detailed report, published in a specialist journal, in order to bring a new technique, or interpretation of analytical results, to the wider attention of conservators and archaeologists.

Archive

All the finds should be packaged for safe transfer to the depositing museum in accordance with that museum's policy on the acceptance of archives.

The finds archive should also include:

- X-radiographs;
- conservation records;
- any photographs and plans produced during the dismantling of soil blocks;
- conservation report;
- full analytical data.

Publicity

Publicity, to raise public awareness, is an essential component of many archaeological projects and can include:

- special or temporary exhibitions;
- television programmes;
- short articles;
- project websites.

All of these are likely to draw on information gleaned from the artefact assemblage by investigative conservation and usually focus on a selected group of items, which have to be worked on in advance of the rest of the project. In some cases the conservation work forms part of the exhibition, with viewing galleries overlooking the treatment areas, as in the conservation of *The Mary Rose* hull in Portsmouth (**www.maryrose.org.uk**), or the Hasholme logboat at Hull and East Riding Museum (**www.hullcc.gov.uk**).

2.6 Small projects

This level of planning may seem excessive for dealing with material from small-scale evaluations, but conservation still needs to be incorporated even if all stages are compressed into one, as often the few objects that are found can be examined, X-rayed and packed for transfer to the archive in the space of a few days.

2.7 Portable Antiquities and Treasure Act

Objects found, often by metal detecting, can be a driver for rapid conservation and examination in order to identify the artefacts to establish their importance and valuation in compliance with The Treasure Act 1996, under which all finds made from gold or silver as well as coins over 300 years old must be reported. Since January 1st 2003, the legislation has been extended to include Prehistoric base-metalwork as well. In Scotland the situation is slightly different in that all archaeological objects must be reported under Treasure Trove.

For more information consult the following websites, which give advice on how to report finds as well as basic conservation and storage for artefacts:

Portable Antiquities Scheme: **www.finds.org.uk**
Treasure Trove in Scotland:
www.treasuretrovescotland.co.uk

Fig 2.2 (far left) Fieldwork: block lifting a group of finds using dry ice. (©Oxford Archaeology North)
Fig 2.3.1 (left top) Assessment: positioning an object for X-raying.
Fig 2.3.2 (left bottom) Examining an X-radiograph.
Fig 2.4 (above) Analysis: micro-excavation in the laboratory.

3 Condition of archaeological materials

Most artefacts that are found on archaeological sites in the UK will have degraded to varying extents during burial (*see* Table 2). A range of factors make the artefact assemblages vastly altered from their original appearance, but if examined closely it is possible to find evidence suggesting the form and history of an object before burial.

3.1 Metalwork

Metal artefacts are found on many archaeological sites, especially urban settlements, and in some graves. They include items made from iron, copper, silver, lead and gold, all of which are commonly found as alloys rather than pure metals. Some are plated or coated with a different metal to give the impression of being made from a more valuable metal, or, in the case of iron, to make the object more resistant to corrosion during use. There is the preferential preservation of some metals when in close contact with base metals, for example composite brooches, where the copper alloy parts are well preserved at the expense of the iron pins, which are heavily corroded (Fig 3.1.1).

Different soil types will influence the condition of metalwork. For instance chalk soils will tend to cause iron to break into small flakes, which can be difficult to repair; in sandy soils, iron objects are usually heavily corroded, although slightly more stable at ambient conditions than those found on chalk. In waterlogged environments, copper alloy and iron objects are often only lightly corroded, sometimes with metallic surfaces visible, and the same deposits can give rise to brightly coloured sulphides (Duncan and Ganiaris 1987; Fell and Ward 1998). Strongly acidic environments may lead to the de-alloying of non-ferrous metals. For example the de-cuprification of bronze to give a tin-rich fragile artefact that appears to be made of pure tin (Selwyn 2004). The high temperatures of cremations and conflagrations may cause metals such as tin and lead to melt, or may result in the production of high-temperature oxidation products such as black oxides on copper and silver alloys and red oxides on iron for example Fell (2004, Fig 3.1.2).

Some types of metal objects such as coins and personal items like brooches are essential for establishing a chronological sequence. For this reason the diagnostic details need to be revealed either by X-radiography or the removal of corrosion accretions, or a combination of both techniques.

Table 2 Survival of metals and organic materials in different soil conditions.

Burial environment	*Some typical situations*	*Materials that may survive*
very acid: pH below 5.5, oxic	heathlands, upland moors, some gravels	Metalwork is heavily corroded and organic materials are preserved by metal salts, or as a soil stain.
slightly acid to neutral: pH 5.5-7.0, oxic	clay vales and lowland plains	Metalwork can be well preserved and in some circumstances also bone, antler and ivory.
basic: pH above 7.0, oxic	chalk and other limestone	Metalwork is well preserved, as well as bone, antler and ivory. Wood, leather and textiles are rare.
acid to basic, anoxic	some well-sealed urban deposits, wetlands, wells, wet ditches and upland moors	Leather, wood and bog bodies are preserved to differing degrees. Bone and similar materials are only preserved in alkaline environments, although collagen can survive in slightly acid soils. Metalwork can be well preserved, sometimes with metallic surfaces.

3.2 Organic materials

Organic materials are particularly susceptible to attack from insects, bacteria and other micro-organisms during burial, but they can be preserved under certain conditions such as:

- waterlogged environments;
- metal ions from nearby metalwork;
- mineralization by calcium phosphates;
- charring;
- desiccation – only found in buildings;
- freezing – rare to non-existent in UK.

Organic materials fall into two main groups – which are based on cellulose and protein – and the chemistry of the burial environment will favour the preservation of one over the other. For example acidic soils such as peat will lead to the good preservation of proteins in the form of leather and wool, but cellulose materials such as wood and vegetable fibres are less likely to survive. Conversely, slightly alkaline soils will favour the preservation of wood and vegetable fibres while leather and animal fibres will be less well preserved. The recognition of differential preservation can be useful in providing negative evidence. For example, vegetable fibres will decay in acid environments and this can be accelerated by the presence of slightly acidic materials such as leather, so it is very rare to have the remains of linen thread preserved in leather garments or shoes.

Waterlogged archaeological organic materials can consist mostly of water and minerals taken up from the soil, with very little of the original organic structure remaining. On drying too quickly, waterlogged objects, especially wooden ones, will shrink and can warp out of shape. In waterlogged levels only anaerobic micro organisms can survive, such as iron-reducing bacteria, and these form microscopic iron sulphides within the wood and to a lesser degree in leather. Iron sulphides rapidly oxidise on exposure to air, with the production of hydrogen sulphide and sulphuric acid, and both of these compounds can cause the further deterioration of objects in wet storage, or even after conservation. Waterlogged organic materials, especially leather, can support the growth of moulds and bacteria that can eat through the leather (Fig 3.2.1) and be harmful to individuals handling this material. It is advisable that wet leather should be recorded and discarded or conserved soon after excavation. Some details of construction or decoration are not readily visible until the object is dry (Fig 3.2.2), and this should be taken into account when discussing the conservation strategy to be used.

Copper alloys and lead will corrode in most damp soils, and the salts produced are toxic to micro-organisms and will preserve any adjacent organic materials that absorb them. Iron corrosion products are also taken up by organic materials, and the salts are deposited within the structure and can even replicate the microscopic features. This can lead to the preservation by mineralization of the organic elements of artefacts, such as knife handles. Inhumations, particularly in sandy soils, produce a very aggressive environment for metalwork and the resulting corrosion can promote extensive preservation of organic materials (Watson 1998). Organic materials can also be preserved as a result of calcification, which most commonly happens in wells and latrines, where insects and other micro fauna and flora may be preserved through calcium phosphate mineralization (Carruthers 2000; English Heritage 2002).

Organic materials can be preserved in carbonised form as the result of a fire, cremation or high temperature industrial process. The most common product is charcoal, but the charred wooden tips of implements and other carbonised environmental remains can also be found.

Desiccation is most likely to happen in buildings in the UK, sometimes leading to the preservation of smoked and mummified remains in chimneys, as well as shoes and other items of clothing concealed behind walls.

3.3 Glass

Glass may be found on many sites, and its deterioration is influenced by its composition and by the burial environment. Glass is made from silica, with other ingredients added to flux and stabilise the silica and form the glass. These agents are either soda or potash to modify or flux the glass, and calcium or lead to stabilise the structure. The resulting glasses can have very different resistance to decay during burial.

Water is the most important factor in the deterioration of glass, and its absence can lead to remarkable preservation of glass of all types. However, potash glass is much more susceptible than soda glass to the leaching

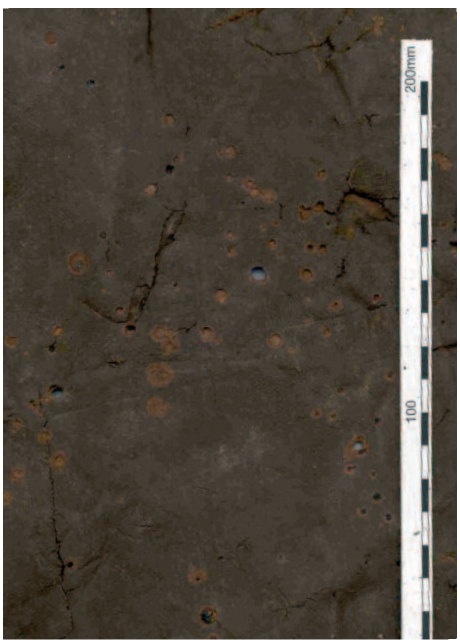


Fig 3.1.1 (opposite top) Copper alloy brooch from Flixton, Suffolk, with an iron pin that has almost completely corroded, and in the process preserved a large area of textile.
Fig 3.1.2 (opposite bottom) Iron chain retrieved after a fire: the surfaces of its links are covered in brightly coloured iron oxides, the result of the conditions to which it was exposed.
Fig 3.2.1 (above left) Freeze-dried leather, the surface of which has been damaged by mould growth in wet storage.
Fig 3.2.2 (above right) Fragment of a Roman leather tent panel with a stamped inscription clearly visible after freeze-drying (photograph by Sue Winterbottom).

and weathering effects of a wet or damp burial environment. Leaching can cause characteristic surface iridescence, lamination and opacity, all of which weaken the glass and can obscure the original colour and surface detail. Weathered glass may be very fragile.

3.4 Jet, shale and amber

Artefacts made from these three natural materials are relatively rare. When excavated, objects made from jet, shale and amber may appear to be in good condition, but deterioration caused by oxidation and leaching may be disguised by a thin film of water from the damp soil, filling the cracks in the matrix (Figs 3.4.1 and 3.4.2). It is advisable to assume that the material is fragile and treat it accordingly. Damp jet, shale and amber should not be allowed to dry out, but should be well packed and kept damp and preferably cool until the conservation assessment takes place.

Assessment should be carried out as soon as possible, as further deterioration may be caused by escalating the oxidation of iron pyrites, which is found as an impurity in shale. If treated inappropriately, all three materials have a tendency to fracture into small pieces, which could result in the actual loss of the object.

Fig 3.4.1 (left) Amber bead with a degraded surface that is beginning to flake.
Fig 3.4.2 (above) When lit from behind, a seemingly well preserved amber bead shows microscopic cracks throughout its structure.

3.5 Ceramics

Ceramic fragments are often among the best preserved and most durable of finds. Well fired ceramics may suffer little visible deterioration during burial. Nevertheless, care should be taken to examine ceramics for evidence of glazes, decoration, surface finishes, industrial remains and carbonised or other deposits on the insides and outsides of the shards, and to ensure that finds processing does not inadvertently remove these. Late medieval tin-glazed vessels, for example, are particularly susceptible to the crazing and loss of the glaze unless handled and processed carefully.

Poorly fired ceramics and unfired clay are more problematical. In damp burial environments, they may become soft, resulting in disintegration or loss of the edges and surfaces upon excavation. It may be necessary to use a block or supported lifting technique to successfully recover fragile sherds and vessels from the ground. Evidence of carbonised deposits on pottery may preclude consolidation of at least some sherds so that any scientific analysis is not compromised. Consolidation may also interfere with the study of ceramic fabrics, colour and inclusions.

3.6 Wallplaster

Daub and unpainted plaster may be recovered from early settlements, and painted wallplaster may be recovered from Roman or later contexts. In a damp burial environment, it is very likely that the cementing materials used in plaster manufacture will have softened, altered or leached out. Likewise, organic fillers such as hair or straw will have been lost, weakening the structure. Excavated plaster may be very soft and fragile, much like poorly fired ceramic, and should be treated with care. Fragments should be examined for traces of surface paint, and also for evidence of the plaster substrate (wooden laths, straw or reeds), which may be preserved as impressions on the reverse of the pieces.

3.7 Stone

Archaeological finds of stone commonly include building materials, such as architectural fragments, but stone artefacts also include flints, sharpening stones, hones, rubbers and mortars. Igneous and metamorphic stone is generally dense and durable and may have suffered little deterioration during burial. Sedimentary rock (such as sandstones and limestones), however, tends to be more porous and less durable, and may even have suffered extensive weathering before burial. Salts from the burial environment may have been absorbed into the stone, and these can cause further damage after excavation as they re-crystallise on or just underneath the surfaces.

All architectural fragments and other stone artefacts should be carefully examined for traces of paint, which may only survive in the deepest-cut and most protected areas of the artefact. Touchstones, hones, hammers and mortars may retain evidence of their use, such as flecks of metal.

3.8 Which objects should be looked at first?

All materials will have altered to a greater or lesser degree while buried and their resulting condition will mean that in some circumstances they should be recorded and conserved, if appropriate, soon after excavation. The following is a rough guide to the order of priority in which materials should be worked on:

1 waterlogged leather and textile
2 waterlogged wood
3 soil blocks containing metalwork and other materials
4 ironwork
5 wet inorganic materials such as glass, jet, shale, amber, wallplaster, and poorly fired ceramics
6 copper alloys and other non-ferrous metalwork
7 bone and antler
8 dry glass, well fired ceramics and stone

4 Detailed examination of artefacts

Investigative conservation work is usually done in two stages: the first stage elucidates the survival of potential evidence in the artefact assemblage and decides on what is worth further investigation, and the second stage facilitates or undertakes the scientific analysis required to produce data to interpret that evidence.

This section discusses the various methods used by conservators and what information they can reveal about artefacts. A more detailed explanation of these processes can be found in Caple (2006, chapter 1).

4.1 Visual examination

Objects are examined with the aid of a low-powered microscope, at magnifications between x10 and x20. This enables the operator to see details that would not be immediately noticeable to the naked eye, for example the stitching in layers of leather, and identifying the different parts of composite objects (see Case Studies 5.3 and 5.4).

It is possible to identify many materials at this magnification, or at least to see if enough of the structure survives to be worth using scanning electron microscopy for more detailed work. It is usually necessary to have access to comparative material in the form of reference collections, so that one can develop the skills needed to identify degraded archaeological materials.

4.2 Infrared and ultraviolet light

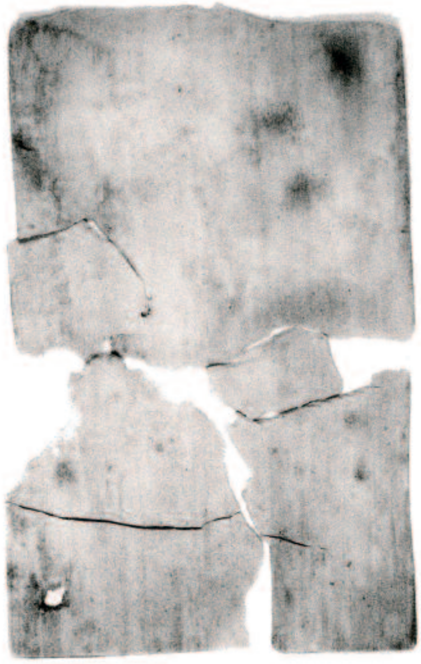
When found, it is hard to distinguish between artefacts made from organic materials such as wood, leather and textiles. Even after conservation all seem to have a fairly uniform brown colour – which means that details such as writing or coloured decoration are barely visible to the naked eye. In these situations photography using an infrared filter or examination under ultraviolet light can enhance the residual detail. For example ink writing on wooden writing tablets (Figs 4.2.1 and 4.2.2) becomes more visible through an infrared filter and this can be further clarified with digital processing.

Under ultraviolet light some pigments and resins fluoresce, so that they can be identified, or at least suitable areas for sampling can be located (Caple 2006).

4.3 X-radiography

X-radiography is a rapid and non-interventive imaging technique for studying metal artefacts and some other materials and composites (Lang and Middleton 2005). It is particularly useful for screening metalwork assemblages as a precursor to assessment for further examination, conservation and finds study (Fell et al 2006).

The response of materials to X-radiography depends on their thickness, density and chemical nature. The technique can be used successfully on soil blocks in order to discover the presence and relationships of finds within the block (Fig 4.3.1). Only metalwork is routinely screened by X-radiography, because the results



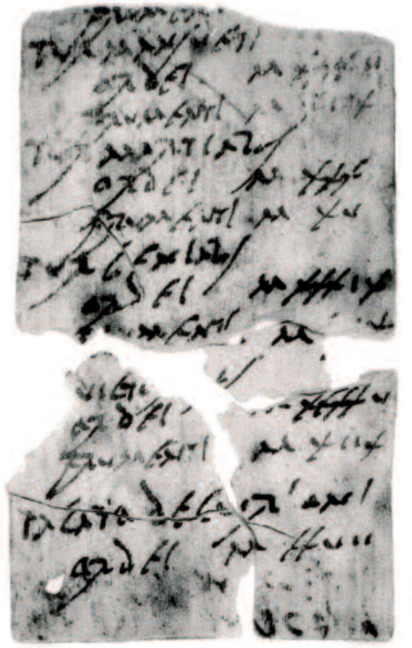


Fig 4.2.1 (above top left) The thin leaf of a writing tablet in normal light.

Fig 4.2.2 (above top right) When viewed through an infrared filter, the writing on it becomes visible.

Fig 4.3.1 (above) Soil block containing a multi-strand bead necklace and part of a brooch: the metal fragments and coloured glass beads show up clearly in the X-radiograph, but the amber beads appear as voids, as this material is more X-ray transparent than the surrounding soil.

provide a cost-effective and non-interventive method of study and archive record. Other materials are sometimes X-rayed for specific research purposes, such as painted medieval window glass (Knight 1989) and investigating damage caused by marine boring worms in wooden test blocks (Palma 2004).

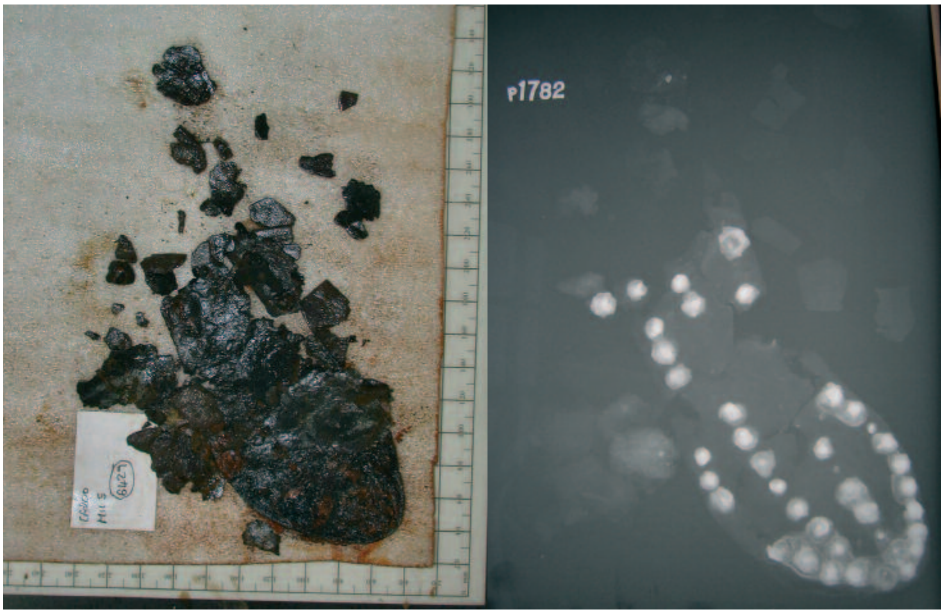
Specific examples of the use of radiography include:

- form, construction and technology of metal artefacts;
- metal inlays, and coatings on metal artefacts (*see* Case Study 5.4);
- repairs;
- composites, such as metal rivets in bone/antler combs, organic handles on iron knives (*see* Case Study 5.2);
- construction of basketry;
- carpentry joints used in complex wooden objects;
- recording hobnailed sole patterns on shoe soles (Fig 4.3.2);
- stitching in leather and thin wooden objects that are obscured by soil, as the stitches are often more X-ray opaque owing to the accumulation of iron minerals by bacteria (Fig 4.3.3);
- X-raying painted glass to reveal the decoration, as an alternative to cleaning it;
- stereo X-radiography to identify the relationship between various metal objects when corroded together, and obscured by accretions (*see* Case Study 5.1).

Conventional X-radiography cannot determine the precise nature of the materials under examination, although with experience the viewer can make an informed guess based on the structure, for example bone, or contrast in the case of iron. Other scientific techniques are required for specific identifications, such as X-ray fluorescence analysis to distinguish between silver and tin.

4.4 Removal of soil and accretions

Depending on the condition of objects it may be essential to remove soil, and in the case of metalwork, some or all of the corrosion products, in order to clarify details not elucidated by visual examination or X-radiography. Extraneous soil and accretions are normally removed with the aid of a microscope and various hand tools such as scalpels, mounted needles and soft brushes. This is a very delicate operation, as the presence of some organic materials can be as subtle as a slight change in texture or colour in the corrosion on an object, for instance the preservation of an ivory inlay on the reverse of a pierced copper alloy buckle (Figs 4.4.1a–c; Watson 2004). In the case of ironwork,



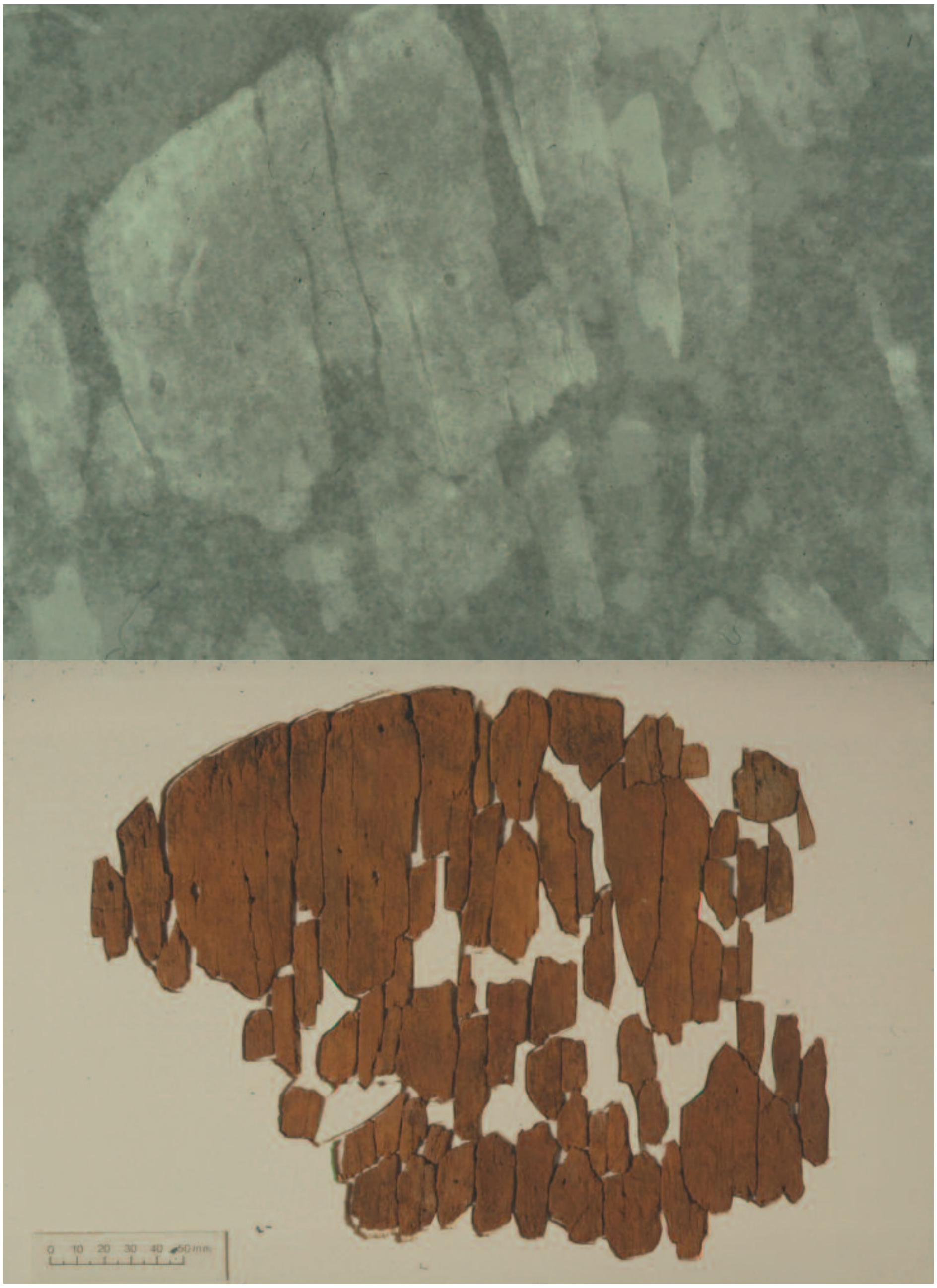


Fig 4.3.2 (above top) A Roman hob-nailed shoe from Carlisle and an X-radiograph revealing the pattern of nails on the sole.
Fig 4.3.3 (above bottom) Stitching on wooden objects can become more visible in X-radiographs owing to the accumulation of iron minerals by bacteria: a thin Neolithic bark object from Runnymede, Surrey and an X-ray revealing the stitch holes.

the corrosion layers can be so hard that a pressurised jet of abrasive (airbrasion) is required to reveal any surface finish or decoration.

Minimal intervention and the advantages for a study archive

As mentioned at the beginning of these guidelines, investigative conservation is directed towards gaining the maximum amount of information with the minimum of intervention. The use of chemical treatments, and the removal of corrosion layers, can change the integrity of an object for further study and should only be undertaken if it is essential for achieving the archaeological objectives of the finds assemblage. A minimalist approach to conservation will avoid the loss of:

- remnant structures in the corrosion layers (Scott 1989);
- non-ferrous metal coatings, inlays, lead/tin solder;
- associated technological evidence such as hammer scale, slag, charcoal;
- mineral preserved organic materials such as textile, wood, horn, etc;
- environmental evidence such as charcoal, beetles, seeds;
- residues – specifically lipids;
- corrosion products as evidence for burial conditions;
- oxidation layers as evidence of the object's history;
- stability of the artefact;
- anything that might be investigated in the future.

Micro-excavation

This is basically small-scale excavation in the laboratory, for the detailed examination and recording of fragile artefacts. Complex groups or assemblages that have been block-lifted on site can vary in size from a small box containing a brooch to a complete inhumation. These groups are likely to include metalwork in association with mineral preserved organic material such as textile, wood, leather and plant materials (Watson and Edwards 1990). The possible interpretation of these remains from burials is outlined in Table 3.

Detailed recording and planning of all stages of micro-excavation are important in order to interpret the relationship between the ephemeral remains and the metalwork, and add the information gained into the site plan. This can be achieved by a variety of means, including line drawings and photographs (Figs 4.4.2 and 4.4.3).

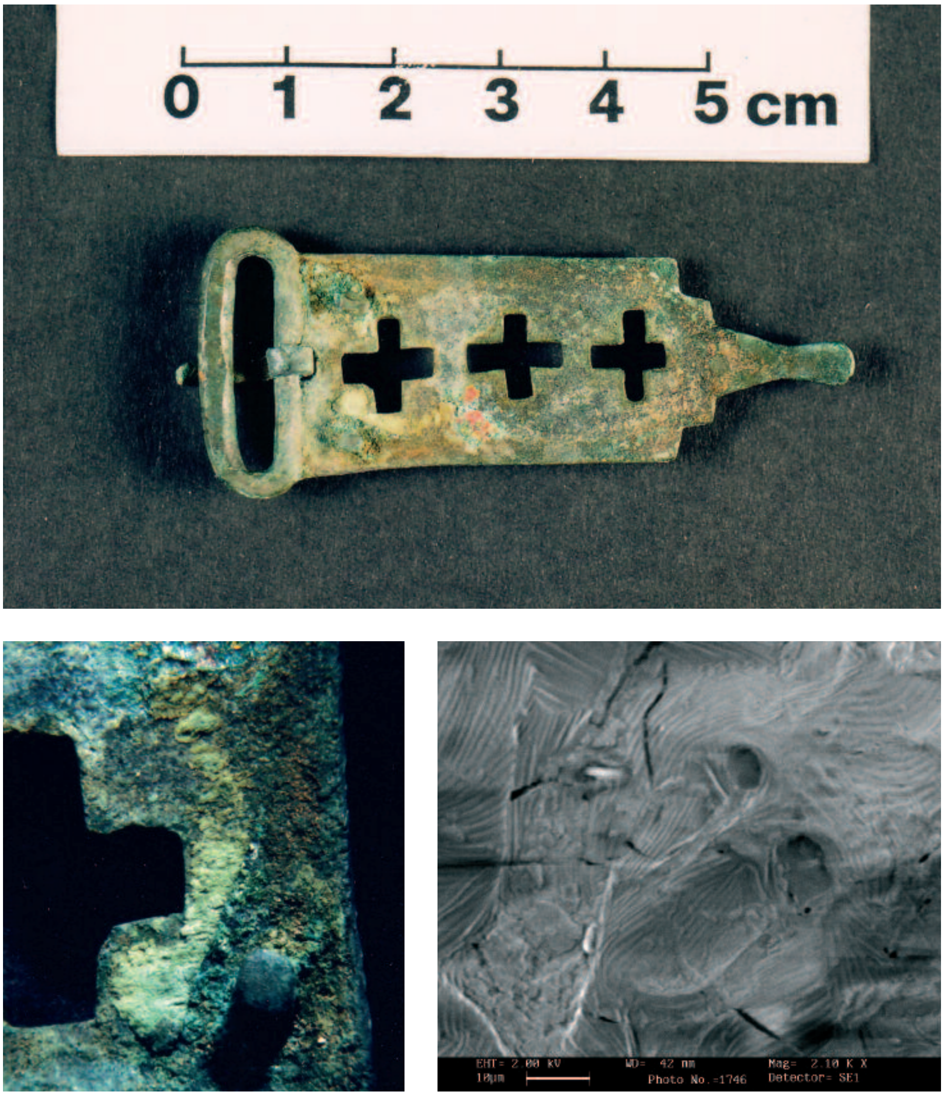
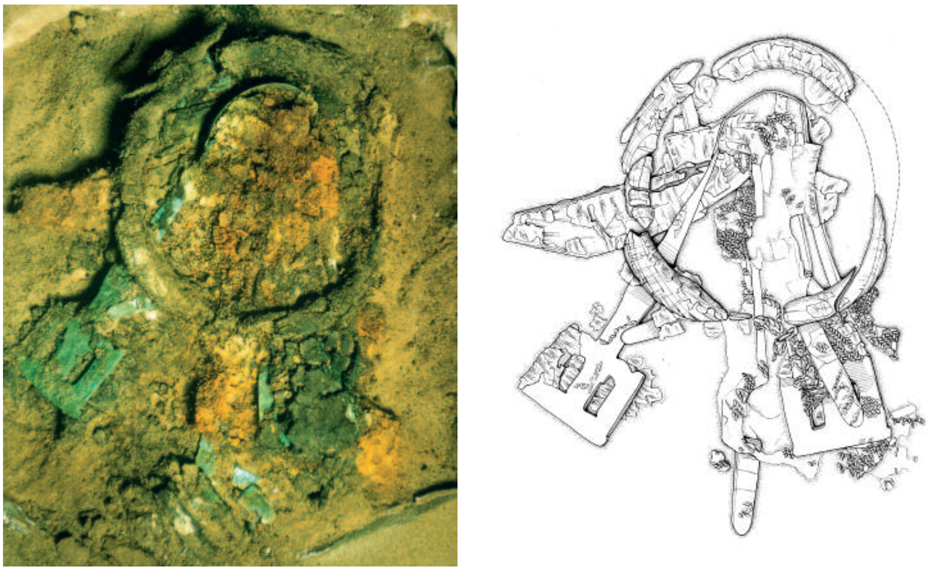


Fig 4.4.1
a. (above top) The remains of an ivory inlay on the reverse of a pierced copper alloy buckle.
b. (above bottom left) Changes in the colour and texture of deposits show the extent of the ivory (white).
c. (above bottom right) SEM examination of the buckle showed that the white material retains the microscopic structure of elephant ivory.

Table 3 Organic material preserved on metalwork placed in graves.

Relationship	*Examples*
1. organic components of metal artefacts	• knife handles • sword hilts • spear shafts • shield board preserved on the metal fittings • belt remains • purse remains • wooden bucket staves • caskets and coffins
2. organic artefacts directly associated with metal objects	• knife sheaths • sword scabbards • purse remains on contents
3. organic materials preserved by proximity of metal objects	• textiles from clothing, covers and containers • wood from coffins, boxes and other containers • plant materials • pupa cases and other insect remains • skin and bone



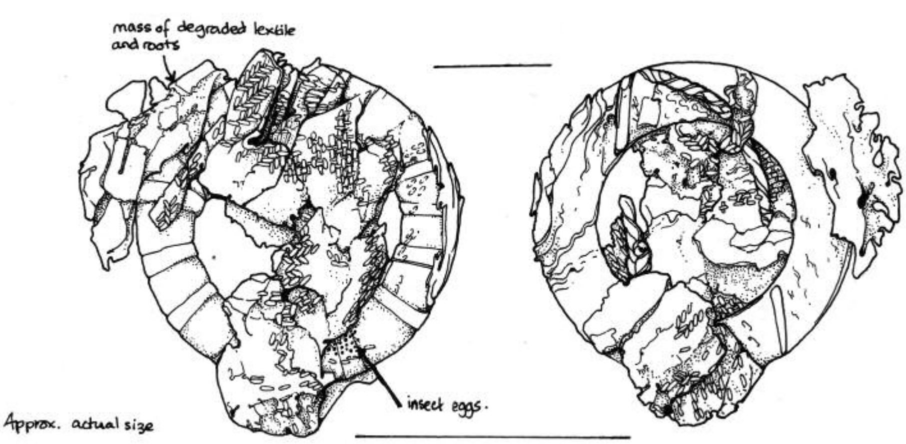


Fig 4.4.2 (above top) A leather purse, partially excavated, and a plan of the different items found.
Fig 4.4.3 (above bottom) A copper alloy brooch with an iron pin, from an Anglo-Saxon burial. This drawing illustrates the layers and variety of organic materials that can be preserved by the copper and iron corrosion products (drawing by J Watson).

4.5 What conservation should be able to provide

The detailed examination of artefacts by most of the above methods is routinely carried out by conservators and, based on the results, the conservator should be able to provide the following information and advice for a project:

1 the form and construction of the objects, so that they can be identified and fully documented, including illustration
2 identify what further analysis will be of value in answering the objectives of the project
3 reveal metal inlays or coatings for analysis, along with any associated organic materials preserved by metal corrosion products that need to be identified
4 recommendations for the long-term storage of the finds archive, including the remedial conservation of extremely vulnerable materials
5 documentation, including a short note on the work done

This is the stage at which some conservators finish their investigative work on the artefacts. The objects are then transferred to diverse specialists for detailed analytical study (*see below*), although conservators who have access to the necessary facilities will continue with some of the techniques listed below. Most conservators are able to give advice on the appropriateness of this work and possible specialists who are able to do it.

4.6 Scientific analysis

New analytical methods are constantly being added to the archaeological science repertoire, but only a limited group are frequently used in the study of artefacts and their associated remains (Caple 2006; Table 4). Some are qualitative, and one can acquire results fairly rapidly, while others require the careful preparation of samples and specialist expertise in interpreting the results, making them much more likely to be used in research projects (Brothwell and Pollard 2001, 585–649; Dungworth and Paynter 2006). Routinely used analytical techniques include: X-ray fluorescence (XRF) analysis, scanning electron microscopy (SEM), X-ray diffraction (XRD) analysis, Fourier-transform infrared and near-infrared spectroscopy (FTIR, FTNIR), radiocarbon dating (C14), metallurgical analysis, gas chromatography and mass spectrometry (GC/MS). Other methods such as isotope and various bio-molecule analyses are not included here as they are rarely employed in artefact studies at the time of writing.

X-ray fluorescence (XRF) analysis

The chemical nature of an inorganic artefact, or sample, can be determined by this non-destructive technique. The item is irradiated with a beam of X-rays, causing fluorescence within the structure, and the spectrum obtained will be diagnostic of the chemical composition at the surface of the artefact. However, corrosion and other surface effects will alter the composition at the surface and the results need careful interpretation.

The technique is particularly useful for:

- distinguishing between different copper alloys, such as bronze and brass;
- identifying metal platings and inlays, such as tinning, silvering, and gilding.
- Modern alloys can sometimes be distinguished from ancient metals, for instance the presence of chrome in steel will indicate a modern alloy.
- Glasses and enamels can also be examined for colourants and opacifiers (Fig 4.6.1).
- Pigments in painted layers on materials such as wallplaster, ceramics and even organic materials like wood, can be identified to mineral type.

Scanning electron microscopy (SEM)

This is high-resolution microscopy, capable of a magnification range in the region of 15 up to tens of thousands, although most analysis is done at x2000 or lower. The images are created by electrons rather than by light energy, with the object or sample being placed in a chamber often under vacuum conditions. A beam of electrons is targeted on the area of interest and produces secondary electrons, backscattered electrons and X-rays, which are collected to produce an image, and for analysis. Unlike optical microscopy, SEM produces a black and white image of the topographical structure of the surface of the sample. The advantages of using this type of microscopy are the very high magnification possible and the crisp images that can be produced, with a good depth of focus.

- Small samples can be examined to identify many organic materials such as wood, bone/antler, ivory, horn and shell.
- Reflected X-rays can be collected for quantitative chemical analysis.
- Back-scattered electrons can be used to map different elements in the area imaged.

X-ray diffraction (XRD) analysis

The mineral or chemical form of an artefact, or sample, is determined from the diffraction pattern obtained when its crystal structure is irradiated with an X-ray beam. Although sampling is necessary, the quantity required is very small.

This technique will determine the precise crystal structure and is useful for:

- identifying corrosion products produced in different burial environments;
- minerals that can be indicators of burning, or other environmental processes;
- paints and pigments made from naturally occurring minerals with a crystalline structure, such as the ochres and umbers, which are ferric oxides in various hydrated and dehydrated forms.

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

These techniques are mainly used for the analysis of organic materials, where a beam of light is transmitted through a sample and the bonds between different types of atom can be distinguished as they absorb different regions of the IR spectrum. The results are presented as spectra, which are then compared to known examples. Normally, samples are mounted in pellets for analysis, or ground into a powder, but in some cases it is possible for the analysis to be done directly onto the object, using portable equipment. Some infrared spectroscopy equipment includes a microscope, where it is possible to analyse small areas or even produce compound maps of sections.

This technique is particularly useful for:

- identifying polymers and resins used in historical times as well as past conservation treatments;
- identifying natural materials such as fibre;
- identifying organic materials, such as jet, shale and lignite (Watts and Pollard 1998);
- modern plastics;
- and can also be used to categorise amorphous inorganic compounds, such as some non-crystalline iron oxides.

Raman-spectroscopy is a similar technique, but a laser beam is used instead of light. The resulting spectra are also matched with known reference materials.

Radiocarbon dating (C14)

Artefactual material may need to be offered up for radiocarbon dating (Case Study 5.6), placing constraints on conservation measures that may result in contamination, and this must be borne in mind during project planning, fieldwork and assessment. It is the project manager's responsibility to ensure that appropriate advice has been taken with regard to scientific dating requirements, and sampling, and that any constraints on conservation are fully discussed, and allowed for, in advance of treatment. Archaeological material submitted for radiocarbon dating should preferably be unprocessed and not consolidated. Ideally it should be placed in an acetate box or plastic bag and clearly labelled to avoid accidental contamination or further processing. Waterlogged material should be kept in the dark, preferably in cold storage.

Whether or not samples have been taken for radiocarbon dating, conservation records should identify the nature of conservation treatment, and chemicals used, so that artefacts later retrieved from archive can be assessed for their potential contribution to future programmes of dating.

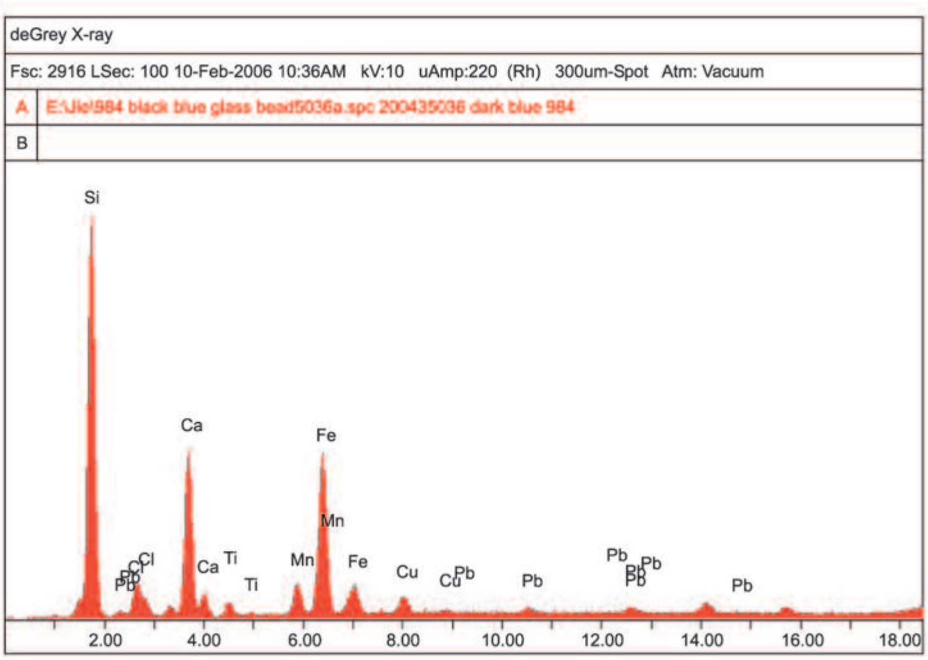


Fig 4.6.1 An XRF spectrum of a glass bead.

Table 4 Analytical methods commonly used with investigative conservation

Technique	*Used to determine*	*Sensitivity*	*Sample required*	*Commonly used for*
XRF	elemental composition	qualitative or semi-quantitative	rarely	metal coatings and inlays; alloys
SEM	structure	high magnification	usually	identify wood, fibres and other materials with well defined microstructures
SEM-EDXA	elemental composition	quantitative	usually	element ratios
XRD	crystalline materials	qualitative	yes	identify corrosion products and pigments
FTIR/FTNIR	organic compounds	qualitative and semi-quantitative	usually	organic residues and amorphous inorganic compounds

Gas chromatography and mass spectrometry (GC/MS)

Ancient food remains can be analysed by gas chromatography and mass spectrometry (GC/MS) to identify lipids (plant and animal oils and fats) absorbed into unglazed ceramic vessels during cooking or storage, or found in charred food deposits on the insides or outsides of pots. The technique identifies the origin of these materials by characterising and matching them to modern reference samples. Archaeological material chosen for lipid analysis should not be processed or conserved, and should be well packed and labelled. Extraction of absorbed lipids is a destructive process, which may have implications for the selection of suitable sherds.

Note: the sherds may be ground to a powder, to help release the fats and oils for analysis.

For specific advice refer to **http://www.brad.ac.uk/staff/bstern/molecular/Sampling%20protocol.html**

Metallography

The methods of forming and constructing metal artefacts can be investigated through metallography by examining the grain structure of the metal or alloy. Analysis usually requires a small sample of metal that is prepared as a polished specimen mounted in resin, and then examined under a metallurgical microscope or SEM.

The technique can yield information on:

- metal and alloy types, along with their properties;
- manufacture and use (eg Fell 2003), such as steel edges applied to knife blades, and pattern-welded sword blades. Even totally corroded artefacts can have a residual metal structure that can be examined by metallography (eg Scott 1989; Tylecote and Gilmour 1986);
- plating and other surface features can be examined in cross-section in the SEM for details of composition or morphology for example Meeks (1993).

5 Interpretation

The interpretation of the combined conservation and analytical work should bring together those results that answer the archaeological questions and spark off new ideas. The implications can be wider than simply identifying the technology of the finds; for example the recognition of imported materials such as objects made from non-indigenous wood species and animal products such as elephant ivory has implications for economic activities. By comparison with the local faunal assemblage, it may be possible to ascertain if artefacts made from animal skins and bones were produced on or near the site. Insects found on grave goods can be indicators of burial rites (Turner-Walker and Scull 1997), and if found on combs can give some insight into personal hygiene (*see* Case Study 5.5).

The following case studies illustrate how investigative conservation can be used:

5.1 X-Radiography to interpret and record a group of corroded metal objects
5.2 Medieval knives
5.3 Anglo-Saxon buckle
5.4 Roman dagger sheaths
5.5 Roman boxwood 'nit' combs
5.6 Possible Mesolithic arrow
5.7 Medieval body armour 'jack of plate'

Case Study 5.1

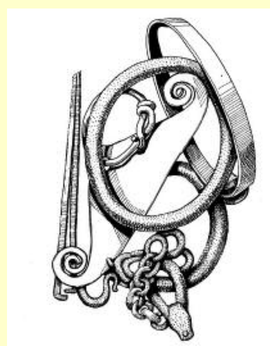
X-Radiography to interpret and record a group of corroded metal objects

Both iron and copper alloy objects produce corrosion products that can preserve organic materials that would otherwise be destroyed under most burial conditions. This means that when a group of metal objects are found covered in mineral-preserved organic materials, there can be a conflict of interests between the recording of the metalwork and the retention of the organic materials. This case study illustrates how it is possible to record such a group of corroded metalwork covered in organic materials.

The small block shown in Fig 5.1.1 is one of three groups of corroded metalwork wrapped in textile, probably the remains of a small bag or purse, found in an Anglo-Saxon grave. It contains at least eight items, including copper alloy rings and a decorative mount, which are clearly visible on the X-radiograph (Fig 5.1.2), along with various iron objects that are fainter and more difficult to interpret. The whole group is wrapped in layers of textile so that only a fragment of one of the copper alloy rings is visible. The metalwork inside these bundles appears to be in good condition, but the mineral-preserved organic material is brittle and fragile and cannot be removed without destroying it.

Stereo X-radiography was used to demonstrate how all the different items relate to one another in order to produce the reconstruction line drawing. By producing a pair of stereo X-ray images, taken a few centimetres apart, and then viewing them through a stereo viewer, it is possible to see a three-dimensional image of all the layers – including which items are connected and how, as well as the positions of the separate objects within the block (Fig 5.1.3).

Fig 5.1.1 (below left) A group of corroded metal objects wrapped in textile.
Fig 5.1.2 (below middle) An X-radiograph of the metal objects wrapped in textile.
Fig 5.1.3 (below right) A drawing of the metal objects in the corroded group in textile: their relative positions have been established by studying stereo pairs of X-radiographs (drawing by J Dobie).



Case Study 5.2

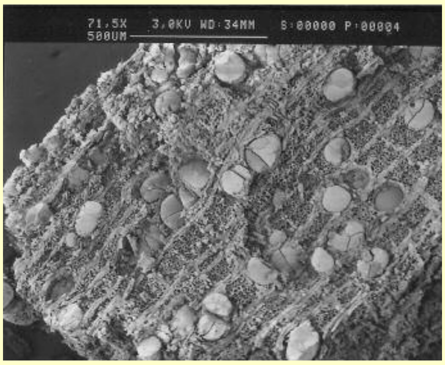
Medieval knives

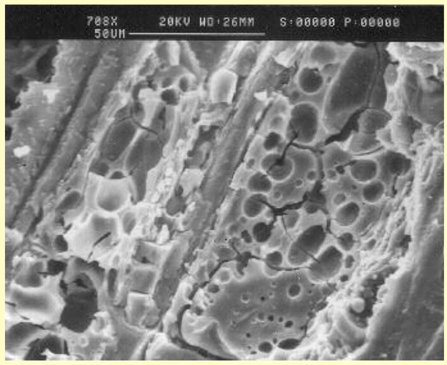
During the medieval period every individual had their own knife for everyday use, and many were embellished to suit their owners' requirements with plain or composite handles. Investigative conservation can contribute to the recording of these finds, as shown in two examples of scale-tang knives with scales of organic material attached to the knife tang and decorated with non-ferrous metal rivets.

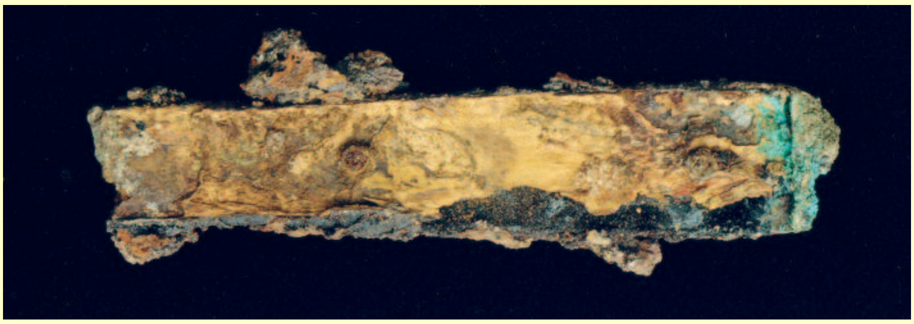
In the first example the wooden handle is attached to the iron tang with alternating circular and trefoil-shaped brass rivets (Fig 5.2.1). The X-radiograph of the side-view illustrates that only the plain rivets are functional, and that the trefoil-shaped ones have been added purely for decoration (Fig 5.2.2). On the radiograph one can also distinguish a thin white line corresponding to the surface of the wooden handle, possibly as a result of iron salts accumulating underneath a non-permeable layer. Examination using the SEM revealed that the wood pores are filled with a glassy material interpreted as a resin or varnish that was applied to the original knife (Figs 5.3.3 and 5.2.4). Wooden scales were most frequently made from maple or box (Cowgill *et al* 1987), and often very knotty wood was selected for its attractive grain pattern.

Knife scales were also made from organic materials other than wood – such as bone, horn or even shell – including this example of mother-of-pearl, shown in Figs 5.2.5 and 5.2.6. Depending on the soil conditions, shell can be well preserved, still retaining its iridescent lustre, but in acid conditions it will deteriorate and the structure will just survive in the iron corrosion products. In this case, the handle itself was examined in the SEM, as it was impossible to sample the powdery deposit remaining on the tang. It was possible to compare the structure of the mineral-preserved shell with a piece that was less deteriorated to confirm the identification (Figs 5.2.7 and 5.2.8). The rivets, shoulder plate and end cap, which attach the scales to the iron tang, can be seen in the X-radiograph. These are all made from brass, which was identified by XRF analysis (Watson and Paynter 2001).

Fig 5.2.1 (above left) A scale-tang knife handle with wooden scales decorated with copper alloy rivets and terminals.
Fig 5.2.2 (above right) An X-radiograph showing two views of the knife handle.
Fig 5.2.3 (below left) An SEM image of part of wooden scale shows that the pores are filled with a glassy material, probably a resin.
Fig 5.2.4 (below right) An SEM image of wood showing that the structure appears to be filled with resin or wax.







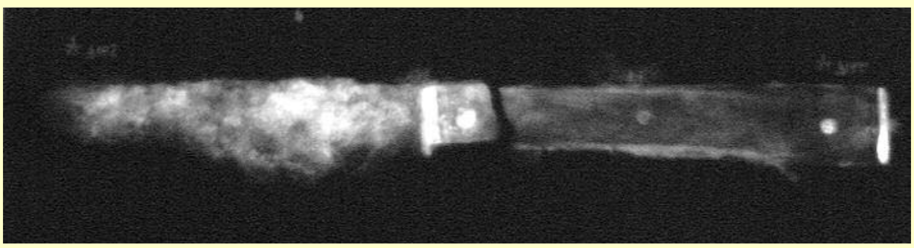
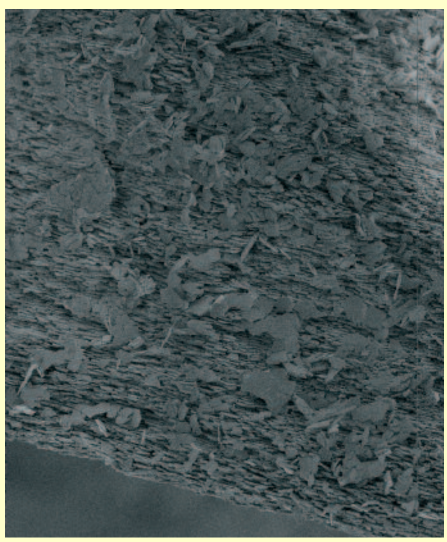


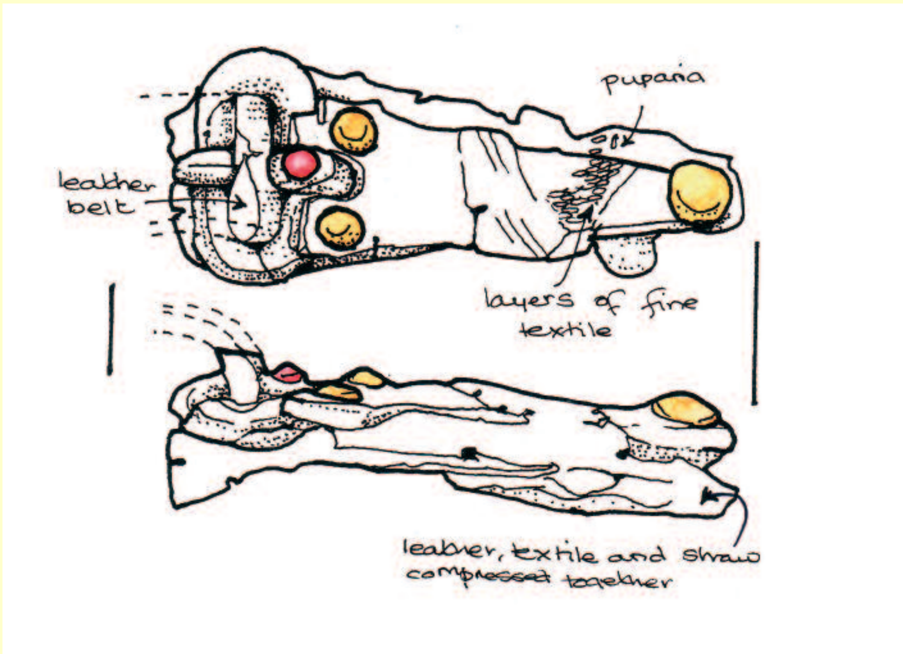
Fig 5.2.5 (above top) An iron knife tang with traces of the organic scales preserved in the iron corrosion.
Fig 5.2.6 (above) An X-radiograph of the complete knife, showing the non-ferrous metal rivets, end cap and shoulder plate (length 120mm).
Fig 5.2.7 (below) An SEM image of the organic material preserved on the tang.
Fig 5.2.8 (right) An SEM image of weathered mother-of-pearl.

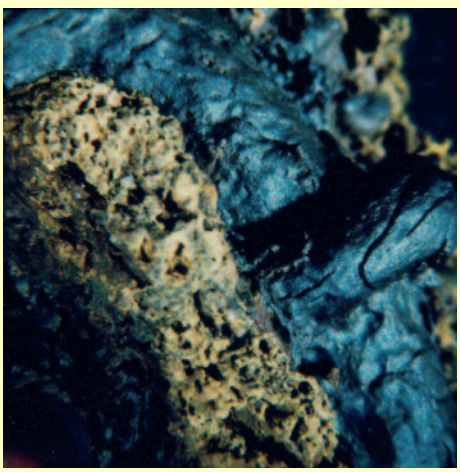


Case Study 5.3

Anglo-Saxon buckle

On close examination this Anglo-Saxon buckle was found to have a cabochon garnet, backed with a gold foil, mounted on the buckle tongue (Figs 5.3.1–4). The buckle plate is decorated with brass rivets, and the surface has been tinned. So originally this buckle may have resembled a silver gilt type, especially with the addition of the garnet. Remains of the leather belt have been preserved in the iron corrosion products and it can be seen that it passes through the loop and is then pulled back over the loop and back through the belt to hold it in place and reveal the garnet and riveted buckle plate (Watson 2002).





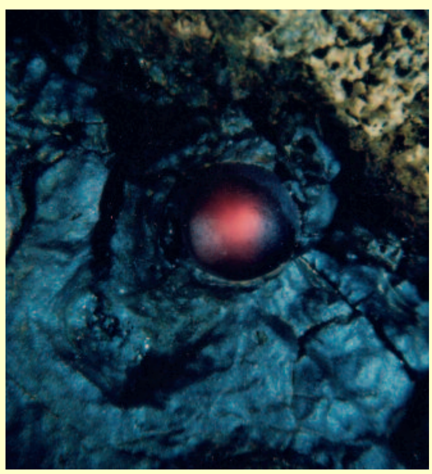


Fig 5.3.1 (right top) An iron buckle after conservation.
Fig 5.3.2 (right bottom) An annotated drawing of the iron buckle and associated organic remains (drawing by J Watson).
Fig 5.3.3 (below left) Remains of the leather belt, which was originally pulled back over the buckle loop.
Fig 5.3.4 (below right) The small cabochon garnet mounted on the buckle tongue: the gold foil behind the stone reflects light and makes the garnet glow red.

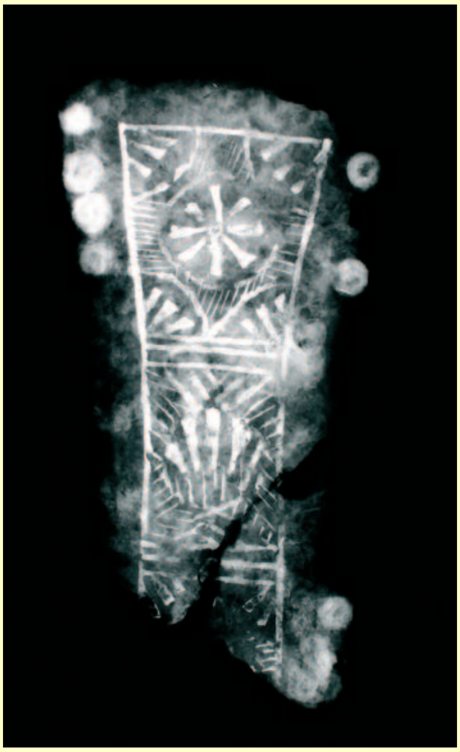
Case Study 5.4

Roman dagger sheaths

Roman dagger sheaths are often complex in construction and highly decorated. Commonly these sheaths comprise plates of an organic material, such as horn, with a decorated metal plate attached to the front. Corrosion of the metal usually obscures these components, as well as the inlaid decoration, although the same corrosion products can preserve the morphology of the organic components through mineralization.

The sheath plate shown here was recognised from the X-radiograph (Fig 5.4.1 and Fig 5.4.2), which revealed the elaborate decoration as well as rivet heads. Closer examination, under low-power microscopy, revealed traces of mineralised horn on one side of the plate. The decoration on the other side of the iron plate and also metal plating on the rivet heads was determined by X-ray fluorescence to be tin. This was analysed after removal of corrosion products from small selected areas.

The tin itself had decayed to a grey powder. This means, of course, that it would not be possible to fully expose the decoration by removing all the accretions, because the decayed tin powder would be lost. Nor would this be desirable for the artefact in terms of loss of strength and stability. However, the form of the plate and the design are clearly visible on the X-radiograph, enabling reconstruction drawings to be made (Fig 5.4.3).



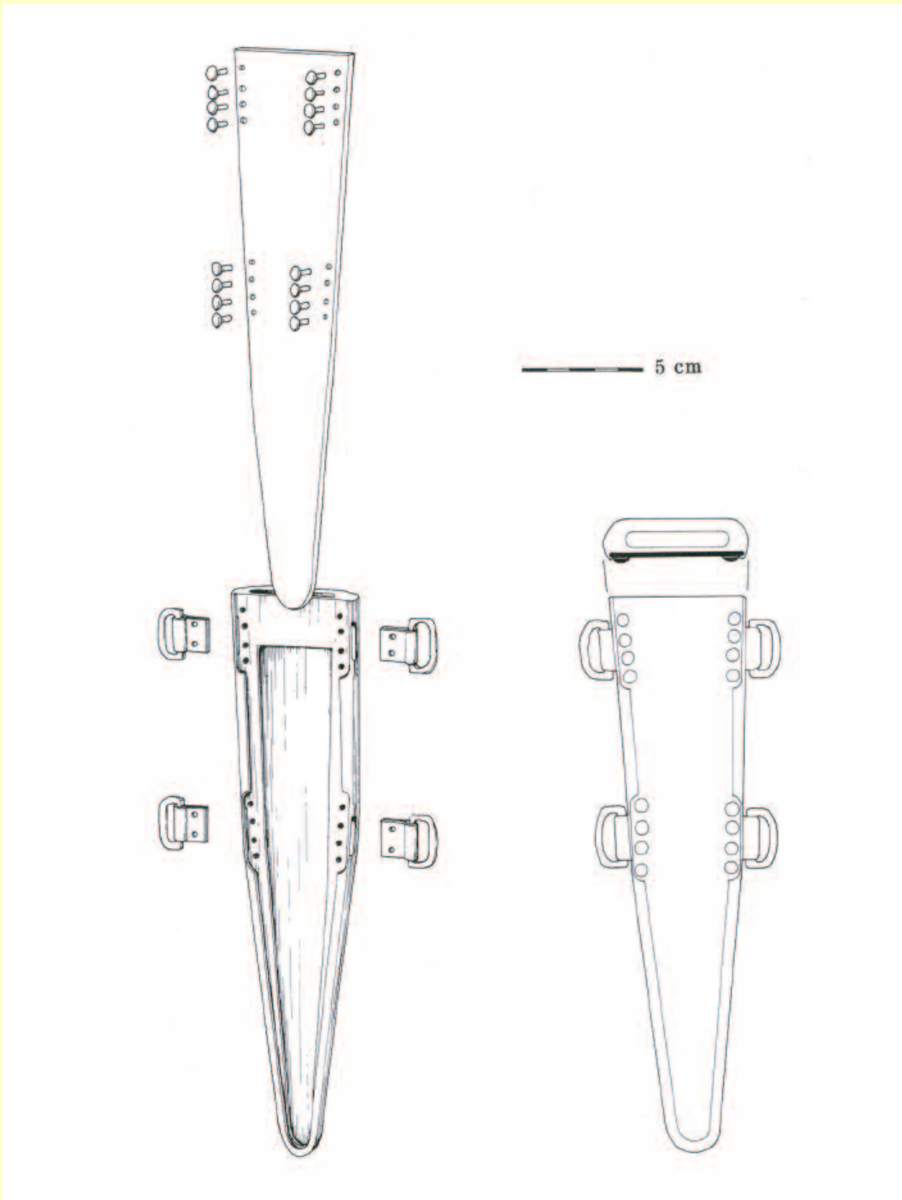


Fig 5.4.1 (top left) An X-radiograph of an inlaid iron plate.
Fig 5.4.2 (top right) A fragment of a Roman dagger scabbard.
Fig 5.4.3 (bottom) A reconstruction of how the various Roman dagger scabbard components would have been assembled (drawing by J Watson).

Case Study 5.5

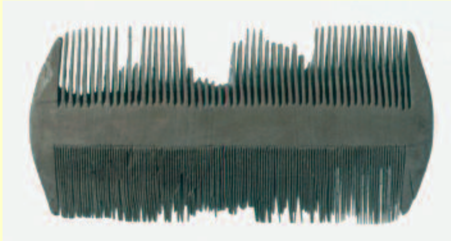
Roman boxwood 'nit' combs

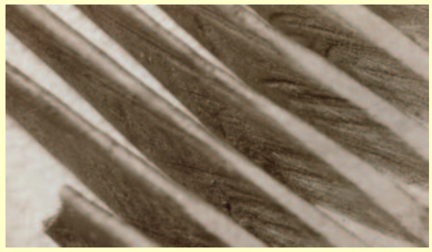
Two Roman combs recovered from anoxic waterlogged deposits were examined for evidence of manufacture and use (Fig 5.5.1). The combs are made of boxwood *(Buxus sp.)* and the teeth are coarsely spaced on one side and finely spaced on the other (Fig 5.5.2). Their appearance is very similar to modern 'nit' combs.

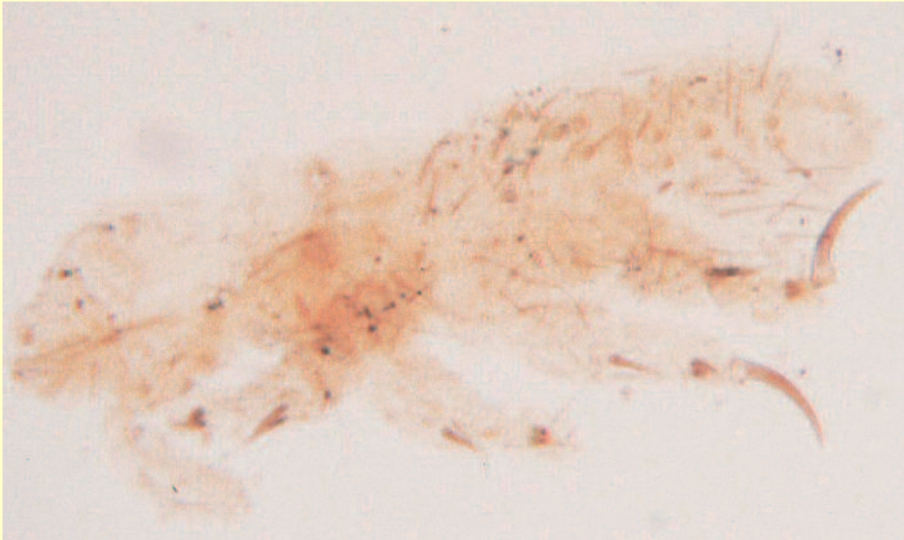
The wet soil residues from between the teeth were collected soon after excavation by carefully removing them with water and a soft brush. These residues were examined under low-power transmitted light microscopy. Numerous fragments of human head lice *(Pediculus humanus capitis)* cuticles were found, ranging from newly hatched larval stages (c 0.8mm long), through juvenile moulting stages or nymphs, to adults (which can grow to 4mm long) (Figs 5.5.3–5). No hairs were found, nor any unhatched eggs or nits, presumably because the softer tissue had not survived.

The combs were later stabilised by freeze-drying, after which the lighter colour of the wood facilitated examination for methods of manufacture, using low-power reflected-light microscopy. Tool marks visible between the wider-spaced teeth suggest that these were cut from both sides of the comb, most probably by sawing, using a 0.2mm wide blade. Tool marks were not visible between the finer-spaced teeth, which average 13–14 per 10mm, owing to their close density.

The anoxic waterlogged deposits had helped to preserve the wooden combs as well as the cuticles of the insects. However, the archaeological significance of these artefacts was only fully realised because the combs were not washed on site and the soil residues were careful examined for evidence of use (Fell 1996; 2000).







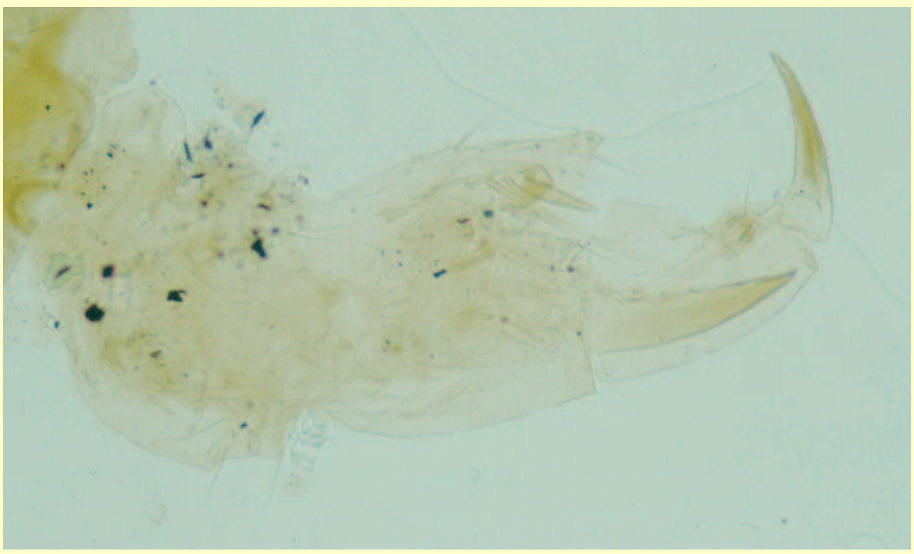


Fig 5.5.1 (top left) A freeze-dried 'nit' comb (length 108mm).
Fig 5.5.2 (top right) Detail of the coarse teeth, showing the saw marks.

Fig 5.5.3 (top) A juvenile louse (length 0.8mm).
Fig 5.5.4 (middle) A recently emerged larva (length 0.8mm).
Fig 5.5.5 (bottom) A detail of a louse claw.

Case Study 5.6

Possible Mesolithic arrow

This chance find was made during the excavation of Mesolithic levels along a former lake edge, where the flints were located after a machine trench was cut through the peat. Four flints were visible *in situ*, while others had been dislodged. This assemblage and its surrounding peat matrix were cut out of the peat with aluminium sheeting, and adjacent samples were taken for pollen analysis and radiocarbon dating.

Back in the laboratory the block was X-rayed and additional flints could just be seen in the X-ray image. Micro-excavation to remove the peat matrix revealed nine flints *in situ*, including the four above (Fig 5.6.1), with at least some as opposing pairs with their retouched edges aligned against the decayed fragments of wood (Fig 5.6.2). From these slight remains it was possible to carry out the following analyses (David 1998):

1 Unlike the fragments of hazel in the peat, the better preserved fragment of wood was identified as willow or poplar, the woods favoured for arrow shafts throughout history.

2 The other wood remains were submitted for radiocarbon dating, and produced a date of 7540-6670cal BC (HAR-6490, 8210 ± 150BP), which compares with the determination of the nearby peat sample, and places the wooden shaft in the late Mesolithic period.

3 The palaeobotanical evidence suggests that the assemblage lay in a rich fen, fringing land dominated by hazel woodland.

4 Organic residue analysis by infrared spectrometry, suggested the presence of a complex mixture of wax and resin, which on further study was refined to indicate beeswax and a pine resin, and this was further supported by gas chromatography. HPLC (high performance liquid chromatography) indicated traces of protein.

These results indicate that this small assemblage preserved in the peat was in all probability the remains of an arrow lost during a hunting foray around Lake Pickering some 7000 years ago (Fig 5.6.3). It has been shown that these types of wood and resins continued to serve the same purpose well into historic times

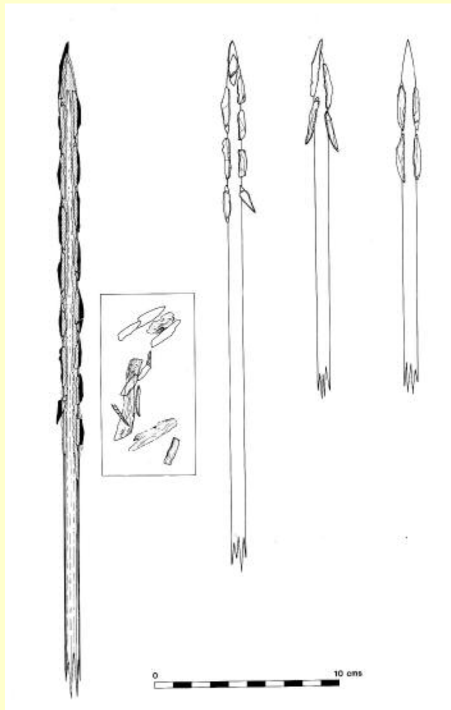


Fig 5.6.1 (left top) A partially excavated soil block revealing the flints and wood fragments.
Fig 5.6.2 (left bottom) The flints are positioned around broken fragments of the arrow shaft among other fragments of wood.
Fig 5.6.3 (above) Possible reconstructions for the tip of this arrow: the reconstruction on the left incorporates all the flints found in the group (drawing by A David).

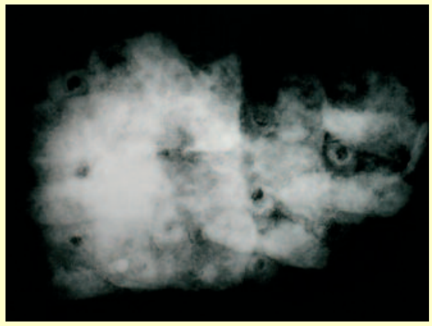
Case Study 5.7

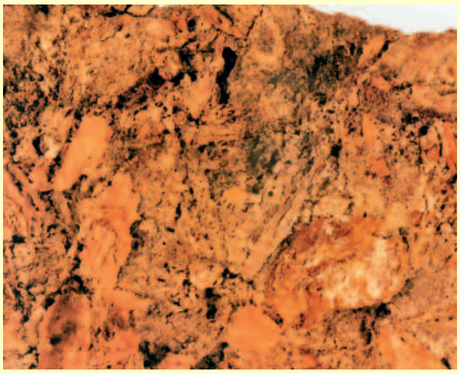
Medieval body armour 'jack of plate'

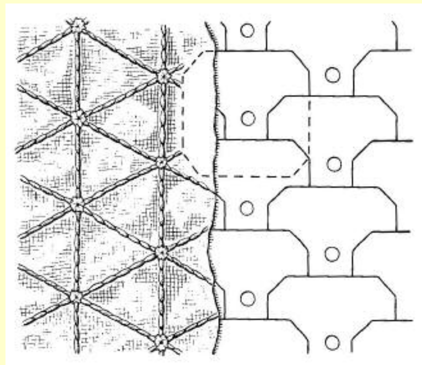
Occasionally, small groups of rectangular metal plates, with clipped corners and a central hole, are found among the remains of ironwork recovered from excavations at medieval castles. Larger corroded groups, probably from whole sections of jackets, are easily identified by X-raying. Using this technique it is possible to see how the plates overlap one another, like fish scales, as they remain in the same alignment as when they were discarded (Figs 5.7.1 and 5.7.2). Some plates show signs of re-use, with pieces cut from plate armour.

In the case illustrated here, the iron corrosion has also preserved layers of organic materials, which on closer examination were found to be the remains of textile, stitching and even the wool padding (Figs 5.7.3 and 5.7.4). This type of armour was often stored in armouries until required, and the fragments of wood preserved on top of the textile may be from the inner surface of a box used for its storage (Fig 5.7.5; Biddle *et al* 2001).

These groups of metal plates stitched between layers of coarse fabric are all that remain of medieval body armour designed to protect the wearer from shot. They became widespread in use from the mid-16th century, and probably looked like the quilted jacket illustrated in Fig 5.7.6 (Eaves 1993).







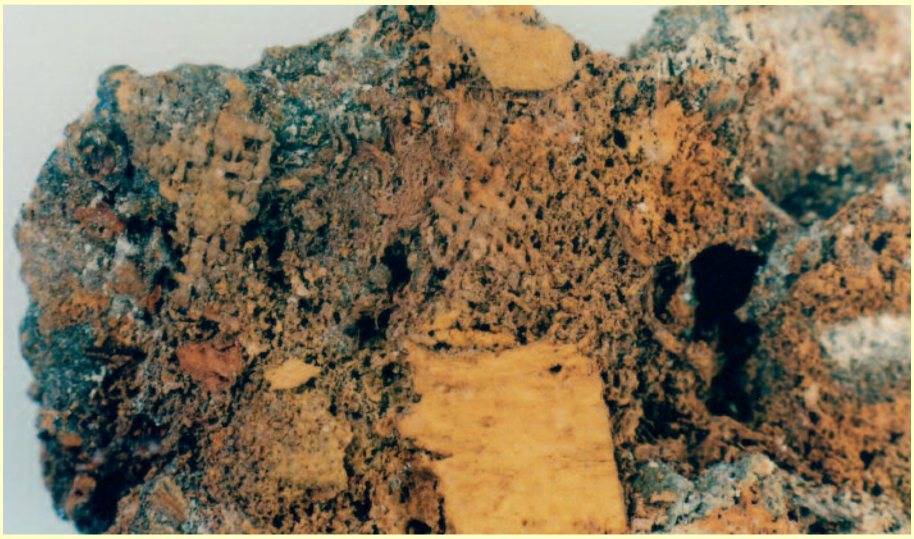


Fig 5.7.1. (top left) Corroded group of iron plates.
Fig 5.7.2. (top right) X-radiograph of corroded plates.
Fig 5.7.3. (middle top left) Textile remains and stitching preserved in the corrosion layers.
Fig 5.7.4. (middle top right) Illustration of the assembled layers.
Fig 5.7.5. (middle bottom) Textile and wood remains.
Fig 5.7.6 (bottom) Reconstruction of the quilted jacket (drawing by C Evans).

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7 Glossary

alloy a mixture of two or more metals – for example bronze, which is an alloy of copper and tin

anaerobic micro organisms mainly bacteria, that can live in anoxic environments, do not metabolise oxygen but can convert elements such as sulphur, iron and manganese into various insoluble minerals

anoxic environment (archaeology) levels from which oxygen has become excluded; life forms present do not metabolise oxygen

block lifting removal of an artefact from the ground along with some of the surrounding soil, the block being wrapped, undercut and supported or frozen to prevent movement of the soil or artefact

brass an alloy of copper and zinc

bronze an alloy of copper and tin

charred material that has been burnt, and is at least in part reduced to carbon as a result of burning, in a reducing atmosphere below 500°C

high performance liquid chromatography used to separate mixtures of organic compounds and identify them by comparison with known examples

inorganic material of mineral origin – for example metal, stone, glass

leaching (glass) the gradual loss of the alkaline component in unstable glass through prolonged contact with moisture, resulting in clouding and lamination of the surface

lipids vegetable oils and animal fats found in foodstuffs and used as binders for pigments

metal corrosion the chemical or electrochemical reaction between metal and its environment, producing a deterioration of the metal and its properties

mineral-preserved preservation of material by the toxic effect of corrosion products in the immediate vicinity, or within the metal artefact

mineral-replaced replacement of organic material by minerals, including calcium carbonate and calcium phosphate

organic material once part of a living organism – for example bone, antler, wood, leather, horn

patina coating formed on a metal surface through oxidation

pH a measure of acidity or alkalinity, where 1 is acid, 7 neutral and 14 alkali

pigment substance of organic or inorganic origin, usually mixed with water, oil or other base and used for colouring

qualitative analysis the 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

reflected light (microscopy) light which is reflected by an object, or illumination from above

stable isotope an isotope of an element which does not undergo radioactive breakdown

transmitted light (microscopy) light from below, which passes through and illuminates a transparent or very thin object (eg glass slide or thin section)

8 Where to get advice

Advice on facilities and conservation laboratories available for commercial and other work can be obtained from the following sources:

1 English Heritage Regional Science Advisors, listed below with their regional offices:

North West (Cheshire, Manchester, former Merseyside, Lancashire and Cumbria)
Sue Stallibrass
Department of Archaeology, Hartley Building, University of Liverpool, Liverpool L69 3GS
telephone: 0151 794 5046
e-mail: sue.stallibrass@liv.ac.uk

North East (Northumberland, Durham, Tyne and Wear, Hadrian's Wall)
Jacqui Huntley
Department of Archaeology, University of Durham, South Road, Durham DH1 3LE
telephone/fax: 0191 334 1137
e-mail: j.p.huntley@durham.ac.uk

Yorkshire and Humber (Yorkshire and former Humberside)
Andy Hammon
EH York Office, 37 Tanner Row, York YO1 6WP
telephone: 01904 601983
e-mail: andy.hammon@english-heritage.org.uk

West Midlands (Herefordshire, Worcestershire, Shropshire, Staffordshire, former west Midlands and Warwickshire)
Lisa Moffett
EH Birmingham Office, 112 Colmore Row, Birmingham B3 3AG
telephone: 0121 625 6875
e-mail: lisa.moffett@english-heritage.org.uk

East Midlands (Derbyshire, Leicestershire, Rutland, Lincolnshire, Nottinghamshire, and Northamptonshire)
Jim Williams
EH Northampton Office, 44 Derngate, Northampton NN1 1UH
telephone: 01604 735451
e-mail: jim.williams@english-heritage.org.uk

East of England (Bedfordshire, Cambridgeshire, Essex, Hertfordshire, Norfolk and Suffolk)
Jen Heathcote
EH Cambridge Office, Brooklands House, 24 Brooklands Avenue, Cambridge CB2 2BU
telephone: 01223 582759
e-mail: jen.heathcote@english-heritage.org.uk

South West (Cornwall, Isles of Scilly, Devon, Dorset, Somerset, Wiltshire and Gloucestershire)
Vanessa Straker
EH Bristol Office, 29 Queen Street, Bristol BS1 4ND
telephone: 0117 975 0689
e-mail: vanessa.straker@english-heritage.org.uk

South East (Kent, Surrey, Sussex, Berkshire, Buckinghamshire, Oxfordshire, Hampshire and Isle of Wight)
Dominique de Moulins
Institute of Archaeology, University College London, 31–34 Gordon Square, London WC1H 0PY
telephone: 0207 679 1539
e-mail: d.moulins@ucl.ac.uk

London
Currently vacant (January 2008)
Up to date information is available from the following websites:
1. HELM/Managing and Protecting/Delivering advice/Regional science advisers
2. EH/Research and Conservation/Archaeology and Buildings/Scientific techniques/RSA home

2 English Heritage, Archaeological Science teams:

Archaeological Conservation
Jacqui Watson
Fort Cumberland, Eastney, Portsmouth PO4 9LD
telephone: 02392 856700
e-mail: jacqui.watson@english-heritage.org.uk

Technology
Justine Bayley
Fort Cumberland, Eastney, Portsmouth PO4 9LD
telephone: 02392 856700
e-mail: justine.bayley@english-heritage.org.uk

Environmental Science
Gill Campbell
Fort Cumberland, Eastney, Portsmouth PO4 9LD
telephone: 02392 856700
e-mail: gill.campbell@english-heritage.org.uk

Scientific Dating
Alex Bayliss
1 Waterhouse Square, 138–142 Holborn, London EC1N 2ST
telephone: 020 7973 3299
e-mail: alex.bayliss@english-heritage.org.uk

3 The Conservation Register of the Institute of Conservation (formerly United Kingdom Institute for Conservation, UKIC).

This is a register of privately practising conservators who are accredited by the Institute and are required to work to professional standards set out by the Institute. The register is free to use and it is possible to search for a conservator by location and specialism:
www.conservationregister.com
e-mail: info@conservationregister.org.uk

4 Many can be found through Finds Liaison Officers for the Portable Antiquities Scheme, and they are listed on the website:
www.finds.org.uk

5 Local archaeological conservation laboratory services can often be found through local authority and county museum services, universities and other institutions, as well as through discussion with the other finds specialists involved in the project 'core team'.

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Jacqui Watson, Vanessa Fell and Jennifer Jones.

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Front cover: Anglo-Saxon silver-gilt keystone brooch set with shell and garnets. The X-radiograph illustrates many of the different components that make up this piece.

Micrographs from left to right:

i. Central piece of shell, magnification approx ×10.
ii. Shell viewed in SEM magnification approx ×500.
iii. Iron preserved textile from reverse of brooch, magnification approx ×10.
iv. Textile viewed in SEM magnification approx ×500.

Back cover: Detail of the central boss from the brooch where a mounted garnet has been set in a piece of polished shell with contrasting silver and 'niello' mounts. Magnification approx ×15.

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