Conservation Skills

Judgement, method and decision making

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6 Objects

Their recording and investigation

6.1 Purpose and nature of recording

As indicated in Section 3.5, recording is a key element in conservation work. The creation of a conservation record recognizes that conservation and restoration work is not an end in itself but part of a series of ongoing processes which last for the whole of the object's life. It also acknowledges that there are many people who will come after the present conservator who will need information about the object and who will undertake further investigation, revelation or preservation work. Thus in the history of conservation the creation of conservation records marks one of the crucial changes from a craft to a profession.

Making a record of the object and its conservation serves a number of separate purposes:

- Conservators are forced to examine the object in detail. This ensures that they are fully aware of all aspects of the object's composition and decay and that the proposed cleaning and conservation work is appropriate. It minimizes the unexpected discoveries which can lead to accidental damage or delays in the conservation process.
- All the information discovered about the object is recorded. This is an essential element in the investigation process, ensuring that all the information uncovered is available to others. The record provides a location for a wide variety of different types of information about the object: X-rays, photographs, analyses, observations and published references.
- A body of evidence is created which can be examined rather than the object itself. This may provide more information than the object and forms a preventive conservation measure limiting the need to handle and observe the object directly (e.g. the costume collection of Warwick Museum, Kavanagh 1990).
- A visual and written record of the object at a given point in time is created in order that changes, such as corrosion, loss or damage which occur during conservation or during subsequent storing, handling and display, can be detected.
- A record of the conservation work and materials used on the object. Details of all chemicals, treatment times and coatings are recorded so that, in the future, the success of a particular conservation treatment or chemical can be established (Sully and Suenson-Taylor 1996). It will also provide health-and-safety information on the exposure levels of various chemicals such as biocides and solvents which objects and conservators have endured. This may lead to the establishment of greater certainty over safe working practices and exposure limits and identifies any risk still posed by an

object to any future conservator as a result of hazardous materials used in its conservation.

- A record of the information necessary to allow an object to be successfully reconserved.
- A valuable example to other conservators proposing to treat similar objects.
- Identifying the object, should its unique identifier (e.g. museum number or site code) be lost or deliberately removed.

The importance of the record is often only recognized when it is shown to be the only source of information. For example, cleaning an object removes evidence/information about the object's past and leaves the conservation record as the only remaining source of that information.

6.2 A conservation record

Whilst the need for a conservation record is unquestionable, the nature and extent of the recording is a matter of judgement. Consequently the information recorded in a conservation record can vary enormously (Oddy and Barker 1971; Corfield 1983; Bradley 1983; Perry 1983; Down 1983; Corfield 1992; Dollery and Henderson 1996). No single recording system is universally used. This is due both to the variation in the type and nature of the object and the fact that the conservation record is often part of a larger sequence of records maintained by an institution such as a museum (Roberts 1985). The individual facts recorded in the conservation record provide information relevant to one or more of the functions mentioned above. The following list indicates the principal facts normally recorded:

Institution name: so that if this record card is misplaced it can be returned.

Object number: every object should have a unique alphanumeric sequence which is permanently placed on the object and which uniquely defines the object. This usually relates to the museum or collection where the object is housed or the place from where it was excavated or recovered. Some objects have several numbers, all of which should be recorded on the conservation record.

Laboratory number: in some institutions this may be the object number, in others every object coming into the laboratory is given a unique number. The object or laboratory number ensure that information, unique to each object, is associated with the correct object.

Owner (curator) of the object: the individual to whom the object belongs or who is responsible for the object and who has agreed to the conservation.

Museum location: (where appropriate) where the object is normally kept.

Numbers or references to further information: this will include the numbers and location of photographic negatives or positives, X-Ray plates, published references, excavation details, records of analysis.

Drawing of the object: every object should be drawn, though the appropriate level of detail will vary. It can be a quick sketch or a full technical drawing (Adkins and Adkins 1989; Griffiths *et al.* 1990). Annotated sketches or drawings are a particularly effective way of providing information about an object.

Photograph: for many objects, in order to depict accurate detail quickly one or more photographs is advisable (Dorrell 1989). Scales, colour card if appropriate and object or laboratory numbers should be included in the photograph. This image supports but does not replace the drawing. All sides of the object are often photographed.

Other images: all corroded archaeological iron objects must be X-rayed, and it is highly advisable for corroded silver and copper-alloy objects. Paintings may often usefully be X-rayed or have an infrared reflectogram taken. Many complex historic and artistic works are also usefully X-rayed, CAT (computerized axial tomography) scanned or γ-radiographed to reveal their method of construction, internal mechanism and condition.

Name: the type of object being recorded. The common or short name, the full or correct name, any trade names, maker's marks or numbers should all be recorded.

Origin details: where is the object from, what culture created it, what date is it?

Dimensions: maximum dimensions of the object expressed as any three of: length, height, width, breadth, depth and thickness. Weight is also sometimes recorded. Measurements should be in SI (metric) units: millimetres and metres, grammes and kilogrammes.

Materials: the principal materials used in the construction and decoration together with the method of identification.

Detailed description: a full description of the object ensuring that details, such as the materials of which each piece of the object is composed, are listed, the presence of paint or other coatings is referred to, the technology of manufacture is noted, information of wear or use is noted, the colour of the various pieces of the object is noted.

Condition: the extent and nature of dirt, damage, corrosion, fading, loss and how fragmentary or fragile the object is should be described. The source of the dirt, damage or decay should be determined and noted.

Conservation treatment: all aspects of the conservation treatment should be recorded, together with who undertook the work and when. Details of the chemicals used, their concentration and any specific temperatures or pressures used should be recorded. Any additional information about the object which comes to light during the cleaning and conservation process should be noted. Basic reasoning behind the conservation work undertaken, especially the initial aims of the proposed conservation work should also be recorded. All this information should be filled in as the conservator goes through the conservation process. Dates for commencement and completion of the treatment should be recorded.

Storage and recommendations: the appropriate conditions in which the object should be stored or displayed should be recorded together with details of any container created specifically to house or support the object and any restrictions on the object's handling or use.

Wherever possible reference should be made to standardized recording systems and thesaurus of terms and definitions where they exist (MDA 1997; Szrajber 1997). All conservation activities should be recorded, even simple cleaning such as washing china or brushing insecticide on to wooden agricultural items. This will aid the interpretation of soiling on the object (see Section 7.3), and the long-term assessment of chemicals, health and safety information, etc.

When treating a large number of similar objects much of this information is repetitive so many conservators have some form of codification or shorthand to describe aspects such as standardized conservation treatments (Corfield 1992). Whilst this can save time there is a risk that the conservation record becomes unintelligible to anyone not familiar with the code. Therefore, the information on the codes must be displayed very prominently beside the conservation records. Computer-based recording systems enable you to economically create records, especially those using standard phrases, in full and can ensure that you use words in a standard thesaurus so ensuring that the record created can readily be located through word-based searching.

The physical form of the record can vary from plastic or paper wallets containing all photographs, written details, X-radiographs, etc. as used in the British Museum up to the 1990s (Bradley 1983) on an A4 or A5 card, with the photographs and X-radiographs in separate indexed storage (University of Durham) to a computer record, backed up by a hard-copy record card (York Archaeological Trust). When computer memories are sufficiently powerful, and a large number of high-quality images can be retained, conservation records will become primarily computer based. Three-dimensional holographic images may eventually form part of the conservation record. The long-term stability of electronic media, hard and floppy discs and magnetic tape, is suspect because of the potential instability of the materials used to construct them (Westheimer 1994); for example, the polyurethane used to adhere the magnetic particles on to the substrate. Even CD-ROMs have a finite life as a result of their polymeric components. Any loss of fidelity would result in potentially undetectable information loss. It is also already clear that rapid software and hardware evolution can leave data stranded on obsolete systems. The computerized data from the 1960 US Federal Census was, by 1975, only capable of being read by two computers, one of which was already a museum exhibit (Westheimer 1994).

The frequent use of paper records, and the importance of maintaining these records, means that they should correspond to the standards developed for libraries and archives (i.e. BS (British Standard) 5454, Walker 1990). Colour is an important component of many objects and it is essential that colour is accurately recorded. This is best achieved through colour photography on good quality film or through using a standardized colour recording system such as L*a*b* (Minolta 1988). One particular area of concern is the stability of colour transparencies (Lavedrine *et al.* 1986; Townsend and Tennent 1993). For all colour photography a standard colour scale should be included, so that the extent of any differential colour fading of the recording medium can be established.

Conservators are the individuals who will study an object most closely, so the responsibility of reporting all the details concerning an object's form, decoration, method of manufacture, composition and state of decay rests primarily with them. They are frequently the only person who examines the object with microscope facilities so should ensure that microscopic details, such as wear, and the identification of materials are recorded. It is important to ensure that the curator, owner or archaeologist responsible for the object should be made aware of any pertinent facts regarding the object which are discovered during the conservation examination. Whilst the conservation record is normally retained by the laboratory which has treated the object, a copy of the record is often made to accompany the object, especially in private conservation work. Separate reports on the composition or condition of the object or proposals for the conservation treatment (see Section 1.6) may also be created.

The key role of records within conservation means that it is essential that time is made in the working day to ensure that the record cards are completed and that any filing and indexing of photographs and X-rays is carried out. The conservator exercises considerable judgement in the extent of the recording for any object. It is possible to waste a large amount of time illustrating and describing the most inconsequential details of an object, information which will never be required. Equally it is possible to ignore information which is crucial to the understanding of the object and neglect to record information which is lost when the object is cleaned. It remains particularly difficult to judge what information will be considered essential by a future generation of conservators.

Referring to Lowenthal's (1996) definitions of history as that which actually happened in the past and heritage as the past used for present-day aims, it is essential that the recording of any object is as near to history as possible. It is research and documentation of the facts. Any interpretation of the facts to enhance understanding about the object should be identified as interpretation and done as objectively as possible. Heritage will be that selected part of the information which is used to accompany the object on display, and is written by the curator conscious of their present-day aims for the exhibition.

6.3 The object

> Before any treatment is carried out the object should be placed in its historical, archaeological or artistic context.
>
> (Coremans 1969: 14)

The complex relationship between an ancient society, the material culture of its objects and the way in which members of a modern Western society interpret the ancient society from its artefacts has been the subject of considerable study (Pearce 1994a). In the nineteenth century Pitt Rivers and others initially interpreted objects as having a simple functional role, the form and construction of the object being directly related to the technological development of the society which made and used the object. The work of twentieth-century anthropologists such as Malinowski and Radcliffe Brown (Leach 1994) showed that complex social structure was invariably reflected within objects, whilst twentieth-century archaeologists have shown that there is a complexity between social belief and the expression of form and decoration of an object – even to the point of detecting the influence of individual

craftsmen (Deetz and Dethlefsen 1994). This has led to an awareness that all objects are culturally and contextually sensitive (Tilley 1994), and that even the materials of their construction have complex meaning and symbolism (McGhee 1994). Thus objects must be understood in terms of the culture and date from which they derive. Objects should also be seen as palimpsests, having an evolving series of meanings over time (Ames 1994). Hodder (1994) has proposed that objects can be seen as possessing three forms of identity:

- An object: raw materials shaped by technology to form an object which performs a function within a given society. It contains information about its origin in 'technomic', 'sociotechnic' and 'ideotechnic' forms.
- Part of a context: associated with other objects it is part of a code or communication which signifies and reinforces a social order or context.
- Embodying and signifying past experience: through its appearance it carries ideas of the past into the present.

As such awareness has developed, systems have started to be developed which assist museum curators, archaeologists and anthropologists investigate and analyse objects, helping them extract both evidence and meaning (Elliot *et al.* 1994; Pearce 1994b; Prown 1994; Batchelor 1994).

For the purposes of conservation there is a need to focus on the information which can be obtained from studying the object directly, both as a historic document and as an aesthetic entity. This is particularly important in order that no information is lost or destroyed without record during the conservation process. Of the object recording and investigating systems proposed by conservators Jaeschke's seven ages of an object (Jaeschke 1996) seeks to highlight the continually changing nature of artefacts, whilst Caple's formalized object construction and use sequence (FOCUS) derives a detailed sequence of events from construction through to its present use, for which there is evidence (Caple 1996).

The study of an artist or craftsman, the work they produced, their materials, technique, the subjects they depict, the style or expression of their work as well as a full appreciation of the time and culture in which they worked can be regarded as connoisseurship (Kirby Talley 1989). Conservators usually have limited time and cannot devote a lifetime's study to a single object, or craftsman. Consequently they use: advice from experts and connoisseurs, existing published information and detailed examination of the object in order to assemble as complete an understanding of the nature of the object as possible. Though the exact details of the object may be initially unfamiliar to the conservator, they will, as a result of their education and experience, have a good background knowledge about the types of material of which the object is composed. To prompt more detailed appreciation of the object two generic systems, which can help make the conservator aware of different aspects of the object as they examine it, are here proposed.

Historic Object Production Sequence: The object is considered as the product of a production process. An object produced from raw materials using the expertise of craftsmen. This alerts the conservator to the skill of an object's manufacture, the materials and facilities required to produce the object and some of the non-visible properties which the object may possess, or which it indicates existed. This approach has similarities to that used by Eileen Hooper Greenhill in her representation 'learning with objects: discussion and analysis' (Pearce 1990, figure 12.4).

Visual Evidence Sequence: The object is considered purely as a source of evidence, focusing on the addition and subtraction of forensic information too and from the object surface. This alerts the conservator for the need to search for, and record all traces of, visual evidence which remains on the object's surface as a result of its manufacture, use, burial and previous conservation activities.

In addition there are a wide variety of analytical techniques, detailed in Section 6.4, which can be used to assist various aspects of these investigations.

Historic Object Production Sequence (HOPS)

Objects are physical manifestations of the thoughts and ideas of a culture. Everything which is created, as opposed to being found, is formed by the action of tools which includes machines (which are in reality complex tools) upon raw materials. The other essential element is the craft or expertise to use the tool or operate the machine. The outcome of this process can be described as the product. This simple classification can be applied to the use of tools such as a carpenter's tools on a piece of wood (raw material) to create a piece of furniture (product). It can equally be applied to less tangible products, thus the blowing of air (the raw material) through a musical instrument (a complex tool) can with the ability of a skilled musician (expertise) be formed into music (product). An author (expert) can, through a pen (tool) paper and ink (raw materials) create a written document (product). Even a machine as complex as a computer uses the raw material of electricity, through the expertise which is the software programme, to calculate or create images or words.

Raw materials	*Tools*	*Expertise*	*Products*
Wood	Carpenter's tools	Joinery	Furniture
Ink, paper	Pen	Ability to write	Writing
Wind	Instrument	Musicality	Music
Electricity	Computer	Software	Images/action
Petrol	Car	Ability to drive	Movement
Coal, water	Steam engine	Ability to operate the machine	Movement
Ingredients	Kitchen implements and cooker	Cookery	Food
Light, film	Camera	Photography	Photograph

Evidence for each of these categories is unevenly represented in the record of the past. A carpenter's tools and even his furniture may survive, but his expertise, his knowledge of joinery, does not survive directly. It must be deduced from the surviving tools and furniture. Where we have survival of the product – such as a painting or a piece of fine furniture – we are familiar with archaeologists or art historians deducing the level of expertise of the artist

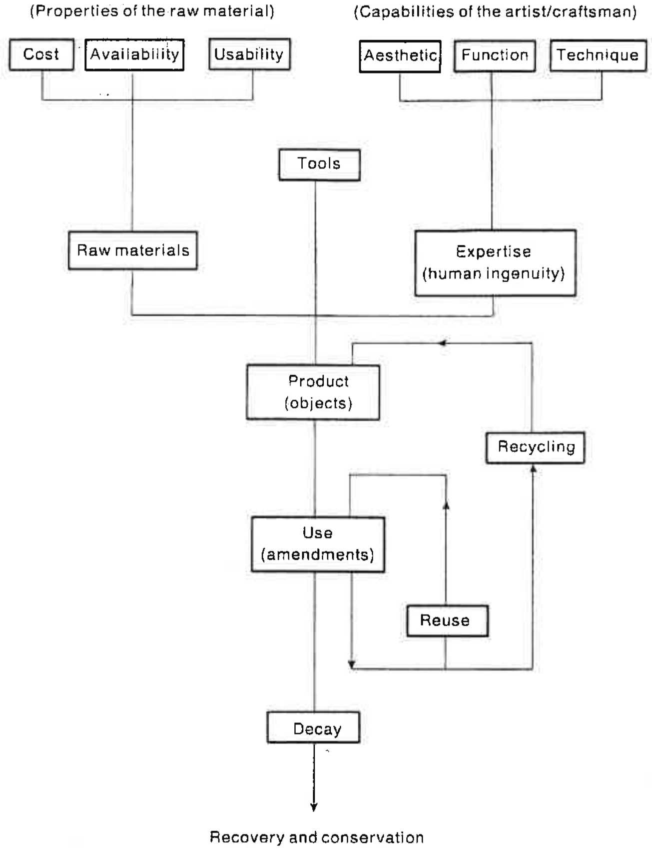

Figure 6.1 Historic Object Production Sequence.

or craftsmen who made the object. Where the product does not survive (e.g. music, or food) the expertise must be deduced from the instruments or tools which remain, such as the surviving kitchen utensils and our knowledge of ingredients which were used. Direct evidence of the expertise is occasionally partially preserved in the form of written description, musical notation and sound, film and video recordings of artists or craftsmen at work, or describing their work. Direct evidence of expertise is extremely patchy until the evolution of mass recording and communication in the nineteenth century. A product can also form raw material for a subsequent process, thus petrol is both the product of an oil refinery and the raw material for movement.

When this holistic view of objects and their genesis is applied in practice (see Figure 6.1), it can be expanded into a fuller sequence of factors which can be explored. With reference to Figure 6.1 we can define:

Capabilities of the artist/craftsman:

Expertise: the sum of the human ingenuity which is used to create the object.

Aesthetic: the non-functional attributes which are given to the object by the artist or craftsman, which make the object notable or appealing to other human beings.

Technique: the abilities which the artist or craftsman processes to transform physical materials into a desired form. It derives from the individual's experience and their knowledge of materials and tools as well as their hand-to-eye coordination. Much of the knowledge an individual possesses is determined by the age and culture in which they live.

Function: the purpose, as understood by the artist/craftsman, which the object is meant to serve.

Properties of the raw materials:

Raw materials: the materials from which every aspect of the object is created, from the pigments used to colour the object to the metal used in the construction of the fastenings in the object. There may be numerous materials used in any one object.

Usability: the properties or physical characteristics of the raw materials selected for use, their toxicity, strength, ease of working, etc.

Cost: the dominant criteria which governs the materials which are selected for creating an object. The material with the most desirable property may well not be selected because of cost. Factors such as cost of creating the material or transporting it to the place of use all affect the cost at the place of manufacture.

Availability: even if a material with the required properties is affordable, if it is not readily available it cannot be used. Often scrap materials which are lying around a workshop are used in manufacture, since they have ready availability and low cost.

Tools: tools can be the simplest objects – such as lumps of stone – through to the most complex machines, which are used to form the object being created. This factor also includes workshop or factory facilities which are used to support the manufacture of the object. The tools and facilities constrain what can be made.

Product (object): the product that is created from the raw materials, using the tools available with the know-how of the artist or craftsman. The product of this process is a specific completed form with function, whether it be movement, sound or has the physical reality of an object such as a chair.

Use: Every action leaves some imprint upon an object. Every use of the object will

induce scratching or wear of its surface, leaving or removing traces of the materials with which it has come into contact. The traces are often so small we cannot detect them, or if detected cannot interpret them. Frequently evidence of later use obscures or obliterates evidence of earlier use.

Reuse: the object retains its basic form but is improved; for example, resharpened or rehafted to allow it to become functional again. This requires input from an artist/craftsman and their associated expertise.

Recycled: the object is reduced to its basic materials and re-formed into a new product; for example, metal is melted and recast. Reused and recycled materials can be involved in the construction of almost any object. The input of recycled material into new objects is determined by similar constraints to those of the raw materials and involves a similar input of expertise from the artist/craftsman.

Eventually the object is discarded, buried, destroyed or taken out of use. If recovered it may then start a new cycle as a product selected for collection and display.

Visual Evidence Sequence (VES)

It is possible to look at objects in many other ways. If an object is examined for the forms of visual evidence derived from the object's surface for the creation and use of the object, eight forms of evidence (A1–D2) in four distinct phases can be identified and recorded for every object.

Manufacture

A1 Material deposited during manufacture and indicative of the technology of manufacture. This includes the material from which the object is made plus traces such as the grit derived from polishing the object or traces of mould material on the surface of a metal casting.

A2 Surface indentations which are caused by the technology of manufacture; for example, tool marks such as punchmarks (Larsen 1987).

Use

B1 Material, sometimes known as ethnic or ethnographic dirt (Oddy 1994), which is deposited on the object's surface from the use of the object or derived from, and characteristic of, the environment through which the object has passed. Examples include: the deposition of a silica sheen on flint implements, food residues found on pots, sweat, urine and faeces on textiles (see Section 7.2). There can be a series of periods of use and alteration. This is most clearly seen in the painted interiors of houses where cross-sections through paint layers can reveal a complex series of repaintings. Layers of dirt particles are often seen to accumulate on any surface which is exposed for a long period. Some regularly applied substances such as leather dressings are adsorbed into the substrate of the material and thus, though present as a record of the use and care of the object, cannot readily be detected.

B2 Damage to the surface of the object caused by wear, or scratches which are related to hard materials impinging on the object during use. These may be hard materials – such as the grinding wheel used to sharpen an axe – or persistent use of soft materials which wear away or polish an object's surface. Such wear marks reveal how clothes were worn or stone axes were hafted. The wear patterns in shoes can reveal the diseases of the feet.

There can be numerous phases of use, repair and reuse.

Decay

C1 Materials accreted during decay: dust, dirt, soil particles, corrosion minerals (e.g. as mineral-replaced organics, see Case study 6A). Such deposits potentially provide information about the burial or storage environment.

C2 Materials lost during decay, especially noticeable in terms of the loss of metal during corrosion or organic material during microbial decay. Such processes lead to considerable loss of evidence of use and manufacture.

Conservation

D1 Materials deposited during the conservation processes such as coatings used to stabilize or protect the object. It is possible to regard the writing on the object of a museum number as a process for the preservation of the object and its associated information.

D2 Traces of processes such as cleaning or repair which result in some form of loss or damage to the object.

Visual evidence of manufacture, use, decay and conservation is present on almost every object's surface. This emphasizes the importance of retaining the original surface of the object (see Section 7.4).

6.4 Scientific analysis

The materials and construction of the object and the decay processes and products of the materials are determined through various analytical, microscopic, imaging and dating techniques in order that:

- The correct conservation treatment will be used to safely arrest the decay of the object and minimize any risk of damage to the object in application of the conservation treatment.
- To confirm the date or cultural affinity of the object. If there is a mismatch between the materials and construction methods used and the envisaged date and cultural affinity of the object, fakes can be discovered (see Case study 2A).
- To add information to the body of knowledge about ancient materials and technology or the materials and technology used by a particular craftsman or artist.

Analysis would be necessary in the case of an unidentified white metal disc since it could be

made of silver or its alloys, iron, aluminium, lead, nickel or its alloys, tin or its alloys, zinc, platinum or even some gold alloys. The resistance of that metal object to decay and its importance as a piece of historic information could vary enormously depending on the metal of which it was made. For example, in the early nineteenth century Napoleon had medals struck in aluminium since it had a higher value than silver. It would also potentially affect the conservation methods and chemicals used to stabilize a decaying object.

Prior to commissioning or undertaking analysis the conservator should consider whether:

- There is a sufficiently good reason (i.e. supporting the conservation aims) for doing the analysis which justifies the expense. Analysis is costly and time consuming.
- The analytical method selected can provide the information required.
- The importance of distinguishing between qualitative information; the presence or absence of a particular element, and quantitative information; the amount of an element present. Quantitative information is more difficult and consequently expensive to obtain.
- The conservator has the ability to understand and interpret the information that is obtained. This usually requires detailed background knowledge and comparative samples or data against which the unknown can be compared. Therefore, it is often as important to get comparative data or expert advice and interpretation as it is to get the initial analyses. There may be several explanations for any particular observed analytical phenomena. For example, the detection of titanium in a rosy pink-coloured painted decoration. Titanium is a naturally occurring impurity in iron oxides and could be present as an impurity or it could be present as titanium (dioxide) white, a strong white pigment mixed with a red to form the pink. In such cases the quantity of titanium involved and/or its mineral form need to be determined to resolve the question.
- The object has a date and cultural context, since this fundamentally affects the interpretation of the analytical information. For example, titanium white was only commercially available after 1918 (Laver 1997). If the object is of pre-twentieth-century date it could be a fake or have later added decoration.
- There are reasons for not examining, sampling or analysing an object. This may be due to an excessive level of damage which would be caused to the object or because of ethical constraints (e.g. where it is inappropriate to damage or otherwise desecrate a sacred object).

Instrumental Analytical Methods (elemental and molecular): Conservators should be familiar with a range of scientific analytical techniques (Pollard and Heron 1996; Skoog and Leary 1992) and their application to conservation (Bromelle and Thomson 1982; ICOM-CC 1993; ICOM-CC 1996).

For analysing metal-corrosion products and minerals, such as pigments, the crystalline properties of the material is the most useful attribute of identification; therefore, X-Ray Diffraction (XRD) is appropriate. There is increasing use of Fourier Transform Infra-Red Spectroscopy (FTIR), which characterizes interatomic bonds, for mineral identification. Because of the large volume of existing information, elemental composition is the most useful form of analysis for metals, glass and ceramics. A wide range of analytical techniques can be used for this. Some of the most common include Energy Dispersive X-Ray Fluorescence (EDXRF), Energy Dispersive X-Ray Analysis (EDX) (invariably mounted as part of a scanning electron microscope), Atomic Absorption Spectroscopy (AAS) Proton Induced X-Ray Emission (PIXE), Induction Coupled Plasma Emission Spectroscopy (ICPES) and Induction Coupled Plasma Mass Spectroscopy (ICPMS). Many of these techniques especially ICPMS and ICPES can detect trace amounts of elements (ppm). Such information can occasionally be used for characterizing the origin of raw materials as a result of the unique occurrence or level of trace elements present. Detecting major and minor element concentration is usually most crucial to conservators; for example, detecting the colouring elements and overall composition of glasses and enamels.

For analysing organic molecules such as 'plastics', dyes, binding and coating media, techniques which determine molecular properties can be used. Such techniques include Mass Spectrometry (MS) which determines molecular weight, High Performance Liquid Chromatography (HPLC) or Gas Chromatography (GC) which determines molecular weight and chemical affinity, Ultra-Violet, Visible, Infra-Red (UV/VIS/IR) spectroscopy or Fourier Transform Infra-Red Spectroscopy (FTIR) which determines molecular bonding. The degradation of materials can make the results of any organic analysis difficult to interpret. It is also possible to test for specific elements or molecules using wet chemical tests and there is increasing use of bioassay techniques to detect the presence of specific complex organic molecules such as enzymes or specific micro-organisms. Thermal-analysis techniques such as Differential Scanning Calorimetry (DSC) or Thermo-Gravimetric Analysis (TG) are increasingly used to resolve the structure and nature of complex compounds whilst techniques such as pyrolysis, GC and MS are useful in identifying the composition of complex organic molecule mixtures.

Conservators should be cautious about the analytical data they receive. They have to judge whether the information provided by the analyst is meaningful and if so what it means.

- The apparent accuracy of many analytical techniques which may quote figures to two decimal places may be illusory since, for certain elements or molecules present in low concentrations, the system may only analyse to an accuracy of ± 20 per cent.
- The operating conditions and sensitivities of analytical instruments can vary enormously. It is important to be aware of the sensitivities and abilities of the analytical system being used.
- The minimum detectable limit of the element, mineral or molecule being analysed should be known. This will ensure that non-detection is not necessarily interpreted as absence; for example, XRD systems may require over 5 per cent of a mineral in crystalline form before it can be detected.
- Some techniques cannot, because of their analytical method, detect certain elements (e.g. Neutron Activation Analysis (NAA) cannot determine lead content), whilst others such as Atomic Absorption Spectroscopy (AAS) only determine the elements they are set up to analyse.
- An element can be present in many different forms (species). For example, copper may be detected in a liquid as metal particles in suspension, as an oxidized mineral form (e.g. $CuCO_3$ in suspension), as a reduced mineral form (e.g. Cu_2O in suspension), dissolved in solution as a soluble ion Cu^{2+}, held in the form of a sequestered complex or deposited in some form against one of the sides of the vessel.

- There is often a need to combine techniques to ascertain a complete picture. For example, to determine the amount and nature of the minerals present in a waterlogged chair it was found to be necessary to ash the samples to determine the total amount of mineral present, to determine the mineral forms through XRD and to determine the elemental composition, quantitatively, using EDXRF (Caple and Murray 1994).
- It is important to ensure that the samples and the analytical equipment are not contaminated since this can lead to misleading results. This should always be checked by running a blank or a control sample of known composition.
- It is important to be aware of natural background levels. Many elements are present in small quantities in the soil, groundwater or atmospheric dust. The level detected must be significantly above background levels in order to have any meaning.
- Samples from archaeological or historic objects are often aged, dirty, oxidized and degraded. They consequently rarely provide simple clear analytical results. Many analysts will not have analysed samples similar to those provided by the conservator and can have difficulty interpreting the results.

Consequently it is essential that conservators are familiar with the capabilities of various analytical techniques and ask sensible questions to which these techniques can provide an answer.

Visualization and imaging: Many visually observed features, structures and patterns are uniquely created by specific tools or manufacturing techniques. Examples of such informative structures include weave details on textiles, laid lines of paper, jointing in wood and the jointing and fabrication methods of manufacture in metal. This form of examination can be extended through enhancing the range of visualization:

- X-radiography. This will reveal changes in the thickness and density of materials enabling features such as: iron objects buried in a mass of corrosion; wormholes and other structural features in wooden objects; earlier images under paintings; and incised designs or decorative metal inlays in corroded, dirty or overpainted metal to be seen (Gilardoni *et al.* 1994; Graham and Eddie 1985; Lang and Middleton 1997).
- Infra-Red Reflectance Imaging. Many minerals and polymers differentially reflect or adsorb infra-red radiation. This has led to the use of infra-red photography for visualisation of paintings to detect under drawing and earlier images beneath the visible latest image (van Schoute and Verougstraete-Marcq 1986; Walmsley *et al.* 1992).

Features observed in 2-D images, such as X-radiographs, are interpreted by the conservator as 3-D images. It is important to seek additional evidence for such interpretations since there are often several possible explanations for features seen on X-radiographs and other 2-D images.

The visual qualities of a material are only one of a large number of physical attributes which it possesses including density (weight), smell, surface texture, hardness, elasticity, drape, reflectance, magnetism, even taste. Through their experience, or comparison with known 'hand specimens', conservators can often successfully identify the materials of which an object is composed, using these attributes.

Microscopy: Many materials are best identified and examined through microscopy which reveals unique visual aspects of their microstructure, enabling their characterization. Wood species (Schweingruber 1978), leather (British Leather Manufacturers Association 1957), vegetable-based fibres (Catling and Grayson 1982), animal-based fibres (Appleyard 1978), pollen (Moore *et al.* 1991), pigments (Feller 1997; Roy 1994), paint cross-sections (Byrne and Cook 1976), dust (McCrone and Delly 1973) and metals (Scott 1991) can all successfully be identified by the conservator with suitable microscopy training. In many cases (e.g. metallography) aspects of the preparation and processing of the materials can also be identified.

There are also many small but important features detected through optical microscopy which relate to use and wear on an object. For example, microscopic examination of a series of Roman boxwood combs revealed the presence of nits, hair lice which infect the human scalp, thus graphically revealing the need for the use of the comb and problems of life in Roman Britain (Fell 1996). Some materials reveal their structure at higher magnifications and with greater depth of field; for these a scanning electron microscope is becoming a standard tool of investigation (see Figure 6.2). Mineral-replaced organic materials (Janaway 1984, see Case study 6A), the wear on tools (Olsen 1988) and the unique marks of tools such as punches (Larsen 1987) have all been effectively identified through this technique.

Identification of materials can enable us to recognize the beliefs of past peoples, the aesthetic considerations of human experience in a historic-object production sequence. Work by McGhee (1994) showed that the pre-Inuit, Thule Culture peoples of northern Canada, used harpoons and ice knives primarily made from ivory (seal or walrus) whilst their arrowheads were made from caribou antler. These materials were selected not for their physical properties, but for their magical sympathy with intended use. This belief system which correlated sea-mammal ivory with winter, women and the sea and antler with men, the land and the summer, also carried on into the verbal traditions of the later Inuit peoples.

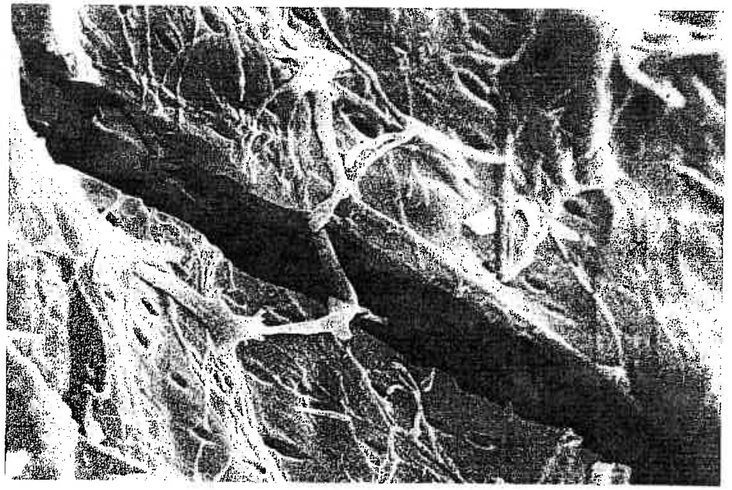

Figure 6.2 Scanning electron micrograph of the charcoal of the timber beams from the neolithic long barrow at Haddenham, Cambridgeshire, showing infestation with both neolithic and modern fungi (photograph by the author and Will Murray).

Dating: The dating of an object is usually undertaken by:

- Typological comparison of its form or decoration with a known series of objects or artistic style or movement.
- The object coming from a known dated context.
- Identification of a material in the object which was introduced or abandoned by a given time period.
- A historic record of the object with either written or visual record; for example, its presence in an oil painting or recorded as the property of a known dated individual.
- Attribution to a known artist or craftsman.

Almost all objects have their date derived through comparison with examples of similar objects from a known culture and date, or they were retrieved from a specific cultural context. Occasionally objects are dated through scientific means. This usually applies to archaeological objects more than 400 years old. Where objects are composed of carbon they can be dated through radiocarbon-dating techniques, or if composed of ceramic or stone which has been heated they can be dated by thermoluminescence (Aitken 1990). Objects of wood, particularly oak, can if they have more than fifty growth rings be dated through dendrochronology (Baillie 1995).

Sampling: True non-destructive analytical techniques are extremely rare. The surface layers of most objects have reacted with the surrounding environment, fundamentally altering their composition; for example, water vapour and oxygen react with metal surfaces to produce an oxidized mineral layer (see Figure 6.3). This may not be detectable to the naked eye but non-destructive techniques, such as EDXRF and reflectance mode FTIR, only analyse the surface composition of the object and thus the result obtained is not necessarily representative of the body of the object. It is misleading to present it or regard it as such. If the conservator wishes to extract typical composition information about an object it will invariably need to be sampled. It is a matter of careful judgement as to the extent to which the visual and structural disruption of the object is acceptable in order to obtain the sample (Roy 1998). In some instances it is not appropriate to sample as the visual damage is not worth the information gained. For some 'low value' objects, of which there are numerous examples, it is worth sacrificing a whole object for the complete and accurate information which can be gained (e.g. the metallographic examination of some of the nails from the Roman fort of Inchtuthil since over 5 tons of nails were recovered). In several cases, such as the Leonardo cartoon (see Case study 13A), existing damage could be utilized to provide a microscopic sample for analysis, information essential to understand the structure of the object and ultimately to lead to its successful conservation. In most cases the samples removed are so small as not to be visually disruptive (e.g. the removal of a few fibres from a textile). Where there is visual disruption, such as when a sample is removed from a neolithic stone axe for petrographic identification, it is possible to restore the missing area.

Almost all major works of art, and even sacred objects such as the Turin Shroud have been sampled; small fragments sacrificed for analysis in order to increase our knowledge

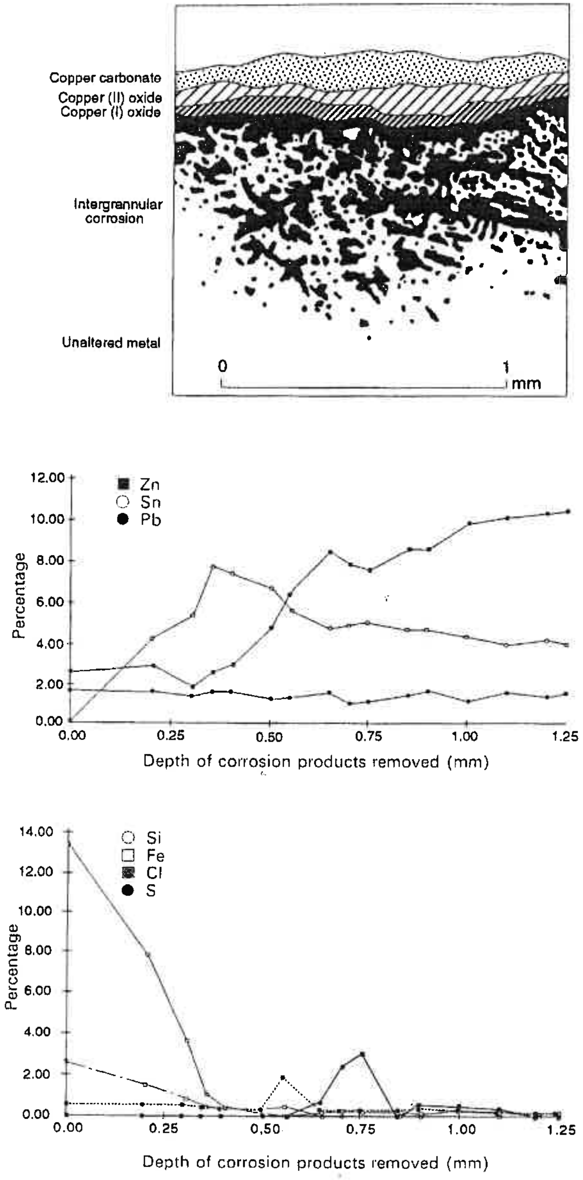

Figure 6.3 Cross-section through copper corrosion (redrawn by Y. Beadnell from Dungworth 1995). Over 1 mm of corrosion crust must be removed before the true copper alloy composition is detected.

about the object. When undertaken it is essential that such sampling is kept to a minimum to avoid any unnecessary damage to the object.) All the information produced must be made available, usually in the form of a report, so as to minimize or eliminate the need for any further sampling. Samples should be carefully stored for potential future reanalysis. The samples and materials removed from an object remain the property of the owner of the object unless specific permission has been given for disposal of these samples and materials (Jaeschke 1996). Wherever possible samples should remain associated with the object or its record and they should always be clearly labelled.

Reporting: Any analytical or dating work which was undertaken as part of the conservation work should be reported to the curator/owner of the object. The report should:

- Describe the object and indicate from where the sample was removed.
- Describe the analytical method used, indicating the accuracy and precision of the method used. Any sample preparation techniques used should also be described as well as any data manipulation and standards used to obtain the analytical data.
- Present the data.
- Interpret the data with reference to comparative analyses.
- Present conclusions drawn from this analytical work.

Consideration should always be given to making the information available to a wider audience. This may mean direct publication or release of the information to individuals who could publish it with larger collections of data at a later date.

How far the conservator goes in recording and analysing an object is always a matter of judgement. Awareness of the nature and uses of the conservation record and balancing the limitations and cost of analytical techniques against the usefulness of the information which can be obtained should lead to justifiable decisions regarding recording and analysis.

6A Case study: Benwell Box (Keepax and Robson 1978)

During the excavation of the Roman villa of Benwell a corroded mass of iron fragments, which were the fittings of a chest or box of second-century-AD date was discovered. The archaeologists and conservators on the excavation judged that that there was considerable potential for gaining further information from this concreted mass and, therefore, decided to lift and carefully excavate it back in the laboratory. The mass of corroded iron and soil was carefully isolated from the surrounding soil, covered in aluminium foil and after a wooden crate had been inverted over this, the gap between the foil covered corroded mass and the crate was filled with expanding polyurethane foam. The corroded mass was detached from the soil beneath and carried away, safely held in its wooden crate, to the conservation laboratory. The soil and corroded iron mass was X-rayed and slowly excavated. No traces of the wood of which the box had originally been composed were recovered. Only the iron nails, corner clamps, straps and hinges remained.

When iron corrodes, it releases ferrous ions into solution. These subsequently oxidize to form ferric-oxyhydroxide minerals (rust). If iron corrodes quickly in

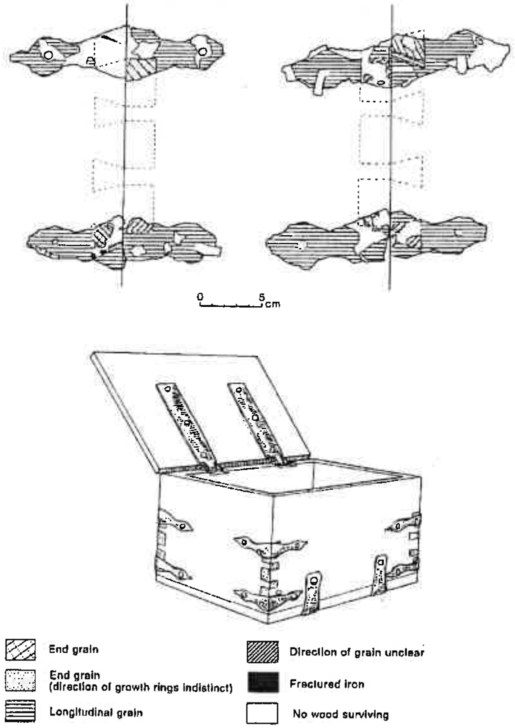

Figure 6.4 The Benwell Box (redrawn by Y. Beadnell from Keepax and Robson 1978). The evidence of the direction of the mineral-replaced wood permitted the original nature of the joints of the box to be deduced and thus an accurate reconstruction of the box to be created.

association with organic material the iron minerals which are formed can be deposited:

- Around the organic material forming a 'cast'. Eventually the organic material, such as wood, textile, leather, skin, horn or bone, will degrade leaving this impression of the decayed organic material and its structure.
- Inside the organic material replacing it as it degrades. This forms an exact copy or 'pseudomorph' of the organic material.
- In both 'cast' and 'pseudomorph' forms.

Such deposits are known as mineral-replaced organics or mineral-preserved organics and they can reproduce all the microscopic aspects of the structure of the organic material (Keepax 1975). This occurred on all the iron fittings of the Benwell Box.

As a result of not cleaning off the rust from the iron fittings of the box and by observing the traces of mineral-replaced organics present on the fittings it was possible to deduce information about the type of wood and the nature of the construction of the box. From the microscopic examination of the microstructure of the mineral it was possible to identify oak (genus *Quercus*) as the wood used for the whole box. By noting the depth of the wood grain on the nails and the length of the nail shank before the points were bent over it was clear that the base board of the box was 22 mm thick, whilst the sides were 25 mm thick, as was the lid. From noting the direction of the wood grain on the corner clamps it was possible to deduce that the four pieces of wood forming the sides of the box were held together with dovetail joints, which in size and shape conformed well to modern carpentry practice. These traces indicate the high level of expertise of the craftsman who constructed this object. The dovetail joints were only used for joining the lower half of the sides of the box; the upper half was a mitred joint. The careful lifting of the mass of soil and corroded iron fittings had preserved the iron straps which ran from the front of the box all the way to the top of the back of the box. These appear to have formed the hinges which ran beneath the lid of the box. The exact dimensions of these straps allowed the height and depth of the box to be established, whilst the positions of the corner clamps which had also been preserved through the careful lifting allowed the approximate width of the box to be established.

Careful examination and recording allowed the preservation and decipherment of the traces of mineral-replaced organics and allowed an accurate reconstruction of the original box to be created (see Figure 6.4). The crucial judgements were the recognition of the potential of the object to reveal information, the use of X-radiography and microscopy to examine and identify the mineralized fragments, the decision not to clean off the evidence, reference to the expertise of others in order to identify the nature of the carpentry techniques involved. The careful recording of this object has subsequently formed a useful reference point for examples of corroded iron fastenings which have been subsequently unearthed.