Objects

Reluctant witnesses to the past

ChrisCaple

Routledge
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Objects

Objects: reluctant witnesses to the past provides a brilliantly clear and comprehensible guide to the different methods and approaches (cultural, scientific and technical) which can be and have been used to study ancient artefacts.

Packed with case studies and examples, from the Bayeux Tapestry to small medieval brass pins, Chris Caple's integral text deals with a full range of materials, from medieval wooden doors to Saxon jewellery, and clearly and simply explains key scientific techniques, technology, anthropological jargon and historical approaches.

He demonstrates:

- how information from objects builds into a picture of the ancient society that made and used them
- the commonly used scientific techniques for object analysis
- how and why object typologies work
- how cultural and economic factors as well as the material properties influence what objects are made of
- how simple observation of an object can build its biography.

Revealing answers to crucial questions such as: Can DNA be obtained from objects? Why do people X-ray ancient artefacts? And can you determine the source of metal objects from their trace elements? *Objects* is an absolutely essential text for students of archaeology, museum studies and conservation.

Chris Caple is Senior Lecturer in archaeological science and conservation at the University of Durham and author of *Conservation Skills: Judgement, Method and Decision Making.*

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Preface

We understand and identify the present through the objects that we and others use every day, the possessions with which we surround ourselves. My car is a functional object that gets me from A to B, but it also identifies the century in which I live and the material culture/society to which I belong. Attributes such as the size, model and colour of my car, plus its accessories and contents, demonstrate my personal taste and wealth, or lack of it! Objects are a reflection of the society and the individuals who make, own and use them; a physical representation of our desires within the limitations imposed by technology, economic circumstances and social acceptability. Objects also indicate the use we make of them. Every scratch and bump on my car tells a story of how good or, more accurately, how bad a driver I am. People in present-day society are familiar with cars, the different makes and models, their prices and reputations, even collision damage, so that when they see my car they can 'read' it. They quickly gain an idea about my wealth, status, aspirations and driving ability.

Ancient objects can similarly say much about the lives of the people of the past. However, if we are to 'read' them correctly we need to gain as much information about them as we can, and we have to know what that information means; what represents luxury and what economy. Gaining this information and understanding it is not always a simple matter. Objects are reluctant witnesses to the past; they have to be questioned carefully and closely if they are to provide accurate information. Objects are enormous potential sources of information: who made them, when they were made, what from, what they meant or symbolized, what function they performed, how they were altered and reused, how they were damaged, why they were discarded or buried. They potentially contain evidence about every facet of their creation, use and disposal.

This book aims to demonstrate how archaeological and historic objects have been and can be investigated. It explores a range of different techniques for analysing artefacts, from visual analysis and typological classification to molecular, elemental and isotopic composition. It demonstrates, through a number of case studies (Table 0.1), how the information recovered from objects is built into a picture of the object's past. It also shows how these facts are combined with other sources of information to provide a wider picture of past societies, and in particular how they made and used objects.

Table 0.1 Case study attributes

Section no.		*Case studies*			
	Section	*1.11*	*2.11*	*2.12*	*3.12*
	Object type	*Helmet*	*Embroidery*	*Portrait*	*Pins*
	Principal material(s)	*Iron and brass*	*Textile*	*Paint and canvas*	*Brass*
1.7	Scale of production[a]	h	w	h	f
2.3	Typology	x			x
2.4	Images		x	x	
2.4	Decorative motifs	x	x		
2.5	Text	x	x		
2.6	Context[b]	d	s	s	
2.7	Colour: pigments, dyes, paint		x	x	
2.7	Surface coating				x
2.8	Movement of ideas/artist[c]			e	
3.1	Origination[d]	c	c	c	r
3.2	Materials: property	x			x
3.3	Materials: culture	x		x	x
3.4	Materials: economics		x		x
3.4	Recycled materials				
3.6	Tool marks				x
3.7	Assembly	x	x	x	x
4.2	Object traded[c]				e
4.2	Materials traded[c]	e			
5.2	Surface deposits				
5.3	Wear use and damage	x	x	x	x
5.3	Fragmentation				
5.4	Repair	x	x	x	
5.5	Decay[e]	b		n	b
6.1	Heirloom	x	x	x	
6.2	Dating: scientific (^{14}C, dendro)				
	Dating: archaeological	x			x
	Dating: stylistic	x	x	x	
6.3	Fake				

Notes

x = a factor clearly observable on this object

a Scale of production: h = hand-made, w = workshop, f = factory

b Context: is = in situ, g = grave, d = discarded, s = another context similar to the original

					Figures	
4.8	*4.9*	*5.8*	*6.7*	*6.8*	*Figure 2.7*	*Figure 3.4*
Pendant	*China*	*Reliquary*	*Mirror*	*Door*	*Brooch*	*Sword*
Gold	*Ceramic*	*Wood and metal*	*Lacquer and metal*	*Wood and paint*	*Copper alloy*	*Iron*
h	f	h	w	h	w	w
x	x				x	x
	x	x	x			
x	x	x	x		x	
	x					
g		d	s	is	g	g
	x		x	x		
		x			x	
	w				e/w	
c/r	r	c	c	c	c/r	c/r
x	x		x	x	x	x
x	x	x	x		x	
x						
x		x			x	
				x		
x		x		x		x
	w	e?				
e		e?		r		
x		x		x	x	x
						x
x				x		
		b	b		b	b
x						
				x		
x		x			x	x
x	x	x		x	x	x
			x			

c Movement of ideas/artist, traded objects or materials: r = regional trade, e = European trade, w = world trade
d Origination: r = made for retail, c = commissioned
e Decay: b = exhibiting the effects of burial, n = exhibiting the effects of neglect

To aid the recovery and presentation of information this book has been laid out in a series of chapters which are based on pragmatic questions that can usefully be asked of objects similar to those identified by Pearce (1994a: Figure 18.2) and that cut across the arts–science divide.

- Form, decoration and depiction (What is it and from which period/culture does it derive?)
- Manufacture (How was it made and what was it made of?)
- Trade in objects and materials (Where was it used, where was it made and from where did its component materials derive?)
- Function (How and why was the object used?)
- Record (Is it genuine? How and what does the object tell us about the past?)

Previous authors have tended to focus on specific areas of academic study:

- the anthropology of artefacts (Schiffer 1987, 1999; Hodder 1982; Appadurai 1986; Dobres 2000),
- the scientific analysis of materials (Brothwell and Pollard 2001; Scott 1991; Lang and Middleton 1997),
- studies of technology (Hodges 1964; Strong and Brown 1976; Blair and Ramsay 1991),
- studies of particular periods or cultures (Clarke *et al.* 1985).

This book seeks to focus on the objects themselves, taking the position of the archaeologist, curator or conservator confronted with an object and considering the different approaches to object study that can be taken, analytical techniques that can be used, and the types of evidence that can be obtained.

Chapter 1

Investigating objects

Theories and approaches

1.1 Definition of objects/artefacts

> Strictly, every piece of evidence of early human activity should be categorized as an artefact.
>
> (Biek 1969: 567)

The word 'artefact' is derived from the Latin terms *ars* or *artis*, meaning skill in joining, and *factum* meaning deed, also *facere* meaning to make or do (Prown 1993: 2). Thus an artefact can be considered to mean any physical entity that is formed by human beings; from a nail to the building it is in. The term 'object' is also widely used to refer to any physical entity created by human beings. It depends on the age, origin and academic orientation of the author as to which term is used. For the purpose of this book, the terms 'artefact' and 'object' are used interchangeably, and whilst references are made to buildings and paintings, the focus is on the types of archaeological and historic objects found in museum displays.

Artefacts are one of the principal methods by which we communicate and mediate with the world around us, Schiffer (1999) suggesting that the constant use of large numbers of artefacts is the principal difference between human beings and animals:

> … never during a person's lifetime are they not being intimate with artefacts.
>
> (Schiffer 1999: 3)

Human beings are sociable animals who are invariably grouped into societies. These share non-biological aspects such as 'knowledge, belief, art, morals, law, custom and many other capabilities and habits' which we can describe as culture (Tylor 1871, in Renfrew and Bahn 1991: 9), the physical remains of which are referred to as material culture. Studying the artefacts of a material culture can inform us about the individuals and societies that created and used them; however,

> … the relationship between material culture and the people who produce it is a complex one.
>
> (Hodder 1991: 2)

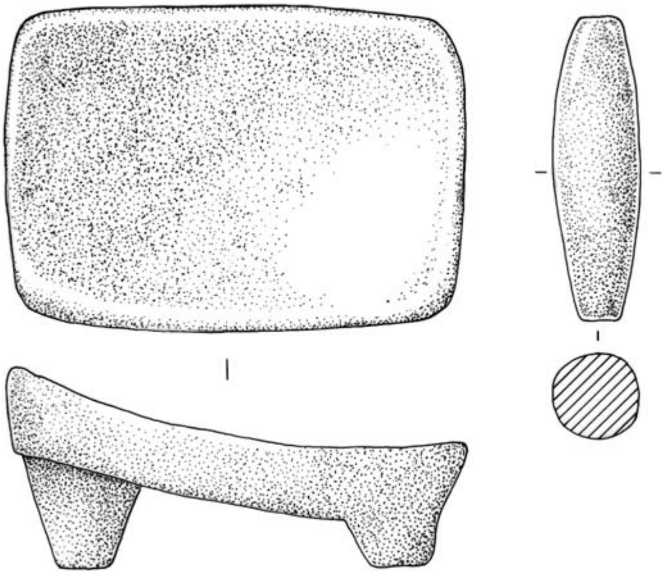


Figure 1.1 *Metate* and *mano*: Mesoamerican maize grinder. (Drawn by Yvonne Beadnell)

1.2 Objects in the present

Modern anthropological studies have provided models for the way in which human societies make and use objects. They usually consider artefacts as part of economic systems, belief systems (religion), wealth display and social ranking (Ember and Ember 1996). However, fieldwork tends to provide examples of object production and the economic, practical and cultural constraints of object use. A good example is provided by the work of Horsfall, Hayden and others in studying the use of grinding stones in contemporary Mayan peoples of Central America (Hayden 1987; Horsfall 1987).

The staple food of the peoples of the Mayan Highlands of Central America is maize flour, ground wet on grindstones, present in most houses of traditional communities such as the village of San Mateo. The lower grindstone (*metate*) is rectangular in shape, often with three small projections or feet at its base (see Figure 1.1). The upper surface is inclined between four and forty degrees, though most usually ten to twenty degrees, up from the horizontal. There is a slight raised rim around the edge of some stones. The upper grindstone (*mano*) is roughly cylindrical, of slightly larger diameter in the centre than at the edges; in many cases the *mano* is slightly wider than the *metate* (see Figure 1.1). Many features relating to the material selection, production and use of these objects could be noted:

- Though the local geology is limestone, 100 of the 120 grindstones were made of vesicular basalt. This imported stone is particularly efficient at grinding maize, the vesicular structure giving an efficient cutting action. It is a hard rock and so does not wear away quickly. The basalt is preferable to other hard rocks such as quartzite or conglomerate, because they gradually break up, producing grit in the flour. Basalt wears away very slowly as a fine powder, thus no grit in the flour. The preference for hard igneous rocks for grindstones is seen throughout Central America, with rocks such as andesite, granites and basalts being traded up to 250 miles from source to point of use.

- The grindstones cost approximately 3.6 per cent of the median annual income; the same level of investment as a small car in Western European societies. Consequently similar levels of concern over the cost-effectiveness, working life, etc., may be expected. There are black and white varieties of basalt grindstone: white is softer, lasting about 15 years; the black is harder and longer-lasting, consequently it is more expensive.
- The design of the grinding stone is very practical and highly evolved for its function. The three projections, legs on the base of the *metate*, allow it to be used on any surface; flat bases or four legs would wobble on all but flat surfaces. The angled upper face allows the most efficient grinding action: if flat, it is difficult or energy-sapping to pull the stone back from its farthest extent. If it slopes too steeply, the user crushes the maize rather than grinding it. The ten- to twenty-degree slope is the most efficient. The raised lip at the edge prevents material being spilt out of the side. The *mano* is wider than the *metate* so that people do not trap their fingers between the two.
- Smaller grindstones are generally used for herbs or coffee-grinding, though some families use the same one for grinding all foods, and some use old maize grinding stones for grinding other materials. Larger ones could be used for washing clothes, and were often found near water sources. Thus the size gives some indication of use, though reuse of old stones and the variations in the type of use lead to a natural variability which partially obscures the size/use relationship.
- Grinding stones were present in all but a couple of houses in the village: those households without one were usually single adults who returned to their parents' house to eat.
- If houses had several grinding stones, they either had different uses, or there were several women in the household, or stones were being stored. Grindstones, unless stored, were present in the kitchen/living rooms, the working areas of the house.
- Earlier pre-conquest household grinding stones were often simpler shapes and softer rocks. The tripod, inclined rectangular form was more often seen for ceremonial uses. However, the conquest brought the use of iron/steel, which allowed stone to be quarried and shaped more easily. Consequently the more efficient and effective shape could be made more cheaply and became more widely available.
- The level of use of stone grindstones in San Mateo was high, as was the level of use of traditional herbs, traditional religious practices and communal activities. In a similar village, Aguacatenango in Mexico, there was far less use of stone grindstones; metal grinding mills, some electrically driven, were more popular, though

> they did not last as long as the stone grindstones. There was little use of traditional herbs; traditional religions had been forsaken for Christian, principally Catholic, beliefs; and there were far fewer communal activities. The stone grindstones appear to be part of a larger cultural tradition. A newer series of cultural objects and beliefs has now developed at Aguacatenango: the older material culture and traditions remain in San Mateo.

The form of the grinding stones was primarily derived from function, though a historical/cultural tradition favouring that design was evident. This led Horsfall (1987: 370), to comment: 'Social tradition too seems to have an influence on form within the limits allowed by functional and technological constraints.'

This information was obtained through direct observation of the use of the object, its manufacture, the selection of the raw materials and its reuse. It was seen in its context – its place of use, surrounded by associated items as part of a complete cultural assemblage. It was possible to talk to the makers and users of the object to discover their reasons for making, shaping and using the object as they did. Large numbers of the object were available to study, so that 'normal' manufacture and use was distinguishable from the unusual. Variations in form, material, use, etc., could be correlated with subtle cultural and social differences. Many of these types of evidence are not available when studying objects of the past, where only fragments survive and there are no manufacturers or users to reveal the reasons for the object's use, manufacture or reuse.

1.3 Objects of the past

The simplest objects are natural materials such as animal bones, which bear the cuts from flint blades used for removing flesh or skin from the animal. The largest and most complex are buildings such as a cathedral, or machines such as an aircraft carrier. Objects form the material culture; the physical remains by which almost all ancient societies are defined, though it is not always an easy matter to identify an object. Stones with smoothed or worn faces can be formed in a stream, on the seashore or beneath a glacier; however, other examples are man-made and form some of the simplest objects studied by archaeologists. Examples of such stones are hone stones used for sharpening metal blades, a number of which were recovered from the thirteenth-century medieval castle of Dryslwyn in west Wales, (see Figure 1.2). A number of factors went into the identification of these particular stones as hone stones and not natural fragments of rock. These included:

- The size and shape to function efficiently; large enough to be useful for sharpening a blade, small enough and conveniently shaped to hold.
- The material of the stone. Soft or glassy stone would not sharpen a blade, only hard vesicular stones such as sandstones are effective for sharpening.
- The smoothing or wear which is characteristic of blade sharpening. Microscopic traces of metal may be found in the polished surface.

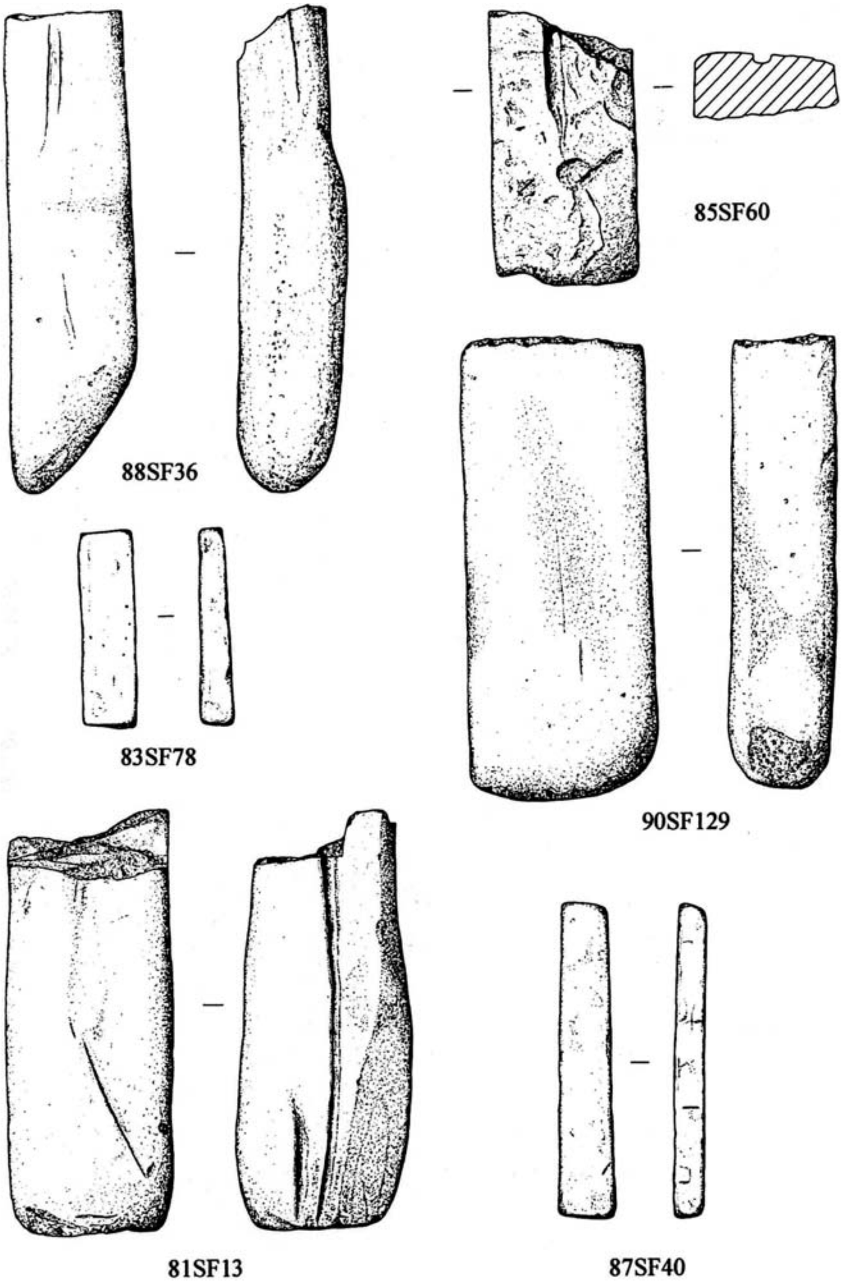


Figure 1.2 Hone stones from Dryslwyn Castle, Wales. (Drawn by Oliver Jessop)

- Comparison by shape, material, size and wear with hone stones recovered from other sites.
- The context of the object – the location of these stones, in a castle, a site of human habitation to which stone had been brought by human agency, not an uninhabited Welsh hilltop of natural weathered stone.

Scientific examination of potential hone stones through techniques such as thin-section petrology (see section 3.12) could provide further confirmation through the identification of the stone type. This could indicate its efficacy as a hone stone and potentially even its origin and thus the extent of trade. Blaunstein Ragstone, for example, was deliberately quarried and shaped into hones in Norway and traded throughout northern Europe in the medieval period, since it was a highly effective stone for metal sharpening. However, it is initial identification, invariably made on the basis of size, shape, type of stone and form of the wear, that normally determines the retention and identification of pieces of material as objects. Scientific analysis usually tells you why.

1.4 Theoretical approaches to objects

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 objects has been the subject of considerable study (Appadurai 1986; Dobres 2000; Hodder 1982, 1987; Miller *et al.* 1991; Schiffer 1972, 1987; Pearce 1994a). In the nineteenth century, Pitt Rivers and other archaeologists initially interpreted objects as having a simple functional role, the form and construction of the object being indicative of the technological development of the society that made and used the object. The work of twentieth-century anthropologists such as Malinowski and Radcliffe-Brown showed that complex social structure was invariably reflected within objects (Leach 1994). Twentieth-century archaeologists have shown that social and personal beliefs are expressed in the 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 which the object was composed have complex meaning and symbolism (McGhee 1994) as well as functional requirements.

The needs of society or the individual determine why a given object is created. Technology is the practical interaction of human/social need with the physical world. As one progresses beyond the basic needs of the individual, society provides the impetus for technical development. Dobres (2000) building on the work of Mauss suggests that all actions, even walking, are learnt through observation and copying those around us. Consequently the way in which people walk, throw a spear or eat a meal is different and discernible between different societies/cultures. Since all technical processes invariably involve a repetitive sequence of actions (*chaîne opératoire*), (Dobres 2000: 154), technical processes are fundamentally culturally mediated and can be considered a social process or agency.

Lemonnier (1993) demonstrated that in practice a large variety of factors are potentially involved in the technological choices such as shaping material to form an object. Since many different object forms and methods of shaping are seen by anthropologists in contemporary societies, he suggested that the vast majority of the factors which determined an object's shape, its composition and its method of manufacture were culturally mediated and dependent for explanation on a detailed understanding on the culture and period from which they derive. However, this seeming dependence on cultural context does not correspond with the fact that many tools, containers, jewellery and other artefacts are similar in form, materials and decoration in many different cultures. Though there may be very slight differences between the ways in which an Englishman and a Frenchman walk (Dobres 2000: 154), these culturally derived differences are minimal compared to the functional requirements imposed by being bipeds of identical physiology. Consequently, the basic form of an object is primarily determined by its intended use and the requirements of the materials of which it is formed. This would suggest that there is an underlying or macro-scale evolution of object form, in which object forms slowly develop over time, very much along the lines of object evolution postulated by Pitt Rivers (M. W. Thompson 1977: 136–56). Beyond this there is variation which is culturally determined. This may be particularly important for determining secondary characteristics such as non-essential shaping and decoration (see section 3.3).

Objects act as symbols encapsulating the beliefs of a given culture at a particular moment in time through their physical form and decoration. This is often preserved through the object's continued survival and is referenced by future generations. Thus objects should also be seen as palimpsests, having an evolving series of meanings over time (Ames 1994). This appreciation of objects as containing a range of information is exemplified by Hodder's assertion (1987), clarified by Pearce (1994b: 12), that objects can be seen as possessing three forms of identity:

- In use, functioning and having an effect on the world.
- The symbolic meaning of the object, its role in the cultural code; as such, every object echoes and reinforces the meanings of the codes of the culture.
- Embodying and signifying past experience: through its appearance it carries ideas and information about the past into the present.

Marx in discussing commodities, i.e. objects, in capitalist societies noted they possessed three values:

- Value from the potential use of an object, 'the utility of the thing' (Marx 1974: 4).
- Value from what can be obtained, bought or exchanged for the object, 'the proportion in which use-values of one kind are exchanged for use-values of another kind' (Marx 1974: 4).
- Since all objects are created by labour, as are all the materials which go into them, they have a value in the labour it took to produce them – a labour or production value: 'As values commodities are nothing but particular masses of congealed labour time' (Marx 1974: 8).

For the purpose of extracting information about the past from objects, it is useful to consider them as:

- instruments (functional)
- symbols (meaning)
- documents (history).

Object as instruments (functional, utilitarian)

Objects have an initial value because they perform a function for the society or the individuals within it. Thus a hammer hammers and a saw saws. Maquet (1993) suggests that an object's role as an instrument can be inferred from its design and the materials from which it is formed. As such, it is independent of its cultural determination.

> … the meaning of an object, what it stands for, is cultural when it is recognized as part of a collective reality built by a group of people. But in most cases it is not culture specific: it is grounded in common human experiences.
>
> (Maquet 1993: 31)

As objects are designed to perform a function, the form and materials used are selected to best perform that function. This is certainly postulated by design theory (Horsfall 1987). So it is possible to work backwards from an object, using clues from the object's form and the materials from which it is made, to determine information about the function of the object. This was demonstrated by Prown (1993: 6–10) in discussing an eighteenth-century teapot, though in doing so he demonstrated the need for considerable cultural knowledge in order to fully appreciate and understand the function of the object. This is the same process undertaken by every archaeologist when confronted with an unknown object.

Objects as symbols (signs, aesthetic entities)

Every object that is made or selected by a human being has shape, colour and texture which that individual, consciously or unconsciously, created or chose from a range of possibilities. These aesthetic inputs may be minimal for functional objects such as bricks, nails or simple tools, but even they are created in a symmetrical form, given a smoothed or finished surface. All objects contain aspects that are definable as being 'aesthetic' (Riegel 1996; Kirby Talley 1996).

Colour excites a response in the viewer, as it is associated with other objects, experiences and emotions. Thus it is a signifier, signal or symbol. It is what the artist/ maker/ owner, or the society in which the object is created, wishes to express to the viewer: '… material culture, all of it, has a symbolic dimension' (Hodder 1991: 3).

Depending on the differing experiences of the viewers, the symbol can mean different things to different viewers. A hammer may be functional to a blacksmith:

it can be seen as a symbol of oppression or a weapon of war. The context in which an object appears invariably helps define its meaning. Since most symbols signify to members of the same culture and since the members of a culture will share many experiences and ideas in common, members of that society can normally 'read' the symbol, within its context, correctly. Present within graves there are numerous examples of using the teeth of animals as jewellery, especially in European prehistory (e.g. Clarke *et al.* 1985: 60) – very symbolic, but do they represent the wearer as a brave and skilful hunter, or as possessing the qualities of the animal whose teeth they wear, or membership of a society, or a belief in the animal as a god or deity, or is it a badge of rank or office? The members of that society may read the meaning clearly: archaeologists, at the distance of thousands of years, probably do so less clearly.

> … artefacts serve both utilitarian and social/ideological functions; they are both tools and signs. This is the underlying reason for the vision of some historians that all objects, no matter how utilitarian and functional must be considered art. All are signs.
>
> (Kingery 1996: 197)

The role of objects as symbols, e.g. as signifiers of power and position, has become increasingly studied (Clarke *et al.* 1985). They form a key means of communication in society (Schiffer 1999). They have also been studied in terms of evolving taste and display (Cross and Keen 2002; Johnson 1996). Objects are not merely the symbolic product of a society, but feed back to define the nature and aspirations of individuals and sections within that society. 'They embody and shape the identity of their makers and users' (Chilton 1999: 1).

The aesthetic quality of objects has been expressed in many ways, e.g. William Morris regarded craftsmen as putting their 'genius' into the objects they created, so endowing the object with a 'soul-like quality'.

Further areas in which the symbolic nature of artefacts has been studied include the following.

Objects as symbols: spirit containers

Many cultures believe in spirit worlds, some believing that spirits can and frequently do reside in objects. Such spirits may derive from the maker (an extension of the beliefs articulated by William Morris), the owner, or a powerful individual or animal. This can make some objects very significant to believers, and place restrictions on object use, ownership, handling, etc. Anointing objects with libations (food, drink, scents, blood) becomes understandable if the object is considered partially human and capable of absorbing or appreciating the offering. Traces of such libation deposits can potentially be analysed and identified (see section 5.2). Without the associated oral tradition or written records to signify the associated belief, it is difficult to identify such objects from external appearance.

Objects as symbols: things of value

One of the clearest ways in which objects are seen as symbols is in the value which society ascribes to them. Some objects clearly have an exchange value well beyond the value of the materials and labour which have gone into their manufacture, or the practical function they perform for society. This socially ascribed value is demonstrated by objects that are part of the *kula* ring and similar exchange systems. *Kula* objects – *soulva* (red shell decorated necklaces) and *mwali* (white shell armbands) – are exchanged between the men of substance on the Massin Islands of New Guinea. The value of the *kula* objects varies depending on their history and the standing of the men who currently hold them or who have held them in the past. Consequently *kula* objects can grow and decline in prestige and thus value. The *kula* objects also bring with them obligations and associations (Appadurai 1986: 18). Works of art, fashionable clothing and objects associated with 'famous' individuals have similarly socially ascribed values, which may not appear to have a basis in reason. Such 'irrational reverence' led Marx to talk of 'the fetishism of commodities'.

Renfrew suggests that value, even for non-functional objects, may not be purely socially ascribed, and that certain materials occur in the form of valued objects from early societies, e.g. gold, amber, silver, shell, crystal, jade, furs (ivory and teeth could be added). These, he notes, are used for display, i.e. as wealth signifiers, by many different societies. These 'prime materials' have some intrinsic properties; visually pleasing, durable and thus retaining their value. They are not easily obtained, so they represent organization and control of resources (Renfrew 1986: 160). The 'prime materials' were formed into objects which, as a result of their initial and often continuing association with prime materials, symbolize wealth value, e.g. torcs in European Bronze and Iron Ages. However, ascribing value to objects/materials appears to have a social benefit in the ability to transfer agricultural surplus into the more usable form of valued objects (Renfrew 1986). Such objects can, through trade, be converted into agricultural produce in times of need, and they are easier and safer to store than food. They also encourage trade between individuals and groups. Contact between tribes aids them when they need support from each other in times of war and famine.

Dominant individuals within the animal kingdom and human societies invariably use display to establish their dominance. Displays through demonstrating wealth may avoid damaging physical confrontation. The social prestige of objects such as works of art stems primarily from their role as wealth indicators and consequently from their display. However, wealth is a highly mobile and easily acquired commodity. It can also be copied in cheaper materials, i.e. fakes and forgery (Jones 1990); consequently many societies have enacted sumptuary laws that limit who can display, wear or use what. This helps to preserve a social hierarchy as distinct from wealth.

Objects as historic documents

The development of science and rational thought through the Age of Enlightenment to the present day has seen a rising quest for the truth supported with physical evidence. Since the nineteenth century there has been an appreciation that objects possess information about their creation and use. The presence and value of this evidence of the past, in every object, were articulated in the late nineteenth century by William Morris (1996) and the members of the Society for the Protection of Ancient Buildings:

> A church of the 11th century might be added to or altered in the 12th, 13th, 14th, 15th, 16th or even 17th or 18th centuries, but every change, whatever history it destroyed, left history in its gap and was alive with the spirit of the deeds done midst its fashioning. The result of all this was a building in which the many changes, though harsh and visible enough, were by their very contrast interesting and instructive and could by no possibility mislead.

In this sense every building and object is a document about its past; it is simply a question of developing the skills and analytical techniques to read this document. It contains information about the materials from which it was made, the way in which it was assembled, and every incident which occurred in its life. In reality we do not yet have the technology to 'read' all of this information, such as the fingerprints and DNA of everyone who has handled the object, and much information is lost, obscured by later activities.

The role of the object as evidence of history is manifest in a number of aspects of object study:

- *Objects as proof.* Objects have been seen as an incontrovertible reality. If you have a belief and if you could find an object that fitted into your belief system, then it would act as proof, to yourself and others, that your beliefs were correct. Thus objects which appeared to be a mermaid's tail or a unicorn's horn were collected, classified and displayed in seventeenth- and eighteenth-century cabinets of curiosities as proof of the existence of such creatures.
- *Objects as typology.* Building on the scientific classification of the natural world by Linnaeus, nineteenth-century archaeologists systematically grouped similar objects by shape, function, material and decoration, into types. These could be correlated with historically attested peoples, periods and places (material cultures). Unknown objects could be related through their object typology to a known material culture past (see section 2.3).
- *Objects as industrial history.* The studies of nineteenth- and twentieth-century objects frequently focus on the industry that made the object. This is because many objects are seemingly identical products produced by machines or humans working in a standardized manufactory system. The reasons for the emergence, importance or demise of an industry, or the economic history and technical developments of the industry, are studied rather than the objects themselves, which merely attest the power and technical development of the industry.

Context

Though as a historic document an object contains information about its past, it does not occur in isolation. Objects are created by individuals or groups in society; they exist with other objects (sets) to perform rituals/activities at a given time and place. Thus objects exist in a context, and can be seen in relation to each of the elements of their context:

- the individual or group in society (culture) which owns/uses/creates them
- the objects which surround them and with which they form a set
- the particular place or space (often a specific room, building or landscape) in which they are used/created
- a particular time (time of day, week, month, year, decade or century)
- a specific series of actions or events.

As objects may have long lives, they may exist in many different contexts through the lifetime of an object.

The functional and symbolic roles of objects are more accurately and completely understood by knowing details of the context from which they derive. For instance, naturally occurring stones with holes through them were often placed in barns and cattle byres to repel witches (Merrifield 1987: 161). Such artefacts are only identified as artefacts performing a highly symbolic function through their presence in such a context.

The presence of an object may imply not a single context but a series of contexts. Thus the presence of a buckle implies a belt, a belt a uniform, a uniform a soldier, a soldier an army (Appadurai 1986). Whilst it is a large assumption to see the presence of an army from a single buckle, it alerts the investigator to the nature of the context and to seek other evidence; either historical record or the presence of other small, easily lost objects such as buttons or bullets, which form part of the 'set'.

1.5 Design theory

Work by Horsfall (1987), using modern anthropological evidence (Hayden 1987), has articulated design theory (Alexander 1964; Pye 1964, 1968) into a form that is useful to archaeologists. Simply expressed, it suggests:

- The physical forms of objects are created or adapted to meet functional needs within the context of known materials, technology, and social and economic conditions.
- A number of constraints operate on the production and final form of the artefact e.g. function, properties of materials, economics of production and use. Conflict between constraints is inevitable, e.g. materials are rarely both cheap and durable, which results in choices.

Ideas that emerge from this theory suggest:

- The concept of the 'best' is usually inapplicable, since there are inevitably a range of workable solutions, and choices are fundamentally context-dependent.

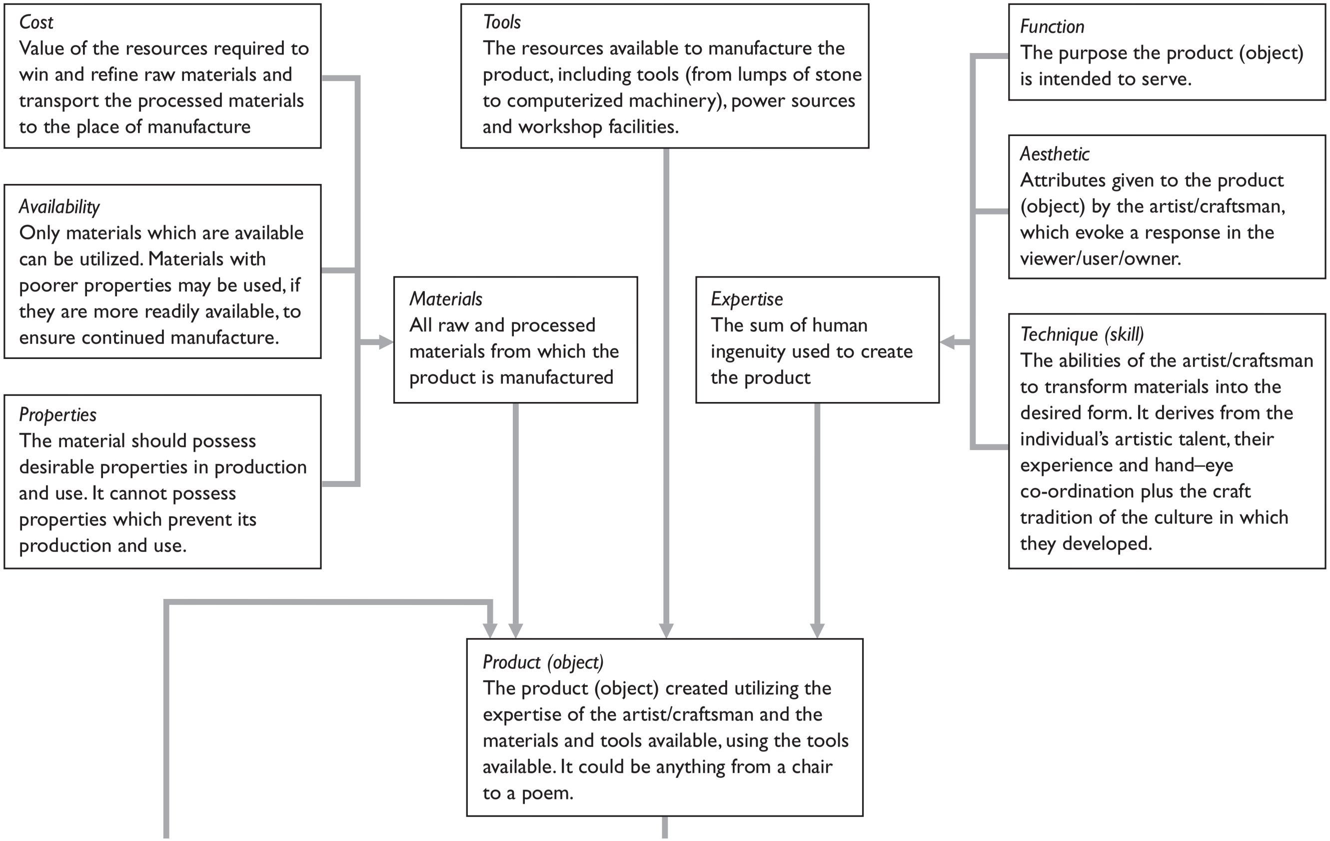
- It is theoretically possible to work backwards from an existing object to deduce the constraints present at its creation/adaption. This process assumes that there will have been an economy of human energy, time and risk in the procurement of materials and the production and use of the object. The conflicts involved in choice mean that diseconomies will have occurred.
- Craft specialization is an evolving process. In times of plenty, a wide range of materials and techniques can be tried, and experimentation and variation can be afforded. In times of shortage or stress, people revert to successful strategies; proven materials and production are used. However, the pressures of shortage can lead to innovative solutions and experimentation with cheaper and more readily available (local) materials.

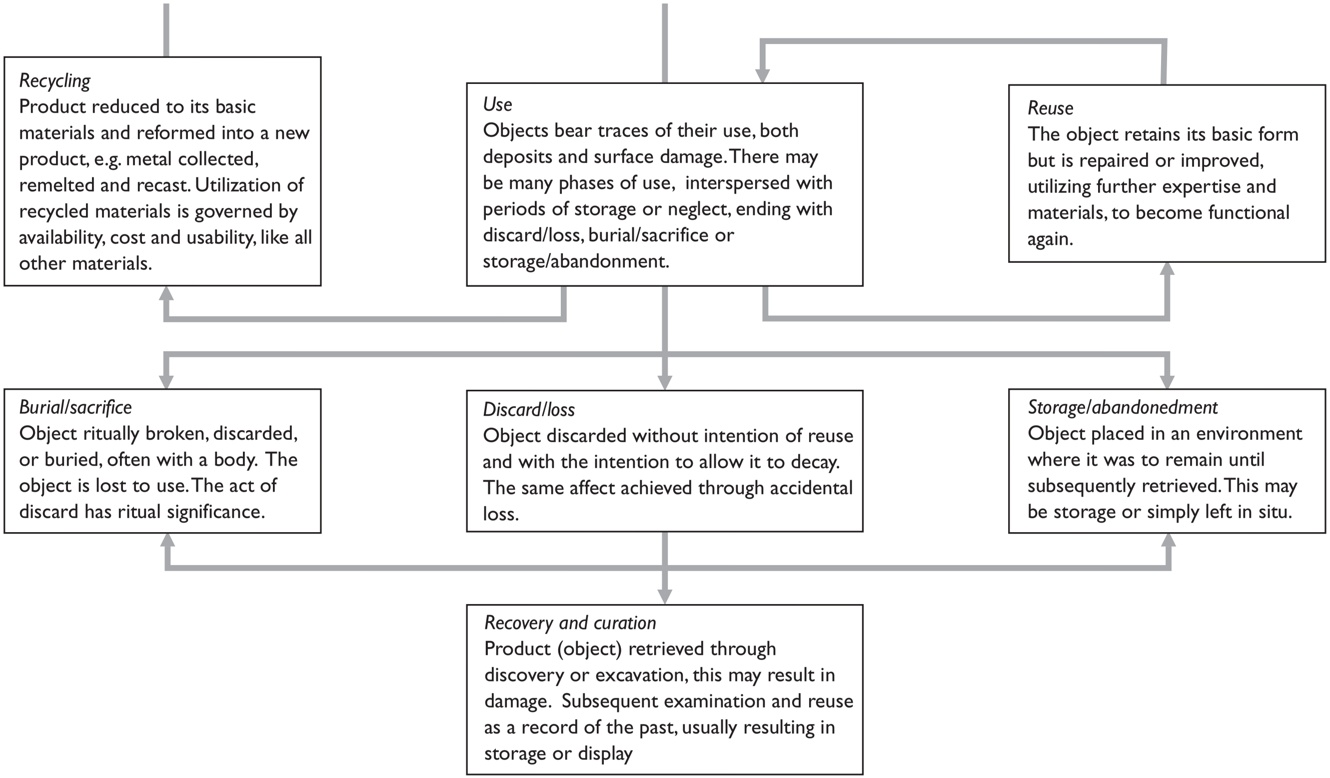
1.6 Objects as production and use sequences (object biographies)

This book primarily explores the use of objects as historic documents, seeking to collate all the cultural, historical and scientific evidence into an artefact life cycle, a holistic appreciation of the object (Appadurai 1986; Miller *et al.* 1991; Kingery 1993; Pearce 1994c). It considers the object as a production and use sequence (OPUS) (see Figure 1.3), in which materials are transformed into products, such as objects, using the expertise of artist/craftsmen (engineers, designers, etc.), utilizing the tools and facilities available. It presupposes demand from the consumer (see section 4.1). The objects are used, and, after cycles that could include reuse and recycling, they are abandoned, sacrificed or lost where they decay. They are eventually retrieved and studied as relics of the past. All the information from the origin of the raw materials to the final marks placed upon the object as part of a museum collection (see section 6.4) is represented in such a structure (Caple 2000: 76). Activities such as trade and distribution occur in the supply of raw materials and in the distribution of manufactured objects. They are also relevant to the recycling of materials and the reuse of objects, as well as to objects in the relic state, as every object from Ancient Egypt or China currently in a European museum attests.

This sequence is similar to that used by Tite (2001: 444), Kingery (1996: 176) and Ross's 'flow model for the life cycle of durable elements' (Ross 1991: 250) which was based on the work of Schiffer (1972: 158). This approach also has similarities to that used by Eileen Hooper Greenhill in her representation 'learning with objects: discussion and analysis' (Pearce 1990: Fig. 12.4). It is particularly relevant to archaeologists, curators and conservators who need to be aware of all the forms of evidence intrinsic to an object so they can recover all the available information about the object and do not destroy or obscure information during cleaning, conservation and presentation processes. Similar, though more complex, 'materials cycle' diagrams are also used in economic recycling literature.

Terms vary between different authors; thus the term 'expertise' is used in OPUS to describe the input of the human creator into artefact production. Other authors have used other terms:


Cost
Value of the resources required to win and refine raw materials and transport the processed materials to the place of manufacture
Availability
Only materials which are available can be utilized. Materials with poorer properties may be used, if they are more readily available, to ensure continued manufacture.
Properties
The material should possess desirable properties in production and use. It cannot possess properties which prevent its production and use.
Materials
All raw and processed materials from which the product is manufactured
Tools
The resources available to manufacture the product, including tools (from lumps of stone to computerized machinery), power sources and workshop facilities.
Expertise
The sum of human ingenuity used to create the product
Function
The purpose the product (object) is intended to serve.
Aesthetic
Attributes given to the product (object) by the artist/craftsman, which evoke a response in the viewer/user/owner.
Technique (skill)
The abilities of the artist/craftsman to transform materials into the desired form. It derives from the individual's artistic talent, their experience and hand–eye co-ordination plus the craft tradition of the culture in which they developed.
Product (object)
The product (object) created utilizing the expertise of the artist/craftsman and the materials and tools available, using the tools available. It could be anything from a chair to a poem.



Recycling
Product reduced to its basic materials and reformed into a new product, e.g. metal collected, remelted and recast. Utilization of recycled materials is governed by availability, cost and usability, like all other materials.

Use
Objects bear traces of their use, both deposits and surface damage. There may be many phases of use, interspersed with periods of storage or neglect, ending with discard/loss, burial/sacrifice or storage/abandonment.

Reuse
The object retains its basic form but is repaired or improved, utilizing further expertise and materials, to become functional again.

Burial/sacrifice
Object ritually broken, discarded, or buried, often with a body. The object is lost to use. The act of discard has ritual significance.

Discard/loss
Object discarded without intention of reuse and with the intention to allow it to decay. The same affect achieved through accidental loss.

Storage/abandonedment
Object placed in an environment where it was to remain until subsequently retrieved. This may be storage or simply left in situ.

Recovery and curation
Product (object) retrieved through discovery or excavation, this may result in damage. Subsequent examination and reuse as a record of the past, usually resulting in storage or display

Figure 1.3 Object production and use sequence (OPUS)

> The balance of tradition and present culture (affecting both customer and maker) and personal psychology of the maker.
>
> (Prown 1993: 3)

> … producer, consumer and producer–product interface.
>
> (Jones 1993)

Many recent American archaeological/anthropological studies (e.g. Chilton 1999) have suggested that technological style, the sequence of operations transforming raw materials into objects (*chaîne opératoire*), is a more stable indicator of cultural traditions than object form or decoration (e.g. Stark 1999: 40). This may be equated with the pre-product stage of OPUS.

By considering an object as the manufactured product of raw materials transformed using the expertise of craftsmen, the investigator focuses on the skill component 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. The term 'technology' refers to a culture-wide level of knowledge and expertise; 'technique' to the skills and choices of the individual craftsmen.

Objects are physical manifestations of the thoughts and ideas of a culture. Everything that is created, as opposed to being found, is formed by the action of tools (which includes machines) 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 tool 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 (artist) be formed into music (product).

Raw materials	*Tools*	*Expertise*	*Products*
wood	carpenters' tools	joinery	furniture
ink, paper	pen	ability to write	writing
coal, water	steam engine	ability to operate the machine	movement
ingredients	kitchen implements and cooker/fire	cookery	food

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 or craftsman 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, or sound or film 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 a raw material for a subsequent process; thus petrol is both the product of an oil refinery and the raw material for movement.

Expertise as defined above also appears to correspond to the definition of 'the practical interaction of human/social need with the physical world' which Dobres (2000) used to define technology, which she explores as a social process or agency.

Using OPUS is intended to lead to a holistic approach to object study, reminding investigators of the range of factors that go into object production and use, leading them to seek evidence/information regarding these processes when examining and researching the object and its context.

1.7 Factors affecting the study of objects

Artefacts, particularly archaeological artefacts, have primarily had their production studied on the basis of the material from which they are made and the technology utilized in creating and shaping that material (H. Hodges 1964).

Scale

Objects can be large, complex hand-crafted items (bespoke objects) used for a long period, e.g. the Coppergate helmet (see section 1.11) or Durham Cathedral doors (see section 6.8). However, they can also be small, simple artefacts, mass-produced in their thousands, in later years produced by a machine or in a factory system, e.g. brass pins (see section 3.12). Whilst both types of object are studied, different approaches are often used to yield the most information.

The unique, hand-crafted 'bespoke' objects are often not typical of the types of objects used by the majority of the people. Usually commissioned by the small number of wealthy people (patrons) who could afford them, they represent the taste of the elite, though the tastes and styles of the masses frequently aped (if in pale imitation) that of the ruling elite. Highly skilled artists/craftsmen are involved in their production. These objects are 'one-offs' and often commemorate personal events such as weddings, for which dresses, portraits and presents are often created. These objects are often made by named artists for known/named patrons. They are usually high-value items created from rare and precious materials, and are normally intended to demonstrate wealth. Materials are frequently imported, and indicate the extent of trade. The high value of the object encourages decoration, innovation and complexity. They may be ceremonial rather than everyday objects, and since they are only brought out and used occasionally they stay 'in use' for a long time. Consequently they are frequently cleaned or repaired or have worn, dowdy or unfashionable parts replaced.

Highly representational, these objects can be deliberately vandalized or destroyed as a symbolic act.

The mass-produced objects are invariably made for everyday use. They are made for low cost and, since they are often lost, broken, worn down and discarded, they are frequently replaced. Their low cost usually means use of local materials. They have minimal decoration and are not made for a specific patron but for retail sale, and thus will quickly respond to changes in demand. Both symbolic objects such as badges and functional objects such as nails and pins were mass-produced. These small simple objects, such as flint flakes, pins, plain cloth or potsherds, require analysis of large numbers in order to provide information about the nature and extent of that industry. They characterize society as a whole, indicating what is typical rather than what is extraordinary.

Analytical tools provide information that is interpreted in different ways depending on the scale of object production. Metrical analysis (measurement) (see section 2.2) can accurately describe the changes in the shape and size of long-lived, bespoke objects, e.g. the portrait of Prince Henry on horseback (see section 2.12). For mass-produced objects such as pins, metrical analysis reveals how the object changed dimensions over time. Similarly, elemental composition of bespoke objects provides information about the luxury imported materials or the latest materials that were available to a society. Compositional analysis of mass-produced objects, such as pins, indicates what metal was cheap and readily available (see section 3.12).

Bespoke, complex, hand-crafted objects are invariably small in number, with only a few tens of comparable objects. Mass-produced objects, such as nails, have tens of thousands, even millions of comparative objects. However, many objects exist between these two extremes, with a few hundred comparative examples. They are crafted objects with some value, some skill in manufacture and use. The materials of which they are made are often selected to have specific properties. Examples include weapons, tools, jewellery, coins, decorative ceramics and textiles. These objects often exhibit wear and reuse, since they are too valuable to discard and have important functions to perform, though they are not as protected and well cared for as the most valuable (bespoke) objects. These objects are produced in small numbers by skilled craftsmen, often in a 'batch' production process.

- *Bespoke objects*
  Rare, luxury, hand-crafted objects
  Tens of comparative objects
  Examples: Coppergate helmet, Bayeux Tapestry
- *Crafted objects*
  Occasional, craft-produced objects
  Hundreds of comparable objects
  Examples: coins, tools, decorated glass and ceramic vessels, jewellery
- *Mass-produced objects*
  Common, functional, mass-produced industrial objects
  Thousands to millions of comparable objects
  Examples: flint flakes, plain cloth, pottery sherds, iron nails, brass pins.

Appropriate research and analysis techniques should be used in the study of artefacts depending on their frequency and quality of manufacture.

Production of objects can be organized on an infinitely variable scale, from the occasional activity of one individual to thousands of full-time workers in a single location, e.g. a shipyard. A number of modes or scales of production were proposed by Peacock (1982) for ceramic production in the Roman Empire. However, they can be seen as appropriate modes/scales for almost all manufacturing processes (Table 1.1). These 'modes of production' have been mapped onto the key variables of labour, raw materials, manufacturing technology and product output, proposed by Cumberpatch, in Andrews and Doonan (2003: 51).

Bias of objects

The objects that have survived for us to study are not the full range of objects that were created, nor are they a representative sub-sample. A number of biases in the survival and selection of objects can be observed.

- Some materials such as stone and bronze are robust and survive well. They are consequently over-represented in museum collections. Organic materials, which decay quite quickly, are under-represented. The pewter dishes of the sixteenth and seventeenth centuries have frequently survived to enter museum collections but, as a result of breakage and decay, only a few ceramic dishes and even fewer wooden dishes, which were probably originally the most common in this period, now remain.
- More artefacts remain from the recent past than the distant past. Oral and written history is often available concerning objects from the recent past, consequently we are more familiar with and better able to accurately interpret objects from the recent past.
- Unusual, valuable and symbolic (bespoke) objects such as wedding dresses have often been retained, but few examples of mundane or typical (mass-produced) clothing, such as overalls or workwear, are treasured and preserved.
- The objects we use become worn out and discarded; objects we do not use survive.

The unusual, valuable and surviving are usually studied, giving a bias to scholarship. We are consequently more aware of the variation in such objects, and this highlights the interest and consequently the collectability of such artefacts. The everyday, cheap and ephemeral are often under-studied and consequently rarely collected, though they are more representative of what is being used by the vast majority of people. Present-day collections are thus inaccurate and incomplete records of the material culture of the past.

Bias of interpreters

Are the interpreters inherently biased or are they objective recoverers of data about the objects, and interpreters of that data?

Table 1.1 Modes of production. (From Peacock 1982)

Level	*Nature of the organization*
Household production	Manufactured products for domestic use. Little if any specialized equipment or facilities.
Household industry	Manufactured products for domestic use and sale/gift/exchange. Manufacture undertaken on a part-time basis at home. Limited equipment and facilities.
Organization production	= Peacock's 'estate production and military production'. One or more individuals with craft skills manufacture products for that organization. Employed full-time by the organization, though not exclusively at that trade, they will have a range of specialized equipment and facilities.
Individual workshop	Products manufactured principally for exchange or sale, by a craftsman whose principal income is from their trade. Individual-worker-scale specialist equipment and facilities present.
Nucleated workshop	Products manufactured exclusively for exchange/sale by full-time craftsman. Substantial investment in specialist equipment and facilities, some of which may be of a scale that indicates shared use and/or multiple users on a site. Nucleation favoured by ready access to raw materials, labour, markets. Organized distribution of products.
Manufactory	Large-scale (mass) production by large numbers of full-time craftsmen/workers (Peacock, = 12+ workers?). Extensive use of specialized equipment machinery, animal- or man-powered. Specialized buildings frequently constructed. High levels of organization, artisans/workers only specialize in certain tasks.
Factory	Identical to a manufactory, but later and larger (Peacock, = AD 1802 and later) with water-/steam-/electric-powered machinery. Highly organized mass production with an increased percentage of workers (smaller percentage of craftsmen) undertaking specialized tasks.

- The ability to recover information from an object is limited by the access to the object, to period and subject specialists and to analytical equipment. Financial resources are more usually available for high-profile objects, e.g. national symbols, than common everyday items.
- Objects are interpreted on the basis of existing knowledge. Initially ceramics were only studied on the basis of their shape (typology). However, since it has been shown that, using thin-section petrological analysis, ceramic fabrics could be analysed to indicate the place of manufacture (Peacock 1977), and that organic residues were preserved in the ceramic body and could be analysed using gas chromatography–mass spectroscopy (GC–MS) to reveal the nature of the contents (Evershed *et al.* 2001), ceramics have begun to be more fully investigated.
- Limitations of the experience of the interpreter. Every investigator when interpreting the facts they have uncovered selects the models that best fit these facts.

The best understood and most powerful models are those derived from their own experience; thus experience shapes every interpreter. Archaeologists with strong military backgrounds, e.g. Sir Mortimer Wheeler, often explained the remains they had recovered in terms of warfare and conflict.

- Simple objects made from materials dictated by the function of the object, derived from a recent period and a culture similar to that of the interpreter, will be much easier to interpret than a complex object that has had several different uses and is made of many materials selected for a variety of cultural and economic reasons, coming from a distant past and a culture foreign to the interpreter.

Prown (1993) suggests that objects as physical entities stimulate sensory responses, e.g. touch and smell, and have properties, e.g. weight and reflectivity, which are universal and appreciated by all human beings regardless of culture. Other sources about the past, such as art and all writing, are highly symbolic, without inherent universal qualities and thus entirely culturally context-dependent. Consequently objects, even with their inherent biases, present-day resources, existing knowledge, experience of the investigator, and cultural closeness of the investigator to the objects, are probably the least biased evidential source about the past that we possess.

1.8 Research and investigation techniques for objects

Material culture research

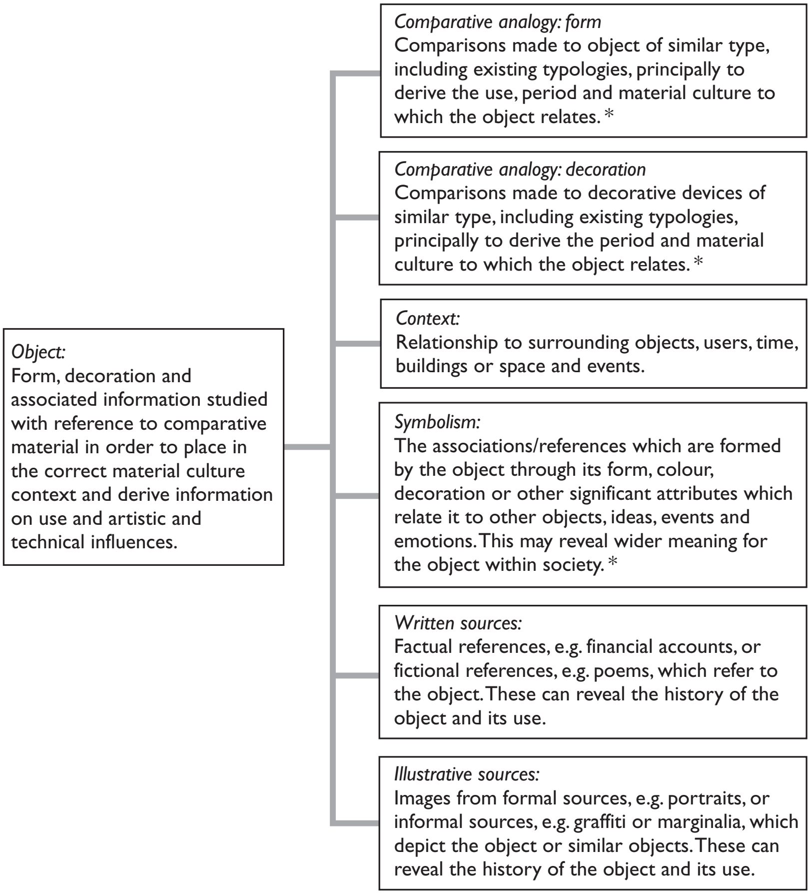
Objects are researched and often interpreted in terms of their physical appearance (form and decoration), which is used to give them a period culture association and thus a date. Their context, when meaningful, provides evidence for use as well as period culture association. The object's history, including ownership, is researched to provide evidence of authenticity, whilst written and pictorial sources provide information on use as well as period culture associations (see Figure 1.4 and Chapter 2).

Scientific and technical investigation

The materials and manufacture of the object, the deposits and damage from use, the decay products and processes are determined through various analytical, microscopic, imaging and dating techniques in order to:

- ascertain how a particular object was made and used;
- confirm the date or cultural affinity of the object: if there is a mismatch between the materials and construction methods used and the period cultural affinity of the object, then period culture attribution and dating can be corrected and fakes identified;
- add information to the body of knowledge about ancient materials and technology or the materials and technology used by a particular craftsman or artist.

It is the information recovered from analysis that is of interest to the study of the



Object:
Form, decoration and associated information studied with reference to comparative material in order to place in the correct material culture context and derive information on use and artistic and technical influences.

Comparative analogy: form
Comparisons made to object of similar type, including existing typologies, principally to derive the use, period and material culture to which the object relates. *

Comparative analogy: decoration
Comparisons made to decorative devices of similar type, including existing typologies, principally to derive the period and material culture to which the object relates. *

Context:
Relationship to surrounding objects, users, time, buildings or space and events.

Symbolism:
The associations/references which are formed by the object through its form, colour, decoration or other significant attributes which relate it to other objects, ideas, events and emotions. This may reveal wider meaning for the object within society. *

Written sources:
Factual references, e.g. financial accounts, or fictional references, e.g. poems, which refer to the object. These can reveal the history of the object and its use.

Illustrative sources:
Images from formal sources, e.g. portraits, or informal sources, e.g. graffiti or marginalia, which depict the object or similar objects. These can reveal the history of the object and its use.

* The analogy is normally made with archaeological parallels, so providing cultural, chronological and geographic context for the object. Analogy with anthropological objects and experimental archaeology material may suggest the use of the object, its symbolism and its possible method of manufacture.

Figure 1.4 Material culture analysis

object; the analytical method is merely a tool for obtaining that information. However, it is important to understand the nature and abilities of the analytical tool used, since it determines the type and quality of the information obtained.

Scientific techniques can be crudely broken down into two groups: visual analysis and elemental and molecular composition.

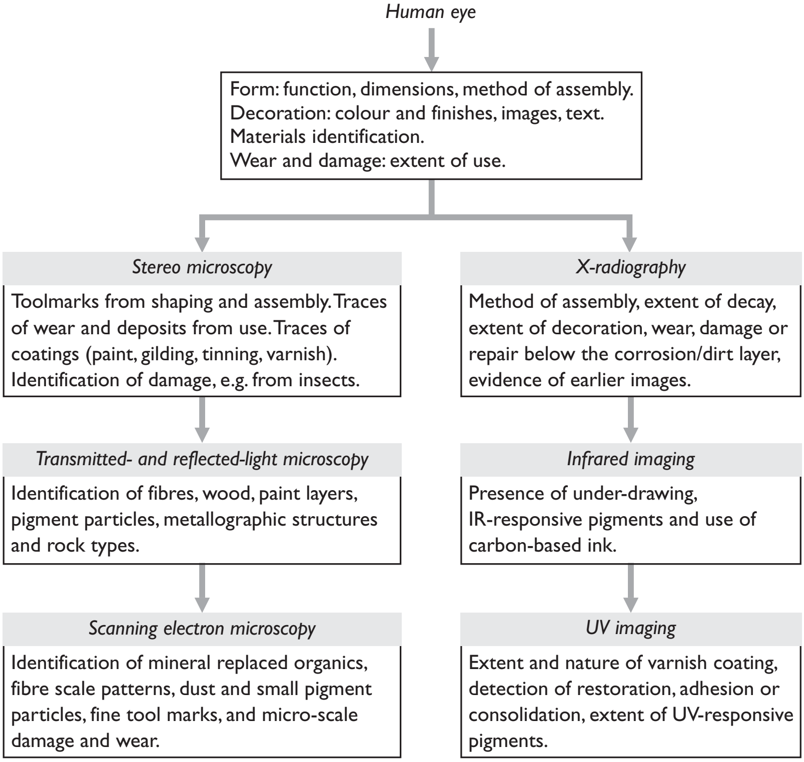
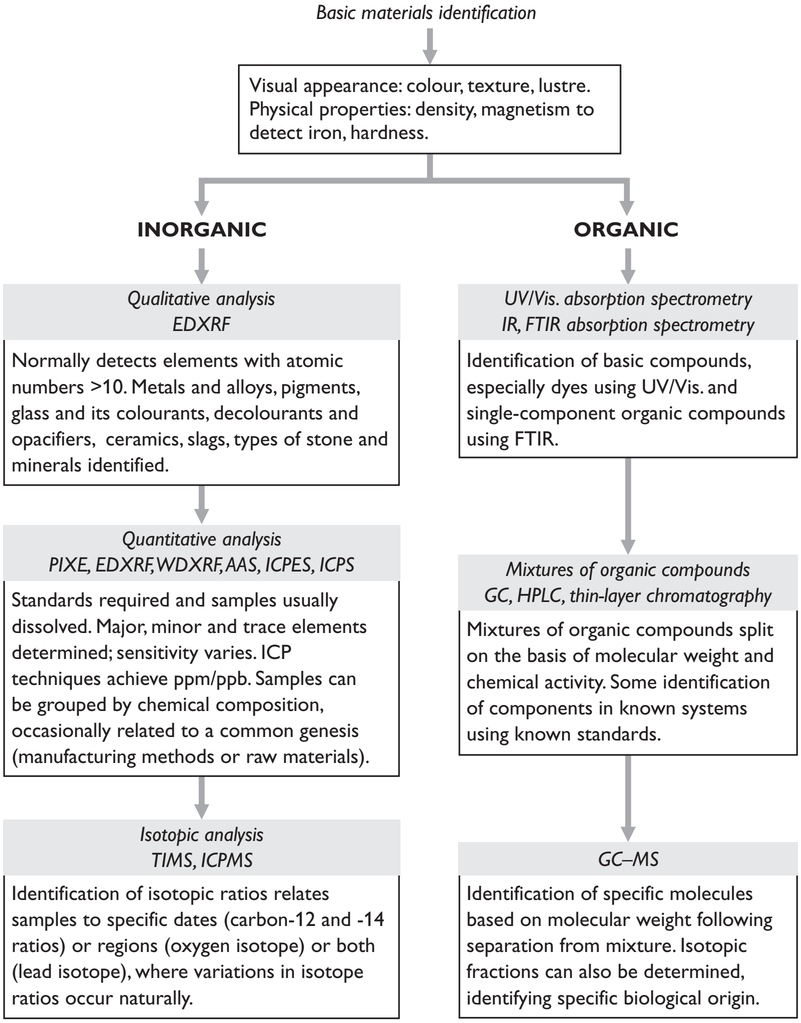


Figure 1.5 Visual analysis

Visual analysis (see Figure 1.5)

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 casting and fabrication methods for metal. This form of examination can be extended through use of light/energy of different wavelengths, such as X-radiography (see section 2.10) and UV and IR light examination (see section 2.9). Such techniques also reveal information about damage, decay and wear. The capability of visual examination can be enhanced by use of microscopy to raise the magnification. Stereo microscopy (see section 1.10), reflected-light microscopy of paint sections (see section 3.11) and metallography (see section 3.10) provide information on the structure/manufacture and use of objects. Transmitted-light microscopy of fibres and wood sections (see section 3.8) and of rocks and ceramics (see section 3.9) together with scanning electron microscopy (see section 5.7) aids materials identification.



Visual appearance: colour, texture, lustre. Physical properties: density, magnetism to detect iron, hardness.

Normally detects elements with atomic numbers >10. Metals and alloys, pigments, glass and its colourants, decolourants and opacifiers, ceramics, slags, types of stone and minerals identified.

Standards required and samples usually dissolved. Major, minor and trace elements determined; sensitivity varies. ICP techniques achieve ppm/ppb. Samples can be grouped by chemical composition, occasionally related to a common genesis (manufacturing methods or raw materials).

Identification of isotopic ratios relates samples to specific dates (carbon-12 and -14 ratios) or regions (oxygen isotope) or both (lead isotope), where variations in isotope ratios occur naturally.

Identification of basic compounds, especially dyes using UV/Vis. and single-component organic compounds using FTIR.

Mixtures of organic compounds split on the basis of molecular weight and chemical activity. Some identification of components in known systems using known standards.

Identification of specific molecules based on molecular weight following separation from mixture. Isotopic fractions can also be determined, identifying specific biological origin.

Figure 1.6 Elemental and molecular analysis

Elemental and molecular composition (see Figure 1.6)

There are a large number of scientific analytical techniques (Pollard and Heron 1996; Skoog *et al.* 1998). Some techniques are appropriate for analysing inorganic materials such as metals, ceramics and glasses. Wavelength-dispersive X-ray fluorescence (WDXRF) and energy-dispersive X-ray fluorescence (EDXRF, see section 4.5) will give information on the elements present in a sample. Induction-coupled plasma mass spectrometry (ICPMS) will give details of the quantities of elements and even isotopes present in a sample (see section 4.6). X-ray diffraction (XRD) provides information and identification of crystalline materials such as minerals and pigments. Other techniques are appropriate for analysing organic materials. Fourier transform infrared absorption spectroscopy (FTIR) or UV/Vis. absorption spectroscopy will identify organic molecules on the basis of their absorption characteristics. Thin-layer chromatography (TLC), high-performance liquid chromatography (HPLC) and gas chromatography (GC, see section 5.6) separate mixtures of organic compounds and identify them through comparison of their chemical activity/structure against known standards.

Although every analytical technique will produce data, investigators should be cautious about the analytical results they receive. They have to judge whether the information provided by the analyst is meaningful to the object and its interpretation and, if so, what that meaning is.

- The apparent accuracy of many analytical techniques, which may quote figures to two decimal places, may be illusory, since for many elements or molecules present in low concentrations the system may only analyse to low levels of accuracy, e.g. ±20 per cent. Investigators should always obtain details of the accuracy and precision of the analytical systems they are using and the range of concentrations to which these figures apply. Such figures are usually different for different elements.
- 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. XRD systems may require over 5 per cent of a mineral in crystalline form before it can be detected.
- An element can be present in many different forms (species). For example, if copper is detected in a liquid, it can be present as metal particles in suspension, as an oxidized mineral (e.g. $CuCO_3$) or a reduced mineral form (e.g. Cu_2O) in suspension, dissolved in solution as a soluble ion (e.g. Cu^{2+}), held in the form of a sequestered ion complex or as an organic compound. Consequently it is often necessary to combine techniques to ascertain a complete picture, as in the case of the minerals deposited in the waterlogged char from the Haddenham neolithic long barrow, which were characterized using ashing, XRD and 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, ground water or atmospheric dust. The element 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. Consequently they rarely provide simple clear analytical results. Analysts who are not familiar with the analysis of historic or archaeological materials often fail to interpret results in a meaningful manner.

The surface layers of most objects have reacted with the surrounding environment, fundamentally altering their composition, i.e. corrosion and decay (Caple 2001: 589). If the investigator wishes to extract typical composition information about an object, it will invariably need to have a sample removed from the body of the object. Though objects potentially can be visually damaged by the removal of samples, such damage, which is often barely detectable, must be judged against the value of the information gained (Roy 1998).

INVESTIGATION TECHNIQUES

1.9 Systematic visual analysis: FOCUS (formalized object construction and use sequences) (Caple 1996)

The need for systems to encourage rigorous thinking is present in a wide range of academic disciplines. Such systems both simplify complex problems and assist in communication between practitioners. No single formalized system exists for systematic recording of objects. When objects are reported in detail, e.g. in archaeological reports, a brief technical description is often written in the jargon of the subject. This is invariably accurately descriptive of the method of manufacture and the current visual appearance, as in this example of a flint flake from the Dryslwyn Castle excavation, described by Dr Mark White (2002).

> Proximal fragment of a flint blade, struck from a bipolar core, with very fine parallel retouch along the left-lateral margin. It is possibly a microlith fragment. No residual cortex. Fresh conditioned with incipient patina on both dorsal and ventral faces. Length 20.5mm, width 19.5mm, thickness 3mm. *94SF1. Context I 34. (Phase 2b).*

For conservators and curators dealing with a large range of objects, a more generalized but still rigorous recording system is required. FOCUS (formalized object construction and use sequence) has been developed specifically for this purpose (Caple 1996). It aims to create a relative chronology of construction and use of the object, assembling all visible evidence into a single tabular form.

To create a FOCUS:

1 All aspects of the object are listed:
  - All the separate parts or pieces of the object are listed. This is usually most effectively achieved using a labelled diagram. Not only are the legs, arms and stretchers of a chair listed, but so are all the fastenings, e.g. nails or screws, and coverings, e.g. coats of paint or varnish.

- All the materials used in the construction of the object are listed. This will include the iron/steel of the nails or screws, as well as descriptions of the colour and texture, e.g. the colour of the wood stain.
- All the traces of wear or use, e.g. scratches, abrasion and traces of earlier paint or other coatings, are also listed.

These three lists are created with the objective of detecting all the information that is readily visible on the object. This activity will challenge the investigator's ability to observe. It will encourage the investigator to seek written sources or expert advice as they confront the problem of naming and describing the various parts of the object and identifying the materials from which they are made.

2a The evidence from the three lists is then placed in chronological order in a single column. The latest element (part, material or trace), and the action of joining it to the object, is placed at the top of the page, and the earliest shaping of the raw materials used to construct the object at the base of the page. Placing in order will present a logic puzzle to the investigators as they try and work out which event occurred before another. Groups of events that happen together and cannot be separated are referred to as phases. Where events cannot be separated, they are recorded one above the other in the most sensible order, but without any blank lines, so signifying continuity. Each event/phase that can be separated in time from another has a blank line between events/phases. Every piece of physical evidence and every material mentioned in the initial lists should be present in the chronologically ordered sequence.

2b Beneath the physical evidence, and in square brackets, investigators describe the deductions that they make from the list of physical evidence. This is an important step, since investigators are often very ready to simply accept the existence of a scratch or nail-hole without questioning why it is there, e.g. the probability that a hinge or other attachment device was originally present.

This has created a deconstruction sequence for the history of the object.

2c A second column to the left of the first is created in which the events or phases of physical evidence are given descriptive names. These are phases of activity, called processes by Schiffer (1999). Where descriptive names are repeated, they are numbered up from the base of the sequence, e.g. Use 1, Use 2. This process is designed to clarify the history of the object, so giving a label to each separate phase of repair and use.

It is essential to try and make the written comments in these two columns as brief as possible but still be communicative.

2d Wherever a longer description or explanation is required, a number is entered in the right-hand evidence and deduction column. The numbered footnotes appear at the base of the FOCUS listing and are an integral part of that sequence. Information such as material identification details, deductions about the previous

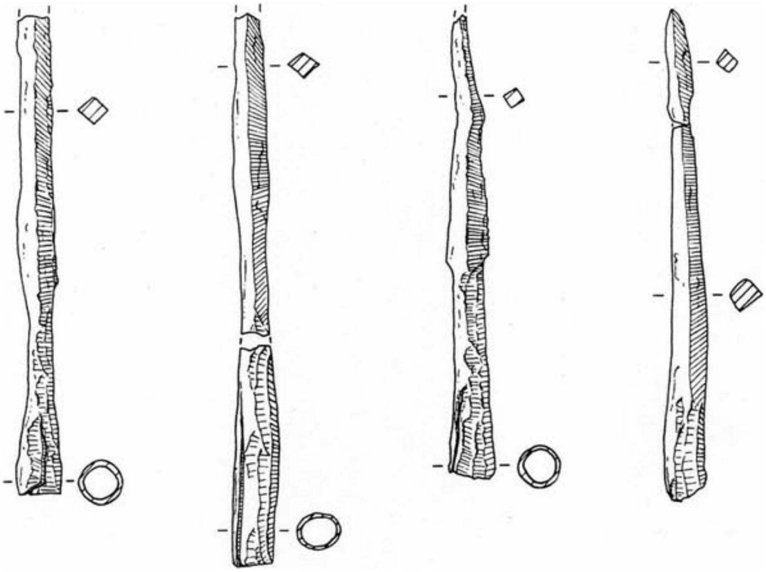


Figure 1.7 Thirteenth-century arrowheads from Dryslwyn Castle, Wales. (Drawn by Oliver Jessop)

> history of materials added to the object, or details about the shaping or fashioning of a part of the object, are typical footnotes.

Figure 1.7 illustrates the application of the FOCUS system.

The importance of understanding the sequence of construction is demonstrated by examples of paleolithic cave art, where analysis of the pigments, infrared photography and surface topography (scratched lines on the rock surface examined with a stereo microscope) were used to determine the sequence in which the images were created. In the French cave of La Marche the details of the harness were shown to be a secondary image added at a later date to the earlier images of horses (Renfrew and Bahn 1991: 284). The FOCUS system has aided investigators to become more aware of the antiquity and the detail of the past history of the objects with which they are dealing.

1.10 Stereo microscopy (binocular, low-magnification microscopy) (Casartelli 1969; Killick 1996; Oddy 1982)

> … the most potent tool remains the human eye, aided by a good binocular microscope at one end and an informed brain at the other.
>
> (Craddock in Jones 1990: 276)

FOCUS for thirteenth-century arrowheads from Dryslwyn Castle (see Figure 1.7)

Object sequence	*Evidence [deduction]*
Buried	• recovered from excavation • object composed of iron oxides [originally iron arrowhead, now corroded[a]] • fibrous structure in corroded base of object [mineral replaced wood from arrow shaft, the original wood having rotted away]
Used	• tip bent [arrow fired at hard surface in Dryslwyn castle in thirteenth century[b]]
Edge sharpened	• point and edge are sharp [sharpened on a hone stone]
Shafted	• fibrous structure in corroded base of object [wooden shaft (ash?) hafted into arrowhead; shaft and feather flights give effective arrow form]
Arrowhead forged	• forge lines and pointed head of diamond-shaped cross section tapering to circular cross section, flaring to form circular socket below[c] [a single piece of metal forged to form the arrowhead]
Wrought iron	• iron minerals form corrosion products • object is magnetic [iron metal blank forged from bloom or from recycled objects with particles of slag and charcoal entrapped in the metal[c]]

Notes

a Evidence from X-ray and cleaning object.

b Excavation revealed castle occupation AD 1220–1420, this arrowhead with others coming from a deposit of siege material dated 1287.

c Evidence from X-ray.

Many of the key features related to the manufacture and use of artefacts are best observed in three dimensions, i.e. with a substantial depth of field and at low magnifications, typically ×2.5 to ×50. This is achieved using a stereo microscope. Almost all conservation laboratories are equipped with stereo microscopes, which are invariably mounted on stands, so creating space to manipulate the object being examined (see Figure 1.8). The wide range of objects and materials that can be examined with this technique and the low level of magnification have often led to its failure to be fully appreciated as a research tool.

The stereo microscope has two complete optical systems from eyepiece to objective; one for each eye. These are mounted at fifteen degrees to each other (seven-and-a-half degrees to the vertical). This reproduces normal vision, where the two images are

Figure 1.8 Stereo microscope in use examining an ancient Egyptian shabti figure. (Photograph by the author and Trevor Woods)

slightly different in each eye: the human brain interprets this to give a 3-D appreciation of the object to the viewer. The term 'binocular microscope' is sometimes used to refer to stereo microscopes, but since any microscope that has two eyepieces could be referred to as binocular, it is unspecific. The term 'low-magnification microscopy' is similarly unspecific, potentially referring to any form of microscopy (biological, metallurgical, petrological) at magnifications up to ×50. 'Stereo microscopy' should be used for those optical microscopes that have 3-D vision.

There are a wide range of stereo microscopes: some have fixed objectives and eyepieces and thus fixed magnifications; others have interchangeable eyepieces and objectives, or zoom magnification capabilities, which can give magnifications from approximately ×6 to ×200. Increase in magnification will lead to a reduction in the depth of field, typically falling from approximately 22 mm at ×6 to 1 mm at ×200 (Casartelli 1969: 126). Photographs can usefully be taken down the eyepieces to record features seen under magnification (see Figure 1.9).

Lighting is important for stereo microscopy. To provide the clearest viewing conditions the object should be illuminated from two angled light sources either side of the object. Objects should also be examined in raking light; a single light source playing light across the surface, typically five to forty degrees to the plane of the object, to highlight low scratches and surface indentations. To be fully appreciated, objects should initially be examined carefully without any magnification, and the nature of

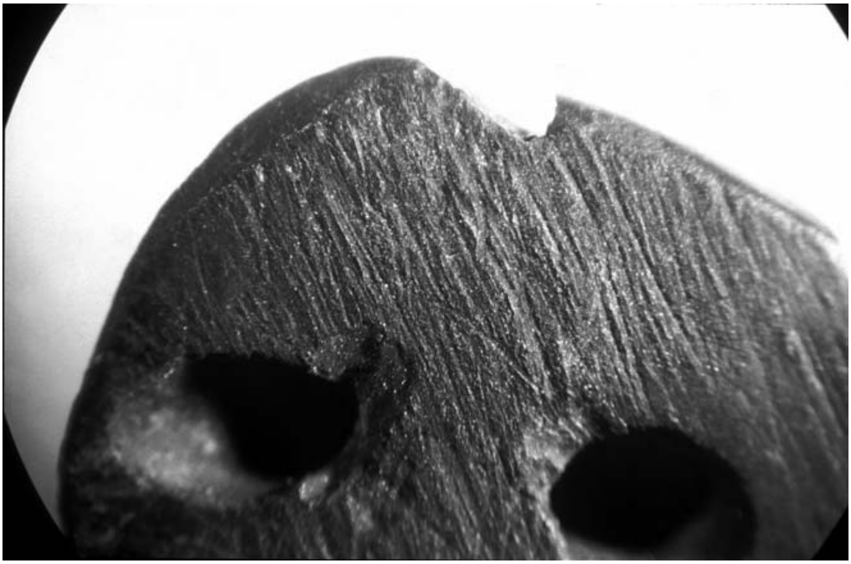


Figure 1.9 Stereo microscope image of a prehistoric jet button, from Ingleby Barwick, with file marks from manufacture. (Photograph courtesy of Jennifer Jones)

the materials and assembly noted. The use of FOCUS or another systematic procedure will aid such identification. Then areas of wear, joints and attachments and areas which have not been coated with paint or polish should be examined with a stereo microscope. This will reveal such things as:

- basic materials of which the object is composed,
- marks of tools or other objects, e.g. moulds, used in the manufacture of the object, or its repair,
- traces of original pigments or coatings,
- details of assembly such as the weave of cloth and the twist of yarn; which layer of pigment overlies which; evidences of pins, tacks or traces of adhesive,
- marks associated with shipping, sale, purchase or ownership,
- evidence of damage, broken-off pieces, vandalism, alteration, cleaning or amendment,
- the extent and nature of wear, scratches and cracking through use,
- deposits related to use,
- damage and decay from discard and/or burial.

These marks can provide information about the date and the culture that made or used the object and its subsequent history. An example occurred in the examination, by Robert Gordon, of file marks present on armaments produced in the Springfield and Harper's Ferry armouries in the 1840s–1880s. These firearms were traditionally considered to have been produced by machine, and this was seen as an example of machinery displacing manual labour. Examination under a stereo microscope showed that, although they had started to use mechanical grinders for cleaning up the cast steel parts of armaments (which produce deep parallel scratches), well into the 1880s they invariably finished the object by hand filing, which produced short, slightly angled grooves. Consequently a more accurate and realistic picture is of only partial replacement of men by machines (Killick 1996: 212).

CASE STUDIES

1.11 Coppergate Anglian helmet (Tweddle 1992)

Archaeological excavations at 16–22 Coppergate in York uncovered the remains of a series of street-front properties occupied from AD 850 to 1050. During subsequent construction work a mechanical excavator uncovered a timber-lined pit and damaged the upper right side of an iron helmet present at the base of the pit (see Figures 1.10 and 1.11).

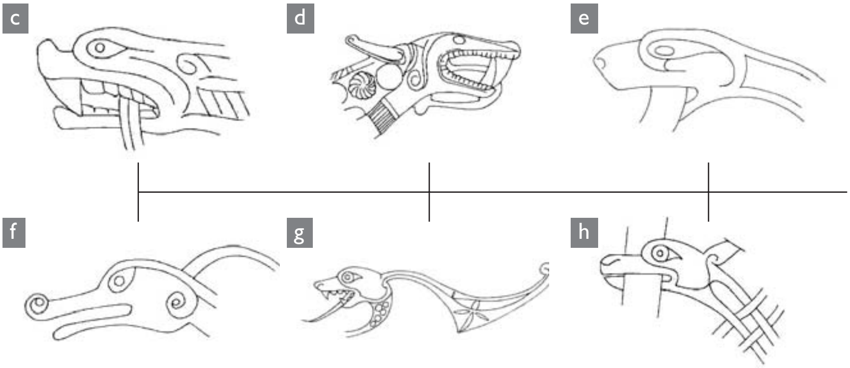
Context

The presence of the waterlogged wood, the minimal corrosion of the iron and copper alloy of the helmet and the presence of corrosion minerals such as chalcopyrite ($CuFeS_2$), bornite (Cu_5FeS_4) and siderite ($FeCO_3$) indicate that there were waterlogged anoxic conditions within the pit. This preserved the helmet and details of the decoration and manufacture. The other British examples of Anglian warrior helmets – Sutton Hoo and Benty Grange – have been highly corroded, because of the oxic (aerobic) burial conditions.

Manufacture

The helmet is a composite structure (see Figures 1.10, 1.11 and 1.12).

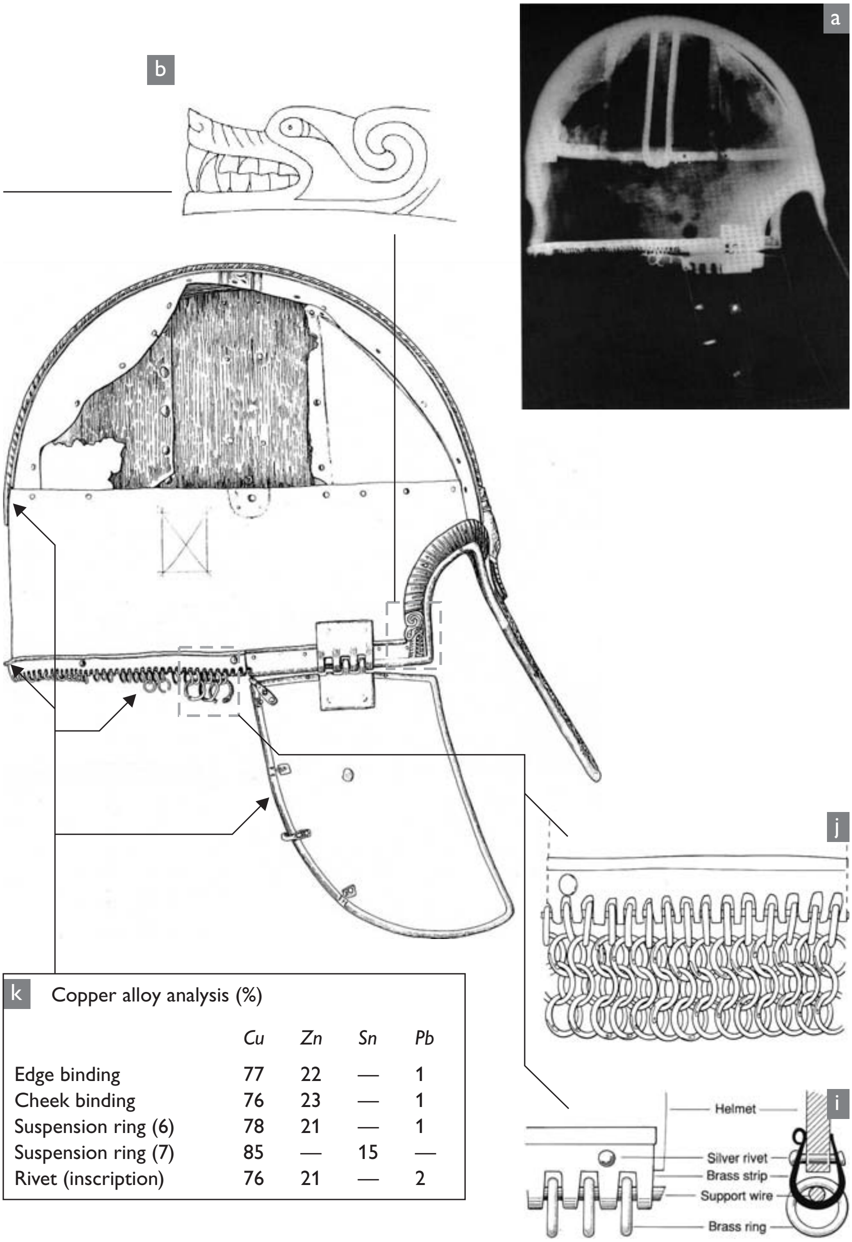
- X-radiography revealed that the helmet is composed of two broad bands of iron; one running around the head (brow band) riveted to one running from the nape of the neck to the nose over the top of the head (nose-to-nape band). To these were riveted side pieces, running from the brow band above each ear to the nose-to-nape band at the top of the head (right and left lateral bands). This formed a framework over the head into which triangular infill plates were riveted, to form a complete dome. The pieces of iron (0.7 to 3 mm thick) were riveted together; the holes for the rivets were formed with a tapering drill and the rivets were hammered flush with the surface. Cheek-pieces were added by creating hinges on the side of the helmet and at the top of the cheek-piece, which have interlocking looped projections through which a steel pin could pass, so securely holding the cheek-piece but allowing it to rotate. The back of the helmet supports a curtain of chain mail that is also connected to the back of each of the cheek-pieces. A strap, probably made of leather, which no longer survives, was riveted to the centre of each cheek-piece (see Figure 1.12). The straps were tied beneath the chin of the wearer to hold the helmet on the head and hold the cheek-pieces secure against the side of the head. An inner cap or cushion, which does not survive, was probably worn inside the helmet to enable it to sit at a



The X-radiograph (a) revealed the riveted band and infill plate method of construction. The incised dragon's head motif (b) is similar to seventh- and eighth-century examples from throughout Britain and Ireland: cross-shaft, Colerne, Wiltshire (c), late eighth century; scabbard mount from the Thames (d), late eighth century; Dundrennan gilded plaque (e), mid-eighth century; Tara Brooch (f), early eighth century; Lindisfarne Gospels (g) and (h), early eighth century. The ring mail protecting the nape of the neck is formed of alternating rows of welded and riveted rings of iron wire (j) suspended by brass rings from a wire running through a pierced brass edging strip which runs around the base of the helmet (i). The metal of the suspension rings, pierced edging strip and edging strip around the cheek-pieces was identified as brass through analysis (k) with an EDXRF system. Rings which had been repaired or replaced were sometimes identifiable since they were made of bronze.

comfortable height for the wearer and to cushion the skull from the hard helmet and the blows it was designed to deflect.

- Metallographic examination (section 3.10) of the iron bands and infill plates showed that the metal was principally ferrite (pure iron phase) with small amounts of pearlite (mixture of pure iron ferrite and cementite – an iron/carbon alloy). This indicated that the metal was effectively a low (0.2 per cent) carbon steel, though the carbon was unevenly distributed. This gave a metal that was tough and would absorb the energy of any impact through deformation, rather than breaking.
- The helmet is asymmetric: the nose-guard is offset to the left and the left eyehole is 4 mm narrower than the right. This leads to suggestions either that the helmet was deliberately made to fit a specific individual who had asymmetric features (wound or deformity) or to give a wider field of view to the right to enable the wearer to better see his own sword. It would be crucial if the helmet was to be effective that the nose-guard exactly protected the wearer's nose. A 'fitting' probably took place whilst the helmet was still composed of steel bands, before even the triangular infill plates were added, to draw on the eyeholes and



Copper alloy analysis (%)

	Cu	*Zn*	*Sn*	*Pb*
Edge binding	77	22	—	1
Cheek binding	76	23	—	1
Suspension ring (6)	78	21	—	1
Suspension ring (7)	85	—	15	—
Rivet (inscription)	76	21	—	2

Figure 1.10 Coppergate Anglian helmet, side view: details of materials and manufacture. (Images courtesy of York Archaeological Trust)

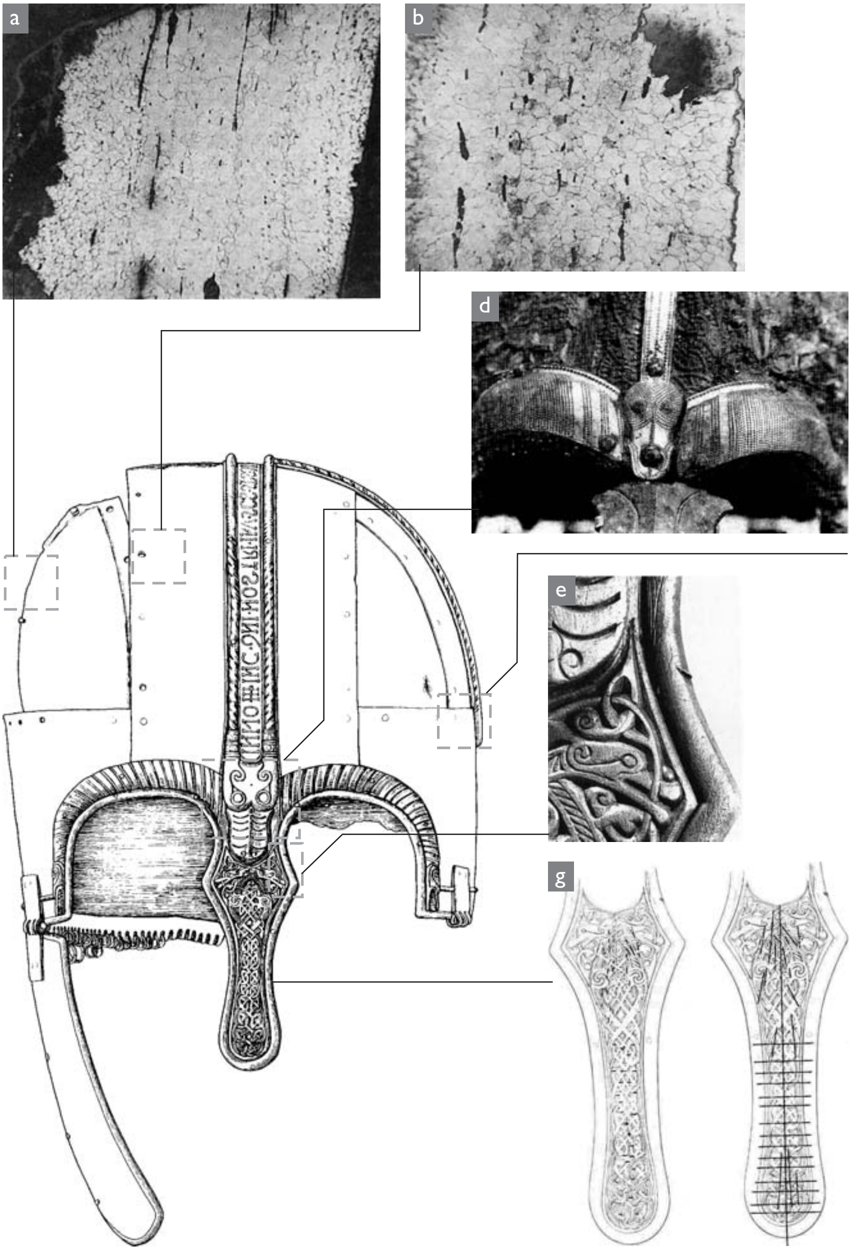
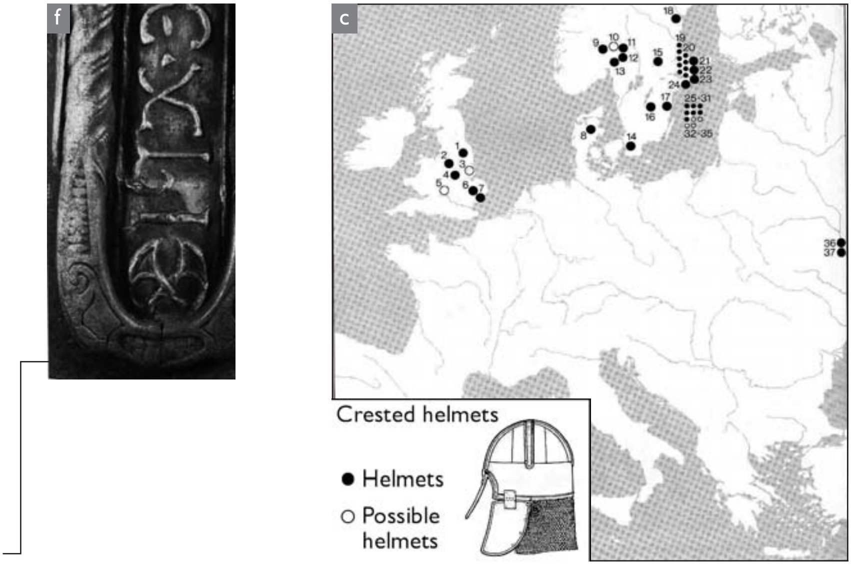


Figure 1.11 Coppergate Anglian helmet, front view: details of materials and manufacture. (Images courtesy of York Archaeological Trust)



The metallographic sections of the nose-to-nape band (b) and infill plate (a) show the use of a tough wrought iron/low-carbon (mild) steel. This is a crested helmet, a type of helmet which has primarily been recovered from Swedish and British contexts of the sixth–eleventh centuries AD. Comparative examples of the helmet form and decoration come from the graves in the Vendel cemetery in Sweden, e.g. Vendel XIV (d). A nick in the nose-guard (e) suggests the Coppergate helmet saw active use, whilst the worn rope decoration around the inscription, especially at the rear of the crest strip (f), indicated that it had frequently been cleaned. Despite this cleaning, traces of the incised lines used for laying out the nose-guard design were still visible, and part of the original grid for laying out this decoration can be reconstructed (g).

nose-guard position, which were probably cut, using saws and files, from the extended nape-to-nose band.

- The edges of the iron helmet have a U-shaped copper alloy edging strip riveted into place. This decorative edging protects the iron sheet, and along the back of the helmet the edging strip projects in a continuous tube below the iron and a series of cuts have been made into it. The top of the mail has a series of copper alloy rings that projected up into the grooves in the edging strip. A wire ran through the edging strip and rings, so suspending the mail from the back of the helmet (see Figure 1.10). At the back of each cheek-piece there are four loops that are attached to the side of the mail using either rings or a wire.
- The eyebrows and nose-guard are castings that fit exactly over the ironwork of the helmet. Cast in copper alloy for this object, they were probably based on a

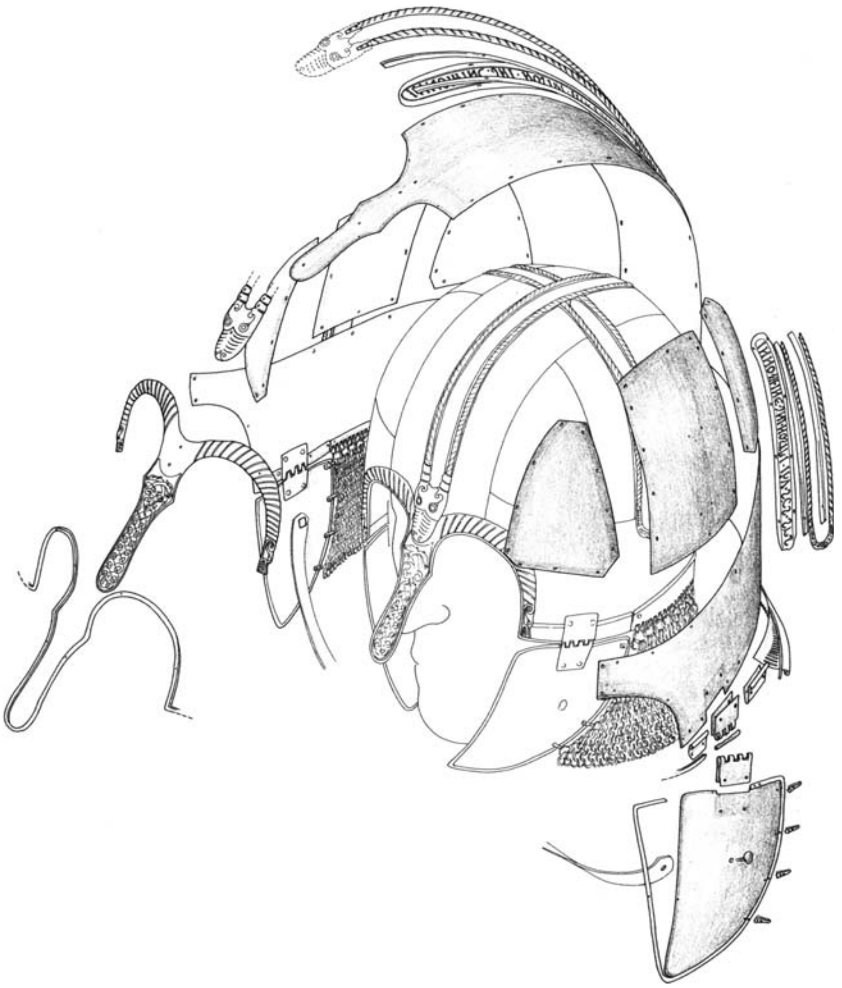


Figure 1.12 Coppergate Anglian helmet: assembly from its components. (Image courtesy of York Archaeological Trust)

wax model formed on the helmet and then detached to form either a lost-wax casting or a two-part mould in which the metal was cast.

- The nape of the neck was protected by chain mail composed of links 7.8–8.2 mm in diameter. The iron wire of which they are formed is 0.9–1.2 mm in diameter. The predominantly circular cross section and the striations down the surface indicate that the wire was made by drawing. Metallographic examination revealed it was a low-carbon steel (0.2 per cent carbon), which made the metal pliable enough to withstand the wire-drawing process and tough enough that it would not break and expose the wearer to increased danger. Examination of the rings with micro-focal X-radiography revealed alternate rows of welded and riveted rings. The welded links were probably formed first and then joined together using the riveted links. Because each link was joined to the two links in the row above it and the two links in the row below it, but neither of the links beside it, it had great flexibility but also formed a dense curtain able to ward off blows. Given the specialist skills and tools used for wire and ring manufacture (rivets in the riveted links are only 0.8–0.9 mm wide) and the large amount of work involved (49 m of wire was used to create the 1947 rings), it is likely that the mail was made by a specialist craftsman.

- Running along the crest of the helm, from nape to nose and across from ear to ear, were a pair of identical inscriptions in repoussé work (metal sheet beaten from the back to produce a raised design). Around the inscriptions were edging strips and roll-moulded (rope pattern) wires. This ensemble was riveted into place forming a cross over the helmet. At the nape and above either ear, the roll-moulded wire formed a curve around the inscription in the form of facing beasts. At the front of the inscription above the nose-guard and between the eyebrows was a shallow, beast's head casting.
- The inscription is in Latin and in translation reads: 'In the name of our Lord Jesus Christ the Holy Spirit and God and to all we say Amen. Oshere.' This inscription indicates that the owner of the helmet was called Oshere. This is a common Anglian name: written records of the period mention both a Northumbrian abbot and a Wessex moneyer (mid-ninth century) called Oshere. The owner was neither of these individuals. Most probably he was a nobleman or warrior living in York in the eighth century AD. The inscription is in the form of a prayer and is obviously intended as added protection for the wearer of the helmet. Oshere was clearly a Christian, though this would not be unusual by the eighth century AD. The script form is described as Anglo-Saxon Capitals, the normal Anglo-Saxon epigraphic script and widely used in this period (Tweddle 1992: 1012–15) and as Northumbrian Display Script (Tweddle 1992: 1170–1).
- The letters of the script, which were formed with a series of punches and points, are reversed, i.e. retrograde. This suggests that the inscription was probably originally to be incised/sunk, but the metalworker having copied out the script has put the strip on inside out. This would suggest that the metalworker did not read Latin – it looked just as sensible to him the wrong way around. It also raises the question of whether Oshere himself could read. If he could, why not get the script turned around to read correctly? There are also a number of abbreviations and grammatical errors in the text, presumably made by the scribe who wrote down the text for the metalworker to copy.

Form, decoration and display

- Typologically the Coppergate helmet is one of a group of early medieval crested helmets, present in Britain and Scandinavia. Most examples come from the cemeteries of Vendel and Valsgarde in Sweden, but the helmets from Sutton Hoo (early sixth century) and Benty Grange (mid-seventh century) in the UK are also of this type (Steuer 1987). The group has a rounded cap form with prominent crests and substantial ear-/cheek-pieces. They often have prominent decorated nose-guards and eyebrows. They are believed to derive from late Roman 'guard helmets'. In terms of its banded construction, Coppergate is similar to the mid-seventh-century helmet from Benty Grange and almost exactly like that from Valsgarde grave VII. Visually the Coppergate helmet resembles helmets from Vendel grave XIV (sixth–seventh centuries) and Broa in Gotland; hinged cheek-pieces, neck protection, flat crests terminating in flat animal heads, hatched eyebrow decoration. However, the use of a mail curtain to protect the nape of the neck and the shaped cheek-pieces are features of the 'Spangenhelme', a group of pointed helmets seen in France, Germany and central Europe (Steuer 1987). The face mask, present on many of the Vendel and Valsgarde helmets, is similar to the Sutton Hoo helmet and appears to be a sixth- to eighth-century feature which is clearly not present on the Coppergate helmet. Later helmets used by the Vikings, the Normans and the English, and depicted in the Bayeux Tapestry, are simpler pointed forms with prominent nose-guards but little neck protection. The Coppergate helmet appears to be a late form of crested helmet, without a face mask, but still with a rounded cap form.
- Decorative devices on the Coppergate helmet can be compared to other decorated metalwork, illustrated manuscripts and carved stone. The variations in decorative form change with period and culture, allowing artistic influences affecting the Coppergate helmet to be discerned:
    - Animal head at the end of the eyebrow. This is an unusually squared-off animal head form with interlocking canines (see Figure 1.10). Biting beasts with bared teeth are seen on late seventh- and eighth-century metalwork and manuscripts, particularly in Northumbrian art, e.g. the Lindisfarne Gospels (AD 698).
    - Top-view animal head at the end of the inscription, between the eyebrows, has parallels in south-west England in eighth/ninth centuries and the sixth-/seventh-century helmet decoration from the Vendel graves in Sweden (see Figure 1.11).
    - The interlocking bipeds with elongated bodies which develop into and are enmeshed in the interlace on the nose-guard (Adcock's pattern A) are the most prominent decorative feature of the Coppergate helmet (see Figure 1.11). The use of bipedal beasts is a widespread eighth-century decorative

form, e.g. the Leningrad Gospels. The depiction of turning beasts' bodies into interlace starts in the mid-eighth century. The head form of the beasts has eighth-century parallels. The spirals behind the eyes of the beasts are seen in the eighth century, are rare after AD 775 and are no longer seen in ninth-century art.

- From the analysis of the separate features, it is clear that the interlaced beasts of the nose-guard are the most diagnostic artistic form of dating on the helmet. The 'beast turning into interlace' form probably occurs after AD 750, but the use of spirals behind the eyes would suggest manufacture before AD 800.
- Helmets have only come from the richest graves, e.g. that of King Redwald at Sutton Hoo. In the 60 or so wills dating to before the Norman conquest, only four mention helmets; those of one bishop, one earl and two thanes. Given the high cost of manufacture of these individually made objects, such helmets were a symbol of wealth and social position.

Trade

- The surface of the copper alloy was analysed by EDXRF and samples drilled from the core of the metal were analysed by Atomic Absorption Spectroscopy (Pollard and Heron 1996: 26–31). These confirmed that all the copper alloy was brass:

Area analysed	*Cu (%)*	*Zn (%)*	*Pb (%)*	*Sn (%)*
Inscription sheet (wrought)	73.5	24.5	1.0	—
Ropework border (cast or wrought)	74.2	24.7	1.1	—
Central animal head (cast)	74.3	24.0	0.9	—

All pieces of original copper alloy on the helmet, whether cast or wrought, were made of a high-zinc brass. This was a high-quality brass, almost certainly imported from Europe, probably from the Meuse valley region – the centre of both the earlier Roman and the later medieval brass-making industry. This metal was selected for its golden colour, and consistently used on the helmet for the edging strips, rivets, wire and castings. Similar high-quality brass is also used for objects from the Sutton Hoo burial.

Use

- Unlike all the other rivets, loops and strips, which are brass, the rivets attaching the suspension loops onto the back of the cheek-pieces are made of bronze, and one of the suspension loops is also bronze. These bronze rivets and the loop were almost certainly repairs carried out during the life of the helmet, probably after the mail curtain had been torn off. Five rivets used to hold the suspension strip, which supports the mail curtain, to the back of the helmet, were dome-headed and made of silver. In both metal and form they are different from any other rivet on the helmet. Again it is likely that these silver rivets are later replacements. Within the mail curtain, rings M56/7 and X50/1 had been repaired, since the sequence of welded and riveted rings was broken at these points. There were also misshapen rings E73, W49, W50–1, Z6 that may also be replacements or repairs. From this use of different materials occurring at several different places on the helmet, a series of between two and four separate phases of repair can be postulated.

- The presence of damage to the helmet indicates use:
  - Dent to the front left infill plate, probably from a projectile.
  - A nick on the side of the nose-guard, which could be from a spear or arrow-head (see Figure 1.11).
  - A dent in the front edging strip of the inscription. This appeared to be the result of a blow to the front of the helmet, though it could equally well have occurred if the helmet was dropped.
- The presence of wear and abrasion indicates that polishing was undertaken to enhance the visual appearances of the object.
  - The fine incised lines that decorated the elongated intertwined bodies of the beasts decorating the nose-guard have been partially removed through wear.
  - There is evidence of wear to the cross-hatch decoration of the eyebrows.
  - The roll-moulding edging to the inscription band has been worn away in a number of places, as have details of the incised opposing beast terminals on the edging at the end of the inscription.
  - The inscription band has suffered wear and pressure from polishing, which has resulted in the flattening of some of the letters, e.g. the word Oshere.

  Regular microscopic striations along the axis of wear confirmed that abrasive cleaners had been used in antiquity for polishing the brasswork. The wear was not always in the most exposed brasswork, thus it had been cleaned carefully to try and preserve the decorative patterns and motifs. Clearly the brasswork of the helmet, especially the inscription band, eyebrows and nose-guard, was kept polished to a shiny condition. This would have presented the greatest contrast with the naturally black iron surface, and suggests that this helmet was worn or displayed. This level of wear would have taken some time to develop, and indicates a long period of use.
- The fact that the left cheek-piece and the mail have been deliberately detached, so damaging the edging strip, and deposited inside the helmet indicates that the helmet was partially disassembled and deliberately hidden/placed in a pit or shallow well, probably with the aim of later retrieval. The internecine struggles of the Northumbrian royal family and aristocracy in the ninth century and the

eventual capture of York by the Vikings in AD 866 presented instances when ownership of an object such as the helmet, with its indication of aristocratic or royal warrior status, might have been undesirable and represent the occasions when the helmet was most likely to have been hidden.

Record/dating

Retrieved from the excavation work ahead of building, the well and its helmet had no stratigraphic relationship with the archaeology of the excavation. Typologically the helmet comes from a period before the bulk of the evidence from the Anglo-Scandinavian occupation from the rest of the site. Dating of several types was obtained:

- Dendrochronology of the timbers of the well gave a felling date of AD 586; thus the well was probably constructed in the early seventh century.
- Small twigs and other organic material from the filling of the well gave a calibrated radiocarbon date range of AD 560–840.
- Sherds of pottery and stratigraphy indicate that the well was filled in *c.* AD 900, prior to the redevelopment of the site *c.* AD 930–5.
- The interlace ornament found decorating the nose-guard was considered to be in use during the period AD 750–75 ± 25.

Thus it would appear that an eighth-century helmet was placed in a seventh-century well and covered by the tenth century.

Chapter 2

Objects as social indicators (form, decoration and display)

WHO?

2.1 Comparative analogy

The collection and appreciation of art, as we understand it today, developed in the seventeenth century, Vasari having created the concept of 'Old Masters' in his *Lives of the Painters, Sculptors and Architects* in 1550 (Kirby Talley 1998). The study of an artist or craftsman, the work they produced, their materials, technique, the subjects they depict and the style or expression of their work, as well as a full appreciation of the time and culture in which they worked, became regarded as connoisseurship (Kirby Talley 1989). Through publication and research this developed into the discipline of art history. Formal classification of objects emerged in the nineteenth century through the development of typology as an essential tool for studying and dating archeological objects. The basis for both the study of objects in archaeology and art history is analogy. The object being researched is compared to similar objects about which information such as culture, date and use is known. If the researched object matches (in part or whole) the comparative object, it is considered probable that the information regarding the comparative object also relates, in whole or part, to the object being researched. There is an underlying assumption that objects with similar shape (form), size, decoration, materials or techniques of manufacture come from the same cultural source; in extreme cases, the same artist or craftsman, and the date and cultural associations of one must apply to the other.

Analogies can be drawn between unreasonable (umbrellas and toadstools) as well as reasonable (see Figure 1.10) objects/forms/decoration (Wylie 1985). Hodder (1982) has argued that analogy is at its strongest when:

- There is not one but many points of similarity: the greater the number of similarities, the stronger the analogy.
- There is a continuum of variation (i.e. intermediate forms) between the analogous objects.
- There is a reason, link or relationship between the analogous objects; such 'rational analogies' are normally based on functional parameters such as use.

Analogies between objects/forms/decoration that are geographically and chronologically similar are invariably more reasonable. Given the strong effect of individual cultures on object form and decoration, cross-cultural analogies, i.e. generalizations, need to be well established (proven) but offer potentially very informative analogies. The process of forming analogies is similar to that used by the human eye and brain to recognize what they are seeing (Caple 2000: 5) and to how an archaeologist recognizes a cave painting as representing a specific prehistoric animal (Hodder 1982: 176).

The cultural and chronological information derived from analogy may not be meaningful, because of

- copying – some objects are deliberately copied by later generations; e.g. Roman statues copy their classical Greek predecessors;
- being widespread – the form and decoration of an object may be widespread and thus present in a number of cultures, or is long-lived;
- simplicity – if the form of an object is a simple functional one, it may be independently developed by several cultures at several different dates;
- idiosyncrasy – objects, or more usually decoration, may be made by an individual who draws little or nothing from contemporary culture.

When reading an object and its decoration, Maquet (1993) suggests that in addition to similarity there are three further types of inference that can be made:

- Association – meanings, ideas and other objects associated with a particular object; e.g. a castle has associations of strength and security.
- Referent – one object signals another without obvious reason. An example is the tradition for painting the robes of the Virgin Mary blue. This derives from the period in medieval Europe when deep blue pigments, e.g. lapis lazuli or azurite, were rare and expensive. To demonstrate his wealth and piety, the painting's sponsor would pay for the Virgin Mary to have deep blue robes. The association continued and the colour blue began to represent the Virgin Mary and her virtues of purity and innocence. Without the knowledge of the sequence of events and beliefs, this is not an obvious association.
- Symbol – the object or decoration symbolizes something that is related to the visual characteristic of the object or decoration, e.g. a portcullis, used by organizations such as the House of Commons and English Heritage to symbolize guardianship.

Identifying these aspects to the object allows the viewer to 'read' the meaning of the object. Some of them may be deliberately created by the artist/craftsman; others may be unconscious, and simply elements of the cultural environment in which they were working.

The ascription of meaning to the shape and decoration of an object may appear initially to be a subjective activity. Thus the untutored may see a pair of crossed lines (+). The numerate may see it as an addition sign, or recognize it as a symbol representing more. Engineers may recognize it as representing positive in terms of electrical polarity; those familiar with European culture of the last 2000 years may see it as a Christian cross. Objectivity derives from many experts interpreting the object or design in the same way (Maquet 1993: 38). This is similar to a scientific proof derived from a repeated experiment, which constantly produces the same result. The publishing of scholarly opinions on the interpretation of the symbolic meaning (significance) of objects followed by their general acceptance and appearance in standard textbooks equates to the repetition of an experiment and the derivation of the same results by different scientists. Gombrich (1972) suggested that there is no right or wrong way to view art: the observer knowledgeable about the culture from which the art derives can see and appreciate a great deal more of the similarities, symbolism, references and associations it contains. The connoisseur may read more into the object than its creator or user ever did, as Prown (1993: 10) demonstrates when he derives the female breast as the inspiration/subliminal reference behind the form and function of an eighteenth-century American pewter teapot.

2.2 Form, style and dimension

The configuration of an object is referred to as its form. When groups of objects share characteristics of form, those resemblances constitute style. In art history the study of such characteristics is referred to as formal or stylistic analysis. Another definition of connoisseurship is where such analysis is used to discriminate between objects (Prown 1994). Working at the speed of the human brain, stylistic analysis is a very quickly applied technique, allowing the connoisseur to place any object in its period and cultural context. Style is the physical embodiment of personal and cultural ideas and, as such, summarizes and communicates cultural and personal beliefs, craft traditions, and functionality of object and materials (Hodder 1982: 191). As such it typically refers to the features characteristic of the products of one or more workshops having common technical abilities and cultural associations. This is most usually applied to refer to the distinctive material culture of an ethnic group (Wobst 1977, 1999), though there is a considerable body of archaeological literature discussing style (Wobst 1999: 119). It can be expressed in more general terms: '… style is any distinctive and therefore recognizable way in which an act is performed or an artefact is made' (Gombrich 1972).

Style has been used to refer both to the small aspects of conscious or unconscious decoration distinctive to one craftsman and to large-scale artistic movements such as Impressionism or to artistic periods such as Art Deco or Romanesque that share a series of architectural or object forms, decorative motifs, materials and techniques. The extent of the stylistic tradition will vary, as will its distinctiveness. Some styles are simple, and very similar object forms such as bowls and containers may be derived independently by several groups. Some are complex and are unlikely to have been developed independently: their presence indicates cultural contact or a common ancestor. Changes in style often provide archaeologists with evidence of contact. This is exemplified by historically attested examples such as the influx of Chinese porcelain

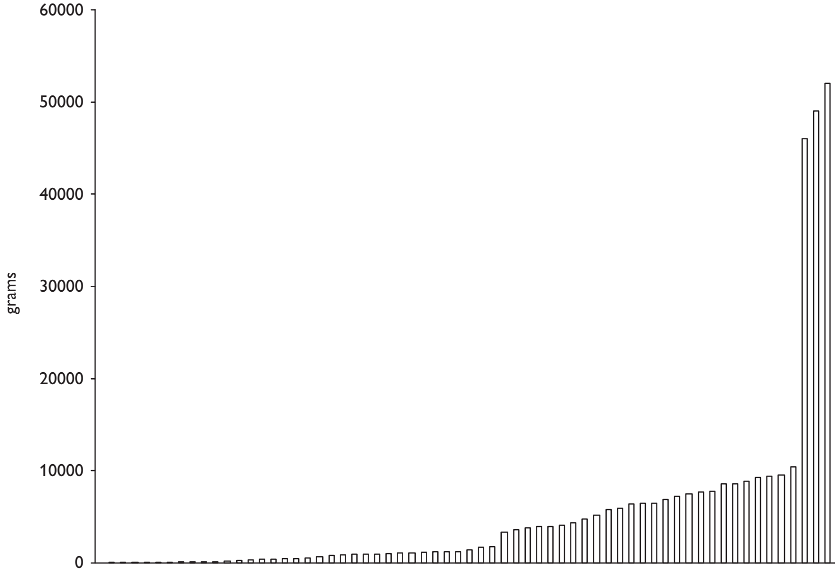


Figure 2.1 Graph of the weight of lithic projectiles recovered from Dryslwyn Castle, Wales. The smallest weight were slingstones; the medium-sized stones (3 to 10 kg) were simply thrown at attackers from the castle walls; the largest were stone balls thrown at the castle by a trebuchet (siege machine).

in the seventeenth century into Holland and England, which led to a fashion in Europe for blue-and-white ceramics (see section 4.9).

Dimensions

Objects examined by an investigator/connoisseur should be described metrically (measured) as well as technically and stylistically (e.g. White 2002): see section 1.9.

- This ensures that the size of the object is correctly appreciated, and thus proposed uses or methods of manufacture are relevant.
- Measurements permit large groups of objects to be subdivided by size. These are most relevant when subgroups with one or more similar dimensions are detected. Arranging dimensions in ascending or descending order can reveal steps in the distribution: see Figure 2.1, which indicates selection of projectiles of particular weights. Such groups may be correlated with specific uses, or be related to other variables, restricted date ranges, specific regions or specific producers. They may also indicate the presence of standards, or limitations imposed by transport, raw material supply, value, etc. Plotting dimensions in the form of histograms can produce graphs with peaks that indicate a prevalent size, a series of peaks indicating

a deliberately created series of sizes. Plotting one dimension against another, forming an X–Y or scatter plot, provides a convenient way of describing/analysing differently shaped objects. Graphing the height and diameter of turned wooden bowls from the Coppergate excavations in York distinguished concentrations of taller narrower containers ('cups') and of broader, shallower 'bowls and platters'. These vessels probably had different uses and were also made by different manufacturing methods – spindle-turned and face-turned (C. Morris 2000: Fig. 1027).

- Exploring the dimensions of objects at different dates or between different cultures can reveal differences that may have cultural or technical reasons (see section 3.12). Changes of dimension describe decay or alteration to objects (see section 2.12).
- Sizes of a number of objects can be described with appropriate terms, i.e. range (between the largest and smallest measurements) or statistical terms such the mean (average) or variance or standard deviation. This enables unusual-sized objects or those with a different ratio of dimensions to be easily noticed. Fakes are, as in the case of the Han mirror (see section 6.7), often first detected because of unusual dimensions. Distributions, described with a mean and standard deviation, can be compared through statistical tests such as a Student's *t* test, to determine and describe differences.
- If dimensions are known, then quantities of materials used to create or process the object can be calculated, giving economic information on the extent and cost of manufacture. Thus the size of the giant tree from which planks were used to construct the doors of Durham Cathedral can be calculated (see section 6.8). If the volume and weight of an object made of one material are known, its density can be calculated and potentially the material identified.

2.3 Typology and classification

Linnaeus in *Systema Naturae* (1735) had shown that grouping together plants and animals that had similar characteristics allowed the 'scientist' to create groups or families of similar organisms. This process brought some order into the seeming disordered complexity of the natural world. This classification process proved popular with scholars in the subsequent centuries, and many things were grouped like with like.

The displays of the Great Exhibition of 1851 in London frequently showed how products had developed, demonstrating the improvements of civilized society and of more recent manufactures. In 1859 the publication of Darwin's *On the Origin of Species* provided the mechanism of natural selection, the survival of better-adapted individuals, to explain the evolution of animal and plant species. Antiquarians such as Pitt Rivers used evolution and natural selection to explain the development of artefacts such as primitive weapons. In 1875 Pitt Rivers gave a lecture to the Royal Institution in London entitled *On the Evolution of Culture*, in which he built on the work of Evans and Wilde to outline sequences of object development, from the simple to the complex. He illustrated his lecture with examples of flint and bronze axes, where objects of similar material and form were related to the chronology of human cultural development – 'human epochs' (M. W. Thompson 1977: 136–56). Thus Pitt Rivers had outlined the subject we know as typology and used it as a potential tool for studying the remains of the past. He also used the technique of stratigraphy, in which younger objects overlay older objects, to confirm his typological sequence. This conjunction of stratigraphy and typology formed the basis for development of the discipline of archaeology. Typology and the evolution of object forms and decorative motifs now encompass a number of ideas:

- Classification is normally undertaken on the basis of four characteristics:
    - function attributes – objects with similar functions have similar shapes,
    - shape attributes – shape and dimensions,
    - surface attributes – decoration, colour and surface finish,
    - technological attributes – materials of manufacture.
- Artefacts that share similar attributes are grouped into types. A balance of attributes is used.
- Groups of artefacts that occur together are referred to as assemblages. Groups of assemblages with similar objects that occur in a geographically and chronologically restricted area are often described as a 'culture' or, more accurately, a 'material culture'. The assemblages are interpreted, by analogy with present-day human activities, to represent people carrying out similar activities, e.g. burial or manufacturing processes. When people engage in the same activities using similar objects, it identifies them as having strong social, ethnic or religious ties, i.e. a tribe or nation. Archaeologists tend to use the more non-specific term 'culture'. However, modern ethnoarchaeological parallels have demonstrated that archaeologists should show caution in moving from object types to tribes, since if you choose different objects, you get different tribes. Objects vary, depending on gender, kinship groupings, occupations and other social groupings (Hodder 1982; Renfrew and Bahn 1991: 168).
- Though sequences of development (typologies) normally run from the simple to the complex, it was recognized from an early date that the shape or decoration of an object could also become simpler and more stylized over time. This is demonstrated by the motif of the horse on the coinages of Iron Age Britain, which becomes increasingly stylized over time.
- In order to create a relative chronology for groups of different artefacts, such as graves each with an assemblage of grave goods, they are arranged in an order (seriation) which assumes that objects of similar type are manufactured for as short a time as possible.
- Human beings identify what they see by reference to previous visual images and understand them from the information associated (cued) from that image (Caple 2000: 2). Consequently the form and decoration of objects are normally created, and identified, with reference to visually similar predecessors.
- When a new type of object (shape or decoration) is developed, its production numbers start slowly, increase over time as the object becomes more popular, and then decrease until it dies out. This gives a shallow Gaussian (bell) or 'battleship'

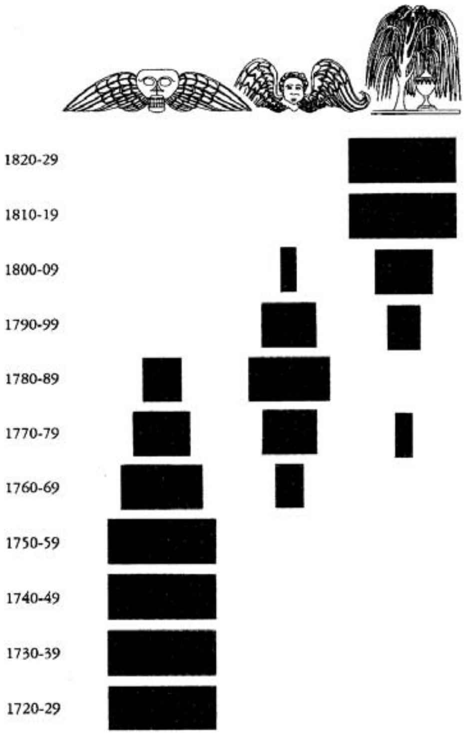


Figure 2.2 The ratio of decorative motifs from gravestones at Stoneham Cemetery, New England. (From *In Small Things Forgotten* by James Deetz, © 1977 James Deetz. Used by permission of Doubleday, a division of Random House Inc.)

curve. When combined with the development from simple to more complex, or more stylized, forms, a sequence of object production is established. This characteristic can be demonstrated with historically dated examples such as the decorative motifs on New England headstones (Deetz and Dethlefsen 1994; Deetz 1996) (see Figure 2.2) and again provides relative dating for the artefacts in a typology.

- As with evolution, in fairly stable or constant conditions, i.e. a relatively settled and peaceful society, there is believed to be a slow or gradual change in object form, decoration or manufacture '… since the consequences of changing raw material or altering processing techniques have been unpredictable; they are not modified without strong impetus' (Kingery 1993: 220).
- However, in periods where there is great change in society, e.g. the emergence of new political or religious groups, or wars, new ideas are clearly prevalent, often leading to dramatic changes in the form, decoration, materials or methods used to manufacture objects.
- There are many influences on the size, shape, decoration and materials of an

> object. Pearce (1994b) describes the importance of family, peer group, cultural icons, personal beliefs and physical reality (e.g. climate) in determining the choice of clothing (fashion) worn by young twentieth-century females. The relative influence of these and other factors will change depending on the type of object. In general, objects with a high degree of functionality change little over time. Thus the form of axes changes little throughout the Roman period, but wall paintings and mosaics change substantially.

An example of a typology, such as that of arrowheads from the high medieval period compiled by Oliver Jessop (see Figure 2.3), shows the variety of forms related in part to function and to the evolution of form over time. Figure 2.4 shows a time chart with the occurrence of the various forms over time, in this case anchored to specific examples from specific sites. The more varied and numerous the objects, the more difficult to establish a consistent and workable typology, as demonstrated by the seventeenth-century ceramics of the Chesapeake/Virginia region (Beaudry *et al.* 1991). It should be emphasized that the objects in a typology category are not identical until the era of mass production. Variation is present as a natural product of human manufacture and as an inherent trait that leads to the evolution of the object form of the next typology category (Wobst 1999: 127).

2.4 Decoration and images on objects

All decoration is significant, acting as a symbol (referent) through association or similarity to remind the viewer, consciously or unconsciously, of other objects or ideas. Even the absence of decoration (a blank canvas) or the absence of expression (a blank look) conveys a message. It takes time and resources to add decoration to an object and makes the object appear more appropriate or appealing. This is undertaken because it:

- increases value
- signifies status and social position
- shows affiliation
- indicates/enables the object to perform a specific role/use, e.g. to hold spirits associated with the object or bless or purify actions with the object (Hodder 1982: 185).

To conserve time and energy, the human mind normally seeks to minimize the visual complexity so that it can recognize objects more quickly and efficiently (Caple 2000: 5); thus plain undecorated simple shapes are simpler to appreciate and might be considered preferable. However, we have evolved because we are curious creatures, and it is in our nature to mentally explore, thus complex forms and decoration intrigue and attract us. We oscillate between these extremes, leading to variable levels of decoration of surfaces depending on the cultural traditions within which we operate. Features such as the presence of repeats of ornamentation and regularity of pattern are, like the beat of a song, a mechanism by which the human mind helps to maintain order in the potential chaos of ornamentation (Gombrich 1984: Chapter 1).

Aspects such as overall decorative scheme/structure may be considered as deriving from the structures or groupings in a society: the motifs derive from cultural symbols and beliefs, whilst the details and execution of the motif may derive from the personality and artistic tradition of the manufacturer (Hodder 1982: 183). This is largely undertaken at a subconscious level, and the design simply regarded as traditional. Whilst much decoration is culturally specific, some of the simplest decorative ideas appear to be cross-cultural, such as incised lines on a pot which accentuate the curve of the ceramic, or regular lines, dots or toothed forms which suggest control and order. The most complex forms of design, such as heraldic devices, provide a large number of messages and ideas, not least of which is their indication of restricted use and notions of ownership. Simple devices like the hair of a figure streaming out behind it suggests movement or wind – things which cannot be directly seen, only felt or their consequences observed.

Decorative designs follow the evolution of object forms as previously discussed. This is exemplified by the images seen on the gravestones of New England. James Deetz noted how the gravestones of different periods had different likelihoods of displaying images, such as a death's head, a cherub or a willow tree (Deetz and Dethlefsen 1994; Deetz 1996). Changes in the relative popularity of these forms are recorded in Figure 2.2.

The early death's head images were a reflection of the religious convictions of the period, the orthodox Puritan beliefs of the seventeenth and eighteenth century emphasizing the mortality and corruptible body of man. This also generated an appropriately direct text on the gravestone, e.g. 'Here lies …'. The more relaxed religious views following the Great Awakening in the mid-eighteenth century led to the adoption of the cherub image, emphasizing the separation of the soul from the body, an image which would have been considered idolatrous in the earlier period. The text on the gravestone subtly indicated the separation of body and soul, e.g. 'Here lies the body of …'. By the early nineteenth century, the role of the soul was increasingly important, with memorials to people buried elsewhere appearing in the graveyards, and memorials to groups of people. The image of the urn and willow emphasized the more abstract quality of such an age and the more intellectual Methodism and Unitarianism increasingly practised. The text also reflected these more cerebral and ethereal beliefs with texts such as 'Sacred to the memory of …' (Deetz and Dethlefsen 1994; Deetz 1996). Thus simple variation in the decoration can be seen to reflect wider social changes and to follow recognizable patterns of social development and artistic expression.

Decoration is not present uniformly throughout a society at any given point in time: there are variations, as one motif is popular in one region but not another, popular with one group in society, but not another. Deetz noted that the new cherub motif, which originally derived from England, was widely used by the intellectual elite of Harvard University buried in the cemetery at Cambridge, Mass. (65 per cent cherub, 5 per cent death's head). However, in Boston, with fewer sophisticates and social leaders, there were far fewer cherubs, and the death's head motif carried on for a considerable period of time. This demonstrates the prominent role of elites in

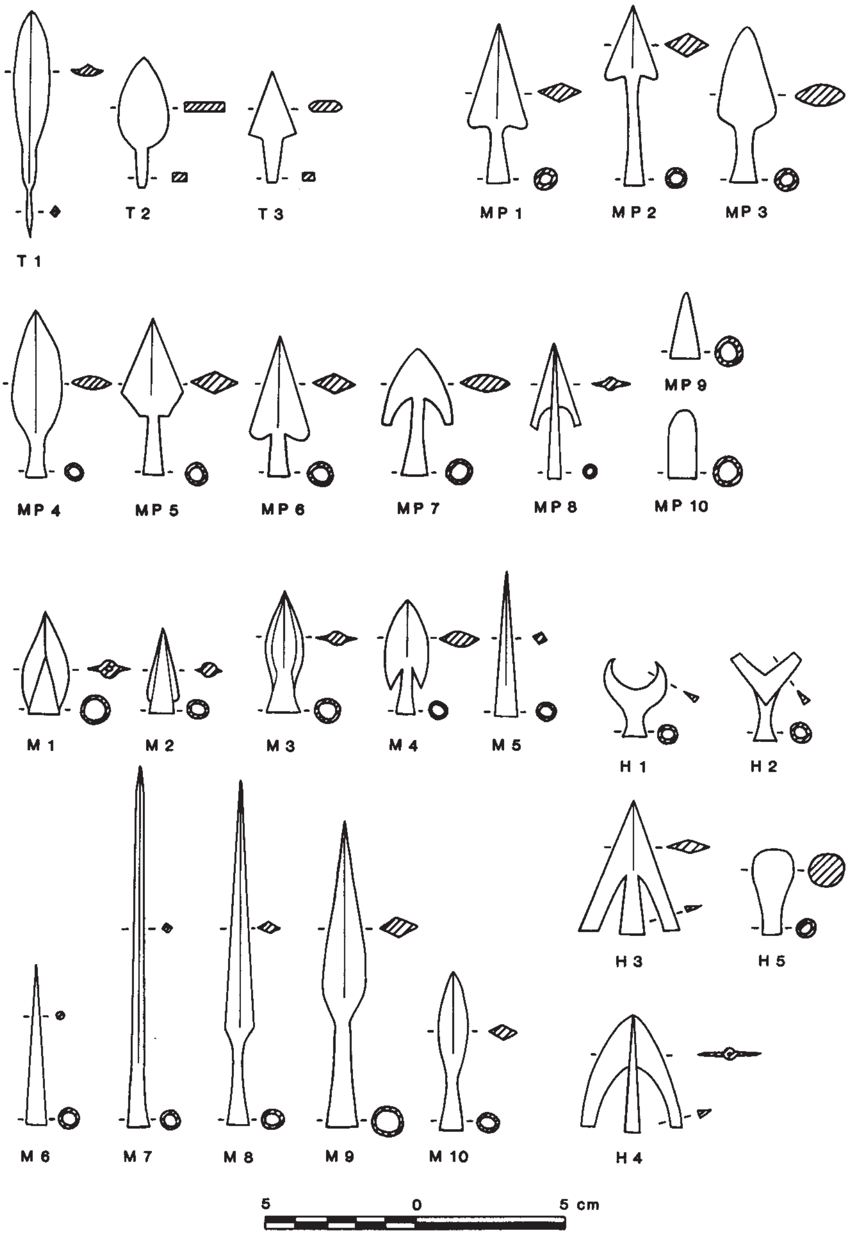
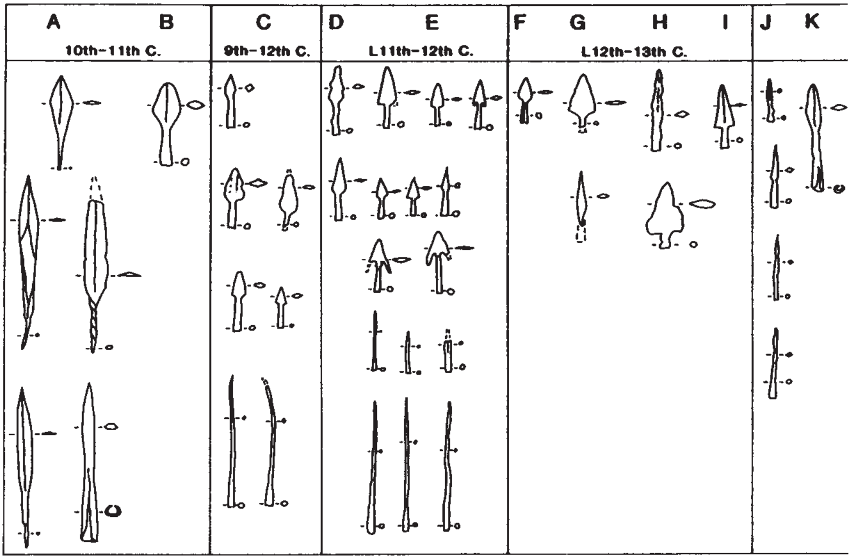


Figure 2.3 British medieval arrowhead typology. (From Jessop 1996)

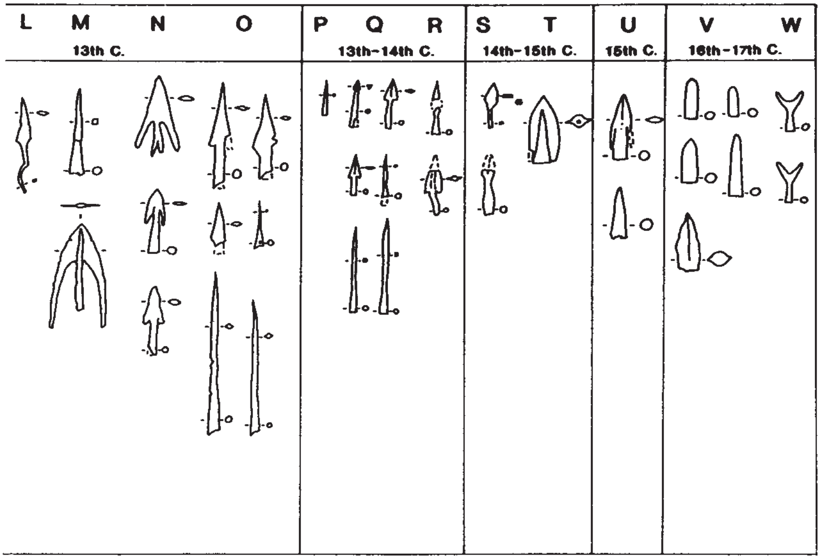


A Coppergate
B Durham
C Goltho
D Great Yarmouth
E Castle Acre
F Glastonbury Tor
G Castle Acre Priory
H Llandough
I Castleskreen
J Castell-Y-Bere
K Red Castle

Figure 2.4 British medieval arrowhead time chart. (From Jessop 1996)

bringing change to any society. Decorative motifs, like other ideas, move slowly through a society, usually starting in urban centres with social elites, and diffusing slowly out into rural hinterlands. The motif of the cherub diffused slowly into the rural areas surrounding the urban centres such as Cambridge and Boston. It travelled approximately one mile per year, arriving in cemeteries ten miles from Boston a decade after it appeared in Boston. Evidence of design evolution is provided by the transformation which the death's head motif underwent in the rural districts of New England. Local stonemasons evolved the death's head form during the eighteenth century. In some instances it acquired cherub features, and in other new forms became a Medusa-like form, as seen in the work of stonemasons such as Ebenezer Soule, working in the Plymouth area of Massachusetts (Deetz 1996: Chapter 4).

Many forms of decoration are simple patterns or motifs, designs that last for a long time. Thus objects with 'ring and dot' decoration occur in Britain from Roman to High Medieval contexts. Many decorative forms re-occur regularly throughout human history. The association with previous cultures can be part of the reason for its use. Thus the revival of classical styles in the Renaissance and Georgian periods derived from the esteem with which the art and ideas of the classical period was held in later ages.



L Butcombe
M Customs House
N Christchurch
O Dyserth Castle
P Doonbought
Q Bramber Castle
R Seafin Castle
S Llantwit Major
T Leith
U Huish
V Free Grammar School
W Basing House

The symbolism of decoration was even more pronounced when recognizable images such animals, plants and humans were depicted. Such images should be 'read' carefully in order to understand which social group, which virtue or vice is represented by the depicted animal. The Wilton Diptych (two-leafed portable altar screen) was made for Richard II and contains an image of the Virgin Mary and surrounding angels, who all have deep blue robes, and necklaces formed of broomclods: a French royal emblem. England was at war with France until 1394 when Richard agreed to marry the French princess in 1396. Since he died in 1399, the presence of the broomclods indicates this diptych must have been painted between 1396 and 1399 (Gordon 1993).

Images could be deliberately manipulated to encourage belief. The image of the emperor or monarch on a coin is invariably flattering. This was often the only image most people would see of their ruler, and the innate human ability to read human faces made this an effective and subtle form of propaganda. Images on objects often give them significance and desirability to one group in society, e.g. Roman glass gladiator cups, which depicted gladiatorial combat, and circus cups, which depicted chariot racing, have been predominantly recovered from Roman military sites (Price 1978).

In some cases the absence of ornament has been seen as desirable:

- In the Second World War the absence of decoration indicated the socially desirable trait of economy.
- From the sixteenth century onwards, some Protestants such as the Puritans shunned ornament and colour since they were regarded as diversions for the human mind, drawing it away from the serious business of life and awareness of God. The absence of ornament removed identifiers of wealth and social status – an idea also used in the present day for uniforms or dress codes in school or at work, in order to minimize competition and conflict.
- In the twentieth century the Modern movement promoted the idea of 'pure' object form and removed ornament from its architecture, interiors and objects. This was an artistic fashion that had aspirations of functionality and egalitarianism.

These anti-decoration philosophies indicate how decoration or ornament is considered as a means of displaying wealth, power and position. It diverts human perception away from the basic nature of the object and suggests other ideas and forms through its presence. Each and every culture has had different forms of decoration. These evolve, providing a convenient dating tool for archaeologists. The absence of decoration can also signify that an object is not finished.

2.5 Text and inscriptions on objects

The written word is a series of symbols that convey complex meaning. The presence of text as letters, numbers or symbols indicates the presence of a writer who is seeking to communicate information to a reader. Text falls into three categories:

- books and manuscripts where the written information is the exclusive purpose of the object, e.g. the Lindisfarne Gospels;
- objects such as gravestones, coins and packaging where there is a relatively small amount of text, but it is a key component in the object's function, e.g. the Bayeux Tapestry (see section 2.11);
- objects such as ceramic vessels or cars where text is not an essential part of the object but is present to provide additional information, such as place of origin, part numbers, a maker's mark or the signature of the artist (see section 2.8), or decoration (see Figure 2.5).

Words or alphanumeric characters can convey simple information, e.g. 'Fire Door', '£22.78', '$22.78', which are often indicative of the object's use and the period or culture (place) from which the object, or at least the writing, derives. They can also convey far more complex ideas such as emotions. To interpret any text it is important to recognize:

- Who is the writer? The manufacturer, the state or other controlling organization, the owner, the user or the artist/craftsman who made it? Subsequent owners or users may add text.
- Who is the reader? This is usually the intended user of the object viewing the

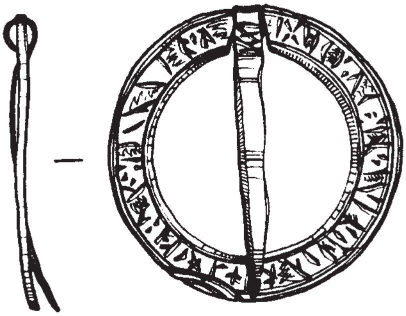


Figure 2.5 Thirteenth-/fourteenth-century brooch from Dryslwyn Castle, Wales. Redknap (1994) has suggested it is decorated with an imitation Latin inscription, whilst Goodall suggests it reads 'X IHESVS NAZARENUS', invoking talismanic or prophylactic properties (Goodall 2002). (Drawn by Oliver Jessop)

work of art, using the coin or reading the book. There may also be unintended users such as later generations of museum visitors. The intended reader is expected to have the cultural knowledge to understand the text, e.g. speak the language; unintended readers may not understand or may misinterpret the words. Thus what a modern schoolchild understands from reading a Shakespeare play is very different from a sixteenth-century theatregoer.

- Why is the writer trying to communicate? The reasons for writing are numerous, from simple instructions and factual information, e.g. 'Exit', to the complex fantasy of a novel. Since the writer is trying to make the reader believe or understand something, all writing comes with inherent bias (see section 5.1).
- What language is used? This may indicate the date and origin of the object (see Figure 2.6), though many inscriptions are often written in formal language and thus appear much earlier than they actually are. This is exemplified by the use of Latin on present-day UK coinage, and roman numerals for dates.
- The style and nature of the lettering – typography. This may indicate date and origin, but also the level of formality, and may contribute to the image projected by the object (see Figure 2.5).
- Punctuation, abbreviations and slang can be interpreted in many ways; formality, familiarity, emotions such as anger, brevity or ignorance. Thus 'RIP' on the gravestone may be simply a standard abbreviation for 'Rest in Peace', but since letters carved in stone are often paid for per letter, such abbreviations may be a cost-saving measure. It is normally necessary to have detailed knowledge of the period culture from which an object derives in order to correctly interpret abbreviations, e.g. 'CCAA' stamped on the base of Roman glass bottles indicates that they were made in Colonia Claudia Ara Agrippensis, modern-day Cologne (Price 1978).
- Words are spelt differently in different languages, regions and cultures. The

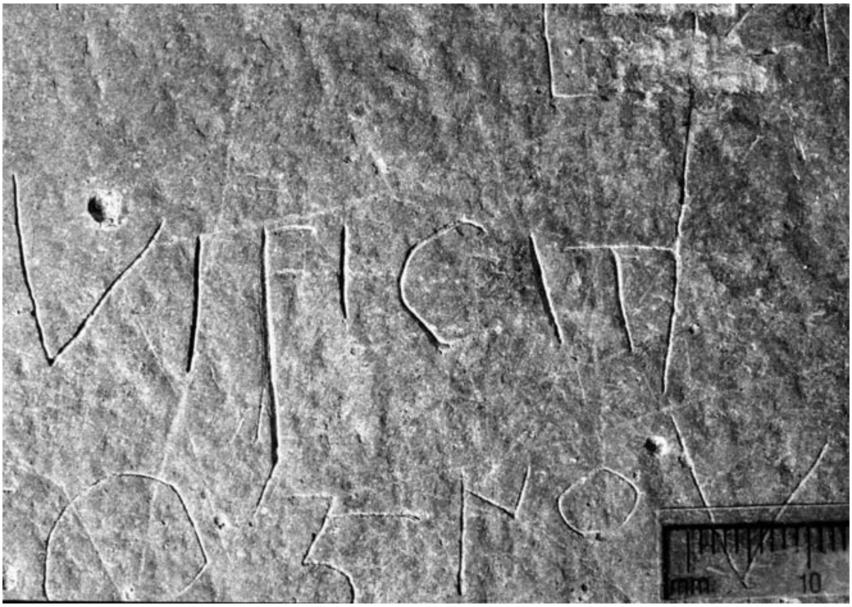


Figure 2.6 Fifth-/sixth-century Latin graffiti from Tintagel, Cornwall, which demonstrate the continuation of the practice of writing in Latin after the Roman period. (Photograph courtesy of Jennifer Jones)

choice and spelling of words in the Bayeux Tapestry indicate it was made in Saxon England rather than Normandy (see section 2.11). Though the misspelling of words may indicate a lack of knowledge or care (see Figure 2.5) it may also be a form of slang or derive from a period when spelling was not standardized.

- Words used can indicate the nature of the relationship between the writer and reader, e.g. the use of 'Father' indicates the level of formality, 'Dad' or 'Pa' a level of informality. Graffiti are familiar and personal and use slang, whilst most dedications and inscriptions have formal language and correct names and titles. Words can also indicate period, culture or region, e.g. 'bairns' – a colloquial term for children in north-east England and Scotland.
- Text is capable of analysis to reveal complex relationships and meaning; e.g. the text on the Coppergate Anglian helmet clearly indicates that the wearer was a Christian (see section 1.9). However, detailed knowledge and analysis of the text of the Lindisfarne Gospels were required to reveal that the observance of some Christian festivals and not others indicated the date at which the text was written (M. P. Brown 2003a).
- Symbols can indicate the function of the objects, and the culture and period from which the writing, if not the object, derives. Thus objects priced in shillings, e.g. '3/-', derive from countries using sterling, principally the United Kingdom, and,

in that case, from before decimalization in 1971, when the shilling ceased to be legal tender.

Advertising material identifying the contents and extolling the virtues of the product and the manufacturer are frequently present on the exterior of many nineteenth- and twentieth-century objects. Because of their exposed position, often only traces of lettering are found. The names of manufacturers, products or trademarks may be short-lived and thus may provide dating for the object. The name of a manufacturer may enable details of the product to be recovered from either trade catalogues or company records. Many machines and other composite objects have part numbers on individual components to allow identification and replacement when worn or damaged. Where companies or individuals own objects, they may wish to demonstrate this through painting, printing, engraving or stamping the family crest, company name, initials or logo on the object. Individual users would often simply scratch their name on an object.

The deliberate use of text by authorities is seen on coinage, it is usually symbolic rather than readable text. All the present British coinage bears the inscription *Elizabeth II D·G·REG·F·D*, where the initials stand for *Dei gratia regina fidei defensor* (Elizabeth II, by the grace of God, queen and defender of the faith). Much of the text is an abbreviated form of Latin, not spoken or written in common usage since the sixteenth century, and the term 'defender of the faith' refers to a title granted by the Pope to Henry VIII in the early sixteenth century, when Britain was a Catholic country. So, whilst text may provide crucial information about an artefact, it may not be contemporary or the literal truth.

Use of text as a mark of authority is seen in the presence of mint marks or the name of the moneyer stamped onto medieval and Roman coins to indicate the date and place of manufacture. To indicate the purity of gold and silver objects, purity symbols began to be stamped on them in London in the thirteenth century. This hallmark system became widespread and trusted, the range of symbols being expanded to include the place and year of manufacture. The system carried royal authority, and was in many ways identical to the guarantee of coinage. It demonstrates the readability and increasing importance of symbols as well as text.

2.6 Context

An object's physical context is derived from:

- The physical material (soil, packing material, frame) that surrounds the object.
- The provenance of the object, i.e. where it is located when found. This can refer to the room and building in which it was recovered as well as the area, region or country in which that building was situated. This may be the museum storeroom or the base of a well of an archaeological site in York.

  Objects such as shoes normally indicate the level of leather-working technology and style of footwear fashion prevalent at the period of manufacture.

However, when recovered from inside the walls of a building, in roofs and below floors, shoes were objects designed to ward off evil, especially witchcraft (Merrifield 1987: 131). Horseshoes similarly could be talismans to ward off evil rather than unique indicators of the presence and use of horses (ibid.: 161).

- The artefacts associated with the object. These may have an important cultural or functional relationship to the object. Thus the other objects and the skeleton found with an object indicate that it is a grave with a series of grave goods, which were almost certainly all buried together at the same time and thus have an important chronological and cultural relationship (see section 4.8).
  Some objects, like cutlery and pieces of china, are part of sets with similar styles and decorative motifs but different form and function. They are bound together as a group in complex, cultural activities such as feasting. The presence of one element indicates the original existence of all the other elements in the set.
  The approach of looking at objects as part of sets or groups can be expanded to a structuralist view of human society, in which all artefacts are related as part of a recognized group (metonymic) and a series of equated groups (metaphorical).
  Associations of unusual groups of objects can have powerful symbolic meanings. The association of pins or nails with hair or other body material, sometimes with cloth shapes and/or urine within a sealed ceramic container – often a Bellarmine jug – usually from a seventeenth-century context, indicates a witch pot. These were created to repel witches, and often secreted in the houses of those who felt themselves cursed (Merrifield 1987: 163–75).

Objects may have many different functions or symbolic meanings; their actual use/symbolism may only be indicated by their context (Hodder 1991: 121–53). For a simple thirteenth-century dagger the context, derived from the surrounding material, location and associated artefacts, determines the object's importance and meaning:

- in a medieval armoury
- in the back of a victim (friend or foe?)
- as an eating implement
- whittling wood to pass the time
- sharpening on a hone stone
- cutting the strings of a purse
- held up as a cross on which to swear
- part of the dress of a knight
- presented as a prize or gift
- as part of a display of arms and armour on the wall of a nineteenth-century country house
- in a museum display case
- thrown away as an offering to the gods or spirits.

The context from which an object is recovered is only the last one in a potentially long history. These final contexts/uses, such as deposition in a grave or discard after it has ceased to be functional, are greatly over-represented in the archaeological record. Only study of the use of an object, through written texts, illustrations and traces of use on the object, will reveal many of the previous contexts in which the object was utilized. The Coppergate Anglian helmet (see section 1.9) and the Winchester Reliquary (see section 5.8) demonstrate that even valuable or religious objects can end up in untypical discard contexts at the end of their lives. Archaeological contexts suffer from problems of residuality (see section 6.2). Historic objects often derive from museums or their role as an 'antique' in historic houses and are thus devoid of their original use context.

Contexts need to be critically evaluated. The north door of Durham Cathedral (see section 6.8) may, like many architectural features, be considered to be '*in situ*', as it has occupied the same position since it was hung in the twelfth century. However, since then the doors have had their original iron scrollwork removed, been given vertical mouldings and been covered with black paint. A small access door was cut through the main doors, and much of the top of the doors was sliced off in the nineteenth century. A twentieth-century removable wood and glass vestibule now normally obscures the back of the doors. The whole of the front of the cathedral had several centimetres of its exterior stonework removed in the late eighteenth century; the medieval front porch was also removed and the entrance remodelled. Much of the remaining stonework has weathered or is modern stone replacement. Consequently there is now little of the object's original appearance or context visible.

One useful context for historic objects is their surrounding packaging material (original toys, etc.), case (cutlery, medical or musical instruments), frame (picture or photograph) or sheath (sword). Such cases, enclosures and packaging provide, through the materials of which they are made, the additional cleaning materials/devices they can contain and the information on the manufacturer printed on them, valuable information about the objects, their care and cleaning, their use, their manufacturer, and the accessories that went with the object. They provide a glimpse of the object as a newly manufactured object. Cases and packaging are often inscribed with the name of the gift-giver or the owner of the object. Such cases, frames and packaging help maintain the object in good condition and add to the value of the object as a historic document, a value often reflected in the increased monetary value of cased, framed or packaged items when sold as antiques. The case should also be seen as an object in its own right. Cases that contain objects are not always originals, and can have their own histories of use and abuse. Some things we regard as objects were originally cases. Thus amphorae, coffins and furniture such as chests of drawers, bookcases and wardrobes are finely wrought cases. The value of the contents or the role of the object as a display item meant, especially in the case of furniture, that it was made with the finest materials and the highest levels of craftsmanship. The Winchester Reliquary (case study, section 5.8), is a case for its relics. Reliquaries and other cases may contain more information about the period and construction than their contents: they often reflect the craftsmanship of the age and stylistic features which date the contents. Cases can be replaced at a later date, e.g. the treasure binding provided for the Lindisfarne Gospels by Bishop Maltby in 1853, where the binding provides a clear indication of nineteenth-century artistic tastes and values, removing the earlier historic bindings but protecting the eighth-century manuscript (M. P. Brown 2003a).

2.7 Coloration and coatings

Whilst the underlying form and materials of an object may primarily be functional, many objects have been given surface finishes which are culturally determined. The colour of an object is an important cultural identifier. Different cultures associate different colours with different emotions, events and activities, e.g. Western European and American culture associates death with the colour black, whilst in China it is associated with white.

Social and religious groups, e.g. political parties, both in the present and the past adopted a colour in order to enable followers to display their beliefs through wearing the colour. Colours acquired associations because of the properties of materials with those colours; e.g. the high value of some pigments, metals and dyes has led to those colours being associated with wealth. In mid-fifteenth-century Flanders the distinctive scarlet red dye, kermes, cost 29 times as much as the less vivid but more commonly available dye, madder (Munro 1983). Associations of wealth, rank and status were reinforced by wearing colours, e.g. the scarlet robes of a cardinal. Efforts to preserve such distinctions led to restrictions on the wearing of coloured clothing such as the Sumptuary Laws – statutes passed between 1337 and 1604 in England that forbade the wearing of specific colours and styles of dress save by those of the appropriate social class.

The changing fashions and social and economic environment in which an object is placed can be revealed by its changing external appearance. Thus a cross section through the paint layers of Battersea Bridge revealed the changing colour of London's bridges, gilded for a coronation and camouflaged during two World Wars (H. Hughes 2002a: 13).

There are numerous ways in which colour and texture may be applied to an object. In particular the expression of value an object projects is frequently enhanced by surface coatings:

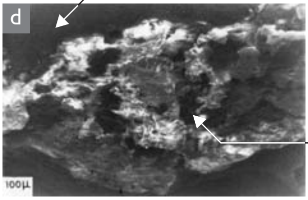
- *Patination* – chemical treatment or controlled natural corrosion can lead to the development of coloured mineral coatings. Variation of the metal, its composition and the chemicals used to treat it can lead to a wide range of possible colours, especially on copper alloys (Hughes and Rowe 1982) (see Figure 2.7). The finest examples of this technique were seen in the Japanese *shakudo* work (La Niece and Craddock 1993).
- *Gilding* – gold is rare; when pure it can be worked to form thin sheets and wires without tearing and, uniquely amongst the early metals, it did not tarnish. This highly reflective metal could thus be formed into thin sheets to cover objects, making them appear valuable solid gold objects. A wide variety of 'gilding' techniques were practised from at least the fourth millennium BC to the present (Oddy *et al.* 1988; Lins and Oddy 1975; Budden 1991; Draymann-Weisser

2000; Bigelow *et al.* 1991). Gilding was often applied directly to the surface of metals, especially copper alloy (burnished, leaf gilded, fire [mercury or amalgam] gilded or attached with adhesive). When applied to materials such as stone or wood, a layer of gesso (calcium sulphate or calcium carbonate in animal glue) was applied to the surface first, followed by a layer of bole (gesso typically coloured red or yellow with iron oxides or clay minerals) onto which the gold was burnished (water gilding) or adhered (oil gilding).

- *White/silvery metal coating* – though silver could be applied in a similar manner to gilding, it could tarnish and was rarely used. More resistant to corrosion, tin was applied from the Roman period onwards as decorative contrast on jewellery, and by the High Medieval period on iron objects, e.g. spurs, as corrosion protection. The tin could be applied molten or to heated objects, as it has a low melting point (232 °C), or chemically deposited, as it was to medieval brass pins (see section 3.12). In the twentieth century, white-metal coatings such as zinc (galvanizing), nickel plating and chromium (chrome) plating were applied to iron/steel to give corrosion-resistant white/silvery metal finishes.

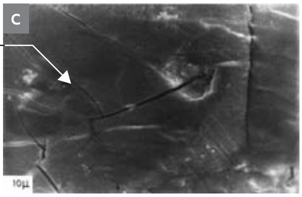
  The highly reflective nature of gold and silver meant that fine incised decoration showed up well as patterns of light and dark on the metal. Coloured stones, e.g. garnets, enamels and niello (a black metal sulphide paste frequently seen decorating silver (La Niece 1983)), were seen decorating jewellery. Base metals such as copper alloys and iron could be kept in polished condition to emulate the reflective gold and silver, e.g. the brass on the Coppergate Anglian helmet, which has clear evidence of being polished.
- *Paint* is formed of pigment particles – coloured minerals and lakes (dyed inert materials) – held in a binder. It is normally applied in a layer to colour the surface of objects or buildings, or applied to rocks and other natural materials. Paint can be used to:
  - cover an object to give the impression of being another material – in the eighteenth-century garden, lead statues were normally painted white in order to imitate the more expensive marble;
  - provide decorative blocks of colour for simple aesthetic effect;
  - create images in a combination of colours and shapes, e.g. oil painting;
  - protect against the effects of handling and weather – external wood surfaces such as doors are often painted.

  Paint layers deteriorate: they can wear off, peel and flake through the effects of human contact and weather. They fade or discolour because of the effects of light, and dull through the effects of dust. Objects and interiors were often repainted:
  - when they started to look aged and shabby, in order to maintain the visual impact of the objects or interiors;
  - to maintain the protection against damage or weather;
  - because there was a regular repainting regime – i.e. they were repainted whether they needed it or not;
  - in new colours in order to make them appear fashionable and demonstrate wealth and taste.



A dense outer phase, rich in tin oxide with significant amounts of copper oxide, with traces of phosphorus and lead minerals

A vesicular inner phase rich in copper oxide with significant amounts of tin oxide

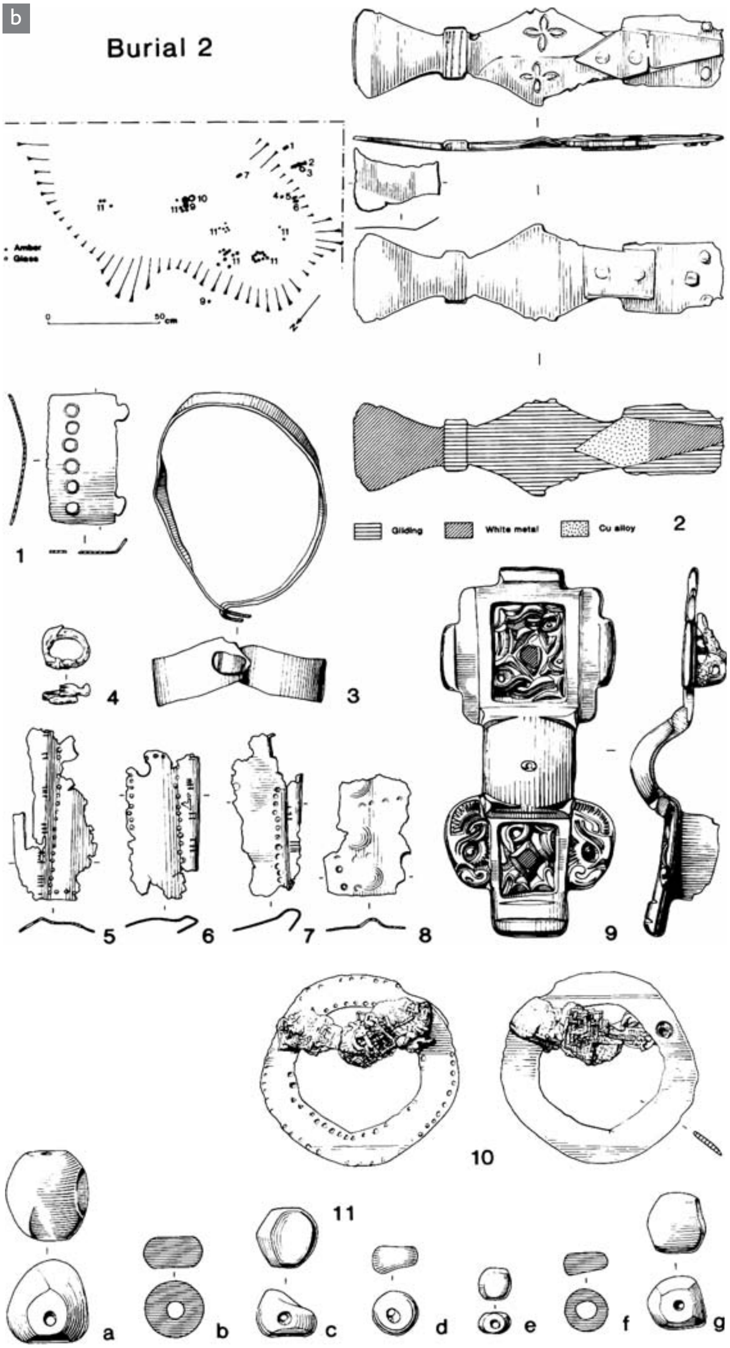


The brooch was recovered from Grave 2 of the Saxon Cemetery on Andrew's Hill at Easington, Co. Durham (Caple and Clogg 2001; Hamerow and Pickin 1995). The large number of grave goods (b) indicated a wealthy female. The brooch is a floral cruciform brooch type, without side and top knobs. The head and foot panels are decorated with Salin Style I zoomorphic ornament and a crudely shaped garnet chip. A very similar example was recovered from the Saxon cemetery at Norton, 15 miles away, suggesting a local manufacturer. The brooch had a coherent black coating, partially worn away from the back due to use, which indicated that it had been deliberately patinated as part of the manufacture process. EDXRF analysis (a) showed the brooch was made of an alloy of bronze with gold. Black patinated copper alloys were occasionally seen in the Roman period (Corinthian bronze), as well as in the later medieval Japanese 'shakudo' objects, they always have traces of gold and silver in the alloy (La Niece and Craddock 1993). SEM analysis of the black patina revealed a dense black outer layer (c) and an inner vesicular structure (d). They were composed of copper and tin oxides. The black patina of shakudo and Corinthian bronze is a black form of the copper mineral cuprite formed by chemical treatment – i.e. patination – of the alloy (Murakami 1993). A seventh-century bangle from Cannington, Somerset (Bayley *et al.* undated), like this brooch, had tin (as oxide) as well as copper oxide in its black patina (drawings from Hamerow and Pickin 1995; photographs courtesy of Jennifer Jones, Phil Clogg and the author).

a Brooch surface analysis (black patina)

Cu	*Sn*	*Zn*	*Pb*	*Au*	*Ag*	*Fe*	*P*
38	30	2	9	14	0	1	4
43	29	2	11	7	0	1	4
44	29	1	8	11	0	1	5
48	27	7	2	11	0	1	3

Figure 2.7 Andrew's Hill black brooch


b
Burial 2
Amber
Glass
0
50cm
N
1
2
3
4
5
6
7
8
9
10
11
Gilding
White metal
Cu alloy
a
b
c
d
e
f
g

Consequently layers of paint build up on objects and room interiors, creating a record of the earlier colours and schemes of decoration. This coloration history is revealed by taking an appropriate number of samples of the full thickness of the paint and mounting them in resin and polishing them so that the full sequence of layers can be viewed in cross section (see section 3.11). Objects often initially considered undecorated can reveal fragmentary traces of paint when examined in detail using a stereo microscope (see section 1.8). Mapping such fragments can allow the colour scheme of the whole object to be deduced.

The colours available over time will change owing to the effects of trade and invention. The palette has grown larger, especially during the twentieth century, when numerous synthetic pigments became available (Harley 1970; Feller 1997; Roy 1994). Techniques such as elemental composition (EDXRF, SEM or ICPMS) or physical properties of the pigments (fracture, shape, etc., revealed under microscopic examination) or crystal/mineral identification (XRD or FTIR) provide factual information which, when coupled with a knowledge of the pigments available at the time, leads to pigment identification. Knowing the earliest date of introduction of any pigment provides a *terminus post quem* (tpq), i.e. 'date after which'. The date for the introduction of the latest original pigments in a painting provides the date after which the painting must have been created. For pictures, the painting technique, the image itself or the history of the object usually provides a more accurate date, as shown by *The Ambassadors* by Hans Holbein (Wyld 1998). Pigment identification is important for detecting fakes.

Variation also occurs in the binding media used. The various binding media have different chemistries and properties and thus different types of use (Mills and White 1987). Identification of paint media can be achieved through noting solubilities in a range of solvents (Horie 1987), chemical staining tests, thin-layer chromatography or FTIR (Fourier transform infrared absorption spectroscopy) (Masschelein-Kleiner 1986). The most accurate method is gas chromatograph and mass spectrometer (GC–MS): see section 5.6.

- Distemper – pigment mixed with a weak animal glue solution. Used extensively for the interior decoration of buildings.
- Watercolour – pigment in a weak solution of a water-soluble gum, e.g. gum arabic. Principally used by British artists for painting pictures on paper.
- Gouache – thick opaque paint, pigments in water-soluble gum e.g. gum arabic solution. Used for painting pictures on paper and decorative objects.
- Oil painting – pigments in a drying oil, principally linseed, but also poppy seed and walnut, which formed a hard, tough film on setting. Linseed oil is recorded as being used in Flanders in the thirteenth century and was used throughout Europe by the sixteenth century. From the eighteenth century, oil paints were commercially produced and used for works of art on canvas as well as decoration of objects and interior woodwork. The large quantities used for interior decoration frequently contained lead minerals to speed drying.
- Egg tempera – pigments mixed with either the yolk, white or whole egg,

  widespread for picture painting on wooden panel and manuscript in the medieval period, continued in use in Italy and southern Europe into the sixteenth century.
  - Acrylics – pigments mixed with acrylic vinyl emulsions, thinned with water, dry relatively quickly to form a tough film. Available in the 1930s, gradually displace oil paint during the twentieth century. Used for painting on many materials, coating objects and painting building interiors.
  - Alkyd resins – pigments mixed with esters of phthalic and terephthalic acids. Create tough highly insoluble paint layers. Available from the 1930s onwards, used for coating objects and building interiors and exteriors.

  The commercial production of paint in the eighteenth century, usually based on drying oil (linseed oil often with lead pigments as driers), gave the possibility of covering objects economically in colour, and thus painted objects started to become more widely seen. This increased in the nineteenth and twentieth centuries as painted objects become more widespread, allowing poor-quality wood or other construction materials to be used, since they were covered with paint. Traditionally for interior woodwork and objects three or more coats were applied:

  - A primer, oil-based, designed to seal the surface.
  - An undercoat with dense cheap pigment (often with extenders) – designed to give a base colour for the top coat and a smooth surface, which set fairly quickly.
  - The top coat, often a gloss coat, with the more expensive pigment and a smooth glossy surface finish, again based on drying oils, which set slowly.

  Earlier medieval polychrome sculpture and later high-quality pieces often had a thin gesso coating applied to the wood to provide a smooth even surface before the paint layers were applied (Kuhn 1986: 32). Ethnographic objects have a very wide range of potential pigments and dyes. Pigments were usually applied direct to the object surface, often with little or no binding medium, since the objects were not intended for anything but short-term ceremonial use.

  Pigments are often only available from a limited number of locations in the world; thus the presence of the pigment indicates trade with that region. The presence of mercury in a bright red pigment, on fragments of thirteenth-century wall painting from a castle in Wales, identifies it as cinnabar. Since Spain was the source of cinnabar for Europe in that period, its presence indicates trade between Wales and Spain.

- Varnish – applied over oil paintings and other painted surfaces in order to protect them and to saturate the colours and make them more visible. Wooden objects were also stained and varnished. Initially clear, varnishes usually yellow with age. They also shrink and crack, and on paintings produce a network of fine cracks (craquelure). Pressure or blows to the object surface can be detected as they often act as centres for the cracking of varnish and paint layers. Though craquelure is often considered a sign of age, such cracking can be faked by using an appropriate mixture of varnishes and artificial ageing techniques such as heating.

From the medieval period onwards, varnishes were made from drying oils plus resins (natural polymer exuded from the trunks of trees) such as copal (fossilized tree resin such as amber), mastic (resin from *Pistacia lentuiscus*), dammar (resin from south-east Asia, *Dipterocarpaceae* spp. – seventeenth century or later in Europe), colophony (distilled resin from larch or pine), sandarac (resin from *Tetraclinis articulata*) or shellac (secretions of the lac insect of south-east Asia – seventeenth century or later in Europe). After the seventeenth century these resins were usually applied in solvents such as turpentine (Kuhn 1986: 25). Since the start of the twentieth century a range of modern polymers (acrylics, cellulose nitrate, cellulose acetate, etc.) have formed cheaper, more stable, less brittle and less yellowing varnishes for paintings and other objects.

- Dyes – organic molecules that can become chemically or physically attached to substrate materials, typically textiles, to make them appear coloured:
  - by direct chemical action (substantive or direct dyes), e.g. turmeric,
  - with the use of a mordant, typically an iron or aluminium salt, e.g. madder,
  - by forming a precipitate, usually through oxidation, in and on the substrate (vat dyes), e.g. indigo.

  In the archaeological and historic past, dyestuffs are water-soluble. Many early dyes have yet to be clearly identified; often simple plant materials such as blackberries were used as dyes. Considerable subtlety is often achieved with variation in the dying conditions, the mordant or the pH of the dye bath (Goodwin 2003). The dyes brought to Europe through the increased trade with the Arab world in the twelfth and thirteenth centuries and with Asia and the New World in the sixteenth and seventeenth centuries gave stronger colours and displaced the native dyes in commercial usage. These were in turn displaced by the synthetic dyes of the nineteenth and twentieth centuries. Twentieth-century repairs and fakes can often be detected through identification of modern synthetic dyes. Dyes are normally identified through analytical techniques such as UV/Vis. spectrometry (Walton 1989b; G. Taylor 1989). For more detailed analysis HPLC has been successfully used (Timar-Balázsy 2000).

  Archaeological textiles, which are normally only preserved in waterlogged, frozen or desiccated conditions, often appear soil-coloured. When tested, however, between half and two-thirds of archaeological textiles have traces of dye present. Some colours, such as the browns and blacks, are often not identified since tannins, some of the principal black/brown dyes, are not easily detected, and textiles are frequently contaminated by tannins from leather objects in the same deposits. Yellows are also difficult to detect because of the masking effects of soil; however, colours such as reds, blues and purples are readily detected by UV/Vis. spectrometry. The value of dye analysis is revealed by Walton, who showed that, in analysis of over 90 Viking Age textiles, from York, London, Dublin, Norway and Denmark, a range of dyes – madder/bedstraw (red), orchil/lichen (purple), woad (blue), weld, kermes and a yellow of unknown origin – were used to colour the fabrics of the eighth- to eleventh-century Anglo-Scandinavian population of north-west Europe. There was an apparent preference by the inhabitants of

> Dublin for purple-coloured garments, whilst those of York and the Saxons of London preferred red. Those textile fragments recovered from Scandinavian graves indicate a marked preference for blue-coloured garments, though clearly factors other than fashion, e.g. symbolic use of blue clothing for those being buried, may be indicated by the results (Walton 1989b).

From the prehistoric period to the present day, objects such as jewellery and clothing have been deliberately coloured. This coloration often involved imported dyes and pigments and sophisticated technological processes. The colours often had social meaning, e.g. status, fashionability, religious belief. To determine an accurate polychrome picture of the past, every object should be examined to determine its original colour and the method of coloration.

2.8 Artists, craftsmen and makers' marks

Many objects are created as a result of individual circumstances. This is exemplified by the creation of a model of an eye made in gold by Benvenuto Cellini, who recorded in his autobiography that, when he was sharpening a series of chisels for carving a marble statue, a sliver of steel had flown into his eye, entering the pupil. It was impossible to extract, so the surgeon dripped blood from the veins of two pigeons into Cellini's eye, which provided him with some relief from what must have been a painful injury. Two days later the steel sliver issued from the eye, which further eased Cellini's discomfort, and subsequently he recovered a great measure of sight in that eye. As the feast of St Lucia was approaching, Cellini sculpted a gold French crown into the form of an eye and got his ten-year-old niece, Liperata, to present it as an offering to God and St Lucia (Symonds 1949: 359).

Whilst the exact circumstances of such an individual object cannot be known without a written record, careful examination of the object and knowledge of the period could allow several aspects of the object's origin and symbolism to be determined. In many Catholic churches, especially those with saints' relics, believers left small models of parts of the human body, representing those parts that were afflicted with pain, in the hope that the offering would encourage the saint to work a miracle and cure their pain. Models were also left as expressions of thanks when their prayers had been answered and a cure for their affliction had occurred (Merrifield 1987: 88). The context of discovering the object/offering would leave little doubt as to the original purpose of the object. Analysis of Cellini's gold eye would reveal that it had a composition identical to a French crown, not unlike the analysis of the Milton Keynes pendant, with its composition derived from Frankish gold coins (see section 4.8). If the composition of the coinage changed over time, this might allow a rough date bracket for the work to be calculated. Study of the artistic modelling of the eye might have noted the similarity of the work to that of the craftsmen/artist Cellini, who was operating during the period. Whilst such an attribution would lack certainty, it would be possible to suggest that at a given time an artist craftsman, such as Cellini, had been commissioned or had a personal reason to make an offering to St Lucia either because someone in his patron's family, or someone personally close to him, had damaged their eye or was losing their sight.

It is possible to see any object, such as a hand-made chair, as part of a material culture of the people, place and period from which it derived. It can be studied in a number of ways: the technology of chair-making (tools and materials); the typology of chairs (stylistic variations by period and geography); the social factors involved in chair manufacture (sale and exchange mechanisms, industrial organization, apprenticeships); or the economics of chair production (production levels, costs of production). However, the owners (users) and makers of the chair see them as individual objects and consider them in far more personal terms – the cost of the chair, how it looks, the problems in making part of the chair or the quality of the workmanship. In the late 1960s Jones (1993) documented the motivations, designs and production of chairs by a series of craftsmen in south-east Kentucky. He discussed the influence of the personality and preferences of the individual craftsmen and their customers in the creation of the objects, an approach to studying objects he describes as 'behavioural', i.e. the objects are considered as a manifestation of human behaviour. Factors he documented included:

- Craftsman's personal preference (aesthetics). Chairmaker Verge: 'I like rounded arms' (Jones 1993: 189).
- Craftsman's personality. 'The posts of Harry's chair flare backwards in a fashion that would never appeal to Aaron, who was soft spoken and tended to be personally undemonstrative' (ibid.: 185).
- Craftsman's self-awareness. Chairmaker Aaron put a notch in the top rail of the chair back, which he regarded as his 'trademark' (ibid.: 187).
- Customer preferences. '… customers always chose the chairs with the notch' (ibid.: 189).
- Specific commissions. Chairmaker Verge: '… but for myself I wouldn't have them rings and nubs. But you gotta make it how the customer wants' (ibid.: 189).
- Craftsmen copying ideas from others as they learn the trade (ibid.: 185).
- The craftsman's sense of perfection, or lack of it.

There were also clearly variations in the level of skill and knowledge between craftsmen. Choices of wood, within a range with physical properties suitable for chair making, varied based on personal (aesthetic) preference and their experience and training (Jones 1993: 189). In such an investigation, which utilizes discussion with the artist/craftsman as its data-gathering method, the importance of the psychology/personality of the artist/craftsman and their communication and interaction with others emerge as key factors in the object creation process.

A further factor which many artists and craftsmen have also noted is that, when working with a material – the product/producer interface (Jones 1993: 194) – certain things suggest themselves: the grain of the wood, the way it splits, the movement of a tool, the emotion of the moment. This is particularly true for artists and those craftsmen working natural materials, with their natural flaws and imperfections.

Technical processes often involve ritual activities. These preserve techniques and activities which, through ritual repetition, may improve the object being manufactured; e.g. stirring a mixture a specific (ritual) number of times ensures it is well mixed. Some rituals, however, appear to confer no technical benefit, e.g. the tradition of bell-founders throwing a silver ring into the bell metal before it is cast. They are probably related to wider social and religious beliefs – sacrificing something of value to the 'gods' whenever something new is made or created, e.g. pots buried under houses, bottles broken over the bows of ships, or harvest festivals (Merrifield 1987).

All these factors are an important element in the manufacturing process for hand-made objects. They reduce in importance with mass-produced objects, overridden by economic factors. However, they form the natural level of variation that should be expected in any hand-crafted object. Such variation, especially over a working lifetime, can be large but is usually small, especially in a stable society. As suggested when describing typology, the uncertainty in maintaining production and sales of objects when changes are made militates against change. Some authorities have suggested more dynamic artistic expression. Banzel, observing the potters in the native American pueblos of the south-western United States in the 1920s, commented '… these potters constantly invent new patterns … because it is as easy as painting old ones and very much more enjoyable' (Kingery 1993: 218). This may be the anthropologist talking, rather than the view of the potters. The scale of production probably influences the extent to which personal expression is present in an object. Production by professional craftsmen and manufactories is limited to/dictated by what the market will tolerate, since they are economically dependent upon sales. Personal or household levels of production can be more idiosyncratic. Similarly, bespoke objects may have more idiosyncratic form and decoration, approved – even required – by the patron/client. Mass production only reproduces the conservative and culturally acceptable/saleable.

Marks and signatures

Craftsmen have put either their names or marks on objects in order to identify them as their products since the Greek and Roman periods. *Terra sigillata* ceramics (Arretine and Samian ware) are often stamped with the name of the potter. This was done initially for practical purposes, e.g. to identify the products of an individual potter when pottery was fired in large communal kilns (Greene 1986: 160). Similarly, medieval masons used to place marks on stone they had carved, since they were often paid on the basis of the pieces they produced – piecework. They usually used simple symbols that were quickly scratched into the surface of the stone, as shown by the examples from Durham Cathedral (see Figure 2.8).

The stamp or signature of the maker on the object eventually became appreciated as a way of signifying to the customer, who presumably had begun to recognize the work of individual craftsmen and request their products from their supplier. Presumably they found the products of a specific craftsman were more robust or had more pleasing aesthetic qualities than those of other craftsmen. As such, signifiers became seen as

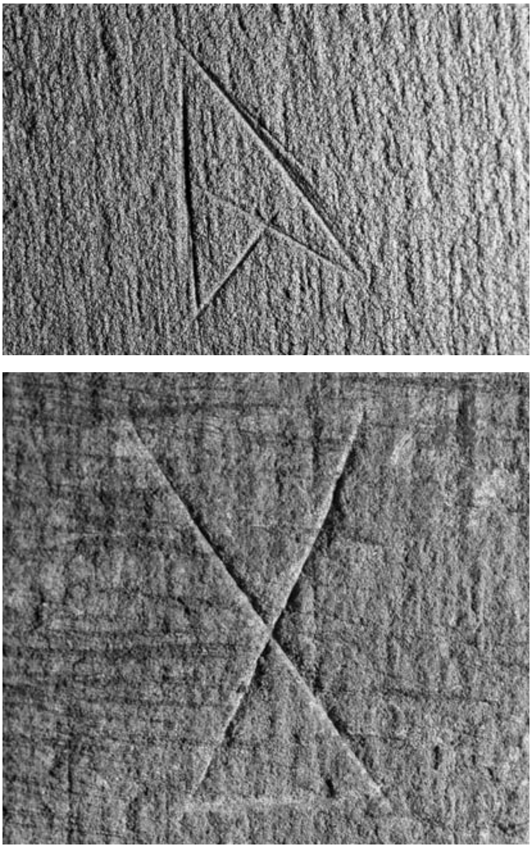


Figure 2.8 Masons' marks from the spiral staircase of the fifteenth-/sixteenth-century gatehouse to Durham Cathedral close. (Photographed by the author)

marks associated with quality; they were often applied to the back or base of objects. This no doubt influenced artists, who were considered initially as craftsmen, and from the sixteenth century we find artists signing their works of art. The signature is recognized as a mark of authenticity, though it can be, and often is, easily faked (Marijnissen 1985). This signifier need not be simply a name, it could be a device (logo) such as the two intertwined letter Gs which were branded onto the back of oak panels made by Gillian Gabron, a panel-maker working in Antwerp in 1619–20 (Marijnissen 1985). The idea of a maker's mark or artist's signature was also applied by groups of craftsmen working in a single workshop, to all the studio works of an artist and his assistants, and eventually to all the products of commercial manufacturing companies. This led to the presence of the manufacturer's logo prominently placed on almost all modern goods, as every passing car demonstrates.

INVESTIGATION TECHNIQUES

2.9 Examination under UV and IR radiation

Examination, with or without magnification, normally occurs in the visible light spectrum, i.e. wavelengths of 380–760 nm. However, it is also possible to examine objects under ultraviolet (10–380 nm) and infrared radiation (760 nm–2 mm).

Ultraviolet (UV) radiation *(de la Rie 1982a, 1982b, 1982c)*

Ultraviolet radiation (light) is absorbed by the electrons of some organic molecules and inorganic materials, which undergo energy transitions and re-emit light in the visible spectrum. Electrons that undergo such transitions are present in a limited number of inorganic minerals used as pigments, such as cadmium yellow and zinc white (de la Rie 1982a). Consequently when UV radiation is shone at a picture using these pigments, these minerals emit light, i.e. fluoresce. A far larger number of organic molecules fluoresce; in particular, drying oils and other resins that have dried and started to yellow. Exposure to daylight and then storage in darkness, the presence of ammonia vapours, and the presence of compounds (such as lead white) that speed the drying of oil films lead to increased fluorescence. Varnishes such as dammar and mastic do fluoresce, but to a lesser extent than oil films. Exposure to strong light can reduce or bleach the yellowing and the fluorescence effect. The removal of yellowed varnish through cleaning, or the presence of more recent varnishes, e.g. as retouching or repairs to the original painting, shows up as darker areas in the fluorescence of the original oil paint. Fluorescence is not always white but can have a colour, depending on the range of wavelengths emitted by the fluorescing pigment or organic resin, e.g. zinc oxide fluoresces a yellow hue, whilst shellac fluoresces orange.

Examination using a UV radiation (light) source will reveal evidence of repairs and restorations that have occurred on an oil painting or any painted or varnished object. It may also give an indication of the pigments and binders or resins used in creating the object.

Infrared (IR) radiation *(van Asperen de Boer 1986, Walmsley* et al. *1992)*

Infrared radiation is divided into near infrared (760 nm–2.5 μm), mid-infrared (2.5–500 μm) and far infrared (0.5–2 mm). Viewing the absorption of far infrared radiation is known as ‘thermal imaging’, and it has applications in the commercial environment, identifying materials on the basis of their differing thermal capacities, e.g. voids in materials and corrosion in metals. The mid- and near infrared radiation corresponds to wavelengths absorbed by stretching and vibration of bonding electrons. Organic materials differentially absorb this radiation, depending upon their molecular composition. An image of the absorption of mid- and near infrared radiation by an object is known as an ‘infrared reflectogram’. These are used primarily in viewing fine art, where the differential absorption of IR radiation is frequently used to look for the under-drawing present beneath many oil paintings. This can reveal the artists' working methods, their original sketches and earlier images.

Most illumination sources produce reasonable quantities of infrared radiation, thus illumination is by tungsten GLS or quartz halogen (tungsten–halogen, quartz–iodine) lamps. The detection of infrared radiation is normally through:

- Film sensitive to infrared radiation. Used in a normal film camera, the addition of a filter such as a Wratten 87A or 87C filter in front of the camera prevents visual spectrum light from entering the camera and ensures that an image of emitted infrared radiation is detected. Different infrared films have different sensitivities; most, however, record in the 800–900 nm range.
- A charge-coupled device (CCD) video camera with its normal infrared radiation filter removed and a visible light filter, e.g. Wratten 87C, in its place.
- A vidicon video camera designed for detecting infrared radiation. Though there is some slight image distortion, these systems are widely available in archives and painting conservation studios.

All provide good images in the near and mid-infrared, though none are particularly sensitive in the 1.8 μm region which Delaney *et al.* (1993) determined was the region for optimum visibility of the most common under-drawing materials.

Most pigments are to a greater or lesser degree transparent to near and mid-infrared radiation. However, materials such as carbon black inks are largely opaque to IR and thus show up well when they were used as under-drawings in paintings or for writing on now faded documents. The use of carbon black inks for writing on thin slivers of wood in the Roman period has meant that, where these slivers survive, in waterlogged conditions such as those found at the Roman forts of Vindolanda and Carlisle on Hadrian's Wall, they can be read using vidicon cameras (Bowman and Thomas 1983) (see Figures 2.9 and 2.10). Paint layers containing carbon black or tin-lead yellow pigments are opaque to infrared radiation, so information beneath these paint layers is obscured. The capture and retention of information as a digital image allows digital image processing, which can enhance the visibility of the image.

2.10 X-radiography (Lang and Middleton 1997)

Just as radiation such as light (wavelength 380–760 nm) can pass through glass, radiation of sufficient energy such as X-rays (wavelength 10^{-9}–10^{-15} m) can pass through solid matter. As X-rays travel through matter, they are attenuated, i.e. lost through absorption by the material, or scattered. The more dense the material through which an X-ray passes, the greater its chance of attenuation. Thus both the composition and the thickness of an object determine the amount of X-radiation which can pass through it. The X-radiation that passes through an object is normally recorded on film. An X-ray image or radiograph gives a two-dimensional (2-D) image of the three-dimensional (3-D) object, compressing thickness and density effects together. The

Figure 2.9 Roman writing tablet, from Annetwell St., Carlisle, viewed in normal lighting conditions. (Photograph courtesy of Jennifer Jones)

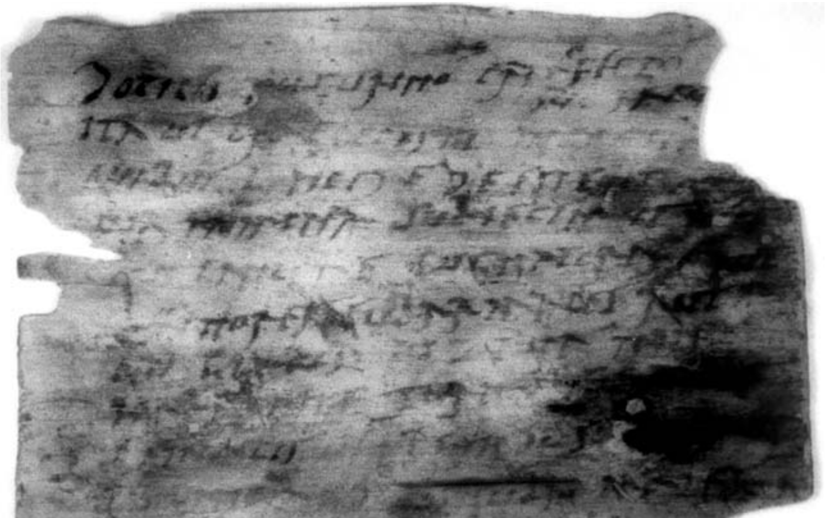


Figure 2.10 Roman writing tablet, from Annetwell St., Carlisle, viewed in infrared radiation. (Photograph courtesy of Jennifer Jones)

image formed is a negative, white where the object is thickest or most dense and black where the object is thinnest or least dense, or where there is no object at all. X-radiographs will reveal the image of dense bone in the less dense flesh of a leg, and the greater thickness of the raised image of a head on a coin. X-radiographs have been used in the study of ancient objects since 1898, when Dr Charles Leonard produced X-radiographs of a mummy (Lang and Middleton 1997: 1). When investigating archaeological or historic objects, radiographs are typically used to reveal:

- the form of objects, especially iron objects such as arrowheads, buried in a mass of corrosion;
- the extent of decoration, such as incised and inlaid designs beneath corrosion and dirt layers;
- structural weaknesses, such as wormholes in wood and cracks in stone;
- methods of construction of ancient artefacts, revealing seams, welds, rivets, folds, solder and other forms of joining used in ancient metal objects: the nails in the stretcher of a painting can reveal how many times it has been covered in canvas;
- earlier images under paintings or layers of over-paint.

X-radiographs are normally taken in small sealed cabinets or lead-lined rooms. Electrically powered X-ray generators are normally used. Increasing the amperage or the time of exposure increases the amount of X-radiation arriving at the film. Increasing the voltage increases the energy (decreases the wavelength) of the X-rays arriving at the film. X-rays are emitted over a range of energies/wavelengths. Soft (low-energy, long-wavelength) X-rays are useful in imaging organic materials: hard (high-energy, short-wavelength) X-rays are useful for imaging metals. Improved images are obtained for archaeological materials such as corroded ironwork or coins, by using filters such as sheets of copper in the X-ray beam or surrounding the film with thin foils of lead, which stop some of the soft X-rays getting through and fogging the film. Placing objects in lead or barium solutions or seating them in lead shot or surrounded by barium putty can reduce X-ray scatter and enhance the images. Use of digital image enhancement techniques on X-ray film images can improve their readability (Clogg and Caple 1996).

A featureless lump of iron corrosion, recovered from the Roman levels in Carlisle, was revealed by X-radiography to be Roman armour (see Figure 2.11). The copper alloy wire, holding the completely mineralized iron scales to each other and the leather beneath, is visible in the X-radiograph as denser (white) lines between the mineralized iron scales (grey). The effect of three dimensions being compressed into two and the distorting effects of large objects distant from the X-ray source is demonstrated by the X-radiograph of the ‘Etruscan Urn’ (see Figure 2.12). This object was formed from the parts of several ancient bronze vessels; a body, a neck and a pair of handles, put together, probably in the eighteenth or nineteenth century, as a fake or pastiche, held together with canvas cloth painted with copper corrosion (see Figure 6.3). The spearate pieces and the different vessel shapes of the neck and body are visible in the X-radiograph, as are the lengths of wire holding the handles into holes punched into the

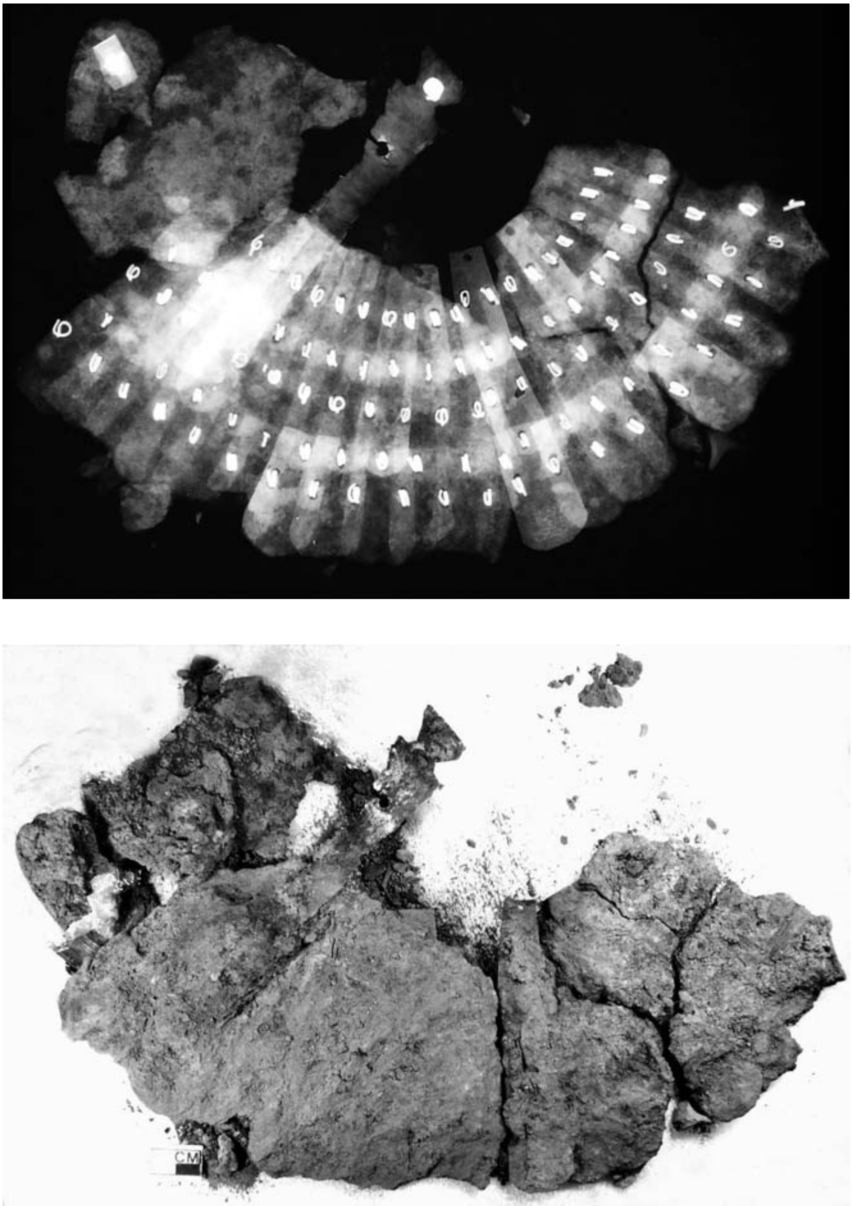


Figure 2.11 X-radiograph of Roman scale armour from Carlisle. X-radiographs can reveal structure in seemingly featureless pieces of iron corrosion (object form as found, below). (X-ray image courtesy of the Board of Trustees of the Royal Armouries; object photograph courtesy of Jennifer Jones)

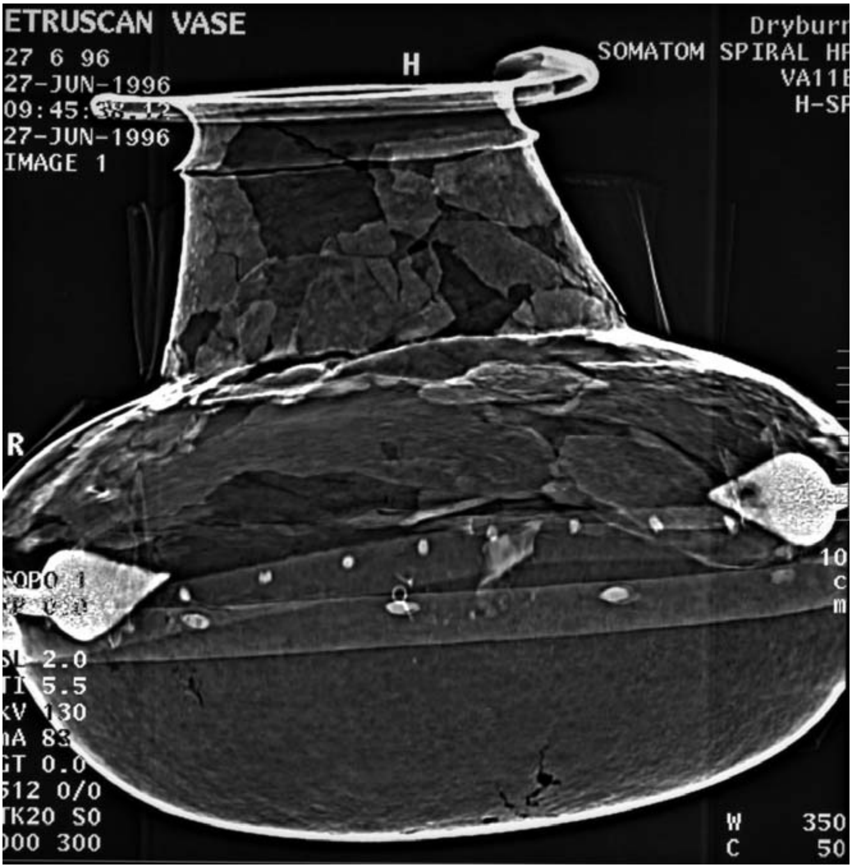


Figure 2.12 X-radiograph of an 'Etruscan' urn, an eighteenth-century pastiche created from parts of several ancient bronze vessels held together with painted plaster and bandages. The image of the 400 mm-diameter vessel is distorted to form a two-dimensional X-radiograph. (Image courtesy of Jeff Veitch and students on the MA in Conservation of Historic Objects (Archaeology) course)

sides of the vessel. The greater the experience of the investigator, the greater their ability to deduce information from the X-radiograph.

Whilst most artefacts are examined by film-based X-radiography, a range of further X-radiography techniques exist:

- CT or CAT (computer-aided tomography) scans have allowed 2-D cross sections through objects and 3-D X-ray images to be created. These have proved particularly valuable in examining mummies.

- Beta or electron radiography – very weakly penetrative radiation – has been used to image watermarks in paper (Daniels and Lang 1997).
- Gamma radiography – highly penetrative radiation – has been used to examine and image very large or dense objects such as statues and cannon.
- Xeroradiography has been used to examine and image a range of objects, especially organic and ceramic artefacts. This technique uses a charged selenium plate and powder-cloud-deposited particles. It highlights edges, and revealed the relic-containing cavities within the wooden core of the Winchester Reliquary (see section 5.8).
- Stereoradiography – two radiographic images of the same object, X-rayed from slightly different positions, when viewed together in a stereo viewer can create the impression of a 3-D object.
- Microfocal X-radiography, using an X-ray system with a very small X-ray source, provides real-time magnified X-ray images of objects.

CASE STUDIES

2.11 Bayeux (Tapestry) embroidery

(Stenton 1957; Gameson 1997)

The Bayeux Tapestry is first mentioned in 1476 in the inventory of the Chapter of Bayeux Cathedral as a ‘a very long narrow strip [hanging?] of linen embroidered with figures and inscriptions representing the conquest of England’ taken out and displayed during the Festival of the Relics (1–14 July).

The Bayeux Tapestry is not a tapestry, but an embroidery created using eight different coloured wools on linen cloth. The present length is 68.38 m and the height 457 to 536 mm. The end of the tapestry is badly damaged and the final scene is not complete; also the final border is missing. The top and bottom edges are folded over and tacked onto a coarser linen backing cloth.

Depiction (form, decoration, display)

Roman and Carolingian rulers recorded their victories as historical narratives in wall paintings and hangings, which decorated their halls and palaces. This practice is mentioned in the poem *Beowulf* and continued into the medieval period. Hangings appear to be depicted in the hall of King Edward the Confessor in the Bayeux Tapestry itself (Collingwood Bruce 1987: Plate XI). The poem *Adelae Comitissae* by Baudri of Bourgueil, written in 1099–1102, describes a hanging which the author imagines is in the apartments of Adelae, the daughter of William the Conqueror. Some authorities believe that he is describing the Bayeux Tapestry, which the author has clearly seen (Brown and Herren 1994). If so, this would date the tapestry and indicates the use of hangings of this type in both private and public rooms.

The use of long sequences of figures as strips of illustration was popular in the early medieval period. The eighth-century Franks casket, like the Bayeux Tapestry, has a strip of images telling a story that moves through time and space. The story or saga was perhaps the most powerful art form of the period, and this type of illustration is the direct corollary of the oral tradition. The Oseberg ship burial (ninth century) produced traces of a long hanging 160–230 mm in width, original length unknown, depicting a saga. This was also made of wool embroidered onto a linen cloth. These long narrow hangings, known in Scandinavia as *tjell* and Germany as *Rücklaken*, died out by the fourteenth to sixteenth centuries.

The Bayeux Tapestry depicts scenes from the period 1064–6 – incidents in the life of Harold Godwinson and Duke William of Normandy and the succession to the English crown, together with appropriate inscriptions. The visual flow of the embroidery is controlled with devices such as trees to separate scenes. There are upper and lower borders (each 70–100 mm high) to the main events, containing beasts, designs

Figure 2.13 Edward the Confessor's burial procession, as depicted in the Bayeux Tapestry. This image of the burial procession of King Edward the Confessor is one of the only illustrations of the eleventh century to depict the large handbells, which are nowadays found as religious relics in a number of Celtic churches (Bourke 2004). They were clearly originally rung accompanying funeral processions. (From Collingwood Bruce 1987)

and plants (see Figure 2.13). Towards the end of the tapestry the lower border is filled with people and objects related to and informing the main pictorial narrative.

In the initial third of the embroidery, Harold Godwinson, leading English noble and likely successor to the English throne, journeys to France, possibly to gain the release of members of his family. Captured by Guy of Ponthieu, he is surrendered to William, Duke of Normandy. Harold joins William in a campaign against Conan of Brittany, raising the siege of Dol and rescuing Norman knights; he is given arms (knighted) by William and swears on holy relics in Bayeux Cathedral. This appears to make him William's man (vassal). In the middle third Harold returns to England, Edward the

Confessor dies and Harold is crowned King of England. William hears of this and starts to prepare an army for invasion. The final third of the tapestry is the Norman army landing in England, ravaging the countryside and constructing a castle. They then prepare for and fight a battle against the Saxons at Hastings. Harold and his brothers Leofwine and Gyrth are killed and the English put to flight.

Harold is depicted 26 times to William's 20 (Cowdrey 1997: 97), and, given his depiction as a brave and respected man and his prominence in the early part of the embroidery, this is not simply a picture of William's acquisition of the English throne. Several messages are readable from this embroidery:

- Bishop Odo of Bayeux, William's half-brother, who appears four times in the tapestry, well beyond the importance that the written accounts accord him, had a significant part in securing the English throne for William.
- Given that Harold was 'rescued' by William from the clutches of Guy of Ponthieu, that Harold swore an oath on relics and accepted arms (knighting) from William, he was William's man. As his lord, William, not Harold, had the legal and moral right to the English throne.
- If, like Harold, you swear falsely on relics, then God will desert you and favour your enemies.

The form of the heroic epic with a moral theme corresponds with the traditional French *chansons de geste*. These are long secular poems, e.g. *Chanson de Roland*, popular by the mid-eleventh century, which emphasize loyalty and feudal obligation and the dire consequences of treason and treachery. Invariably they feature bloody battles. The heroes have both valour and good sense, an accurate description of the depictions of both William and Odo. Adversaries are worthy foes, but have broken codes and oaths, a scenario that exactly matches the depiction of Harold in the Bayeux Tapestry (Dodwell 1997).

The figures are depicted in the Romanesque manner with jutting jaw and hunched shoulders, and gesturing with their hands. This style of human depiction is seen in the Utrecht Psalter and was widely used in Anglo-Saxon art, especially that executed at Canterbury, in the eleventh century.

Manufacture

The Bayeux Tapestry is formed from nine pieces of linen (13.7, 13.9, 8.2, 7.7, 5.5, 7.1, 7.2, 2.6 and 2.4 m long) (Boardman 2003: 188). The linen thread used for the cloth of the embroidery was hand-spun and has variable-diameter fibres with 1–4.4 (typically 2.7–3.7) twists per centimetre (Oger, in press). The cloth of pieces 1 and 2 was joined after they had been embroidered (borders are of different heights and no overlapping embroidery); all the other pieces of cloth were joined to the end of the tapestry before it was embroidered. The inscriptions are in dark blue thread in pieces 1–4, but alternating coloured threads in the later pieces. The depiction of chain mail in the early pieces is variable – diamonds, squares, etc. – and often small and fussy; only in the later pieces does it settle down to a consistent pattern of clearly visible rings. These variations suggest that the embroiderers were evolving and standardizing their depictions as the tapestry progressed.

The embroidery is formed using two techniques:

- *Laid and couch work*. A series of threads is sewn (laid) tightly packed, parallel to each other, to cover an area. Then a second series of threads is laid at approximately 3 mm intervals at ninety degrees to the first. The second threads are couched down to secure all threads in place. This fills areas of design with dense blocks of colour.
- *Stem or outline stitch*. Every figure or object has its outline depicted in a coloured thread, a series of overlapping stitches. The needle emerges to the right of each stitch to form the next stitch. This results in a continuous line, which forms letters and objects such as spear shafts, as well as edging every area of laid and couch work.

These techniques create images formed of simple blocks of colour and outline, which, like a comic book, encourages the depiction of simple images and narrative tales. The linen cloth is treated as background. In the late medieval period, tent and cross-stitch methods replaced the laid and couch work. Other examples of hangings or long embroideries are those in the churches of Overhögdal (thirteenth/fourteenth centuries) and Røn (*c.* 1200), where the same technique of stem stitch outline and laid-and-couch infill was used. Though the technique died out in France and the rest of Europe, it continued in medieval Iceland. Fragments also come from the Norwegian stave churches of Urnes and Bergund. This embroidery technique was popular and long-lived in the Scandinavian world and, as such, would have been widely used in Scandinavian-influenced areas such as Britain and Normandy.

Most surviving medieval embroideries use silk, gold and silver threads. In the Bayeux embroidery only eight colours of woollen embroidery thread were used: terracotta red, blue-green, sage green, buff, full blue, dark green, yellow, very dark blue (intended for black). It is possible to suggest that, since there are blue and green horses, the colours are not intended to be naturalistic, merely intended to contrast with one another to show up the design. However, this explanation takes no account of the changing of dye colours through the effects of light and oxygen.

When analysis of the dyes was undertaken, the presence of aluminium indicated that a mordant such as alum had been used to dye the blue, green, red and yellow wool. Thin-layer chromatography identified the presence of compounds such as luteolin and apigenin (present in woad, the blue dye), alizarin and purpurin (present in madder, the red and possibly yellow dyes), and indigotin (present in indigo, the blue and blue/black dye). Combinations of these dyes and variations in the mordant and dyeing conditions could have created all the colours used in the embroidery. However, other as yet undetected dyes may also have been used, though there were no traces of tannins used for the black (Oger 2004).

Like most valuable objects of this period, the embroidery would have been commissioned by a wealthy patron. In the life of St Dunstan (*Vita Sancti Dunstani*), St Dunstan as a young cleric is required to draw designs for a young noblewoman to embroider. Given the use of inscriptions, the narrative form, and the book-like quality of the images, the designs for the Bayeux Tapestry were probably drawn up by a cleric who was a gifted artist, for his patron. Needlework was traditionally undertaken by gentlewomen. There are minor mistakes in the needlework, e.g. legs of the same individual, in crowd scenes such as Harold's coronation, embroidered in different colours. There are also historically inaccurate images which would suggest that the artist/designer was not fully aware of the history but was given instructions, information and possibly even some written phrases by his patron which he formulated into the tapestry design.

Where

Given the subject of the embroidery, it must have been produced in England, Normandy or France. The raw materials (linen, wool and dyes) would have been readily available in both England and Normandy. Almost all authorities agree that it was made in England:

- The spelling of words such as Ædwardus rather than Edwardus, and Ceastra rather than Castra, and the use of a Ð (= th) in the name Gyrth are distinctively Anglo-Saxon (Old English). 'Bagais' is a Saxon spelling of a Latinized French name: a local Bayeux cleric would have used 'Baiocae'. 'Wilglem' for William would also have come from people whose natural form of expression was Anglo-Saxon, although one word in the text 'parabolant' undoubtedly is Norman-French-influenced.
- The Normans are referred to in the embroidery as 'Franci', as they are in the *Anglo-Saxon Chronicles*, rather than 'Normani', which is how the Normans would have referred to themselves.
- The needlework skills of English women were renowned throughout Europe. William of Poitiers declared 'the women of the English race excel in embroidery and cloth of gold.'
- Though the Bayeux Tapestry depicts a Norman victory at Hastings, the story as portrayed does not correspond with crude Norman propaganda, and thus

incidents such as the Norman setbacks in the Battle of Hastings are pictured. Indeed it corresponds reasonably well with the English version of events, such as the details of the death of Edward the Confessor described in the *Vita Ædwardi Regis*, which was probably produced by a Canterbury monk.

- Canterbury was a renowned centre for the production of illustrated manuscripts and artworks in the eleventh century. Many aspects of the style of depiction used in the Bayeux tapestry correspond to the artistic styles and traditions of Canterbury (Wormald 1957). Normandy, except Mont-Saint-Michel, had virtually no tradition of artistic works and manuscripts (Gameson 1997: 162) and, whilst some artistic works were produced in Flanders and northern France, southern Britain had a much stronger reputation.
- Specific images used in the Bayeux Tapestry correspond well to images which had either previously been drawn in illustrated manuscripts from St Augustine's, Canterbury, or were present in books in the library. Examples include:
  - The trees, which depict pollarded forms and which are merging into interlace designs of earlier centuries, have their closest parallel in the Ælfric Heptateuch, an English illuminated manuscript of the second quarter of the eleventh century.
  - A Norman forager depicted after landing in England carrying a rope is nearly identical to a figure in the *Psychomachia* of Prudentius, a manuscript present in St Augustine's, Canterbury.
  - Though there are many depictions of the Last Supper, an image which inspired the feasting scene before the Battle of Hastings in the Bayeux Tapestry (in which Odo plays the role of Christ), an example in St Augustine's Gospels, in Canterbury, uniquely pictures the Last Supper at a partially depicted round table, which matches that used in the Bayeux Tapestry.
- Manuscripts from southern England, such as the Tiberius Psalter, like the Bayeux Tapestry, frequently use the word *hic* in the inscriptions associated with images.

Thus Canterbury is the most likely place for the production of the Bayeux Tapestry.

The person prominently featured in the embroidery, well beyond his likely role in events, is Duke William's half-brother Odo, who, though Bishop of Bayeux, was more accurately 'a baron with the benefit of clergy' (Dodwell 1997). Several of Odo's vassals are named in the embroidery and, as Earl of Kent, he controlled the area around Canterbury, the likely source for the embroidery. The tapestry provided a clear exposition of the legal justification for Norman rule, yet a recognition of the valour of Harold and the Saxons. With lands in England and Normandy and a need to placate his Saxon vassals, but emphasize the legality of Norman rule, the tapestry clearly depicts Odo's viewpoint. Thus it is likely that the tapestry was commissioned by Bishop Odo of Bayeux. Such an origin would also explain why the embroidery eventually came into the possession of Bayeux Cathedral.

Use

This embroidery, at about 68 m long and 0.5 m high, was intended to be displayed around the walls of a room. The images in the tapestry reinforce the power of the relics of Bayeux, since the embroidery depicts the fate of Harold, who swore on the relics to be William's man and then broke his oath and accepted the crown of England. This could have been an appropriate subject for a hanging in the new cathedral at Bayeux, which was consecrated in 1077. However, this embroidery was probably initially a secular hanging, since some obvious religious imagery associated with these events of 1064–6 that could have been present, e.g. the papal banner, William's prayers and the processing of relics to encourage favourable winds, were not present. It was more probably displayed in a secular setting such as the great hall of Odo, Bishop of Bayeux and Earl of Kent. As a man with many land holdings, Odo probably moved around England and Normandy and, since it was portable, the embroidery could move with him.

Hangings had been authorized, even recommended, by the Council of Arras (1025) as one of the means of edifying and informing the Christian faithful. Though perhaps initially a secular object, this embroidery emphasized the holiness of the Bayeux relics and was thus suitable for ecclesiastical display. Consequently it was recycled into the cathedral as a backdrop for the Feast of the Relics. The robust Christianity that launched the crusades would have no problem showing fighting in an invasion, which had been blessed by Pope Alexander II.

The presence of the inscriptions in Latin can be taken to suggest that at least a number of the intended viewers of the embroidery could read Latin, which, as the language of government and the church, gave credence and authority to the depiction. The text was large enough to be seen at distance, as would be expected if it were hung around the walls of a hall or church. The text inscriptions to identify places and key individuals such as Bishop Odo, Duke William of Normandy and Harold Godwinson are present to ensure that this embroidery was read correctly. It was clearly important that it was read correctly even in the eleventh century. The text is often broken up by the image and, to aid understanding, two or three points or dots are placed between the words. This and devices such as the short simple sentences and simple grammar would aid reading of the text. Another key device used was the repetition of the word *hic* (here), which occurs regularly through the text. The repetition and the hard sound would give a rhythmic beat, which, together with the narrative form, suggests that the text would be read out loud to others. These features emphasize the link between this elongated figurative depiction, the oral tradition of the sagas and the *chanson de geste*.

The fact that the dyes of the embroidery fabric are not completely faded, there is little darkening and discoloration due to dust and there is no great distortion as a result of suspension, indicates that this embroidery has not remained hung in a room for decades. It would appear likely that this embroidery was normally rolled, away from the light, save for occasional use. Its fifteenth-century role, hung in the nave of Bayeux Cathedral during the Festival of the Relics, would appear to be typical of the use it received throughout its life.

Record/dating

The authenticity of the tapestry as an original late eleventh-century document has never been doubted by the scholars who have studied the tapestry.

Medieval depictions of the past always placed past actions in current settings, thus even biblical stories are depicted with garments, buildings, weapons of the medieval period. Study of the tapestry since 1740 has never shown any aspect that would be out of place in an eleventh-century setting. For example, the figures in the embroidery accurately depict the arms and armour of the mid-eleventh century, e.g. the widespread use of coats of mail is depicted, but surcoats adopted in the mid- to late twelfth century are absent.

Historical details can be compared with the written accounts. Norman accounts include *Gesta Guillelmi ducis Normannorum et regis Anglorum* by William of Poitiers and *Gesta Normannorum Ducum* by William of Jumièges, both written within a decade of the battle. Saxon accounts are sketchy, described briefly in several of the *Anglo-Saxon Chronicles* (versions C, D and E) and in *Vita Ædwardi Regis*, a hagiography of the reign of Edward the Confessor. The events depicted on the embroidery correspond with these contemporary accounts.

Consequently the tapestry is considered to have been created shortly after the events in the late eleventh or very early twelfth century, and no further dating proof, such as radiocarbon dating, has been considered necessary. As an authentic eleventh-century image it provides a wealth of detailed information about Norman and Saxon clothing, weaponry, buildings and rituals (see Figure 2.13). Some features, such as moustaches for almost all Saxons and shaved backs of the heads for most Normans, are characteristics probably based in reality but exaggerated to provide a convenient visual grammar to aid reading the embroidery.

Since Odo was probably the man who commissioned this work, it was almost certainly created between 1067 and 1082, when he was at the height of his wealth, controlled the county of Kent and would have sought to celebrate the accession of William to the throne of England.

The embroidery was extensively restored in 1842; chain-stitched modern machine-twisted and dyed thread was used. Many of the key scenes are actually restored images, e.g. only fragments of either of the figures depicting Harold at his death are now original. This should give caution regarding overly detailed interpretation of the image. Reference should always be made to Montfaucon's and Stothard's drawn images (1770s and 1816–18 respectively) created before the restoration.

2.12 Portrait of Prince Henry on horseback
(McClure 1992; Woodhuysen-Keller *et al.* 1988)

Prince Henry, the eldest son of James I, was born in 1594 and created Prince of Wales in 1610. He attracted artists and scholars to his court, as he sought to emulate other young European princes. His court artist was Peake the Elder (*c.* 1551–1619), who completed a number of pictures of the prince, almost certainly including this one of the prince on horseback. Prince Henry died of typhoid in 1612, leaving his younger brother Charles to eventually inherit the throne of England, Wales and Scotland as Charles I. This portrait of Prince Henry on horseback was almost certainly painted between 1610 and 1612.

This oil painting (2.31 m × 2.2 m) came to the twentieth century as a portrait of the prince dressed in seventeenth-century armour on a grey steed with a black mane, riding in front of a tree with a distant landscape in the background (see Figure 2.14). The Prince of Wales's emblem, three feathers, hangs from a branch of the tree, proclaiming the identity of the rider. Examination of this portrait revealed that the canvas had been re-lined three times and, following a cleaning test to remove the thick yellowing varnish, that there were traces of a very different landscape beneath the present one. An infrared reflectogram (section 2.9) revealed that there was another figure present in an earlier version of the picture. An X-radiograph (section 4.6) revealed that, not only was there an earlier image beneath the present one, but there were losses (damage) to that earlier image. This was visible in X-radiograph since flesh tones were, prior to the eighteenth century, invariably painted using lead white. This shows up on the X-radiograph as white 'radio-opaque' material in which missing flakes show up as dark angular shapes. Since these losses were not visible on the present surface, it must have been restored at a later date, filled and painted over. The presence of damage implies a period of use and thus a sequence of original painting, use and damage, repair and subsequent repainting was indicated by the X-radiograph. Visual analysis suggested that the image of the prince was high-quality artistic work, whilst the leafy and landscape background was poorer-quality work. The build-up of paint around the figure of the prince and evidence from cross sections of paint samples removed from a damaged area (section 3.11) indicated that additional paint had been added to the background.

Evidence of the pattern of craquelure and nail holes in the edge of the canvas derived from its attachment to the stretcher revealed that the painting had been cut down and its shape changed several times.

All the later overpainting was subsequently removed so that the original image (see Figure 2.15) could be seen.

Form, decoration and display

The original picture depicted the young Prince Henry on a tilt horse, a large heavy white horse used for jousting (tilting). Henry is on his way to a joust accompanied by a winged, older, naked male figure, Father Time, who carries Henry's lance and plumed helmet. Henry is wearing, tied to his arm, a favour of red, white and blue cloth which is twisted and tied to the forelock of Time. This is interpreted as representing seizing the opportunity (McClure 1992: 65). Behind these figures is a brick wall containing two stone plaques depicting the three-feathers emblem of the Prince of Wales. An open gateway in the wall shows a garden of pollarded trees, footbridge and stream behind the wall. This may be a reference to Henry's garden at his palace of Richmond (Strong 1986).

The initial images that may have prompted Henry to seek an equestrian portrait of himself were the equestrian portraits of Henri II of France by Clouet and Henri IV of France by Zuccaro. In both cases the riders were depicted riding in front of walls of buildings. In 1574 Zuccaro came to England and probably met Peake the Elder. Though the picture perhaps started as simple equestrian portrait, influences such as Dürer's 1513 picture *The Knight, Death and the Devil* with its depiction of an old man – Death – carrying the lance of a knight probably influenced Peake. He subsequently added the old man, Father Time, in an almost identical pose to Dürer's figure of Death, to his equestrian portrait of Henry. The allegorical content would have appealed to Henry and the early seventeenth-century intellectuals of his court. Thus Peake's original portrait draws on a continental European tradition of royal equestrian portraits and medieval and Renaissance allegory.

The later repainted image of the prince on a grey steed against a distant 'Arcadian' landscape sweeps away the earlier medieval image, which appeared old and outdated. The similarity of the repainted image to that of Van Dyck's portrait of Charles I on a dashing grey steed can be no coincidence. This was the way seventeenth-century monarchy 'should be' depicted, and it was almost certainly copied by an unknown artist who amended Peake's earlier portrait to this latest fashion.

Manufacture

The original painting was 2.337 × 2.337 m (92 × 92 in) and was originally composed of two 1.168 m (46 in) strips of canvas sewn together. This fabric was probably originally attached to a loom (temporary frame) while the painting was being undertaken and then applied to a wooden stretcher afterwards. The initial red ground of the painting was given a layer of thick gritty grey paint. There is no evidence of under-drawing from

Figure 2.14 Portrait of Prince Henry on horseback, as it appeared between the early eighteenth and late twentieth centuries. (From the collection at Parham Park, West Sussex. Copyright: Hamilton Kerr Institute)

the infrared reflectogram, though this may mean that it was drawn in red chalk or umber, which do not show up under infrared radiation. The prince in his armour and his horse were painted first, followed by the wall, the sky and then the foreground. The figure of Time was added later; the red colour of the wall is visible through his wings. The artist used pigments common in the early seventeenth century, such as azurite and lead white for the sky, and charcoal black and smalt for the prince's armour. The present left edge of the canvas is the only extant original canvas edge. The artist was able to divide up the 92 in square canvas into a 16 × 16 grid, which was the technique favoured by the artists of this period. The composition is properly

Figure 2.15 Portrait of Prince Henry on horseback, restored to its original early seventeenth-century appearance. (From the collection at Parham Park, West Sussex. Copyright: Hamilton Kerr Institute)

centred in such a grid, and the proportions and all the key points correspond to lines or points on the grid, e.g. in the wall there are exactly four bricks between the horizontal grid lines. There were a number of *pentimenti* – changes by the artist to his original image – e.g. raising the legs of the horse and the wings of Father Time. The lack of craquelure patterns in the original paint layer, normally derived from being bent over a stretcher, indicates that this painting was originally mounted flat on a stretcher in the seventeenth-century tradition, i.e. nailed flat onto the front of the stretcher. A frame concealed the attachment to the stretcher.

Use

The presence of creases and loss of paint indicated that the picture had been removed from its original stretcher, rolled up and stored. It is probable that this occurred during the period of the English Civil War and the Commonwealth which followed (1642–60), when having a royal portrait on view would have been potentially dangerous to the owner.

Subsequently the picture was restored for public display. However, to fit it onto another stretcher, 140 mm (5½ in) were removed from the right-hand side of the picture, so cutting off the tip of the right wing of Father Time. The pattern of cracking across the picture suggests that the new stretcher had the form of an upper square with diagonal strengthening at each corner, two horizontal braces and a lower rectangle with strengthening across the bottom corners. This suggests that the picture was made to fit an existing stretcher, or pair of joined stretchers. The red brick wall was painted grey to imitate stone blocks; brick – popular and expensive in the sixteenth and early seventeenth centuries – was less fashionable by the mid- to late seventeenth century. Minor changes were made to the prince's armour, and losses were filled with a yellow-white, semi-translucent filler and retouched to match the painting. The paint cross section revealed that a thick varnish was also applied to the picture, seeping down into the cracks that had formed in the original paint layer during rolling and storage. This indicates that the varnish application occurred at least 30–50 years after the original painting had been completed, so that cracks could have formed.

Following a period of use, which caused the new paint to start to age and crack, there was a substantial repainting of the portrait. The medieval iconography, including the image of Father Time, and the wall were overpainted with a tree and distant landscape. The large, white tilt horse was transformed into a dashing grey steed with black mane and clear musculature. One of the three-feather emblems was incongruously retained and appears to hang from a branch of the tree. The canvas was squared up and approximately 115 mm (4½ in) were removed from the top of the canvas. This required a new stretcher. The overpainting was undertaken using the blue lake pigment indigo, and any losses or damage were filled with a dense yellow filler and retouched to match the painting. Given the ageing of the previous restoration, this repainting must have occurred at the end of the seventeenth or in the early eighteenth century.

Following another period of use and ageing of the paint, further restoration followed. This involved double-lining the canvas and restoring the missing strip from the top of the picture. The restored 90–100 mm (3½–4 in) strip was painted with Prussian blue, suggesting a restoration after 1725, when this pigment had come into use. The pressure applied during the lining process slightly impressed the leaves and other parts of the overpainted image into the original paintwork. Any losses or damage were filled with a grey filler and retouched to match the painting, and it is likely that a new stretcher was provided.

In 1902 a further restoration took place, in which a third re-lining took place together with filling-in and reintegration of paint losses. A new stretcher, of the same dimensions as the previous stretcher, may also have been provided at this date, since all sides have at least two sets of nail holes. Yet another restoration occurred in 1946, when minor structural repairs and cleaning were undertaken, prior to the most recent research and subsequent restoration of 1985 (Woodhuysen-Keller *et al.* 1988).

Record

The history of this painting, established from detailed examination of the object, proved that, as a portrait of royalty, it was a highly potent visual symbol. It indicated certain beliefs and, as such, was a potentially dangerous object in seventeenth-century England. However, the subsequent repainting shows that by the late seventeenth/early eighteenth century it was considered important that the monarchy was seen in the fashionable 'Arcadian' context and not the unfashionable medieval allegorical context. Investigation of this portrait showed that an object could have a long period of continuous use; perhaps 350 years on display. The compositional change of materials, such as the blue pigments, reflected changes in technology. They also reflected changes in aesthetic taste, even in the proportions of a picture.

This painting provides a clear example that many 'new' objects are not in fact new; merely old objects given a new façade and reused.

Chapter 3

Objects as products (manufacture)

HOW?

3.1 Introduction

A wide range of terms have been used to describe the factors which influence the selection of materials and methods used in object production (e.g. Kingery 1996: 183). They can be reduced to three basic groups of factors – physical properties, economic constraints and cultural influences:

- Physical properties: materials with appropriate attributes such as strength, hardness, colour, etc., are selected because they are the most effective in use, e.g. flint and obsidian, which throughout prehistory were flaked to give sharp-edged tools.
- Economic constraints: materials normally have to be available and cost-effective. Expensive or rare materials were not used when cheaper alternatives were available, provided the alternatives could do the job adequately. Thus jewellery was often made of gilded copper alloy rather than solid gold.
- Cultural influence: ideas about the materials appropriate to use for particular objects are determined by the cultural and religious beliefs of the society. 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 the 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. The concept of what is valuable, beautiful, magic or of religious significance varies from culture to culture.

These factors influence not only the material used to make an object, but also the techniques and materials used in the design and manufacture of the product.

Much of the published archaeological work on artefact production has concentrated on the prehistoric period and used ethnographic parallels. Whilst British and American authors, e.g. Henderson (1989b), have primarily focused on the properties of materials, materials supply, etc., French authors, e.g. Lemonnier (1993), have often focused on the role of culture on technological choices.

The manufacture of any physical object does not start from a specific raw material. It is an iterative (repeating and evolving) process; somebody uses a piece of material (an object) to carry out an action (a process). As they repeat the process, they improve the object they are using. Subsequently they continue to improve the object in the choice of the material from which it is made, the shape of the object, and the way they use it. An object eventually emerges from this process with a specific shape (or range of shapes) and made from a specific materials (or range of materials) which enable the object to function effectively. In both symbolic and functional terms it forms part of the material culture of the group using it. If there is a first step, it is the intended function of the object; the requirement to move something comes before either the cart or the horse.

The requirement to communicate over time and distance accurately and to form a lasting record has led to the evolution of writing and materials on which to write. These have included carving on stone, painting on plaster walls, clay and wax tablets, papyrus, parchment, paper and now electronic formats. The functional requirement has been a flat, blank material that would accept marks. The materials change according to available resources and technical sophistication, but the underlying function remains. It is worth noting that developments have sought to give us more blank space for less cost, making materials thinner and cheaper, and to speed up the process of copying and distributing.

Required objects may be:

- commissioned, that is, made to a client's specific requirements;
- made for retail, manufactured for sale in a free market;
- a directed manufacture or created for a restricted market (between retail and commissioned), i.e. may be made with some indication from clients of what they would like to see and purchase, or for restricted markets where other goods are excluded so that a sale is almost guaranteed, i.e. a monopoly supplier such as the guilds in medieval towns.

Commissioned objects were usually expensive and idiosyncratic 'bespoke' objects made for a single client, such as the Winchester Reliquary (see section 5.8) or the Bayeux Tapestry (see section 2.11). Retail objects were made to the demands of the market, usually as large numbers of similar objects that were highly functional or reflected cultural tastes, such as brass pins (see section 3.12) or blue-and-white porcelain (see section 4.9).

The scale of production (see section 1.7) is crucial to the development of production techniques. Bespoke, high-value objects frequently reflect traditional production techniques or can be associated with new and novel techniques and materials. The high value of the object means that the higher cost of an 'old-fashioned', inefficient process or the use of innovative, non-standard 'new' material or production technology is not an important factor. Only crafted and mass-produced items 'accurately' reflect the technical level of the society in which they are produced. Simpler methods of production such as hand-forming ceramics often require minimal organization but take a long time to manufacture each object. In contrast, more complex production methods, even just having a simple device such as a potter's wheel, require more complex organization and resources to supply or build the device, but subsequently take less time to manufacture each object.

3.2 Materials: technical properties

All products are directly or indirectly manufactured from materials. Selection of a suitable material normally occurs in two stages:

- exclusion of materials with inappropriate properties;
- selection of materials with the best properties.

For some uses, as with flint and steel for making a spark, the physical properties of the material are crucial. However, physical properties are often not the crucial factor in the final decision, and a range of materials with suitable properties are considered, economic and cultural factors such as availability and cost determining the one finally selected. The feedback loop of experience in using an object made of different materials leads to the selection of materials with the most appropriate properties (Kingery 1996: 181).

Factors related to physical properties that could go into the selection process would include:

- The large range of physical properties that a material can possess, such as hardness, strength, malleability, plasticity, elasticity, insulation, conductivity, sonorousness, electrical conductivity, magnetism, colour, transparency, density, texture, adhesion, viscosity, corrosion resistance, smell, taste, nutritional value, toxicity, antiseptic properties, solubility, absorbency, buoyancy, the melting/boiling/freezing point, impermeability to water, explosiveness, flammability, radioactivity, incandescence, reflectivity, flakeability. An object invariably needs more than one property. A nail needs to fasten together pieces of wood and not decay, and, whilst making it of gold would ensure that it would not decay, pure gold would be too soft to penetrate the wood. Consequently almost all objects are made of materials having a balance of properties that best enable the object to perform its function.
- With natural materials there is variation in the material. Owing to the cellular structure of wood there are differences, especially in the working properties, of the wood depending on whereabouts on the tree it was cut from. Radially and tangentially cut planks have very different shrinkage, splitting and warping characteristics. There is considerable difference between the timbers derived from different tree species, leading to very different uses (see Table 3.1). There is considerable difference between the dark, hard and robust heartwood at the centre of a tree and the softer, lighter and warpable outer sapwood. These differences in properties were exploited by carpenters and joiners of the past, who

removed the softer sapwood from good-quality timber during construction so that it would not split, as was the case with the north doors of Durham Cathedral (see section 6.8). The finest-quality longbows were traditionally made of yew, cut from the junction between the heartwood and sapwood, the heartwood being very strong in compression and the sapwood having elastic properties in tension. Such longbows have an enhanced range because of their natural composite characteristics (Hardy 1992).

- The changes in physical properties can be exploited. Oak can be shaped when relatively fresh, i.e. partially seasoned 'green' oak, but after several years it hardens as it becomes fully seasoned. Many buildings in medieval Britain were made from frameworks of oak created, shaped and fitted together in the green state.
- Materials such as metals can have their properties altered, usually enhanced, by controlling the alloy composition, or working the metal in a specific way. Craddock's analysis of Roman copper alloy artefacts from throughout the Roman Empire showed that different alloys were deliberately created for objects with specific uses (Craddock 1975):

Object	*Alloy and reason*
Mirror	Bronze, almost all had 18–21% tin. High-tin bronze (speculum) is highly reflective.
Bells and cymbals	Bronze, no lead. Lead deadens the sonorous quality of the bell or cymbal.
Statuettes	80% bronze and leaded bronze, 20% brass, lead content up to 30%. No specific physical requirements, so any copper alloy can be used, including scrap. Large amounts of cheaper lead, which makes the alloy brittle, can safely be added to reduce the overall cost.
Trumpets	Leaded bronze. Complex casting required the pouring and casting qualities of leaded bronze.
Lamps	80% bronze, 20% brass, all low lead content. Little physical requirement is made of this object, so any copper alloy can be used, including scrap. Additions of lead would make it heavy and risk shattering if dropped.
Statues	Leaded bronze: 2–12% tin, 0–3% lead. Low lead to keep the statue robust and allow it to be gilded.

All man-made materials such as metal, glass and ceramic can have their composition controlled in order that they possess the desired physical properties in the final material or during the manufacturing process. This is exemplified by the small percentage of lead that was frequently added to improve the ability of copper alloys to flow when molten, so ensuring they would form complete, accurate thin-walled castings.

To ascertain if a material has been selected for its properties, it is essential to be able to identify that material accurately. In the case of wood this can initially be undertaken by reference to its colour, grain pattern, smell and growth ring pattern. This is a skill all experienced woodworkers develop; it can also be learnt and supported from

Table 3.1 The properties and uses of selected wood species

Species	*Properties*	*Uses*
Alder	Durable when wet; soft	Used in wet ground, e.g. trackways, glass-blowing moulds and tools
Apple	Works well, sweet-flavoured smoke	Turned into bowls and carved for ornament, used for smoking meats and cheese to preserve
	Edible fruit	Fruit
Ash	Tough elastic wood	Oars, handles, shafts (especially spears and arrows), wheel spokes
Beech	Works well	Turned and carved into furniture and ornaments, barrel staves
	Edible nuts – mast	Animal food
	Long-lasting leaves	Insulation
Birch	Quick-, straight-growing	Charcoal, arrow shafts
	Bark = tough	Bark containers, roofing, writing surface
	Sap = antiseptic and adhesive	Adhesive, waterproofing agent, chewing gum
Box	Fine-grained, does not splinter	Combs, stamps, chessmen and small intricate carvings
Cherry	Works well	Turned into bowls and carved for ornament
	Edible fruit	Fruit
Elder	Soft, fast-growing	Fuel
Elm	Hard and durable wood, long-lasting in wet conditions	Wheel hubs, coffins, drains, bridges, waterfronts, axle blocks
Hazel	Fast-, straight-growing, supple younger shoots	Coppiced for young shoots providing fuel, and woven for hurdles and fencing, split and woven for containers
	Edible nuts	Nuts
Holly	Magical associations and durable wood	Pegs and small ritual objects
Hornbeam	Tough, does not easily split	Wheels, axles, spokes, rims, yokes, mallets, handles
Juniper	Dark wood	Decorative inlay
	Berries	Flavouring
Larch	Weathers well	Exterior woodwork, e.g. telegraph poles
	Resin	Distilled for turpentine
Lime	Works well	Small carved objects
	Bast fibres below bark	Cloth

Maple	Tough, works well, does not splinter easily	Turned for bowls, used for handles and rollers in mangles
Oak	Plentiful in antiquity, very strong and durable, weathers well.	Structures: almost all pre-20th-century buildings in north-west Europe used oak beams or framing. Coffins, boat framing and planking, waterfronts
	Bark rich in polyphenols	Tanning
	Edible nuts – acorns	Animal food
	Rich preservative smoke	Smoking meats, fish, cheese to preserve
Pear	Works well	Turned into bowls and carved. Glass-blowing moulds and tools
Pine	Plentiful	Used for planking and construction, increasingly widespread use in post-medieval Europe
	Resin	Distilled for pitch, which provides waterproofing and varnish
Poplar	Does not splinter	Clogs
Sweet chestnut	Durable, weathers well	Fencing and posts
	Bark rich in polyphenols	Tanning
Silver fir	Splits in thin even strips	Roman writing tablets, barrel staves
Willow	Fast-growing, supple shoots	Coppiced for young shoots used for fuel; woven for hurdles and fencing, woven for containers, i.e. wickerwork
Yew	Tough, does not easily split	Longbows, decorative carvings

reference books, e.g. *What Wood is That?* (Edlin 1969). However, the most certain form of identification is through examination of a microscopic thin section (see section 3.8) and the observation of microstructural details, e.g. vessel form, pits, etc., and reference to a standard textbook of microscopic wood morphology (Schweingruber 1978). Leather can be identified to species level through microscopic analysis of the grain pattern (derived from the hairs that have been removed from the hide) (British Leather Manufacturers Association 1957). Consequently the uses of the leather from different types of animal can be identified (Grew and Neergaarde 1988; Mould *et al.* 2003). Raw materials such as wood and fibres used in their natural state permit easy identification; however, where materials are not used in their raw state but have been chemically and physically modified, as in paper, or have become degraded, they are far harder to identify.

It can never be assumed that the materials of an object are the same as those that have previously been identified, nor that they must be a specific material because it was technically the best material or because it made economic sense. This is the imposition of incomplete twenty-first-century understanding, and assumes technical knowledge of economic circumstances at a point in the past for which there is no evidence.

Having identified the material, the interpretation of the data is not always straightforward. In Britain, shafts for spears and arrows are normally made from ash, since it is a tough, widely available wood. However, if the wood from a spear shaft was identified as pine, there could be any one of a number of reasons:

- Time pressure and lack of resources, e.g. castle under siege, denied access to ash.
- Lack of awareness by the maker of the spear of the properties of ash or pine.
- Importation of the spear from a country, such as Norway, which has little ash and a lot of pine.
- The user came with his spear from a country, such as Norway, which has little ash and a lot of pine.
- Pine was cheaper and cost was an important consideration.
- Pine was available and the better physical properties of ash were not important.

Cultural, contextual, economic and human factors are crucial in correctly interpreting the significance of the use of a particular material. Further evidence invariably needs to be sought to determine the reason for the use of this material.

3.3 Materials: cultural influences

Factors that do not clearly relate to the selection of a material for technical suitability or economic viability are usually considered to be cultural factors/constraints. Such factors often relate to the visual appearance such as decoration, or the selection of one manufacturing method or material over another (van de Leeuw 1993; Hodder 1991: 91).

Many materials are selected for their decorative or symbolic quality, as is shown by the wooden furniture recovered from a series of eighth-century BC Phrygian tombs outside Gordion in Turkey. One of the most complete was recovered from tumulus MM: an inlaid, tri-legged table with an intricate strutwork form and panels of inlaid geometric design. The table was made of light golden yellow boxwood (*Buxus sempervirens*) inlaid with dark juniper wood (*Juniperus foetidissima*) with a walnut top (*Juglans regia L.*). The whole construction was designed to show the beauty of the decorative wood grain and the skill of the joiner (Payton 1984; Simpson 1996). It is, however, culturally mediated criteria that determine what is considered beautiful, desirable or simply appropriate (see Chapter 2).

Another example is provided by the gravestones in the graveyard of the village of Strata Florida in Wales, which are almost all black. The earliest nineteenth-century examples in the graveyard are made of slate, almost certainly from a local source. This developed the tradition of black gravestones. Later gravestones are also black, principally black marble and black granite. These stones are not local to Wales but are imported from continental Europe. Local people are now paying for imported gravestones and selecting black, even if it is more expensive than alternatives, to maintain this cultural tradition (Caple 2000: Figure 5.1). Material selection based on cultural constraints rather than economic or superior technical properties of the material.

The culturally ascribed nature of value was seen in the use of colours derived from specific dyes to indicate rank or position (see section 2.7) and in the tableware fashionable in the eighteenth century. At this time, pewter wares were four to six times as expensive as ceramics. As the newly fashionable creamware ceramics captured much of the tableware market, previous ceramic forms, e.g. delftware, ceased to sell, and production halted. However, pewter production continued unaffected since the pewter was primarily placed on display as a demonstration of wealth (Smart-Martin 1991).

Sander van der Leeuw found 25 different methods being used for making round-bottomed ceramic vessels, in civilizations ranging from the ancient Middle East to medieval Dutch and modern-day India. All had access to a 'fast' potter's wheel, but either did not use it or only used it as part of the process. Many adopted what could be seen as 'traditional' practices, leading to the suggestion that the technical choices in this manufacturing process were largely culturally determined. Van der Leeuw (1993) is almost certainly correct when he suggests that for many production processes, in many traditional societies, individual manufacturers do not face competition from more efficient producers, owing to the cultural preferences of those traditional societies. Hodder (1982) similarly showed that the organization of ceramic production, e.g. gender of the potter, location of the workshop and scale of production, varied between African tribes depending on cultural choices.

Petrequin, in discussing the technical choices of the neolithic cultures around the Jura mountains, details the peoples known as the Beaufort Gap cultivators, who obtained a hard green crystalline rock from the Alps which they pecked into shape to form axe blades. The cultivators then began to obtain supplies of a more brittle black rock from the Vosges mountains to make axe blades, which they continued to peck into shape. It took several generations before they learnt that the black rock was more effectively and efficiently worked by flaking it and subsequently polishing the blade. This created axe blades of distinctive square or rectangular cross section. This shape became a cultural norm, which they retained even when they returned to using the green crystalline alpine rock for their axe blades. This appears to demonstrate both that materials and cultural constraints can determine the shape of objects, regardless of technical 'common sense', and that technical traditions are powerful forces that take some time to change.

Where objects are created with highly inappropriate materials or are of a highly inappropriate size, they may be representational, and intended for use in ritual or for magic purposes. Examples include bone objects carved in the form of Bronze Age daggers in their sheaths, recovered from the river Thames (Merrifield 1987: Figure 3). Some objects when present in smaller form, made of tough materials such as wood or bone, could also be interpreted as toys. Context is crucial to ritual or plaything interpretation.

3.4 Materials: economic constraints

For any and every material a range of economic and supply factors influence the type and nature of the material used in the manufacture of an object.

Exploitation of raw materials

Economic constraints on materials are particularly evident as a result of scarcity, leading to high values. Such scarcity may result from:

- limited natural availability of materials such as precious metal ores;
- limited technical expertise to detect, extract or exploit the material;
- exhaustion, especially of biological materials that regenerate slowly, such as wood;
- processing costs such as transport, which are required to ensure the material is in a usable form in the required place;
- politics, warfare, hoarding, trade agreements, weather and other man-made and natural disruptions to the supply of goods.

To overcome shortages and exploit high values (prices) there is greater use of smaller and poorer-quality examples of the natural material, and reuse of materials. There are often signs of experimentation with alternative materials, and poorer-quality alternative materials are frequently substituted.

- Oak was the most common tree species throughout the Roman Empire, used for almost all types of constructional work. Its abundance is suggested in the low price that could be charged according to the Edict of Diocletian of AD 301 (Meiggs 1982). The higher prices of other timbers may reflect lower abundance:

Tree	*Size[a] (ft)*	*Price (denarii)*
Oak	21 × 5.7	6
Beech	21 × 3	21
Cypress	18 × 3	30
Fir/pine	45 × 6	80

[a] Length × girth measured on a squared-up log

- The size of timber was also crucial, with large timbers always at a premium. The Edict of Diocletian shows the higher prices that could be charged for larger pieces of timber:

Tree	*Length[a] (ft)*	*Price (denarii)*
Fir	37½	5 000
Fir	52½	12 000
Fir	75	50 000

[a] Girth 5½ or 6 ft, measured as before

- The lack of a suitable material could lead to technical innovation. By the fifteenth century the lack of large timbers in the forests of England for houses built of 'cruck' form (a natural A-frame construction) meant that this type of construction, used since the Saxon period, declined. The box-frame construction form, which used small timbers, increased, though there was huge regional variation. Development in the forms of roofing, such as hammer-beam roofs, may also be the result of difficulties in obtaining long lengths of timber to span the building.
- Where a material with the most appropriate properties was in short supply, or extremely expensive, alternatives were exploited. The consumption of oak in southern and eastern England had occurred to such an extent by the fifteenth century that houses in London were being constructed with pine, a poorer quality wood which often splinters and splits. This was aided by the opening up of the Baltic in the fourteenth century, with 'white' timber (pine and fir) being shipped from Russia, Latvia, Lithuania and Poland to the ports of western Europe (Postan 1973: 98), to meet the demand for timber.

  In the Roman and medieval periods, fine-toothed combs were essential for combing lice out of hair. The Romans frequently made combs from box, a fine-grained timber that did not splinter. Very limited supplies of box from British woods and faltering import trade following the fall of the Roman Empire led to the exclusive use of bone and antler for making combs in medieval Britain from the fifth to the thirteenth centuries (C. Morris 2000: 2311; MacGregor *et al.* 1999).

Noting the size and quality of the raw materials used in an object, and comparing it to the range of size and quality of materials available to that period/culture, provides an indicator of the wealth and status of the object and indirectly of its user/owner, although there can be considerable variations in the availability of materials between different regions.

Invariably people exploited local resources wherever possible. These were both cheaper and more familiar to them as craftsmen. This led to differences in the use of materials that are related simply to local geography and biology rather than complex arguments regarding different properties or cultural biases. One example of this is the wood used for panel paintings in the fifteenth and sixteenth centuries (Marijnissen 1985):

	Oak	*Poplar*	*Lime*	*Walnut*	*Conifer*
Flemish	100%	—	—	—	—
Dutch	100%	—	—	—	—
Italian	2%	90%	2%	3%	4%
German	20%	—	22%	1%	54%
Spanish	6%	36%	—	8%	43%

Here readily available local woods have been used, but only wood with highly appropriate properties was selected. Thus oak was used in Flanders, since it was more dimensionally stable than pine or birch.

Transport

One of the principal costs and limitations on the location of material exploitation was transport. In the Roman period the cost of carrying goods, per mile, by river was five times the cost of moving them by sea, and moving them by land was 28 times as expensive as moving them by sea (Duncan Jones 1974; Greene 1986: 42). Water transport continued to be the cheapest method of transport through the medieval period (Postan 1973: 123) into the eighteenth century, although land transport to and from the water and the costs of loading and unloading only made water transport significantly beneficial on longer journeys (Lawrence 1999: 95–108):

> … six or eight men therefore, by help of water-carriage can carry and bring back in the same time the same quantity of goods between London and Edinburgh, as fifty broad wheeled wagons, attended by a hundred men, and drawn by four hundred horses.
>
> (A. Smith 1776)

These costs reflected the differences in the volume and weight that could be moved by the various eighteenth-century transportation methods (Bagwell 1974; Greene 1986: 42).

Transport method	*Weight*
Packhorse (on bridle path)	2–3 cwt[a]
Team of horses pulling a heavy wagon on a soft road	1 ton
Team of horses pulling a heavy wagon on a hard road	2 tons
Single horse pulling a wagon on an iron-railed coalfield wagonway	8 tons
Single horse towing a barge on a river	30 tons
Single horse towing a barge on a canal	50 tons

[a] 100–150 kg

Water transport remained the most cost-effective transport mechanism, especially for heavy and large volume goods with low value, e.g. coal, over long distances. The relative cost of transport was lower for smaller high-value items such as jewellery.

There were other costs. In the fourteenth century, wine in Bordeaux cost 9 *livres* (per barrel) but the cost of loading, unloading, customs duty and a marginal profit had raised the cost to 14 *livres* by the time it reached London. Similarly wool at £8 per sack in the Cotswolds would sell for £11 in Calais and £20 in Venice, with risk and profits rising for longer journeys (Postan 1973: 124). Local goods were invariably cheaper than imported goods with all their associated transport cost.

Reductions in materials costs

By reducing the amount or quality of material present in an object, the costs were lowered:

- Reducing the volume of material used in the manufacture of objects. Though this could be a reduction in size, it was usually a case of making objects thinner or hollow whilst maintaining the outline size. The late Bronze Age saw the development of socketed axes and tools, which meant many more objects could be created with less metal. This saving of metal stimulated technical developments, e.g. the gold lunulae of the Bronze Age are often very thin, to maximize the effect of the gold, but often thickened at the edge to avoid tearing (J. Taylor 1985: 184). Similarly the gold sheet metal cups from Rillaton and Ringlemere are corrugated to give rigidity to the thin gold sheet forming the cup.
- Reducing the quality of materials used in their manufacture, e.g. the widespread adoption of wood pulp for papermaking (mid-nineteenth century) was due to its cheapness compared to cotton and linen rags. The paper created was, however, of much poorer quality.
- Copying expensive objects in cheaper materials. Tin-glazed ceramics, such as British and Dutch delftwares, copy the form and appearance of expensive imported Chinese porcelain (see section 4.9).

Combinations of these techniques could be used. It is possible for the state to mint more coins using less precious metal, either by making the coins smaller and thinner, i.e. less weight, or by reducing the amount of gold or silver in the coinage metal, i.e. debasement. This is most clearly seen in the decline in the amount of silver, through both debasement and weight/size reduction, in the Roman denarius (or its equivalent). This is matched by a similar engineered decline in the amount of gold in the aureus (or its equivalent): see Figure 3.1 (Casey 1980: 10). Debasement also occurred in Frankish gold coinage: see Milton Keynes pendant (section 4.8). It was, however, crucial that the socially ascribed value remained the same so that it could buy the same amount of goods and services. Thus this was not purely a technical process, but a balance of technical value and social value.

Reductions in manufacturing costs

By reducing the amount of time and skill required to manufacture a given object, more objects could be produced from fewer, less skilled, and thus less expensive craftsmen; this lowered the cost of each individual object:

- Craft specialization, where a single worker becomes highly efficient at a process through repetition. Initially individuals exploited natural talents for art or hunting. Later specialization was applied to almost all manufacturing processes. Pin-making, described by Adam Smith in his *Wealth of Nations* in 1776, was split into a number of separate specialized processes that allowed the production of 4,800 pins per person per day, far more than could be made by an individual taking every step to produce a pin.
- To undertake all the processes to manufacture an object required the greater knowledge and skills of a craftsman: it was cheaper to hire unskilled labour.

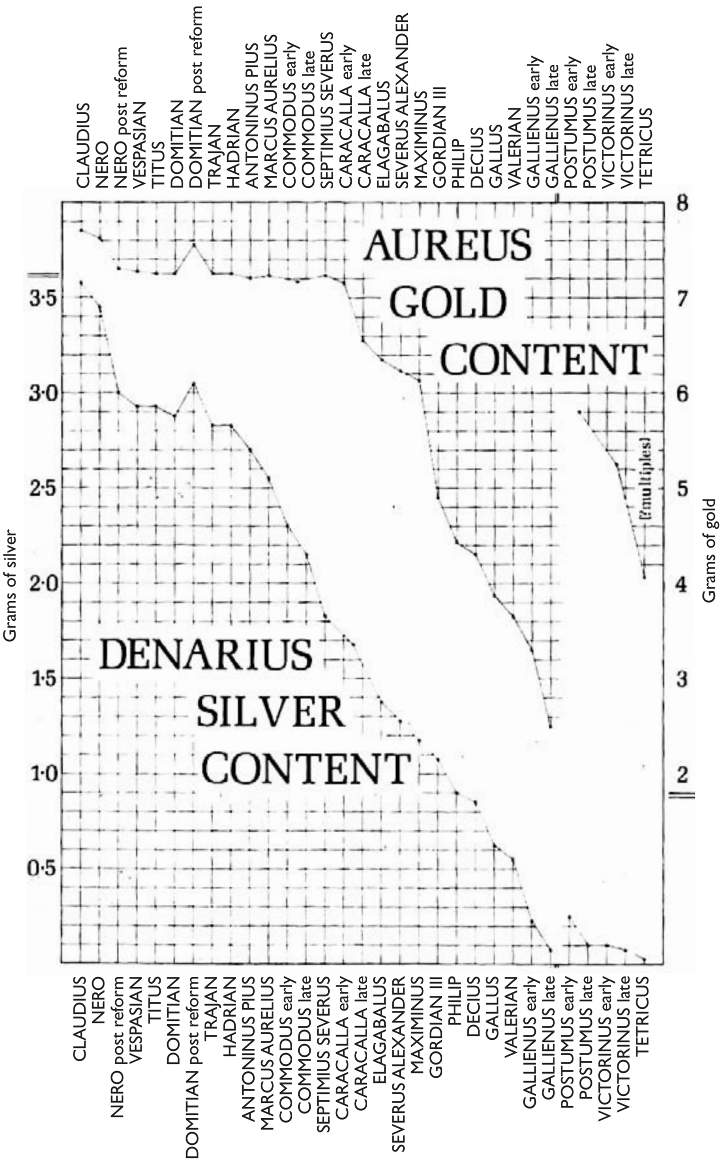


Figure 3.1 The weight of silver in Roman denarius coinage and the weight of gold in Roman aureus coinage. (From Casey 1980)

Complex tasks were broken down into a sequence of simple, single operations which cheap unskilled labour such as children or women could perform. The endless repetition of a single process encouraged speed and, since workers specialized in one task made few errors and so little waste, the process was cost-effective.

- Rather than have individual craftsmen shaping objects, the use of templates and moulds allowed less skilled practitioners to achieve the required shape. This encouraged standardized object forms, usually described as 'factory' products.
- Machines could be used to take over simple unskilled repetitive tasks, which led to increased efficiency and lower running costs than human labour.
- The sharing of tools, craftsmen, expertise, fuel and raw material sources meant that grouping industries together, as is seen in many early medieval towns, gave beneficial economies to the members of such groups – lower costs derived from buying and transporting materials in bulk and sharing facilities. Increased capacity could lead to the creation of larger kilns and forges and lower fuel costs.
- Using repetitive standardized methods reduced waste, since there was no experimentation, and products were all familiar and saleable to the customer, so none remained unsold.

Any culture that brings together large groups of craftsmen for production and takes craft specialization to its logical conclusion will create a manufactory (factory) system, see Table 1.1. An example of such specialization is demonstrated in the fifth-century BC Chinese lacquer industry. An inscription on the base of a lacquer bowl reads:

> Made in the fourth year of the Yuanshi reign period at the Western Factory in Shu Commandery. Imperial pattern. A lacquered, carved, and painted wood cup with gilt-bronze handles. Capacity one sheng sixteen yue. Priming by Yi, lacquering by Li, outer coat by Dang, gilding of the handles by Gu, painting by Ding, inscription carved by Feng, cleaning and polishing by Ping, inspected and passed by Zong. Director, Ahang; Manager, Liang; Deputy, Feng; assistant, Long; Chief Clerk, Bao.
>
> (Bagley 1993: 240)

As inscriptions rarely survive in the archaeological record, manufactories are normally archaeologically identified either from the large-scale specialized industrial evidence, such as the neolithic flint mines as at Grimes Graves, in which a large number of workers would have been employed (Mercer 1976), or from a large number of almost identical products, e.g. Roman Samian ceramics (Peacock 1982).

In a contemporary anthropological study of ceramic production in the Tuxtla mountains of central America, Arnold (1999) determined that the ceramics could be:

- Fired in an updraught kiln: though this took some time to get up to temperature, used a large amount of good hardwood fuel, it took up little space and gave consistent results (few pots failing during firing).
- Fired in the open (bonfire/clamp kiln): though this took a short time and used

> less and poorer-quality fuel (leaves and branches), it took up more space and more pots failed during firing.

It was factors such as the time, space and type of fuel available, and/or the investment of time in making a kiln, which determined the type of firing pots received. Simple notions that people had developed technically from open firing in bonfires/clamp kilns to updraught kilns, are naive: 'just because you can doesn't mean you do'.

Reused materials

Durable materials not greatly worn or damaged by their initial use, such as stone, brick, tile and wood, can be reused. The term reuse is applied to reclaimed material that is used again for a purpose similar to its original use. It is also referred to as 'product life extension' (PLE) in modern recycling economics. Good-quality freestone and substantial pieces of wood can be reused several times, though they frequently bear marks of their previous use (see Figure 3.2). Often available with little or no transport costs near the use site, reused materials are often highly cost-effective. The availability of surplus materials at low cost during an economic slump or the shortage of fresh materials during and following a war often result in reuse of materials.

Large volumes of reusable wood, stone and tile from first- and early second-century buildings in Roman London appear to have provided a ready supply of building materials for new buildings during the later second and third centuries AD. New building materials are only seen again in Roman London in the late third century (Betts, personal communication). The detection of reused material often depends on the extent and quality of the repair and reshaping it has undergone, e.g. the central garnet in the Milton Keynes pendant (see section 4.8).

Less durable materials such as fabrics and leather, which become worn and damaged through use, could not be as easily reused, except to be cut into smaller pieces and used for patches and repairs (see section 5.4).

Recycled materials

Recycled materials are those that can be collected and either remelted (e.g. metal or glass) to form new objects or disaggregated and re-formed into new materials, as linen rags are reconstituted to form paper.

Recycled objects are an important source for any material that is economic to collect. This applies to high-value materials in dense population centres where costs of collection, transport, storage and sorting are low because of the use of cheap labour such as children. When there are material shortages, e.g. during sieges or periods of economic hardship, recycling becomes particularly important. High-cost materials like gold were always worth recycling, and they, like metal and glass, are consequently far less common as archaeological finds than ceramics, for which there was no recycling process. The differences in the availability of materials and their value led to differential levels of recycling in different periods, cultures and places (see Figures 4.5 and 4.6).

Figure 3.2 Reused Roman altar stone. This stone was initially a Roman altar to the God Jupiter (right face). It was re-erected as an altar and inscribed (left face) in the third century AD in the fort of Piercebridge, Co. Durham. It was later reused as a column capital (back face) in Gainford Church a few miles from Piercebridge (RIB 1022). (Photograph by Jeff Veitch, courtesy of Durham Cathedral)

Evidence for recycling comes in the form of hoards, some of which contain broken and damaged objects and casting waste and have been interpreted as (metal-)founders' hoards of recycled material (Rowlands 1976; Bradley 1987). Pits containing 50 kg of pieces of broken glass, found at Guildhall Yard, London, have been interpreted as cullet – broken glass about to be remelted and recycled. Roman writers record the exchange of broken pieces of glass for small trinkets in first-century Rome; almost certainly evidence for recycling. Traditionally up to 30 per cent of any glass melt is recycled glass. Such levels of recycling may explain why materials such as metals and glass change composition gradually over time.

Economics determine whether it is more expensive to obtain or create new materials than old materials and whether the old materials retain their form and are reused, or are broken down and recycled. Glass bottles were often collected and reused in the early twentieth century, since they were expensive to produce (Busch 1991). By the late twentieth century, they were collected and recycled since through automation they were cheap to form into shape, but the material was still expensive.

3.5 New materials

Economic factors do not stay constant through time. This is perhaps best exemplified by changes in the perception of the value of 'new materials'. Technological development, in particular the arrival and use of new materials and new technical processes occurs in at least two stages:

- Inception – a new material or process is discovered or imported.
- Exploitation – the new process or material is widely used. This occurs because the demand for the material/process created is fashionable or it has economic or technical benefits over previous materials and processes.

This is exemplified by the wheel, which was used on toys by the Inca civilization, but was never exploited and scaled up to make wheeled vehicles. Influences such as the presence of a rigid social structure, the presence of slave labour, the lack of immediate use or benefit have all been cited as reasons for the failure to move into the exploitation phase.

Archaeological evidence suggests that new materials appear (inception) many years before they are produced in significant quantities and utilized (Renfrew 1986). There is the need for a market – a use for a material before it becomes valuable and sought after. Renfrew observed that the move from the neolithic to the metal-using communities of the Chalcolithic and Bronze Ages coincided with a move from communal cultures (communal burial rites in long barrows, etc.) to individual wealth and social stratification (single burial with valuable grave goods). It also coincided with the first uses of metals, whether gold, copper or copper alloy, as symbols and personal adornments (Renfrew 1986: 146). Thus they may have been the key materials for displaying wealth in the changing social structure. It was at a later date that the properties of the materials were appreciated and they were used for making tools (Renfrew 1986: 152).

After the initial discovery/appreciation of a new material, social, economic and technical properties of the material all affect its future exploitation by any society. Spratt (1982) suggested there were six stages, A to F, in the innovation and development process, based on modern examples of critical path analysis and cash flow curves. However, it can be suggested that five stages of development, based on archaeological evidence, are discernible and thus consequently more useful for artefact studies. Owing to the paucity of the archaeological and historical records there is often limited trace of some of these stages.

- Stage 1: rare. Initially new materials such as iron in the third millennium BC, or aluminium in the mid-nineteenth century, were rare and thus valuable; aluminium cost $500 per pound in the 1850s, more than twice the price of gold or platinum (G. D. Smith 1988). Consequently these materials were used for high-value objects, e.g. jewellery. At the court of France in the 1850s the knives, forks and spoons were made of aluminium, since it was more valuable and more fashionable than gold or silver. The object forms are invariably traditional ones, since there is no experience of using the new materials or of their properties, at either craftsman or consumer level.
- Stage 2: fashionable. The new material becomes popular as it is a sign of wealth and prestige, especially if the supply of material is limited, e.g. porcelain in Europe in the seventeenth and eighteenth centuries, which retained a high value due to costly importation from China. In the 1860s aluminium was $17 per pound, a similar price to silver. Consequently it continued to be used for display items such as jewellery, demonstrating wealth. The materials or products may be copied in an effort to benefit from their high prices and fashionability; e.g. the imitation of porcelain by white tin-glazed delftwares (see section 4.9).
- Stage 3: available and appreciated. Craftsmen become more familiar with the new material, appreciating and exploring its new and unique properties. Consequently the range of products made in this period of experimentation with the new material grows. The customer has also become familiar with the new material and starts to demand more useful and impressive objects. Though the first bronze axes were of similar shapes to their stone counterparts, as metalworkers became more familiar with the material, its manufacture and shaping, thinner axe forms were cast. This created lighter, more effective metal axes.

  The appreciation of the properties of the new material and the ability to manufacture it in a range of forms eventually gives rise to completely new uses or the total replacement of earlier materials. By the 1880s the price of aluminium had fallen to approximately $8 per pound and its properties – light weight and corrosion resistance – were beginning to be appreciated, as it was used to make navigation instruments, clocks and some statues (G. D. Smith 1988).
- Stage 4: competitive, innovative and exploitative. Once the use of the material is well established, the only ways to benefit from making objects are to reduce the cost of making them, so making your objects cheaper than other producers', or to

increase the level of object consumption: see earlier sections *Reductions in materials costs* and *Reductions in manufacturing costs*. This is exemplified by technical developments of the twentieth century such as the development of the cold rolling of steel and the electrolytic plating of tin onto the steel, which reduced the amount of materials used in making a tin can. Twenty per cent less metal was used to make a tin can in 1978 than in 1958.

Aluminium began to be made by the cheaper electrolysis process in 1888. This increased the amount of aluminium available, and the price fell by 1892 to between 85 and 54 cents per pound. This meant that it was available for widespread use, exploiting its properties. Saucepans and other pots and pans start to be manufactured, exploiting the fact that aluminium is light and corrosion-resistant. As its price became lower and its property of softness was appreciated, production of thin sheets and foils that were impermeable to oxygen and thus could keep food fresh was undertaken. This was seen in the form of cans for carbonated drinks and foil used for milk bottle tops, and as 'silver paper' for wrapping chocolate and other foodstuffs. Completely new products and new uses for materials are developed in stages 3 and 4.

- Stage 5: continued use. Though new materials normally displaced older traditional materials, the latter were retained for making some objects:
  - for which they are uniquely suited – 'niche' uses. Despite flint having been used to strike iron to create a spark for nearly 3000 years, this material has not been bettered and it is still used in modern lighters;
  - for high-cost quality products where the 'cheapness' of the new material is no advantage. The values of 'tradition' and 'quality' become associated with the more expensive/luxury products in the older material, and these are not displaced by the new material. This associated status is a culturally defined value. Examples include the use of leather for seats in present-day cars or for bookbinding.

  The new object shapes developed in Stages 3 and 4 to exploit the new material become fashionable. Old materials respond by taking on the new fashionable shapes, even though it sometimes makes little sense in technical terms. Thus some flint daggers and stone axe-heads clearly mimic the new bronze forms, e.g. the stone axe-head from Hillend, Penicuik, Midlothian (Clarke *et al.* 1985: 85).

It is important to know which materials are being used in the manufacture of objects in order to consider their properties in relation to the object form and identify the stage of development of the material.

3.6 Marks of manufacture (tool marks)

The tools that shape and create objects leave distinctive marks. From these the processes and sometimes the individual tools involved in creating and shaping the object can be determined. Where there is a direct imprint of the tool on the object, such as a punch mark or an axe-made facet, then the tool mark may be unique to the tool, reflecting the shape of the tool which had developed through damage and wear. Detection of such marks indicates the presence/use of a specific tool. However, where there is continuous or repeated contact between the tool and the object surface, such as with a hammer, saw or drill, then the marks created obscure each other and leave no clear unique tool imprint. In such cases a specific tool cannot be identified. Tool marks can indicate the level of technology being practised by the culture undertaking the manufacture, indicate the skills and knowledge of the craftsmen undertaking this work and even give some indication of the organization of the manufacturing industry.

The use of silicon rubber to take accurate impressions of the punch marks that decorated the plates which make up a large silver Iron Age cauldron, the Gunderstrup Cauldron, enabled them to be analysed with a scanning electron microscope (see section 5.7). Individual punches could, through the shape, cracks and damage visible in their impressions, be uniquely identified. Systematic analysis of all punch marks on all plates revealed that three separate sets of punches had been used, which did not overlap. One set was used on the Bull Plate, a late addition to the base of the cauldron, and the other two sets for all the inner and outer plates that formed the sides of the cauldron (Larsen 1987). Clearly there were two separate sets of tools and thus two separate craftsmen at work. Two craftsmen within one workshop are likely, since the iconography used in the panels was very similar.

Since shaping materials utilizes a small number of basic principles, in a variety of materials it is possible to detect basic shaping techniques from the marks left in the object. For example, the majority of the ceramic vessels made in prehistoric north-west Europe and in the early medieval period were made by hand, by coiling and finger-forming lumps of clay. They are distinguished by their shallowly irregular surface; the sherds have an irregular cross section. The whole vessels are not accurately circular in plan. Ceramics made on a potter's wheel will have accurately smooth surfaces and be accurately circular in plan, and the sherds will have even thickness. The presence of a standard cross section for the vessel may denote the use of a template, as seen in the production of undecorated Roman Samian pottery. Careful identification of the production method is important to distinguish between supposedly similar ceramics, especially where, as in the case of the thirteenth-century ceramics from the Welsh castle of Dryslwyn, wheel-thrown and hand-formed ceramics, in identical fabrics and forms, were supplied to the same site (Webster 2002). The more technically advanced wheel-thrown manufacture had not fully replaced the earlier hand-formed technology in thirteenth-century Britain, though the hand-formed vessels had mimicked the form of the wheel-thrown vessels (see *New materials*, Stage 5, above).

Moulding and casting

Moulds can be and have been used to shape any material that has a liquid or plastic state and sets to a solid. Thus glass can be poured or blown into a mould, ceramics have been formed by pouring clay into absorbent moulds, and polymers are frequently shaped in moulds. Metals such as gold, silver, all copper alloys, lead, pewter and cast iron can be cast in moulds. Two forms of mould are:

- Piece moulds: normally with two or more mould parts, usually made from clay, bronze, steel or even sand formed around a model of the desired object. The mould pieces, each bearing the partial impression, are combined any number of times to form a hollow-shaped space into which material is poured to cast replicas of the original. Objects with only one shaped side, or those destined to receive further working, could be cast in an open mould.
- Investment moulds – a single-piece mould, usually of clay formed around a model in meltable material, e.g. wax, hence 'lost-wax casting'. The model is melted and poured out, the mould fired and metal or other material cast into the space created. The mould is then broken into fragments to retrieve the casting. Objects cast in this manner are usually complex 3-D shapes and can be highly decorated.

Material formed in a mould usually has one or more of the following features:

- flash marks – raised lines or ridges of material where material has seeped between the edges of the different parts of the mould: these can sometimes be in negative form if air is trapped along this line;
- runners and risers, which are tubes of solidified material, where the liquid casting material was poured in and exited the mould;
- offsets, when parts of the mould are mis-aligned, leading to very slight offsets between the halves or parts of an object;
- poorly defined decoration when the liquid casting material is so viscous that it fails to form exactly to the intricate contours of the decoration of the mould: decoration is usually in low relief and without undercuts;
- spacers for holding internal forms in large body castings: these are either made of a material that is incorporated into the casting material, such as chaplets, or removed and later filled;
- a smooth but non-reflective matt surface;
- a bulky form, vessels often having thick walls unless material was spun or blown into the mould, e.g. glass.

Cutting and working

Incised marks on the surface often betray the use of a specific type of tool:

- Broad ridges or fine striations spiralling around a vessel or object normally indicate an artefact which has been formed by spinning or turning, such as a ceramic vessel formed on a potter's wheel or turntable. Wooden, stone or metal artefacts will have been cut, or in the case of sheet metal gently bent, into shape on a lathe. The spinning motion creates centrifugal force pushing the spinning material outwards, which is counteracted by the shaping tools or the potter's hands pushing

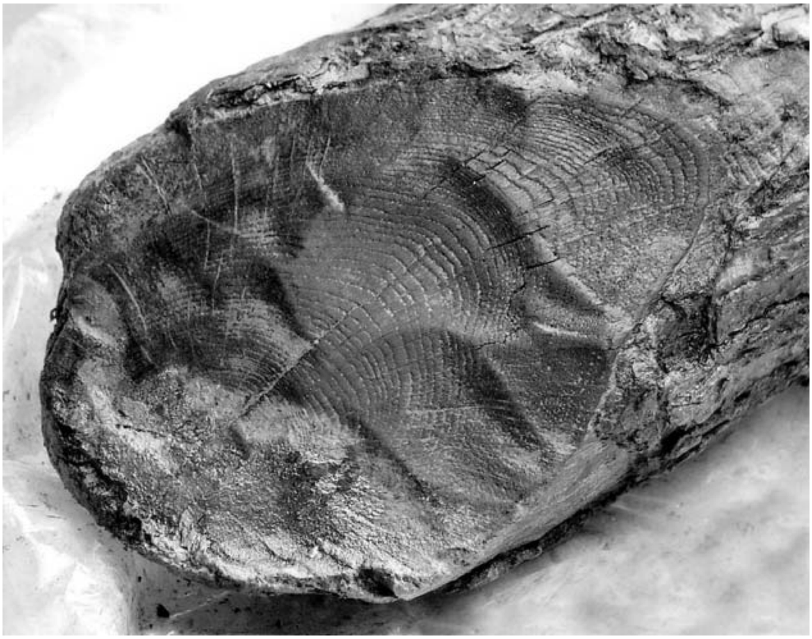


Figure 3.3 Tool marks – facets created by an axe – forming the point of a wooden stake, from Staithes, North Yorkshire. (Photograph courtesy of Jennifer Jones).

in. This invariably creates a vessel or object of circular plan or section with slight striations around its circumference.

- Parallel striations usually indicate the use of a file (metal or coarse stone, e.g. sandstone). Longer, dense striations are caused by the use of mechanical grinding wheels, whilst fine parallel scratch-marks result from the use of an abrasive for polishing the surface. Such polishing often removes marks of other tools, as exemplified by the neolithic stone axe from Tongland, Kirkcudbrightshire, where the deep scars from the initial flaking could not be removed despite vigorous polishing (Clarke *et al.* 1985: 167). Irregular and roughly parallel striations of variable depth on the edge of an object can be caused by the use of a multi-toothed metal saw, usually used for soft materials such as wood and soft stone. Parallel striations along a wire indicate wire drawing, and, along sheet, the use of rollers.
- Fine circular scratches are usually due to abrasive polishing, whilst deeper cuts are due to drilling, cutting, routing or turning. If found along the edge of an object they can indicate that a circular saw was used, though this detail is normally associated with nineteenth- and twentieth-century wood and stone artefacts.
- Smooth, shallow dished facets denote shaping with a sharp blade. Tools such as axes, adzes and chisels, and blades such as planes, spokeshaves or drawknives make these type of marks in materials such as soft stones, wood (see Figure 3.3),

and soft metals. Also some non-crystalline minerals such as flint, obsidian or glass can be flaked by applying pressure to a single point to produce shallow facets.

- Small flat facets usually denote hammering, where deformable material, usually metal, has been worked into shape using implements such as hammers or mallets.

As early as 1699, antiquarians noted that they could see the facets from axes used to fell and shape prehistoric timber that was preserved in waterlogged contexts (Sands 1997: 6–8). Workers on the Somerset Levels Project noted that on some, though not all, axe facets there were slight ridges and grooves, which resulted from nicks or burrs on the edge of the blade. Such a pattern of damage or signature would come about through use and would be unique to each axe. Noting an identical pattern of ridges and grooves on the axe-cut facets of timbers from different trackways (A and D) running across Tinney's ground (1100–1000 BC), John Coles and Bryony Orme suggested that different pieces of wood had been cut by the same axe, so indicating that the tracks were roughly contemporary (Coles and Orme 1985: 44). Given the date of the trackways, this was almost certainly a bronze axe.

Further examples of signatures from bronze axes were revealed at the Meare Heath trackway in the Somerset Levels and Oakbank crannog in Loch Tay (Sands 1997), whilst at the neolithic site of Alvastra in Sweden distinctive axe signatures created by stone axes were noted. O'Sullivan (1997) suggested, using data from the prehistoric trackways such as Longford and Corlea in Ireland, that shorter, deeper facets are cut with stone axes, longer, shallower ones by bronze, and the longest and shallowest ones with iron axes. However, Sands (1997) has suggested that the method of hafting the axe could be an equally, or more, significant factor than the material of the blade in determining the nature of the axe facets.

Axe signatures, like most tool marks, are most effectively recorded by taking photographs, in raking light, either of freshly exposed wood from waterlogged contexts where such tool signatures are clearly visible or of silicon rubber casts taken from such freshly excavated wood. Although computer programs can be used to match what are effectively black and white line patterns, the curve of the axe blade, the curve of the cut and the natural variation in the wood mean that this is still a comparison best made by the human eye. Often only part of the axe blade is recorded in any one facet; therefore many partial signatures need to be fitted together to provide the full-width signature of the axe blade.

Tools such as axes will, through use, gradually change their signature and when resharpened will lose it. The rate of tool use and resharpening will vary enormously from days to years, depending on use and cultural tradition. Coles suggested, from dendrochronological evidence, that pieces of wood bearing distinctive axe signatures had been cut and used within a six- to twelve-month period (Coles *et al.* 1988). Experimental work by Sands (1997) suggested that the signature of the axe blade could remain for years.

Any group of contemporary or near-contemporary objects that have visible tool marks can be analysed for distinctive tool signatures. Tool marks are usually seen on the back or base of objects – surfaces that are not normally visible. On visible surfaces polishing or the application of a coating such as paint has often obscured the marks of manufacture. Since marks of manufacture are not normally intended to be seen, their presence often denotes a poorer-quality product or unfinished object. In the late twentieth century and during the Arts and Crafts movement of the late nineteenth century, tool marks and evidence of craftsmanship and manufacture became fashionable with some sections of the population. Objects with visible tool marks became associated with being 'hand-made', rather than mass-produced machine-made objects, and consequently have an enhanced value. Some fine-quality papers of the late twentieth century have had lines deliberately pressed into the surface of smooth machine-made paper to simulate the pattern of the wire deckle used in making hand-made paper.

3.7 Assembly

Most objects are composites (several pieces assembled together) usually made of different materials, e.g. the Coppergate Anglian helmet (see section 1.11, Figure 1.12). Assembly can involve jointing materials, sticking materials together, fixing devices such as rivets, lashing or sewing materials together or fusing or interweaving materials. The way in which an object is assembled can provide information about the manufacturing methods, the sequences of operations and the skills and social organization of the manufacturing industry. The assembly and the materials used differ in nature between different cultures, and change over time. This is demonstrated by the portrait of Prince Henry on horseback (see section 2.12). In the seventeenth century the canvas was nailed flat onto the stretcher, whilst in later centuries the canvas was folded over and nailed to the back or sides of the stretcher. Thus the method of assembly can be used as an identifier of the cultural or chronological origin of the object.

- Jointing is normally seen between pieces of hard material, such as wood and stone. Detailed studies of jointing, especially in medieval carpentry, have been made (Hewett 1980, 1982) and show the preference for certain joints at certain periods and places. The construction of wooden wells and waterfronts in Roman London in the first and second centuries AD is characterized by simple lap joints, while the more complex and time-consuming dovetail joints, which are stronger and more secure, were utilized in the third century AD (Milne 1985: 65). See Durham Cathedral door (section 6.8).
- Weaving is normally undertaken using flexible, thin stranded materials such as fibres or withies interlaced in a regular order to form textiles or basketry. Irregular intermeshing is seen in fine short-strand materials such as felt and paper. There are a large number of variations in the spinning of fibres to form threads and in the weaving of threads to form textiles. Variations in the direction (Z or S spun) or the tightness of the twist of the fibres to form the threads, the fineness (thickness) of the threads, density of the weave (number of warp/vertical and weft/horizontal threads per centimetre) and the different weave types/patterns (number of warps between wefts and wefts between warps) create considerable visual effects

in the cloth produced (Walton and Eastwood 1983; Henry 1994; Schoeser 2003; Crowfoot *et al.* 1992). The preferences of the weavers (manufacturers) and the wearers (customers) for particular types of woven cloth (fashion, wealth display, practicality or social acceptability/familiarity) resulted in particular types of cloth being associated with particular periods and cultures. An example is Birka weave cloth (Z,Z-spun diamond twill) which was popular in the ninth–tenth centuries in western Norway, where it was traditionally made. However, it was also exported to places such as the Viking town of Birka (where it was first identified and named) and to Scandinavian settlements in Britain such as Orphir (Orkney) and York (Henry 1994: 60, 180, 197).

- Securing devices such as nails, screws, pins, tacks, staples, rivets, nuts and bolts, dowels, usually used for securing softer, solid materials such as wood, leather, etc., plus all forms of sewing and ropes, thongs or other thin flexible materials used for tying or lashing things together. Prehistoric wooden structures were held together with wooden pegs (tree nails), as metal was too rare and expensive to be used for securing devices. However, by the first and second centuries AD the Romans were using large quantities of iron nails to construct many of their military wooden buildings. This was because the economic basis had changed; iron was produced on an industrial scale, making iron nails cheap. The cost of the nail was now less than that for the time taken to cut a joint in the wood or bore a hole for a tree-nail. By the eighteenth century, screws are seen holding high-quality wooden objects together. The screws were hand-cut, with irregular spiralling of the cut groove, which ran all the way to the head, and thus were expensive to make; hence their use in high-quality furniture. By the nineteenth century, machine-made screws had become widely available, mechanized production making them cheaper. The presence of machine-made screws in eighteenth-century and earlier furniture indicates a repair or a fake. Metals such as iron were often riveted into place; the technique could be used on large objects such as nineteenth-century iron bridges and ships, though it was also used on fine jewellery. It was used to join the ends of 1–2 mm diameter iron wire that formed the alternate rows of links in the mail on the Coppergate Anglian helmet (see section 1.11). Pieces of textile and leather were normally sewn together using thread (Mould *et al.* 2003; Walton 1989a: 404).
- Adhesion. Any material that flows like a liquid over surfaces and then sets solid, e.g. molten wax, solder, glues, tars and resins, mortar and cement, can act as an adhesive, bonding those surfaces together. Animal glues (boiled-down collagenous animal material such as hooves and hide) were used as the principal adhesives for wood and similar materials throughout the historic period. Earlier examples do not survive; however, prehistoric peoples certainly used birch-bark tar adhesive, traces of which have survived (see section 5.2). A wide variety of polymers from cellulose nitrate to cyanoacrylates ('superglue') have been used as adhesives in the twentieth century. Pieces of stone are normally mortared into place to form walls and buildings. Lime mortar, setting by a chemical reaction with the air, has been used in northern Europe from the Roman period onwards. Portland cement

mortar, which is harder and faster-setting, generally superseded lime mortar in the twentieth century.

- Fusion, where two materials were either melted or softened and fused together. Pieces of clay such as handles were luted (fused with wet clay) onto the body of the pot. Handles and foot rings were applied onto glass vessels with molten glass. Metals could be joined by soldering, fusing two pieces together with a metal of lower melting point, e.g. copper alloy soldered with soft solder (tin–lead alloy), though the latter is technically an adhesive because it is a separate material and the metal body does not melt. True fusion of metals occurs with welding; this makes the metal surface molten. The fusion process for iron requires the use of high temperatures, whereas pieces of pure gold will fuse if hammered together at room temperature. Heat and a flux, to lower the melting point, were used to fuse the filigree wire decoration onto the backing plate in the Milton Keynes pendant (see section 4.8).

Evidence of weaving can be obtained from impressions on pottery. Details of wood jointing, textile fibres and weaves are visible in iron corrosion crusts, where the mineral has cast or copied the form of adjacent organic material, as on the Roman box at Benwell (Keepax and Robinson 1978) and the Viking scabbard from Scar (see Figure 3.4).

Measurement and setting-out

A key element in creating any complex artefact was the ability to plan and set it out using measurement. From around 3000 BC on, rings of standing stones have specific sizes, which archaeologists such as Thom (1967) suggest indicates that multiples of a standardized unit of length, the 'megalithic yard', were being used in prehistoric Britain. The recovery of yardsticks from Egyptian tombs and the exact setting-out of the Egyptian pyramids indicates that in this, as in all other ancient urban civilizations, there is clear evidence of numeracy and standard units of length and weight. The ability to measure was widespread in all ancient civilizations, and concepts such as symmetry, regularity and ratio were important to those creating ancient artefacts.

Evidence of setting-out is present in many artefacts. Marks of setting-out, as indentations and faint grey lines from a lead point, are visible on the back of the decorated pages of the Lindisfarne Gospel (M. P. Brown 2003a, 2003b). There are traces of a series of very fine incised lines on the nose-guard of the Coppergate Anglian helmet (see Figure 1.11). These appear to be the remains of a grid and setting-out lines that were used to create the interlace design which decorates the front of the nose-guard (Tweddle 1992: 1047–8). Finely scribed lines were used in the setting-out of most carved wood, stone and incised metalwork, and indicate the use of instruments such as compasses, dividers and rules as well as the associated mathematical knowledge.

There is evidence of lines, numbers or simple designs cut into the pieces of wood, from complex assemblies such as roof constructions, to indicate the order in which the pieces were supposed to be joined together. Even small diagrams can be found indicating the nature of assembly. Marks were also placed on pieces of wood and stone to indicate the exact position of components. Carpenters often scored a series of lines

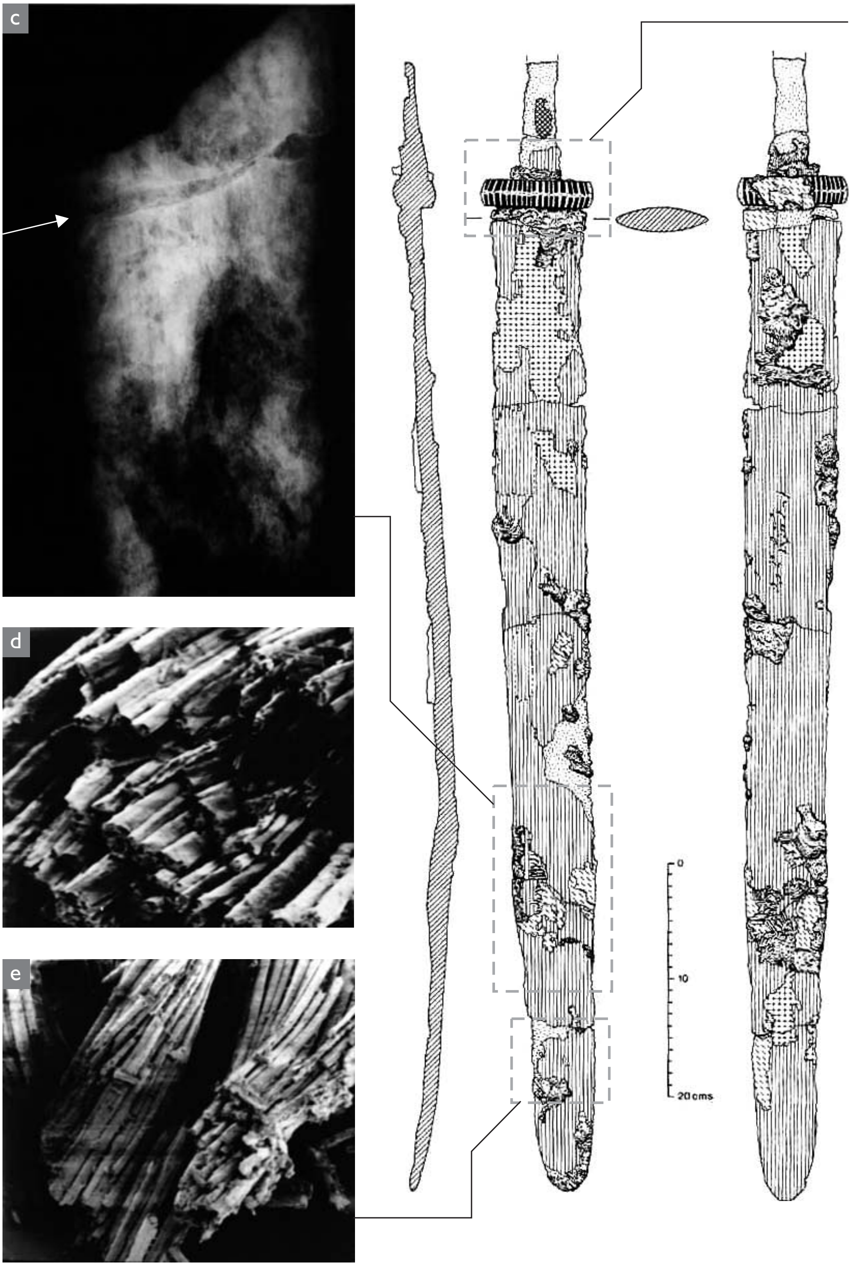
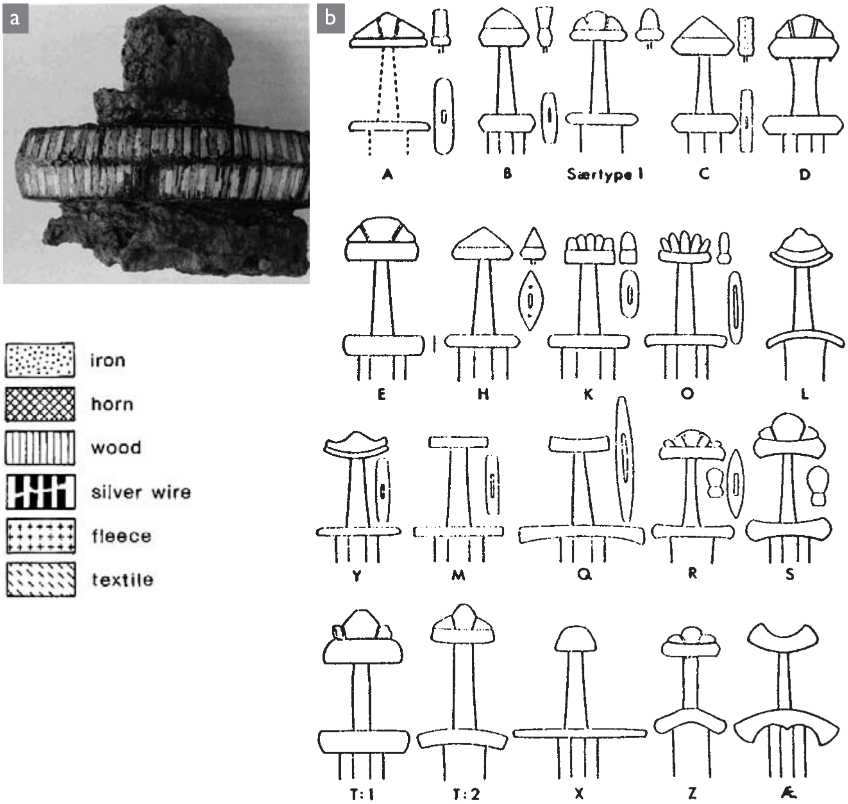


Figure 3.4 Scar Viking sword and scabbard. (© Crown copyright, reproduced courtesy of Historic Scotland and Kim Nissan)



This sword was retrieved from beside a male, buried with a wealthy old lady (rich grave goods) and a child (slave?) in a Viking boat burial, radiocarbon-dated to the period AD 875–950, located at Scar on the Orcadian island of Sanday (Owen and Dalland 1999). The cleaning of the sword revealed white and yellow metal wires (silver and brass identified using EDXRF) inlaid into the hilt (a). The keeled form of the sword guard and the vertical decoration means that the hilt of this sword corresponds to Petersen's type H (b), which were produced *c.* AD 800–900 (Petersen 1919). The X-radiograph of the sword (c) revealed deliberate breaking of the sword blade (arrowed) prior to reinsertion into the scabbard and burial in the grave. The blade was simple, without any inscription or fuller (central groove) and was made of low-carbon steel, not pattern-welded. This simpler form of blade is like others of the ninth and tenth centuries (Lang and Ager 1989). SEM examination of the corroded iron revealed the mineral replaced organic remains of the scabbard, which had been composed of ash laths tied together with a linen binding (d and e) and a fleece lining. The sword grip was made of horn and wood, held in place/decorated with tin binding strips (Nissan 1992). The use of a textile and fabric scabbard was appropriate for storage of the sword; cf. leather scabbards for swords in constant use. With a decorated hilt but a simple blade, this is the sword of a settled Viking farmer, intended for display more than use.

Figure 3.5 Transmitted-light microscope. (Photograph by the author)

across a join, and the pieces had to be adjusted so that the lines exactly met up, in order to achieve the correct position – a technique also used by those creating glass and metal objects using moulds (Price, personal communication).

INVESTIGATION TECHNIQUES

3.8 Microscopy: fibre and wood identification (Appleyard 1978; Catling and Grayson 1982; Schweingruber 1978)

Fibres and thin slivers of wood can be examined using a transmitted-light microscope to reveal features of the microscopic morphology, which allow them to be identified to the species level. Aspects such as plant/animal disease, evidence of plant/animal domestication, manufacturing processes and damage through decay can sometimes also be noted.

The transmitted-light microscope (see Figure 3.5) focuses light from an external or

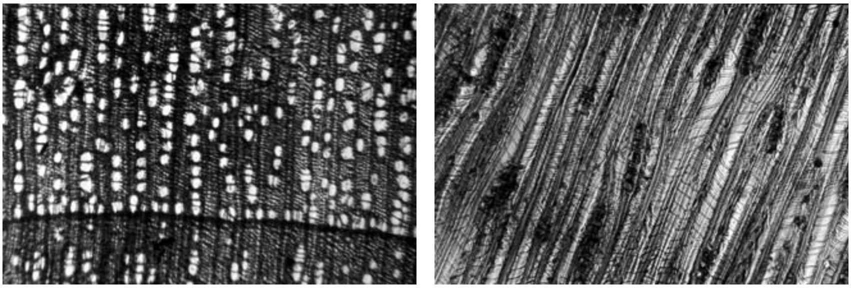


Figure 3.6 Photomicrographs of archaeological wood. Left: radial section of yew (*Taxus baccata),* from a bucket stave, Keays Lane, Carlisle. Right: tangential section of alder *(Alnus* spp.), from a drainpipe, Millennium Site, Carlisle. (Photographs courtesy of Jennifer Jones)

internal source through a condenser beneath the stage to form a narrow beam of light which passes up through the sample into the objective lens, and through the eyepieces to the viewer. The magnification at which the sample is viewed is the product of the magnifications of the eyepiece and the objective. Examination normally starts at low magnification (×20) and proceeds to higher magnification as specific features are observed. Samples can be prepared in a number of different ways, depending on the features that the investigator wishes to observe.

- Wood (Schweingruber 1978). Pieces of waterlogged or partially degraded wood have thin slivers pared from their surface using a razor blade. This can also be done for hard dry wood, though slivers may also be created from larger samples using a microtome. These slivers should ideally be taken from the radial, tangential and transverse planes of the wood. They are normally mounted on a microscope slide with a 50:50 mix of glycerol and water, and protected with a cover slip. For decayed and waterlogged wood it is important to try and get wood which is firm enough to cut and sufficiently undecayed that microscopic features will still be visible (see Figure 3.6). Fresh wood can be stained to bring up diagnostic features using safranin 1 per cent for three to five minutes then rinsed off in alcohol (Schweingruber 1978: 211); however, archaeological wood is usually darkened from soil staining, so biological staining techniques are often ineffective. The presence of differentiated types of vessel and simple pits will indicate a hardwood such as oak or beech. Single vessel type, resin canals and bordered pits will indicate a softwood such as pine. The relative sizes of the vessels through the year in transverse section will identify ring-porous species (large spring vessels), e.g. oak and ash, from diffuse-porous species (relatively even vessel size) such as lime, alder and birch. More detailed analysis of the vessel sizes and the pore (pit) distribution will allow identification to species level. Reference to standard textbooks, e.g. Schweingruber (1978), is usually required to aid identification (see Figure 3.6).

- Fibres (Appleyard 1978; Catling and Grayson 1982; Greaves and Saville 1995). Several fibres are normally pulled from the threads of the object being examined. Warp, weft, stitching and embroidery threads all need to be sampled separately since they may be made of different fibres. Several fibres are sampled, since mixtures of fibres were sometimes used to form the thread. The fibres are mounted onto a slide using a 50:50 mix of glycerol and water, and covered with a cover slip. If bundles of vegetable fibres are seen, it may be necessary to macerate them – soak in a 50:50 solution of 20 per cent hydrogen peroxide and acetic acid, typically for one to two days – until they are separated.

  The fibres are normally sufficiently transparent to reveal internal features:

  - Vegetable fibres (cotton, linen, hemp, jute, etc.): fibre cell ends, lumen, pits, cell walls and cross-markings which can, when compared to standard texts such as Catling and Grayson (1982), identify the fibres to species level.
  - Animal fibres (sheep wools and animal hairs, silks): medulla form, pigment distribution and surface features such as scale patterns which can, when compared to standard texts such as Appleyard (1978), identify animal fibes to species level.

  For vegetable fibres it is possible to stain the fibres using dyes such as Chlorazol Black to bring up diagnostic features. However, decayed and soil-stained archaeological fibres often do not respond well to staining, whilst historic fibres may already be dyed. Archaeological fibres are usually partially decayed and thus diagnostic features are frequently missing or visually altered. Basic identification of fibre type is often all that is possible.

3.9 Microscopy: petrology
(Kerr 1977; Kempe and Harvey 1983)

When thin slices of rock, typically 0.03 mm thick, are viewed in transmitted light, the minerals in the rock are transparent to light and display a range of shapes and light-altering properties which allow them to be identified. By noting the range of minerals present and their relative abundance, plus other morphological features, the rock itself can be identified. By reference to comparative examples and geological maps the likely source of the rock can be deduced, though if the rock lacks distinctive minerals or fossil fragments the source identification may be very generalized.

A sample, typically 4 mm thick and 20 mm square, is cut from the object using a circular saw. Thinner slices can be cut with a thin wire saw. One side of the sample is ground flat; it is then stuck to a microscope slide using a transparent cement, e.g. Canada balsam or Lakeside adhesive, and the remaining rock is ground down until it is only 0.03 mm (30 µm) thick and the minerals have become transparent, at which point it is covered with a cover slip stuck down with the transparent cement.

Examination is undertaken using a petrological microscope, which is similar to a transmitted-light microscope, but has polarizing filters beneath the condenser and above the objective. Examination normally starts at low magnification (×20) without filters and proceeds to higher magnification as specific features are observed. The sample is examined in normal and plane-polarized light and through crossed polarizing filters. This allows features such as the size, shape, fracture and colour of the minerals, their birefringence colours, their extinction angle and other physical and light-altering properties to be identified. Reference to standard textbooks, e.g. *Rutley's Elements of Mineralogy* (Read 1970), aids mineral identification. The use of a point counter to record the numbers of different mineral types as they appear under cross-hairs as the investigator scans across the thin section will allow the percentage of different minerals to be determined and thus the rock type to be identified.

In addition to identification of the stone used for buildings, statues, mosaics and objects such as stone axes, ceramics (pottery, bricks and tile) and mortar can be analysed by thin-section petrology. This enables large groups of visually similar material to be subdivided, usually on the basis of the distribution of the size and shape of their mineral inclusions. Sometimes the origin of the temper used in the ceramic or the sand in the mortar can be determined when distinctive minerals or microfossils can be matched to specific geological sources.

3.10 Microscopy: metallography

(Scott 1991; F. C. Thompson 1969)

Metal is composed of microscopic grains containing atoms in regular crystalline arrangements. If the metal is alloyed, heated, melted, hammered or distorted in any way, it alters the shape of the grains and/or the crystalline structure of the atoms. Exposing and viewing the grains and their crystalline arrangement to reveal the composition and the history of heating and deformation of the metal is metallography.

A small sample of metal is normally cut from a meaningful position on the object, such as from the cutting edge of a sword blade. The sample is mounted in resin then polished using increasingly fine grades of abrasive paper and finally given a mirror finish by polishing on fast spinning wheels covered with cloth impregnated with very fine diamond paste (1–5 μm) or fine alumina suspensions. The specimen is then degreased, mounted flat and viewed in the 'as polished' condition down a metallurgical microscope.

Metallurgical microscopes contain a prism, or mirrors, allowing light to be shone down onto the sample and be reflected back through the objective into the eyepiece. Materials with different reflective properties from the metal, such as slag particles, carbon flakes or cracks and corrosion, are visible in this 'as polished' condition. The specimen is normally examined initially at low magnification, typically ×20 or ×40, and subsequently at high magnifications (×100 to ×200). Specimens are subsequently etched; a chemical solution is applied to the surface of the metal for a few seconds or minutes and then washed off. The samples are then dried and re-examined under the metallurgical microscope. The etching solution dissolves away the most chemically reactive atoms of the metal, which are normally located at the edges of metal grains and where distortions have occurred in the crystalline structure. When the metal is re-examined under the microscope, it contains a network of lines (microstructures) formed where the metal surface, eaten away by the etchant, no longer reflects light back up the eyepiece. The patterns of these lines are interpreted by the metallurgist with reference to known patterns derived from specimens that have received known treatments. Alloys composed of two or more metals will normally have a number of possible different crystalline phases depending on the atomic percentage of the elements present, the temperature to which the metal was heated, and the cooling rate of the metal. In metals with two or more different crystalline phases present, the phases are usually distinguished by having different chemical properties and thus etching at different rates. One is invariably brighter than the other. Some etchants will give different colours to specific types of metal or crystalline phase. In under-etched specimens not all features are visible, and in over-etched specimens some features are obscured. The etched image is often recorded in drawn or photographic form. To etch iron and steel, etchants such as 2 per cent nital (nitric acid in alcohol) are used. The samples from the Coppergate Anglian helmet (see section 1.10) were etched with nital. To etch metals such as copper alloys, 10 per cent ferric chloride solution (acidified with 2 per cent hydrochloric acid) is normally used (Scott 1991: 72), though in the case of the pins and wires (see Figures 3.7 and 3.8) a freshly made-up ammonium hydroxide/hydrogen peroxide solution was used, since ferric chloride solution over-etched the very small grains created by the wire-drawing process.

3.11 Microscopy: paint cross sections

(Garrido and Cabrera 1986; H. Hughes 2002b)

Many objects, house interiors and oil paintings have been painted and repainted a number of times. Identification of these paint layers allows the visual history of the object or interior to be revealed. Initial attempts to uncover the earlier layers of paint that covered objects used paint scrapes, where the overlying paint had been removed in a sequential manner to expose areas of each of the paint layers beneath. Such scrapes revealed many paint layers; however, it is now considered more accurate to remove small fragments of paint, 1–10mm square, which incorporate the full thickness of the paint layers, ideally with some traces of the wood or plaster substrate. These fragments are typically mounted on edge in polyester casting resin, then polished away using increasingly fine grades of emery cloth. The polishing continues until the sequence of layers is visible and a fine polished finish has been achieved. The samples are then mounted on a metallurgical microscope and viewed in reflected light. The specimen is normally examined initially at low magnification, typically ×5 to ×10, and subsequently at high magnifications (×50 to ×100). Specimens are often photographed or drawn in realistic or schematic format to show the layers of paint and dirt that can be seen (see Figure 6.8). Examination in UV light can often reveal further layers of paint or varnish, since the binding medium fluoresces in slightly different colours depending on variations in its age and composition. Samples are usually taken from different parts of an object, from different architectural features in a room or different areas of a painting. When the sequences are compared it can reveal that different parts of the object/room/painting were painted in different colours at different times. However, caution should be exercised when comparing paint sequences from different parts of an object, room or painting, since paint can be deliberately removed, e.g. to allow redecoration or as part of a specific alteration or decoration. Other factors that should be considered when examining a paint cross section include:

- The layers are not laid down at consistent rates; there may have been several decades between repaintings in the eighteenth and nineteenth centuries. Redecoration can occur every two to three years in late twentieth-century homes.
- Some layers of paint were primers and undercoats and do not represent a colour seen by the viewers of the object or interior.
- Some layers only show up under fluorescent light.
- Layers of dirt and decayed (yellowed or cracked) paint surface can be present if there is a long period between repaintings, or high levels of dirt and dust.
- Clear layers of varnish may be present within the paint sequence.
- Layers can be removed by natural flaking as well as through more deliberate stripping or scratching off.
- Sometimes layers are very thin and simply do not show up in the cross section.

Paint cross sections show many more layers than are revealed by paint scrapes (Bristow 2002). For oil paintings, the layers usually describe the way in which the original artist built up the original painting, using different layers of colour. It also reveals alterations and restoration work. In architectural paintwork there are often many layers of repainting. These usually divide into phases with many layers of a similar colour, when the room was simply repainted its existing colour to make it look fresh and new, then the colour changes and there are often many layers of the new colour, prompted by changes in interior design taste.

CASE STUDIES

3.12 Medieval brass pins (Caple 1986, 1992)

Context

A collection of 880 small copper alloy dress pins was recovered from the resonance passages beneath the choir stalls of Whitefriars Church in Coventry. The pins were deposited when the church was in use, between 1545 and 1558. From this assemblage a sample of 198 pins was analysed metrically; 38 were cut and polished for metallographic examination and elemental compositional analysis using EDXRF (Caple 2005). Details of three typical pins are given here:

- Coventry Whitefriars: WF 62 I (4) Pin 37.
  A wound wire headed pin, head type A (Tylecote 1972; Caple 1992). 1.8 to 1.9 turns of head wire. Length 35.5 mm, shaft diameter 0.8 mm, head diameter 1.82 × 1.9 mm. The pin shaft is made of leaded brass: copper 75.4 per cent, zinc 18.4 per cent, lead 5.5 per cent.
- Coventry Whitefriars: WF 62 I (4) Pin 33.
  A wound wire headed pin, head type B (Tylecote 1972; Caple 1992). 2 turns of head wire, traces of tinning on the shaft and head. Length 20 mm, shaft diameter 0.62 mm, head diameter 1.55 × 1.6mm. The pin shaft is made of leaded brass: copper 77.2 per cent, zinc 18.8 per cent, lead 3.4 per cent.
- Coventry Whitefriars: WF 62 I (4) Pin 38.
  A wound wire headed pin, head type C (Tylecote 1972; Caple 1992). 2 turns of head wire, traces of tinning. The head is spherical, with a tear of metal at the base of the head. The shaft has a constriction or neck below the head. Two black lines run down the length of the shaft. Length 16.5 mm, shaft diameter 0.62 mm, head diameter 1.29 × 1.4 mm. The pin shaft is made of leaded brass: copper 69 per cent, zinc 27.2 per cent, lead 3.2 per cent.

Form and decoration

Pins made of copper alloy wire, with heads formed of two twists of wire stuck or crimped into place (see Figures 3.7 and 3.8), are known as wound wire headed pins and first appear in the UK in thirteenth- and fourteenth-century urban sites in cities such as Southampton. These objects are dress pins, primarily used for holding together women's garments. The increasing complexity of clothing in the fourteenth and fifteenth centuries led to a huge increase in the use of dress pins. They became widely used in the sixteenth to eighteenth centuries and continued to be manufactured and used into the twentieth century. Such pins were used throughout Europe and are found in all countries visited by Europeans during this period.

There are three major head form variants for wound wire headed pins.

- A – two twists of wire stuck onto the top of the shaft with a flux or adhesive,
- B – two twists of wire loosely crimped and sometimes stuck onto the top of the shaft,
- C – two twists of wire tightly crimped onto the top of the shaft forming a spherical head.

There are at least fourteen further minor head forms of wound wire pinhead (Caple 1986). A large percentage of A-type heads is seen in the fifteenth century, with B-type heads becoming prevalent in the sixteenth century, whilst C-type heads become dominant after 1700 (Caple 1992). The pins from Whitefriars fit the distribution well; 32 per cent A-type heads, 57 per cent B-type heads and 10 per cent C-type heads.

The distribution of A-, B- and C-type wire headed pins from dated contexts:

Moulsham St., Chelmsford (Caple 1985)

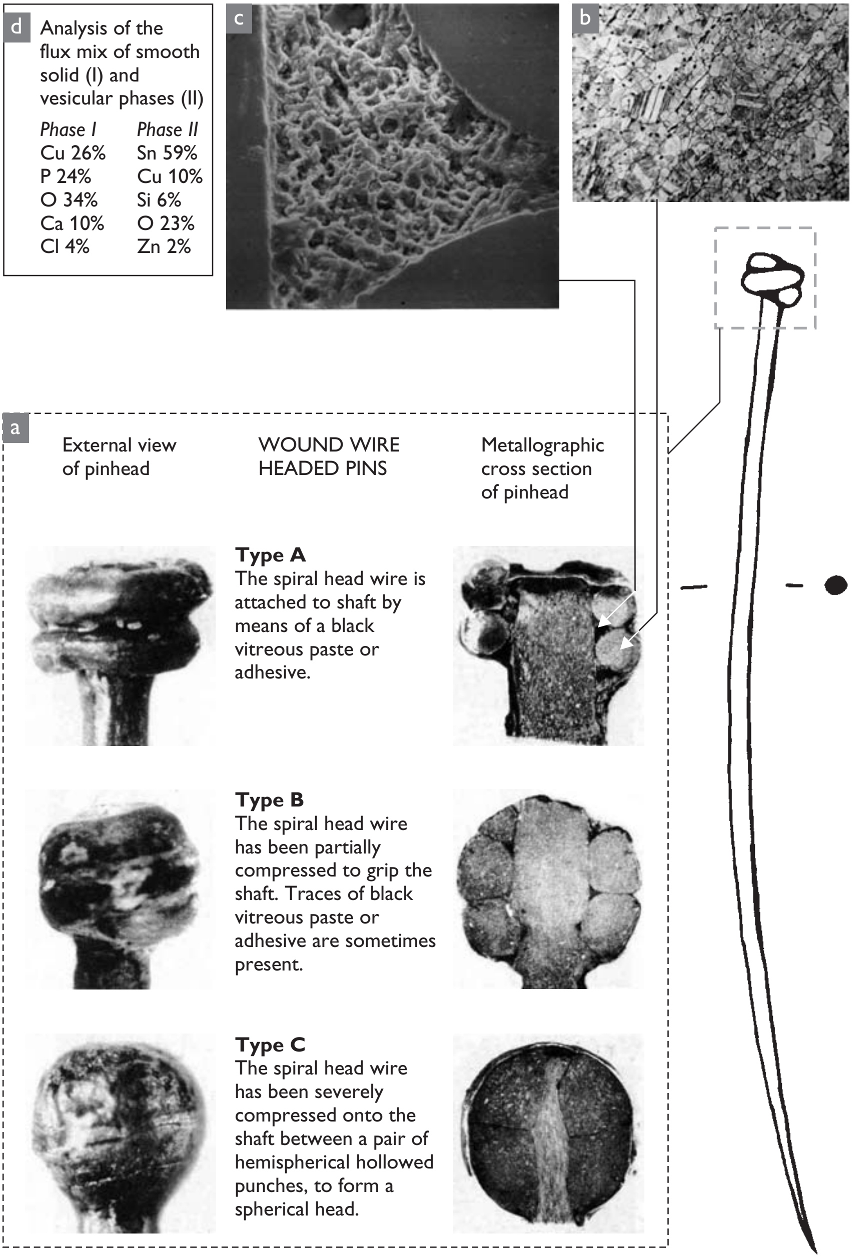
Date	*Type A*	*Type B*	*Type C*
1560–1590	41%	29%	29%
1590–1630	24%	28%	31%
1630–1670	8%	29%	63%

Exeter (Goodall 1984)

Date	*Type A*	*Types B/C*
1450–1500	85%	15%
1500–1550	96%	4%
1550–1600	52%	48%
1650–1700	12%	88%
1700–1750	10%	90%

Metrical analysis of many thousands of pins has revealed:

- Length: wound wire headed pins from deposits dated before 1500 have mean pin lengths over 40 mm because of the prevalence of pins 40–50 mm in length at this date. The pins of the period 1500 to 1630 are generally slightly shorter, with mean lengths of 29 to 35 mm, largely as a result of the absence of the longer 40–50 mm pins. The later period 1630 to 1730 saw pins becoming even shorter, with means in the range of 25 to 30 mm. There is a corresponding decrease in the diameters of the wire used in the manufacture of pins. The decrease in length and increase in fineness of pins in the post-medieval period can be related to the increasingly fine weave of fabrics during this period and the desire for pins to be



d Analysis of the flux mix of smooth solid (I) and vesicular phases (II)

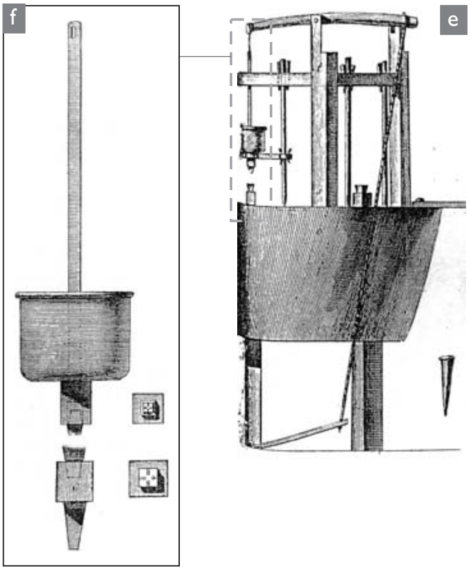
Phase I	*Phase II*
Cu 26%	Sn 59%
P 24%	Cu 10%
O 34%	Si 6%
Ca 10%	O 23%
Cl 4%	Zn 2%

Type A
The spiral head wire is attached to shaft by means of a black vitreous paste or adhesive.

Type B
The spiral head wire has been partially compressed to grip the shaft. Traces of black vitreous paste or adhesive are sometimes present.

Type C
The spiral head wire has been severely compressed onto the shaft between a pair of hemispherical hollowed punches, to form a spherical head.

Figure 3.7 Wound wire headed pins: details of materials and manufacture. (Images by the author and from Diderot 1771–80)



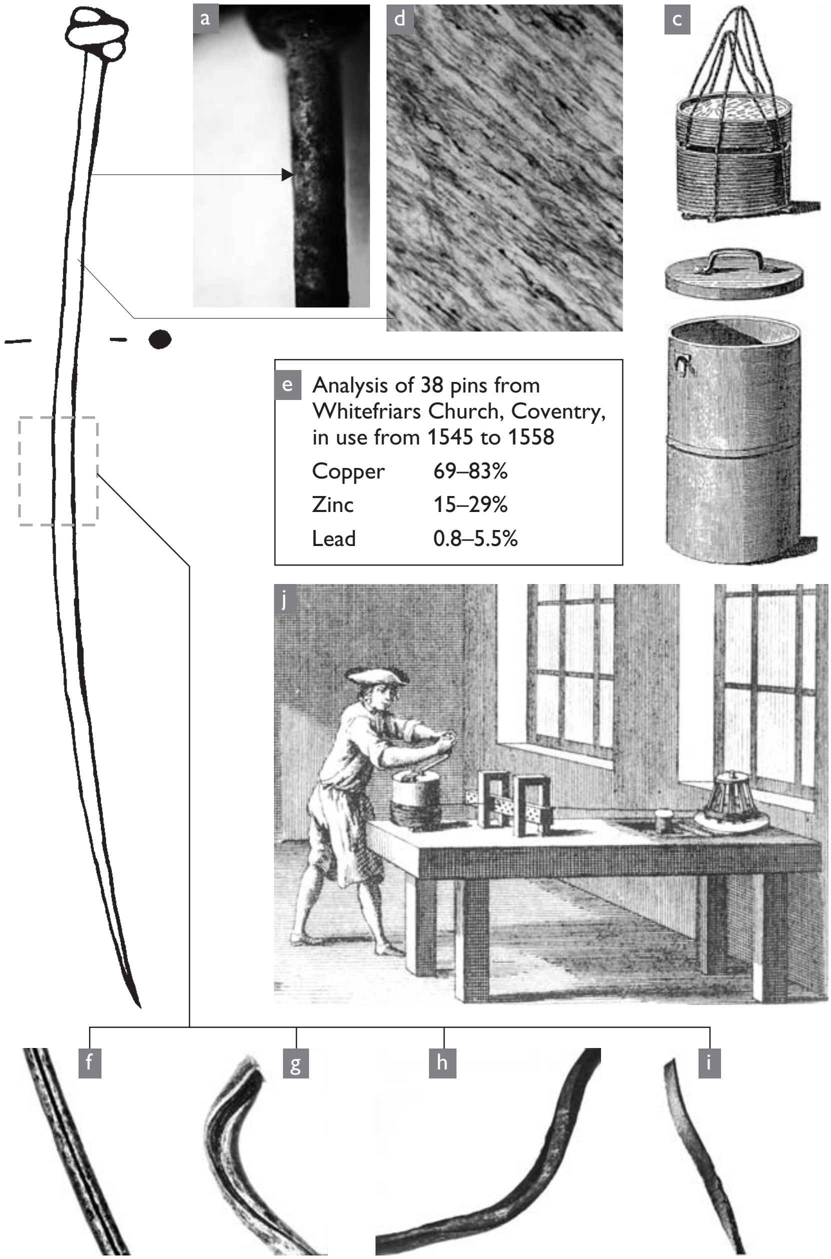
The wire head of the pin was wound, in two turns, around the top of the shaft (a). Metallographic examination revealed that this head wire had been heated (annealed) (b) to soften it, making it easier to wind. The early ‘A’ type pin heads were held in place with a flux or solder. SEM analysis revealed the vesicular nature of this flux (c) and its composition (d). In later ‘B’ and ‘C’ head forms the wire was crimped in place with hollow punches. By the eighteenth century these were in the form of a pin heading machine, illustrated by Diderot (e, f) which could crimp four pinheads in place with a single depression of a pedal-operated drop punch.

less visible and less damaging. The mean length of pins from Whitefriars of 27.4 mm (*n* = 198) is lower than on other sites of this date. The distribution of pin sizes shows that there are a large number of shorter 20–30 mm pins in this collection. This is probably due to the fact that most churchgoers would have worn their ‘Sunday best’ to church, and finer cloths would require finer pins.

- The overall distribution of pin lengths indicates that a number of pin lengths appear to be unusually well represented, standing above the general distribution. In this instance pin lengths of; 20, 25, 27/28, 30, 32, 34/35, 41 and 44 mm appear as peaks in the distribution. These probably represent specific pin sizes made at the time. From the fourteenth and fifteenth through to the nineteenth century, writers use a variety of names and numbers to refer to the different sizes and types of pin.

Manufacture

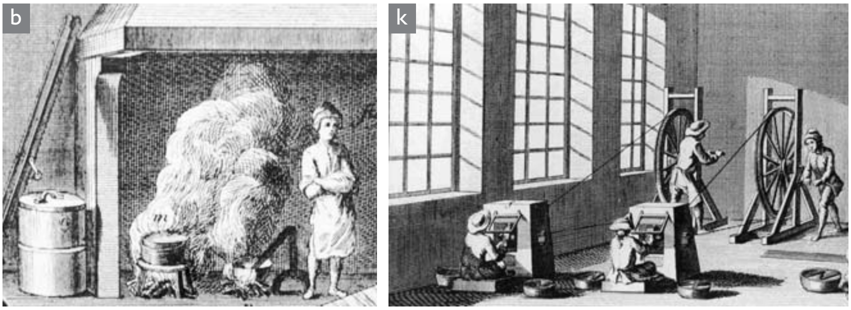
- Visual analysis revealed that almost all the pins had one, and occasionally two, lines down the shaft. Archaeological finds of narrow ribbons of metal and partially drawn wires of C- and U-shaped cross section from Coventry (see Figure 3.8) indicate that sheet metal was cut to form narrow ribbons which were then drawn through the circular holes of a draw plate to form solid circular-section wire. This type of wire drawing leaves a long vertical line down the wire/pin shaft, and this type of wire was used for pin manufacture.



e Analysis of 38 pins from Whitefriars Church, Coventry, in use from 1545 to 1558

Copper	69–83%
Zinc	15–29%
Lead	0.8–5.5%

Figure 3.8 Wound wire headed pins: details of materials and manufacture. (Images by the author and from Diderot 1771–80)



The wire from which the pins were formed was originally a thin ribbon of sheet metal (i) drawn through a series of circular holes in a drawplate (j) to form a wire with a line running along its length (f, g, h). The brass wire (e) was left in the drawn state (d) (distorted, elongated grains) to form the pin shaft since it formed a rigid wire shaft. After cutting to length, the tip of the pin shaft was pointed using a grinding wheel (k). Traces of a white metal coating (identified as tin by EDXRF analysis) are often found beneath the pinhead (a). This is the remains of a complete coating of tin applied by immersing the brass pins on mesh trays into a solution of tin granules boiled in wine lees (potassium tartrate) (b, c).

- Metallographic examination of the pin wire revealed that the pin shaft had metal grains in an elongated form with many strain lines visible; a classic deformed ‘worked’ or ‘drawn’ grain structure (see Figure 3.8). The pin shaft was deliberately left in this condition, the working (wire drawing) having made the metal rigid. Illustrations in Diderot’s *Encyclopédie ou Dictionnaire Raisonné des Sciences, des Arts et des Métiers* (1771–80) (see Figure 3.8) showed that the wire was drawn by hand using winches and windlasses through draw plates until it had the correct thickness for use in pin manufacture.
- Examination of pins under the stereo microscope revealed traces of a white or silvery metal coating on the shafts of many of the pins. This had largely worn off. In most cases, traces usually only remained where they were protected near the head. Analysis by EDXRF and SEM confirmed that the pins had been given a very thin coating (a few micrometres thick) of tin. Diderot’s illustrations (Diderot 1771–80) (see Figure 3.8) and the descriptions of pin manufacturing by Adam Smith (1776) indicated that tin was dissolved in ‘a solution of tartar’ or ‘wine lees’ (potassium tartrate solution) in which the brass pins were boiled. This caused tin to be electrochemically deposited on the surface of the brass, giving a shiny silver pin that protected the brass from corrosion during use, and so avoided staining garments.
- Metallographic examination revealed that the pins were pointed through a grinding process and not through hammering. Diderot’s illustrations (Diderot 1771–80) and the descriptions of pin manufacturing by Adam Smith (1776)

showed that by the eighteenth century, children were used to point pins on grinding wheels. In the medieval period, the leg bones of animals are often found with thin grooves in them. These are known as pinners' bones, and the grooves were formed from sharpening the points of pins.

- Metallographic examination revealed that the head wires of the wound wire headed pins were formed from metal with 'an equiaxed grain structure with twins', which indicates that the metal had been annealed. Elemental analysis by EDXRF of the metal of the head wires and the shafts had shown that they had identical compositions. Thus the same wire which was used for the shafts was annealed (heated in a fire to soften the wire, which had work-hardened from drawing) then wound around a mandrel into a tight spiral, then two turns were cut off and attached to the shaft to form the head of the pin.
- Metallographic examination revealed that the A-type heads are stuck onto the top of the pin shaft using a flux or adhesive. This appears to be the standard method for late medieval pins produced in Britain. SEM analysis of the flux revealed a two-phase material: a dense phase rich in copper, phosphorus and calcium, and a vesicular matrix whose principal component is tin, probably tin oxide (Caple 1986) (see Figure 3.7). Reference, in a statute issued by Henry VIII, to the prohibition from selling pins unless the heads were 'soldered fast to the shank' almost certainly refers to the attachment of this A-type head, though it was not solder that was used.
- Metallography revealed that the C-type heads had been deformed into a spherical form by two small hemispherical punches and had thus been pressed or crimped onto the top of the shaft, which was deformed during this crimping process. Diderot's illustrations (Diderot 1771–80) showed the use of a foot-operated weighted head punch machine at which six workers could work simultaneously crimping on pinheads (see Figure 3.7). Adam Smith (1776) suggested that 4,800 pins per person per day were produced by pin manufacturing workshops. For an eight-hour working day, that would mean heading ten pins per minute. The punches, in addition to attaching the heads and making them spherical, often caused a neck to be formed in the pin shaft below the head, a tear of excess metal to form below the head, and slight ridges to form in the head wire caught between the two punches, which did not meet properly.
- B-type heads often have traces of attachment flux and the rounded head of a lightly punched head wire.
- Elemental analysis by EDXRF of hundreds of medieval wound wire headed pins and associated wires have indicated that the vast majority of wound wire headed pins were made of brass containing low levels of lead. Occasionally small percentages of tin were also present. A large range was observed in the composition of pins, even within a single dated phase from one site, which suggests that in the

post-medieval period a wide range of elemental variation within the alloy was tolerated for wire and pin production. Analysis of pins and wires from numerous sites throughout the country showed a similarly wide variation in composition. However, when the mean values of the alloy constituents are examined, a clear, consistent overall change – decreasing tin content and increasing zinc content – is observable in pins and wires from the fourteenth to the nineteenth centuries (Caple 1986).

Date (century)	*Mean zinc content (%)*	*Mean tin content (%)*	*Number of samples*
14th	17.3	1.6	36
15th	18.1	0.9	14
16th	20.9	0.5	69
17th	23.2	0.2	31
18th	23.5	0.3	29
19th	24.6	0.1	31

The pins from Whitefriars have an average composition of copper 74.6 per cent, zinc 22 per cent, and no tin was detected. Thus they are similar to other sixteenth- and seventeenth-century compositions. These alloys were also similar to those found in some of the few sheet and wrought metal analyses obtained for this period. Similar developments in the composition of copper alloys have been noted for memorial brasses and jettons (Caple 1986; Pollard and Heron 1996: 196–238). It would appear to be the general metal supply that is changing, and not specifically the metal used in the manufacture of wires and pins.

Trade and economics

Written records provide evidence of the emergence of the trade of ‘pinner’ in cities such as York. There were no pinners on the town council (the ‘forty-eight’) in 1311 and 1341. References in the York Memorandum Book indicate that the ordinances (rules of a guild) for pinners’ apprentices were being laid down from the period of the ‘Great Pestilence’ of 1349 onwards, suggesting a mid-fourteenth-century date for the emergence of the Pinners’ Guild in York. The occurrence of two pinners on the town council in 1379 indicates the establishment of this as a manufacturing trade in York by the late fourteenth century (Caple 1992). A similar fourteenth-century emergence of pinners is recorded in London, with the occurrence of pinners on the town council for 1376, though it is the early fifteenth century before they are recorded in smaller towns such as Coventry. Given the prevalence of A-type pinheads in the archaeological record at this date, it is likely that the Pinners’ Guild members produced type-A wound wire headed pins.

The Pinners’ Guild of York expanded rapidly in the late fourteenth century, with twelve pinners in the 1381 Lay Poll Tax Records (Bartlett 1958). However, by 1482/3 the Pinners' Guild was merged with that of the Wiredrawers, and after 1579 pinners are no longer represented on the town council. The decline in the fortunes of the industry coincides with records of the importation of pins into Britain from the Continent. These begin as early as 1439/40, when the Venetian galley of Franciscus Dandolo landed at Southampton a cargo (part of which is recorded in Figure 4.1) including 44,000 pins (Cobb 1961). This importation continued and expanded through the later fifteenth and early sixteenth centuries. Import controls were attempted in the fifteenth century by Edward IV and subsequently by Richard III. Stronger measures were attempted in the sixteenth century by Henry VIII, with edicts banning the sale of sub-standard pins, a measure aimed at suppressing the importation of pins. Later in the century Elizabeth I specifically banned the importation of pins in an effort to protect the British pin producers. These decrees appear to have had little effect, as the imports continued. This reflects the declining power of the guilds of pinners, who were theoretically able to confiscate sub-standard pins and could use this to disrupt pin imports through seizure and checking, but they appear to have been unable to afford the necessary scrutineers to protect their monopoly. The seventeenth century saw an increase in the number of grocers who acted as retail outlets for pins as well as many other small manufactured goods, the Pinners' Guild monopoly being apparently no longer even locally enforced (Caple 1986).

The importation of pins continued into the seventeenth century, but the introduction of pin-making machines in 1626 by John Tilsley and the development of the brass industry in Bristol in the eighteenth century, using copper from South Wales and calamine (zinc ore) from the Mendips, led to the establishment and growth of brass wire and pin manufacturing industries in the Stroud, Bristol and Gloucester regions. Through the eighteenth-century development of the pin-making manufactories, high productivity levels and low costs of production were achieved. The low-cost pins produced were exported throughout the world. The pin-making machines employed in these manufactories produced the crimped wire C-type pinhead. It is likely that this efficient method of production was that used on the Continent in the fifteenth to seventeenth centuries, which gave rise to the cheap pins imported into Britain. By the nineteenth century the cost of labour became the dominant factor in production, which consequently switched to large towns such as London, Birmingham and Warrington, where labour was cheap and plentiful.

Use

The pin industry was fuelled by the demands of female fashion of the fourteenth and fifteenth centuries, which was becoming far more intricate, with frequent folds and tucks in garments. The written records often indicate women of status as being the customers of pinners, e.g. the Duchess of Orleans, who in 1400 bought several thousand long, sharp pins from a pinner in Paris, Jehon de Areconmer. Flemish painters of the fifteenth century, e.g. Rogier van der Weyden, often depict pins in the garments of their female portraits.

The vast majority of pins recovered from archaeological excavation are worn to the extent that the tin coating has often been removed from their surface. This testifies both to their use and to the thinness of the tin coating.

In addition the large numbers of pins often recovered from archaeological sites of the post-medieval period indicate frequent loss of pins and thus high levels of usage.

Chapter 4

Objects and materials as trade goods (provenance)

WHERE?

4.1 Trade and exchange

> A basic prerequisite of exchange of products is that different regions have varying access to natural resources, labour and capital.
>
> (Ringstedt 1987: 469)

The differential distribution of natural resources leads to a potential natural variability in the economic conditions pertaining in different parts of the world. This is accentuated by the variabilities in the level of technological and cultural development of different human societies, as well as their level of consumption. This leads to different values for objects and materials, which encourages trade – the movement of materials, objects and services, from a place of lower value to a place of higher value.

Trade, though principal, is not the only mechanism of object movement. Social contact between groups or individuals involves activities such as gift-giving (Bradley and Edmonds 1993: 12), whilst warfare leads to object transfer in the form of looting or the payment of tribute/ransoms. Such contact increases the awareness by one culture of the technical and artistic abilities of others, and can lead to benefits such as trade, knowledge transfer and cooperative activity.

Trade is most usually detected in the form of objects, e.g. the presence of pottery from Turkey and North Africa on sites on the Welsh coast in the fifth and sixth centuries AD (see page 144). It is also present in the form of written accounts such as port books, which record details of the ships entering harbour, the origins of the ship, its master, and the cargo it carried (see Figure 4.1). In addition to objects, components that go to make up the object, e.g. materials, ideas, techniques and artists themselves, can be traded. The detection of trade involving materials or objects without regionally distinctive form or decoration is difficult, and may rely solely on the ability to source materials accurately. Objects and the materials of which they are made and which they contain provide some of the clearest evidence of cultural contact.

Though trade can occur in raw materials, such as rocks and minerals, metal ores, plants or animals, these are usually bulky and contain much unwanted or waste material. Consequently they are rarely moved far from their origin; they are usually processed near the source to extract the desired material, e.g. the metal contained in

fo77r			
4 April			
De galea unde Franciscus Dandolo est patronus, intrante 4 die Aprilis:			Ankr. 6s. 8d. plegius Pawlus Morell’
De Pawlo Morell’	pro	20 barellis saponis nigri val. 20 li	Cust. 5s Pontag. 5d
		1 dolio vini	Cust. 4d. Cran. 4d
		7 fardell’ de safferon	Cust. (3li. 10s.)
		(valeu 10s. la lb.)	Pontag. (7d.)
		8 bal’ et 1 balett papiri	(Costom 3s. 1d. ob.
		val. (12 li. 10d.)	pountage 2d.)
		6 barellis vini	Cust. (6d.)
fo77v			
De George de palaise	pro	1 barello saponis nigri val. 20s	Cust. 3d.r.
De Benedicto de Sancta Cruce	pro	9 banquers val. 30s.	Cust. 4d.ob.r.
De Lazaro de Nicoll’	pro	4 banquers, 1 grose de lasys, 4 ketels, val. 23s. 4d.	Cust. 3d.ob.r.
		18 ulnis panni linii	Cust. 1d.r.
De Peanoche de Per	pro	1 dosyn et di. De sporis, 1 pare linthiaminum, 6 grosys poynt’, 8 dosyn’ cultellorum, 8,000 pynnes, 8 dosyn’ myrrors, val. 53s. 4d.	Cust. 8d.r.
De George Nicoll’	pro	1 grose et di. De poynt’, 3 dosyn’ cultellorum, 1 dosyn gerdell’, 2 dosyn’ sher’, val. 10s.	Cust. 1d.ob.r.
		14 ulnis panni linii	Cust. Ob.r.
De Andrea de negr’	pro	2 dosyn’ patellis eneis val. 13s.4d.	Cust. 2d.r.
		9 parvis combys de every et 2 hatt’, val. 6s. 8d.	Cust. 1d.r.

Figure 4.1 Record in the Southampton Port Book for 1439–40. Goods imported on the Venetian galley of Franciscus Dandolo. Spices such as pepper and saffron plus manufactured goods such as pins formed part of the cargo. (From Cobb 1961)

the ore. This creates a series of processed or refined materials which, though sometimes referred to as raw materials, are not. Materials may receive several processing steps and may be traded between any pair of steps:

Sheep → wool → thread → cloth → dyed cloth → garment
Copper → brass → sheet → wire → pin
Timber → planks → furniture
Stone → rough-out → stone axe-head → hafted axe
Sand → glass ingot → glass vessel

The presence of ingots of glass and 'oxhide' ingots of copper on the wreck of the Bronze Age ship at Ulu Burun off the south coast of Turkey indicates that these processed materials could, if sufficiently valuable, also be traded over great distances (Bass *et al.* 1984, 1989). Materials never suffer from the ethnic associations of finished objects and are often robust; this can make them easier commodities to transport and trade than completed objects. Since their form is not important, breakage is no longer a problem, making them cheaper and easier to handle and thus more economic to move.

As well as objects and materials, the makers of objects – artists/craftsmen – could also move. The presence of a Syrian flagmaker is commemorated by a gravestone on Hadrian's Wall, whilst in the Renaissance the painter Hans Holbein (the younger), a native of Augsburg, Germany and citizen of Basle (Switzerland) worked in the English court for much of the 1530s. Artists and craftsmen moved to where there was need for their skill and they could make a good and safe living. Wars and religious persecution encouraged craftsmen to move to safer locations; e.g. in the eighteenth century many Huguenots fled from France to England following religious persecution, bringing crafts such as silk-weaving to Spitalfields, London.

To develop trade there needs to be a demand; the desire for new and exotic objects or materials. This was exemplified by the two cargoes of Chinese porcelain that created the demand for porcelain in north-west Europe in the seventeenth century (see section 4.9). The movement of ideas, especially the perception of what is desirable, is one of the most powerful forces driving trade. The importance of ideas is seen through the efforts to impress through gift-giving, entertaining visitors and the creation of impressive buildings such as the Roman palace at Fishbourne, a hugely lavish and opulent villa constructed in Britain in the first century AD as a deliberate demonstration of the advanced nature of Roman civilization.

When anthropologists in the 1960s and 1970s explored the trade networks that supplied objects and other goods, in the early twentieth century, to the small American town of Silcott, Washington, the vast majority of objects were of local manufacture. Most were made by the people themselves or by their friends and neighbours – goods given without direct payment, as the community helped and supported each other. Only 1043, out of many thousands of objects, could be accurately provenanced. Of these, 76 per cent came from over 1500 miles away, from the factories of Chicago and New England, and were complex manufactured items or materials that could not be obtained locally (Adams 1991). This pattern of principally local supply with a few imported materials or complex manufactured objects appears to hold true for many earlier communities. Analysis of the stone fragments recovered from the builders' yard at the Roman palace of Fishbourne (Cunliffe 1971) showed the presence of low-value building stone recovered from local sources, whilst more expensive decorative stone was imported from the Mediterranean region. High-value materials clearly could be traded over great distances, but low-value materials were only traded over short distances. Consequently, determining the origin of a material can sometimes indicate its value.

Many traded materials degrade; only a few materials survive to leave archaeological traces. Other traded commodities, e.g. services, are all but archaeologically invisible;

consequently only parts of any trade system are usually visible. The pottery from Turkey and North Africa at sites on the Welsh coasts in the fifth and sixth centuries AD is not from trade in ceramics, but the remains of amphorae which carried wine and olive oil. Detailed analysis and provenancing studies need to be undertaken in order to ascertain the origin of many objects and materials that lack distinctive cultural traits.

In exploring the mechanism for movement of goods within and between societies, Geary (1986) notes that in pre-commercial sparsely populated societies, i.e. those without coinage, a significant merchant class or even significant urban markets, the mechanisms for movement of goods were limited.

- High-status goods such as jewellery, relics or gospel books – i.e. bespoke objects – are moved by gift-giving, which, by analogy with ethnographic parallels such as the *kula* ring, sees local 'big men', chieftains, exchange gifts with each other. Such gifts bring with them obligations and thus bind the groups together in a complex social web of friendships and obligations. This process was widespread in the early medieval period, though by the high and later medieval periods it was largely confined to the aristocracy and monarchs. It is exemplified by the supply of relics from the pope to monasteries and bishops (Geary 1986), as a form of patronage. This may have applied to the Winchester Reliquary (see section 5.8).
- High-status goods were also obtained by theft, including war, looting and ransom. Such a mechanism encourages the creation and retention of a warrior class for whom the seizure of large numbers of objects and booty was one of the principal reasons for war.
- Most lower-value commodities were traded by bartering. This balanced out local needs and surpluses. It applied to necessities such as food, basic materials and tools.

The presence of many high-status, bespoke objects in the hoards of the early Viking period indicates that in the ninth century gift-giving and theft were a significant factor in the movement of objects. The objects themselves were in part made with regard to this type of exchange. However, in the later Viking hoards of the eleventh century, far more coinage is found, indicating that commercial transactions are starting to dominate the object exchange systems. The chieftain-based societies of the sixth to the ninth centuries around the North Sea had established groups of workshops and craftsmen to ensure a supply of gift objects. Those with good trade links grew into the urban settlements (Bradley 1987; R. Hodges 1982). This process occurred at different times in different civilizations. Increasing populations and the development of settlements encourage commercial activity and discourage self-sufficiency. This leads to urban living, which creates a market/constant demand for goods and encourages craft specialization and the development of merchant classes. Though many objects are primarily functional, the complexity of the social interactions in a highly populous environment encourages the need for social organization that can generate a need for symbolic objects, e.g. coins rather than bullion.

Modern economic systems are often nominally based on a free-market economy where everything has a value and can be traded. In reality the state exercises some limitation and control through taxation (excise duty), bans on the importation of some goods (e.g. drugs), and licensing of some materials such as solvents. Earlier societies saw greater control of the import, manufacture and sale of goods, e.g. the medieval guild system or restrictions on the owning and wearing of objects, e.g. medieval sumptuary laws. The control of valuable imports is often suggested as a mechanism by which prehistoric elites exercised power. Consequently trade, though stemming from an economic and technical necessity, is a culturally mediated activity.

4.2 Modelling trade and distributions

Archaeologists and anthropologists have suggested that a number of systems exist for trading goods. They include:

- Direct access. The group travels to the resource, such as a quarry, which it exploits directly. It may pay a toll or tax to other groups to use this resource, or give offerings to deities.
- Reciprocity (group-to-group trading). One group goes to the territory of another group to trade goods. This can be done in a specific location within the territory of one of the groups, or at the boundary between territories.
- Down-the-line trading. The group-to-group exchanges occur, with a limited percentage of the material received from one group available for trading to the next group. The value increases as scarcity and distance from source rise.
- Redistribution centre. A central authority receives and stores surplus goods from one or more groups and then redistributes it to other groups. This allows a central tax or toll to be taken to support the central authority. It enables a wide range of different resources to be exploited by a civilization. Examples include the Minoan palace economy.
- Market. Groups or their representatives go to a central place to barter and exchange or purchase goods. There are many variant forms:
    - annual fairs such as the Goose Fair at Nottingham;
    - seasonal or weekly markets present in many rural communities, often associated with livestock sales;
    - shops.

  The market is usually located on access routes and often becomes a place of settlement. It may be in a neutral territory, e.g. a free port, or an accessible point such as a gateway community. It can encompass colonies, embassies or other protected areas to encourage trade.
- Contracted. Verbal or written agreements reached between groups or individuals with subsequent movement of goods and separate transfer of exchanged goods, services or funds at a later date. Examples of such contracts include bridal dowries, protection money, e.g. Danegeld, or commercial contracts, e.g. Roman military contracts which supplied goods to distant military garrisons.
- Freelance merchant trader, who acquires goods in one location and transports

them to one or more locations for subsequent sale. This may give high availability of goods within the trader's access area.

- Itinerant artisan. This individual comes to the materials, which he uses to manufacture an object in the territory of a group. He may bring some specialist tools as well as ideas and materials not native to the group tradition. Such artisans, e.g. tinkers, will usually move around a restricted range of clients, repairing or manufacturing required objects.

Little direct evidence for the trade mechanism usually survives, though the creation of markets usually led to settlements such as towns. However, the distribution of objects or materials from a source may provide information on the trade mechanism. Distance decay or 'fall-off' curves record the amount of an assemblage from a particular source graphed against the distance from that source, e.g. prehistoric obsidian assemblages in the Mediterranean and Middle East (Renfrew 1977; Renfrew and Bahn 1991: 325–6). Where the percentage of obsidian from a single source was high (over 80 per cent) and declined in a slow, linear manner, i.e. related to distance, Renfrew suggested direct access and exploitation of the resource occurred. Where the curve declined at an exponential rate, down-the-line exchange (e.g. from one village to another) occurred, whilst higher than normal amounts (multi-modal distributions) represent redistribution or trading centres. A curve with one or more changes in slope represented changes in trading pattern, e.g. changes in supplier of the goods, such as the presence of merchants (Renfrew and Bahn 1991: 322; R. Hodges 1982: 19). Many of the more sophisticated trading mechanisms, e.g. dendritic central-place system, are based on partial commercial trading (R. Hodges 1982: 16). However, some caution is required, since several different trade/exchange mechanisms can give similar fall-off curves (Bradley and Edmonds 1993: 8), and complex family or social relationships, which appear to have determined the supply of greenstone axes from Mt. William in south-east Australia (Renfrew and Bahn 1991: 331), are not easy to interpret using fall-off curves.

Maps of find spots of objects/materials correlated with geographic features such as rivers, mountains or the coast can describe a trade route, as shown by the distribution of imported fifth- and sixth-century AD Mediterranean pottery along the coast of Wales, indicating a primarily coastal trading route (see Figure 4.2) (Arnold and Davies 2000). Where there are large numbers of objects, the number of objects per unit area can be calculated. These can be plotted as contours denoting areas with similar concentrations of objects. This 'surface trend analysis' can show up concentrations of objects or materials. These are noted around the source of a material, but also from areas of settlement, or from trading or redistribution centres (see Figures 4.3 and 4.4). The provenance of a material or object cannot be certainly established simply from being at the centre of the highest concentration of finds (see Figure 4.3 and section 5.3). Where there are large volumes of objects such as ceramics, the percentage of pottery in the assemblage made in a particular production centre is plotted on a graph against the distance from the production centre. Variation from a simple linear drop-off in percentage of assemblage with distance is often seen to

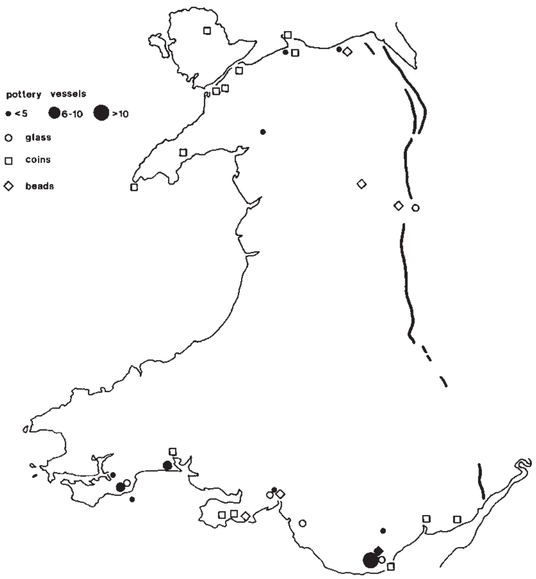


Figure 4.2 Distribution of Mediterranean pottery imported to Wales in the fifth and sixth centuries AD. (From Arnold and Davies 2000)

reflect factors such as difficulties in transport, or competing producers (Peacock 1982: 168).

Identifying the provenances of materials on a site indicates the trade network supplying the site. The stone used in the Fishbourne Palace shows the owner was of sufficient wealth to access material through a trade network that stretched throughout the Roman Empire. A wide range of goods from different regions were found on the wreck of the Bronze Age ship at Ulu Burun: copper from Cyprus; amphorae containing 'terebinth' resin for incense (Pollard and Heron 1996: 250) from Syria/Palestine; glass ingots, ebony, hippopotamus and elephant ivory probably from North Africa and Egypt; tin ingots probably from southern Anatolia, and pottery and bronze objects from Greece, Cyprus, Egypt and the Levant. This led to the interpretation that the vessel was trading around the whole of the East Mediterranean, calling at many ports (Bass *et al.* 1984, 1989). Mapping the occurrences of objects, or the places from which objects or materials derive, enables us to determine trade routes, and thus likely routes of cultural as well as economic contact. The numbers and distributions of objects can sometimes indicate the extent and nature of the trading mechanism.

4.3 Provenance: natural materials

The notion that the provenance of an object can be determined simply by 'analysing' it is deeply naive. Objects are not normally single entities but composites of many

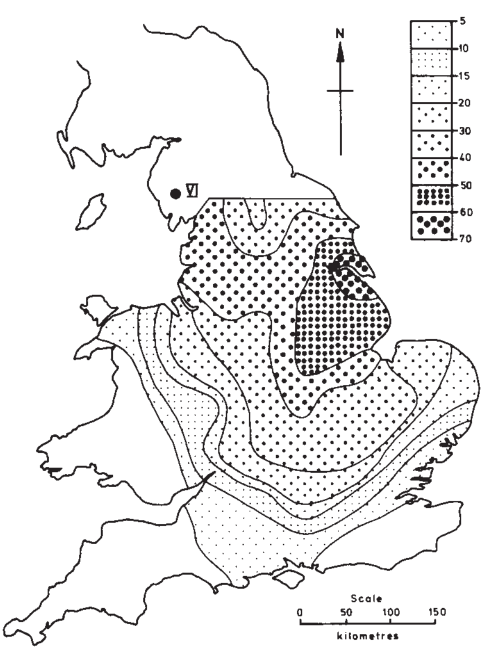


Figure 4.3 Distribution of Group VI neolithic stone axes. (From Clough and Cummins 1979, image courtesy of CBA)

different materials, potentially derived from many different places, and assembled, sometimes to a client's specification, by craftsmen/artists with potentially diverse cultural backgrounds. The objects created may contain recycled or reused material and may be altered or amended during their working lives. To provenance a single material requires it to have a unique characteristic, such as composition, which exactly matches that from a natural source, available to the manufacturing culture, from a single location. To achieve this, extensive knowledge of the composition and extent of natural source materials and of the technology and trade networks of the manufacturing culture is required, and must be demonstrated.

Analysis of the elemental composition of archaeological or ethnographic artefacts may allow a homogeneous group of objects to be subgrouped on the basis of their composition. As with grouping on the basis of dimensions, there may be several reasons for the presence of elements in similar quantities or ratios in an object, e.g. use of traditional recipes, elements with similar chemical properties, or similar technical processes, as well as the use of raw materials from similar or related sources. Several production centres may make products of a single chemical subgroup, or a single production centre may make products of two or more subgroups. Chemical subgroupings do not directly correlate with a specific technical or cultural entity.

Ethnographic examples show that different potters from the same village (or

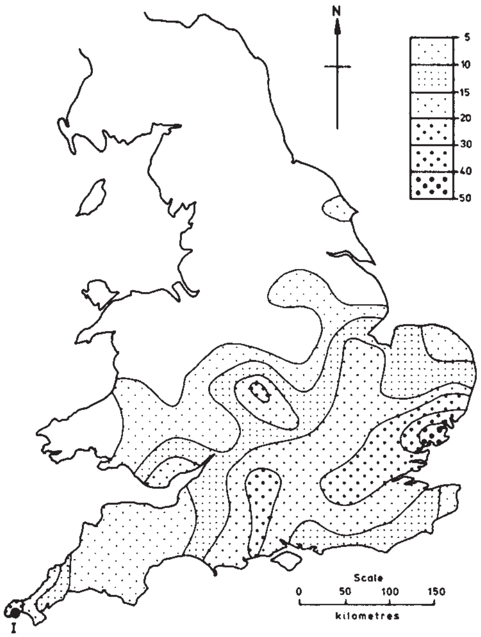


Figure 4.4 Distribution of Group I neolithic stone axes. (From Clough and Cummins 1979, images courtesy of CBA)

production centre) normally obtain their raw materials from the same location, which is normally local, normally within 1 km and invariably within 7 km. Consequently production centres where they are using local raw materials can have sufficient chemical differences to be distinguished as chemical subgroups. Where the chemical differences are smaller, e.g. between individual potters using different tempers and firing conditions, subgroups could not be detected (Arnold 1999). Where evidence of production, e.g. kiln wasters, are found to have the same chemical composition as a ceramic subgroup, it might be imagined that the source location had been established. However, the kiln wasters site would only represent one of an unknown number of possible sources, since other production centres may have made ceramics using clays from the same source. Thus care is needed in the interpretation of compositional elemental analysis, particular where provenance is concerned.

Biological

Any aspect of the chemistry, isotopic composition or physical structure that varies uniquely between animal or plant species may be used to identify the species. Many plants and animals have limited geographic distribution, since they only thrive in specific climatic, geological or biological environments. Consequently identification of species can lead to provenancing of the material in broad regional terms and demonstrates trade contacts. As well as direct plant and animal products such as wood and leather, the chemicals that make up dyes or resins often vary between species. Consequently analysis of varnishes, colours, adhesives, waterproofing agents, etc., can indicate the origin of the material and potentially the object, as seen in the case of amber.

An example of provenancing biological material was *Spondylus gaederopus*, a marine species occurring in both the Black Sea and the Mediterranean, from which shells were found at inland neolithic settlements of *c.* 4000 BC in the Balkans and central Europe. This shell must have been imported from the coast, and demonstrated long-distance trade in prestige goods early in the European Neolithic (Renfrew 1986). Recent analysis of the oxygen isotope ratio has revealed that the *Spondylus* shells came from the Mediterranean rather than the Black Sea. The slight difference in the temperature of the two seas led to differences in the oxygen isotope ratio in shells created in those seas.

Microscopic identification of textile fibres (see section 3.8), from the Hallstatt Iron Age graves, as silk indicates the existence of trade from China to Europe in the pre-Roman period. However, accurate identification is required, for whilst ivory objects from Britain in the Roman and High Medieval periods comes almost exclusively from elephant ivory, and indicate a trade with Africa (or India), in the period AD 600–1200 some of the ivory objects, such as the Lewis chessmen (one of which is depicted on the front cover of this book), are derived from walrus ivory and thus indicate trade between Scandinavia and the Highlands and Islands of Scotland (Stratford 1997: 54).

Mineral

Rocks and minerals have discrete distribution across the Earth's surface, and provide clear potential for provenance studies. One of the earliest examples of using scientific analysis to successfully determine the provenance of material, and thus a potential trade and transport system, was the work of Dr H. H. Thomas. He used petrological thin-section analysis (see section 3.9) on samples from the 'bluestones' of Stonehenge to determine that there were three types of bluestone – spotted dolerite, rhyolite and volcanic ash – all of which derived from the Preseli Mountains in north Pembrokeshire, Wales (Thomas 1923). Recent work with a larger data set by Williams-Thorpe and Thorpe (1992; Henderson 2000: 315), has confirmed this original provenance. However, *c.* 1890, thin-section petrology had previously been tried unsuccessfully by Lepsius in an attempt to determine the sources of marble used in classical statuary (Herz 1987). This attempt failed because the combination of minerals identified was not unique to a single source. Any object containing minerals, whether pottery with sand temper, mortar or precious stones in jewellery, can potentially provide suitable samples for mineral identification and thus provenancing.

Chemical composition

Wet chemical methods of analysis enabled nineteenth-century scientists such as Sir Humphry Davy to analyse ancient materials (Pollard and Heron 1996: 3). Much of this effort sought to determine the history of human technical advancement and so extend C. J. Thomson's basic three-age system which described mankind's development in terms of increasing material sophistication; stone, bronze, iron. Subsequently the gross chemical composition of materials was determined in order to study developing technology and the economics of materials supply.

Trace elements

The availability of analytical techniques such as optical emission spectroscopy by the 1950s led to the determination of minor and trace element compositions of archaeological objects (Hughes 1979). Pittioni (1957, 1958) suggested that in certain circumstances the patterns of trace elements present in a copper ore could be carried through to the metal upon smelting, and so the trace element distribution of a metal could fingerprint its ore and hence its place of origin. A substantial number of analyses were subsequently undertaken for ancient copper and bronze artefacts (Junghans *et al.* 1960, 1968). Work was undertaken on a range of archaeological materials such as ceramics (Asaro and Perlman 1969) and glass (Sayre 1965) using an increasingly sophisticated range of analytical techniques, e.g. neutron activation analysis and atomic absorption spectroscopy (Tite 1972). Analysts sought groups of objects with similar trace element compositions and, if possible, a reason for this similarity – normally a common provenance for the material. Initially grouping objects purely on the basis of percentages of the various trace elements, following the example of Otto and Witter (1952), produced groups of objects without any cultural or chronological relationship (Junghans *et al.* 1960). This provided little or no archaeologically meaningful information, so subsequent programmes selected chronologically and culturally restricted groups of data. They also used more powerful statistical techniques for detecting grouping, using the increasingly available computers (Wilson and Pollard 2001). This produced groupings but often failed to find provenances. Pollard (1983) demonstrated that different groupings could be attained from a single data set, depending upon the statistical technique used and the parameters chosen. As shown by the case of obsidian, initial hopes for a simple chemical discrimination between sources has, with the discovery of an increasing number of possible sources, and the heterogeneity within sources, become a far more complex process. Analytical techniques have grown increasingly powerful, and techniques such as ICPMS (see section 4.7) can include isotopic determination as well as trace element detection to the parts per billion level. However, as a result of the high costs, complexity and failure of earlier programmes to establish provenances clearly, enthusiasm in the archaeological community for such elemental studies has waned (Wilson and Pollard 2001).

Four key factors affect trace element studies (from Wilson and Pollard 2001):

- Elements must come through from the natural state to the material analysed without alteration. This may not occur in practice (Tylecote 1970), since:
    - The processing of materials, in particular pyrotechnical processes, exhibits loss of trace elements as gas to the furnace lining and to the slag. This has

  been shown to vary depending on the temperature and oxidizing/reducing conditions within the furnace (Pollard *et al.* 1991a, 1991b; Budd *et al.* 1992; Budd 1993). Even fractionation of the isotopic components of metals such as zinc has been demonstrated (Budd *et al.* 1999).
  - The addition of other metals to form alloys or the use of recycled scrap metal, the addition of temper to ceramics or of recycled cullet to glass will distort the trace element levels present in the material, which no longer accurately represent those of the original individual raw materials.
  - Decay on the exterior surface of the object will greatly distort the elemental composition. Inter-granular corrosion can occur well below the visible level (Caple 2001: 86).
- Elements must be accurately determined. Complex multi-element standards with similar composition to the archaeological material and in a similar physical state should be analysed alongside the archaeological material in order to demonstrate that the analytical procedures are accurate. To demonstrate the precision of the analytical equipment, repeated analysis of the standard is required.
- The data produced must be archaeologically meaningful. All the probable and possible sources of material must be analysed. Early analytical work with a small number of sources of easily distinguished material often gave a false impression of the ability to determine the provenance of archaeological material. Large numbers of sources have often shown considerable overlap in chemical and isotopic signatures. Work by Timberlake and others (Timberlake 1991; Crew and Crew 1990) has proved a point made previously by Briggs (1978) that many of the sources of copper ores utilized in the Bronze Age remain to be rediscovered.
- Many natural materials exhibit considerable chemical inhomegeneity. If a source is to be distinguished from another, the intra-site elemental variability must be well below the inter-site variability. Analytical work on copper ores and their derived metal (Biek 1957; Coghlan *et al.* 1963; Friedman *et al.* 1966; Bowman *et al.* 1975; Rapp *et al.* 1980) has demonstrated that there could be large variation in the trace element levels within a mine and within an ore body. As it has been shown that the certainty of ascribing a metal to even the correct type of ore body, (native metal, oxide or sulphide ore) on the basis of trace element levels, can be less than 75 per cent (Bowman *et al.* 1975). The chances of accurately ascribing a metal to the correct ore source would clearly be considerably less.

Isotopic variation

Most elements have isotopes: chemically identical atoms but with differing numbers of neutrons in the nucleus. Some isotopes decay radioactively, e.g. ^{14}C (carbon-14). Others, e.g. ^{12}C and ^{13}C, are stable. The stable isotopes of an element are normally present in a fixed ratio, but where they go through changes in their physical state, e.g. evaporating from a liquid to a gas, or through a biological process, e.g. absorption by a plant, then fractionation can occur – the preferential use of one isotope over another. This leads to a change in the isotopic ratio. Isotopic measurement determines if a physical, biological or chemical fractionation process has occurred, and its extent. Since these fractionation processes vary geographically, e.g. with climate, vegetation etc., stable isotope ratios can indicate a broad provenance. Examples include the ^{18}O:^{16}O ratio ($\delta^{18}O$), which varies with water temperature, and the ^{13}C:^{12}C ratio ($\delta^{13}C$), which varies between plant groups. Consequently rocks such as limestones and marbles formed in different sea and river systems can have different oxygen isotope ratios. Tooth and bone can also have different oxygen isotope ratios, depending on the source of water consumed by the animal. The $\delta^{13}C$ value in tooth and bone will vary depending on the food sources utilized by the animal; thus walrus ivory will have different $\delta^{13}C$ and $\delta^{18}O$ values from elephant ivory.

4.4 Provenance: natural materials – examples

Obsidian *(Williams-Thorpe 1995; Cann, Dixon and Renfrew 1969; Henderson 2000)*

Obsidian is formed from volcanic magma which cooled so fast that it did not develop crystalline form, but solidified as a glass. This allows it to be flaked, like flint, to form blades with very sharp edges. This material was used by the prehistoric peoples of the Mediterranean region, south-east Europe and the Middle East, where natural outcrops occur, from *c.* 7000 BC to *c.* 200 BC, by which time it had largely been replaced by metal. Obsidian only occurs in fresh lava flows, and there are few workable deposits over ten million years old. Consequently there are a limited number of obsidian sources present in the world, mainly in zones of recent volcanic activity. The presence of obsidian artefacts in the Minoan palace of Knossos led the excavator, Sir Arthur Evans, to speculate, on the basis of colour and texture, that the obsidian had been imported to Crete from the island of Lipari. Attempts to characterize the different sources of obsidian uniquely on the basis of their visual appearance and major element compositions were unsuccessful. Work by Renfrew, Cann and Dixon in the 1960s (Cann, Dixon and Renfrew 1969) using optical emission spectroscopy (OES) (Britton and Richards 1969) allowed a number of different geological sources to be identified on the basis of their elemental composition, in particular the ratio of the trace elements barium and zirconium. From this work many archaeological samples were provenanced. This indicated that obsidian had been exploited on the islands of Lipari and Giali and exported to centres of human habitation throughout the eastern Mediterranean. It also showed that obsidian was traded from central Anatolia to the settlements of the Levant and from the Lake Van region of eastern Anatolia to the settlements of the Tigris and Euphrates valleys and beyond. However, it did not uniquely characterize all the geological sources, e.g. the obsidians of Melos, Giali, the Carpathian mountain sources and sources in Armenia could not be resolved. Subsequent work by Aspinall, Warren, Hallam, Renfrew and others, using neutron activation analysis (NAA) to determine up to sixteen trace elements, achieved higher degrees of separation of the sources by means of lanthanum vs. caesium concentrations, or scandium or lanthanum/scandium ratios vs. cobalt/scandium ratios. This differentiated sources such as Melos. Further work by Gale (1981) used mass spectrometry and X-ray fluorescence (wavelength-dispersive) to determine the strontium/rubidium ratios, and the ratio of the strontium isotopes to rubidium also gave good separation of the obsidian sources. Most of the work done in this area has used NAA, though techniques such as fission track dating and, later, potassium–argon dating have enabled the dating of the samples also to be used as a characterizing feature. This dating work potentially allows different lava flows created from separate volcanic events at the same location to be differentiated. The work, summarized by Williams-Thorpe (1995) and Pollard and Heron (1996: 81–103), has given some confidence to the provenancing of obsidian tools in the Middle East, south-eastern Europe and the Mediterranean and to the proposal of trade/exchange/manufacture and distribution networks.

Copper alloys

The problems of provenancing were emphasized when the copper from the Great Orme Bronze Age copper mine, probably the largest and most important centre of British production of copper in the middle Bronze Age, could not be detected in the compositions of copper alloy objects from the British Bronze Age (Craddock 1994). The problems and limitations of large-scale trace element programmes and provenance studies were clearly outlined by Tylecote (1970), and have been emphasized and amplified by subsequent work (Budd *et al.* 1992). There is now considerable scepticism (Dungworth 1996; Budd *et al.* 1992; Wilson and Pollard 2001) about the concept of provenancing copper objects through trace elements. There does, however, remain some potential in the work of Northover and others in exploring the subgrouping of objects of specific cultural (typological) origins. Similarities in their trace and minor element distributions may be indicative of some commonality in their origin and pyrotechnic history (Northover 1982), the 'metal created by a uniform production method' (Junghans *et al.* 1960) or *Ausgangsmaterial* (Butler and Van der Waals 1964, 1966) or *Materialgruppen* (Waterbolk and Butler 1965). The development of lead isotope analysis and its application to the copper, lead and silver metallurgy of the eastern Mediterranean (Gale and Stos-Gale 1982; Stos-Gale *et al.* 1997) has led to confident statements – 'it successfully distinguishes lead from different sources in a way that trace element analysis has failed to do' (Renfrew and Bahn 1991: 318) – though this confidence may be somewhat premature (Wilson and Pollard 2001: 513).

The seductive prospect of sourcing copper alloy objects occasionally rears its head in discussion of metal analysis, and is proving to be a ghost that is difficult to lay, as shown by the XRF analyses of the uncleaned exterior of 200 Renaissance medals, where it was suggested 'trace elements may suggest ore sources and trade routes' (Glinsman and Hayek 1993). Such views must now be seen as naive.

Amber *(Beck 1982; Fraquent 1987)*

Amber (succinite) is normally considered to be the fossilized resin of *Pinus succinifera*. Since it is principally a copolymer of communol and communic acid cross-linked with partial succinylation, it is more probable that it was originally derived from a tree of the *Araucoriaceae* family (Mills and White 1987: 96–9). In Europe it occurs as nodules within soft rock geological strata, principally in Poland and Lithuania. It is exposed on the Baltic coast and, since it floats, it is found on the Baltic and North Sea coast, as well as in the Black Sea, where it is carried by the river Dnieper. Amber beads were discovered in the nineteenth century on Mediterranean sites such as the shaft graves of Mycenae. These beads were initially suspected as being made from Italian or Sicilian amber (simetite): however, when they were analysed by Otto Helm it was discovered that upon heating they released succinic acid, a characteristic of Baltic amber. Later infrared absorption spectroscopy, principally undertaken by Beck, revealed a distinctive spectrum characteristic of Baltic amber (Beck 1982) with a C–O bond vibrational stretching in the 1110–1250 cm^{-1} region of the infrared spectrum. Later work has shown that only gas chromatography (GC) and gas chromatography–mass spectrometry (GC–MS) (see section 5.6) give the full compositional spectrum, which is essential for analysing weathered specimens. GC and GC–MS work continues to support the original identification that the Mycenaean shaft grave beads were made of Baltic amber (Mills and White 1987: 96–9). However, since Baltic amber is moved by natural sources from its geological origin, trade routes from the Black Sea coast, eastern Europe and anywhere along the Baltic or North Sea coasts could have supplied amber to Greece.

Marble *(Herz 1987)*

Since the late nineteenth century, archaeologists and scientists have been trying to correlate fragments of Greek and Roman carved marble, whether used for statues, inscriptions or in buildings, with specific quarries. Such a technique would allow them to identify fakes and forgeries, potentially connect pieces of marble from the same statue or inscription (or at least prove if they were not connected), and provide information about the ancient trade in marble. Initial work using thin-section and trace element analysis foundered because of the high level of variation within the quarry/source and low-level variation between sources, i.e. higher levels of intra- than inter-source variation. However, the ratios of oxygen and carbon isotopes in marbles were found to vary to a useful degree between marble sources (Craig and Craig 1972). The ratio of isotopes, ^{18}O to ^{16}O ($\delta^{18}O$) and ^{13}C to ^{12}C ($\delta^{13}C$), varied because isotopic fractionation occurred during the biological and chemical formation of calcium carbonate, depending on the temperature of the water and the metamorphic processes that turned limestone into marble.

The ratio of $\delta^{13}C$ to $\delta^{18}O$ values can frequently distinguish the various eastern Mediterranean marble sources (Herz 1987: 40). Where there is some overlap in the $\delta^{13}C$ and $\delta^{18}O$ values of the different marble sources, contemporary ancient written information on the quarries that were utilized in antiquity and the periods when they were worked (Dworakowska 1975, 1983) provided sufficient additional information to identify sources which could have supplied the marble for any specific object. A further aid to the separation of the marble in overlapping oxygen and carbon isotope groups was provided by trace elements determined using neutron activation analysis, and grain size measurement. This work has even allowed the location of the area of the quarry or mountain source of the marble to be suggested (Herz and Waelkens 1988; Fant 1988). These analytical techniques were used to identify the source of the marble used at the Mausoleum at Halicarnassus. This mausoleum was constructed around 350 BC for the members of the Mausolus dynasty, who ruled the area around Halicarnassus in south-western Turkey. The marble was imported from throughout the region. Much of the sculptural carving, such as the horses and parts of the chariot from the sculpture on the apex of the monument, were created from marble imported from Mt Pentelikon, near Athens. The building itself was made of marble from the Dokimeion-Iasos region of Turkey, faced with the more highly regarded marble from Mt Pentelikon and Ephesus. The finest-quality fine-grained marble, which was mined underground on the island of Paros, was reserved for use on the heads of the human sculptures which decorated the monument (Walker and Mathews 1988).

4.5 Provenance: form and man-made materials – examples

Objects such as coins produced by a specific culture are a good indicator of provenance. Considerable numbers of Islamic (Kufic) silver coins in Viking hoards speak of trade, plunder or payment for services (Graham-Campbell 2001: 110) and clearly indicate economic and cultural contact. The presence of Roman coins in India provides similar evidence of contact. Written descriptions of trade with India, primarily for spices, by Roman writers (Warmington 1928) clearly suggest that these coins derive from trade. In areas beyond the empires of Rome and Islam, coins probably circulated with a value related to their precious metal content rather than their face value. Thus, although provenance of the object is reasonably certain, the level of cultural contact, even the level of aesthetic appreciation, is a matter of interpretation. Any object with symbols or devices is, save for copies and fakes (see section 6.3), invariably highly culture-specific. Mint marks on coins and hallmarks on gold and silver objects can indicate the city in which the object was produced.

For many imported objects that are nearly identical in form and materials to those produced within the importing country it is impossible to tell import from home produced. Though port records show that brass wire pins were imported in the medieval period from continental Europe (see Figure 4.1), they are indistinguishable from those made in Britain. This is true for many simple functional objects. However, the underlying slight differences in natural materials and technology can result in differences in the costs of materials in different countries and in different regions of one country. These subtle differences in the materials supply can manifest themselves in variations in the composition of objects, depending on their provenance. One such example is provided by Brownsword and Pitt (1983), whose analysis of domestic copper alloy objects of the fifteenth and sixteenth centuries revealed compositional differences for candlesticks on the basis of geographic origin. Flemish socket and pricket candlesticks were composed of a brass with 15–22 per cent zinc and less than 2

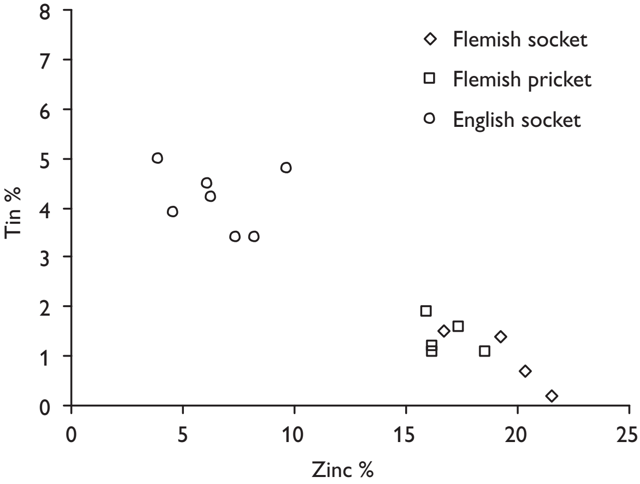


Figure 4.5 Graph of the percentage of zinc vs. tin for English and Flemish candlesticks of the fifteenth and sixteenth centuries. (Brownsword and Pitt 1983)

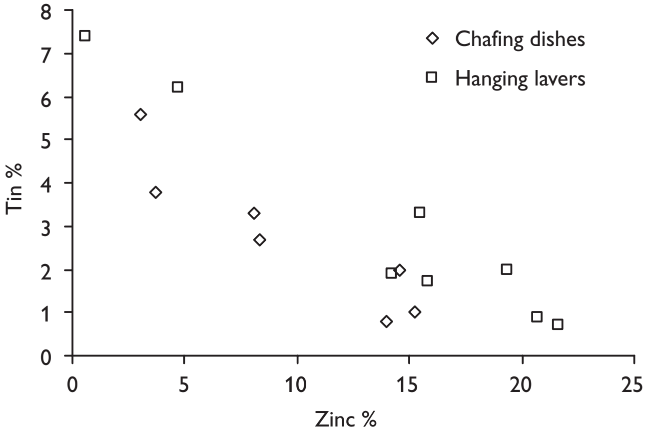


Figure 4.6 Graph of the percentage of zinc vs. tin for English and Flemish hanging lavers and chafing dishes of the fifteenth and sixteenth centuries. (Brownsword and Pitt 1983)

per cent tin, whilst English candlesticks were composed of a copper alloy with 3–10 per cent zinc and 2–6 per cent tin (see Figure 4.5). This difference in composition was also seen in the chafing dishes and hanging lavers analysed (see Figure 4.6). Since the principal source of brass in Europe was the Meuse valley region in Flanders, it is not surprising to see copper alloy objects made in Flanders composed primarily of brass.

Analyses of other objects suggest that greater use of bronze was made in Britain, and at this date it is likely that a mixture of imported brass and scrap metal including bronze was available and used in Britain. Though such economic differences can be manifest in alloy compositions and, as such, provide a basis for identifying imported objects or materials, it demonstrates the need to analyse large groups of well-dated and provenanced objects. The analysis of a single chafing dish – copper 76 per cent, zinc 14 per cent, tin 2 per cent, lead 8 per cent – would mean little without the ability to compare it to other dated and provenanced examples. With such comparative data a Flemish origin can be postulated.

INVESTIGATION TECHNIQUES

4.6 EDXRF: energy-dispersive X-ray fluorescence

(Skoog *et al.* 1998: 272–96; Pollard and Heron 1996: 36–49; R. Jenkins 1988)

When X-rays pass through matter, they interact with it in a number of ways. They can cause fluorescence in which X-rays of discrete energy/wavelength are emitted that are characteristic of the elements present in the sample. Detection can occur either through separation of the different wavelengths of the fluorescence radiation, using a crystal, and detection of the individual wavelengths (wavelength-dispersive X-ray fluorescence, WDXRF), or detection of all the fluorescence radiation, which is separated electronically into the individual energies (energy-dispersive X-ray fluorescence, EDXRF). Through detection and quantification of these X-ray fluorescence emissions the composition of the sample can be accurately determined. This technique, in particular EDXRF (see Figure 4.7), has been used since the late 1960s to analyse archaeological material.

X-radiation is normally produced from an X-ray tube by applying a high voltage, though radioactive sources have been used for portable systems. X-rays of a range of wavelengths (*Bremsstrahlung*) and a strong emission of a wavelength characteristic of the anode target material, usually rhodium or tungsten, are emitted. They pass into a chamber in which the sample is located, which can be under vacuum, or a flow of helium to improve detection of elements with low atomic numbers. The primary X-ray beam penetrates into the sample, where the X-rays knock electrons out of the inner shells of the atoms, creating vacancies. Outer-shell electrons drop into the inner shell vacancies, emitting energy in the form of X-rays with specific energies related to the atom in which these electron movements are occurring, the electron shell from which they have come and the one into which they are descending. As there are several electrons in different shells that could fill the inner shell vacancy, a number of X-ray emissions with slightly different energies occur. Since there are a series of shells, the descent of one electron creates another vacancy that is subsequently filled, giving a cascade effect. This generates a series of emissions: $K\alpha_1$, $K\alpha_2$, $K\beta_1$, $K\beta_2$, $L\alpha_1$, $L\alpha_2$, $L\beta_1$, $L\beta_2$, $L\gamma_1$, $L\gamma_2$, etc. This X-ray fluorescence or secondary X-radiation then passes through the sample, where it can induce further X-ray fluorescence reactions with other

Figure 4.7 Link Systems XR200 energy-dispersive X-ray fluorescence (EDXRF) system. (Photograph courtesy of Jennifer Jones and Phil Clogg)

elements within the matrix, leading to tertiary radiation, before it escapes the sample and passes through a beryllium protective window (almost transparent to X-rays) into a detector. The detector, which is kept at liquid nitrogen temperatures, converts the radiation into an electrical signal or pulse whose amplitude is related to the energy of the X-radiation. These pulses are measured and counted in a multi-channel pulse height analyser and displayed as a histogram of number of pulses of X-radiation against energy (or wavelength). This produces a spectrum (see Figure 4.8) composed of a series of peaks, each the emission of one or more elements in the sample. A computer attached to the EDXRF can identify the peaks, so providing qualitative analysis – the elements present in the sample. The peak heights, corrected for the

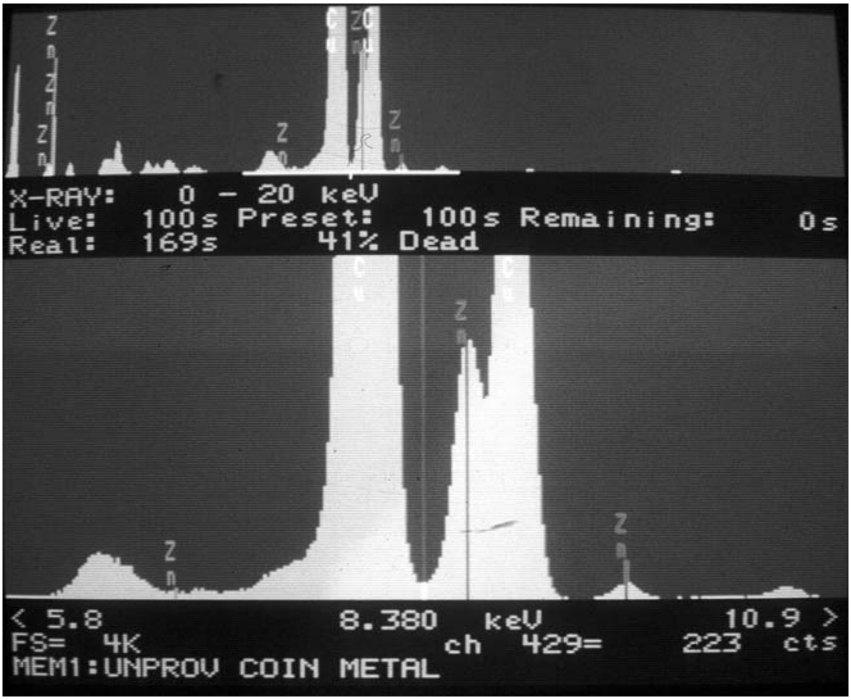


Figure 4.8 Spectrum of a brass coin analysed on an EDXRF system. The compositional analysis of a Roman brass coin, with copper and zinc peaks evident. (Photograph courtesy of Jennifer Jones and Phil Clogg).

sensitivity of the system, provide a crude approximation to the amount of element present – semi-quantitative analysis. Through calculating the peak areas and comparing them to single-element spectra stored in the memory and to multi-element standards of similar composition that have also been analysed, it is possible to derive a quantitative estimate of the composition of the sample. There are a number of limitations to the EDXRF technique:

- The matrix of the sample can absorb this radiation so that it never escapes to the detector; this effectively forms the maximum depth at which an element can be detected. The elements of lower atomic number have lower energy emissions and are more likely to be absorbed than those of elements with higher atomic numbers. Ninety per cent of the secondary radiation for a low-atomic-number element such as sodium in a light matrix such as glass is lost within 14 μm of the surface, 122 μm for calcium and 0.5 mm plus for lead (Pollard and Heron 1996: 44). This means that EDXRF is effectively a surface analysis technique.
- Only elements with an atomic number above 11 (sodium) can normally be

analysed with EDXRF, since the secondary radiation from elements such as carbon, nitrogen and oxygen is absorbed by the beryllium window and thus is not detected. This leads to inaccuracies in calculating the composition of the matrix, so frequently the operator is required to put in estimates of the mineral form of the element, usually as an oxide.

- Frequently EDXRF is used as qualitative or semi-quantitative analytical tool, e.g. to determine alloy type or glass colourant – a function it performs well and which provides useful archaeological information. Though it is often referred to as a non-destructive technique, the exterior of many archaeological and historical objects are frequently covered in corrosion and decay products. Consequently surface analysis does not accurately represent the composition of the object under analysis. If accurate quantitative analysis of the object composition is required, the object may need to be sampled, e.g. drilled, to get uncorroded material out of the centre of the object, or may need to have the corroded exterior abraded off.
- For accurate quantitative analysis, the analyst requires a number of standards of known composition. This can sometimes prove difficult for archaeological materials, as appropriate analysed standards are sometimes not available.
- Sample chambers can limit the size of some objects analysed. However, sampled material can be analysed in a wide range of forms: powder (usually pressed into pellets), liquids, drillings or solid blocks or fragments.
- With good samples and appropriate multi-element analytical standards, modern EDXRF systems can achieve an accuracy of 0.1 per cent for major elements and minimum detectable levels of 10–20 ppm for trace elements, little different from those of WDXRF systems (Pollard and Heron 1996: 48).

EDXRF has proved particularly beneficial for looking at the developments of copper alloys (Dungworth 1996, 1997; Bayley 1992), the debasement of coinage alloys (Caple *et al.* 1995) and the composition of glass and the colourants used (Henderson 1989a), and simply for identifying unknown materials (Hall *et al.* 1973).

4.7 ICPS: induction-coupled plasma spectrometry

(Skoog *et al.* 1998: 253–71; Pollard and Heron 1996: 31–6)

The earliest multi-element determination techniques used on archaeological objects, such as optical emission spectroscopy (OES) and atomic emission spectroscopy (AES), worked by detecting the emissions of light by samples of the object which were in ionized gaseous form. In this state, electron transitions were occurring from higher to lower energy levels, and emitting radiation of discrete wavelengths. These radiations, some of which were in the form of visible light, could be measured in terms of wavelength, which could be related to the presence of a specific element, and in terms of intensity, which could be related to the quantity of that element present in the sample. Subsequent analytical techniques such as atomic absorption spectroscopy (AAS) were based on the fact that these ionized gases would also absorb energy of discrete wavelengths. Limited accuracy and precision troubled OES and AES, whilst AAS only detected the specific element being analysed for.

These techniques have been succeeded by ICP-AES (induction-coupled plasma atomic emission spectrometry). In this technique the sample, usually in aqueous solution, is nebulized and carried with the argon gas into an argon plasma. This is a stream of argon gas, which is ionized and then raised, by a surrounding plume of spiralling argon, into a fluctuating magnetic field created by a powerful radio frequency induction coil. This induces the charged particles to flow through the gas in a circular motion, which, through friction, raises the temperature (ohmic heating) in the plasma to 8 000–10 000 °C. This becomes a self-sustaining reaction that ionizes further argon entering the plasma plume. The analytical samples in the argon become completely dissociated in the ionized plasma, and emit radiation, including in the UV and visible region, as a result of electron transitions. The emitted radiation passes into a spectrometer such as a slew-scan spectrometer, which splits the light up into the different wavelengths using a diffraction grating, and the wavelengths are focused in sequence onto a photomultiplier tube. The latter acts as a detector and converts the light into an electrical signal, which is normally displayed as a peak whose area is proportional to the intensity of the light and thus the concentration of the element in the sample. Systems can, using a second photomultiplier tube and operating under vacuum, cover the UV as well as the visible light spectrum, i.e. 160–800 nm, which allows the detection of almost all elements. The addition of a known amount of yttrium to the analysed sample as an internal standard helps calibrate the system, and this, together with calibration graphs established with standards of known concentration, allows accurate quantitative results to be obtained (Skoog *et al.* 1998: 242). ICP-AES systems give fairly quick results for all elements and have detection levels from 100 to 0.5 ppb (parts per billion), which are comparable to atomic absorption spectroscopy (flame), and precision levels of approximately 1.5 per cent in normal usage (Pollard and Heron 1996: 34). The advantage of determining a full suite of elements quickly has led to this technique replacing AAS. There are many possible variations in the source or spectrometer of ICP-AES systems, such as polychromator spectrometers, which have up to 60 photomultiplier tubes and give quick precise results.

Originally mass spectrometers used a thermal ionization source (TIMS), in which a sample was deposited on a wire and heated electronically to vaporize it, or a spark source (SSMS), in which a vaporized sample formed a gas ionized through bombardment with a stream of electrons. The positively charged ions were accelerated, through the use of charged plates with a central slit, into a curved tube operated in a vacuum of 10^{-5}–10^{-8} Torr within a strong magnetic field. This bent the ion beam as it passed down the tube, the extent of deflection being governed by the weight of the ion and its charge. Careful control of this magnetic field allowed the ions to be focused one at a time onto a detection device, normally an electron multiplier.

The development of plasma torches has enabled them to be used as sources for mass spectrometers (induction-coupled plasma mass spectrometers, ICPMS). The ionized gas emerging from the top of the plasma plume is fed into the spectrometer, where the positive ions are accelerated by using charged plates. The beam of ions is focused by a magnetic lens and fed into the mass spectrometer analyser, where they are separated and detected. Developments in mass spectrometer analysers have included quadrupole systems, which allow rapid scanning of ions of mass 3 to 300, and double focusing analysers, which have increased resolution (working into the parts per trillion range) and are very effective for measuring isotopic ratios.

Laser ablation can be used in conjunction with ICP systems. This enables a laser beam with high power densities (10^{12} W/cm) to vaporize a few square micrometres of a sample. The vaporized material is drawn into the plasma torch with a flow of argon, and proceeds through the ICPMS system as previously described. This allows very specific parts of an object to be analysed and the elemental and isotopic composition to be determined. Such systems are effective at determining the chemical nature and depth of surface phenomena such as decay or ceramic glazes.

In general, ICPMS systems can detect more than 90 per cent of the elements in the periodic table and they have detection limits of 10 ppb for most elements.

The move to use isotopic measurements, as well as trace elements, for archaeological provenance work has led to the use of ICPMS systems. The plasma sources ensure that there are no problems with incomplete dissociation, which caused some problems with AAS work on silicates, e.g. ceramics. The high cost of these analytical systems and the need for clean rooms for preparation of samples mean that they are rarely cost-effective for analysing single objects, but are powerful instruments for analytical programmes that determine hundreds or thousands of samples.

CASE STUDIES

4.8 Milton Keynes pendant (Caple *et al.* 1995)

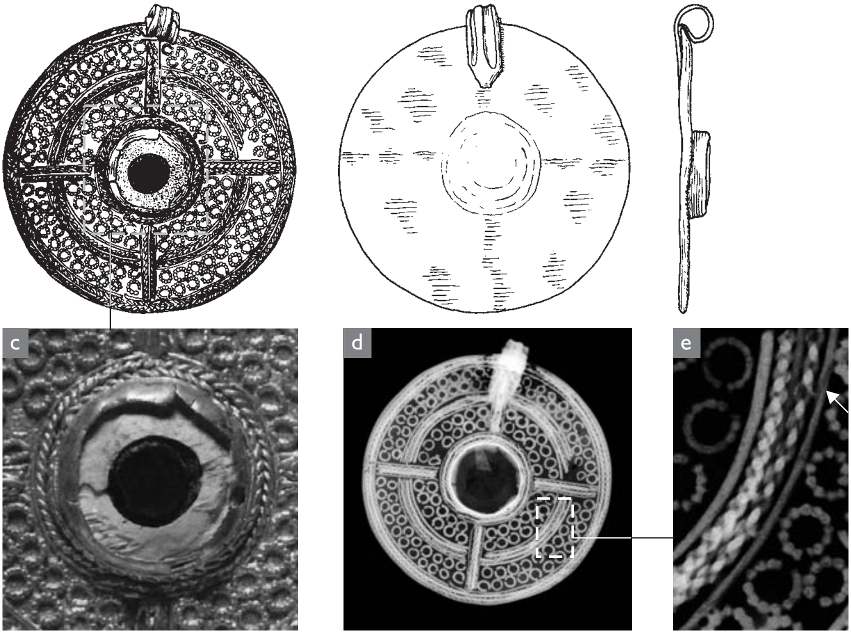
Context

Excavation of the deserted medieval settlement of Westbury-by-Shenley ahead of re-development unearthed a group of seven Saxon inhumation graves; four females, one male and two unsexed skeletons. Analysis of the skeletons showed that at least two had a congenital deformity in their teeth. This may suggest that this cemetery is composed of the members of an extended family group from an as yet undetected farm or small settlement. The grave goods from six of the graves were poor, and indicated a general mid-Saxon date for the cemetery. Grave 55280 was very different from the others. It contained the body of a young woman 25–35 years of age who was unusually and disrespectfully buried in a prone (downward-facing) position. Her hand and lower arms were missing; this could be due to factors of bone decay, or they could have been cut off prior to burial. The excavator suggested that possible mutilation together with prone burial would indicate that the woman had committed a crime such as adultery (Ivens *et al.* 1995). The woman was a high-status individual, as indicated by the extensive range of grave goods:

- gold and garnet pendant (Milton Keynes pendant)
- series of silver rings
- beads of shell and glass
- iron pin
- silver plaque or mount
- copper alloy fragments found around the neck and upper torso
- iron knife (Evison type 4)
- a pair of iron shears, probably originally wrapped in textile.

Manufacture

The pendant, which has been subject to intensive investigation, has the form of a thin disc, 26 mm in diameter, decorated with a central garnet, 2–3 mm in diameter, with surrounding shell annulus in a bezel surrounded by filigree. This wirework has the form of three concentric rings of ‘herringbone’ filigree: one to form the border design, another to divide the disc into inner and outer fields, and a third to encircle the bezel. The pendant is further divided into quadrants by a cruciform motif, also of herringbone filigree. The fields thus defined are filled with regularly spaced rings of beaded wire. A suspension loop is attached to the back. The herringbone filigree is made up of two pairs of twisted wires wound in opposite directions to give a chevron or herringbone effect. In most cases the pairs of twisted wires are surmounted

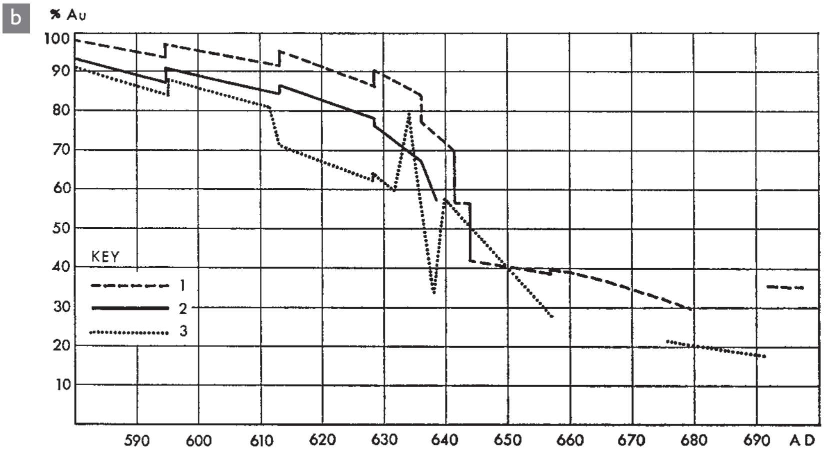


a **Pendant analysis** (%)

	Au	*Ag*	*Cu*
Backing sheet	69	28	2
Front: filigree	64	34	3
Suspension loop	61	34	5
Front: central bezel	69	28	2
Front: fused area	71	25	4

Analysis using EDXRF showed that the Milton Keynes pendant was composed of an alloy of gold and silver. The metal derived from Merovingian coinage, in which the gold was increasingly debased with silver over time (b). The composition of the pendant suggested it was derived from Merovingian coins of the early to mid-seventh century. This date corresponded to the style of the pendant and the other objects in the grave. The increased presence of copper in the area of fused decoration suggested that copper filings and flux had been used to solder the wire components in place. The different silver content and visual evidence of the suspension loop indicated that it was a later replacement. The grozed (chipped) edge of the central garnet (c) suggested that it was cut down from a larger garnet present in an earlier piece of jewellery and reused. Stereo microscopic examination of the white annulus identified the white powdery and striated appearance of degraded shell. X-radiography (d) revealed the melted filigree work in the area of the replacement loop and that the object was composed of block twisted wire (shallow twist on arrowed wire) (e).

Figure 4.9 Milton Keynes pendant: details of materials and manufacture (Ivens *et al.* 1995). (Drawing of the brooch reproduced with the permission of the Buckinghamshire Archaeological Society; photograph and X-ray images courtesy of Phil Clogg; graph from Kent (1972), with permission)



by a central length of plain wire, but this is absent (never present) in places (see Figure 4.9).

The basic design may have been laid out on the backing sheet; the accuracy shown in the layout of the pendant suggests the use of compasses, though no clear marks are visible. The most logical order of construction, supported by evidence of several of the beaded circles being tailored to fit into cells, is that the borders of herringbone wire must have been the first elements to be located on the backing sheet, followed by the numerous tiny circles of beaded wire. Overlapping wires indicate that the bezel and parts of the decorative wires surrounding it were added after the filigree decoration had been soldered into place. The suspension loop was the last element to be added.

The fact that there are no visible longitudinal striations and that there are a wide range of diameters of different wires, from 0.19 mm to 0.32 mm, suggests that the wire was not drawn. Remains of helical creases, which are only clearly visible on the X-radiographs, demonstrate that the wire was made by block-twisting (square or rectangular section sheet metal strip twisted to form a tight/solid helix). The well-rounded section of wire indicates that the soft gold was rolled and compacted between two hard, flat surfaces after being block-twisted.

The beads on the beaded wires making up the filigree circles have outer diameters of between 0.24 mm and 0.34 mm with a separation of approximately 0.26 mm. It is possible to see that some of the beads have a slight waist in the middle at the point of maximum diameter, confirming that a swage or grooved tool was used in their manufacture. Examination of the radiographs shows that many of the beaded circles also demonstrate evidence of the helical seams visible on the unbeaded wire, indicating that block-twisted wire was also used as the raw material for the manufacture of the beaded wires. The wire was beaded by rolling a grooved tool over the wire or hammering it into a swage block with beaded depressions; techniques described by the twelfth-century monk and metalworker Theophilus (Hawthorne and Smith 1979). The beaded wire was then formed into circles by winding the beaded wire around a rod approximately 0.69 mm in diameter to form a helix and then cutting off single turns.

The lack of evidence for melting or distortion of the filigree wire suggests that all the filigree wire elements were soldered onto the base plate in a single operation, as described by Theophilus. He used a wheat flour paste to secure the components in place before coating the surface with finely ground copper oxide in suspension in an alkaline soap solution. When carefully heated, the carbon monoxide generated by the charring wheat flour reduces the copper oxide to copper metal, which on contact with the gold forms a low-melting-point alloy which is then drawn into the joint by capillary action. The piece is then removed from the fire and sprinkled with water before the work can collapse into a molten mass. Pickling in a mineral acid or hot vinegar would remove excess flux and copper oxide. Some of the beaded circles exhibit shallow moat depressions delineating the outlines of the wire where it is joined to the backing sheet. Such marks are consistent with the surface being briefly molten during the soldering process. X-ray fluorescence analysis of the pendant reveals a slightly higher silver and copper content on the front filigree-decorated face than the reverse, indicating the use of a finely divided copper or copper–silver solder.

Area analysed	*Au (%)*	*Ag (%)*	*Cu (%)*	*Fe (%)*	*Mn (%)*
Backing sheet	69.30	28.41	2.08	0.22	0.18
Front – edge of filigree	63.50	33.62	2.74	0.22	0.10
Central bezel	69.00	28.28	2.10	0.19	0.17

The bezel has been formed by bending a strip of sheet gold, identical in composition to the backing sheet, into a collar with the ends butted together, held closed by the single loop of plain wire and a circle of herringbone-twisted wires at the base of the bezel. This was then soldered together. The completed bezel was inserted into the central, circular cell of the pendant and soldered into place by bridging the parts to be soldered with small pieces of sheet solder or *paillons* held in place by dabs of a suitable flux, e.g. tallow, and then heated. A large *paillon* of solder that the goldsmith must have placed inside the bezel has fallen over and become fused to the base sheet, and is clearly visible on the X-radiograph. The bezel overlaps the twisted wires of the central cell, indicating that the bezel was applied after the filigree decoration.

Within the bezel the shell annulus was drilled from the back, since the hole in the centre is tapered, with the largest diameter at the rear. The garnet, which was confirmed as garnet and not glass through EDXRF analysis, appears to have been secured in place, within the tapering hole of the annulus, using a white (probably lime-based) cement. Since the hole in the shell is larger than the garnet, it is likely that the colour and texture of the cement closely matched that of the surrounding shell. The garnet was presumably set into the shell before it, in turn, was cemented into the bezel, which was then soldered to the filigree-decorated backing plate.

At this point the excess backing sheet was trimmed off around the outer border and the cut edge burnished over onto the outermost wire.

Trade

The alloy composition of Anglo-Saxon gold jewellery changes from one of high-purity gold (over 90 per cent gold), in the late sixth century, to a silver and gold alloy (less than 30 per cent gold) by the late seventh century. The Merovingian coinage of north-western Europe, which was supported by the gold coinage of the Byzantine Empire, is considered to be the source of metal for the gold jewellery of the period. The reduction in the supply of Byzantine gold by the Heraclian emperors resulted in the increasing debasement of the Merovingian coinage with silver throughout the seventh century. By the eighth century the gold standard was abandoned and a silver standard adopted by the kingdoms of north-western Europe. This debasement is reflected in the gold content of the coins minted by the Merovingian kings and has been represented in the form of a time vs. fineness graph (Kent 1972). The analyses of Anglo-Saxon pendants and other jewellery by Brown and Schweizer (1973) and Hawkes *et al.* (1966) showed agreement between the archaeological and stylistic dating and the date derived from the alloy composition using Kent's time vs. fineness graph. The gold composition of the back of the Milton Keynes pendant

Area analysed	*Au (%)*	*Ag (%)*	*Cu (%)*	*Fe (%)*	*Mn (%)*
Backing sheet	69.30	28.41	2.08	0.22	0.18

would suggest a date on Kent's graph of 632–42. This is only an approximate date for the minting of the Merovingian coinage used. Allowing time for the circulation of the coinage, the date of manufacture of the pendant is probably ten to fifteen years later. The coin date may thus be seen as a *terminus post quem* for the manufacture of the piece.

The quality of garnet used is not found in Britain, so will have been imported from southern Russia or possibly India. This importation probably occurred mainly around the sixth century, when most of the high-quality garnet jewellery, such as the purse mounts from the Sutton Hoo burial, are made (Bimson 1985). Many garnets in later jewellery are reused from this period.

Decoration

Gold-applied pendants with filigree ornament are known from a number of seventh-century contexts: e.g. Acklam Wold, East Riding, Yorks.; Monkton, Kent; Lechlade, Glos.; Faversham, Kent (Caple *et al.* 1995). The majority have been found in Kent. The pendants generally incorporate a cruciform motif and may have had Christian connotations. They were strung, often along with wire beads, onto a necklace of a type widely worn by Anglo-Saxon women in the seventh century in imitation of current Byzantine fashion (Hyslop 1963; Hawkes and Meaney 1970). The association of the Milton Keynes pendant with wire rings has parallels at Winchester (Lower Brook St.); Leighton Buzzard, Beds.; and Finglesham, Kent (Hyslop 1963; Hawkes and Meaney 1970). The Milton Keynes pendant is a fairly unambitious example in comparison, say, to the pendants from Lechlade and Faversham. The decoration is, however, competently laid out and carefully executed.

No clear typological sequence can be offered for Anglo-Saxon filigree-decorated pendants; however, as a group they broadly date to the second and third quarters of the seventh century, a date confirmed by the results of the gold analysis.

The motif of the cross within the decoration could be considered to imply Christian beliefs, as could the east–west orientation of the graves. The presence of grave goods and not using obviously consecrated ground, such as a churchyard, could indicate pagan beliefs. These graves correspond most closely to Leeds's (1936) 'final phase' cemeteries in the pagan tradition. Christianity was becoming accepted throughout this area of England by AD 650. An object created around this period and used before deposition is likely to have been present in a society that was utilizing some Christian symbols, but not yet fully practising Christianity.

Use

The suspension loop takes the form of a narrow strip of thin gold with two broad furrows running along its length. This strip was bent into a 'p' shape, the long tail tucked underneath the top of the pendant and soldered into place. The solder in this joint may have had too high a melting point, resulting in the metal being overheated, since there is clear evidence of melting and collapse of the wire filigree immediately adjacent to the suspension loop. However, the loop is made of a more debased gold than the pendant.

Area analysed	*Au (%)*	*Ag (%)*	*Cu (%)*	*Fe (%)*	*Mn (%)*
Backing sheet	69.30	28.41	2.08	0.22	0.18
Front – edge of filigree	63.50	33.62	2.74	0.22	0.10
Suspension loop	61.20	34.03	4.60	0.11	0.21

This might suggest that it is a later addition to the piece, added when the general composition of gold jewellery had further degenerated in fineness. The occurrence of loops with more debased compositions is paralleled in the analyses of Brown and Schweizer (1973). It is usually interpreted as a later addition to the pendant, a replacement after the breakage or loss of the initial loop. Although there are no signs of an initial loop on the Milton Keynes piece, the clumsy nature of the attachment and the debased nature of the alloy suggest that it is indeed a later addition or replacement.

The flat garnet, which was set into the drilled shell annulus, had chipped facets around its edge, indicating that it had been reshaped into its present circular form. By the mid-seventh century, slab garnets in polychrome jewellery, popular in the fifth and sixth centuries, had been largely replaced by garnets set *en cabochon*, and the use of slab garnet in an ornament of this date is unusual. It was probably salvaged from another piece of jewellery, possibly a family heirloom, and rather crudely reshaped to fit a new setting (Hawkes 1974; Hawkes and Hogarth 1974).

A consideration of the worn nature of various areas of the pendant, particularly the loop, the projecting filigree decoration and the back, together with the probability that the loop was a later replacement, suggests the pendant had been in use for some time prior to deposition. As argued above, a mid-seventh-century date appears likely for the manufacture of this piece; its deposition, however, would probably have occurred some years later, in the second half of the seventh century. The pendant was an obvious display of wealth, made of imported materials and with a good quality of workmanship. The probable reuse of the garnet from an earlier heirloom piece and the use of the new Christian symbol, in a necklace type which imitated Byzantine fashion, provides a brief glimpse of the range of divergent ideas which were present in seventh-century English society.

4.9 Blue-and-white china (to AD 1800)

(Archer 1997; Yeo and Martin 1978)

Objects which initially appear similar can have very different origins and tell very different stories of trade and manufacture. Fragments of blue-and-white ceramics unearthed in London in a sixteenth- to eighteenth-century context could have several origins.

Chinese porcelain

Porcelains were being made in the area of Jingdezhen (Ching-te Chen) in Jiangxi province during the Tang dynasty (Table 4.1) (Yeo and Martin 1978). By the Song dynasty a translucent white porcelain with a slightly bluish glaze known as *qingbai* or *yingqing* (*ch'iang-pai* or *ying-ch'ing*) was being made (Glasgow Museums 1997). Analysis by Tite *et al.* (1984) suggests that the *qingbai* porcelain was formed from naturally occurring kaolinized porcelain stone. By the late Yuan dynasty a thick porcelain with a white opaque glaze, *shufu*, and a white porcelain with red or blue underglaze decoration were being manufactured. The Jingdezhen region had become a centre for porcelain production because separate deposits of kaolin (china clay) and *baidunzi* (*petuntse* or

Table 4.1 Chinese chronology. (From Glasgow Museums 1997)

Period	*Dates*
Neolithic	7th millennium – *c.* 1600 BC
Shang dynasty	*c.* 1600 – *c.* 1027 BC
Western Zhou (Chou) dynasty	*c.* 1027 – 771 BC
Eastern Zhou (Chou) dynasty	771 – 256 BC
• Spring and Autumn Annals period	722 – 481 BC
• Warring States period	403 – 221 BC
Qin dynasty	221 – 206 BC
Han dynasty	206 BC – AD 220
• Western Han dynasty	206 BC – AD 8
• Interregnum	AD 8 – 23
• Eastern Han dynasty	AD 25 – 220
Three Kingdoms and Western Jin	AD 219 – 316
Eastern Jin and Five Principalities	AD 317 – 419
Nanbeichao I and II	AD 420 – 580
Sui dynasty	AD 581 – 618
Tang (T'ang) dynasty	AD 618 – 907
Five dynasties	AD 907 – 960
Liao dynasty	AD 947 – 1125
Song (Sung) dynasty	AD 960 – 1279
• Northern Song dynasty	AD 960 – 1126
• Southern Song dynasty	AD 1127 – 1279
Jin (Chin) dynasty	AD 1115 – 1234
Yuan dynasty	AD 1260 – 1368
Ming dynasty	AD 1368 – 1644
Qing (Ch'ing) dynasty	AD 1644 – 1912
Republic	AD 1912 – 1949
People's Republic	AD 1949 –

'porcelain stone'), a white feldspathic mineral, were mined nearby. When these materials were combined, shaped and fired at temperatures of 1280–1350 °C, porcelain was produced (Joseph 1971: 10). The *shufu* and blue underglaze-decorated porcelain was based on a mixture of kaolin and porcelain stone, with a glaze, composed of porcelain stone, limestone and glaze ash (bracken and wood ash), added after the blue pigment had been painted onto the initial body form.

Cobalt was first used as a colourant for lead glazes in the Tang dynasty. It was imported from the Middle East. It occurs naturally as a cobalt-nickel-iron mineral in Qamsar near Kashan, Iran. This mineral was almost certainly the colourant used to

Figure 4.10 Chinese blue-and-white porcelain. Ming dynasty white porcelain dish, with blue underglaze decoration. Central image is a bunch of lotus, sagittaria and water chestnut tied with a ribbon, surrounded by a composite flower scroll. Object on display at the Oriental Museum, University of Durham. (Photograph by Jeff Veitch; image courtesy of The Oriental Museum, University of Durham)

make Persian ‘faience’ pottery of the ninth and twelfth to fourteenth centuries. It is identified as a source of the cobalt colourant in 1302 by Abu’l Qasim (Kleinmann 1990), though other sources probably also existed. Cobalt oxides are one of the few colourants that can survive being heated to *c.* 1300 °C, the temperatures for firing porcelain. Towards the end of the Song dynasty, i.e. in the late thirteenth century, cobalt pigments were painted as designs onto the Chinese porcelain bodies before firing, which produced blue-and-white porcelain. The earliest dated complete examples of Chinese blue-and-white porcelain are two temple vases (in the Percival David

Foundation, London) dated to 1351. These are well-developed and -executed pieces, and most authors suggest production had started by the late thirteenth century, with Yeo quoting several examples of sherds from Song dynasty contexts (Yeo and Martin 1978: 20–4). In addition to the blue-and-white porcelain, red-and-white porcelain was created, using copper oxide as the underglaze decoration pigment. Much of the early production of the Yuan dynasty appears to have been designed for export both to the Middle East and to south-east Asia. The Mongol emperors of the Yuan dynasty had extensive contacts and encouraged trade across their territories and beyond. The founding of the Ming dynasty in 1368 by Hongwu resulted in the setting-up of twenty official kilns in Jingdezhen. Production increased, and the finest products went to the Imperial court, whilst others were specifically made for export to the Middle East, many bearing Islamic inscriptions from the Koran. From the reign of the Xuande emperor, the official porcelain is stamped with the emperor's name, theoretically enabling accurate dating of forms and decorative styles, although, for cultural reasons, reign marks are not always reliable in practice.

The early blue-and-white porcelain of the Yuan and early Ming period is seen to have a relatively pure blue colour. EDXRF analysis (section 4.6) has shown it to have a manganese/cobalt ratio of less than 0.5. After 1425, i.e. the middle and later Ming, the manganese/cobalt ratios are variable, usually higher, and from the Qing (Ch'ing) period up to *c.* 1950 are two and above (Joseph 1971; Yap and Tang 1984). Though the initial cobalt colourant was imported from Iranian sources, after 1425 Chinese sources of cobalt, rich in manganese, were being used, probably in conjunction with some imported material. After the mid-fifteenth century, the blue colour often becomes paler and the pigment is more finely ground. This is almost certainly related to the use of the new Chinese cobalt mineral sources. The manganese-rich Chinese cobalt is exclusively used from the Qing dynasty onwards. Difficulty in obtaining supplies of the Iranian blue cobalt pigment (Glasgow Museums 1997: 52) may have led to the development of the Chinese cobalt sources.

Some blue-and-white porcelain may, like silk, have reached north-western Europe in very small quantities prior to the sixteenth century, through trade with Venice and the Middle East. By the mid-sixteenth century the Portugese had established a thriving sea trade with the Far East through the ports of Malacca (1511) and Macau (1557), over which they had established control. The Chinese began to make blue-and-white porcelain specifically for the Portuguese/European market. Pieces of Chinese porcelain decorated with Portuguese coats of arms have been discovered (Yeo and Martin 1978: 73). The Dutch captured two Portuguese vessels (carracks), *San Iago* in 1602 and *Santa Caterina* in 1604, filled with porcelain trading between their Indonesian ports and China (Archer 1997). Brought back to Holland, the imported Chinese blue-and-white porcelain became very popular throughout north-western Europe. The huge demand for blue-and-white porcelain enabled the Dutch, operating from the port of Batavia (Jakarta), to become the principal traders with the Far East. In the eighteenth century, the British East India Company replaced the Dutch as the principal trader bringing blue-and-white porcelain to north-western Europe. However, the high transport costs of this long-distance trade and the development of European delftware and porcelain production meant that the trade ceased to be economically viable by the nineteenth century (Archer 1997: 33).

Maiolica and delftware

The use of tin to create an opaque-white-glazed ceramic spread from the Middle East through Spain to Italy. By the fifteenth century the Italians were producing fine-quality pottery made of red clays, with a white tin-glaze background and vibrant coloured designs in blue, yellow, green and purple, known as maiolica. During the fifteenth century, Venetian galleys brought large quantities of maiolica ware to the ports of north-western Europe, e.g. Southampton and London. Around 1500, Italian potters such as Guido Andriesz moved to Antwerp and began producing maiolica wares. In the seventeenth century many of the Dutch maiolica factories moved to Delft, which had good water transport and empty factories from a declining brewing industry, which is why the white tin-glaze wares of the Netherlands and England became known as Delft or delftware. Subsequently, potters such as Jasper Andries, Guido's son, came from the Netherlands to Britain and set up production – Jasper in Norwich in 1567 (Laing 2003: 115) and Jacob Jansen in 1570 in London. This industry produced large numbers of tiles (internal wall tiles), plates, Chinese-style bowls, drug jars and other wares. Chinese blue-and-white decorated porcelain became increasingly popular throughout the seventeenth century following the arrival of captured Portuguese carracks of 1602 and 1604. Much of the delftware production switched to production of blue-and-white decorated forms, and often imitated Chinese designs. Delftwares became thinner and completely white-glazed as they consciously attempted to copy and compete with the expensive imported Chinese porcelain (Charleston 1968: 159). By the first half of the eighteenth century, large numbers of factories had opened up in Liverpool, London, Bristol and Ireland (Archer 1997: 570–1), producing delftwares for export to the colonies in America and the Caribbean, much of it in the blue-on-white Chinese style.

The eighteenth-century English delftwares were made from local red earthenware clays mixed with pipeclays, normally from Poole in Dorset, to make it paler, plus a calcareous clay from East Anglia to reduce shrinkage. The clays were made into the vessel forms by potters using either simple kick wheels or moulds and, after drying, were fired to form a biscuit ware. The white glaze was prepared by fusing sand, soda, potash, lead and tin to form a glassy frit, which was ground to form a slurry into which the pots were dipped and dried. Then the design was then painted on in cobalt blue pigments, a slurry of powdered frit formed from cobalt mineral fused with lead oxide (massicot). The designs, though derived from images on Chinese and other ceramics, were normally taken from pattern books, e.g. *The Ladies Amusement*, *The Draughtsman's Assistant*. The glazed wares were then placed in large fireclay drums, which protected them from the soot, ash and flames of the kiln, and were fired to around 1000 °C. This fused the glaze and made its outer skin transparent above a white base, and turned the cobalt pigment a bright blue colour. Slight changes in the firing temperature of the kiln could cause failure, and it is estimated that only 25 per cent of the china came out properly fired. Much of the slightly blemished ware was sold as seconds, giving ownership of delftware and later porcelains to a larger number of the population.

Delftware was sold through a number of sources:

- Most factories had a warehouse with a showroom where both wholesale purchasers and retail customers could see and purchase the factory wares.
- The factories accepted orders from individuals and organizations, who commissioned particular designs, monograms, coats of arms, etc., on standard forms. Such commissions could be arranged direct with the factory or through agents who were based in different towns or areas of the country. Such objects blur the distinction between bespoke and mass-produced objects.
- Many large towns and cities had specialist shops that supplied the ceramic products from one or more factories. Many members of the Glass-Sellers company also sold delftware.
- Smaller towns had general shops that supplied a wide range of goods, including delftware.
- Itinerant vendors, e.g. 'Baskit women', obtained delftware and china on credit and then sold it door to door or on street corners. Such pedlars, who operated in both urban and rural environments, with their low overheads provided stiff competition to shopkeepers.
- Agents were often present at markets and fairs, where large purchases of goods such as ceramics were often made by farmers.
- Delftware was exported to the Caribbean, America and other colonies. It was principally sold to merchants who shipped the material overseas and direct to large plantation owners. There was also export of delftware from Britain into mainland Europe, where the Seven Years War (1756–63) disrupted trade.

European porcelain

The first commercial production of porcelain in Europe began in Meissen in 1710 (Charleston 1968: 212). Only after 1750 was there any significant spread of production to other German states and throughout Europe. Meissen was a hard-paste porcelain, formed from refined traditional potting clays and kaolin. Production of soft-paste porcelain in France developed in the early to mid-eighteenth century, with the production of Sèvres becoming dominant. In England the use of calcined bone with clay, which made the softer 'bone china', began in the works at Bow *c.* 1750. This proved to be the basis of the English 'china' industry (Charleston 1968: 247). Factories at Derby and Worcester produced soft-paste porcelains in a variety of forms throughout the latter half of the eighteenth century. By 1770 hard-paste porcelain was being made in Bristol, using china clay from Cornwall. A significant proportion of these early porcelains used blue underglaze decoration, imitating the imported Chinese porcelain that had inspired their production. However, an increasingly wide range of colours and decorative devices and forms were used.

The production of Continental porcelain after 1710 and of British porcelain after 1750 captured some of the market for top-quality delftware. The availability of this material and its competitive price certainly led to a considerable reduction in the importation of Chinese porcelain. In the 1770s–80s, creamware – an earthenware with a rich creamy glaze – became popular and captured many of the markets previously supplied by delftware. Consequently many delftware factories closed and production levels fell dramatically (Archer 1997: 23–8).

Use

The demand for delftware and, after 1750, for porcelain was not only to supply fine wares for the table, where it competed with pewter and silver, but also for the new fashion for hot drinks. The introduction of tea, coffee and chocolate-drinking between 1690 and 1710 led to a demand for drinking vessels which, unlike metal, did not transmit heat. Since delftware and porcelain are not porous, no organic residues will be retained in the ceramic fabric for analysis; thus it is not possible to provide independent analytical proof of the beverages consumed in these containers.

Record

Sherds of blue-and-white china recovered from excavation in London could have come from several sources:

- Imported Chinese porcelain. This would be a well-fired white body, decorated with Chinese scenes and foliage, clearly and accurately executed with quick, flowing brushwork. Such ceramics were always costly and indicated a high-status household.
- Delftware. A red-pink fabric with dense white glaze with blue decoration. English or, if from sixteenth-century contexts, Dutch manufacture, with decoration of Chinese-style scenes and foliage, often inaccurately and tentatively executed. Often standard devices or scenes used. The quality of ceramic production and

the date will indicate the relative wealth of the owner. Popular with the urban merchant and artisan classes.

- Early Continental or English porcelain. A well-fired white ceramic body, of variable hardness depending on date and place of manufacture. Decorated with Chinese-style scenes and foliage, often of standard stylized pattern. Such ceramics were costly if of an eighteenth-century date, and indicate a wealthy household.

As the value of early blue-and-white Chinese porcelain rose, later periods attempted to copy the forms and decoration of the earlier period. By the twentieth century forgeries had become common. Analysis of the manganese/cobalt ratio has proved useful for detecting both modern and ancient fakes purporting to be early pre-fifteenth-century blue-and-white porcelain. It has also been noted that blue-and-white porcelain made in Jingdezhen prior to 1950 has an almost constant, relatively low level of barium. Variable and high levels of barium are detected in blue-and-white ceramics made after 1950 (Yap and Tang 1985). Thus analysis of the levels of barium enables fakes of the late twentieth century to be distinguished from earlier porcelain.

Chapter 5

Objects as functional implements (use)

WHY?

5.1 Introduction

Maquet (1993) suggested that the function of an object could be understood from its shape and knowledge of the physical world. Whilst this may be true for some simple tool forms, in reality a detailed knowledge of the period/material culture from which the object derives is often necessary for accurate object identification. The function of collar studs is unknown to many of today's students, barely 70 years after they were in daily use. The further any culture is from our present experience, the more difficult it is to accurately identify the use to which any object was put. However, clues can be gained by careful research and examination, and some basic idea of function can usually be gained even if a complete appreciation is lacking.

Evidence of the use of objects can take many forms. Context has already been discussed (see section 2.6). Evidence forms also include:

Text about an object

Most contemporary sources merely describe objects in passing. The seventeenth-century diarist Samuel Pepys indicates that on the day of the burial of the Duke of York, Pepys, as a civil servant, was expected to make a display of mourning.

> I bought a pair of short black stockings to wear over a pair of silk ones for mourning.
>
> (Latham and Matthews 1976: 251)

Such comments indicate the social/cultural use of objects, which are not obvious unless one understands the custom (see section 2.8). Some objects and activities are inexplicable without written information.

References in the Bible and other ancient texts refer to the use of cedar wood from the forests of Lebanon for almost all carpentry work. Other woods are barely mentioned, and it would suggest that Lebanon was filled with forests of cedar trees and that it was virtually the only wood in use for high-quality wooden artefacts. The properties of cedar wood – taking a high polish, good working properties, attractive grain pattern and pleasant odour – commend it for use for furniture and internal structural use. However, analysis has shown that fir/pine, oak and juniper trees grew just as widely in the forests of the Lebanon, and archaeological evidence indicates they were just as widely used as cedar (Meiggs 1982: 49–87). This sounds a warning about the reliability of written texts. Whilst the writers and leaders of a society (or a later society) invariably express stereotypical views, writing to impress their readers, practitioners take a more pragmatic view and use any and all appropriate, cheap and available materials that will do the job.

The accuracy of written statements depends on the extent of the authors' knowledge of their subject and their need, desire or opportunity to be accurate. Every writer has a reason for writing, and the reader needs to be aware of why the text was written in order to judge how much credence they should place upon it. Some literary forms such as accounts, e.g. port books (see Figure 4.1), diaries and technical treatises are more likely to be accurate than others such as poems, songs and works of fiction.

Images of objects

Contemporary images can record the nature of artefacts and their use. Images occur in many forms:

- Wall paintings: Egyptian wall paintings, many preserved on the walls of rock-cut tombs and in temples, record everyday activities such as the netting of birds – activities and objects we would struggle to interpret fully without such images. Roman houses and medieval churches also contain wall paintings depicting people using tools, weapons and other objects.
- Low- and high-relief sculptures such as Roman tombstones record the tools and activities of the trade of the person commemorated (Strong and Brown 1976: 176).
- Illustrations (sketches or paintings) in books, on wooden panels, furniture, or ceramics or on framed canvas. The Luttrell Psalter and other medieval texts such as books of hours record the activities of peasants in the landscape, including details such as the yoking together of oxen to pull the plough (Basing 1990). Some authors have already gathered together images of object use, e.g. Neergaard (1987) for medieval knives, shears and scissors in medieval Europe.
- Graffiti, both marginalia drawn in books and images scratched on stone or wood. These vary from the obscene to the technical drawings of craftsmen, and are present from all periods and cultures.
- Stained glass, principally present in medieval and later churches, can depict activities and objects such as the bell-founders window in York Minster.
- Images on ceramics, glass or metal can be seen in forms such as the raised decoration from manufacture in a mould, e.g. Roman gladiator cups (Price 1978) or the repoussédecoration of sheet metal. Coins are stamped with images that frequently depict hairstyles, chariots and a wide range of weaponry and other symbols of power.
- Textiles such as the Bayeux (Tapestry) Embroidery (see Figure 2.13).

The accuracy of the image depends on:

- The knowledge of the artist; they often had little knowledge or understanding of the objects, people or activities they were depicting.
- The need to simplify an image so that it could be drawn (carved, raised, sewn, etc.) and understood. Such simplification led to a shorthand visual image, such as the small number of planks forming the boats depicted in the Bayeux Tapestry.
- The artists depicted what they wanted to see rather than what was there. Artistic licence was used to compose a visually pleasing or appropriate image. Stereotypes were often used. Until the twentieth century, art was primarily illustrative, decorative or commemorative, not challenging.

Consequently an image cannot be accepted at face value. The reasons for the creation of the image, an assessment of the accuracy of the artist (by assessing their depiction of known objects/people/events/buildings) and their skill at rendering reality must be made, and the image of the object interpreted within this context.

Physical evidence

Some objects are created to be used only once, such as a tin can or a coffin. Frequently items made of fragile impermanent materials are not meant to last, but are meant to be used once and then discarded. Many twentieth-century objects, e.g. paper plates and ethnographic costumes or masks, are made for a single dance or ceremony. Some items cannot perform the function they portray; e.g. the terracotta figures in the tombs of Chinese emperors. Any object of an inappropriate size or made from an inappropriate material is probably primarily symbolic; consequently these objects will not have any traces of use. However, until the material wealth of the late twentieth century, most functional objects had long histories of use; they were often repaired and reused.

In theory every contact between an object and the rest of the world leaves a trace, from the DNA and fingerprints of the user to the wear from the object as it is dragged across a surface. Three categories of evidence can be identified:

- deposits: material deposited on, or, in the case of porous materials, absorbed into the surface, usually from contact with soft or liquid matter (see section 5.2);
- physical damage: scratches and dents from occasional contact with hard materials or wear/polish from prolonged contact with any form of material (see section 5.3);
- decay: chemical reaction between the object and the surrounding environment, which may include light, gas, water, chemicals, biological organisms, and physical materials such as dust (see section 5.5).

How much information can be recovered in the form of physical evidence of use depends on the nature of the material, the nature of the use, the extent of the use and the ability and facilities available to the investigator.

5.2 Deposits on object surfaces

The dirt (soiling) and decay products on the surface of an object may be categorized (Caple 2000: 91):

- primary materials: the substance of the original object;
- secondary materials: layers of materials added to the object through its working life, e.g. paint layers;
- soiling – ethnic dirt: solid matter deposited during use, ethnographical or ethnic deposits (Oddy 1994);
- decay products: the layer of material produced from reaction between primary or secondary materials of the object and water, light, oxygen or biological organisms; often mixed with the next category;
- soiling – burial material: solid matter deposited during burial;
- tertiary material: material such as museum number or conservation materials added to the object after it has entered the collection;
- soiling – museum dirt: solid matter deposited during exhibition or storage.

Soiling may occur in the form of soil from burial or dust from storage, or as caked-on mud, grease, oil, dirt, sweat and blood from use. It is important to identify the type of soiling accurately, since some can be highly informative about the use of the object; some is not.

The 'ethnic dirt' type of soiling provides crucial information about the nature of use of the object. It is important to analyse these deposits or retain them for future analysis. Examples include the hood worn by Robert Merrick, the 'Elephant Man', which, when undergoing conservation, was not wet-cleaned, since it was felt that future analytical techniques might be able to recover further information regarding his medical condition from the body staining of this cloth (Eastop and Brooks 1996). In many instances the type of material recovered and the position from which these deposits were recovered indicate the nature of the use of the object. The recovery of parts of human head lice (*Pediculus humanus*), utilizing a stereo microscope, from the fine teeth (13–14 per cm) of two double-sided boxwood 'H' combs from the Roman fort of Ribchester (Fell 1996) demonstrates the role of these combs as 'nit' combs. Only combs with such fine teeth would be effective at removing such small insects from the scalp.

All events, including damage, discard, burial and even the recovery and collecting of the object, are part of an object's life – part of the truth about the object. If this is correct, then everything up to the present moment, even the deposits of museum dust which gently fall upon it ('soiling – museum dirt'), are part of the full history of the object. Whilst the museum career, even its coating of dust, can be regarded as part of the history of the object, it is not an important or informative part of the object's life.

The Vix crater is one of the most important examples of Greek metalwork imported into north-western Europe in the pre-Roman Iron Age, and demonstrates the contact between prehistoric Europe and the classical world. All traces of soil and degraded leather that surrounded this object ('soiling – burial') when found were cleaned off in the 1950s, as it was perceived that ‘they harmed the beauty of the object’ (France-Lanord 1996). The classical scenes depicted in the metalwork were seen as more important than the evidence that, for burial, it was wrapped in a piece of leather. By the 1970s the importance of the evidence that can still be recovered from such deposits began to be appreciated, and such deposits are now normally retained on the object by archaeological conservators, e.g. the Scar Viking sword and scabbard (see Figure 3.4).

Porous materials can absorb material during their use, traces of which are retained, even protected, in their porous matrix and can now, using modern analytical techniques, be detected and identified. EDXRF analysis of sherds of Stamford ware discovered on Anglo-Scandinavian sites in York by Justine Bayley revealed deposits of a white/yellow material – lead oxide (litharge) – on the surface. This allowed the sherds to be identified as used as cupels, refining trays/vessels in which lead was oxidized, so separating it from the silver (or gold), which remained as metal (Bayley 1992).

A wide range of different organic deposits have been detected on artefacts:

Organic residues

The organic residues present on an artefact – greases, oils, fats, resins and proteins – normally derive from its use. These may be lubricants on an engine part, adhesives on a flint arrowhead or residues from cooking in a ceramic vessel. Accurate identification of the residues present can enable investigators to identify the plant or animal materials used in the object’s construction and with which it has had contact. Traces of organic residues on historic objects have often dried and oxidized, reacting with light and oxygen (Mills and White 1987). For archaeological objects, burial has invariably resulted in the decay of proteins and carbohydrates; however, the detection and identification of hydrophobic substances such as fats and oils (lipids), plant leaf waxes absorbed into ceramics (Evershed *et al.* 1992, 2001) and tree resins on artefacts (Pollard and Heron 1996) has proved possible. Analysis, especially using gas chromatography (see section 5.6), has shown itself to be effective in isolating and characterizing the organic molecules present.

Lipids (fats and oils), present in both plants and animals, are composed primarily of triacylglycerols (esters of glycerol and fatty acids). Most lipids are not unique to particular species, but the ratios of the various triacylglycerols, and the fatty acids from which they are composed, vary between species and between animals and plants. A number of approaches have been taken to characterizing them:

- The acquisition of full gas chromatograms for a large number of comparative modern samples has derived a series of patterns in the triacylglycerols, diacylglycerols, monoacylglycerols and fatty acids. From these patterns, characteristics related to lipid origin emerged, e.g.
    - High proportions of saturated fatty acids normally derive from animal sources; less stable unsaturated fats are more prevalent in plants.
    - Cholesterol is always present in animal lipids.

  - Branched odd-numbered carbon chain fatty acids and isomers have greater probability of coming from ruminants (cattle and sheep) than other animal sources.
  - Dairy sources have a broad range of triacylglycerol species, including many short-chain fatty acids.
  - Porcine (pig) fats contain a more restrictive range of triacylyglycerols with 48–54 carbon atoms in the chain (Reid *et al.* 2002).
- The presence in the gas chromatogram of relatively distinctive groups of organic compounds can be indicative. For example, *n*-alkanes and palmitic wax esters indicate the presence of beeswax. Complex mixtures of unresolvable peaks of triacylglycerols, formed from polyunsaturated fatty acids, characterize fish oils (Reid *et al.* 2002).
- The use of a gas chromatograph followed by combustion and a mass spectrometer capable of measuring carbon isotopes (GC–C–IRMS) can reveal the source of the carbon forming the various fatty acids. The ratio of carbon isotopes depends on the food sources and the metabolism of the animal from which the lipids derive. Most animals have sufficient differences in diet and metabolism to allow the lipid to be characterized. Thus graphing the ratio of carbon 13 to carbon 12 ($\delta^{13}C$) for fatty acids of carbon chain length 16 and 18 will enable groups such as ruminants (cattle, sheep), non-ruminants (pig) and dairy to be distinguished (Evershed *et al.* 2001). Thus, though horses were held in high esteem in Celtic cultures, the cooking of horse flesh is attested in the early to mid-thirteenth-century Welsh castle of Dryslwyn, from evidence of residues on a cooking pot (Reid *et al.* 2002).

Through the use of a gas chromatograph followed by a mass spectrometer (GC–MS), the presence of specific molecules that are unique to particular host materials can be detected. The presence of nonacosane and related long-chain alkyl compounds in medieval/Saxon potsherds from West Cotton, Northamptonshire, indicated the presence of epicuticle leaf waxes from the *Brassica* family, e.g. from cabbage soup (Evershed *et al.* 1992). The presence of compounds such as 5β-stanols, derived from the microbial reduction of cholesterol, sitosterol and related compounds in the guts of animals, indicates that the soil in which it is found has been manured. The relative proportions of the 5β-stanols may give some indication of the source species of the manure. Similarly the presence of bile acids indicates material which has been through an animal's digestive tract, with some acids derived from specific species. Hyodeoxycholic acid is the product of a porcine gut (Evershed *et al.* 2001).

The use of organic materials for medicinal purposes was almost certainly widespread. The use of birch-bark tar as a chewing gum is demonstrated by specimens from the neolithic site of Hornstaad-Horne I, in which there are human teeth-marks. It has been suggested it was primarily used for medicinal purposes (Pollard and Heron 1996: 258). The occurrence of cannabis, identified through compounds such as tetrahydrocannabinol in material recovered from the burial of a young girl from Roman Palestine who died in childbirth, suggests that cannabis was used to provide pain relief (Pollard and Heron 1996: 262). Substances were also taken for narcotic effect, and these can also be identified from their molecular composition. The presence of alkaloids – dimethyltryptamine, 5-methoxydimethyltryptamine and 5-hydroxy-N,N-dimethyltryptamine (bufotenine) – in a powder recovered from an eighth-century AD grave in northern Chile, together with grave goods associated with snuff-taking, would suggest the powder was a narcotic snuff (Pollard and Heron 1996: 263). Residues of wine have been identified on ceramics from the Bronze Age site of Godin Tepe, Iran and the Byzantine site of Gebel Adda in Egypt, through the identification of tartaric acid compounds using infrared absorption spectroscopy (Badler *et al.* 1990).

Saps and resins of trees have proved to have useful adhesive and waterproofing qualities. Through the use of gas chromatography and mass spectrometry (GC–MS), the components of such resins can be derived, and the presence of specific compounds or groups of compounds can indicate the species of tree from which the material derives. The properties of the resin and its location on the object indicate likely use.

- The resins derived from softwood trees, e.g. members of the genus *Pinus*, are characterized by the presence of diterpenoids (20-atom carbon-chain polymers). Initially soft, these resins are often heat-treated; low-temperature heating creates tar or pitch, a thicker material which was widely used, e.g. for caulking ships such as the *Mary Rose* (Evershed *et al.* 2001). Distillation at gentle heat can result in the creation of more specific materials such as colophony rosin, which often formed the basis of wood varnishes in the post-medieval period. The presence of diterpenoids, e.g. in the amphorae from the wreck of a Gallo-Roman trading vessel off Guernsey (Evershed 1993) attests the use of these amphorae for transporting pitch in the Roman period or may derive from sealing these porous ceramics.
- The resins from hardwood trees, e.g. members of the genus *Betula* (birch), are characterized by the presence of triterpenoid (30-atom carbon-chain polymers). Most frequently detected on archaeological material is betulin, the principal triterpenoid of birch bark. The properties of this material as an adhesive can be improved through heating in a sealed container. Such material was being created and used as an adhesive for hafting the flint arrowheads in the Neolithic. The copper axe of ‘Ötzi’, a neolithic man of *c.* 3330 BC recovered from an Alpine glacier, was attached to its haft using birch-bark tar and lashed with rawhide strips (Spindler 1995: 89, 124; Pollard and Heron 1996). It was also the principal component of the adhesive used in the Roman period to mend a broken ceramic (Charters *et al.* 1993).

The matching of specific triterpenoids, or groups of triterpenoids, from archaeological deposits with similar ones derived from modern materials has allowed the identification of some specific tree saps and resins, such as the identification of some pieces of frankincense recovered from a house at Qasr Ibrim (Van Bergen *et al.* 1997). The resin, known as Chios turpentine, derived from the *Pistacia atlantica*, has been detected in around 100 Canaanite amphorae from the Late Bronze Age wreck at Ulu Burun (Mills and White 1987). In both these cases the resin was probably used as incense.

Blood

Blood contains cells such as erythrocytes (red cells, for oxygen transport) and leukocytes (white cells, to fight disease) in plasma. Besides the haemoglobin in the red cells, plasma contains other proteins such as albumin (water regulation and fatty acid transport), globulins (α, β, γ: antibodies and lipid transport) and fibrinogen (for blood-clotting). Detection of these proteins in residues allows them to be identified as blood.

Early results reported by Loy (1983) raised expectations that bloodstains could be detected on stone axes and that they could be identified to species level. Such hopes were premature. Many of the simple strips and sticks (Chemstrips, Hemastix) used in such tests have been impregnated with chemical and enzyme agents designed to react with fresh body tissue and secretions to give a positive or negative test for a specific protein. Tests showed that they frequently gave false positives when testing ancient artefacts (Custer *et al.* 1988; Smith and Wilson 2001). Similarly the technique of precipitation of haemoglobin protein crystals from solutions of blood residues derived from stone artefacts has been shown to be insufficiently accurate or rigorous to give reliable results at species level (Smith and Wilson 2001).

Precise immunological techniques such as Ouchterlony, crossover-immuno-electrophoresis (CIEP), radio-immunoassay (RIA) and enzyme-linked immunoassay (ELISA) introduce specific antibodies to samples. The creation of antibody–antigen complex forms which are revealed by staining with a dye (Ouchterlony and CIEP), generating enzyme activity (ELISA) or creating a detectable radio-labelled complex (RIA) (Smith and Wilson 2001) indicates the presence of a specific antigen protein in the sample and thus identifies a specific animal species. Testing of modern samples demonstrates the accuracy of the techniques; however, testing of ancient samples with these techniques has given contradictory results. These tests frequently failed to detect bloodstains on stone objects that had been buried for two years. At best, these techniques only detect a percentage of those objects that have had blood present on them, and species identification is currently unreliable. Similarly the technique of dot blotting, which utilizes a peroxidase-labelled protein A that binds to immunoglobulin G and is used to identify mammalian blood, has been shown to give positive results with dog faeces and crushed insects (Smith and Wilson 2001). Whilst medical sciences develop further techniques such as isoelectric focusing (IEF), rigorous testing on realistic known materials which have experienced burial conditions will be required before any credence can be placed on such techniques. Museum dust can test positive for protein; however, it is not ancient blood residues, but the skin flakes and sweat of numerous museum assistants!

DNA (deoxyribonucleic acid)

DNA is present in the cells of every plant and animal. It provides molecular instructions to build the numerous proteins which form every living organism. It takes the form of a long polymer based on sequences of four nucleotides which carry the triphosphates of the amino acids adenine, cytosine, guanine and thymine (A, C, G, T). The sugar-phosphate parts of these nucleotides are chemically linked with their neighbours to form two chains or 'backbones', arranged in a double helix that is held together by base pairs – amino acids which form bonds with each other, i.e. A with T and C with G. Each human cell contains 24 chromosomes, each composed of a pair of helices, which contain up to 250 million base pairs. Genes are areas of the nucleotide chain – specific sequences of base pairs that convey biological characteristics such as hair colour – usually separated by long stretches of non-coding DNA known as STR.

The mitochondria present in animal and plant cells reproduce asexually, and thus evolve very slowly through imprecise copying of the DNA sequence from one generation to another. This occurs at a regular rate; so, by determining the extent of variation, the time that has elapsed from a single origin can be calculated. The offspring of plants and animals that reproduce sexually have DNA drawn from both parents. This gives rise to huge variety, effectively making the DNA of such individuals unique.

DNA chains undergo hydrolysis (chemical breakdown by water); however, living cells repair this damage. Once the organism dies, such repair ceases and the DNA chains start to break down into short fragments. In 3000-year-old charred wheat, the fragments are *c.* 50–70 base pairs; human and animal DNA in bone probably has *c.* 300 base pairs (T. Brown 2001). This is why there will never be sufficient ancient DNA to reconstitute ancient plants, animals or hominids. However, small fragments (100–150 base pairs) are sufficient for the researcher to infer characteristics such as sex, species, and kinship affinities.

The development of polymerase chain reactions (PCR) allows small sequences of DNA to be accurately copied numerous times, then subsequently separated and analysed, e.g. by gel electrophoresis. One of the largest problems with ancient DNA is that it is easily contaminated with modern DNA from archaeologists, scientists, modern fungi and bacteria. Any contaminant DNA may also be copied by the PCR and obscure the fragmentary ancient DNA. Contamination problems have raised doubts over the accuracy of the results of many publications about ancient DNA (Smith and Wilson 2001), especially analyses of human remains. Comparative samples, blanks and controls should be undertaken (and published) with every ancient DNA analysis to demonstrate that the work was free of contamination (Cooper and Poinar 2000). Questions must be carefully phrased and comparative samples obtained if the analysable partial fragments of DNA are to provide answers, as seen in the DNA work on the bones of the Romanov family (Gill *et al.* 1994).

DNA analysis can be used to relate organic materials, such as traces of blood, from an object reputedly owned by a specific historic figure to descendants of that person. This can confirm the historical association of objects, but extreme care is needed, since contamination problems are rife, e.g. due to sweat from hands and skin particles from all who have subsequently handled the object. Bone is usually the best material to analyse for ancient DNA, since the contaminated exterior can be removed and only the internal material sampled. Results from ancient specimens, such as the detection of mitochondrial DNA in mammalian blood residues recovered from stone tools 35–65,000 years old (Hardy *et al.* 1997), are rare.

Figure 5.1 Worn stone steps indicating heavy use. (Photograph by the author)

5.3 Wear and damage

The surface of any object contains almost all the information about the object. It bears marks of manufacture, coloured coatings and decorative designs, deposits from use and wear. It is also, quite literally, the part of the object which comes into contact with the rest of the world, so the surface and its information is gradually knocked, worn or scratched off or subsequently decays. Information about the original appearance and manufacture of the object is gradually lost, and replaced by evidence of later use.

Visual examination of wear, e.g. with a stereo microscope or SEM can reveal, through comparison with modern analogues, the nature (direction, force, extent) of the wearing process and impacting object(s). The direction and movement of people are revealed by the wear they inflict on floor surfaces, as demonstrated by any flight of well-used steps, which become dished with the passage of many feet (see Figure 5.1). The shoes themselves are eventually worn through and either repaired or discarded. Traces of wear, plus evidence of holes and splitting of seams, of shoes recovered from excavations in London revealed that complaints such as bunions (*hallux vulgaris*) and arthritic joint (*hallux rigidus*) or hammer toe afflicted the citizens of medieval London (Grew and de Neergaard 1988: 105–11). Simple wear – the rubbing of one surface on another, e.g. jewellery on the fabric to which it is pinned – creates areas of smoothness and polish, even wearing away surface coatings such as the worn patination on the back of the Andrew's Hill brooch (see Figure 2.7). Textiles, ropes, leather and other materials made of microscopic fibres develop rounded ends to the fibres as a result of rubbing and gradual wear; irregular broken ends derive from bursting or tearing; irregular frayed ends from flexing; smooth flat ends from cutting with a knife; or stepped ends from cutting with scissors or shears. The woven matrix of textiles is loosened and gives rise to frayed edges, familiar on collars and cuffs, due to prolonged wear.

The edge or point of any tool will become blunt, rounded and less effective with wear: axes, sword blades, pins, needles, knives, chisels, scissors, saws, drills, pens, etc. This makes them less efficient tools, at which time they may be discarded; or more usually they are sharpened. Repeated sharpening wears away the edge of the blade, changing the shape of the blade (Neergaard 1987). It also wears away the hone stones used for sharpening (see Figure 1.2), leaving a smooth surface, characteristic of wear on hard materials such as stone, bone, glass and metal.

In addition to removing dirt, the process of cleaning also removes small amounts of the object's surface. This is true for both chemical cleaning agents, such as silver cleaners, which partially dissolve silver corrosion products, and cleaning agents which contain abrasive particles, e.g. 'Brasso'. Such wearing away from cleaning can result in flattening and loss of definition of raised or incised decoration, e.g. the Coppergate Anglian helmet (see section 1.11), and the loss of coatings such as gilding and tinning, which are often only left as traces in the recessed or protected areas of the object (see Figure 5.2).

Where two parts of an object come into contact on a regular basis, whether a hinge, clock mechanism or machine, they will receive and cause wear in the specific location where there is contact. Where only parts of the object survive, the extent and location of wear can indicate the nature of contact and thus give clues to the nature of the mechanism. Cogs, geared wheels, spindles or rollers are all subject to rotary motion and wear. Such surfaces are often lubricated with oil or grease, which leaves surface deposits. The presence of such oily deposits can indicate the presence of a lubricated joint and thus of motion and regular contact.

The nature and extent of wear, dents and abrasions indicate the level of use. Used and unused objects can be detected from the presence or absence of signs of wear, although wear can be faked, as it is with modern 'reproduction' antique furniture which is 'distressed' to give an aged or antique look.

Stone tool microwear

Microwear on prehistoric lithic artefacts is the only area where wear has been studied to the point that it has become a significant analytical tool for archaeologists. The rounding of the edges of stone tools and areas of polish were noted by early antiquarians (Evans 1872). Polish was particularly clear in the case of pieces of stone used to form composite sickle blades which had acquired a distinctive sheen – sickle gloss. Work by Seminov (1964), Tringham *et al.* (1974), Keeley (1980) and subsequently by Unrath *et al.* (1986) and Newcomer *et al.* (1986) demonstrated, through experimental archaeology, that the wear on the edge of a lithic blade was related to the nature of the use of the tool and the materials upon which it was used. Some diagnostic features were visible with stereo microscopy, more detail was observable using SEM, with its high magnification and good depth of field (see section 5.7). Blind testing showed that the technique could readily identify the areas of the tool which were being used; micro-features indicated the direction of motion of the tool and the extent of use. It also enabled the type of action employed with the tool, e.g. scraping

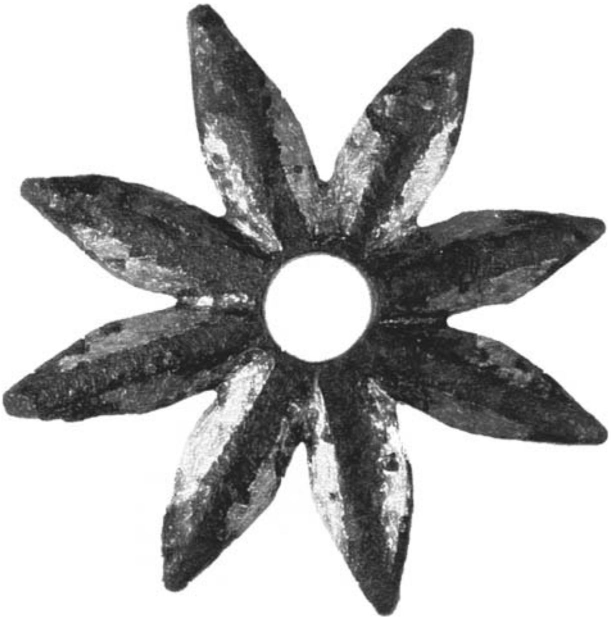


Figure 5.2 Gilded multi-point spur rowel from Keays Lane, Carlisle**.** Worn spur rowel, the gilding is only visible in the valleys between the raised ridges. (Photograph by Jennifer Jones)

or piercing, to be identified. At higher magnification, features related to the material being worked could be identified, though this was at a lower level of accuracy.

Three primary types of feature are used (Dumont 1988):

- Edge damage: flaking or rounding of the edge (arête) indicates the hardness of the materials being cut.
- Polish: is probably achieved through very fine abrasion – harder, silica-rich materials giving deeper polishes. Referred to as 'sickle gloss' where seen on stone blades used in composite prehistoric sickles, it was suggested that the gloss may be due to some deposition of silica. Meeks *et al.* (1982) examined cross sections through glossed sickle blades and showed that such deposition must be extremely thin if present at all.
- Striations: if these run parallel to the blade edge they indicate sawing or grooving actions; perpendicular to the edge of the blade, they indicate cutting, slicing or scraping actions.

The extent and exact micromorphology of these features vary with type of tool, its use and the material cut. Features are usually sufficient to diagnose use on a hard or a soft material. Six material types can usually be distinguished: wood, bone, hide, antler, non-woody plants and meat, though other categories, e.g. stone, have been identified. The water content of the material can affect the nature and extent of wear. Wear on fresh (wet) hide is low, but it is higher on dry hide, and highest on semi-dry hide (Hayden 1990: 94). Some objects have distinctive forms and distinctive wear/micro-features, which allow the type of use or hafting to be proposed, e.g. microlith arrowheads (Nuzhnyi 1990) and ice picks (Volkov 1990).

The wear data is normally compared to contextual site information:

- Object form. Stone tools from the Middle Paleolithic show no clear relationship between the tool form and the wear type, However, in the Upper Paleolithic there is some correspondence, e.g. burins with bone working, and end scraper with skin and hide scraping (Ibáñez and González 2003). Wear has been shown to occur on some flakes not normally considered tools, whilst other 'tools' have had no signs of wear. There was a wide range of tool types on general habitation sites and a restricted range of tool types on sites which have specialized or seasonal activities. Recycling in the form of small stone cores from broken and recycled flint and quartzite objects occurs on general habitation sites and not in the areas of specialized activity.
- Finds. Any surviving bone or wood finds are used to compare and contrast with the stone tool wear analysis data. Wear analysis on a sample of the stone tools from the mesolithic site of Starr Carr, Yorkshire, showed that the primary activity on the site was woodworking (42 per cent of the use episodes) with little evidence of butchery (3 per cent of use episodes). Since the site was waterlogged, the presence of worked wood was able to confirm this interpretation.
- Site stratigraphy. Reassembling the flakes of stone has been utilized on several sites to explore chronology and the distribution of material from an original block of stone. The fact that 18 per cent of the flint pieces could be reassembled from throughout the cave site of Meer II in Belgium indicated that, although the site had 450 mm depth of deposit, it had been deposited during a very short period of occupation (Renfrew and Bahn 1991: 281).
- Spatial analysis. Work by Knuttsson (1990) on the site of Bjurselet showed that debris from the site was heaped into crescentic dumps around the site. These dumps contained worn and used tools and large manufacturing debris. Small fragmentary debris from stone tool working remained in the places of manufacture.

The accumulation of evidence on the different types of tool use can give rise to larger theories. The dominant presence of stone tools with microwear indicating woodworking and meat-cutting in the Lower and Middle Paleolithic contrasts with the considerable numbers of tools with hide working traces in the Upper Paleolithic. Hayden has suggested that the basic forms of hide manufacture, defleshing and curing wet hides, e.g. smoking, chewing or rubbing in animal brains or fish oils, required the use of few tools. However, more advanced forms of hide working, such as true tanning with tree barks and the cutting of hides to form garments, required a lot of working of dry and semi-dry leather with tools. Thus he suggest that leather-tanning to make clothing, comparable to that used by native American Indians, was being undertaken in the Upper Paleolithic and that this was a means of displaying wealth (Hayden 1990).

Broken and damaged objects

The repeated use of an object will cause stress to be placed on it. This can lead to strain, weakening of the material, cracking, creasing and fracturing, and eventually to object failure and breakage. One the most familiar examples of this is seen in the corners of the pages of a well-used book. These are weakened by constant turning, and if it continues, a crease develops across the corner and eventually the corner of the page can detach. The weakening of a material and the breakage of an object depends on:

- The nature of the material. Cheap paper of the late nineteenth and twentieth centuries was made with mechanical wood pulp and becomes yellow and brittle with age. Consequently the corners on newspapers of this period frequently break off after being turned a few times, whereas the higher-quality paper, especially the earlier rag papers made with linen fibres, can be turned many times with little damage.
- The force being applied (and the direction of the force, since many materials are anisotropic, having different properties in different directions).

Though objects may be damaged, they often can continue to function. Only when they cease to function are they broken. Objects that have been broken can be repaired and reused, discarded, recycled or retained with a symbolic function. Many objects made of paper, textiles, plastics, wood and most metals continue in use even when damaged. Objects made of materials such as glass, stone, ceramics and some metals, such as cast iron, are brittle and can suffer catastrophic failure, smashing when dropped, so losing all strength and integrity as functioning objects.

Surfaces were often deliberately damaged – ‘keyed’, scratched, dented or marked – in order that a new coating would securely bind to the old surface.

Though accidental breakage can occur through use, it is also possible to see deliberate breakage. This was an act that removed an object from functional usage and rendered it purely symbolic. Examples of this are seen in the deliberate breaking or sacrifice of objects placed in graves, as shown by the Viking Sanday sword (see Figure 3.4), or finds thrown into sacred places, such as bent swords and pierced shields thrown into the bogs and rivers of Late Bronze Age and Iron Age Europe (Merrifield 1987: 29, 101). Deliberately broken and fragmented objects are occasionally found in or under buildings, seemingly part of ritual activities, though a detailed appreciation of the context is crucial for such an interpretation (Chapman 2000). Damaged and broken objects can be just as powerful and readable as symbols as complete objects (Wobst 1999: 123–4). Where fragments of the same object are dispersed over a number of distinct locations, deliberate ritual breakage and deposition can be inferred. Iconoclasm, the disfigurement of symbolic images such as regal or religious statues, frequently indicates the conscious rejection of religious ideas or civil authorities, as exemplified by the expurgation of the image and name of the pharaoh Ahkenaten from the records and remains of Ancient Egypt (Quirke and Spencer 1992: 82).

5.4 Repair and reuse

Repair permits the continued use of an object by correcting a fault, e.g. the replacement of a damaged part such as the loop on the Milton Keynes pendant (see section 4.8), or the mending of a hole or tear. These are more likely to be seen in large, complex, expensive 'bespoke' objects, since they could not be easily or cheaply replaced and often had symbolic value, e.g. the Coppergate Anglian helmet (see section 1.11). Small mass-produced objects such as pins were usually replaced because they were not easy to repair and they were cheap and widely available. The decision to repair or replace is, however, a relative one. It is often simpler, quicker and cheaper to repair an object, especially a functional object that is in constant use, rather than suffer the delay involved in purchasing a replacement. During the twentieth century the cost of repair, primarily the cost of skilled labour, rose considerably, whilst the cost of replacements, primarily the cost of materials, fell in relative terms. The cost of labour, especially skilled labour and materials, has fluctuated through human history. The point at which people replace rather than repair varies between individuals, between societies and over time. It is principally determined by:

- social and cultural norms or traditions regarding repair;
- personal wealth – the value of one's time versus the cost of replacement;
- the social stigma or kudos attached to old and repaired objects.

Consequently the presence of a repair indicates something of the relative values of the object, materials, manufactured goods, labour and the social traditions regarding repair.

Some historic machines and tools that have been in use for many years include parts that have been replaced several times. This leads to questions of authenticity (see section 6.1).

> If I replaced the handle of my grandfather's axe, and my father replaced the axe-head, is it still my grandfather's axe?

Many objects in historic collections show evidence of repair, e.g. Smallsword CA1112 from York Castle Museum, whose leather grip is recorded as a replacement (Newman 1985: 79). Repairs or replacement are normally identified because:

- The materials fail to match the style, finish and materials of the original.
- The workmanship, usually inferior, is inconsistent with the original.

- There is a slight difference in size compared with the original.
- There are signs of later attachment, e.g. traces of adhesive, solder, rivets, non-original materials.

Repairs do not always return an object to its original function; thus Roman Samian vessels where the sherds of the pot are held together with rivets and strips of lead (Marsh 1981) could no longer hold a liquid, only dry goods. The cost of the repairs indicates that such vessels retain great value to their owners – continuing to perform a symbolic function (see section 6.1).

Reuse often implies that an object has changed use, often after a period of repair, alteration or adaption, e.g. the sheet metal on the back of the Winchester Reliquary (see section 5.8). Objects containing reused materials are often regilded or repainted. Additions or alterations are often undertaken as a series of measures, a phase of refurbishment, in order to bring an object back into use and appear fashionable or make it presentable. This may often correspond with major changes in visual taste, as shown by the changes to the portrait of Prince Henry on horseback (see section 2.12). High-value items such as gemstones are frequently reused, as shown by the reshaped and reused garnet in the Milton Keynes pendant (see section 4.8). Similarly lace collars and cuffs were often removed from old garments and sewn onto new ones.

Some objects were reused complete; neolithic stone axes were collected by the Romans and later generations, who, believing them to be thunderbolts from the gods, put them in the roofs of their houses to protect them from being hit by lightning. Consequently the distribution maps of neolithic axes (see Figures 4.3 and 4.4) may in part reflect concentrations of Roman housing in cities such as London and Chelmsford (Merrifield 1987: 9).

Some objects were designed with the expectation of repair and reuse. Thus clothing was constructed with hems and generous seams, which allowed the garment to be lengthened, shortened, or let in or out in order to better fit the wearer. Garments were normally reused, often passing down from one child to the next or from master to servant. Larger garments could be unpicked and the pieces of cloth reused to make smaller garments, or pieces combined so as to form composite objects such as patchwork quilts. The presence of stitch-holes, folds along the line of hems and seams, and differentially faded areas of dyed cloth are difficult to disguise, and are indicative of earlier use. Pieces of a cloak were found cut up to form the inner linings for a series of medieval shoes (Cooke and Lomas 1987). Many pieces of cloth were eventually torn up to form rags, which in the medieval period were often used to wrap around feet or to bind wounds, or were used as toilet paper.

Some materials, such as wood, are extremely easy to reuse. Evidence of joints, the presence of nails or other fixing devices, and weathering of exposed surfaces can be present on pieces of wood, indicating previous use. After a useful life, wood could finally be broken up and used as firewood, and thus little survives to the present. Good-quality stone such as freestone (stone without bedding planes or faults) was often reused (see Figure 3.1).

Materials such as glass were collected and recycled, since glass objects could not normally be repaired, whilst metal could be both recycled and repaired (see section 3.4).

The use of repaired objects and reused material increases in times of austerity and hardship, when access to new materials is limited. Petrequin (1993: 64), in discussing the technical choices of the cultures around the Jura mountains in the European Neolithic, details the use of antler sleeves – sockets holding stone axe-heads into their wooden hafts – by the people inhabiting the western slope of the Jura. Prior to 3100 BC, antler sleeves were made from fresh antler, the supply of deer and their forest habitat appearing to be plentiful. The economy was a mixture of hunting and light farming, using clearings made in the forest with the axes. Between 3100 and 2900 BC there is evidence of repair and reuse of antler sleeves. This resulted in the development of hybrid tool forms. By this time the forest had been largely cleared, the deer had been killed or driven off, thus the supply of antler for sheaths virtually ceased. Hunting died away and farming became the mainstay of the economy; new antler was obtained from shed antler rather than cut from hunted specimens. The farmers changed the tool forms, adapting them to reuse old sheaths and even directly hafting the axe-heads into the wooden haft.

5.5 Decay

It is convenient to break decay down into two categories:

- neglect/storage, when the object is no longer in active use, but is available for use, usually stored or discarded above the ground;
- burial, when the object is beneath the surface of the ground or under water, normally surrounded by soil and/or water.

Neglect/storage

Decay can occur to the surface of an object during its working life, but more usually during periods of neglect between uses.

- Wooden objects are subject to attack by wood-boring beetles, e.g. *Anobium punctatum* (woodworm), which leave circular flight holes 1–5 mm in diameter in the wood surface. They also burrow beneath the surface of the wood, weakening it and leading to eventual collapse. Moths, e.g. *Tineola bisselliella*, can attack woollen garments, leaving large irregular holes, whilst beetles, e.g. *Anthrenus* spp. or *Attagenus* spp., can also eat fur, feathers and other proteinaceous materials, grazing the surfaces and causing numerous holes and losses. Insect attack occurs on a seasonal basis and is often indicative of objects being stored for a long time. Fungal attack can also occur to wooden, paper and textile objects stored in damp places; this weakens the wood and leads to cracking, often in a cuboidal pattern at the surface. Infestations of mould indicate occasionally damp conditions and lead to white or black discoloration of the surface.

- Light can yellow modern wood-pulp paper and varnished surfaces such as oil paintings. This yellowing usually indicates long periods exposed to high levels of light. Picture varnishes are occasionally replaced to minimize this yellowing effect. Light can have a bleaching effect on dyed cloth, some paint pigments and wood. The original colour of garments is often only present in the folds of seams and hems that have been protected from the light. Well-worn garments are often revealed by such fading and by traces of wear. Similarly wooden furniture which has been bleached by light, invariably sunlight, indicates that it was at some time present near a window or door.
- Exposure to weather, exposure to the action of wind, rain and frost leads to the loss of coating such as paint and varnish, the corrosion of metal, the cracking and greying of wood and the loss of surface of stone, through crust formation and exfoliation or erosion. The effects of vegetation – mosses, algae and lichens – as well as dirt and dust accumulation lead to discoloration of porous surfaces such as stone.
- Dust will accumulate, especially on horizontal surfaces if they are left for long periods. This will lead to permanent surface discoloration of light-coloured porous materials such as the horizontal surfaces of stone, paper and textile objects. This dark discoloration is often seen on the tops of books and the horizontal surfaces of marble statues. Dust particles can often remain trapped in porous surfaces, or on polymers such as picture varnish, and are visible under magnification.
- The handling of metals can lead to corrosion, induced by the sweat from hands. This can etch the fingerprint of the handler onto the object surface. Handling is also attested by the greasy dirt deposited by hands on porous surfaces such as paper, parchment and textiles. The Lindisfarne Gospels page corners show the blackening from turning by many dirty hands over 1300 years (M. P. Brown 2003a).
- Periods of storage in damp conditions can lead to rusting of iron, and corrosion of other metals. If left unchecked, iron corrosion will force off paint layers and other surface finishes, and eat into the metal surface. The red of rusting iron and the green of corroding copper alloys will stain paper, textile, bone, stone, wood and any other porous material in contact with the metal.

Periods of storage often occur on a seasonal basis, e.g. for tools, clothes and cooking utensils, which often only have a specific season when they are used. Some objects are prepared for storage: dust covers placed over fine furniture, iron blades oiled and insecticides applied, e.g. mothballs placed in unused garments. Traces of preserving oils, insecticides or fungicides may be recoverable from object surfaces, and indicate storage and awareness of the risk of biological attack or corrosion.

Burial

Once an object has been buried in the ground, all its materials, save for any gold, undergo decay. This is due to the presence of oxygen and water, which promote the corrosion of metals and sustains the micro-organisms that decay organic material. Consequently only in desiccated, frozen or waterlogged conditions, where either oxygen or liquid water is excluded, is the full range of materials and objects used in the past preserved (Caple 2001). Decay normally starts at a rapid rate, but slows because of the build-up of protective decay layers and the establishment of a chemical equilibrium between the object and its burial environment. It will continue until the object is completely lost. Cotton strips placed in 'normal' moist aerobic soils can be consumed by micro-organisms in a few months. Wood can last decades, and metals centuries. A variety of evidence regarding the objects, their surrounding material and the decay process is preserved in or on the object.

- Metals such as iron, silver and copper corrode, building up corrosion products above and below the original object surface, usually leaving the original surface buried within the corrosion layer. (It can be located by X-radiography and exposed with careful cleaning by a conservator.) For materials such as glass and wood, the material below the original surface decays to form a very soft decay layer, easily damaged with the consequent loss of information. The water in soil supports partially degraded wood, leather, textile and glass, which will dry out upon excavation, becoming cracked and fissured. The original surface of decayed materials such as glass often flakes off when they dry out.
- The build-up of corrosion minerals in materials that corrode quickly, such as iron, can take up the form of surrounding organic material before it decays; mineral replaced 'organics'. This enables materials such as skin, leather, wood and textiles to be identified (Janaway 1984, 1987; Watson 1988; Keepax 1975) as well as the structure of composite organic objects such as wooden boxes (Keepax and Robson 1978) and scabbards (Owen and Dalland 1999; Nissan 1992) (see Figure 3.4).
- The presence of organisms such as nematode worms, which feed off the decaying flesh of a buried corpse, can be attested through casts of the organisms formed in the corroding metals present in the grave. Similarly, traces of fungi can be found in the wood which they are slowly degrading, e.g. wood-degrading fungi present in the charred remains of the mortuary chamber beneath Haddenham long barrow (see Figure 5.5).
- The crushed and broken nature of objects can indicate the collapse of a grave. This can bend soft metal such as gold, e.g. the Bush Barrow lozenge (Kinnes *et al.* 1988; Shell and Robinson 1988). Where metal has corroded and mineralized, it breaks into many pieces, e.g. the Sutton Hoo helmet (Williams 1992). It is important to distinguish between breaks and distortion resulting from burial and deliberate breakage and damage to objects prior to burial, as in the case of the Scar Viking sword and scabbard (see Figure 3.4).
- Staining, especially from iron salts deposited from the groundwater, in or on the object surface. This is principally encountered in porous materials such as ceramics, stone and bone, and it is highly visible in light-coloured materials such as marble.

INVESTIGATION TECHNIQUES

5.6 GC: gas chromatography (GC–MS: gas chromatography and mass spectrometry)

(Pollard and Heron 1996: 66–72; Mills and White 1987: 14–16; Skoog *et al.* 1998: 201–24)

Organic materials such as foodstuffs, adhesives and natural dyes are composed of complex mixtures of molecules. They can be separated and identified using gas chromatography. In antiquity, organic residues such as lipids were absorbed into porous ceramics. They are removed and purified through dissolution in solvents such as chloroform and methanol (2:1). A synthetic standard such as *n*-tetratriacontane is normally added to the sample before evaporating to provide a solid residue. This residue is then usually derivatized, e.g. chemically treated to produce methyl esters, to enable it to be readily separated by subsequent gas chromatography.

The material is then injected into a gas chromatography column. Packed columns (coiled glass tubes up to 5 m long, 2–6 mm in diameter, packed with fine-grained support media coated with a stationary phase) have been replaced by capillary columns – coiled tubes, increasingly made of flexible quartz and up to 100 m long, 0.2–2 mm in diameter, coated internally with a stationary phase such as immobilized dimethyl polysiloxane. A carrier gas – normally helium, though hydrogen, argon and nitrogen have also been used – is fed under constant pressure through the column. The column is located in an oven, which runs at a raised temperature. Increasingly GC is performed using rising temperatures, e.g. 10 °C per minute to a temperature of 350 °C. This is sometimes referred to as high-temperature gas chromatography (HT-GC). This increasing temperature volatilizes the different components of the sample, which are then carried through the column at different rates. Their retention time in the column depends on several factors: the pressure and nature of the carrier gas, the oven temperature, the molecular weight and the affinity of the sample molecules for the stationary phase coating the column walls.

The molecules finally emerge from the column to a detector. The most widely used detector is the flame ionization detector (FID). A hydrogen–air flame burns below two charged plates, and the resistance between the plates is measured. Organic molecules arriving into the flame create an ionized gas and an increase in current passing between the two plates. The resistance or the passage of current, which creates a measure of relative intensity, is graphed against the retention time, giving a trace of peaks, which signify the amounts of organic molecules present in the sample and the retention time (see Figure 5.3). The presence of a known standard helps calibrate the system. Comparison with known compounds and libraries of spectra allows groups of peaks to be identified and related to specific materials.

GC was previously only effective for materials that would volatilize in oven temperatures; thus many larger molecules such as rubbers and resins could not be analysed by the technique. However, the development of pyrolysis gas chromatography (Py-GC),

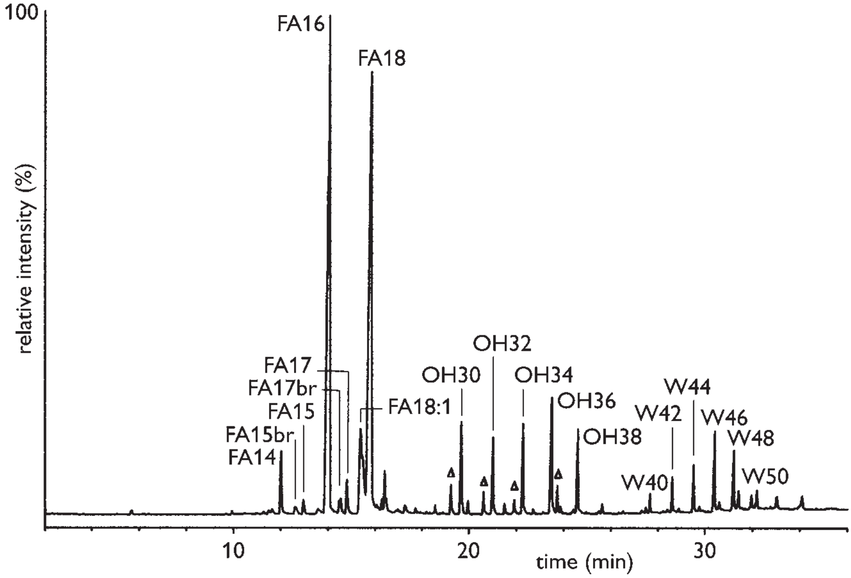


Figure 5.3 Gas chromatogram. Sample D24 from Dryslwyn Castle, showing beeswax [palmitic wax esters (W peaks) and their alcohol degradation products (OH peaks)] and degraded lipid residues (FA peaks). (Image courtesy of Mark Copley and the author)

which heats solid material samples and breaks them into smaller volatile components, has allowed larger molecules to be characterized by GC through identification of their thermal breakdown products.

In some instances it was not always possible to identify the organic molecule on the basis of GC. To provide more accurate molecular identification, specially adapted mass spectrometers replaced flame ionization detectors to create GC–MS systems. Mass spectrometers (see section 4.7) such as the smaller quadrupole mass spectrometers, which have faster scanning times and lower operating voltages but also lower mass resolution, are used with GC systems for identification of organic materials. Examples of the use of GC and GC–MS are given in section 5.2.

5.7 SEM: scanning electron microscopy
(Olsen 1988; Goldstein *et al.* 1992)

The scanning electron microscope (see Figure 5.4) uses a beam of electrons rather than light to image the object. This allows it to achieve high magnifications, up to ×100,000, though normally magnifications in the range ×10 to ×5,000 are used. The wavelength of light limits optical microscopy to magnifications of ×1,000 to ×1,500. Scanning electron microscopy also creates a clear image with a good depth of field,

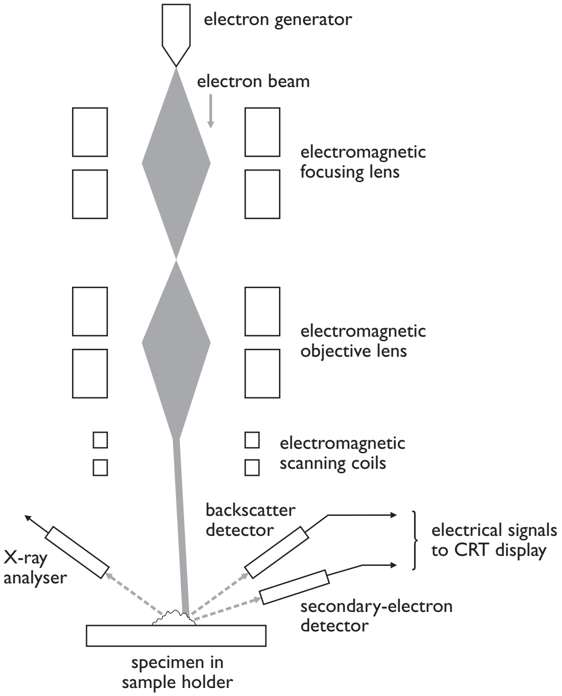


Figure 5.4 Scanning electron microscope

roughly 300 times better than for optical microscopy (Olsen 1988: 3), allowing the viewer to see 3-D images at high magnification. Most SEMs also have the ability to analyse the composition of the artefact being examined.

Wherever possible, samples are broken off the object to be analysed, since cutting with a blade distorts the surface. The samples, which can be microscopic in size to avoid visual damage to an object, are stuck to small aluminium stubs using an adhesive that makes the specimen electrically conductive. Samples can also be mounted in a resin, like metallographic specimens, and polished and organic materials are normally freeze-dried. To gain better-quality pictures and to enable the samples to be examined at higher magnifications, samples are usually sputter-coated with either a gold or a carbon coating, in order to make the surface a better conductor. The stub and sample are normally placed in a holder and inserted into a chamber beneath the column of the SEM, and the system is put under vacuum. A tungsten filament at the top of the column is heated to provide a stream of electrons, which are accelerated to high speed using a high voltage and focused to a fine beam, as small as 1 μm in diameter, using electromagnetic lenses. This fine beam of electrons is scanned across the surface of the object in two dimensions, using a series of scanning coils (see Figure 5.4). The electrons that hit the object surface create a number of effects:

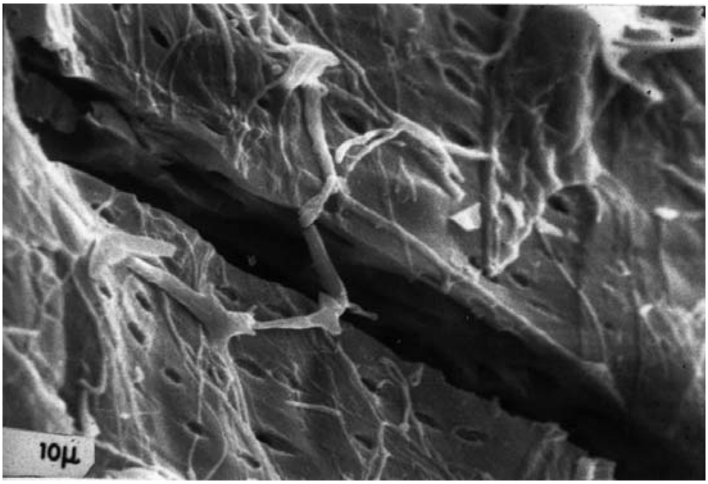


Figure 5.5 SEM image of fungal hyphae in carbonized wood. Fungal hyphae present in the carbonized wood of the burial chamber from the neolithic long barrow at Haddenham, Cambridgeshire. Carbonized hyphae (severed by the crack) reveal fungal attack on the wooden structure in the Neolithic; modern fungal hyphae (crossing the crack) show attack on this archaeological carbonaceous material in the present. (Photograph by the author and Will Murray)

- Secondary electron emission: the electron beam knocks electrons off the atoms at the surface of the specimen. These secondary electrons are detected by a low-energy electron detector. More electrons are knocked off the upper/higher parts of the specimen, fewer from the atoms in the valleys of the specimen. The monochrome image created has lighter upper surface areas and darker lower ones, a surface morphology that mimics the effect of light on a surface, providing us with a familiar surface topography image (see Figure 5.5). This technique enabled investigators to detect very slight visual effects such as wood grain effects on the surface of Peruvian ‘plume’ gold cups, so indicating they were beaten into shape over a wooden former (Goodburn-Brown 1988). Marks made by individual tools, such as the punches used to manufacture the Gunderstrup Cauldron, can be identified (Larsen 1987) (see section 3.6).
- Backscattered electron emission: some of the primary electrons from the beam are bounced back by the nuclei of the atoms in the specimen. They are detected by a high-energy electron detector. Elements with a large nucleus, i.e. heavy elements such as silver or lead, are more effective electron reflectors than light elements with small nuclei. Detecting across the specimen’s surface builds up a map of the distribution of the heavier elements (Meeks 1988).
- X-ray analysis: this is essentially similar to the EDXRF system described in

section 4.6, but rather than a primary X-ray beam, the electron beam displaces inner electrons from some of the atoms in the sample surface. Such analytical systems are often referred to as EDX or EDAX. The system can perform qualitative and quantitative analysis, and modern SEM systems with EDXRF analytical capabilities are normally capable of operating in four modes:

- a single spot, with a small beam diameter; such systems can analyse inclusions in rocks or slag particles in metal;
- a line across the specimen, or part of the specimen, often used across mounted sections to reveal details about coatings or corrosion on metals;
- an area of the specimen for a general composition;
- a single element across an area, giving a map of the presence of the element in the scanned area – elemental mapping.

Archaeological and historic artefact samples are usually examined in secondary electron emission mode, initially at low magnification. This may be viewed with lower voltages and slower scanning speeds. Since the stub is in a holder which can be moved using a series of external screws, the specimen can be positioned at a place of interest and oriented to achieve the best image. Subsequently specimens can, if required, be examined with backscattered electron and EDAX analysis capabilities.

For larger objects that will not fit into the SEM, areas of the object's surface can be moulded in materials such as silicon rubber, then mounted on stubs, coated with carbon and viewed in the SEM. This can give an accurate and detailed (negative) image, but no analytical information. Only dried materials can be analysed in normal SEMs, so organic materials are normally desiccated by freeze-drying or critical-point drying, coated and examined.

CASE STUDIES

5.8 Winchester Reliquary

(Hinton *et al.* 1981; Keene 1987)

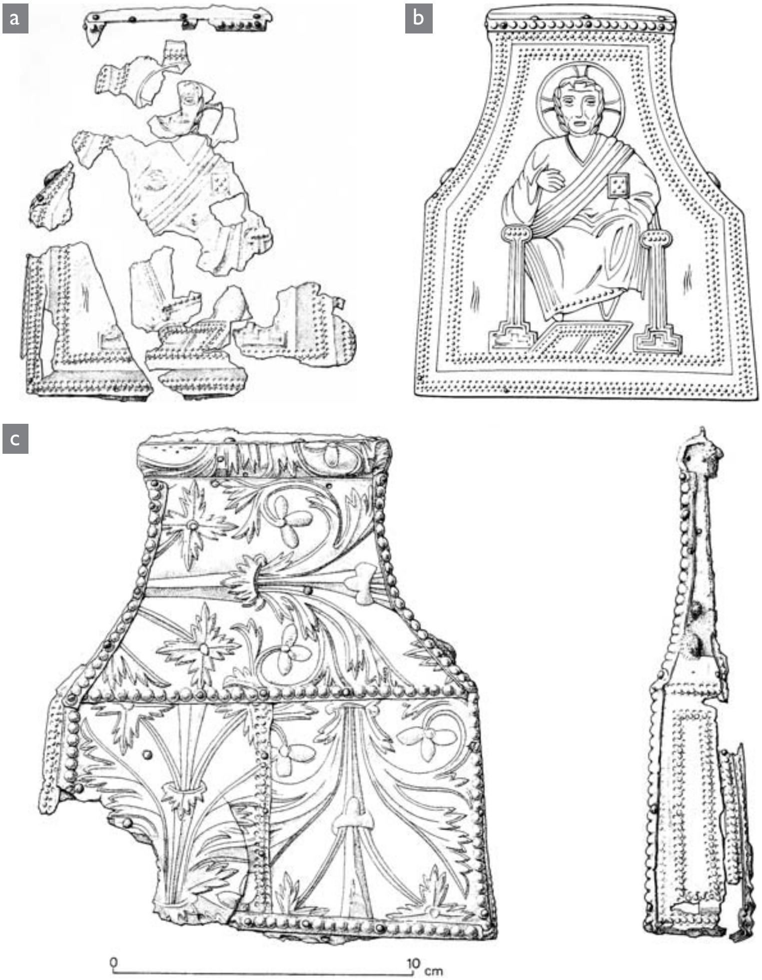
Context

The reliquary was discovered near the base of a two-metre-deep latrine pit, probably associated with a group of late Saxon houses fronting onto the predecessor of modern Sussex St., in the Saxon suburbs of Winchester. The reliquary was a large thin purse shape, a type known as a burse reliquary. It had a wooden core covered in sheet metal, though the front sheet had been torn off and the lower left corner of the wooden core was missing. Further fragments of metal were found deposited beside the reliquary in the latrine pit. Reliquaries were richly decorated containers that held the relics of a saint or other holy objects. They were venerated and worshipped; many were reputed to be responsible for miracles. Significant numbers of reliquaries were created between the seventh and eleventh centuries AD during the height of their popularity. Though normally located in churches, reliquaries were often taken in procession to bless people and places.

Manufacture

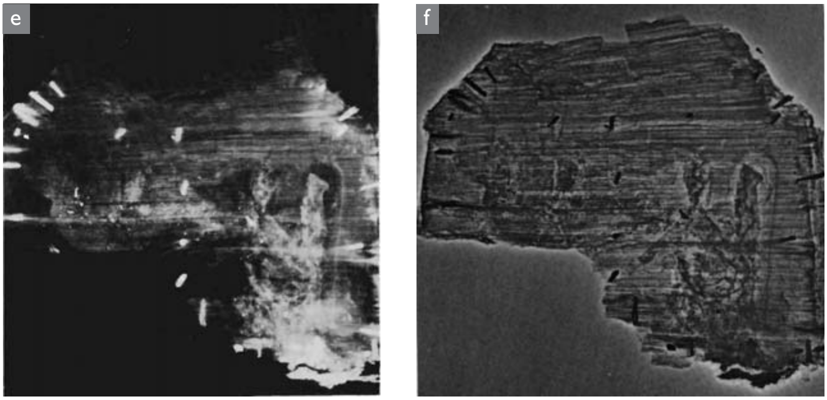
The reliquary was 150 mm wide, 175 mm high and 35 mm thick at the base, tapering to 10 mm at the top (see Figure 5.6). The metal of the reliquary was corroded with green corrosion products, the wood degraded and wet, though the conditions were not waterlogged. Examination of the object utilized X-radiography and xeroradiography (section 2.10), followed by partial disassembly and cleaning prior to conservation.

- The wooden core was formed from two sheets of wood; a flat piece of material currently projects from between the two sheets.
- Analysis of microscopic samples of the wood showed that it was beech, a hardwood, frequently used for basic woodwork and carving.
- The X-radiograph showed that there were channels cut into one or both pieces of wood, which formed cavities when the pieces of wood were placed together. These cavities contained the relics, at least one of which was still *in situ*.
- The density of the relic, revealed by X-radiography, indicated that it was not metal and did not have the structure of fabric or wood, and is probably a small roll of parchment, which may contain dust, hair or similar small 'holy' fragments. Alternatively it could be a piece of leather or bone.
- The piece of flat material that protruded from between the two pieces of wood was seen to have the fibrillar texture of skin when a fragment was examined under an SEM (section 5.7). This is almost certainly a piece of parchment which



The mercury gilded bronze sheet (identified by EDXRF), had been torn off the front of the wooden ‘purse-shaped’ reliquary and was in fragmentary condition (a). It was reconstructed to reveal it depicted ‘Christ in Majesty’ (b), a depiction of ninth- to tenth-century date, probably of local manufacture. The acanthus-leafed decorated gilded sheet metal on the back (c) had a leaf form popular in Metz in Germany, from where this sheet metal probably originated. The beechwood of the reliquary had hollows carved into it, revealed by the X-radiograph (e) and xeroradiograph (f), which contained at least one relic and a scrap of parchment which may have been a document of authenticity.

Figure 5.6 Winchester Reliquary: details of materials and manufacture. (Drawings from Hinton *et al*. 1981, courtesy of Winchester City Council; X-ray and xeroradiograph images from Keene (1987), courtesy of Suzanne Keene)



probably originally had information written on it detailing the nature of the relic and confirming its authenticity. These ‘authentiques’ were a common feature of reliquaries.

- The sheet metal was analysed using EDXRF (see section 4.6): it was a low-tin leaded bronze, with a trace of arsenic in the alloy. The composition of the sheet metal on the front and the back was very similar. The sheet metal on both the front and back was decorated with a raised design. This repoussé work was hammered, freehand, from the back since there is no evidence of hammering into moulds. The edge of the raised design had been accentuated by an impressed groove chased in from the front. Fine lines in the groove suggest a blunt steel chisel was used.
- Cleaning revealed that the exposed surface of the bronze sheets on the front and back of the reliquary were both gilded. The sheet on the front of the reliquary was ‘thicker, brighter and shinier’ than that on the back. Clearly there are slightly different gilding histories which have different visual appearances. However, analysis with EDXRF revealed that gilding on both contained mercury, and thus the bronze sheet had been mercury-gilded, the most common gilding technique in the medieval period, probably applied after the raised designs were created.
- On the shoulder of the left side of the reliquary were two iron nails/rivets, with a halo of material surrounding them, stained with iron corrosion products. It is likely that this represents the attachment points for a strap, the halo being the degraded remains of a textile or leather strap. The lack of any discernible microstructure prevented more exact identification. Two corresponding holes were seen in the left side of the wooden reliquary. The sheet metal from the right side was not recovered.

- The metal sheet on the back of the reliquary was composed of several pieces cut from a larger sheet which had been decorated with a raised acanthus leaf design with beaded decoration at its edge. Pieces of this sheet had been cut out and attached with 10-mm-long copper tacks to the wooden reliquary. The pieces were oriented in such a way that their raised beaded edging framed the reliquary, and, where this was not possible, additional strips of raised beaded decoration had been cut from the original sheet and added to give a complete beaded border around the edge. Given the large size of the acanthus design and its poor fit to the reliquary, this decorated sheet had clearly been intended for another object. However, the lack of nail holes or other evidence of attachment suggests it had not actually been used.
- A three-quarter-cylinder of the acanthus leaf decorated sheet was bent over the top of the reliquary.
- The metal sheet on the front of the reliquary was decorated with a raised design of a seated figure, Christ in Majesty. Around the edge, and on the footstool, which was part of the central design, was a double row of raised dots with lines of circular punchmarks either side. This 'dot and dimple' border was also used to decorate the sheet metal of the sides (only one remained) and a single line of 'dot and dimple' decoration had been added to one of the sheets in the centre of the back, hammered on top of the acanthus leaf decoration. The Christ in Majesty panel exactly fits the reliquary and appears to have been deliberately made for this object.

Form and decoration

Britain lost its reliquaries as a result of the Reformation, but there are a number of similar purse or burse reliquaries with wooden cores and covered in sheet metal remaining in continental Europe. A ninth-century example from Saint-Maurice d'Agaune has a silver gilt sheet metal covering; another ninth-century example with six cavities in its wooden core comes from St Ephanusbirsa in Vienna. Earlier examples such as the seventh-century example in the Musée de Cluny, Paris, are also found. One continental reliquary, Coffret de Mortain, which has the more common form of a small house-shaped chest, was almost certainly made in Britain, since its runic letter inscriptions are of Mercian or Anglian origin. Reliquaries of purse form were made and used throughout Europe, including Britain in the seventh- to tenth-century period.

The raised decoration on the sheet metal of the front and back has both similarities and differences with decorative images and motifs of the seventh- to tenth-century period.

- The acanthus design on the reverse has the form of a tree stem with calices or nodes (two forms are visible) supporting a multi-pointed acanthus frond, a trefoil flower on a curling stem and a quatrefoil acanthus leaf on a straight stem, all with beaded border. The spiky and heavy-veined acanthus leaves are paralleled in both an eighth-century screen from Metz and ninth-century ivories from Metz. The roundel in the trefoil leaf is paralleled in late tenth-century English art, e.g. the Benedictional of St Ethelwold. Other features such as trefoil leaves are found in both English and Carolingian art in the ninth century. Consequently this gilded repoussé decorated sheet metalwork was probably made in the Metz area, or possibly in Winchester and greatly influenced by the artistic output from the Metz area, in the ninth century.

- The 'Christ in Majesty' figure is rare in British and Continental art, though it does occur. A comparable Christ figure, depicted with a limp left hand, lacking any clear gesture, is present on the stole and maniple of Bishop Frithestan of Winchester, probably embroidered in the early tenth century in Winchester. The heavy lines of the robe passing diagonally across the chest is paralleled in British (insular) art of the ninth century, continuing in Winchester into the early tenth century. The double beaded border occurs in seventh- to ninth-century insular art, and the footstool appears to be an insular development from Mediterranean originals, as exemplified in the Mathew picture in the Lindisfarne Gospels (M. P. Brown 2003a). The clean-shaven Christ is normally seen in Continental European depictions; in most insular art, Christ is bearded. On balance this is probably late ninth- or early tenth-century work from Britain, most probably from Winchester but with significant continental European influence.

Use

The gilding was worn off the high points of the metal sheets on both front and back, probably as a result of touching by devotees, although the lack of surface scratches might suggest some care, e.g. storage under a cloth cover. The edge of the front sheet near the broken corner was held in place with a couple of tacks. This suggests that there had been damage to the corner and then some attempts to care for and repair the damage before the final phase of loss and damage to this object.

Visually the gilding appeared to be missing from the centre of the back sheet; however, EDXRF analysis indicated that it had exactly the same composition as the gilded areas. Thus it is likely that the surface gilding had been absorbed into the copper alloy, a phenomenon which occurs during uncontrolled heating to several hundred degrees centigrade. Since it is unlikely that such a damaged piece of metal would have been used to decorate a reliquary, this probably occurred during the working life of the object. It is possible that the church in which it was stored was damaged or burnt down by fire.

The fragments found beside the reliquary were the sheet metal which originally covered the front of the reliquary, but which had been torn off, and then deliberately folded up. The damage indicates that it had been torn from the front of the reliquary, possibly in the hope that it was pure gold and could be melted down for bullion. Upon discovery that it was merely gilded sheet bronze, it was folded up and thrown away, together with the rest of the reliquary.

Trade

All the materials, such as beechwood, low-tin leaded sheet bronze and gold, were available in the British Isles. Artistic ideas such as thin-pointed and deep-veined acanthus leaves were imported from continental Europe through the form of images in illuminated manuscripts, carved ivories and other artworks.

Conclusion

It is likely that an existing sheet of gilded repoussé acanthus decoration, probably originally made in Metz, was cut down to fit the back of a wooden purse reliquary. The presence of the lines of the 'dimple and dot' decoration on the front, side and back sheets of metal suggests that the manufacture of the front and side sheets and the cutting-up and adaptation of the back sheet to cover the back of the reliquary all occurred in one workshop at the same time. Given the similarity in composition of the front and back metal sheets, it seems likely that the front sheet was originally a piece of the acanthus-leaf-decorated sheet, which was beaten flat and had the 'Christ in Majesty' design added. Given the design affinities of the Christ in Majesty, all this work was probably executed in Winchester in the late ninth or early tenth century.

The object came from the deliberate infilling of a latrine pit with soil containing late ninth- or early tenth-century pottery. This may suggest deposition as an early tenth-century event. It is a religious object, which speaks of the beliefs of the late Saxon people of Winchester and it would have been an important part of the contents of a late Saxon church. The evidence of wear and repair on the reliquary metalwork suggests years of devotion and religious use. However, tearing off the front metal sheet, possibly in the belief that it was solid gold, was an act of sacrilege. The context from which it was recovered suggests that it had been deliberately discarded in a place where it would not be discovered: a further act of sacrilege. This suggests the reliquary was stolen, or looted during a period of warfare, and then discarded: evidence of greed and fear of apprehension at the end of this object's working life. This reliquary provides a graphic picture of contrasting beliefs and events in early tenth-century Winchester.

Chapter 6

Objects as record (information/education)

WHEN?

6.1 Heirlooms and proof of the past

From the time of the ancient civilizations to the present, human beings have collected objects (Lewis 1992). Among the principal types of object collected are items from an earlier human past, indicating the importance which the past has for people (Lowenthal 1994). Many reasons for such collecting have been advanced (Pearce 1995; Akin 1996; Caple 2000: 15); they can be grouped into two basic forces:

- A personal past: objects from a person's childhood or their grandfather's medals, objects which mean a lot in emotional and personal terms, i.e. heirlooms. These objects are used to evoke memories; they are souvenirs or mementos. They are not primarily intended for others to see, and are normally confined to someone's personal space, their rooms or houses. They provide people with a comforting sense of where they are from, where they fit in the world. Interest in such objects, which are often considered attractive or interesting by the individual, grows into a hobby, and the objects into a collection. Many personal art and antique collections start in this manner.
- An authoritative past: objects of the past are used to educate or convince those who view them, to see and understand the world as the collecting and displaying authority does, i.e. the past as a proof. Medieval churches were filled with the relics of saints, which promoted miracles – reinforcing the supernatural powers of a Christian god. British nineteenth-century art galleries and museums displayed Victorian ideas of good taste and the 'correct' view of history. This 'truth past' is a recognition that the past is powerful; to quote Big Brother in George Orwell's *Nineteen Eighty-Four*:

  > Who controls the past, controls the future; who controls the present controls the past.
  >
  > (Orwell 1949)

Many private collections are a combination of the two instincts: a genuine love of the object and the desire to show their collection to others so they will 'read and understand it' and then, no doubt, believe/appreciate as the collector does. This has led every interest group, every industry and every nation to tell its story, prove its importance and justify its present/presence with a museum.

The concept of proof and 'the truth' has evolved in present-day society. No longer does the word of a gentleman guarantee a truth. Since the Age of Enlightenment and the rise in educational standards of the twentieth century, people have demanded high levels of certainty; they expect facts and figures (evidence) to be presented. Indeed we seek and expect 'physical' evidence or 'cast iron' proof; for most of us 'seeing is believing'. In this sense, the objects of the past are historic documents (see section 1.4), the physical proof of the past, 'the nearest thing to an objective past' (Lipe 1987). This need to see things with our own eyes follows a childhood instinct to touch things with our hands and continues a process we start at birth, assembling information and constructing a framework of knowledge and understanding in order to be able to function efficiently in the world in which we find ourselves (Caple 2000: Chapter 1).

Objects such as religious relics have acted as a focus for worship for many religions, a physical manifestation of divinity. They formed a conduit between this physical world and the world eternal (Pomain 1994). Pilgrims flocked to see, and if possible, touch or even kiss relics, such as the Turin Shroud. The use of relics was encouraged by the Church, finding it a useful focus for believers, with instances of miracles increasing when relics were rediscovered or rehoused in expensive new shrines or even progressed in procession (Geary 1986). In the medieval world, physical evidence such as fossils or ancient Roman coins proved the presence of a supernatural world of giants and mermaids. These pieces of physical evidence were collected and presented in 'cabinets of curiosities' in the seventeenth and eighteenth centuries, ultimately giving rise to the museums and collections of the modern era (Lewis 1992; Pearce 1995).

Old and desirable

There are periods for any society, especially following a period of austerity such as the Second World War, when new goods and styles are highly fashionable. There are also periods, often of social and economic change, when traditional styles and artefacts are popular. However, in most periods, as Willmott (2001: 103) observes for Britain in the early seventeenth century, with its new blue-and-white pattern Delft ceramics and maiolica ware with traditional armorial shield designs (Archer 1997), there is evidence of both new fashions and traditional styles.

The presence of older objects such as pewter dishes, not for serving food but for display, in late eighteenth-century homes, exemplifies the value of an object's age; presumably they were displayed to emphasize the long-term social standing of the family (Smart-Martin 1991). Willmott (2001) drew attention to a group of seventeenth-century wineglasses that had been repaired with lead strips or wire, especially at the stem. Such objects would no longer function effectively as drinking vessels, though they had clearly been repaired, which would appear to give them a symbolic function. Again these may have acted as heirlooms or status symbols, a role which may also have been given to the Roman Samian vessels repaired with riveted lead strips or butterfly rivets (Marsh 1981; Ward 1993). Such obvious and non-functional repairs can be distinguished from other repairs, that kept objects functioning (e.g. Charters *et al.* 1993). Though obvious, the repairs may have acted in the same way as patina, indicating age and an earlier 'life' for the vessel. Any and all objects may show signs of repair. However, such repairs may not be subtle or invisible: they may even have been deliberately emphasized to show the age and importance of the object.

Authenticity

The need for objects such as medieval Christian relics to be accepted as truly holy led the church to issue authenticities, scraps of parchment attesting to the fact that these were genuine relics of the saint (see section 5.8). Such authenticities indicate the awareness of fake relics. The importance of establishing and confirming authenticity had also been appreciated by the English State by the thirteenth century, when the practice of hallmarking gold and silver objects began (see section 2.5). Similar desires to guarantee authenticity because of the higher value of authentic artefacts led artists to sign their works of art (see section 2.8).

As the cabinets of curiosities gave way to museum collections, and study of the past led objects to be placed in material cultures and typologies, a greater degree of truth and certainty was required. The concept of authenticity was more strictly applied. Mermaids and other 'curiosities' were relegated from natural phenomena to folk art. Incidents such as the Van Meegeren affair (Jones 1990; Marijnissen 1985) and Piltdown Man highlighted the limitations of some scholars and the abilities of gifted forgers to fake objects. This led to the development and use of scientific analysis and dating techniques to determine authenticity. These created a clear distinction between the authentic objects from a historic period and fakes or pastiches (see section 6.3). However, in recent years more detailed appreciation of ancient artefacts has started to raise the question of the degree of authenticity of many objects we have considered 'authentic'. Detailed examination has often revealed:

- Many objects have been cleaned, altered and repaired, often during the working lifetime of the object. Thus the object is far from completely original. Many objects such as the York Anglian helmet show evidence of repair, but these would not be considered as anything other than authentic. As the repairs become more extensive and later in date, the percentage of the original object becomes less. The original surface may be substantially obscured by later coatings, e.g. the portrait of Prince Henry on horseback (see section 2.12). The Bayeux Tapestry has extensive later restoration, which raises questions of the accuracy of some of the depictions (see section 2.11). At what stage does an object cease to be authentic?
- The surface of the object we currently see is often not the original object exterior. It may have been lost through the effects of decay or be buried within the corrosion crust of a corroding metal artefact (see section 5.5). The surface may have been lost through use, or removed through cleaning. Durham Cathedral is built of a beautiful honey-coloured stone that had by the eighteenth century become

blackened with soot and degraded by weathering. The cathedral architect, John Wooler, in the 1770s and 1780s had stonemasons chisel two to three inches of stone off the whole of the outside of the cathedral (Roberts 1994). This changed the dimensions of every exterior architectural detail. All the openings were four to six inches wider, whilst the pillars and all other decorative motifs were two to six inches thinner. This has considerably altered the proportions of the exterior stonework features of this cathedral. However, which is more authentic: a stone-coloured building which looks from a distance as the medieval architect intended, or a black building with original surface features?It may depend on how close to the building you are standing when you answer the question. A similar loss of surface evidence has occurred to many of the archaeological metal objects that were electrolytically stripped in the early twentieth century. Though this technique stabilized the object and halted any further decay, in removing all the corrosion layers it removed valuable surface evidence (Norman 1988).

- We do not see objects with the same eyes as their original makers, nor the eyes of their intended audience. Thus not only does a Roman altar in a present-day museum not look like an original altar (see Figure 6.1), since the effects of weathering and cleaning have removed all trace of the paint which would have originally covered the whole object, but it is not seen with the reverence due to a religious artefact. It is not perceived as a holy place at which one can directly communicate with a deity, e.g. through the sacrifice of an animal. This problem is particularly noted with ethnographic objects, where the symbolism and power of objects, the meaning of their decorative designs, the presence of the spirit of the maker, is rarely fully known to the curator, let alone appreciated by the museum visitor. In what sense is the object authentic to us?
- Whilst it may be imagined that authentic objects, the 'real thing', are the most powerful and meaningful, and copies are pale imitations, this is far from true. The copies may be exact likenesses, indistinguishable from the original artefact, and if the viewers cannot touch or analyse the objects they may have no way of determining which is the original. Some copies are now more informative than the originals. In the case of the Parthenon marbles, plaster casts of some of the frieze panels made by Lord Elgin's team in 1802, have preserved the clarity and detail of the figures, whilst the frieze panels themselves which remained on the building have been much eroded by centuries of pollution (Neils 2001; I. Jenkins 1994; Brommer 1979; Robertson 1975).
- Early extensively restored objects such as the Piranesi vase may possess the apparent detail of an original object, but given the 'in the style of' approach of restorers in the nineteenth century, who reconstructed objects with little or no evidence, such objects cannot be seen as authentic (Miller 1992).

Objects through their form, function and decoration usually appear to derive from a given material culture of a given period. This is implicit, but it can also be explicit in the form of a label. Many copies of objects seek to portray themselves not as the original, but as a copy or merely an object which has borrowed some historic

Figure 6.1 Roman stone altar from the Roman fort of Carrawburgh (RIB1539), on display in the Museum of Archaeology, University of Durham, devoid of its original painted surface, without ritual context or sacrificial offering. (Photograph by Jeff Veitch, image courtesy of Durham Cathedral)

features. Authenticity is perhaps the degree to which an object is or is not what it claims to be.

Whilst scientific tests to determine date, or appropriate pigment or alloy composition, are often important for determining the authenticity of many objects, they are costly, time-consuming processes. A good knowledge of the typology of objects – the types of materials, fixings, tools, etc., used by the craftsmen of the relevant period/

material culture (Bly 2002) – will enable any investigator to quickly check the authenticity of almost any object. A knowledgeable visual inspection has led to the quick and simple detection of thousands of fakes. Given the effects of decay and the alterations during and after a working life, a simple categorization of an object as authentic or not authentic is frequently inappropriate. It is more informative to examine an object carefully and establish the extent and nature of original material, and of all later additions, and so develop a detailed biography of the object's life (see section 1.9).

6.2 Dating

Dating is the process of putting an object into a framework of the past, a framework which contains all the other information about the past: other objects, buildings, historical events, religions, literature, music, etc. Pieces of the framework have convenient labels, e.g. the Renaissance or the Romano-British period. Parts of the framework, such as European prehistory, were initially relative; stone tools came before those of bronze, but they lacked absolute dates. Other parts of the framework were more detailed, as in the case of ancient civilizations such as Ancient Egypt, China or the Roman Empire, where sequences of rulers, pharaohs and emperors had been established through coins and inscriptions. Written histories for Roman and medieval Europe meant that there was a dated framework, though it was often difficult to place objects accurately in this framework. Scholarship eventually allowed these different chronologies to be related to a single measure of time based on solar cycles, i.e. years. In the last fifty years have we been able to use scientific or 'absolute' dating methods to date objects made of materials from periods and cultures where there were no written dates, to form a complete calendrical framework of the past.

Dating objects can be considered as operating at two levels:

- Relative date: placing an object in the correct material cultural context to which it relates. A term such as 'Roman' or 'Art Nouveau' places an object with others in a material culture environment which has a series of associated historical events.
- Absolute date: placing the object in a precise moment in time, normally defined in an annual calendrical framework. This allows historical, even astronomical, events to be related to material cultures. It also enables seemingly unrelated objects and untypical artefacts to be associated with known material cultures. Different material cultures can be accurately related one to another; climate and vegetation change can be related to human history. The association of all this evidence allows us to gain a more holistic view of the past.

A wide range of techniques are used for dating artefacts. Most are dated through a combination of several techniques.

- Typological comparison of form or decoration with a known series of objects or an artistic style or movement (see Chapter 2).

- The date at which a material was first used, or a manufacturing technique was first practised, within a specific material culture provides an earliest date after which (*terminus post quem*) an object containing that material or utilizing that technique, from that culture, could have been made. This is exemplified by the detection of traces of mercury on a gilded object. Since fire gilding (with mercury or amalgam) only began to be used in the Roman period, any object (or, to be accurate, its gilding) with traces of mercury in the gilding must date either to the Roman period or later (Oddy *et al.* 1988).
- Archaeological context: the finds in an archaeological deposit provide, through typology or an absolute dating technique, dates for any associated objects. The latest date from an object in the context stratagraphically beneath the deposit containing the archaeological object will provide the date after which the object was deposited (*terminus post quem*). The date of deposition of the context stratigraphically above the layer containing the object will provide the date before which it was deposited (*terminus ante quem*). The problem of residuality, the incorporation of older material into archaeological deposits, means that such dating rarely provides an unambiguous date from the material in the deposit: it must be interpreted, and the residual material discounted for the purpose of dating the deposit. The degree of contamination of the archaeological deposit with later material depends on the skill of the excavator and the nature of the deposits.
- Historical context: the finds associated with an historic object rarely come, like archaeological material, from a sealed context. In a context, such as a historic house, objects have been accumulated over many years, so providing no contextual dating evidence.
- Historic association. An attribution of an object to a known artist or craftsman can provide a date. This may be on the basis of a signature or style. The level of certainty of the attribution may vary. An object may have the name or initials of an owner or an organization inscribed onto it, and this may also provide an associated historic date.
- Recording. Occasionally an object is recognized as being depicted in an image such as a photograph or oil painting, or referred to in written texts such as a will. Provided this image or literary reference is dated, then a date by which the object was in use will have been established.
- Image. The object itself can depict something that can be dated. The image and the object bearing it must have been created after the event it records (*terminus post quem*). Images can have a long currency, e.g. Queen Victoria was still depicted on coins as a young woman in her twenties when she was in her forties. The coins remained in circulation for a further sixty years.
- Dating or hallmarking. Whilst modern coins may have dates in years, coins from earlier reigns or those issued by the Roman emperors record the year of the reign and thus have to be converted to calendric dates. Dates on paintings or carved into furniture are potentially useful, though they may have been added later. They should always be examined to ensure they are contemporary with the work

and that the work matches the claimed date in terms of style, materials and technique. One of the stamps in a series of hallmarks depicts the date of hallmarking of the piece, which was normally made in that or the preceding year.

- Scientific (absolute) dating technique: dendrochronology (Baillie 1995; Aitken 1990). Fluctuations in the thickness of the growth ring of trees are principally determined by climate, and the ratio of the thicknesses of successive rings provides a unique pattern. Samples of wood produce patterns that can be matched to master chronologies, which stretch from the present to prehistory for species such as oak. Thus objects made of oak grown in Europe that can provide samples of 50 to 100 rings, such as panel paintings, furniture and structural timbers from ships and houses, etc., can be dated, as in the case of Durham Cathedral door (section 6.8).
- Scientific (absolute) dating technique: radiocarbon dating (Aitken 1990; R. E. Taylor 2001). Determination of the proportion of the ratio of the radioactive ^{14}C isotope to the stable ^{12}C isotope allows a determination of age to be made, since ^{14}C is present in almost constant amounts in all living material and decays at a known rate (half-life, defined as 5730 years) after the organism dies. Radiocarbon dates are expressed as a date range to account for the errors in counting, and are corrected using a calibration graph for fluctuations in the amount of ^{14}C in the biosphere. All organic material (wood, bone, textile, paper, leather, polymer) more than four hundred years old can be dated. Samples containing as little as 1mg of carbon can be used for accelerator mass spectrometry (AMS) ^{14}C dating (Hedges *et al.* 1989). Using several uncontaminated samples enables a more accurate date to be obtained, e.g. Durham Cathedral door (see section 6.8).
- Scientific (absolute) dating technique: thermoluminescence (Aitken 1990; Fleming 1975). Heating the small quartz and feldspar crystals present in ceramics causes them to emit light flashes which derive from electrons emitted by natural radioactive minerals trapped in these crystals. By monitoring the number of light flashes and determining the level of natural radioactivity and the ability of the crystals to trap electrons, the length of time the crystals have been trapping electrons, i.e. the time since the ceramic was last heated (used or made), can be determined. This technique is usually applied to archaeological objects more than one hundred years old. It can be used for almost all ceramic artefacts (brick, tile, pottery, terracotta statues, etc.) and burnt stone, and has proved highly effective in detecting modern forgeries (e.g. Peacock 1973). Several grams of sample are required.

Other scientific (absolute) dating techniques, e.g. potassium–argon, uranium–thorium, archaeomagnetic dating and electron spin resonance, have little direct role in dating artefacts, though they can date deposits associated with archaeological artefacts.

Dating an object allows it to be placed accurately in the existing framework of ancient civilizations and historic events that makes up our past, and enables fakes and forgeries to be revealed.

6.3 Fakes and forgeries

There are many different terms used to describe objects of the same or similar visual appearance to an original:

- copy or replica: an object of nearly identical visual appearance to an original object, sometimes made of similar materials, but without the intention to pass it off as the original object (see Figure 6.2);
- fake or forgery: an object of very similar visual appearance to an original object, sometimes made of similar materials, with the intention of passing it off as the original object;
- reproduction: an object with a similar visual appearance to an object of a given period;
- pastiche: an object with the general appearance to the objects of a given period, which is normally composed of one or more parts of ancient objects (see Figure 6.3);
- restoration: largely an original object with areas of damage or loss repaired to appear as an original.

The presence of two or more objects of near identical visual appearance may occur with mass-produced items, such as Roman Samian pottery. Copying or faking occurs when there is an earlier object that is subsequently replicated.

> Each society, each generation fakes the thing it covets most.
>
> (Jones 1990: 13)

Every society gives enhanced value to certain objects, far beyond the costs of their materials and manufacture. High values encourage fakers to produce copies that can be passed off as the original in order to benefit the producer. Forgeries were often created not purely for commercial reasons, but to ‘substantiate’ people’s beliefs. Monks in the medieval period created relics which were reputed to have powers to perform miracles, in order both to promote their religious beliefs as well as to draw people to the monastery housing the relics in order to gain money from them. The Cottingley fairy photographs were created by Elsie Wright and Frances Griffiths, to convince their parents they had been playing with fairies, though these images subsequently convinced many other people that fairies existed (Jones 1990: 88). Such forgeries for the purposes of substantiating a belief and/or gaining wealth have been going on from an extremely early period, with examples from Ancient Mesopotamia and Ancient Egypt (Jones 1990: 62). The prevalence of such objects should cause any investigator to question the genuineness of every object as well as to question the extent to which any image or text portrays the truth. In periods of intense belief, such as wars, faking objects, forging documents, and even fabricating complete identities are considered acceptable by society (Montague 1953).

A forgery is normally detected for various reasons:

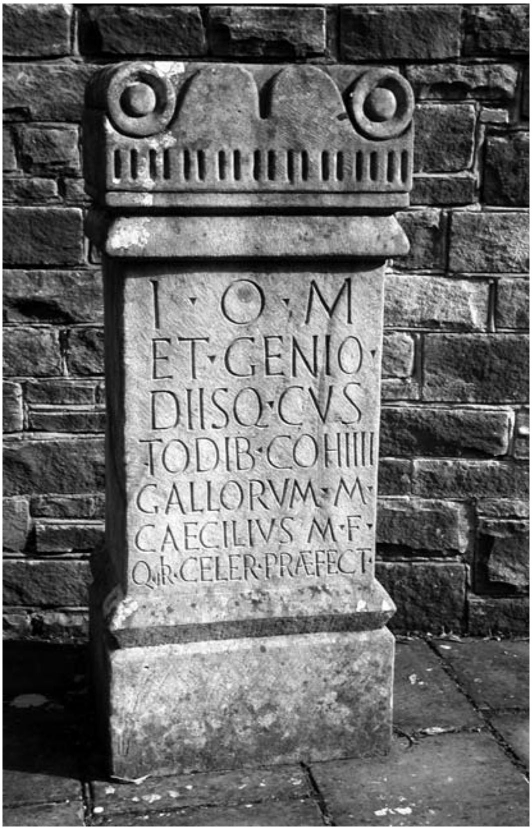


Figure 6.2 Replica Roman stone altar. A twentieth-century replica of a Roman altar on display in the garden of Vindolanda Museum. Clearly labelled as a replica, it is almost identical to the real thing (see Figure 6.1). (Photograph by the author)

- Inaccurate materials or techniques are used in its manufacture, which were not available in the period and by the culture from which the object is supposed to derive. Thus the 'Madonna of the Veil' painting sold as 'probably by Botticelli' in 1930 was revealed as an early twentieth-century fake; Prussian blue, a nineteenth-century pigment, was used rather than lapis lazuli (Jones 1990: 34).
- It uses an inaccurate object form or decoration (style), inappropriate for the period or the culture from which the object purports to derive. At least one critic noted that the Madonna depicted in the Madonna of the Veil had the appearance of a 1920s film star (Jones 1990: 34).
- Textual forgeries can be detected because they refer to events that had not yet occurred. The state of knowledge of the forger, frequently the historical orthodoxy of the day, is often revealed to be inaccurate by later scholarship.

- All ancient materials show signs of decay and the discoloration of use and age, the effects of light and handling, etc. Forged artefacts often fake these to give the impression of age; e.g. the use of tea or coffee stains to blemish documents. Corrosion crusts such as copper carbonate develop slowly on buried metals, forming coherent 'patinas'. Faked objects are given patinas formed from powdered minerals stuck to the outside of the metal, or are chemically treated to quickly form mineral crusts such as copper acetate. The detection, through microscopic examination, of the corrosion crust structure and analytical identification of minerals (using techniques such as XRD), confirms forgery.

Forgery is most readily perpetrated when there is a large demand for ancient objects and the purchasers are not very knowledgeable or discerning. Periods such as the Ming dynasty in China saw Shang dynasty bronzes being prized and faked, whilst in Europe in both the Renaissance and the seventeenth to nineteenth centuries classical statues were highly valued and faked. Contemporary fakes such as counterfeit coins were made in many periods (Tylecote 1986: 116–17); these are revealed by compositional analysis and detailed numismatic examination.

Between complete genuine objects of the past and fakes lie restored objects – original objects to which material has been added to mimic what the restorer believes was the original shape/decoration/colour. What is considered 'acceptable' restoration will vary with the time and culture in which the restoration work was done. Modern museum-standard restoration requires considerable evidence and a high degree of certainty from the restorer before restoration work is undertaken. The work is normally reversible (Caple 2000: 128). In some areas, e.g. archaeology, the restoration is normally detectable upon close inspection. In other areas, e.g. oil paintings, it may take scientific examination with UV light to reveal restoration. Where there is uncertainty over the original form, the unrestored object is displayed. From the Renaissance until the twentieth century it was not considered appropriate to display damaged or partial objects; consequently there was often extensive restoration, as shown in the case of the Piranesi Vase (Miller 1992) and the placing of newly carved heads on classical marble torsos. The artists who did this work, such as Cavaceppi (1716–99), were highly regarded as artists and sculptors. If any element of the original object did not correspond with their perception of the past, then it was altered. Pastiches – pieces of different classical objects – were combined to form complete new objects (see Figure 6.3). The distinction between restored, original and fake objects was frequently blurred during this period, e.g. the Townley Discobolus (Jones 1990: 140).

Since prehistory, copies of objects have been made in easily shaped materials, as symbolic representations, e.g. to act as tokens or offerings, such as Cellini's model of an eye in gold (see section 2.8). By the medieval period, copies or replicas of holy objects were frequently being made as souvenirs to sell to pilgrims who visited holy sites. Pilgrimage formed one of the roots of modern tourism. The development of the Grand Tour in the eighteenth century saw wealthy young British aristocrats journeying around the sites of classical Mediterranean civilizations. It led to a market in

Figure 6.3 An 'Etruscan' urn; an eighteenth-century pastiche created from parts of several ancient bronze vessels held together with painted plaster and bandages. (Photographs by Jeff Veitch)

creating copies of great works of art to sell to these wealthy cultural tourists. This trade continued in the nineteenth century, and dispersed examples of 'classical beauty', often in the form of plaster casts such as those seen in the Copies Gallery of the Victoria and Albert Museum, throughout Europe and North America. As museums of the twentieth century increasingly held and displayed real objects of antiquity, replicas were made primarily for sale to the visiting public, to commemorate their visit. Such objects are normally distinguishable from true objects because they are stamped with modern makers' marks, are often smaller in size than the real thing, or are made of cheap casting materials such as plaster of Paris and polyester casting resin.

6.4 Objects as part of collections

Upon entering collections, objects move from 'technofunction to socio or ideofunction' (Schiffer 1987: 32), i.e. their role becomes that of historic documents, supporting the activities of research and education. The types of object that are collected and displayed depend on the political, social, educational and economic climate. In the modern era the extent and nature of agricultural and industrial development have been shown to influence the volume and nature of ancient objects collected (Kristiansen 1996). Ideas of cultural and personal importance are very different. Thus personal possessions, such as wedding dresses, form heirlooms of a personal past, and many have been donated to museums, though modern educationally oriented museums seeking to collect and show 'typical life in present and past centuries' require everyday garments. The bias in favour of robust materials is demonstrated by the prevalence of prehistoric stone and metal artefacts in museums, which contrasts with the rich assemblage of objects of organic material recovered from a fully equipped prehistoric man, such as Ötzi, revealed by a retreating alpine glacier (Spindler 1995). All objects from collections, private or public, should be seen as the product of the collecting process, a highly biased cultural activity, and as the product of the decay process.

Objects do not simply enter a collection and remain preserved 'as found' in perpetuity: they have a life as collected objects. John Casey identified a small number of late Roman coins that appeared in areas of Scotland. They were not evidence of late Roman occupation, but were collected and brought back from the Near East by crusaders of the thirteenth century (Casey 1986: 109). Moving from one collection to another as they are bought and sold, objects are divorced from much of their associated information, making them harder to interpret.

Once objects are in collections, they form a historic document/record not only of the period(s) in which they were created and used, but also of the period and culture of the collection of which they are part. Any object from a collection (and almost all objects of the past that we see are part of private or public collections) will, when carefully examined, reveal physical traces of its context as part of a collection. These include:

- Numbers, letters or symbols written either on the object, on material attached to the object or on packaging material which surrounds the object. These may relate the object to the collection of which it is part and to information about the object. Objects which have been part of more than one collection will often have several groups of numbers, letters or symbols on the object or its associated packaging.

- Areas where material has detached from the object. It is important to determine if this occurred:
    - during the life of the object (evidence of subsequent wear and covered by decay);
    - at the end of the life of the object, possibly leading to its discard (no evidence of wear, but covered by decay);
    - during the original recovery (excavation or removal) of the object, or during its subsequent cleaning, handling in storage or as a result of placing on display (fresh breaks with no evidence of decay).
- Repairs such as re-adhesion of broken pieces frequently occurred during the collection context of an object. Contemporary repairs to archaeological objects rarely survive (cf. Charters *et al.* 1993), and historic objects that broke during use frequently failed to retain decorative or non-essential pieces.
- Objects which have been heavily cleaned. In the nineteenth and early twentieth centuries many objects were cleaned with abrasive polishes, since it was fashionable to see 'cleaned' objects. Many classical statues, altars and decorative friezes that had originally been painted, such as the Parthenon marbles, had all traces of paint and weathered stone removed (Oddy 2002).
- Inscribed stones often have paint added by modern collectors to pick out the inscription. Modern collectors/enthusiasts frequently repaint nineteenth- and twentieth-century objects such as cars, cycles, motorcycles, planes, boats/ships, trains and rolling stock, and horse-drawn carriages, which have exterior painted finishes. Almost all such objects, even with paintwork in good condition, have been repainted. Furniture and oil paintings were often re-varnished when part of a collection in order to enhance the colour and visibility of the artefact.
- Areas of restoration are often visible when objects are carefully examined. Under UV light (see section 2.9) the fluorescence of modern polymers and varnishes is much lower than that of aged varnish. Consequently restored areas show as darker patches on a light background.
- Evidence of mounting is often present on the object:
    - areas of adhesive to stick the object to backing boards;
    - marks cut into the surface from the attachment of suspension cords;
    - areas deliberately flattened, or pieces of mounting material attached to the object, to ensure that it sits flat or stands upright;
    - rings or other suspension devices;
    - nails, screws or pins to attach the object to a backing;
    - holes from nails, tacks or screws, or from thread for attaching paper, fabric or similar material to backing boards;
    - iron staining from the presence of pins, nails, tacks or screws.

  There can be holes of several sizes and spacing present on an object, e.g. on the back of oil-painting canvas, indicating that it has been attached to stretchers, frames or backing boards on different occasions.

- In the nineteenth and early twentieth centuries collectors were often very confident about the original shape, decoration and style which their objects possessed. Consequently later additions or even parts of the original object were removed in order to made them appear 'correct' in the collector's eyes. Parts of the glass sherds of the Portland Vase, which was reassembled after being smashed in 1845, were ground down to make them better fit the reassembled form (Williams 1989). Extensive, and what would now be seen as speculative, 'in the style of' restoration often dates to this period in the collection's history.
- False or new decorative bases or covers were often added to objects in collections from the sixteenth to nineteenth centuries, e.g. the Treasure Binding of the Lindisfarne Gospels, or the base and rim of the Lycurgus Cup. Such improvements and additions were initiated by collectors seeking to make their objects appear more aesthetically pleasing.
- In working objects, many moving parts wore away and were replaced. This continued when objects entered collections. Examination of any working mechanism should look at the level of wear present on the different components. Unworn or very lightly worn components may derive from a period when the object had become part of the collection.
- In seeking to clean and stabilize iron and copper alloy archaeological artefacts in the nineteenth and early twentieth centuries, the outer corroded layer was often removed by chemical action or electrolytic stripping. This left an exposed, often pitted metal surface without corrosion, and thus the object was stable. The process removed the original surface often present within the corrosion layer, and traces of paint, or other decorative finish, plus the tool marks and surface wear or deposits from use.
- Wax or varnish coatings were often applied to metals in order to 'protect' them against future corrosion. These are invariably from the collection context.
- Often only parts of objects were collected. These were usually the most decorative or readily collected elements of an object such as *tsaube*, the guard on Japanese swords; the rest of the sword was often discarded.
- Splashes of paint from decorating occurring in the vicinity, since objects were often not moved or covered during such activities. Pen, pencil or crayon marks, or images, symbols or words occur scratched into the surface of the object, together with vandalism from decades of museum visitors – usually the young and the bored.
- Certain types of object have been subject to the removal of samples for analysis. This has resulted in holes or losses in the object. Copper alloy and some silver artefacts may have narrow-diameter holes drilled into the body of the metal, so that drillings of uncorroded metal could be obtained for analysis. Some stone artefacts, such as the neolithic stone axes in museums throughout Britain, have had pieces cut out of them for petrological identification (see section 3.9). Some iron and copper alloy objects have V-shaped notches cut into the edges of

blades and axes to provide samples for metallurgical identification (see section 3.10).

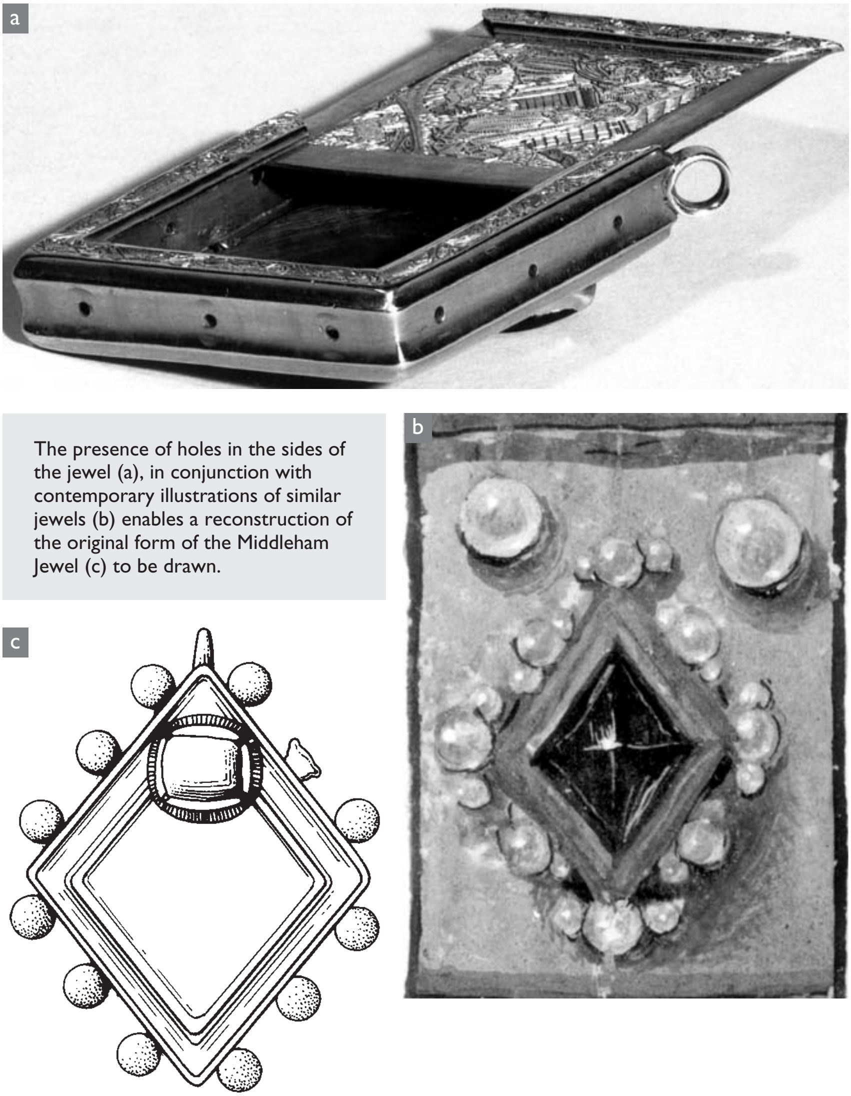
- Many of the signs of neglect or storage, such as insect damage (see section 5.5) can relate to the collection phase of an object's life, but are not unique to that phase.

These examples illustrate the types of often dramatic changes that have occurred to objects during the collection phase of their lives. However, the clearest indication of the fact that an object is part of a collection is that it has been researched, it is cared for and it is housed in suitable conditions. For objects in public ownership there is controlled access available to the object and associated information.

6.5 Conclusion

An accurate picture of the past is difficult to achieve, but if museums and their collections have a value to the present, it is to reveal the truth about the past. Much of what we see today and consider to be the past is inaccurate: the picture does not match the label. Churches and cathedrals we describe as medieval have interiors whitewashed by the Reformation or stripped by the Victorians. They are not the gaudily painted interiors of the medieval period, preserved in only rare instances, e.g. Kempley in Gloucestershire, but the gaunt interiors of later generations. Objects as they appear today are shadows of their former selves. Objects such as the Middleham Jewel, when studied carefully, reveal holes along its sides which, comparison with contemporary illustrations of similar jewellery suggests, may have originally had a border of pearls (see Figure 6.4) (Cherry 1994). It is clearly important to know this information, since the removal of the pearls was a deliberate act and part of the history of the object, perhaps to be reused in another piece of jewellery, or sold to raise much-needed money. It would be inaccurate to restore the object to its probable original appearance, since we cannot be certain exactly what it was, and in restoring it we would obscure the final acts in its history. However, it was important to undertake the investigation and associated research, and to suggest in words and images what the original form of the jewel was.

A key role for any and every object in a collection, particularly objects that are part of public collections, is that of a research and education resource for the future. The informative role of corrosion (mineral-preserved organics, original surface), of stains and surface deposits (traces of decoration, organic residues or DNA from use) and the original surface (marks of manufacture and use) have been established. This creates an important and challenging role for museums and archives: to preserve this potential information intact and unaltered. It also creates a responsibility to ensure that the information – the evidence of the past – is extracted from objects. Through education, courses and even through this book, the responsibility to teach following generations how to examine objects and extract information from these silent, reluctant witnesses to the past is discharged. The responsibility to obtain such information from objects now, in part, falls to the reader.



The presence of holes in the sides of the jewel (a), in conjunction with contemporary illustrations of similar jewels (b) enables a reconstruction of the original form of the Middleham Jewel (c) to be drawn.

Figure 6.4 The Middleham Jewel (Cherry 1994). (Photograph and reconstruction drawing of the object courtesy of York Museums Trust (Yorkshire Museum); the manuscript image, MS Douce 8, p. 441 detail, courtesy of the Bodleian Library, University of Oxford)

INVESTIGATION TECHNIQUES

6.6 Recording and reporting (Thornes 1999)

The record/report of an object provides a substantial amount of information about the object and prevents unnecessary handling, with its associated risk of damage to the object. In a number of cases, objects have been destroyed or lost and only the records remain. This often exposes the poverty of the visual and written records that remain.

Examination		*Recording*	*Research*
Context		Drawings	Form
Object	– materials	Photographs	Decoration
	– assembly	Dimensions	History of ownership
	– use and damage	Description	Materials and techniques
	– discard and decay		Use

Whilst an object can easily be photographed, it is a real skill to photograph it well (Dorrell 1989; Thornes 1999). Techniques such as photographing objects on glass over an empty space to avoid shadows are advisable. Front lighting reduces the surface texture of the object; a balance of front and side lighting will both illuminate the object and provide some modelling, i.e. bring out its three-dimensional characteristics. Light is often bounced back from reflective objects, i.e. glare, and should be minimized or avoided by careful positioning of lights. If an object is too close to the camera, part of it may be out of focus and the object image may be distorted; too distant, and the object loses texture and detail. For record purposes the object should be photographed with a scale, though scales are often omitted for publicity shots or images showing specific features. If photographing in digital format, the largest number of pixels available should be used. If photographing using film, black and white is more stable for archive purposes than colour. Since most objects are coloured, the exact colour is important. Photographing the object in colour (film or digital) alongside a standard commercial colour reference (Kodak or GretagMacbeth) will enable the colour balance of the image to be accurately reproduced. Several images with different lighting conditions, different views and different exposures should be taken and the most accurate and informative used.

All objects being recorded and reported should be drawn, since this forces the investigator to look carefully at the object and decide on the shape, nature and meaning of every blemish on the object's surface. Objects are three-dimensional and thus, for all objects except drawings and photographs, cross sections through the object or side views should always be drawn as well as a front view, e.g. the Coppergate helmet (Figures 1.10 and 1.11). Detailed conventions such as lighting coming from the top left, standard forms of shading and for illustrating vessels (see Figure 6.5) exist for drawing archaeological objects (Adkins and Adkins 1989; Griffiths *et al.* 1990). Conventions also exist for making technical drawings of machinery, buildings, etc. These conventions should be followed, and the techniques applied where appropriate

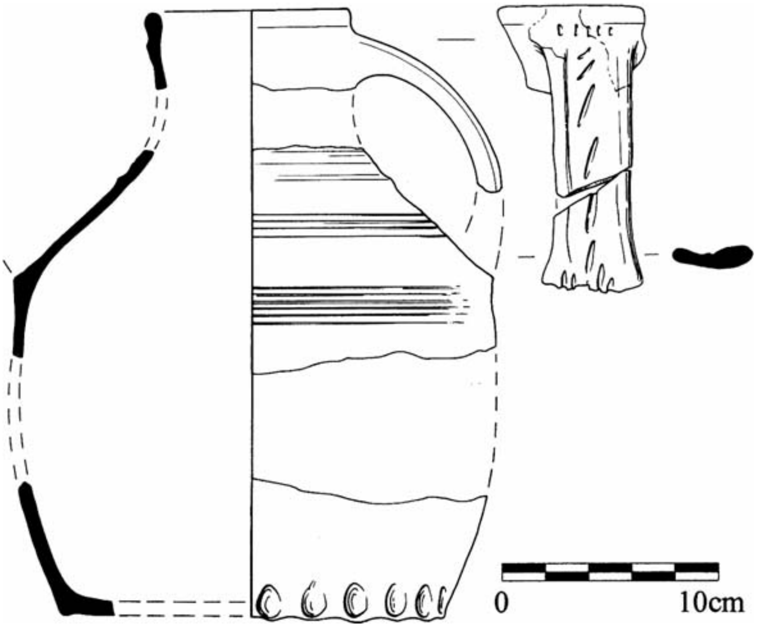


Figure 6.5 Archaeological illustration of a thirteenth-century ceramic vessel from Dryslwyn Castle, Wales. (Drawn by Oliver Jessop)

to a wide range of historic objects. Labelled drawings are always useful: impressionistic sketches (life drawing) rarely so. The object should be accurately drawn at an appropriate and specified scale. Though there is a real skill in drawing objects well, with a little practice and through following conventions, every investigator can draw objects reasonably accurately.

A written report on the objects should be presented using the appropriate technical terminology to describe the object. This should include accurate measurements. Throughout Europe, SI (metric) units, e.g. millimetres and metres, should be used. Detailed visual analysis, e.g. using FOCUS, should have been undertaken to ensure that the investigator has obtained a complete list of the materials used in the construction of the object, has ascertained the technical names of the various parts of the object, and established a clear sequence of the object's construction and use, based on evidence provided by the object.

The context from which the object derives, where known, should be described, as should the object's history of ownership/origin. The form of the object should be described and correlated with the function of the object and with any existing typologies. The object's date and material culture context should also be discussed. Dating may be derived from context, object form and associated typology, scientific dating methods, etc. The decorative elements of the object should be described and their derivation discussed, including the artistic tradition of which they were a part. The object form and decoration often provide information on the cultural affinities of the producer or owner. Materials, technology and artistry of manufacture often indicate the wealth or status of owners of the object and the technical development and trade networks of the society/period culture from which the object derives. Comparative analogies, arguments and important background information should be supported by references. Where the research and analysis have revealed an earlier (original or undecayed) object form or decoration that is significantly different from the object's present appearance, it is appropriate to provide a reconstruction drawing/image of the earlier form and decoration.

The object report can vary from a few lines, such as the description of a piece of flint in section 1.9, to a book complete with CD (M. P. Brown 2003a). The length, style and level of technical detail and background information will vary, depending on the aims of the report, envisaged readership, importance of the object and available resources. The format of the report should follow the accepted traditions for reporting such objects.

CASE STUDIES

6.7 Han dynasty lacquered mirror (Ball 1995)

Rich and powerful individuals of the Chinese Han dynasty (206 BC–AD 220) were buried in graves with possessions, such as mirrors, for use in the afterlife and to signify their wealth and high status. These graves were robbed by later generations, and a thriving market collecting artefacts became established in China. From the late nineteenth century, American and European collectors also began to collect such artefacts. High values and a large number of collectors led to the production of fakes.

A unique bronze mirror, 264 mm in diameter, maximum thickness 11.5 mm, with slightly convex front and back surfaces, the back decorated with lacquerwork, was purchased in 1937 by the notable collector Sir William Burrell (see Figure 6.6). The front of the mirror had traces of a smooth white metal coating. The back was decorated in black lacquer with slightly raised red lacquer figures with white highlights. The decoration comprised:

- an outer ring of serpent design;
- a circle of twelve figures (six pairs of nearly identical opposing figures): a dragon being ridden, a small dragon, a man with a tool or weapon, a man on horseback with a ribbon, a man with a tool or weapon and a small dragon;
- an inner circle of six dragons;
- a final central design of two dragons.

In the very centre was a simple loop attachment, which photographs indicated had been intact in 1937, but by 1995 had corroded away. This loop was originally used to support the mirror on an adjustable wooden stand that faced the user when sitting or kneeling.

Form, decoration, depiction

Mirrors of the earliest types from the Zhou and Shang dynasties (Table 4.1) have a variety of shapes. By the Warring States period and Han dynasties, all mirrors are circular, normally 30–250 mm in diameter. In the later Tang dynasty, lobed forms become popular (Swallow 1937: 14). Warring States Period mirrors are often thin and brittle; later Han mirrors are thicker. This circular mirror, at 264 mm, appears to be a very large mirror of the Han period.

Lacquerwork was expensive, a lacquer cup being described as ten times more expensive that a bronze cup (Wang 1982: 83). Thus, a large lacquer-decorated mirror would have been a very expensive item and would presumably have derived from the grave of a member of the imperial family or a wealthy aristocrat.

The X-radiograph (a) of the mirror indicates, a plain casting with a simple raised ring on the back. EDXRF analysis indicates that the mirror is not bronze but brass and the silver metal coating on the front of the mirror is tin. Flow patterns suggested it was melted onto the surface. A cross section (e) through the lacquer which covers the back of the mirror, showed black lacquer probably coloured with carbon black (c) above a water-sensitive ground containing clay minerals (d). The red lacquer decorated figures did not contain vermilion (mercuric sulphide). All the lacquer was thickened with minerals such as barium sulphate. An iron support ring was present in the back of the mirror. A layer of deliberately discoloured varnish, containing post-AD 1500 pigments covered the lacquer. None of these characteristics match any other Han dynasty figure; all indicate that this object is a fake.

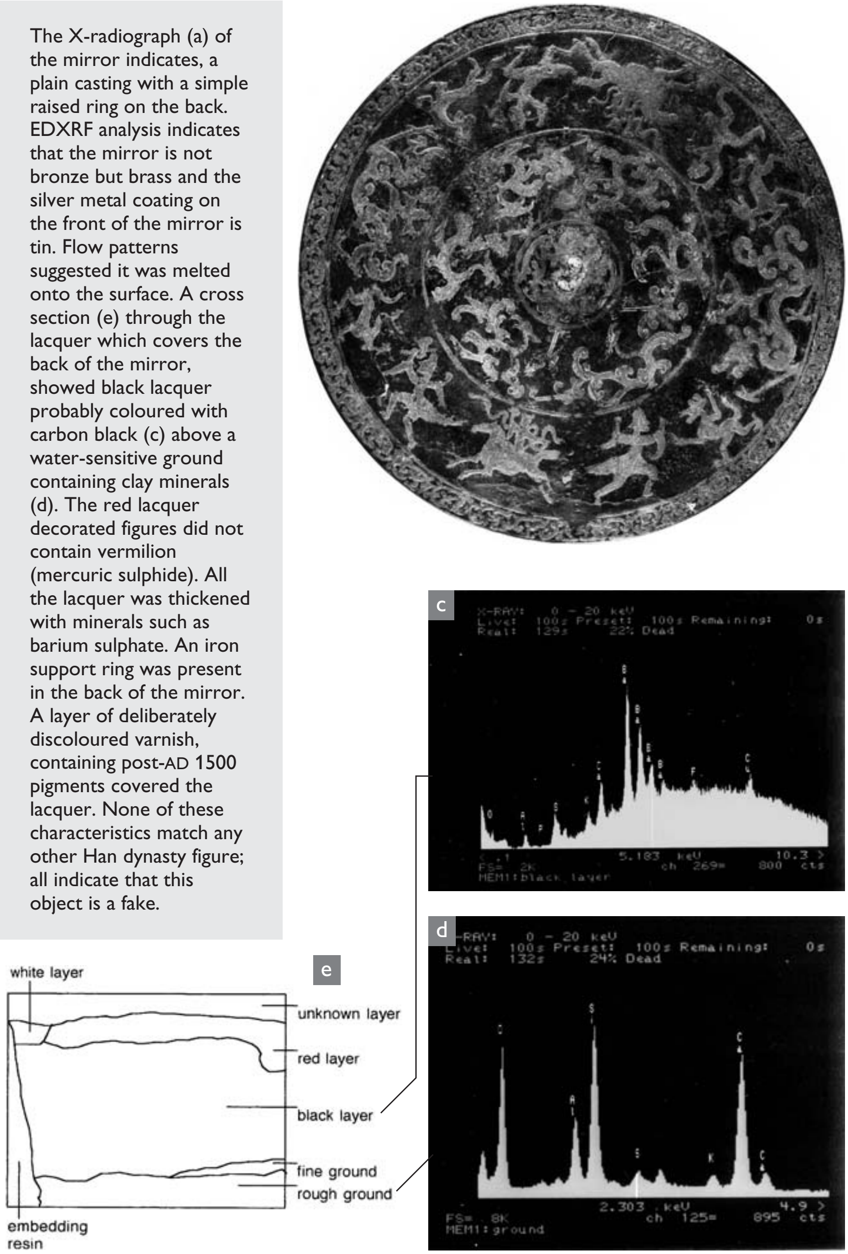
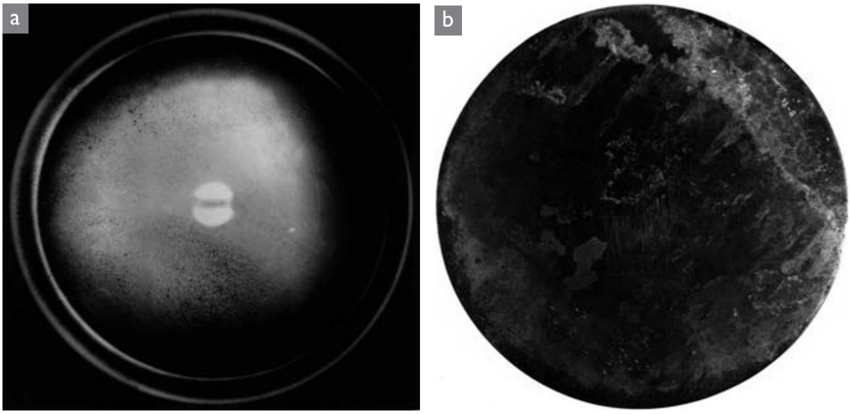


Figure 6.6 Han dynasty mirror: details of materials and manufacture. (Images courtesy of Marieanne Davy Ball and Glasgow Museums)



Mirrors were normally cast from solid bronze. Written texts indicate that mirrors were considered symbolic and represented the light of the heavens, so the backs of mirrors were normally decorated with signs and symbols representing constellations of stars or heavenly deities. The size of the mirror and the decoration on its back varied depending on the date of its production (Wang 1982). The presence of the simple loop at the back of the mirror and the border design of serpents are both characteristics of early Western Han period (second–first centuries BC) mirrors such as those retrieved from the tombs at Mawangdui (e.g. Wang 1982: Figure 14; Bulling 1960: Plate 3). However, the outer ring of twelve pictorial figures and the inner ring of six figures are similar to the decoration of the 'pictorial figures' style, depicting in naturalistic form people, beasts and deities, seen in the late Eastern Han period (second–third centuries AD). At this time the central loop was a large hemispherical boss, and the borders had either more naturalistic animal forms or patterns. Consequently, the elements on the back of this mirror do not seem to be appropriate. Experts Jessica Rawson (Oxford) and Professor Wu Hung (Chicago) suggested that the spatial nature of the design and the iconography of this object do not appear appropriate for the period.

Manufacture

Lacquer is formed from the sap of the *Rhus vernicifera* (*verniciflua*) tree, which is purified, concentrated and mixed with a drying oil, e.g. tung oil, and pigments to form lacquer. This is painted onto a suitable substrate in many coats, which dry in high-humidity conditions. First used in China in the Neolithic, *c.* 5000 BC, complete lacquered objects are recovered from Shang dynasty tombs, e.g. Taixicun in Gaocheng, Hebei province. High-quality lacquerwork, such as that recovered from the tombs, e.g. Mawangdui in Changsha (Wang 1982: 80), was produced during the Han dynasty, with many workshops under direct imperial control. Early lacquer is often coloured with charcoal (black) or vermilion (red). There are no published examples of lacquer decorated mirrors from the Han dynasty. All other examples of Han dynasty mirrors are relief-cast bronze, though many are patinated black (Swallow 1937: 25).

An X-radiograph revealed that the metal had, as was normal with almost all Chinese copper alloy metalwork, been cast into shape, small bubbles visible in the X-ray indicating the previous molten state of the metal. Marks of a file around the rim suggested that flash marks (narrow fringes of metal that solidify between the parts of the mould) had been filed off. There was no design visible on the X-radiograph. Thus, uniquely, there was no design cast into the back of the mirror.

The metal of the rim of the mirror was sampled by drilling. This provided core metal for EDXRF analysis and revealed the metal to be a leaded brass:

Area analysed	*Cu (%)*	*Zn (%)*	*Pb (%)*	*Sn (%)*
Rim	72.0	15.9	9.4	2.1

The metal used for making Han dynasty mirrors was a high-tin bronze. Analyses by Riederer *et al*. (1977) and Gettens (1969), also Swallow (1937), indicate that only high-tin bronzes were used, with typically 20–25 per cent tin, 4.5 per cent lead, and zinc present in trace amounts. High-tin bronzes are used for mirror production because the bronze, when polished, forms a reflective silvery mirror surface. Though one or two low-zinc brass objects (below 9 per cent Zn) have been ascribed to the Han dynasty, brass only comes into regular production and use in the later Ming dynasty (1368–1643).

The front surface of the yellow brass metal of the mirror body had been covered with a layer of silvery-white metal, in which flow lines were visible. EDXRF analysis of the surface of the mirror revealed copper, zinc and lead from the brass beneath, and high levels of tin. Thus, the silvery-white metal coating is almost certainly pure tin, which has a melting point of 232 °C and can be easily melted and subsequently polished to give a silvery metal surface similar to high-tin bronze alloys, e.g. speculum metal.

Han mirrors have bronze support loops or knobs cast as part of the object. EDXRF analysis of a sample from beside the corroded loop at the back of the mirror revealed that it was iron.

A section through a fragment of lacquer, when mounted in casting resin, cut, polished and examined under a microscope, revealed a series of layers:

- *Brown varnish layer*
  FTIR analysis indicated that the organic material was paraffin wax. Proteins and amines were also detected in the varnish, which may be unidentified colouring agents. Examined under a polarized-light microscope, many different pigment particles could be observed: chalk, gypsum or barytes, carbon black, possible

particle of smalt (a blue glassy pigment present after AD 1500) and a blue flake pigment, probably ultramarine. This layer would appear to be a varnish, primarily composed of paraffin wax – a material that has only been available for the last hundred years – which had a diverse range of pigments added to the varnish to give it an aged brownish coloration.

- *White lacquer/paint*
  The pigment particles, examined under a polarized-light microscope, had a refractive index below 1.66, and this corresponds to gypsum. Many were small round particles, the normal particle form of chalk. There were also coccoliths, microscopic fossil microfauna normally found in chalk deposits. SEM with EDX analysis facility revealed barium, probably the mineral barytes (barium sulphate). The lacquer also contained lead. Lead white (lead carbonate) was the most widely used white pigment until the mid-twentieth century. This white lacquer was pigmented with white lead, chalk, barytes and gypsum.
- *Red lacquer*
  SEM with EDX analysis facility revealed that the red lacquer layer was rich in barium, probably barytes (barium sulphate) but little else. No trace of vermilion (mercury sulphide), the pigment used for colouring lacquer red in the Han dynasty, was detected. Tests with hydrochloric acid and potassium ferrocyanide indicated that iron oxide, frequently used as a red colorant, was not present. Under the microscope a sample melted in a holding resin 'Melt Mount' suggested the pigment could be organic, e.g. 'dragon's blood', a natural red resin. The red lacquer thus has both organic and inorganic properties; the red coloration is probably principally due to dyed particles of barytes (barium sulphate).
- *Black lacquer*
  SEM with EDX analysis facility revealed that the black lacquer layer was rich in calcium and silica. Under a polarized-light microscope, many inert pigment particles, which probably included anhydrite of gypsum (calcium sulphate), chalk (calcium carbonate), witherite (barium carbonate) and barytes (barium sulphate) as well as silicates, were seen. The principal colouring particles in this black lacquer layer were carbon fragments.
- *Upper fine ground*
  This had a fine texture with very little pigment, suggesting that it was a sizing layer to seal the coarse ground before the application of the lacquer layers. SEM with EDX analysis facility revealed that the fine ground contained lead, probably lead white (lead carbonate), and calcium, probably gypsum (calcium sulphate).
- *Lower coarse ground*
  Visual analysis under a microscope suggested that the layer had a coarse texture with general brown-grey coloration with flecks of red and white pigment. This appears to be a levelling layer, a base or ground to support the upper lacquer

> layers. SEM with EDX analysis facility revealed aluminium and silicon, indicating the presence of clays (alumino-silicates). XRD analysis revealed that crystalline minerals present in the ground included quartz and the clay minerals kaolin and illite/mica.

The lack of evidence for the slowly built-up layer structure suggests that this lacquer was not applied in traditional liquid form. The fact that the red lacquer figures are lifting away from the black background in a number of places and the high mineral content suggest the lacquerwork was made as a stiff paste, rolled into a thin layer and applied. The black lacquer was applied onto the clay-rich ground layers, which had built up the back of the mirror into a convex shape. The red lacquer lines and figures were then cut out and placed on top of the black lacquer layer and smoothed down. Brushmarks in the white paint/lacquer would suggest that this was subsequently painted onto the red figures, using a brush, to create the highlights.

Conclusion

If buried, the clay-rich ground would have absorbed water, expanded and pushed off the remaining lacquer. Consequently, this mirror has never been exposed to burial in damp soil. Features such as:

- the use of brass rather than bronze
- the use of tin to create a silvery front surface
- the use of a lake (dyed mineral) pigment rather than vermilion to create red lacquer
- the lacquer decoration of a mirror
- the use of quickly created mineral-rich paste lacquerwork decoration
- the mixture of features from early and late Han mirrors

are all unparalleled for this period and indicate that the object being examined is a fake. It was probably made in the late nineteenth or early twentieth century to meet the demand from collectors. It is probable that the varnish layer, which contains paraffin wax and post-AD 1500 pigments, was applied at the same time the fake was made. There would be no need to colour the varnish if it were being used as a preservative measure, but there would be if it were being made to look yellowed with age as part of the faking process.

6.8 Durham Cathedral door (Caple 1999)

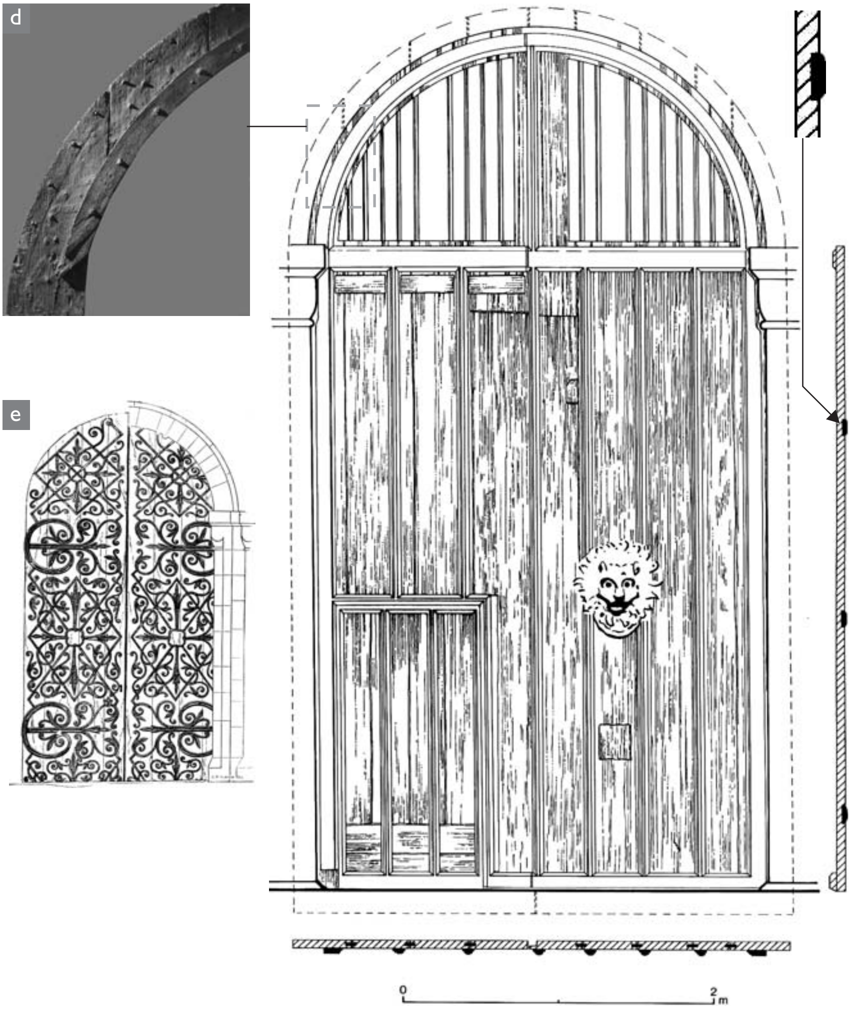
Following the creation of the Norman Romanesque cathedral of 1093–1133 (Jarret and Mason 1995) there were further substantial phases of building of the cathedral, with the late twelfth-century construction of the Galilee Chapel by Bishop Hugh le Puiset. The rebuilding of the east end of the church as the Chapel of the Nine Altars was completed by Bishop Bek in the 1280s, whilst in the fourteenth century there were the several additions to the cathedral's fabric by Bishop Hatfield. The Reformation brought considerable removal of decorative material from the church, whilst the Civil War led to invasion by the Scots who, in 1640, destroyed the cathedral's font and its cover (Roberts 1994). In 1650–1 Cromwell kept three thousand Scottish prisoners in the cathedral over the winter, who are believed to have burnt many of the cathedral's wooden fixtures and fittings. Following the Restoration the cathedral was enthusiastically restored by Bishop Cosin, with the addition of wooden fixtures such as the font cover (1663) and the choir stalls (1665) (Roberts 1994). These events raise doubts that the original doors of the twelfth century would have survived intact to the present day.

In 1991 the removal of Victorian louvres and the restoration of the vertical plank form of the cathedral's north door (see Figure 6.7) necessitated the cutting of several of the north door planks and enabled a thorough investigation of the doors to be undertaken.

Manufacture

The north and south doors of Durham Cathedral have the form of two leaves or wings, both composed of wooden planks. The wood of the door was identified as oak (*Quercus* spp.), the major wood used for constructional purposes such as doors, floors, roofs etc. in the medieval period. As was normal for high-quality medieval joinery, all traces of the soft sapwood had been removed from the planks; only the more sturdy, rot-resistant, heartwood was used. Plank doors are known from Iron Age sites such as Glastonbury Lake Village (Crossley 1951) and continue to the present day.

The leaves of the north door of Durham Cathedral are composed of a series of substantial planks which have grooves or mortices cut into their sides, into which are slotted free tongues or tenons, separate long thin strips of wood, which run the length of the plank. The leaf of each door is composed of four or five planks, with three or four free tenons. Three thin tapering horizontal ledges are present on the back of the door to hold the vertical planks together. The ledges are roughly semi-circular in cross section and are attached to the planks by sliding them into shallow dove-tailed grooves which have been cut across the full width of the back of each door plank (see Figure 6.7, door cross section). These 'wedged' ledges hold the door planks firmly in position without any need for nails, creating a door that is thinner and lighter than other medieval doors. The use of the countersunk 'wedged ledges' is paralleled by Hewett (1980, 1982) in the doors of Eastwood, Heybridge and Elmstead churches in Essex, all of which are believed to date from the later half of the twelfth century, and in



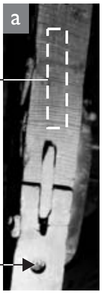
The north doors of Durham cathedral are constructed of large oak planks fastened together with floating tenons (a) and wedged ledges. Photographs of the cross sections through the planks enabled them to be dated dendrochronologically (b). Samples (a) were removed and subject to radiocarbon dating (c). This established an early twelfth-century date for the construction of the doors. When photographed in raking light, the north doors (d) revealed a pattern of old nails and raised ridges created by the presence of iron strapwork, which originally decorated the front of the door. This was similar to, but a different pattern from, the iron strapwork which currently decorates the south door of the cathedral (e).

Figure 6.7 North doors of Durham Cathedral: details of materials and manufacture. (Images from Caple 1999)

b Dendrochronology
South door sequence best fit ($t = 6.46$) with Carlisle sequence, final ring AD 1094. Including an allowance for sapwood, a fell date of AD 1099–1134 is likely.
North door sequence, best fit ($t = 5.59$) with Carlisle sequence with rings leading to a final ring from AD 1094. Including an allowance for sapwood, a fell date of AD 1099–1134 is likely.

c Radiocarbon

South door, west leaf, plank 2, sample S1 (OxA–4098)	1190 ± 70 years BP
South door, west leaf, plank 2, sample S2 (OxA–4199)	1070 ± 65 years BP
North door, east leaf, plank 4, sample N1 (OxA–4100)	900 ± 70 years BP
North door, east leaf, plank 4, sample N2 (OxA–4101)	1205 ± 70 years BP



a door of eleventh–twelfth century date from Westminster Abbey (Hewett 1980; Geddes, personal communication). Hewett (1980, 1985) gives no other examples of doors made with free tenons running the length of the planks, though short free tenons are used to join planks edge to edge on doors such as those of Kempley Church, which are dated to *c.* 1100. The south door of Durham Cathedral is made in exactly the same manner as the north door, though with smaller planks. Almost all doors from the later medieval and post-medieval period have V-edge notched planks and substantial horizontal ledges or cross-bracing nailed into place (Hewett 1980; Crossley 1951). Such doors are quicker to create, require far less carpentry skill to make, and are thicker and heavier than wedged-ledge and free-tenon doors.

Decoration

The south (monks') door is covered with iron strapwork (see Figure 6.7) nailed onto the door, which Geddes suggests, on the basis of the swaged profiles for the strapwork, the design and decoration of the scrolls and the decorative form of the hinges, was probably of late twelfth-century date and the work of Bishop le Puiset (Geddes 1980). This may have replaced thinner, plainer, earlier twelfth-century strapwork (Geddes, personal communication). This strapwork undoubtedly improved the rigidity of the door and may have been an integral structural element of the thin, wedged-ledge and free-tenon doors, as well as a decorative element. The presence of occasional iron nail shanks in the north door and traces of raised patterns in the door's surface (see Figure 6.7) indicates that it too originally was covered in iron strapwork. It was removed before the vertical raised moulding was attached. Three short pieces of thin iron bar, present beneath the raised edge moulding on the west side of the west leaf of the north door, may be all that remains of the original strapwork on the north door.

The hinges on the south door are described as 'cranked band and gudgeon hinges'

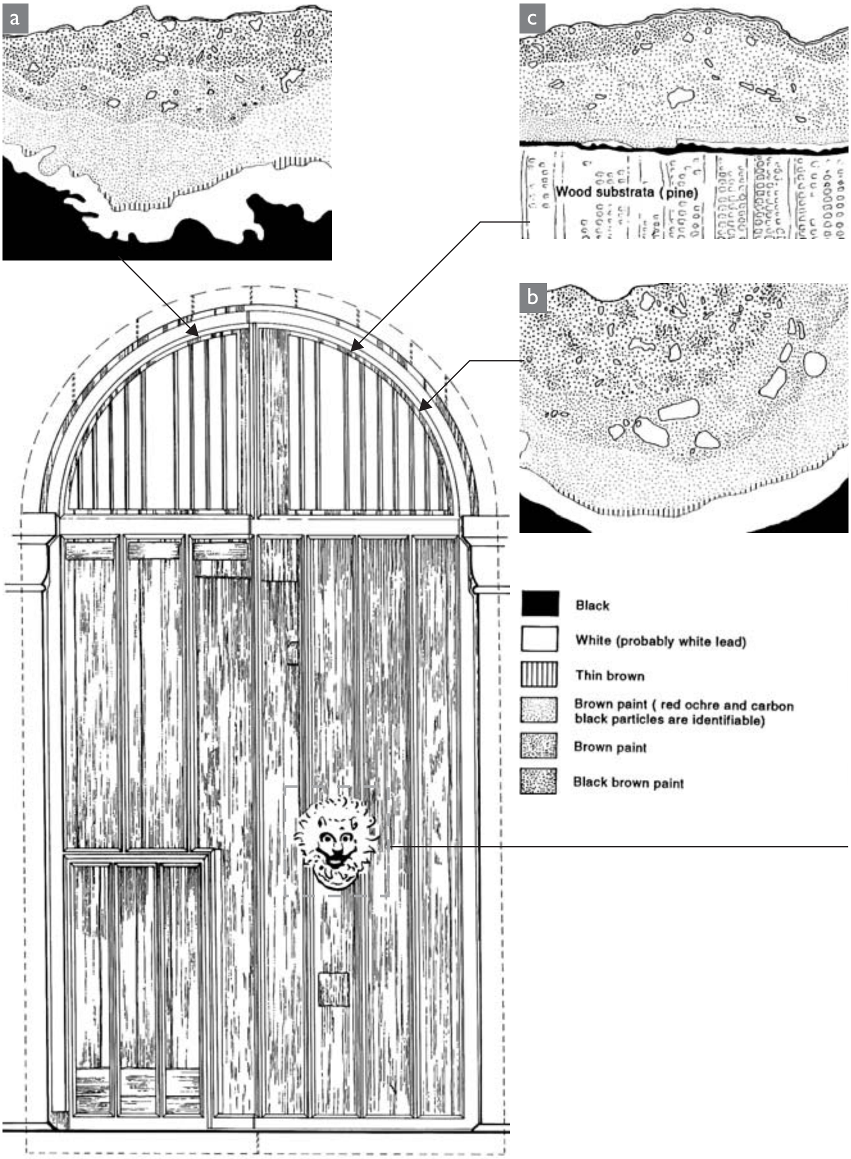


Figure 6.8 North doors of Durham Cathedral: details of materials and manufacture. (Images from Caple 1999)

(Emery, personal communication). They form part of the decorative strapwork affixed to the front of the door and are bent through ninety degrees in order that the hinge loop is at the back of the door, so that the door hinge is protected and yet can swing freely. The present hinges on the north door are at the back of the door and thus cannot have been part of any decorative strapwork scheme, and consequently are not the original hinges.

On the front of the north door, smaller raised vertical mouldings of wood were added for decorative effect and to cover some of the long vertical jointing between the planks, so making the door more waterproof. A similar raised moulding, of slightly wider form, was added to frame the outer edge of the door. These vertical and edge framing mouldings are a common decorative and functional device of the late medieval period, often added to earlier doors, as is the case for the north doors of Wells Cathedral (Hewett 1985). The vertical moulding was sampled and identified as pine (*Pinus* spp.). Pine was rarely used in the high medieval period, since it was scarce in England, but by the late medieval period it was imported from Scandinavia and the Baltic. These vertical mouldings mark a second phase of construction activity, possibly work undertaken by Bishop Cosin in the refurbishment of the church in the seventeenth century.

A small wicket door known as 'the eye of the needle' has been cut into the east leaf of the north door (see Figure 6.7). It is framed and edged by the raised moulding and has two vertical raised mouldings dividing the door surface. It appears likely that the wicket door was created at the same time as the moulding was applied to the rest of

The paint samples (a, b, c) show the sequence of painted decoration on the cathedral door. The fact that the full sequence is seen on samples from the vertical pine decorative moulding strips, probably added in the seventeenth century, as well as on the oak plank of the door, indicates that the paint layers probably run from the seventeenth to the twentieth century. The bronze sanctuary ring (d) is a fine piece of Romanesque art, probably a local casting, because of its idiosyncratic form. The eye sockets have been damaged, probably because they originally contained glass or jewel eyes, prised out during the Reformation.

the door. To aid access, the sill was lowered in both the nineteenth and twentieth centuries (Curry, personal communication).

In the centre right of the west leaf of the north door is a ‘knocker’, cast in leaded tin bronze (10 per cent tin), in the form of a cat’s head with pointed ears and a surrounding mane (see Figure 6.8). It has a ring gripped in its jaws. In the absence of a knocker plate, this was almost certainly a sanctuary ring (Geddes 1982). The form of the beast’s head is similar to those depicted on a roundel and miniature corbel from Canterbury (1180), and from those forming the feet of bronze candlesticks in Milan (1200) and Rheims (1125–50). All are probably derived from cat-like beasts illustrated in earlier manuscripts, e.g. an eleventh-century manuscript from Carilef, Normandy. A literary reference to a different arrangement of door furniture in 1152–3 led Geddes (1982) to suggest that this sanctuary ring was commissioned and placed on the north door by Bishop Hugh le Puiset, *c.* 1175, when it became the principal entrance to the cathedral following the construction of the Galilee Chapel.

Two samples of paint from the oak planks of the north door and one sample from the pine moulding were obtained and mounted for paint cross-sectional analysis (section 3.11) (see Figure 6.8).

- The full range of paint layers was seen in the sections above the oak and above the pine; thus the door was painted after the pine moulding was added.
- The surface of the oak wood appeared dark and old, possibly even stained, and appeared to be of some antiquity (Darrah, personal communication). The pine and the paint layers generally appear younger and fresher in cross section and were probably added to the weathered surface of an earlier oak door.
- A series of layers are identifiable in the paint; most though not all were distinguishable in every section:
  - wax or varnish
  - black-brown paint
  - brown paint
  - brown paint (red ochre and carbon black particles are identifiable)
  - thin brown
  - white (probably white lead)
  - black
  - wood substrate (oak/pine).
- The wax/varnish coat is extremely degraded, milky with age; its loss of transparency is leading to the greying appearance of the door at present. It was probably applied in the twentieth century to protect and weatherproof the door.
- The brown layers have coalesced and there are probably many thinner layers within these thick layers. The colour of the north door in recent decades has clearly been black or dark brown; carbon black and red ochre were mixed,

probably to simulate a dark oak coloration. Such colouring schemes would suggest a late eighteenth- or nineteenth-century date for this phase of the paintwork (Larson, personal communication).

- The white and thin brown paint layers may indicate that at some point in the past the door was painted in a mock wood scheme – white background with variable brown streaking or perhaps a red and white pattern design.
- The small number of paint layers does not suggest a painted scheme of great antiquity, nor does the condition of the paint (Darrah, personal communication). The present paint layers are almost certainly post-medieval and are most probably the paint coatings of the eighteenth to twentieth centuries. If the door were, as was previously suggested, repaired in the seventeenth century as part of the work of Bishop Cosin and the vertical pine mouldings were applied, then the first layers of paint could have been applied.

Use

The sanctuary 'knocker' has flanges behind the eye sockets, which indicate that there were originally glass, gem or stone 'eyes' in the sockets. These had been removed at some point in the past, probably in 1530, when, as part of the dissolution of the monasteries, the King's Commissioners came to Durham Cathedral to remove all its precious metals and valuables (Geddes 1982). There is a hole in the forehead of the beast, the result of deliberate damage of unknown date, whilst the sanctuary ring has been broken and repaired at least once during its working life.

The central planks of the north door which form the edges of leaves are different from the other planks in the door since they:

- are bowed and distorted;
- have repairs in the form of pieces added at the top of the plank (see Figure 6.7);
- have nails attaching these planks to two of the three ledges.

These features indicate that these two planks have at one time or another been wrenched off the door. This resulted in the splitting, loss and damage to the edges of the adjoining plank, partially exposing the free tenon between the planks. The most likely period for such extensive damage to these planks is the seventeenth century and the Civil War disturbance. It is possible that the doors were repaired as part of the work of Bishop Cosin. There are two iron cramps on the back of each leaf of the north door, whose purpose is clearly to hold the existing planks in compression. These cramps were applied after the outer door plank was repaired to prevent the loosening of the original ledge and plank joints.

From historic records and archaeological excavation, it appears that in the 1780s Nicholson removed the north porch and remodelled the north doorway (Geddes

1982, Carne 1996). This would have exposed the door to greater weathering and consequently increased the need to repaint it.

The wear on the edges of the leaves of the door, the wicket gate and the sanctuary ring attest the constant use of this entrance over many years, whilst the replacement of the sanctuary ring with a replica in the late 1970s indicates the value the original had acquired, and its perceived vulnerability by the late twentieth century.

Dating

Dendrochronology

The 1991 repair work enabled sections through the planks at either end of each leaf of the door to be planed, polished, photographed and dendrochronologically dated (section 6.2) (Baillie 1995; Caple 1999). The initial results indicated that all four planks from the north door were probably from the same tree, but failed to give a good match to any master chronology. Since a small wicket door, which cut through the planks of the south door, west leaf, already existed, it was also possible to plane, polish, photograph and dendrochronologicaly date the planks of this door. The growth ring data revealed:

- All four planks from the south door were probably from the same tree, and it is likely that all seventeen of the 5–6 m high planks from the north and south doors derive from a single substantial straight oak tree.
- The ring patterns of the planks of the doors could be combined to form a ring sequence of 160 to 192 years that could be cross-dated definitively with two medieval oak chronologies (giving $t = 6.46$ against Carlisle and $t = 5.05$ against East Midlands), with an end date of AD 1094. Adding an allowance for sapwood of 15–50 rings (Hillam *et al.* 1987) suggests a felling date in the range 1109–44 for the timber used to make the Durham Cathedral doors.

Radiocarbon dating

Samples (9 mm in diameter and 17 mm in length) of solid oak wood were obtained, from the cross sections of the exposed planks, using a high-speed router (see Figure 6.7). The samples were submitted to the Oxford Radiocarbon Accelerator laboratory for AMS dating (section 6.2) (Hedges *et al.* 1989) and the dates were published in the Archaeometry Datelist 20 (Hedges *et al.* 1995).

South door, west leaf, plank 2, sample S1 (OxA–4098)	1190 ± 70 years BP
South door, west leaf, plank 2, sample S2 (OxA–4199)	1070 ± 65 years BP
North door, east leaf, plank 4, sample N1 (OxA–4100)	900 ± 70 years BP
North door, east leaf, plank 4, sample N2 (OxA–4101)	1205 ± 70 years BP

The dates were calibrated using the program OxCal 2.18 (Bronk Ramsey 1995). Further calculation enabled the date ranges to become more focused, since the two radiocarbon dates from each plank were a known number of annual growth rings, i.e. a known number of years apart. The best estimate for the outer ring of plank 2 from the west leaf of the south door is 869–1073 (or slightly later). The best estimate for the outer ring of plank 4 from the east leaf of the north door is 935–1094. These are entirely consistent with the dendrochronological dates from the Queen's University Laboratory.

Conclusion

The dendrochronology and radiocarbon dating unequivocally indicates that both the north and south doors of Durham Cathedral are of early twelfth-century construction. This single giant oak tree, felled between 1109 and 1144, most probably in the 1120s, was probably split to form planks and seasoned before it was assembled into a door and installed in the cathedral during the final phases of the construction of the nave, which occurred between 1128 and 1133. The use of the floating-tenon and wedged-ledge construction gave the door lightness and strength. Either when constructed or shortly afterwards, the application of iron strapwork to the exterior of the doors increased their strength and beauty. A large cast bronze sanctuary ring was added to the north door when it became the principal entrance to the cathedral. Later use, in particular the vicissitudes of the seventeenth century, led to damage to the door, particularly the planking at the edges of the leaves. Subsequent refurbishment led to the removal of the strapwork, the application of vertical pine moulding strips and possibly a red/brown and white external paint coating to the front of the door. Iron cramps, cross-bracing and new hinges were added to the back of the door. Wicket gates were cut into both the north and south doors at this or a later period. Subsequent centuries saw the occasional repainting of the cathedral's north door to a more sombre brown, and later black, colour. In the twentieth century a protective coat of wax or varnish was applied.

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