NON-FERROUS METALWORKING IN ENGLAND
LATE IRON AGE TO EARLY MEDIEVAL

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Evidence for non-ferrous metalworking in the late Iron Age to early medieval periods comes mainly from archaeological finds, though Roman and medieval writings supply some supporting information. A gazetteer of sites which have produced evidence for metalworking is provided and these finds are categorised and described together with details of the processes in which they were used or produced. The spatial and temporal distributions of finds of all types are also discussed and reasons suggested for some of the patterns that emerge. The processes for which evidence is presented include refining, alloying, melting, casting, smithing and decorating.

The majority of the data derives from the working of copper and its alloys though gold, silver, lead, tin and their alloys are also covered. The uses made of different alloys throughout the period of the study is also discussed. A more detailed survey of Roman copper alloy usage is based on analyses of over 3,000 late Iron Age and Roman brooches and nearly 900 other objects. Nearly 1,000 of the brooch analyses were quantitative ones carried out by atomic absorption spectrometry while the remainder were qualitative X-ray fluorescence analyses. Many of the metalworking finds were also analysed qualitatively by X-ray fluorescence.

These two strands of evidence are complementary and together provide a mass of evidence for how metals and alloys were worked and the uses that were made of them.

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First mention must go to Leo Biek who made me see what a fascinating and little known subject ancient technology was.

Many archaeologists, who asked me to examine groups of finds from their excavations, have supplied the raw material for this study. The successive Heads of the Ancient Monuments Laboratory (AML) have allowed me to include in this thesis the information I collected from these finds in the course of my work at the Laboratory.

The programme of analyses of Roman brooches was initiated as a study of the brooches from Richborough after discussions between myself, Ian Cross and Sarnia Butcher. The latter has played a major role, providing typological identifications of most of the brooches analysed and has taught me much of what I now know about Roman brooches.

Many temporary staff (mainly students working for me in their vacations) have assisted with the analysis of copper alloy objects; their contributions are set out in detail in Appendix C. Colleagues who have worked, or do work, with me in the AML have also carried out analyses and/or have reported on groups of technological finds; their contribution to the former is shown in Appendix C while the latter is acknowledged by reference to their AML Reports.

Marcos Guillen wrote the computer programmes used to produce the ternary diagrams in Chapter 10 and the distribution maps in Chapter 11.

The geographical range of this thesis may appear illogical as it ignores finds from modern Wales and southern Scotland which have direct parallels in the English material. The choice of area to be covered was governed by my employment, working for English Heritage and its predecessor, which meant that the material available to me for study came almost exclusively from England. The literature survey, which forms an additional part of this thesis, was designed to cover the same area. The small amount of material from outside England that I have seen suggests that it is only the number and distribution of sites which would have been altered had a wider geographical range been studied.

The reasons for the terminal dates chosen for this study are discussed in the introduction but no mention is made there of the chronological subdivisions used in analysing the data. The terms used are Iron Age, Roman, Early Saxon, Middle Saxon, Late Saxon and early medieval. Iron Age refers to the period before the Claudian conquest of 43 AD and Roman to the period from then to the early 5th century. The term Saxon is used in a chronological sense and without cultural connotations and thus is taken to include other descriptors such as Anglo-Saxon, Anglian, Anglo-Scandinavian and Viking. A few contemporary sites in the south west are described as post-Roman. The boundaries between Early, Middle and Late Saxon lie in the later part of the 7th century and the late 9th century respectively. Medieval is used (in a more limited sense than is common nowadays) to describe the period post-dating the Norman conquest of 1066, and early medieval thus refers to the period from then to the early 13th century.

Chapters 1-9 and Appendices A and C were substantially complete by the end of 1988. The AAS analyses had been completed by 1986 though about half the XRF analyses were made after this date. There was no systematic literature search after the beginning of 1990, though further information from my own work after that date was added.

CHAPTER 1
INTRODUCTION

Evidence for non-ferrous metal working has been known to archaeologists for a considerable period of time but only relatively recently has it been drawn together into any sort of consolidated statement. The last quarter century or so has seen a number of publications on this theme, but few of them mention Britain in Iron Age and later times and fewer still concentrate on this area and period.

<u>The present situation</u>

There is no one source to which reference can be made for detailed, up to date and in depth information on non-ferrous metalworking in Britain from Iron Age to medieval times. Singer *et al* attempt a global survey in their *History of Technology* (1954-58) and understandably only produce a general outline, somewhat patchy in its coverage and devoid of many specific examples. Those that are given tend to come from the areas and periods where techniques were developed. Similarly Forbes (1964A and 1964B) devotes two volumes of his survey of ancient technology to metallurgy but covers the Mediterranean civilisations in far greater depth than the barbarian fringes of the then known world. Hodges (1964) deals extensively with the examination of artefacts and the techniques used to produce them but his examples are general ones and do not offer much specific illumination when dealing with particular periods and areas.

Of far more direct relevance is Tylecote's *Metallurgy in Archaeology* (1962A) but even that concentrates on the Bronze Age and has relatively little to say about copper alloy working in later periods. His *History of Metallurgy* (Tylecote 1976) also concentrates on early periods of non-ferrous metalworking but has a limited amount of general information about the periods of interest here. Now a revised version of the earlier book is available (Tylecote 1986A) and this adds some but by no means all of the extra information now available. It shares both the virtues and vices of the earlier version in presenting a single example of every type of find but fails to identify which forms and processes are commonplace and which unique at any time or place.

Other publications dealing with more limited periods or specific techniques are relatively common (eg Strong and Brown 1976, Lins and Oddy 1975) and the evidence from continental Europe is considered in some depth by Oldeberg (1942-3 and 1966) and more recently by Tylecote (1987). Further data from England is available in any number of excavation reports (many of which are noted in Appendix A) but all too often the finds are simply catalogued or described with no attempt at discussion or interpretation.

Outline of thesis

This thesis is an attempt to fill the gap noted above by surveying the published information, supplying new data, and interpreting the whole to give an overall picture of non-ferrous metalworking in England over the periods considered. Where the term 'metalworking' is used below, the expansion 'non-ferrous metalworking' should be understood as working ferrous metals involved a different range of processes.

The main questions that can be posed (and to which answers will be offered) are:-

What continuity or change is discernible in metalworking practices in England in the millennium and a half covered by this survey? Can the origins of the changes be determined or reasons for them be suggested?

Is there any pattern in the use of different alloys and, if so, is this related to date, manufacturing method or intended use, or to other, non-technical factors such as fashion?

By the later Iron Age most of the basic techniques of working non-ferrous metals were well understood and there were relatively few additions to the smiths' repertoire during the periods covered by this study. For this reason it is divided up by technique rather than by period as the latter would lead to much repetition.

The terminal dates for the study have been selected for good reasons. Bronze Age metallurgy has already been considered in detail; Tylecote (1986A) summarises much of this work. The early Iron Age has so far provided little evidence of metalworking and what there is seems to be an extension of the late Bronze Age tradition (eg Northover 1984). The later Iron Age has produced far more material and so, by starting this study in the last century or so BC, a base level of native technology can be defined, against which the effects of the Roman conquest of Gaul and Britain can clearly be seen.

At the other end of the timescale the Norman conquest might be thought to be a suitable boundary but its changes were political rather than economic and the growth of towns in late Saxon and Norman England was a continuous phenomenon so a more significant line can be drawn at the end of the 12th century AD. By then the country was covered by a network of urban centres where metalworkers flourished (Postan 1975). By the 13th century their work was being regulated by craft guilds and this centralization and control developed further in the later middle ages when production was on a far larger scale than in earlier times.

Most of the discussion below relates to the working of copper alloys and the precious metals, gold and silver, but lead and its alloys with tin are also included. Most of the techniques apply to many or all of these metals so considering them together saves duplication. The specific uses of particular metals are described in Chapter 10.

A study of metalworking must necessarily deal with both techniques and materials; in some cases the two are interdependent. The physical evidence for techniques comes from two major sources. First are the finished objects which show what kinds of things were being produced and sometimes can indicate how they were made. Tools, industrial wastes and by-products are more direct indicators of the processes being carried out. From these sources and from contemporary documents the techniques of the metalworkers can be reconstructed; this information is presented in Chapters 3-8. The materials used by the craftsmen, which are discussed in Chapters 9-10, are easier to determine; chemical analysis indicates the composition of the metal used.

Much of the data on which the conclusions presented here are based is summarised in Appendices A and C. The data in Appendix A is a mixture of published and unpublished information. The unpublished material is mainly work that I have carried out at the Ancient Monuments Laboratory (formerly part of the Directorate of Ancient Monuments and Historic Buildings, Department of the Environment, and now part of English Heritage, the Historic Buildings and Monuments Commission for England) though some of it has been done by others, either working with me or under my direction. This work is all referenced by its Ancient Monuments Laboratory (AML) Report Number. These reports are not formally published but are available for consultation both in the Laboratory and in the National Monuments Record. Fiched copies of reports produced since 1986 are available on demand from the Laboratory. All AML Reports are destined for eventual publication as part of the relevant archaeological excavation report. Where this stage has been reached reference is also made to the published version but the AML Report reference is retained as it often contains more detailed information than the published version. The analyses presented in Appendix C are all the results of work that has been carried out in the Ancient Monuments Laboratory under my direction and a substantial proportion are my own work; details of individual contributions are given in Appendix C.

Much of the unpublished work reported here provides further examples of objects and techniques already known, or just expands their geographical or temporal range. In a number of areas however the information or interpretation presented is new.

On the metalworking techniques side, particular attention should be paid both to the identification of cementation crucibles for the manufacture of brass and to the identification of 'heating trays' in England and their interpretation as cupels or assay crucibles (see Chapter 4). Most of these 'heating trays' are late Saxon in date which perhaps explains the previous ignorance of their existence as no major late Saxon metalworking sites had been examined before I started my investigations. It is also this period that has produced copious evidence for silver working (see Chapter 11). Evidence for parting silver from gold has also been identified (see Chapter 4). A further major point relates to metal melting crucibles. Many of these bear traces of an added outer layer of clay but this has received scant attention in the literature. The functions of these additions and their occurrence are discussed in Chapter 5.

On the materials side, the analyses of copper alloy objects presented here (in Appendix C) are a large and significant corpus when compared with all the others, both published and unpublished, which have been carried out on objects of these periods. That all the objects come from controlled excavations and so have a firm provenance, unlike some items in museum collections, adds to the significance of the analyses. When the work that developed into this thesis began in 1975 most archaeologists assumed that all copper alloy objects were bronze despite earlier publications identifying other alloys such as brass (eg Fox and St John Hope 1901, 245); many are now aware of the extra information that analyses can provide (see Chapter 10). A further innovation was in presenting copper alloy analyses on ternary diagrams (Bayley and Butcher 1981), a format which has subsequently been taken up by others (eg Brownsword 1987).

CHAPTER 2

SOURCES OF INFORMATION

There are three main sources of information for non-ferrous metalworking in antiquity. These are the material excavated from archaeological sites, the documents written in antiquity that survive to the present, and current and recent craft practices. Modern scientific investigations can provide additional data from studies of all these sources of information.

The material archaeological evidence is presented in Appendix A as a gazetteer of individual sites and the data is summarised in Tables 2.1-2.7 and the distribution maps in Chapter 11. Material from many but not all of these sites is referred to in the chapters on techniques and materials.

A number of ancient authors' writings contain information which is applicable to the present study. It should however be noted that none of them was writing specifically about England so the practices they describe may not be directly relevant, though they are the best information of this type that exists.

Although modern craftsmen may know in advance that a particular process will work and the reason for its success, the ways they handle their materials are still directly descended from those of the ancient metal workers; indeed even their workshops would contain few surprises, except perhaps in the ways in which high temperatures are produced and controlled. It is therefore useful to consider modern craft practice when describing the methods of manufacture used in antiquity.

As mentioned above, scientific investigations can allow us to know why certain materials or techniques were used in antiquity. In those times they were used because it was known that they worked; we can now know why they worked and thus appreciate more fully the empirical knowledge of the craftsmen of antiquity. As a caveat, it should be remembered that failures are not likely to have survived; they would have gone back into the melting pot for reprocessing!

Excavated material

The excavated evidence for metalworking presented in Appendix A has been summarised in Tables 2.1-2.7 where it is divided into ten categories. These categories are cupels and parting vessels, crucibles, object moulds, ingot moulds, ingots, part manufactures, scrap, waste, tools and models. These categories are defined as follows:
Cupels are shallow dish or disc-shaped vessels (heating trays) used for

refining or assaying precious metals; potsherds reused as cupels are included. Also included are vessels used for parting gold from silver (bracketed in the Tables). All these finds can be considered a subset of the crucibles category.

Crucibles are portable containers, normally made of ceramics, in which metals were heated and usually melted.

Object moulds are closed moulds in which objects were cast directly in their final form, or something close to it.

Ingot moulds are open moulds in which bars or blanks of other shapes were cast for further working.

Ingots include both the metal cast in ingot moulds and other large pieces intended as the raw material of the smith.

Part manufactures are metal that has been cast, often in an ingot mould, and then worked so it is on its way to becoming a usable object. Such things as bars, rods, wire and part-made objects are included as are rough castings that have not been fettled.

Scrap is the by-products of working solid metal, such things as offcuts, sheet fragments, clippings, turnings and filings. The term is also applied to broken objects that were collected for recycling.

Waste is the by-products of working with liquid metal and includes metal-rich slag, solidified spillages of molten metal, sprues and runners removed from castings, and failed and blow-holey castings.

Tools are such things as hammers, files and punches. Many of these can also be used for working iron or non-metallic materials so only those where the association with non-ferrous metals is fairly definite are cited. A few tools, such as dies for producing repetitive patterns in sheet metal, which can be more positively identified with non-ferrous metal working are also included even where there is no contextual link with metal working.

Models etc include the patterns from which piece moulds were made and the roughed-out designs found eg on bone and described as motif or trial pieces.

Table 2.1 - Iron Age sites

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Ancaster: Gap				1							-	-	-	-	-	-
Ancaster: Quarry								yes			0	-	-	-	-	-
Bagendon		yes		100+		yes			yes		0	0	-	-	-	-
Baldock						yes					0	-	-	-	-	-
Basingstoke: Viables Farm		1									-	-	-	-	-	-
Beckford		yes	yes				yes	yes			0	-	-	-	-	-
Bottesford				1							-	-	-	-	-	-
Braughing				1							-	0	-	-	-	-
Braughing: Wickham Kennels				4+		yes					0	0	0	-	-	-
Bredon Hill								yes	yes		0	-	-	-	-	-
Breedon on the Hill		1									-	-	-	-	-	-
Caburn		yes							yes		-	-	-	-	-	-
Canterbury: 44 Watling Street		yes					yes	yes			0	-	-	-	-	-
Canterbury: Marlowes IV and Theatre		4		1							0	-	0	-	-	-
Christon		1	?					yes			0	-	-	-	-	-
Chun Castle					1			yes			-	-	-	-	0	-
Chysauster							yes		yes		-	-	-	-	0	-
Colchester: Sheepen		yes		29+							-	0	-	-	-	-
Cressingham				yes							-	0	-	-	-	-
Croft Ambrey		yes				yes					0	-	-	-	-	-
Danebury		16					yes	yes	yes		0	-	-	-	-	-
Dragonby		yes									-	-	-	-	-	-
Duston				1							-	-	-	-	-	-
Foxholes Farm		1									0	-	-	-	-	-
Gatesbury				yes							-	0	-	-	-	-
Glastonbury Lake Village		24	?1	?1			yes	yes	yes		0	-	-	-	-	-
Grimsby: Weelsby Ave		yes	yes								0	-	-	-	-	-
Gussage All Saints		c.600	7380		1			yes	yes		0	-	-	-	-	-
Ham Hill									yes		-	-	-	-	-	-
Hartburn				1							-	-	-	-	-	-
Hengistbury Head		yes			2		yes	yes	yes		0	0	0	0	-	-
Hod Hill				?1							-	-	-	-	-	-
Hunsbury									yes		-	-	-	-	-	-
Ilchester			1								-	-	-	-	-	-
Kingsdown Camp			yes					yes			0	-	-	-	-	-
Leicester: Blackfriars Street				3							-	-	-	-	-	-
Long Wittenham		1?									-	-	-	-	-	-
Maiden Castle		4+					yes	yes			0	-	-	-	-	-
Meare		yes									0	-	-	-	-	-
Mingies Ditch		2	1?								-	-	-	-	-	-
Mucking		1						?			-	-	-	-	-	-
Oare									yes		-	-	-	-	-	-
Old Sleaford				3000+							-	0	-	-	-	-
Pilsdon Pen		1									-	-	0	-	-	-
Polden Hills									yes		-	-	-	-	-	-
Poundbury		2									0	-	-	-	-	-
Rampton		2									0	-	-	-	-	-
Red Moor, Lanlivery								yes			-	-	-	-	0	-
Ringstead						yes					0	-	-	-	-	-
Rochester				10							-	0	-	-	-	-
Santon						yes	yes		yes		0	-	-	-	-	-
Scotton				1							-	-	-	-	-	-
Silchester		yes	yes	yes							0	0	-	-	-	-
Snettisham					1	1					-	0	0	-	-	-

Table 2.1 (continued)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
South Cadbury						yes	yes		yes		0	-	0	-	-	-
St Albans (Verulamium)		yes		many							-	-	0	-	-	-
St Mawgan in Pyder		yes			1		yes	yes			0	-	-	-	0	-
Stanwick		yes	1		yes		yes	yes			0	-	-	-	-	-
Sutton Walls		1							yes		0	-	-	-	-	-
Swallowcliffe Down								yes	yes		0	-	-	-	-	-
Swarling											0	-	-	-	-	-
Thetford: Fison Way		243	49	109	2			yes			0	0	-	-	-	-
Thorpe Thewles		11		2							-	-	-	-	-	-
Trevelgue								yes			0	-	-	-	0	-
Waldringfield			30+								0	-	-	-	-	-
Weekley		1									-	-	-	-	-	-
Wetwang Slack		17	yes								0	-	-	-	-	-
Winchester		1		1				yes			0	-	-	-	-	-
Windlesham											0	-	-	-	-	-
Winklebury		1			1						0	-	-	-	-	-
Winnall Down		4									0	-	-	-	-	-
Winterbourne Monkton Down		1									-	-	-	-	-	-
Wolsty Hall				1							0	-	-	-	-	-
Woodmancote: The Ditches				1							-	-	0	-	-	-
Wookey Hole Cavern		1									-	-	-	-	-	-

Table 2.2 - Roman sites

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Alcester		6	1								0	-	-	-	-	-
Alcester: 1-5 Bleachfield Street		13									-	-	-	-	-	-
Alcester: Gateway Supermarket		1					yes	yes			0	-	-	-	-	-
Baldock		20+			yes?	yes	yes				0	-	-	-	-	0
Baldock: Upper Walls Common											0	-	-	-	-	-
Bath			1		1						-	-	-	-	-	0
Bath: Abbey Green							yes	yes			-	-	-	0	-	-
Benwell							yes				-	-	-	-	-	0
Bletsoe			2								-	-	-	-	-	-
Bodinar							yes				-	-	-	-	0	-
Box		2					yes	yes			0	-	-	-	-	-
Boxgrove		1		yes							0	-	-	-	-	-
Brampton											0	-	-	-	-	-
Braughing		3+		1				yes			0	-	-	-	-	-
Brislington			2				yes				-	-	-	0	-	0
Bristol: Filwood Park						yes					-	-	-	0	-	-
Brough on Humber		1			5		yes				0	-	-	0	-	-
Brough on Noe							yes	yes			-	-	-	0	-	-
Brough under Stainmore						yes		yes		model	0	-	-	0	-	-
Caister by Yarmouth	1	8						yes	yes		0	0	-	-	-	-
Caistor by Norwich		yes	yes					yes			0	-	-	-	-	-
Camerton			4								-	-	-	-	-	0
Canterbury					4						-	0	-	-	-	-
Canterbury: 7 Palace St		1									0	-	-	-	-	-
Canterbury: Cakebread Robey		yes									0	-	-	-	-	-
Canterbury: Marlowes III and Cakebread Robey		9									0	-	-	-	-	-
Canterbury: St John's Lane		1									0	-	-	-	-	-
Carlisle		1									0	-	-	-	-	-
Carlisle: Castle Street							yes		yes		0	-	-	-	-	-
Carlisle: Fisher Street		yes					yes				0	-	-	0	-	-
Carlisle: Keays Lane		2						yes			0	-	-	-	-	-
Carn Euny							yes				-	-	-	-	0	-
Carnanton					1						-	-	-	-	0	-
Carsington					2						-	-	-	0	-	-
Castle Gotha			1				yes	yes			0	-	-	-	0	-
Castleford			c.800								0	-	-	-	-	-
Castleford			100's								0	-	-	-	-	-
Castleford		c.25									0	0	-	-	-	-
Castor		1									-	-	-	-	-	-
Catterick		1					yes				0	-	-	-	-	-
Catterick: Bainesse Farm		1									0	-	-	-	-	-
Charterhouse		2			12+						-	0	-	0	-	-
Chedworth		yes					yes				0	-	-	-	-	-
Chelmsford: Sites CHAA and CHN		yes						yes			0	-	-	-	-	-
Chester-le-Street: Middle Chare		1									-	-	-	-	-	-
Chester: Hunter Street School	2	4						yes			0	0	0	0	-	-
Chester: Hunters Walk		1						yes			0	-	-	-	-	-
Chester: Site GFC		3									0	-	-	-	-	-
Chesterfield		4									-	0	-	-	-	-

Table 2.2 (continued)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Chew Park								yes			-	0	-	0	-	-
Chichester: Chapel St	(21)	30				yes	yes				-	0	0	-	-	-
Chichester: Greyfriars		1									0	-	-	-	-	-
Cirencester	1	3+									0	-	0	0	-	-
Cirencester: Bath Gate Cemetery		4									0	0	-	-	-	-
Claydon Pike		2			1			yes			0	-	-	-	-	-
Colchester: Balkerne Lane		3									0	-	-	-	-	-
Colchester: Castle		1									0	-	-	-	-	-
Colchester: Culver St		65						yes			0	0	0	-	-	-
Colchester: Lion Walk		yes					yes	yes			0	0	-	0	-	-
Colchester: Sheepen		21+	5+	2	2	yes	yes	yes			0	-	-	-	-	-
Combe Down			?								-	-	-	-	-	0
Compton Dando		yes	100's			1					0	-	-	-	-	-
Corbridge					1		1				-	-	-	-	-	0
Corbridge: Red House site		1						yes			0	-	-	0	-	-
Cottenham								yes			0	-	-	-	-	-
Dalton Parlours		yes									0	-	-	-	-	-
Dewlish		1									0	-	-	-	-	-
Doncaster		5									0	0	-	-	-	-
Doncaster: Frenchgate and St Sepuchre Gate		1						yes			-	0	-	0	-	-
Dorchester											-	-	-	0	-	-
Dorchester: Greyhound Yard		4	1								0	-	-	-	-	-
Dorchester: Methodist Chapel		1									-	-	-	-	-	-
Dorchester: Wollaston House							yes	yes			0	-	-	-	-	-
Droitwich											0	-	-	-	-	-
East Harptree					5						-	0	-	-	-	-
Eccles		iron									-	-	-	-	-	-
Edington			many								-	-	-	-	-	-
Elmswell		1									-	-	-	-	-	-
Exeter: Bartholomew East Street		yes									-	-	-	-	-	-
Exeter: Basilica							yes	yes			0	-	-	-	-	-
Exeter: Frienhay Street	2?(7)	2									0	0	0	-	-	-
Exeter: Rack Street		5						yes			0	-	-	-	-	-
Exeter: South St		6									-	-	-	-	-	-
Exeter: Trichay Street		2				yes	yes	yes			0	-	-	-	-	-
Exeter: near South Gate											-	0	-	0	-	-
Faxfleet					1						-	-	-	0	-	-
Frocester Court			yes					yes			0	-	-	-	-	-
Gatcombe							yes	yes			0	-	-	0	-	0
Gestingthorpe		yes	yes			yes	yes	yes			0	-	-	-	-	-
Gloucester: 1 Alvin Street					1						0	-	-	-	-	-
Gloucester: 10 Lower Quay Street		1									-	-	0	-	-	-
Gloucester: 63-71 Northgate Street			1								-	-	-	-	-	-
Gloucester: Coppice Corner					1						0	-	-	-	-	-
Gloucester: Kingsholm		6				yes	yes	yes			0	0	-	0	-	-
Gloucester: Westgate Street		1	3								-	0	-	-	-	0
Godmanchester		yes					yes	yes			0	-	-	-	-	-
Gorhambury		4		1			yes	yes			0	0	0	-	-	-
Great Casterton		1									0	-	-	-	-	-

Table 2.2 (continued)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Great Dunmow		1						yes			0	-	-	-	-	-
Great Witcombe			yes								-	-	-	-	-	0
Green Ore					4			yes			-	0	-	0	-	-
Hacheston								yes			0	-	-	-	-	0
Halstock			12								-	-	-	-	-	-
Halton Chesters									2		-	-	-	-	-	-
Hambleden		1					yes		yes		0	-	-	-	-	-
Harpham		4	4+			yes	yes				0	-	-	-	-	-
Headington Wick		yes									-	-	-	-	-	-
Heronbridge		10+	yes					yes			0	-	-	0	-	-
Herriott's Bridge		2				yes	yes	yes			-	0	-	0	-	-
Heybridge						yes	yes	yes			0	-	-	-	-	-
Hockwold					1	yes	yes	yes			-	-	-	-	-	0
Housesteads		1	1								-	-	-	-	-	-
Ickham							yes	yes			-	-	-	0	-	0
Kelvedon											-	-	-	-	-	-
Kenchester		yes	?	?				yes		yes	0	-	-	0	-	-
Keynsham		1	1								-	-	-	-	-	-
Keynsham: Manor Woods			2								-	-	-	-	-	-
Kingscote											0	-	-	-	-	-
Kirkby Thore											0	-	-	-	-	-
Langridge			1								-	-	-	-	-	0
Langton		5	1								0	-	-	0	-	0
Lansdown			40+								0	-	-	-	-	0
Lechlade: Rough Ground Farm		1									-	-	-	-	-	-
Leicester		yes	2					yes			0	0	-	0	-	-
Leicester: The Shires			yes								-	-	-	-	-	-
Lincoln			yes								-	-	-	-	-	-
Lincoln: Flaxengate	(12)										-	0	0	-	-	-
Lincoln: Grantham Place	(1)										-	0	0	-	-	-
Lincoln: Silver Street/ Saltergate	(10)										-	0	0	-	-	-
Lincoln: St Mary's Guildhall			yes				yes				0	-	-	-	-	-
Lingwell Gate		1	yes								-	-	-	-	-	-
Littlecote Park											0	-	-	-	-	-
London: 85 London Wall			700+					yes			0	-	-	-	-	-
London: Battersea/River Thames					10						-	-	-	-	-	0
London: Copthall Avenue	3?	6									0	0	0	-	-	-
London: Crosby Square								yes			0	-	-	-	-	-
London: Newgate Street			2								-	-	-	-	-	-
London: S of Cannon Street	(7)	1					yes				-	0	0	-	-	-
London: St Helen's Place		1									0	-	-	-	-	-
London: Tenter Street		1									0	-	-	-	-	-
London: Tower of London					1						-	0	-	-	-	-
London: Walbrook							yes				-	-	-	-	-	0
Long Bennington		2	1?								0	-	-	-	-	-
Longthorpe		1					yes				0	-	-	-	-	-
Looe Island					1						0	-	-	-	-	-
Lullingstone		2			5						0	-	-	-	-	-
Lydney Park						yes	yes	yes		model	0	-	-	0	-	-
Magiovinium		4						yes			0	-	-	-	-	-
Malton		yes	1				yes	yes			0	-	-	-	-	-
Matlock Moor											-	-	-	0	-	-

Table 2.2 (continued)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Melandra											-	-	-	0	-	-
Milton Keynes: Bancroft villa (MK 105)		1									0	-	-	-	-	-
Minsterley											-	-	-	0	-	-
Murton High Crags				1							-	-	-	-	-	-
Nanstallon		yes									-	0	-	-	0	-
Neatham		yes	1					yes			0	-	-	-	-	0
Needham				1							-	-	-	-	-	-
Nettleton		4	6								0	-	-	-	-	0
North Leigh						yes		yes			0	-	-	-	-	-
Norton											-	-	0	-	-	-
Oldcroft						4					-	0	-	-	-	-
Oulton									yes		0	-	-	-	-	-
Owmby						yes					0	-	-	-	-	-
Pakenham		5	1					36			0	0	-	-	-	-
Par Beach, St Martin's					1						-	-	-	-	0	-
Piddington							yes	yes			0	-	-	0	-	-
Piercebridge	1	12	1								0	0	-	-	-	-
Poole's Cavern						yes	yes	yes	yes	model	0	-	-	0	-	-
Portchester Castle		1									0	-	-	-	-	-
Porthmeor					yes		yes		yes		-	-	-	-	0	-
Poundbury							yes	yes			-	-	-	0	-	-
Richborough		yes			3			yes			0	0	-	0	-	-
Rocester			c.90								0	-	-	-	-	-
Rockbourne: West Park Villa		2			1						0	-	-	-	0	-
Rudston		8	2	1			yes	yes			0	-	-	-	-	-
Rushmore									yes		-	-	-	-	-	-
Saltersford		yes				yes		yes	yes		0	-	-	-	-	-
Scarcliffe											-	-	-	0	-	-
Sewingshields		1	yes								0	-	-	-	-	-
Silchester		6+	7		1	1		yes	yes	yes	0	0	-	0	-	0
Snailbeach											-	-	-	0	-	-
Snettisham						yes	yes		yes		-	0	0	-	-	-
Snettisham		c.50	c.30								0	-	-	-	-	-
Snodland		1					yes				0	-	-	-	-	-
South Shields		2	1		1?	yes	yes				0	-	-	-	-	-
Southampton (Clausentum)					2						-	-	-	0	-	-
Southwark: 1-7 St Thomas Street		1									0	-	-	-	-	-
Southwark: 107-115 Borough High Street								yes			-	0	-	0	-	-
Southwark: 201-211 Borough High Street						1		yes			0	-	-	-	-	-
Southwark: Arcadia Buildings		yes	?yes								0	-	-	-	-	-
Southwark: Bonded Warehouse, Montague Close								yes			0	-	-	-	-	-
Southwark: Cathedral Crypt								yes			-	0	-	0	-	-
Southwark: District Heating Scheme		2									0	0	-	-	-	-
Southwark: Toppings Wharf							yes	yes			0	-	-	-	-	-
Springhead						?					0	-	-	0	-	-
St Albans (Verulamium)	4	c.50					yes	yes	yes		0	0	0	-	-	-
St Just in Penwith			2								-	-	-	-	-	0
Stanmore					1						-	0	-	-	-	-
Stanwick			1								-	-	-	-	-	-

Table 2.2 (continued)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Stanwix						yes	yes	yes			0	-	-	-	-	-
Stoke Gifford		yes					yes	yes			0	-	-	-	-	-
Studland		3		1							0	-	-	-	-	-
Tarrant Hinton								yes			-	-	-	0	-	-
Templebrough		3+					yes	yes			0	-	-	0	-	-
Thistleton		2									-	-	-	-	-	-
Thorpe						yes					0	-	-	0	-	-
Tiddington		yes						yes			0	0	-	0	-	-
Towcester			1				yes				-	-	-	0	-	0
Towcester: St Lawrence's Church		yes					yes	yes			0	-	-	-	-	-
Tower Knowe				1							-	-	-	-	-	-
Trethurgy					1						-	-	-	-	0	-
Tripontium					1						-	-	-	0	-	-
Uley			1?			yes	yes	yes			0	0	-	0	-	-
Vindolanda		yes		6				yes			0	-	-	-	-	-
Wall (Letocetum)											-	-	-	0	-	-
Walton-le-Dale		3									0	0	-	-	-	-
Ware						yes					0	-	-	-	-	-
Water Newton			yes								-	-	-	-	-	-
Wattisfield			12								-	-	-	-	-	-
Westbury			1								-	-	-	-	-	0
Weston-under-Penyard							yes	yes			0	-	-	-	-	-
Whatley								yes			-	-	-	0	-	-
Whitchurch								yes			0	-	-	0	-	-
Whitchurch		4	350								0	-	-	-	-	-
Wick			1								-	-	-	-	-	0
Wicklewood					yes	yes	yes	yes			0	0	-	0	-	0
Wilderspool		yes					yes			model	0	-	-	0	-	-
Wilderspool: Loushers Lane		1	yes								0	-	-	-	-	-
Wimbourne					yes						-	-	0	-	-	-
Winchester		11			?						0	-	-	-	-	-
Winchester: Staple Gardens		6									0	0	-	-	-	-
Winchester: Victoria Road								yes			-	0	-	0	-	-
Witcombe			1								-	-	-	-	-	0
Woodeaton					3		1				0	-	-	-	-	-
Wroxeter		yes	yes			yes		yes	yes		0	0	-	0	-	0
York: Aldwark			yes								-	-	-	-	-	-
York: Church Street		1									-	-	-	-	-	-
York: Parliament Street			1								-	-	-	-	-	0
York: Rougier Street		3									0	-	-	-	-	-
York: St Mary Bishophill Senior		1					yes				0	-	-	-	-	-
York: Tanner Row	4	1	1?								0	-	0	-	-	-
York: [Yorkshire Museum]		4									0	-	-	-	-	-

Table 2.3 - Early Saxon sites (5th-7th century)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Ash									1		-	-	0	-	-	-
Barton on Humber									yes		-	-	-	-	-	-
Bury St Edmunds									yes		-	-	-	-	-	-
Cassington: Purwell Farm								yes			0	-	-	-	-	-
Chalton							1				0	-	-	-	-	-
Finglesham									yes		-	-	-	-	-	-
Glastonbury Tor		2									0	-	-	-	-	-
Icklingham: Mitchell's Hill									1		-	-	-	-	-	-
Kingston Down									1		-	-	0	-	-	-
Louth									1		-	-	-	-	-	-
Lullingstone									1		-	-	-	-	-	-
Mucking		yes	2+								-	-	-	-	-	-
Ozengell									1		-	-	0	-	-	-
Rochester: 30 High Street									yes		-	-	-	-	-	-
Salmonby									yes		-	-	-	-	-	-
Spong Hill		1									-	-	-	-	-	-
Sutton Courtney		1?									-	-	-	-	-	-
Tattershall Thorpe							yes		yes		0	-	-	-	-	-
Tintagel		1	1?					yes		1	0	-	-	-	-	-
West Stow		?									-	-	-	-	-	-
Woodeaton								yes			-	-	-	-	-	-
Yeavering		13									0	-	-	-	-	-
Salisbury			-	-	-	-			1		-	-	-	-	-	-

Table 2.4 - Middle Saxon sites (7th-9th century)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Barrow on Humber	1	yes	yes								0	0	-	-	-	-
Canterbury: Cakebread Robey			yes								-	-	-	-	-	-
Carlisle: The Lanes			2								-	-	-	-	-	-
Hartlepool: Church Close		yes	yes								0	0	-	-	-	-
Huntingdon										model	0	-	-	-	-	0
Jarrow		3									0	-	-	-	-	-
London: Jubilee Hall		2						yes			0	0	-	0	-	-
Prah Sands					4						-	-	-	-	0	-
Sevington						yes					-	-	-	-	-	-
Southampton (Hamwih)	6	50+	6	4+			yes	yes	yes		0	0	0	0	-	-
Wharram Percy		5	15						yes		0	-	-	-	-	-
Whitby Abbey				2					1		-	-	0	-	-	-
York: 46-54 Fishergate		36		1							0	0	-	-	-	-
Boscarne					1						-	-	-	-	0	-

Table 2.5 - Late Saxon sites (mainly 10th/11th century)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Bedford: Empire Cinema Site		yes									0	0	-	-	-	-
Bowes: Old Spital Farm					17			3			-	0	-	-	-	-
Canterbury: Marlowes IV			2					1			0	-	-	-	-	-
Cheddar	3?	59	1			yes		yes			0	0	0	-	-	-
Chester: Castle Esplanade					23+75						-	0	-	-	-	-
Chester: Cuppin Street				1							-	-	-	-	-	-
Chester: Lower Bridge Street				1							-	-	-	-	-	-
Croydon					4						-	0	-	-	-	-
Cuerdale					183+	168+					-	0	-	-	-	-
Easingwold					1						-	0	-	-	-	-
Gloucester: St Oswald's Priory			yes					yes			0	-	-	-	-	-
Goldsborough					1+1						-	0	-	-	-	-
Holy Island								yes			-	-	-	0	-	-
Ipswich	lots	yes	c.20		1						0	-	0	-	-	-
Lincoln: Bailgate											0	-	-	-	-	-
Lincoln: Dane's Terrace		c.20									-	-	-	-	-	-
Lincoln: Flaxengate	yes	100's	yes	5		yes	yes	yes			0	0	-	0	-	-
Lincoln: Grantham Place		10		1				yes			-	-	-	-	-	-
Lincoln: Holmes Grain				2							-	-	-	-	-	-
Lincoln: Hungate		20						yes			0	-	-	-	-	-
Lincoln: Silver Street/ Saltergate	yes	200+		1				yes			0	0	0	0	-	-
London: Aldersgate Street										yes	-	-	-	0	-	-
London: Cheapside						yes					-	-	-	-	-	0
London: Milk Street		10		1							0	0	-	-	-	-
London: various sites in the city		132									0	0	-	0	-	-
Netherton	yes	yes	yes?				yes	yes			0	0	0	-	-	-
North Elmham		1									0	-	-	-	-	-
Northampton: Black Lion Hill		1									0	-	-	-	-	-
Northampton: Chalk Lane	5	c.100						yes			0	0	-	-	-	-
Northampton: Marefair	1	c.12					yes	yes			0	0	-	-	-	-
Northampton: St Peter's Street		1				yes		yes			0	-	-	0	-	-
Northampton: St Peter's Gardens	1	8							yes		0	0	-	-	-	-
Northampton: The Green		2									0	-	-	-	-	-
Norwich											0	-	-	-	-	-
Norwich: Fishergate	1										-	0	-	-	-	-
Oxford		yes		1							0	0	-	-	-	-
Portchester Castle		1									-	-	-	-	-	-
Scotby					6						-	0	-	-	-	-
Southampton: Brewhouse Lane			1								-	-	-	-	-	-
Southwark: Tooley Street										1	-	-	-	-	-	-
Thetford: Brandon Road (Site 5756)		2	yes					yes			0	0	-	-	-	-
Thetford: Minstergate		13									-	0	-	-	-	-
Thetford: Red Castle		3									-	-	-	-	-	-
Thetford: Redcastle Furze		few		1					4		0	-	-	-	-	-
Thetford: Site 1092		2		1?		yes					-	-	-	-	-	-
Thetford: Site 4	1	2									0	0	-	-	-	-

Table 2.5 (continued)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Thetford: Sites 1 and 2	2	35	1	2		yes	yes		yes		0	0	-	0	-	-
Thetford: Star Lane		1									-	-	-	-	-	-
Winchester: Castle Yard	3	23									-	0	-	-	-	-
Winchester: Cathedral Green	2	34	yes					yes			0	0	-	-	-	-
Winchester: Cathedral Car Park	1(1)										-	0	0	-	-	-
Winchester: Lower Brook Street	1(4)	17						1	2		0	0	0	-	-	-
Winchester: Wolvesey Palace	12	27									0	0	0	-	-	-
Winchester: western suburbs		18						yes			0	-	-	-	-	-
York: 1 Kings Square				1							-	-	-	-	-	-
York: 16-22 Coppergate	19 (15)	975	11	12	4	yes	yes	yes	yes	yes	0	0	0	0	0	0
York: 22 Piccadilly	(65)										-	0	0	-	-	-
York: 9 Blake Street		yes	1								-	-	-	-	-	-
York: Castle										1	-	-	-	-	-	-
York: Hungate		few									-	-	-	-	-	-
York: Parliament Street		1									0	-	-	-	-	-
York: Tanner Row		3									0	-	-	-	-	-

Table 2.6 - Early medieval sites (mainly 12th/13th century)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Bath: Citizen House		1									-	-	-	-	-	-
Binham Priory		lots									0	-	-	-	-	-
Bury St Edmunds Abbey						yes		yes			-	0	-	0	-	-
Canterbury: 41 St George's Street		30						yes			0	0	-	-	-	-
Canterbury: Cakebread Robey					1		yes	yes			0	-	-	-	-	-
Canterbury: St Augustine's			yes			yes		yes			0	-	-	-	-	-
Canterbury: St John's Lane								yes			-	0	-	0	-	-
Carlisle: Annetwell Street	(1)										-	0	0	-	-	-
Castle Rising		30?	yes					yes			0	-	-	0	-	-
Cirencester: St Mary's Abbey	1	1									0	0	-	-	-	-
Colchester: various sites	1?	6									0	0	-	-	-	-
Coventry: Much Park Street		6	7			yes		yes			0	-	-	-	-	-
Dorchester: Greyhound Yard		1?									-	-	-	-	-	-
Exeter: 34-8 Bartholomew Street East			yes								-	-	-	-	-	-
Exeter: St Mary Major											0	-	-	-	-	-
Exeter: various sites		50+	3					yes			-	-	-	-	-	-
Gloucester: Westgate Street	?1										-	-	-	-	-	-
Hartlepool											0	-	-	-	-	-
Ilchester		5									-	-	-	-	-	-
Lincoln: Lucy Tower		5	1								-	-	-	-	-	-
Lincoln: Michaelgate		c.70									-	-	-	-	-	-
Lincoln: Spring Hill	2	1									-	-	-	-	-	-
Lincoln: Swan Street			2								0	-	-	-	-	-
Lincoln: The Lawn			yes					yes			0	-	-	-	-	-
Lincoln: The Park	1		1								-	-	0	-	-	-
Lincoln: West Parade		23									-	-	-	-	-	-
London: St Mary at Hill, Lower Thames St		1									-	-	-	-	-	-
Norwich: 73 St Benedict's Street		1									0	-	-	-	-	-
Norwich: Castle Mall			yes					yes			0	-	-	-	-	-
Norwich: World's End Lane			yes					yes			0	-	-	-	-	-
Nottingham: Lace Market area											0	-	-	-	-	-
Old Sarum		2							yes		0	-	-	-	-	-
Ravensden											0	-	-	-	-	-
Romsey Abbey			few					yes			0	-	-	-	-	-
Thetford: Guildhall (Site 25296)	6(1)	9						yes			0	0	0	0	-	-
Thetford: Site 5759		1	yes					yes			0	0	-	-	-	-
Thurgarton			yes								0	-	-	-	-	-
Thurleigh											0	-	-	-	-	-
Winchcombe: North Street		1									-	-	-	-	-	-
Winchester: Assize Courts	3	37									0	0	-	-	-	-
Winchester: Lower Brook Street	8	145						4			0	0	-	-	-	-
Winchester: Staple Gardens								yes			-	0	-	0	-	-
Winchester: western suburbs	?1	27						yes			0	0	-	0	-	-
York: Bedern			yes								0	-	-	-	-	-
York: Feasegate		1									0	-	-	-	-	-

Table 2.7 - Medieval sites (not closely dated)

Site	cupel (part)	cruc	obj mould	ingot mould	ingot	part manuf	scrap	waste	tools	model etc	Cu	Ag	Au	Pb	Sn	PbSn
Barton on Humber: St Peter's Church											0	-	-	0	-	-
Bristol: Victoria Street			yes								0	-	-	-	-	-
Charterhouse		2									-	-	-	-	-	-
Christchurch Priory			yes								-	-	-	-	-	-
Colchester: Gilberd School			yes					yes			0	-	-	-	-	-
Grove Priory											-	-	-	0	-	-
Gunnerside											-	-	-	0	-	-
Hadstock: St Botolph's Church											0	-	-	0	-	-
Hereford: Bewell House											0	-	-	-	-	-
Lyveden			1								-	-	-	-	-	-
Milton Keynes (MK 636)				1							-	-	-	-	-	-
Norwich: Bacon's House			yes								0	-	-	-	-	-
Norwich: Magdalen Street											0	-	-	-	-	-
Norwich: Pottergate							yes				0	-	-	-	-	-
Thornton: St Peter's Church											0	-	-	-	-	-
Trereife					1						-	-	-	-	0	-
Wadsley		1									-	-	-	-	-	-
Wallingford: St Michael's Church											0	-	-	-	-	-
York: 34 Shambles						yes	yes				0	-	-	-	-	-
York: Goodramgate											0	-	-	-	-	-

Where the information in Tables 2.1-2.7 comes from published sources the exact nature of the finds is not always clear so the divisions between different categories, particularly part manufactures, scrap and waste, are in some cases not as precise as in others. The terms most commonly used in the literature are scrap and waste but they are rarely defined so the correspondence with the categories defined above can only be assumed.

The nature of the metals being worked is also recorded in Tables 2.1-2.7. It should be noted that there is no indication of which categories of finds relate to which metals as this would require a 10 x 6 matrix for each site; this information is however contained in Appendix A.

The frequency of each category of finds in each period is summarised in Table 2.8 (the poorly dated medieval material in Table 2.7 has been omitted). The figures represent the number of sites where each category is present and give no special weight to the few sites which have produced large quantities of metalworking finds. Large quantities are by and large a coincidence of survival and excavation. More usually a few fragments represent what must originally have been a larger group of material.

Table 2.8 - Summary of finds from Tables 2.1-2.6

	Iron Age	Roman	Early Saxon	Middle Saxon	Late Saxon	Early Medieval	Total
No of sites	75	241	22	13	63	46	460
cupel	-	8	-	2	17	9	36
parting vessel	-	6	-	-	4	2	12
crucible	39	121	7	7	38	24	236
object mould	13	64	2	6	12	15	112
ingot mould	24	12	-	3	13	-	52
ingot	8	34	-	2	9	1	54
part manufacture	8	30	-	1	8	3	50
scrap	11	60	2	1	5	1	80
waste	20	76	3	2	17	17	135
tool	16	14	13	3	5	1	52
model etc	-	6	1	1	4	-	12

- - - - -

The overall frequency of finds in the ten categories is very variable with crucibles well in the lead, followed by object moulds, scrap and waste and then ingots, ingot moulds, part manufactures and tools. Cupels are slightly less common and models and parting vessels rarities. This pattern is predictable as both crucibles and object moulds were often used only once and then had no value and were discarded. The high frequency of scrap and waste is more surprising as most of this material could easily have been recycled. Perhaps actual frequencies are distorted by the way archaeologists collect and identify finds; metal is carefully collected and often conserved so the presence of scrap and waste may be noted even when other indicators of metal working were not identified.

The low frequencies of the other categories of finds can be explained as follows:

Ingot moulds were used repeatedly and so were never made in large numbers. Ingots were large and hence valuable pieces of metal. Part manufactures had a value because of the work already done to the metal and so were not usually discarded, faulty pieces would have been remelted and reused. Tools would have had a long life and an association with metalworking is usually not specifically identified. Cupels and parting vessels are indicators of uncommon processes. Models were probably often made of organic materials which do not survive well on many archaeological sites.

The reasons suggested here for the differing frequencies of each category of finds relates to the nature of the processes for which they provide evidence. The differences between the various periods have more complex origins which are discussed in Chapter 11. The metals and alloys being worked also have an effect on the nature of the finds which is considered in Chapter 10.

Ancient authors

It is necessary to remember that none of the ancient authors mentioned in this section wrote in English and so difficulties in translation as well as inaccuracies due to damaged or incorrectly copied manuscripts must be added to any imprecision in what was originally written. This can lead to subtle though significant differences in interpretation and hence in the information extracted from the text. One example of this is the two modern translations of Theophilus' *De Diversis Artibus* by Dodwell (1961) and Hawthorne and Smith (1979).

None of the classical authors whose work has come down to us were craftsmen or technologists. They were generalists reporting what they were told or read, often in detail but without questioning its truth or validity. Even where their information is sound there is little or no interpretation and certainly no extrapolation from the particular to the general.

Much information was copied time and again with one writer quoting from an earlier one so it is dangerous to date the appearance of a technique by the oldest surviving literary reference to it. Most authors were not writing specifically about metalworking, even when they were compiling a technical work, but make passing reference to a material or process which can have a metallurgical use or function. Examples are the various allusions to calamine and brass making by Strabo (quoting Theopompus), Dioscorides and Pliny (Bayley 1990A).

Pliny was writing in the mid 1st century AD and had travelled outside Italy but his experiences were effectively restricted to the Mediterranean world. He does however devote large parts of two books of his *Historia Naturalis* to metals and metalworking and so provides much information arranged in a fairly systematic way. Bailey, who translated these books (1929 and 1932), notes in his introduction that:

> "Pliny is often accused of being a mere collector of facts from other writers, and of failing to test their accuracy ... He recounts facts, but he seldom attempts a generalisation based on these facts ... We are struck by the contrast between the very considerable amount of accurate knowledge about the properties [of materials] and the almost entire absence of theorising ... In antiquity one was interested in facts or theories, but not, as a rule, in both."

Pliny is not therefore an ideal source but he is no worse than the rest of the classical authors and does have the advantage of presenting a relatively large and detailed body of information. It is necessary however to realise there are inconsistencies, especially in his use of technical terms, and that the names he uses are not always applied as in modern practice.

He mentions gold and silver and their refining, copper alloys, lead and tin alloys and their composition and the materials used for soldering and plating. The details he reports appear in the relevant places in the chapters below, referred to by their book and paragraph numbers (eg Bk 34, 160). The translation used is that of Bailey (1929 and 1932).

Two other manuscripts that survive are the so called Leyden and Stockholm papyri which date to the end of the 3rd century AD (Caley 1926 and 1927). They are lists of recipes, often in an abbreviated or incomplete form, that craftsmen could have used as reminders, though not as full instructions. They appear to have been collected over a period of time as there is considerable duplication and overlap between individual recipes. Topics covered include purifying metals and testing for purity, making alloys, surface colouring and imitating precious metals. There were originally many similar papyri but most of them were systematically destroyed in the 4th century (Brown 1913). Some of the recipes in them did however survive and form the basis for later compilations, both Arabic and European. There is a continuity between Graeco-Egyptian knowledge (which was taken over *en bloc* by the Romans) and that of later times, extending well into the medieval period. In the post-Roman world various technical manuscripts were assembled, copied and added to over the centuries and sometimes commentaries on them produced, but there is no indication of a new or practical input until the appearance of Theophilus' *De Diversis Artibus* in the first half of the 12th century.

The earlier post Roman manuscripts include *Compositiones ad tingenda musiva* (Hedfors 1932) which dates to the end of the 8th century and the *Mappae Clavicula* (Smith and Hawthorne 1974) which was compiled early in the 9th century. These are clearly both compilations, whether gathered together at one time or assembled over a period. The information in them is not grouped by topic or arranged in any logical order. There is clear evidence of copying as very similar blocks of text are found in several manuscripts and there is duplication within one manuscript as added recipes reproduce existing information. They contain some factual, practical information for such things as soldering and gilding but also almost alchemical recipes, eg for making gold. A full discussion of the various manuscripts and their relationships and date are given by both Hawthorne and Smith (1979) and Dodwell (1961).

Theophilus' *De Diversis Artibus*, written in the early 12th century, is quite different in content. It is made up of three books describing the work of the painter, glass worker and metal worker respectively and was written by a practising craftsman who presents a comprehensive range of information in an orderly and logical fashion. It is a thoroughly practical handbook and the detailed descriptions indicate a familiarity with almost all of the processes being written about. It is not copied from earlier works though some of the practical information they contain is part of the working tradition on which Theophilus based his descriptions and which he interpreted and emended in the light of his own experience. He was a Benedictine monk, a German working in the north west of the country and can probably be equated with Roger of Helmarshausen, a few of whose works survive to this day (Hawthorne and Smith 1979).

Book III on metalworking, which comprises the major part of the work, starts with instructions on how to lay out a workshop and build furnaces. It includes details of techniques such as refining, casting and decorating metalwork. Much of this information is referred to (by its chapter number, eg Ch 87) in Chapters 4-8. The translation used is that of Hawthorne and Smith (1979).

By the 16th century there were a number of technical treatises being written and printed; like Theophilus, their statements are based on actual observations and personal experience. Among the earliest are Biringuccio's *De la pirotechnia* (1540) and Agricola's *De re metallica* (1561). These are accessible in modern translations by Smith and Gnudi (1942) and Hoover and Hoover (1950) respectively. Although written several centuries after the close of the period covered by this thesis, large parts of these books are describing established practices which were identical to those of earlier times and so are relevant here; Forbes (1956) noted that non-ferrous metallurgy hardly changed from antiquity till the 16th century.

The descriptions in the books and manuscripts mentioned here can often be illustrated by archaeological finds of the period and region of this study and conversely, other descriptions in them can be used to illuminate the more cryptic archaeological evidence and widen our understanding of the techniques of the metal workers of antiquity.

<u>Modern craft practice and metallurgy</u>

Modern metallurgy describes and explains the properties of metals and alloys in terms of their crystal structure and how it reacts to applied forces. In antiquity these properties were equally well known, but in an empirical fashion. The approach was essentially practical; if a manufacturing method or alloy composition suited the intended product then it would be used. This is reflected in a high correlation between methods of manufacture and alloy composition (see Chapter 10).

Metal working was not the only area where ancient technology was sophisticated and highly-developed but unaware of the theoretical basis for its knowledge. This, in part, explains much of the observed conservatism in technique (see Chapters 4-8) as it was only with the rise of scientific experiment in the post-medieval era and the willingness, or ability, to generalise from the particular that technical innovation became commonplace. The preoccupation with why things work or fail is essentially a modern one; even the medieval alchemists were interested only in the results of their experiments rather than in the general principles that they demonstrated. With the development of metallurgy as an exact science in the later 19th century, objective numerical measures of physical properties came into existence and these can be used to quantify the suitability of different alloys for particular uses (see Chapter 9).

There are many modern books which describe how metals can be worked (eg Bedford (1971), Cairns and Gilbert (1967), Garside (1957), Jastrzebski (1959) and Kempster (1975)). They detail the processes that can be used, the effects they have on the properties of metals of different compositions and the type of finished product obtained. They include both purely practical workshop manuals and other descriptions of modern technology dealing with metals at a macroscopic level, as well as those that are more theoretical, considering metals on a microscopic scale, describing processes as changes in the arrangement of atoms which give rise to altered crystal structures and hence properties.

Some of the processes now current (eg centrifugal casting, rolling sheet metal and electroplating) were not known in antiquity but many others that are still current have been practised for thousands of years (eg investment casting and forging). The necessary operating conditions for each process and other information derived from modern metallurgy are outlined in the chapters on techniques (Chapters 3-8). The effects of these processes on the properties of the metals are described in Chapter 9.

Experiments to replicate ancient processes and products are a further aspect of modern metallurgy that can help explain the metalworking activities of the past. These cover the whole spectrum from smelting (eg Tylecote and Merkel 1985) to casting (Evans 1976) and decorating (Lowery *et al* 1971). Individual pieces of work are quoted where appropriate in Chapters 4-8.

CHAPTER 3

METAL PRODUCTION

Metal production involves a number of steps, starting with the location and mining of the ore and progressing through its beneficiation and roasting (where appropriate) to smelting. This chapter is essentially a summary based on a literature survey. Note that mine sites are not included in Appendix A.

Ore sources and mining

The primary sources of metals were ore bodies which contain concentrations of minerals. These zones of mineralisation are not evenly distributed but are located in particular geological formations, mainly areas of igneous or metamorphic rock. Briggs (1988) has argued that transported boulders and gravels may have been exploited by small-scale ore collection in the past. Much tin, at all periods, has been obtained from secondary deposits of this type. The only parts of England with exploitable primary non-ferrous mineral deposits are the Lake District, Pennines, Welsh Marches, Mendips, Devon and Cornwall. Modern geological maps mark mineral deposits, but not all those now known were exploited in the past. This is either because the ores were inaccessible or because they were too low grade for their exploitation to have been economic. In addition there were probably some small deposits which were mined in the past but which have now been completely worked out.

These ore bodies usually contain a range of minerals and so can be a source of more than one metal. Some of the lead deposits worked in antiquity contained silver in economically extractable quantities (this was the main source of silver in antiquity) while copper ores contained a whole range of other metals, some in more than trace amounts. Zinc and lead minerals were often found together, as in the Mendips, but tin was usually found on its own.

Evidence for which ore bodies were worked at which periods comes from ancient authors and documents and from surviving mine structures or debris. Physical remains have rarely been identified, especially for the earlier periods despite the fact that later workings do not remove all traces of previous activity (Craddock and Gale 1988). Few of the known early mines can be dated with any certainty. The literature abounds with references to ore bodies or areas which were exploited at different periods. This information is summarised in Table 3.1 for English sites and those on the Welsh/English border. Many of the best known areas are however in Wales, eg the gold mines at Dolaucothi (Lewis and Jones 1969)

Table 3.1 - Areas of England exploited for minerals

Key: 1) = Pre-Roman 2) = Roman 3) = Saxon

4) = 10th century or later

COPPER

1) Alderley Edge and possibly Cornwall (Clark 1952)

Cheshire, Shropshire (Forbes 1956)

2) possibly the Lake District (Hamilton 1926)

Cornwall (associated with tin ores), Llanymynech (Healy 1978)

Llanymynech (Davies 1935)

Cornwall, Devon (Forbes 1956)

3) possibly Shropshire (Hill 1981)

4) -

LEAD (AND SILVER)

1) probably Mendips (Clark 1952)

2) Wharfdale (incl Greenhow Hill), Swaledale, Wensleydale (Clough 1962)

Shelve (Salop) (Scarth 1875)

mainly Mendips, Stiperstones (Salop), N Derbyshire but also Swaledale and Greenhow Hill (Gowland 1901)

Wharfdale, Mendips (Davies 1935)

3) Derbyshire (Richardson 1974)

Mendips, Derbyshire (Hill 1981)

4) Derbyshire (Richardson 1974)

Swaledale, Wensleydale, Nidderdale (Davies 1935)

Yorkshire, Durham, Derbyshire, Mendips, South Devon (Homer 1991)

TIN

1) Cornwall (Forbes 1954, Clark 1952, Penhallurick 1986)

Britain (Caesar, Diodorus and Strabo)

2) Cornwall (Bromehead 1956, Richardson 1974, Penhallurick 1986)

3) Cornwall (Hedges 1964, Penhallurick 1986)

4) Cornwall (Forbes 1956)

Devon, Cornwall (Richardson 1974, Penhallurick 1986, Homer 1991)

GOLD

1) -

2) Cornwall (Davies 1935, Healy 1978)

3) -

4) -

ZINC

The first evidence of exploitation of Mendip zinc ores dates to the 16th century (Richardson 1974)

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and copper mines in north Wales and Anglesey (Healy 1978).

For the Roman period Davies (1935) surveyed all the information then available for the whole of Europe and, as Lewis and Jones (1969) comment "... the subject of Roman mining appears to have developed little since [then]." Healy (1978) has no extra information on English mines. If the technology of mining is considered then Bromehead's (1956) comment that "... Roman Britain does not yield anything that is not better illustrated in lands less remote from the centre of government" is a salutary warning against making too much from the minimal evidence that survives.

In post-Roman times the position is, if anything, worse. Hill (1981), dealing with the Saxon period, says "... we have no evidence for the sources of ... metals in England at the time " but Loyn (1991) quotes documents referring to lead production in Derbyshire.

Once the ore had been mined it had to be physically separated from as much of the gangue as possible and broken into suitably sized pieces for smelting. This preparatory work was usually carried out close to the mines to minimise the transport of waste material. Some ores were roasted prior to smelting to convert the minerals present to more readily reducible ones or to help break up the nodules.

Smelting

Smelting is the first stage of metalworking to involve the use of refractory ceramics - for furnace structures. They reappear later when metal refining, melting and casting are considered. Tite *et al* (1985) summarise the range of refractories and their uses and note that in examining them it is essential first to positively identify their association with metalworking, then to identify the process and the metal(s) involved and finally to record the details of that process such as working temperature. Most of the refractories recorded here (listed in Tables 2.1-2.7 as waste) are from sites far removed from ore sources and are thus unlikely to be from smelting furnaces as smelting sites are normally located in or near the areas where ores were mined, as smelted metal was more readily transportable than the ores. The association of these refractories with processes other than smelting is supported by the generally low level of vitrification noted.

The general principles of early smelting are well known. For example Forbes (1964B) describes the multiple stages necessary to obtain a good yield of copper but admits that simpler though less efficient processes were possible if rich ores were used and low extraction rates considered acceptable. The slags produced contained significant amounts of metal and have often been resmelted in more recent times.

A few locations in the West Country have been claimed as tin smelting sites (Penhallurick 1986) and there is evidence for lead smelting from sites on Mendip and in the Peak District and further north in the Pennines (Tylecote 1962A). Overall however the material evidence for metal smelting in the period covered by this study is almost as elusive as that for mining. Continental Europe and the Mediterranean world offer better examples (eg Tylecote 1987).

As noted above, ore bodies usually contain a range of minerals so the smelted metal is often not very pure and thus has to undergo purifying and refining processes. These are described in Chapter 4. Crude, unrefined metal ingots are not normally found so the primary refining must thus be considered as the final stage in the smelting process. The end product was usable, 'pure' metal ingots that were traded and then used by metalworkers as the raw material for their crafts.

Ingots

Ingots vary in size and shape and weigh from a few hundred grams up to 80 kg or more. The examples quoted below are all Roman as there are no ingots securely dated to the other periods under consideration here, except the small bar ingots which are described in Chapter 5 together with the moulds in which they were cast.

About 80 rectangular lead ingots with trapezoidal sections are known though most of these are not listed in Appendix A (see instead Tylecote 1986A, Tables 38-9); purity is well over 99% (Tylecote 1962A). Most are of desilvered metal though a few early ones have higher silver levels (Whittick 1982); it was economic to desilver lead containing over 0.06% silver. They are most frequently found in or along routes from production areas. Typical dimensions are 50 x 14 x 12 cm with a weight of around 80 kg (250 Roman pounds). Most have cast-in official inscriptions and can thus be dated from *c.*60 AD to the third quarter of the 2nd century; after this date it is thought the mines went out of imperial ownership.

Tin ingots are known in a variety of forms (Penhallurick 1986) but most finds are poorly dated. Todd (1987) lists a number of certain or probable Roman examples from the south west peninsula which are mostly oval in plan and of plano-convex section. Weights vary considerably but the maximum quoted is under 20 kg. Purity is high.

Copper ingots are scarce but Roman examples from Wales have a circular, plano-convex form and some are stamped (Kelly 1976); purity is around 99%.

Silver ingots of a flat, oxhide shape with official stamps, which usually weigh about one Roman pound (320 gm), appear in the 4th century when it is suggested they were used to pay the military. Painter (1981) describes the 11 examples then known from Britain and Johns and Potter (1985) add further items to the list, including a rectangular ingot. Silver content varies but is normally over 95%.

As well as single element ingots, a number of large ingots of various alloys are also known. Although they are not the primary product of smelting operations they had a similar function as a bulk source of metal for craftsmen and so are included here.

The most widely known examples are pewter ingots which are usually plano-convex and oval or circular in shape. Hughes (1980) noted a correlation between shape and composition in a group from London that he analysed. Compositionally they fall into three groups with around 95%, 67% and 50% tin respectively.

Recent excavations have discovered a number of copper alloy ingots. A circular, plano-convex one from Claydon Pike was brass (Northover, forthcoming) as were two small rectangular ones from Gloucester; that from Alvin Street had been broken from a longer bar with a shallow D-section, originally made up of several similar units. The large rectangular brass sheet from Colchester: Sheepen should also be mentioned here though it was heavily worked and not in an as-cast state; it weighed 9.36 kg (Musty 1975). The same site also produced an off-cut from a large rectangular bronze bar (Bayley 1985B).

CHAPTER 4

REFINING AND ALLOYING

Two distinct processes, refining and alloying, are involved in transforming crude smelted metal into the raw material of the metal smith. Some refining was usually carried out as a secondary stage of smelting to remove impurities or separate the components of metal smelted from mixed ores and this often took place at the smelting site. Other refining processes were carried out at the place where the metal was being used.

Refining

Unlike most high temperature metallurgical processes which are carried out under reducing conditions, refining makes use of the varying redox potentials of the different metals to separate them by controlled oxidation. Oxidation on its own though is not always a sufficiently powerful technique and preliminary physical segregation based on the very varied mutual solubilities of the metals is also employed. The techniques used in the past depended on the composition of the original metal and the relative proportions of the different elements present.

Native gold often contained silver (Tylecote 1987), some newly smelted copper contained significant quantities of gold and/or silver as well as other impurities, while argentiferous lead was the main source of silver in antiquity. Much British lead was very low in silver and primitive lead smelting at times produced metal more than 99.9% pure (Tylecote 1986A). The tin produced was also normally quite pure and so did not require refining.

Cupellation was the refining process which was used to separate noble metals from base metals, while parting separated silver from gold. Where copper was a major component of a precious metal alloy, liquation could be used as a preliminary step before cupellation. Simple oxidation was also used.

The existence of these refining techniques shows that craftsmen had ways of judging or measuring purity. The use of touchstones for estimating the purity of gold is well known and examples have been found on sites of various dates from Iron Age times onwards (eg Clifford 1961, Moore and Oddy 1985). Precious metals could also be tested by fire assay (ie cupellation) though Theophilus (Ch 50) suggests that simpler methods such as the properties of the solid metal were also used. Malleability is one of the properties of base metals that, when taken together with colour and taste, would have provided a reasonable estimate of their composition. Theophilus describes just this sort of test; red hot copper that breaks or splits when hammered is insufficiently refined (Ch 67).

Oxidation

Oxidation can remove the more reactive and volatile elements from a melt and simultaneously increases the relative proportions of nobler elements. For example, if impure copper is melted under oxidising conditions any silver or gold is retained while elements such as arsenic, lead and iron are incorporated into a crucible slag which can be skimmed off the melt (Tylecote 1982). The refining action of oxidation was apparently well known in antiquity as Pliny, when talking about copper and its alloys, notes that malleable copper has had the impurities roasted out of it (Bk 34, 95). During refining some cuprous oxide also forms and dissolves in the melt which leads to brittleness on solidification (Gowland 1921). Refined copper is therefore reduced by poling back, leaving a neutral melt with improved physical properties. Precious metals can also be refined by oxidation as described by Theophilus (Ch 50). Pliny refers to this obliquely by noting that [pure] gold loses nothing on heating and is not discoloured (Bk 33, 59).

Although some crucibles contain far more massive slag deposits than others it is not possible to differentiate between refining and melting crucibles on this basis. Accidentally oxidising conditions could produce a massive crucible slag in a melting crucible and the slag composition is unlikely to be a reliable guide as fuel, fluxes and the crucible fabric as well as the metal all contribute to it in unknown proportions.

Cupellation

As noted in Chapter 3, silver is most commonly found in the form of argentiferous lead ores which on smelting yield lead containing a variable but small amount of silver. To refine the silver the major constituent, the lead, has to be removed. In antiquity, this operation was economic with silver contents as low as 0.06% (Gowland 1901); lead from the Mendips contained up to 0.4% silver (Elkington 1976). The process involves melting the argentiferous lead in a shallow hearth, and blowing air across the surface of the melt to oxidise it. The litharge (PbO) that forms either volatilises, is scraped away or is absorbed by or reacts with the hearth lining, leaving a globule of pure silver behind. Percy (1870) gives a detailed description of this process. The lead could be recovered by resmelting the litharge and lead-rich hearth lining. The earliest known English hearth of this kind is that from Hengistbury, thought to date to the late Iron Age (Gowland 1915). The hearth was lined with bone ash which is porous and will physically absorb the litharge while also being less susceptible to attack by metal oxides than siliceous materials such as fired clay (Garside 1957). Cupellation thus seems to have arrived in this country in a fully developed form rather than evolving here. Cupellation hearths are not common archaeological finds. Many must have existed in smelting areas such as the Mendips but these have not been recorded archaeologically, perhaps because they would normally have been resmelted to recover the lead.

A further aspect of cupellation is that litharge acts as an oxidising agent and any other base metals present are oxidised and their oxides either volatilise or dissolve in the litharge and are thus also removed from the silver (Gowland 1921). For this reason cupellation could be used not only as a method of obtaining silver from the crude metal smelted from mixed ores, but also as a method of refining recycled metal and as a test of the purity of precious metal.

When refining existing metal or testing its purity, lead was added to the precious metal; Theophilus provides one of the earliest good descriptions of this process (Ch 23). Pliny's description (Bk 33, 95) is less detailed but notes that the method universally used was heating with lead and that the silver floated on top like oil on water. This shows the litharge must have been absorbed into a porous hearth as silver is denser than litharge (SG silver = 10.5, SG litharge = 9.5). Gold behaves in a similar way to silver so cupellation can be used to purify or refine gold too (cf Theophilus Ch 69).

When the metal to be purified contained a considerable proportion of copper it was more efficient first to separate the silver and copper physically by the process variously known as lead soaking or liquation. This was done by melting the metal with up to three or four times its weight of lead. Nearly all the silver together with 2-3% of the copper dissolved in the lead and, as lead is virtually insoluble in copper, the solidified melt contained two intimately mixed phases, one of copper and the other of silver (and gold, if present) dissolved in the lead. If this leaded metal was then heated gently (at 500-700^{o}C, ie above the melting point of lead but below that of copper) the lead-rich phase would melt and trickle out, taking the precious metals with it, leaving behind a 'sponge' of copper. The lead could then be cupelled to recover the silver and the copper melted and refined to expel any remaining lead as described by Theophilus (Ch 67).

Hawthorne and Smith (1979) note that this process is supposed to be a 15th century development but that Theophilus' description of copper smelting (Ch 63) apparently includes a reference to it. Fox and St John Hope (1894) quote Prof Roberts-Austen's comment on a sample from Roman Silchester containing 68% copper, 12% lead and 0.13% silver which he considered could have been intended for liquation. Tylecote (1986B) has suggested the copper in litharge cakes (see below) is evidence for a Roman liquation process but it could be argued that copper-rich litharge is more likely to be an indicator of cupellation without prior liquation as only a few percent of copper will dissolve in the lead.

The known English cupellation hearths (including that at Hengistbury mentioned above) all have associated wastes that are rich in both copper and lead and so were probably used to extract silver from a copper-rich matrix.

Far commoner than hearths are litharge cakes, a by-product of cupellation, many of which are found to contain significant amounts (of the order of 10%) of copper (Bayley and McDonnell 1990A). Most of the litharge cakes are not from metal production sites and this, coupled with their composition, suggests that they were produced when silver was refined or recycled rather than being evidence for primary extractive metallurgy. There are records of copper-free litharge in lead production areas, eg Chew Valley Lake (Rahtz and Greenfield 1977), but these are the exception.

Litharge cakes are known from both Roman and late Saxon/Viking contexts in a number of towns (see Table 4.1). Typically they are mid-grey coloured round discs up to 3 or 4 cm thick, 7-15 cm diameter and plano-convex or concavo-convex in section with a central depression in the upper surface (Figure 4.1). Fragments are found more often than complete examples. Major elements present are lead and copper while silver, when detected, is always on the upper surface, usually only at the rim of the central depression which marks the edge of the solidifying pool of silver. This rim was sometimes cut away in antiquity, presumably to reclaim the silver it contained. SEM/EDAX analyses of a section through a Roman litharge cake showed the presence of calcium phosphate (Bayley and McDonnell 1990A) and further work on a 12th/13th century specimen has produced similar results, suggesting litharge cakes formed when molten litharge was absorbed into a bone ash hearth lining. Gowland (1900) obtained comparable results (by wet chemistry) from the cupellation debris from Silchester. These litharge cakes are thus the 'fossilised' remains of bone ash lined cupellation hearths.

Flat fired-clay discs, with a lead-rich vitrified upper surface with an eroded patch of a size and shape that would fit a small litharge cake have been found together with litharge cakes in late Saxon contexts

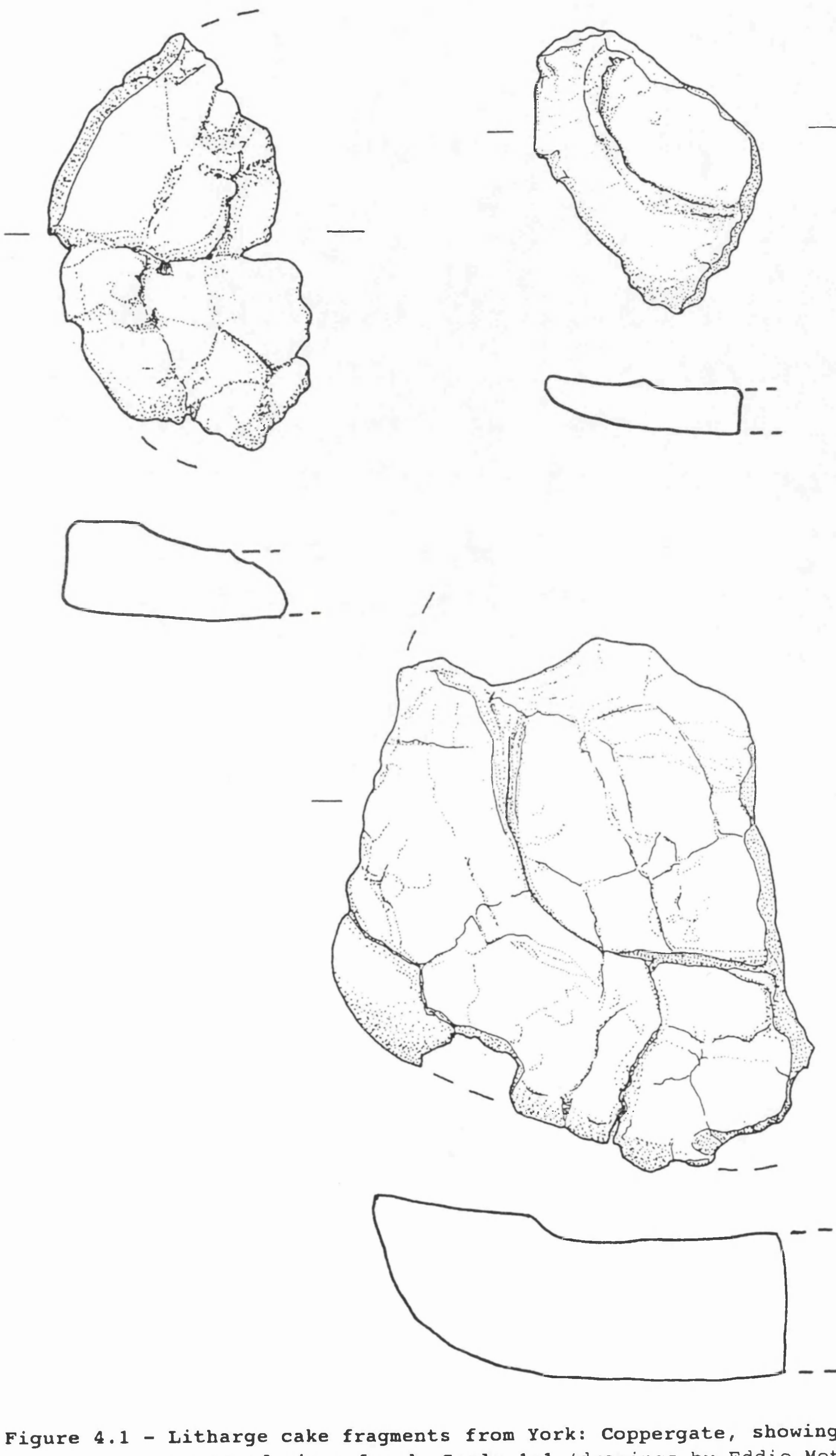

Figure 4.1 - Litharge cake fragments from York: Coppergate, showing the range of sizes found. Scale 1:1 (drawings by Eddie Moth, York Archaeological Trust)

* Roesdahl, who had discussed these finds with the late Prof M J O'Kelly, suggested two ways they could have been used. The first was "in refining silver by the method described by Theophilus" but the use considered more likely was "to hold silver objects while filigree and granulation was added" (1977, 196).

in Winchester (Bayley and Barclay 1990) and have been interpreted as the 'hearth' on which the litharge cake formed (Figure 4.2). The associated litharge cakes have not yet been analysed to see if they contain bone ash. If not, this would appear to be a regression in technique from the Roman bone ash hearth as the litharge cannot be physically absorbed by the ceramic but reacts chemically with it, producing the lead-rich vitrified surface.

Table 4.1 - Sites producing litharge cakes and/or cupellation hearths

Site	Date (of find context)
Hengistbury Head *	late Iron Age
Doncaster: Frenchgate	2nd century ?
Exeter: near the south gate *	55-155/160 AD
Southwark: 107-15 Borough High St	later 3rd century
Leicester *	late 4th century
Silchester *	Roman
Southwark: Cathedral Crypt	Roman
Tiddington	Roman
Uley	Roman
Winchester: Victoria Road	Roman
Southampton (Hamwih)	middle Saxon
? London: Jubilee Hall	middle Saxon
York: Coppergate	mainly 10th century
Bury St Edmunds Abbey	early medieval ?
Lincoln: Flaxengate	late Saxon
Lincoln: Saltergate/Silver Street	late Saxon
Winchester: Staple Gardens	late Saxon
Winchester: Lower Brook Street	mainly late 11th-12th century
Canterbury: St John's Lane	12-14th century
Thetford: Guildhall	late 12th/13th century
Winchester: western suburbs	mid/late 12th-14th century
Winchester: Wolvesey Palace	?late 14th century (?residual)

* = cupellation hearth rather than litharge cakes recorded

See Appendix A for full details and references

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__Cupels__

Similar but smaller ceramic discs and dishes are also known, some as small as 3 cm diameter (Figure 4.3). These objects, first differentiated from crucibles on Scandinavian sites, eg by Roesdahl (1977), were not specifically identified and were described as 'heating trays', a term that has come over into English usage (eg Bayley 1982B).* Further work has shown that their correct interpretation is as cupels, ie vessels in which cupellation was carried out (Bayley 1988A and 1991B, Foley 1981, Tite *et al* 1985). Their small size indicates only small scale cupellation, either to refine a small amount of metal for immediate use or to assay (test the purity of) a sample of a larger quantity of precious metal. A few have been noted on Roman sites but most are of middle or late Saxon date. The

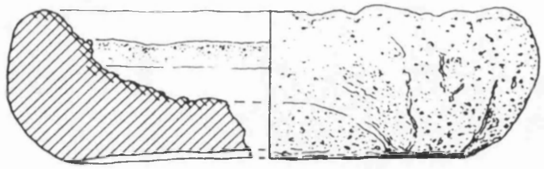

Figure 4.2 - Fired clay disc with eroded, lead-rich vitrified upper surface from Winchester: Wolvesey Palace (Bayley and Barclay 1990). Scale 1:2

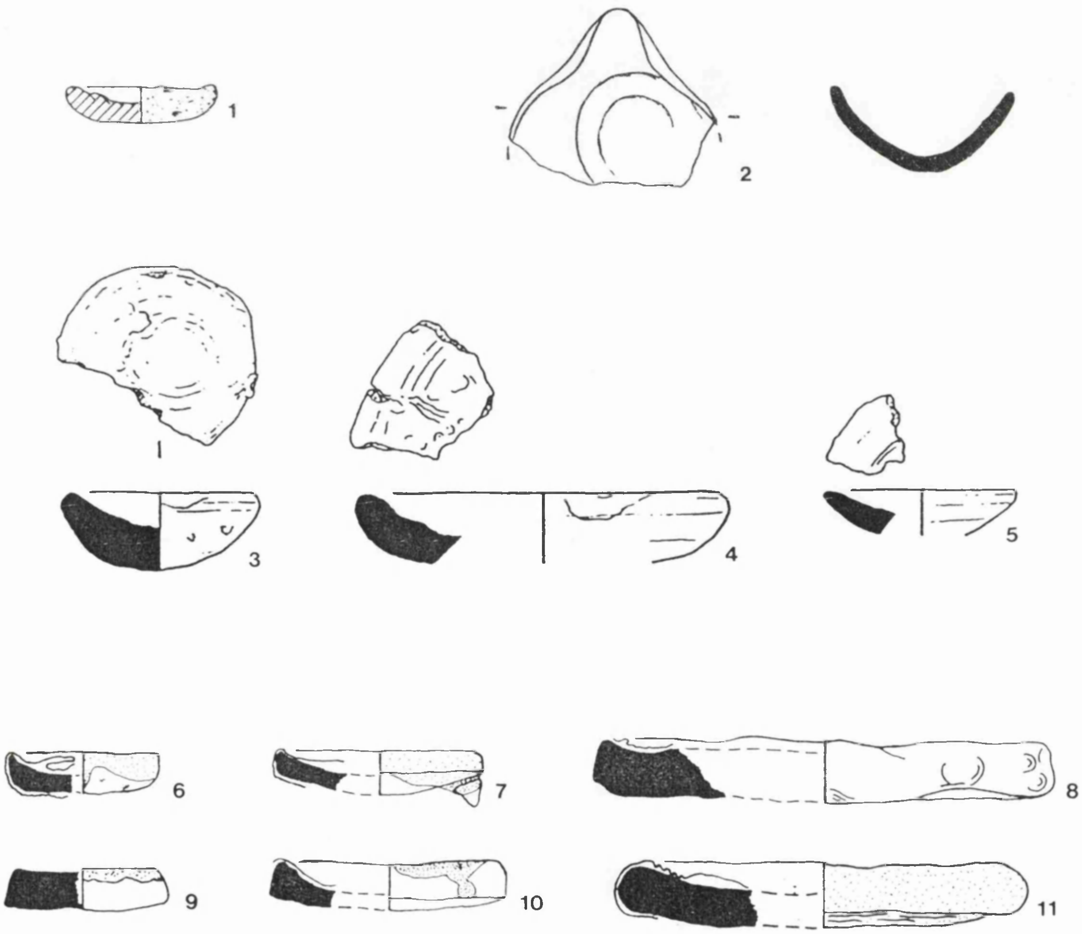

Figure 4.3 - Cupels from [1] Winchester: Cathedral Yard (Bayley and Barclay 1990), [2] Verulamium, [3-5] York: Coppergate (Mainman 1990) and [6-11] Lincoln: Flaxengate (Gilmour 1988). [5] was used for gold, the rest for silver. Scale 1:2

sites where they have been identified are recorded in Tables 2.2-2.6.

Some Roman cupels are Type 3 crucibles (cf Chapter 5) while others are similar to later cupels, which are usually made of a clay fabric that is not very highly tempered and may contain finely divided charred organic matter. They were heated from above as the bases are often poorly fired and the top surface is always highly vitrified and often has a circular depression in it (where the refined precious metal solidified). Analysis nearly always detects lead in considerable quantities and droplets of silver are often trapped in the vitreous surface which can be coloured red by traces of copper in it. This colouration, which is produced by copper in a reduced state, and the grey (reduced fired) ceramic were initially cited as reasons why these objects could not be cupels as cupellation is an oxidising process (Bayley 1982B). Consideration of an Ellingham diagram however shows that there are a range of conditions where lead is oxidised to litharge but copper is still present in a reduced form at the required operating temperature of around 1000°C (Figure 4.4). This explains away the apparent dilemma and allows heating trays to be unequivocally identified as cupels. Replication experiments by Foley (1981) reproduced the form of the vitrified surface seen in Saxon examples, reinforcing the identification of heating trays as cupels. The presence of trapped droplets of silver in the vitreous surface of some of the ancient examples suggests that the operating temperatures were at times barely adequate, as the silver had not coalesced into a single large drop that could be easily removed.

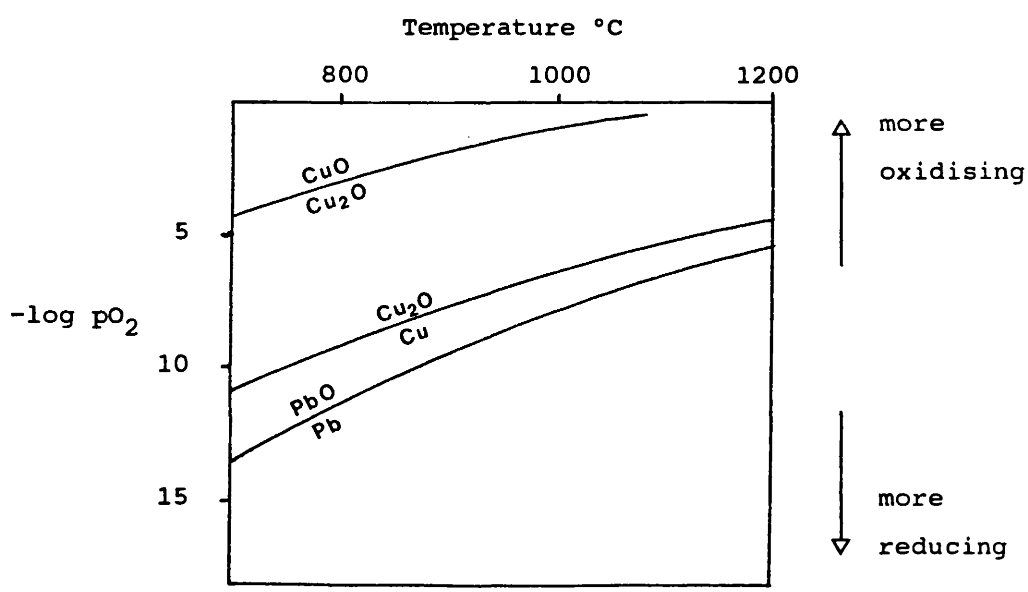

Figure 4.4 - Ellingham diagram showing the range of partial oxygen pressures within which cupels were used. Lead is oxidised to litharge but copper is still present in a sufficiently reduced form to colour vitreous deposits red.

As well as purpose-made cupels, sherds from broken pots have been found with analytically identical vitreous deposits on them; they were apparently used as makeshift cupels. A further group of related finds are blocks about 50 mm across and 20 mm thick, made of fluxed and fused quartz chips which came from the York: Coppergate site (Bayley forthcoming). They have a hollow in their upper surface and traces of gold were detected, though little else.

Where only low levels of lead are found in the vitreous layers on cupels, any trapped metal droplets are always of gold rather than silver. While some do definitely appear to have been used to refine gold, perhaps by oxidation as much as by cupellation, others may have had a second use, to hold small quantities of gold filings or scrapings while they were melted with a blow-pipe to produce a usable piece of metal. A shallow Saxo-Norman crucible (not a cupel) from London has definitely been used in this way as traces of gold were left behind, trapped in a thin, localised vitreous surface outlining where the gold drop had solidified (AML 11/87).

Modern cupels are made of bone ash which gives better separation of the precious metal and lead-rich phase, but they were apparently unknown at the periods discussed here although Theophilus describes coating a ceramic dish thickly with ashes (Ch 23); the earliest surviving English bone ash cupels are those from Legge's Mount at the Tower of London which date to the 16th century (Oddy 1983).

Parting

While cupellation is a very efficient method of separating silver and gold from base metals, it is incapable of separating the two noble metals. Nowadays this separation can be effected by using nitric acid but its production is not recorded until the 14th century AD (Taylor and Singer 1957). Before then, parting was either a slow, solid-state reaction in which thin sheets of the mixed alloy were heated in contact with an aggressive medium, or a repetitive reaction of the molten alloy.

The first of these is the salt process, of which a number of similar though not identical descriptions have been published (eg Forbes 1964A, Notton 1974 and Tylecote 1987). Agricola (Hoover and Hoover 1950) also gives a detailed description of the process. Theophilus' similar description (Ch 33) can be summarised as follows: The metal was hammered out into thin sheets and packed into a ceramic vessel interleaved with a mixture of one part by weight of common salt and two parts of powdered brick or well-burnt clay moistened with urine. The vessel had another one luted on with clay to act as a lid, was dried and then heated in a furnace for a day and a night. The gold was then removed, melted and the whole process repeated.

If the original metal was fairly pure gold-silver, the silver would be converted into silver chloride which volatilises and would be absorbed by the brick dust and by the walls of the vessel. The majority would be in the brick dust and could be recovered. If on the other hand the original metal was a gold-silver-copper alloy, both the silver and copper would react with the salt. Notton (1974) describes two experiments to replicate the salt process, parting a ternary alloy. In the first the metal was put into an open crucible with a mixture of salt and brick dust heaped over it and heated at 800°C for several hours until no more salt fumes were evolved. All the copper and most of the silver were removed from the metal (the gold content increased from 37.5% to 93%), the white crucible was stained a pinky-brown colour and the non-metallic contents of the crucible had acquired a turquoise 'glaze'. Silver was recovered from crystalline deposits of sublimed salt in the cooler parts of the furnace. In the second experiment the metal and salt were sealed into a pot with the same satisfactory outcome.

Previous to this study only one group of parting vessels had been identified, from a late 1st century context in London (Marsden 1975). Recent finds from other towns provide some further physical evidence for the salt process and for the diversity of vessels used (Bayley 1991A). There is no common shape; some are wheel thrown and others handmade (Figures 4.5-4.6). Despite this range, there are a number of common features which help in their identification as parting vessels. There is variation in how discernible these features are, but in all cases they are present to some degree.

Table 4.2 - Sites producing parting vessels

Site	Date
Chichester: Chapel Street	1st century
Exeter: Frienhay Street	mid-late 1st century
London: S of Cannon Street	*c*.70-85 AD
Lincoln: Flaxengate	4th century
Lincoln: Saltergate/Silver Street	4th century
Lincoln: Grantham Place	Roman ?
York: 16-22 Coppergate	10th century
York: 22 Piccadilly	10th century
Carlisle: Annetwell Street	early medieval
Thetford: Guildhall	late 12th/13th century

- - - - -

Some vessels are oxidised fired and others reduced but all have a somewhat bleached appearance on their inner surfaces; this paler coloured zone can penetrate the vessel wall to some depth. The bleaching is caused by high concentrations of chloride ions which react with the iron in the clay fabric, forming ferric chloride which is volatile and so is removed from the clay. A similar effect is seen in briquetage and in ceramics made with saline clays (Matson 1971).

A second visual effect is a pinkish or purplish colour which is seen on the bleached areas and is due to the redeposition of the mobilised iron as haematite. In some cases specular haematite crystals which presumably grew by deposition from the vapour phase are present; largest sizes are of the order of a millimetre. This redeposited haematite is most notable near the rims where the vapours could most easily leave the sealed vessels.

In some groups the outer surface of the vessels and/or their lids carried a 'glaze' distinct from the fuel ash glazes that are commonly found on metal melting crucibles (see Chapter 5). These were alkali glazes, presumably produced by reaction of the sodium ions from the dissociated salt with the silicate fabric of the vessel. It is not clear to me why the glaze is only found on the outer surfaces but Notton's (1974) experiments produced a similar effect.

XRF analyses of the inner surfaces of parting vessels regularly detect silver, and sometimes traces of gold, but other non-ferrous metals, which are ubiquitous on metal melting crucibles, are absent. Where sandy deposits survive on the inside of the vessels, higher silver concentrations are found; this is presumably the remains of the 'cement' with which the metal sheets were interleaved.

The sherds from Chichester are oxidised fired and show no vitrification and only slight bleaching and purplish pink colours. Those from Exeter are also handmade and of similar internal appearance though the outer surfaces of both vessels and lids are mostly glazed, some a pale olive green and another a deep bottle green, possibly due to the presence of copper. The London vessels and their lids are wheel thrown; a thick layer of added clay of a different type has been used to lute them together (seal the join) in an attempt to make it vapour-proof. The bleaching effect is very marked in these vessels and extends to the area of the luting clay nearest the join between pot and lid. The redeposited haematite is correspondingly abundant, a distinct deposit being visible especially near this join on both the inner surfaces of the pot and lid and on the luting clay.

The Lincoln parting vessels are dishes, probably of Crambeck ware which was made in the 4th century (Personal communication, Rob Perring 1991). Though most of the metalworking evidence from these sites

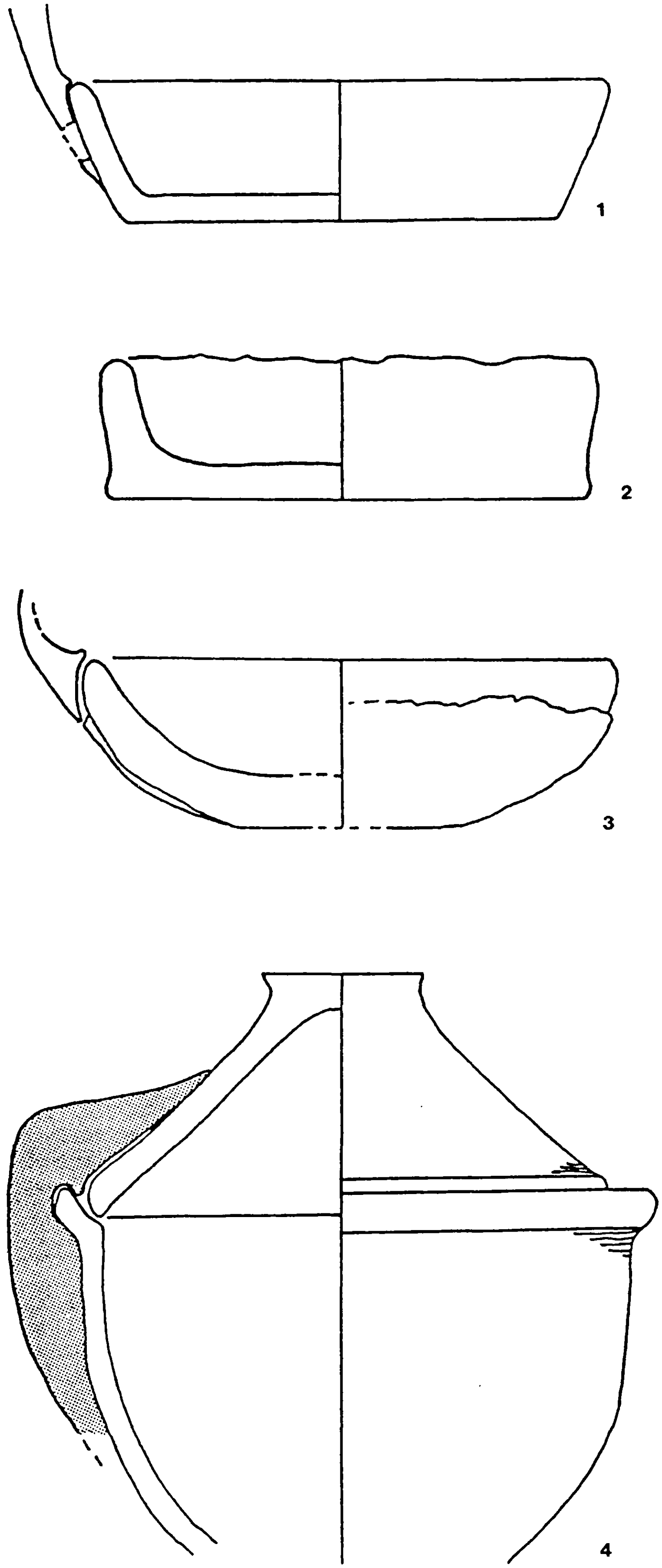

Figure 4.5 - Sketch drawings of Roman parting vessels from [1] Lincoln, [2] Chichester, [3] Exeter and [4] London. The stippling indicates the luting clay used to seal the lids onto the London vessels. Scale 1:2

is late Saxon, the parting vessels were found in contexts dated 4th-9th century onwards and are thus probably residual Roman material; there is much other residual Roman pottery. The dishes are highly coloured and have massive specular haematite deposits inside them (XRD analysis by Steve Wyles, Laboratory of the Government Chemist, 1979). A crude handmade lid in a different (?local) fabric was added to the dishes and smoothed down to seal it onto their outer surfaces. This lid material is mainly 'glazed' to a deep turquoise colour which led to its original identification as alkali glazed Islamic pottery (Adams 1979). Notton's (1974) experiments produced visually identical material when a mixed gold-silver-copper alloy was parted. Other bits of vitrified clay attached to the outside of the parting vessels looks similar to two small sherds tentatively identified as Chinese (Adams 1980) but these now appear to be just further, more highly vitrified fragments of the parting vessel lids.

The parting vessels from York are visually less spectacular. They are sherds from fairly coarse hand made ceramic vessels which were roughly cuboid (see Figure 4.6) and uniformly reduced fired, to a pale grey colour. All the sherds are lightly vitrified on their outer surfaces, most notably on the bases, and this appears to be a fuel ash 'glaze'; the vitrified surface was olive green, coloured by traces of iron from the clay. Most of the inner surfaces are whitened and some have pale greyish sandy deposits on them or have patches of purplish-pink colouration. There are slight traces of added clay layers on the outsides of some of the sherds, including some at the rim suggesting lids were luted on. Also found were a number of small pieces of vitrified clay of a pale olive green colour (also seen on some of the Exeter vessels) and part of a clay slab, vitrified on one side, which also had detectable traces of silver; these are probably detached luting clay and a lid fragment respectively.

Copper was not detected except on the Lincoln and Exeter vessels so in most cases cupellation appears to have been carried out prior to parting - or the gold-silver alloys were originally copper free.

The second method of parting mentioned by Forbes (1964A) is also described by Theophilus (Ch 70) and involved melting the gold-silver alloy, adding sulphur and mixing well. The melt was then cast and the ingot hammered to break off the brittle black silver sulphide and the whole process repeated until the gold was pure. The silver could be recovered by cupellation. No archaeological evidence of this process has so far been noted.

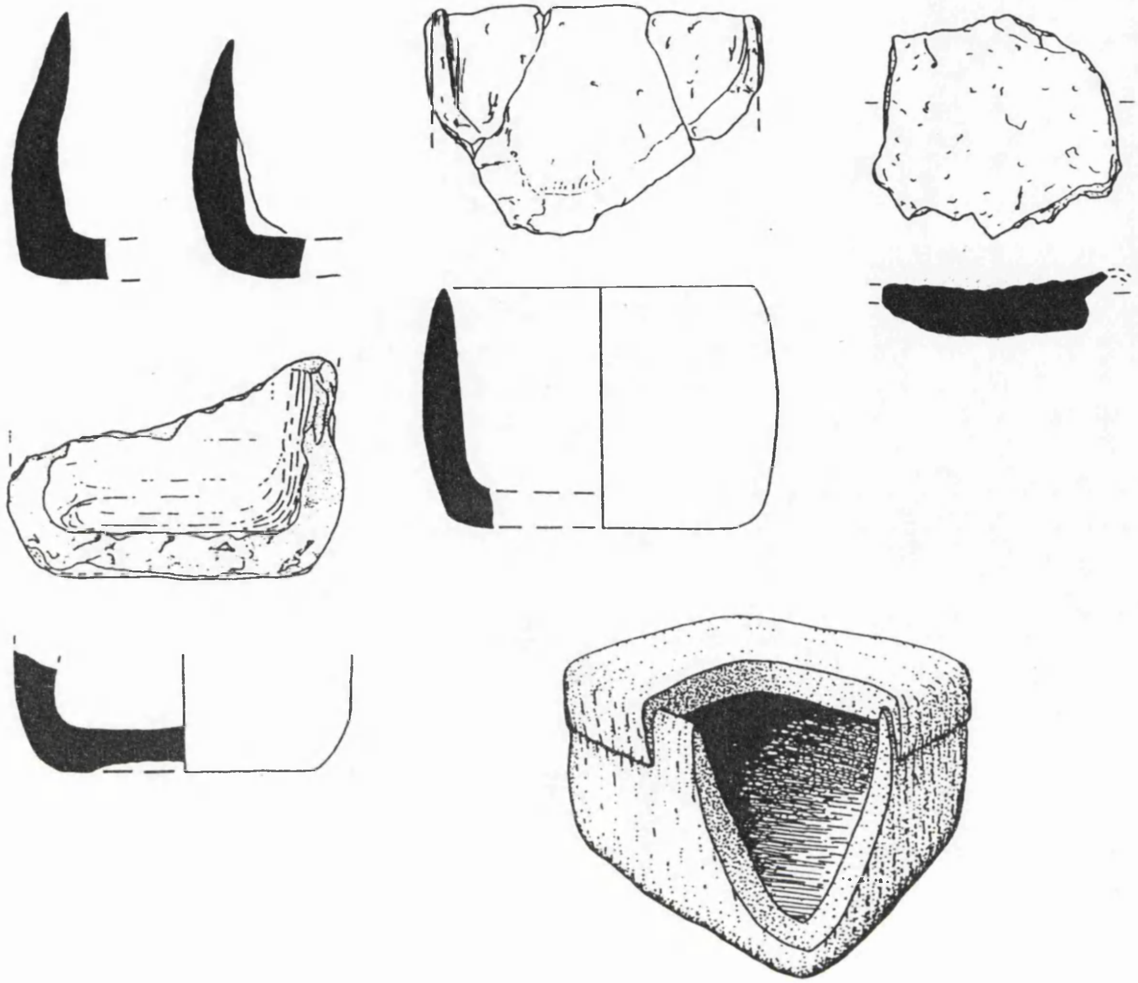

Figure 4.6 - Sherds of parting vessels including a lid fragment [top right] from York: 22 Piccadilly. Scale 1:2 (drawings and reconstruction by Eddie Moth, York Archaeological Trust)

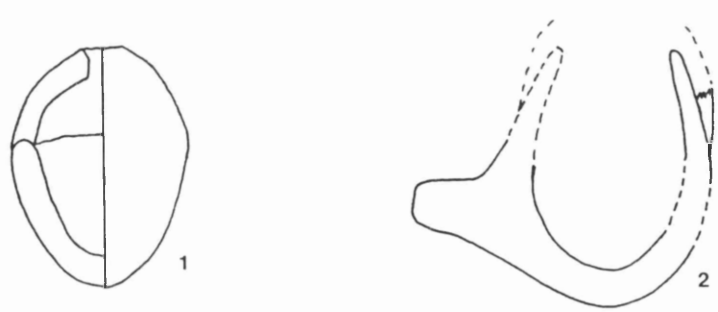

Figure 4.7 - Sketch drawings of cementation crucibles from [1] Canterbury: 7 Palace Street and [2] Colchester: Culver Street. Scale 1:2

Alloying

Alloying can be looked on as the reverse of refining as, instead of removing impurities, metals are deliberately mixed. There are many reasons for using alloys rather than pure metals but the most important from the craftsman's point of view is that they have improved properties and so are more useful and usable than pure metals (Kempster 1975). Alloying precious metals is usually known as debasement and though low levels of additions have a beneficial hardening effect the main reason for producing heavily debased alloys was an economic one.

The easiest way to produce an alloy is to melt the metal with the highest melting point and then add the other metal or metals and homogenise the melt. To make bronzes, copper is melted and refined (oxidised and then poled back) and "... then, and only then, should the tin be added ... and lead also if desired" (Tylecote 1982). Northover (1988) has suggested that structures sometimes seen in crucible slags show the addition of cassiterite to molten copper to form bronze but admits the residues are very difficult to distinguish from those of bronze melted under highly oxidising conditions.

When leaded copper alloys are being made and cast it is essential that the melt is well mixed just before it is poured as lead is basically insoluble in copper and will otherwise segregate, falling to the bottom of the crucible. Where there has been insufficient mixing, large castings will show a concentration gradient with more lead in the parts of the casting to fill last. Other factors, eg cooling rates, can also affect the distribution of lead within castings.

Producing precious metal alloys is no problem. The noblest metal is melted first and the baser metals which are more susceptible to oxidation then added. Prolonged heating can lead to loss of baser metals and the production of an alloy of higher fineness than intended.

Base metal alloys too suffer from differential oxidation of their components, as has been mentioned above in the context of metal refining. The more volatile elements are preferentially lost, even when remelting is carefully carried out. Caley (1964) says that 10% of the zinc present in an alloy is lost each time it is remelted and Tylecote (personal communication, 1988) has estimated that 5% of the lead in a leaded bronze is lost into the crucible slag in three melts.

Cementation

Brass making was a completely different process from making other copper alloys as metallic zinc was not available in Britain until the 17th century AD. This is because zinc has a very low boiling point

(907°C) and at the temperature at which it is reduced from its ores it is a vapour and so has to be distilled. Despite this, brass was in widespread use in the Mediterranean world from the 2nd or 1st century BC and it spread across Europe with the Romans, reaching Britain in the early 1st century AD, a few decades in advance of the Claudian conquest. It is generally accepted that Roman brass was made by the cementation process (Tylecote 1962A, Craddock 1978) in which finely divided copper is heated to about 950-1000°C in contact with calamine (zinc oxide or carbonate) and charcoal. The zinc ore is reduced to metallic zinc vapour which diffuses into the copper, forming brass. As the zinc content of the solid metal increases, its melting point drops and it eventually melts and homogenises. Werner (1970) and Haedecke studied the thermodynamics of the cementation process and showed that in practice the maximum zinc content obtainable at 1000°C was 28% which compares well with the actual values found in analysed antiquities. 17th century experiments by Champion produced cementation brass with 33.3% zinc (Craddock 1978), so brass with zinc contents of 28-33% may accidentally have been produced earlier.

Until recently there has been no archaeological evidence for cementation. Now finds of cementation crucibles from Colchester: Culver Street and Canterbury: Cakebread Robey and 7 Palace Street (Bayley 1984A) fill the gap, in part at least. They are of a fabric quite unlike any other crucible, one which is very friable, contains little mineral temper and is deeply vitrified. They are also analytically distinct with zinc levels appreciably higher than for brass-melting crucibles. They have applied lids to keep the zinc vapour (from the calamine of the charge) in contact with the copper. The small size of these crucibles, with diameters of only a few centimetres and a volume of 25 ml for the one from Canterbury: 7 Palace Street (Figure 4.7), indicates only small scale brass production but larger versions must have existed as large quantities of brass were used, especially in the 1st century AD (see Chapter 10).

CHAPTER 5

METAL MELTING AND CASTING

Once metal had been won from its ores and refined it was ready for use, either on its own or alloyed with other elements. The next step in making it into an object was to melt it and then cast it, either directly into its final form in suitable moulds or into ingots or blanks which were then smithed to shape. The melting was normally carried out in a crucible heated in a hearth or furnace, though when large quantities of metal were involved a reverbatory-type furnace may have been used instead. Theophilus (Ch 64) describes an elaborate furnace but structures of this sort are not known in the archaeological record. Where small numbers of crucibles were used, a heap of charcoal and a pair of bellows were all that were required, though shallow pits were sometimes used to contain the fire.

The material remains that may be found where metal melting and casting were practised are crucibles, moulds, new and scrap metal, slags carrying traces of metal and hearths and/or furnaces. All these classes of material are considered in turn below.

Crucibles

'Crucible' is used as a generic term to describe a whole range of vessels used in high temperature processes. The commonest by far in archaeological contexts are metal-melting crucibles and that is the meaning here, unless the term is otherwise qualified. The function of a crucible is to contain the metal being melted, protecting it from loss and contamination, and to provide a means of transport for it when molten so it can be poured into a mould.

All crucibles must therefore share certain properties so they may perform these functions. The most important of these are strength and an ability to withstand high temperatures. Strength is vital as the walls of the crucible must be able to support the weight of metal it contains, particularly when it is lifted or tipped to let the molten metal run into a mould. In general, larger crucibles have thicker walls and are made of coarser fabrics, both of which tend to increase their strength.

The behaviour of a crucible at high temperatures is mainly a function of the fabric of which it is made. Refractory fabrics are little affected by heat and can be divided into three classes with differing chemical natures (Garside 1957). These are acid refractories, silica and fireclays, which react with metallic bases to form silicates, basic refractories such as magnesia and alumina which react with siliceous materials, and neutral refractories, eg graphite and bone ash, which have a slightly basic character. Although basic refractories would appear most suitable for metal melting they were not used in antiquity; instead the main crucible fabrics were acid refractories, silica-clay mixtures. Clays with low levels of fluxing impurities (iron oxides and alkalis) were preferred as high concentrations drastically reduce the initial softening temperature of the fabric. Most ancient crucible fabrics contain a high proportion of silica which improves refractoriness, though too much can be a disadvantage, particularly where particle sizes are small, as it undergoes an increase of volume at 573^{o}C due to a change in its crystal habit. This produces stresses in the crucible walls and in severe cases leads to spauling, though often the initial firing of the crucible produced voids round the silica grains which allow subsequent volume change cycles with a minimum of further stresses. In some crucibles grog is used as well as, or instead of, added silica (Tylecote 1982). Theophilus (Ch 22 and 65) describes making crucibles from white (iron free) clay and adding crushed used crucibles, ie grog, as temper.

One major problem with acid refractories is their tendency to react with the melt, producing a crucible slag (see below). Additions of graphite or carbon (as charcoal) give the fabric a more neutral character and thus reduce this tendency (Tylecote 1982). Some crucibles were made of fabrics that contained finely divided organic matter which would have had much the same effect and could also have helped to maintain reducing conditions within the crucible, reducing the production of metal oxides and thus slag. If conditions became too oxidising and the organic matter burnt out, the increased porosity would reduce the heat transfer through the fabric which could be an advantage if the crucible was being heated from above. Graphite does not regularly appear in crucible fabrics until the post-medieval period though Iron Age crucibles from Manching, Bavaria are graphitic (Kappel 1969).

In addition to possessing strength and refractoriness, crucible fabrics must resist more than superficial dissolution by the melt, have adequate density to avoid leakage and be resistant to thermal shock. This last point will be discussed further below. The functionality of a vessel is determined not only by its fabric but also by its form, though this is seldom a critical factor. As is shown below, a wide range of forms have been used as crucibles and the pros and cons of each will be discussed.

All crucibles are reduced fired as metals must be melted under reducing conditions to prevent them from being oxidised and lost into a massive crucible slag. The exceptions are refining crucibles where some elements are deliberately oxidised to remove them from the melt (see

Chapter 4, above).

Most of the crucibles used in antiquity are vitrified to a greater or lesser extent. Sometimes there is just a slight 'glaze' on the surface while at the other end of the spectrum the fabric can be vitrified all through and bloated. The degree of vitrification is a measure of how refractory the crucible fabric is, ie how suitable it is for the use to which it was put. The distribution of the vitrified areas on the vessel can suggest whether it was heated from below or above. Vitrification on the outside of a crucible is usually caused by fluxing of the surface by the ash in the fire in which it was heated (Bayley 1985E). These fuel ash 'glazes' or slags often contain traces of metal, either physically bound as discrete droplets or chemically combined with the slag layer itself; most noticeable is the bright red colour produced by traces of copper. Vitrification on the inner surface is the crucible slag which is formed by the reaction of metal oxides from the melt with some fuel ash and the crucible fabric (Tylecote 1982). Analysis of these slag layers can indicate the nature of the metal or alloy being melted, particularly where metal droplets are trapped in them. A successful craftsman kept this waste to a minimum.

Some crucibles have an added outer layer of less refractory clay which was applied before the crucible was used or, occasionally, over an already vitrified surface. Two distinct patterns of additions are found. The first is a fairly even and relatively thick covering of the whole of the outside of the vessel. This layer is normally deeply vitrified and was obviously very soft when at high temperatures as it often carries impressions of pieces of wood or charcoal from the fire; somewhat surprisingly, tong marks are not normally noted. The purpose of this extra layer is not known but a number of possible reasons for its application can be suggested. It would protect the crucible proper from the fire so its strength would not be reduced by the dissolution of fabric by fluxing and vitrification and would also reduce the thermal shock experienced by the crucible as it was removed from the fire, so making it less liable to crack. It would also increase the thermal capacity of the crucible which could be vital in giving the craftsman slightly longer in which to pour the metal before it resolidified (Tylecote (1982) quotes a figure of 2-5 seconds) as the temperatures readily obtainable in antiquity meant that melts could not be superheated to the levels they can be today.

The alternative pattern of application is a minimal or non-existent layer of extra clay on the lower part of the crucible which increases in thickness towards the rim. In a few cases the extra outer layer of clay can be seen to have continued upwards, above the rim of the crucible, suggesting it formed a structural addition to the vessel. This can take various forms, such as a pouring lip or a lid, and are described in more detail below. Occasionally the addition is in the same fabric as the crucible itself, indicating that it must have been made and used at one place. Tylecote (1982) commends lidded crucibles as conserving heat while pouring but notes the difficulty of filling them with solid metal. This problem disappears if lids are applied after the crucible has been filled. With unlidded crucibles more metal can be added to the charge as it melts, but this would be difficult if a lid was in place. The few lidded crucibles studied, eg Hartlepool: Church Close, seem to bear this out as the 'tide mark' on the inside is lower down than on open crucibles.

Crucible charges could be covered with charcoal to minimise oxidation. Once the crucible charge was molten any metal oxides present were fluxed and the resulting slag that formed was skimmed off the surface to prevent it entering the mould and the melt was then poured. Theophilus (Ch 25) describes throwing salt on molten silver, but when casting brass (Ch 61), describes using a cloth pad to keep back the dirt and ashes from the moulds. An added clay bar across the lip would have a similar function.

Where volumes are given for crucibles these are normally the brimful capacities. The maximum usable volume is only 70 or 80% of this figure and is often indicated by a change in colour or a 'tide-mark' in the slag inside the crucible.

<u>Chronological sequence of metal melting crucibles</u>

Vessels of many different forms and fabrics were used as crucibles during the periods covered by this study. Tylecote (1986A, Fig 50) illustrates a range but fails to note which are common and which rare in each period. He also provides a typology which is purely descriptive (ibid, Table 58) and so fails to take into account the development of one type into others and also separates related types. His typology is not used here but a concordance of types is provided (see Table 5.1). What are described here are the main forms in use at any particular period; this is not a complete typology. It does however produce useful and meaningful groups from the data in Appendix A.

In the earlier Iron Age there is relatively little evidence for non-ferrous metalworking and the few crucibles known, eg Christon (AML 4634), appear to be similar to those used in the later Bronze Age, eg Dainton (Needham 1980).

Table 5.1 - Crucible typology

Type No		Description	Fig No	Type*
1	H	shallow triangular + 3 lips	5.1	A1
2	H	deeper triangular + 3 lips	5.2	A2
3	H	shallow hemispherical + 1 lip	5.3	B1
4	W	beaker, flat-based	5.5	?B4
4/5		transitional type	5.6	?B6
5	W	conical	5.7	B3/G1
	H		5.8	B3/G1
6	H	thumb pot	5.4	B1
6A	H	thumb pot + perforation near rim	5.4	B1A
7	W/H	bag-shaped or bi-conical+ 1 lip	5.10	F
8	H	hemispherical: max diam below rim	5.11	?B4
	H	max diam at rim	5.12	B1
9	H	thimble-shaped	5.14	B1
10	W	pedestal + 1 lip	5.13	B6
11	H	half-pear shaped + lid	5.9	

Notes:

H = hand-made

W = wheel-thrown

W/H = wheel-thrown and hand finished

* The type codes in the right hand column are those defined by Tylecote (1986A).

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For the later Iron Age the number of sites with evidence for metalworking and the quantity of metalworking finds is far greater (see Appendix A and Table 2.1). The typical crucible form was then triangular in plan with three pouring lips formed in the rim of a hand-made bowl. The most intense vitrification on these vessels is always round the rim which shows they were heated from above; the outside of the base is sometimes even oxidised fired. There is some variation in form with crucibles from sites such as Gussage All Saints (Spratling 1979) and Glastonbury Lake Village (Bulleid and Gray 1911 and 1917), which date to the 1st century BC, being relatively shallow (Type 1: Figure 5.1) while those from later sites that belong to or run into the 1st century AD, such as Thetford: Fison Way (AML 3761) and Meare (Bulleid and Gray 1953), are deeper (Type 2: Figure 5.2). There are intermediate forms and many fragments cannot be positively assigned to one type or the other. Some shallow triangular crucibles such as that from Sutton Walls (Kenyon 1953) are dated to the 1st century AD but none of the deeper crucibles date

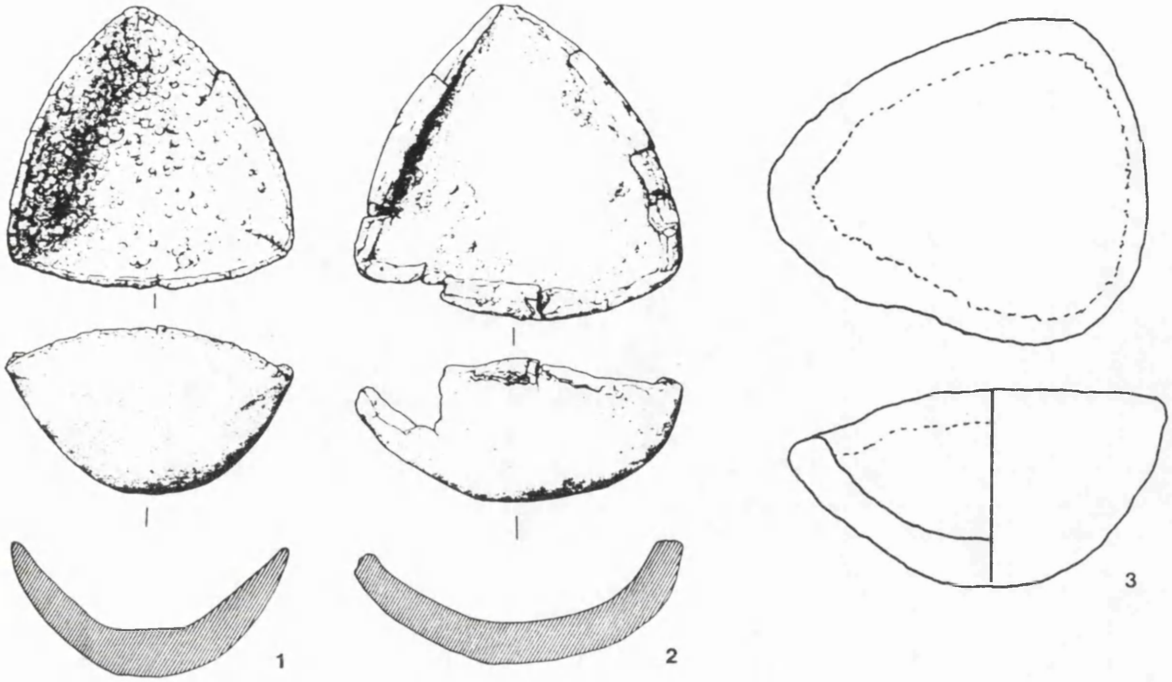

Figure 5.1 - Type 1 crucibles from [1-2] Gussage All Saints (Spratling 1979) and [3] Sutton Walls (sketch after Kenyon 1953). Scale 1:2

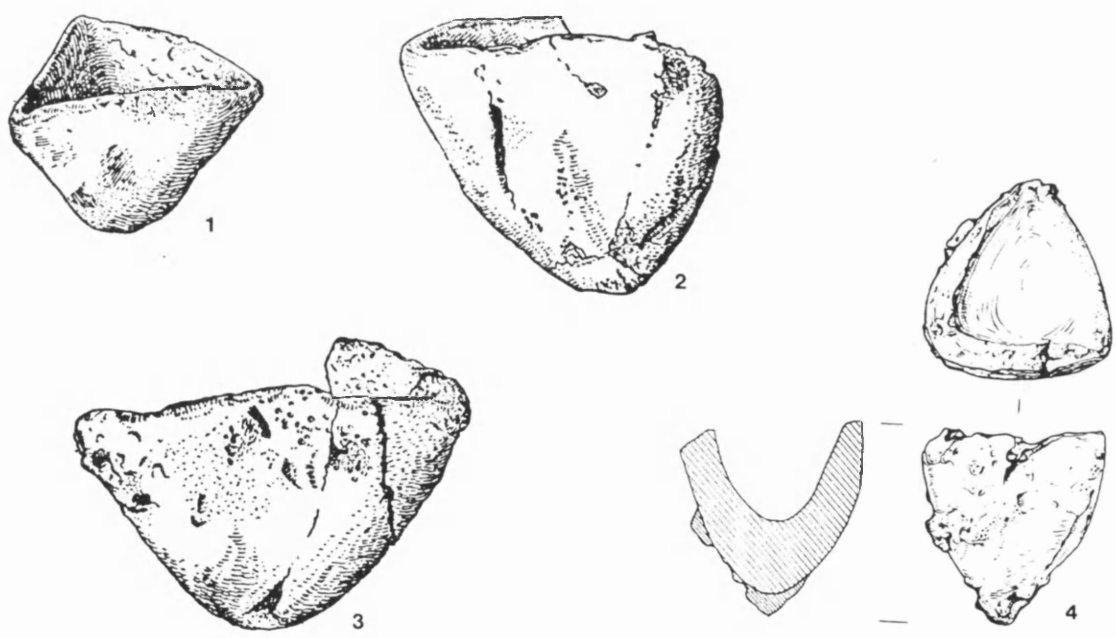

Figure 5.2 - Type 2 crucibles from [1-3] Meare (Bulleid and Gray 1953) and [4] Mucking (Jones 1980). Scale 1:2

before the late 1st century BC, so the development would seem to be from shallow to deeper forms. The triangular form of these crucibles meant they could be tipped and the molten metal poured out over any one of the three lips. Most of the crucibles are made of highly tempered, sandy fabrics which have been studied in detail by Howard (1983). A range of sizes are known, the larger ones being thicker walled and of coarser fabrics. The illustrations are of average sized vessels.

When the metal deposits on these crucibles are analysed, sometimes all that is detectable is a trace of copper which could indicate the melting of unalloyed copper or could be considered as non-specific evidence for metal melting (see Appendix B for fuller discussion of this point). In other cases there is evidence for the melting of both leaded and unleaded bronze, silver (a single case only) and gold. There is no evidence that these crucibles were ever used to melt zinc-containing alloys.

Increasing the depth of the crucibles decreased the surface to volume ratio and so decreased the proportion of metal liable to be oxidised and lost to the crucible slag. At the same time, as the surface in contact with the fire was reduced, so too would be the heat transferred to the crucible and thus the time taken to melt the metal must have increased.

Triangular crucibles continued in use into the later 1st century AD and beyond in those areas of northern and western Britain which were not Romanised or where the Roman presence arrived later than in southern England. Where triangular crucibles are found in the south in late 1st century contexts, the possibility of their being residual must be considered.

A new crucible form appears in Britain from around the time of the Conquest. It is a hand-made, shallow hemispherical crucible with a single small pouring lip pinched out of the rim (Type 3: Figure 5.3) and may be a development of the triangular, Iron Age type; like them they were heated from above. Examples are known from pre-Conquest levels at Silchester and from Roman contexts as far afield as Colchester (Bayley 1984D and 1985B) and Doncaster (Bayley 1986A) where they were used for silver and for copper alloys containing both tin and zinc.

Hand-made crucibles continued in use throughout the Roman occupation of Britain. Most are small thumb pots though a variety of forms are recorded. Typical examples have diameters of under 50 mm and volumes of the order of 20 ml (Type 6: Figure 5.4). A variant has a hole in the side just below the rim (Type 6A: Figure 5.4) and was lidded (cf Bachmann 1976); the hole provided an outlet for the molten metal while

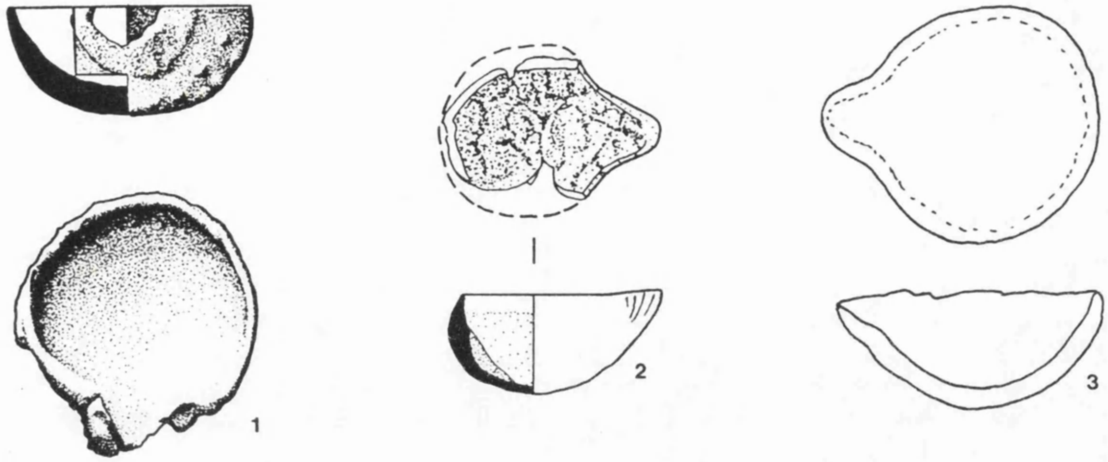

Figure 5.3 - Type 3 crucibles from [1] Doncaster: St Sepulchre Gate (Bayley 1986A), [2] Colchester: Castle (Bayley 1984D) and [3] Colchester: Sheepen. Scale 1:2

the crucible wall above held back any floating slag. These small crucibles were used to melt a whole range of metals including gold and silver. They cannot be considered as specifically Roman in form (with the exception of Type 6A) but do make up a significant proportion of the crucibles from Roman sites, both early and late. They are made in a whole range of fabrics, some of them not very refractory.

The specifically Roman forms were wheel thrown, relatively large in size and often had an extra outer layer (see above). Although this added clay seldom survives above rim level, its form often suggests that it originally did so. These wheel thrown crucibles have no built-in pouring lip and it is tempting to suggest that one was formed in the added clay although no complete example is known to me. The commonest form in the late 1st and 2nd centuries is a beaker with a beaded rim and a flat, semi-pedestal base (Type 4: Figure 5.5). These are found in a whole range of sizes from 50 mm to nearly 200 mm high which correspond to volumes of up to 400 ml. Wall thickness increases with size. The fabrics of the crucible proper are quite refractory and are not normally more than superficially vitrified. The added outer layer is however deeply altered all over, indicating that these crucibles were heated from below. This was possible as the improved fabrics meant the crucibles were relatively thin walled for their size and could be considered as thermal conductors rather than insulators. The small surface to volume ratio minimised metal oxidation.

A few later Roman crucibles with very narrow pedestal bases are known (Figure 5.6) and these would appear to be an intermediate form between Type 4 crucibles and the conical-based crucibles (eg Draper 1985,

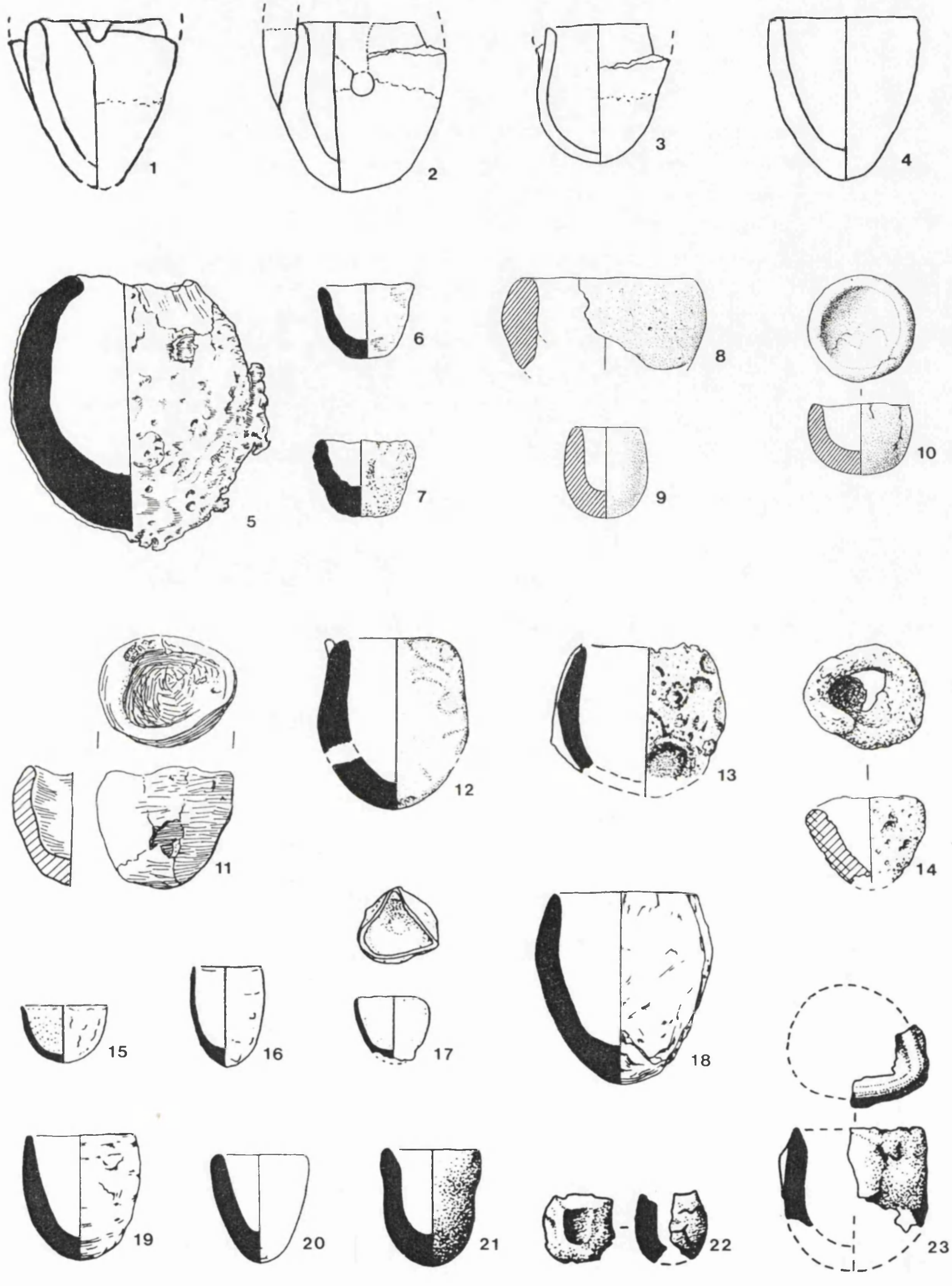

Figure 5.4 - Type 6A crucibles from [1] Heronbridge (Hartley 1954) and [2-3] Verulamium. Type 6 crucibles from [4] Heronbridge (Hartley 1954), [5-7] Verulamium (Frere 1972), [8-10] Gorhambury (Bayley 1990B), [11] Southampton (Addyman and Hill 1969), [12-13] Lincoln: Flaxengate (Gilmour 1988), [14] Winchester (Bayley and Barclay 1990), [15-17] York: Coppergate (Bayley forthcoming), [18-20] Thetford (Bayley 1984E) and [21-23] Cheddar (Biek 1979). [1-10] are Roman, [11-23] Saxon. Scale 1:2

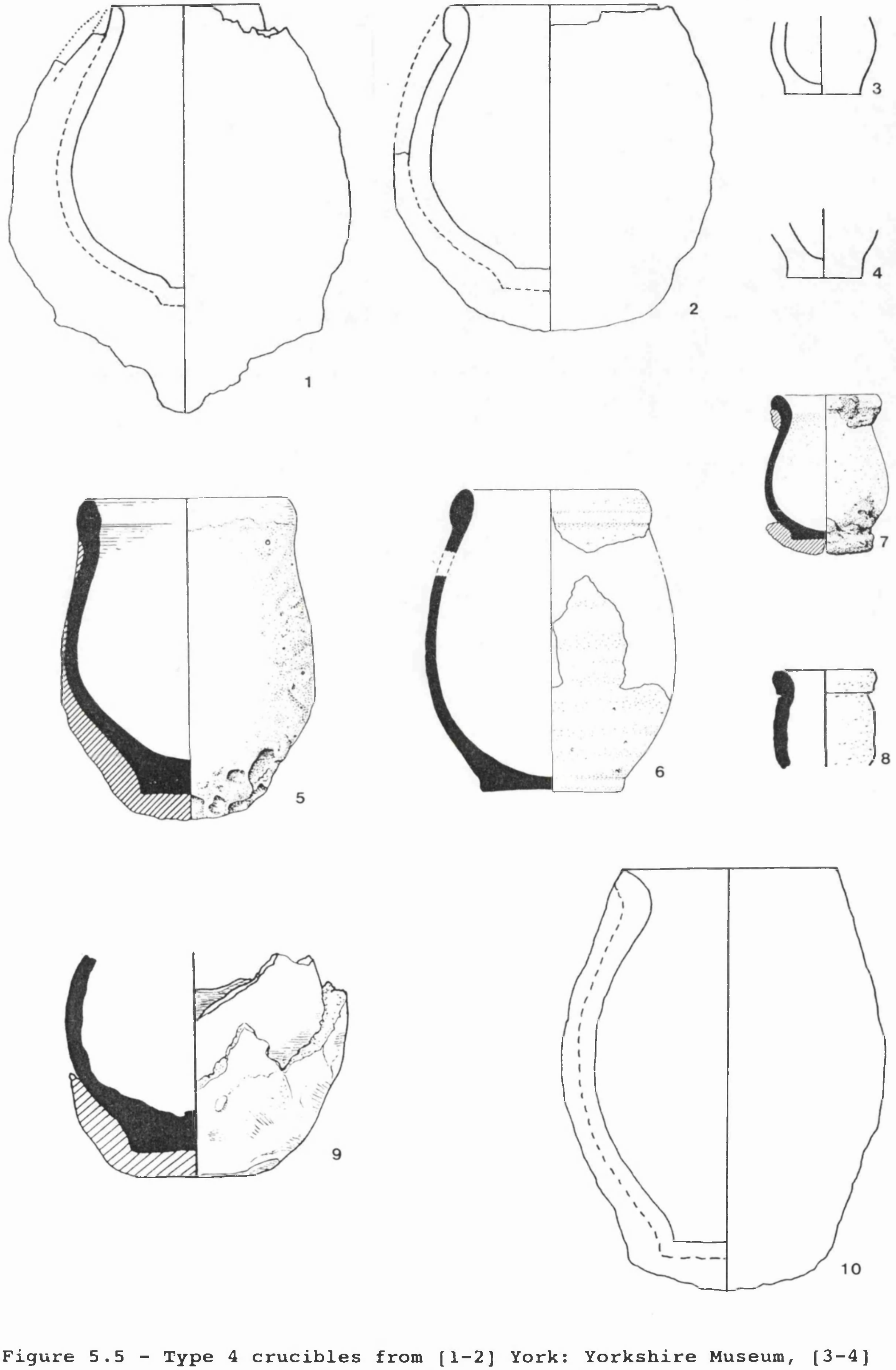

Figure 5.5 - Type 4 crucibles from [1-2] York: Yorkshire Museum, [3-4] Chester: Hunter Street School, [5] Baldock (Stead and Rigby 1986), [6-7] Colchester: Lion Walk (Bayley 1984C), [8-9] Verulamium (Frere 1972) and [10] Chichester: Greyfriars. Scale 1:2

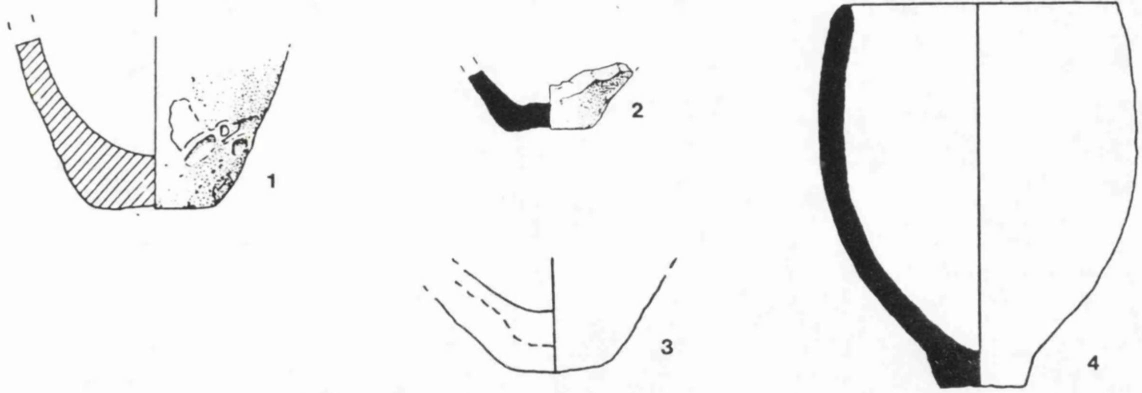

Figure 5.6 - Type 4/5 crucibles from [1] Gloucester: Lower Quay Street (Garrod and Heighway 1985), [2] Gestingthorpe (Draper 1985), [3] Alcester and [4] Snodland. Scale 1:2

Fig 38 - holding 300 ml of metal) which are known from the 3rd century onwards (Type 5: Figure 5.7). Contemporary variants of this wheel-thrown, conical form are hand-made crucibles with a similar though usually slightly more rounded profile (Figure 5.8). Some are truly circular (AML 3862) while others have a slightly triangular plan (Bayley 1984B) reminiscent of Type 2, though without the pouring lips. Added outer layers are not of the all-over variety and so may represent the provision of a lip and/or lid. The crucible illustrated by Brailsford (1964, Fig 39, 3) appears to show an addition of this type. Volumes are in the range 200-400 ml and differentiate these hand made crucibles from the far smaller Type 6 ones, though in some cases the forms are not that dissimilar. These typical Roman crucibles were used to melt a wide range of different copper alloys and some of the smaller Type 4 vessels were used to melt gold. Silver has not yet been detected on any Type 4, 4/5 or 5 crucibles.

Post Roman crucibles, in common with other pottery vessels, are hand-made. Maximum volumes are much reduced with sizes of up to 20 ml being typical. Few finds from England date before AD 700 but earlier material is known from Wales and Scotland. Dinas Powys produced a number of half-pear shaped crucibles with knobbed lids (Type 11: Figure 5.9) from 7th century levels (Alcock 1963, Figs 30 and 31) which had been used to melt gold and copper alloys containing both zinc and tin. Crucibles of similar shape were recently found both at Hartlepool: Church Close where they dated to c. AD 700 and had been used to melt silver (Bayley 1988C) and at Wharram Percy where they are thought to date to the 8th century and were used to melt copper alloys (AML 26/91). At Dunadd, in Scotland, a number of different crucible forms were found which at the moment can only be dated within the 6th - 9th centuries. Here each form

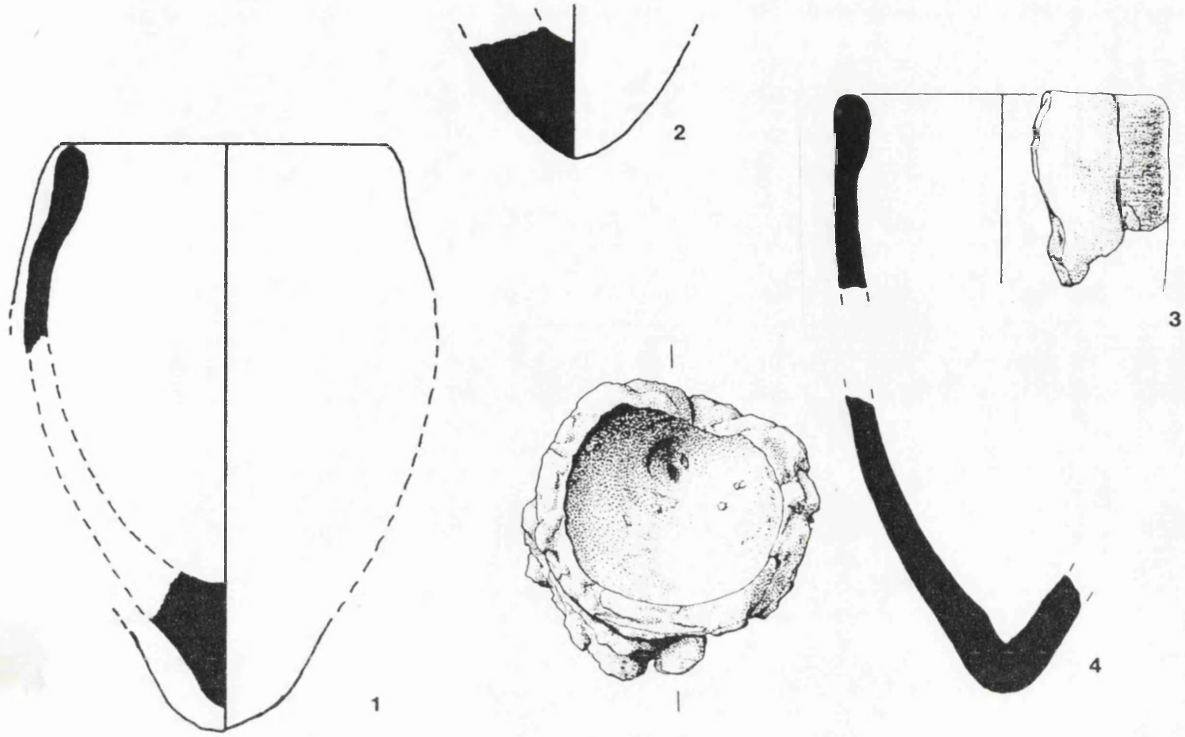

Figure 5.7 - Wheel thrown Type 5 crucibles from [1] Silchester, [2] Alcester and [3-4] Gestingthorpe (Draper 1985). Scale 1:2

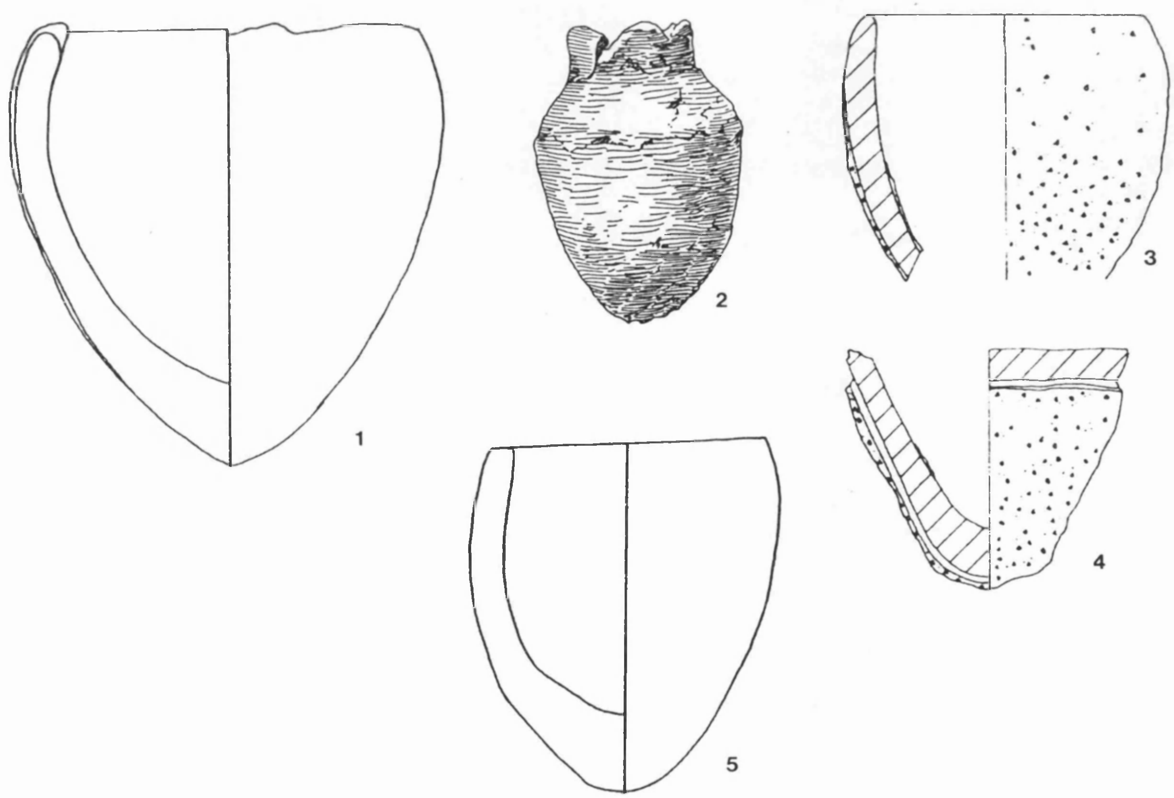

Figure 5.8 - Hand made Type 5 crucibles from [1] Canterbury: Marlowes III and Cakebread Robey, [2] Lingwell Gate (Brailsford 1964), [3-4] Langton (Goodall 1972) and [5] Sewingshields (Bayley 1984B). Scale 1:2

is preferentially, though not uniquely, associated with a specific metal (AML 4237). The lidded crucibles were mainly used for melting silver while similar though smaller one-piece crucibles, with the rim pinched together to give a partly-lidded effect, were used for gold and silver. Both thimble-shaped (cf Figure 5.14) and thick-walled hemispherical crucibles were used mainly for copper alloys, the metal in the latter apparently containing far less zinc.

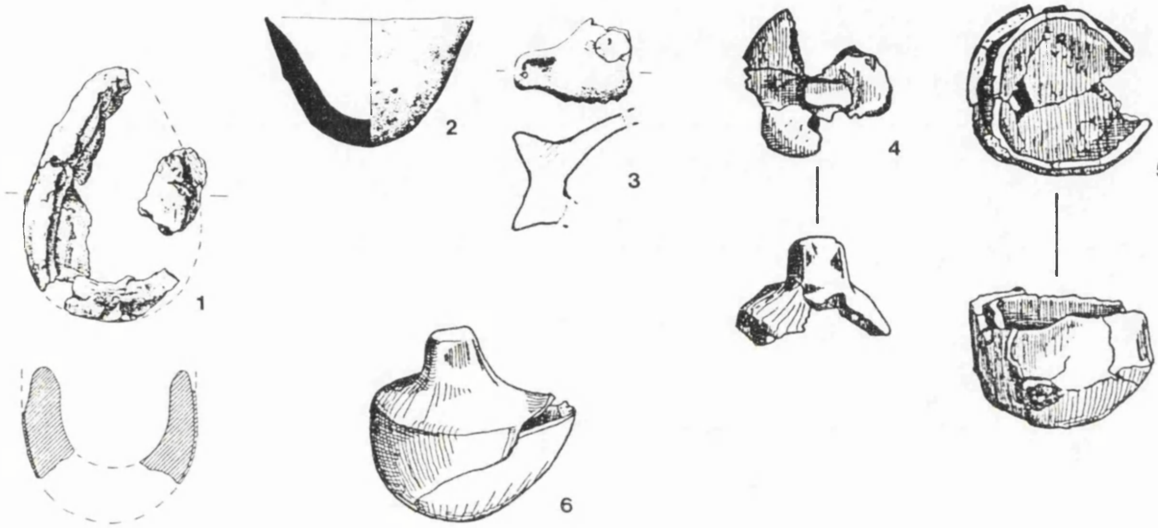

Figure 5.9 - Type 11 crucibles from [1] Wharram Percy, [2-3] Hartlepool: Church Close (Bayley 1988E) and [4-6] Dinas Powys (Alcock 1963). [3-4] are knobbed lids and [6] a reconstruction. Scale 1:2 (drawing [1] by Peter Dunn, English Heritage)

The only Middle Saxon site to produce more than a few crucible sherds is Southampton (Hamwih) where parts of more than 50 crucibles dating to the 8th and earlier 9th centuries have been found. These were used for melting both silver and a whole range of different copper alloys (Addyman and Hill 1969, AML 3934 and 2/86). The more complete vessels suggest that the normal form was a small thumb pot about 30-40 mm across with a brimful capacity of 10-15 ml and no pouring lip (Type 6: Figure 5.4). Fabrics were not very refractory; their original nature is often hidden by the extreme vitrification they have undergone.

For the late Saxon and early medieval period, from the late 9th or 10th century onwards, a number of sites have produced large assemblages (hundreds of sherds) of crucibles. Those from Winchester are mainly hand-made and of not very refractory fabrics (Bayley and Barclay 1990) while those from the Flaxengate site in Lincoln (AML 2998 and Gilmour 1988) and the Coppergate site in York (Mainman 1990 and Bayley forthcoming) are largely wheel thrown Stamford ware with hand finished bases. This fabric, which is highly refractory, was also used for a whole range of high quality domestic vessels and some of the crucible forms also had domestic uses, eg as lamps (Kilmurry 1980). Contemporary crucibles from Northampton (eg Bayley 1979A and 1981), Thetford (Bayley 1984E) and London (Bayley *et al* 1991) are split between hand-made and wheel thrown forms in a variety of different fabrics, including some Stamford ware in London. Maximum crucible size increases again dramatically at this period with average diameters of the order of 50-100 mm though both larger and smaller examples are known. Apart from the Stamford ware which is always bag-shaped or bi-conical with a pinched out lip (Type 7: Figure 5.10) and other fabrics made up in similar shapes, the forms are generally hemispherical with sides that are straight or slightly splayed or in-curving (Type 8: Figures 5.11 and 5.12). Almost all these crucibles are round bottomed. Exceptions are the small wheel thrown crucibles from Northampton used to melt silver (Bayley 1981, Figure 24) which have a semi-pedestal base and a pinched out lip (Type 10: Figure 5.13); their fabric is similar to that of Stamford ware. Several sites in the town have produced examples but none are yet known from other areas.

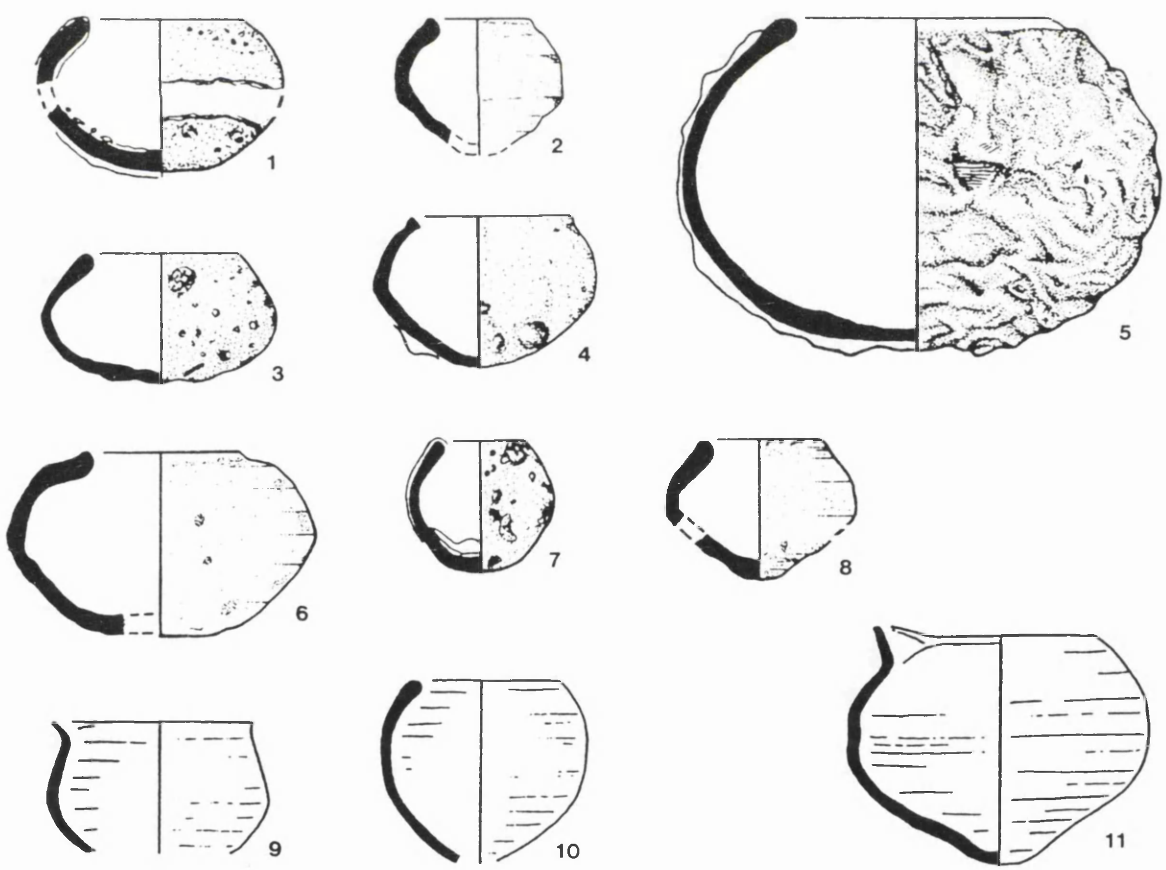

Figure 5.10 - Type 7 crucibles from [1-8] Lincoln: Flaxengate (Gilmour 1988) and [9-11] York: Coppergate (Mainman 1990). Scale 1:2

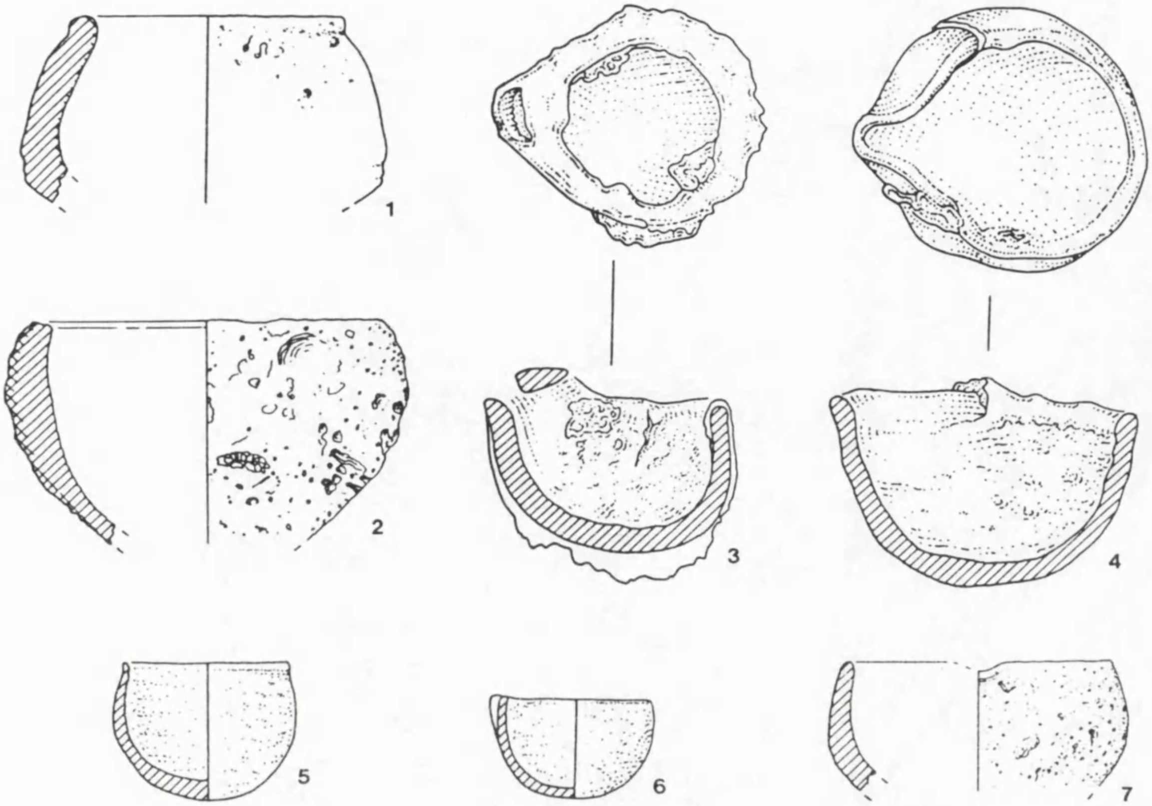

Figure 5.11 - Type 8 crucibles (with maximum diameter below the rim) from [1-2, 7] Winchester (Bayley and Barclay 1990) and [3-6] London (Bayley et al 1991). Scale 1:2

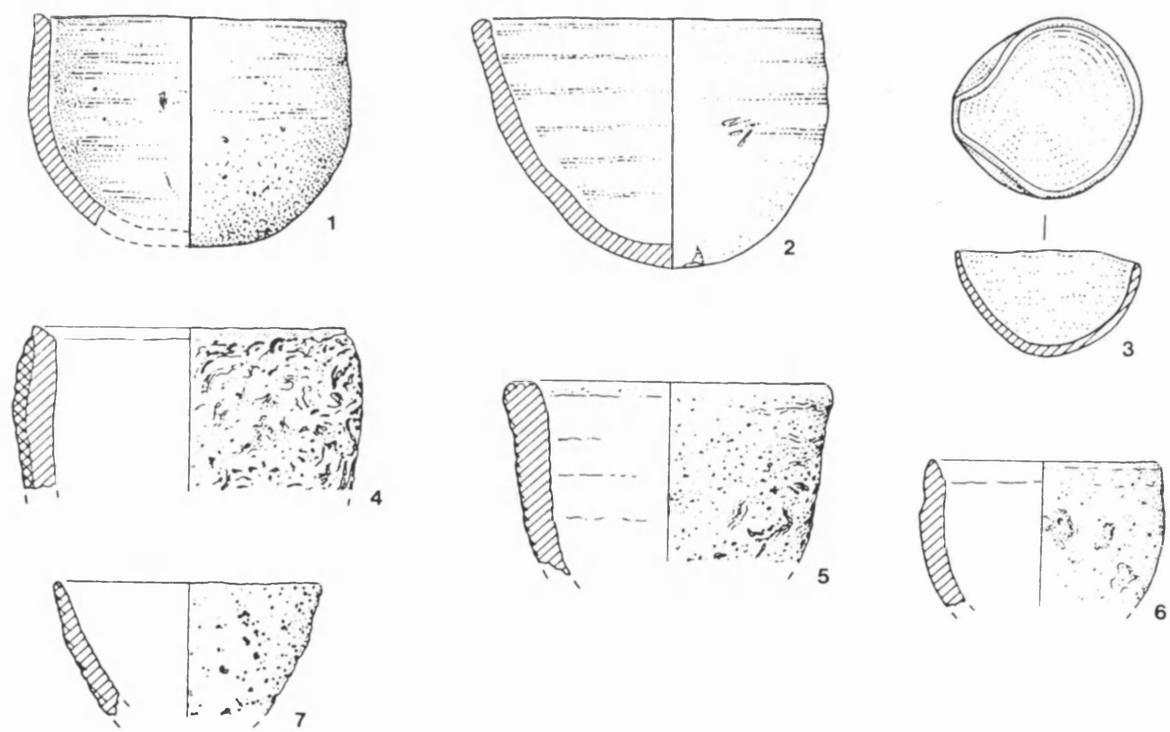

Figure 5.12 - Type 8 crucibles (with maximum diameter at rim) from [1-3] London (Bayley et al 1991) and [4-7] Winchester (Bayley and Barclay 1990). Scale 1:2

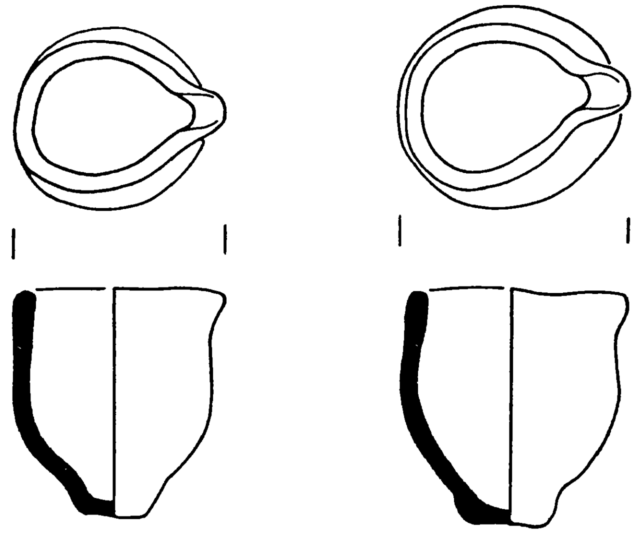

Figure 5.13 - Type 10 crucibles from Northampton: Chalk Lane (Bayley 1981). Scale 1:2

Late Saxon crucibles were used to melt both silver and a whole range of copper alloys, often containing both tin and zinc, though in varying proportions. Gold is found too, but is far less frequent. In general, it seems to be crucible size which is the major factor in determining which metal is melted in which crucible. At Flaxengate, silver is commoner at one period, but date seems the major variable here as similar crucibles are found at other periods when they were used for copper alloys. The majority of the Coppergate crucibles were used to melt silver though both copper alloys and gold were noted as well. Most of the gold was not in Stamford ware crucibles but in very small, thin-walled thumb pots (Mainman 1990, Fig 204, 2333-7). These were probably chosen because of their size rather than their form or fabric. In London, crucibles of three fabrics were found and the metal in them tends to correlate with size rather than fabric (Bayley *et al* 1991). Silver was found mainly in Stamford ware and London ware crucibles (with diameters of 30-80 mm) while the larger London ware (*c*.150 mm diameter) and all sizes of the Early Medieval Coarse Ware crucibles were used for copper alloys with the leaded alloys mainly in the larger vessels. The Stamford ware had been brought some considerable distance to London so presumably it was seen as having superior qualities which made this worthwhile and may explain its main use - for the precious metal silver.

Excavations in Parliament Street, York have produced a single, complete thimble-shaped crucible (Type 9: Figure 5.14), which is a most unusual form in England (Bayley in Tweddle 1986). It can however be readily paralleled on Viking period metal working sites in Scandinavia, eg Ribe (Brinch Madsen 1984), Haithabu and Kaupang, and as such may well be an import from there.

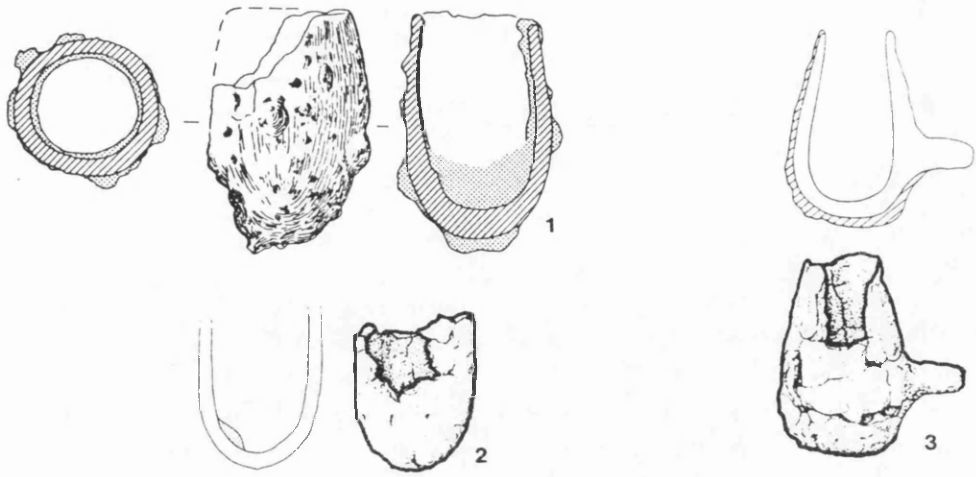

Figure 5.14 - Type 9 crucibles from [1] York: Parliament Street (Tweddle 1986) and [2-3] Ribe, Jutland (Brinch Madsen 1984). Scale 1:2

It is at this period that extra outer layers reappear. They are most commonly found on the thin walled, wheel thrown crucibles such as those made of Stamford ware, where their function seems mainly to increase thermal capacity and prevent fluxing and vitrification of the surface. There is little evidence they extended above the rim but provided a fairly uniform all over covering. In a few cases, mainly on crucibles from London, an alternative pattern of additions is visible with the extra clay mainly concentrated around the rim or lip. A complete crucible provided the explanation for this disposition as it still had a bar, formed of the added clay, across the lip which would have kept back any slag or charcoal floating on the molten metal when it was poured (Figure 5.11, 3-4).

Moulds

There are two distinct types of moulds, those where ingots or blanks were cast for subsequent working and those where an object or objects were cast in something very close to their final form. Stone and ceramics were used for both types of mould but fired clay is certainly the dominant material for object moulds in the periods covered by this study. Other materials such as wood and antler can be used to make moulds for lead and tin alloys because of their low melting points. Theophilus describes using wood moulds to make lead cames (Bk II, Ch 26) and MacGregor (1985) describes antler trinket moulds.

Oxide films on melts can cause wetting of non-carbonaceous mould fabrics by the metal being cast. Melting under a charcoal blanket, careful skimming on pouring and a good finish to the mould can minimise this wetting, and so produce a casting that does not adhere to the mould. The precious metals silver and gold always form spheroids on melting, even under oxidising conditions, and so do not wet moulds unless they are heavily debased. A mould generally shows little if any sign of vitrification as, unlike a crucible, it is not subjected to high temperatures for a long time. These two points, when taken together, mean that analysing moulds to determine the metal cast in them is very rarely successful as little metal is left behind and these traces are only physically attached rather than chemically bound and so rarely survive both burial and rediscovery. (See Appendix B for further discussion of analytical results and their interpretation.)

Some clay moulds have two or more layers of different fabrics; the inner one is invariably finest as it carries the detail of the design. More often, moulds are of a single fabric but appear to have multiple layers as the part nearest the metal is usually blackened while the rest is oxidised fired and so appears red or brown (or white if an iron-free clay has been used). Moulds are not normally made of the same fabrics as contemporary crucibles as the properties required are quite different. They are usually less heavily tempered as they are not required to be as refractory and a lack of coarse particles is an advantage when reproducing fine detail.

All moulds have to be heated before use to thoroughly dry them and to prevent thermal shock induced failure. As only low levels of superheating of the metal melt were possible, heating the mould helped prevent incomplete runs, though slow cooling tends to increase segregation, particularly in alloys with a wide freezing range like bronze. The resulting dendritic structure of the casting is often revealed by corrosion where one phase is preferentially attacked. Castings have to be fettled, ie the sprue, runners and casting flashes (if any) removed, and finished as for wrought metalwork (see Chapter 6 for details).

<u>Ingot moulds</u>

These are open, one-piece moulds in which simple shapes such as bars or discs were cast for subsequent working into rods, wire or sheet (see Chapter 6). Most ingot moulds are of stone as they must be capable of repeated use, although some are made from reused brick or tile which has been carved to shape as though it were stone. Some are of quite coarse-textured stone but this does not matter as the surface finish of the ingot is not critical. Ingot moulds are regularly found on late Saxon and Anglo-Scandinavian sites (eg Mason 1985) but are not unknown at other periods (see Tables 2.1-2.6). Most have more than one shape cut into them (Figure 5.15).

As has been mentioned above, traces of the metal cast in a mould rarely survive, though with ingot moulds the chances are improved as they are used repeatedly over a period of time. In the case of ingot moulds from York and Lincoln, which were analysed before they were washed, the results have been encouraging and, where positive, suggest that the metal cast was usually silver (AML 3465 and 4163). This is not surprising when the number of silver bar ingot fragments found in hoards is considered (eg Kruse 1988). Theophilus (Ch 25) describes casting silver in an ingot mould that has been heated on the fire and had a dressing of molten wax applied. The discolouration of the mould fabric often noted in and around the cut-out shapes may be due to the dressing applied to the moulds and/or extreme localised heating caused by the molten metal. However, complete and fragmentary copper alloy bar ingots are also found so base metal must have been cast in a similar way. At Haithabu, in Schleswig, complete copper alloy bar ingots have been found and they are of the order of 300 mm long, far bigger than any ingot moulds known in Britain or Scandinavia. A possible mechanism for their production is that a temporary groove was made in the trampled earth of the workshop floor and the molten metal then poured in. One bar ingot fragment from York: Coppergate has a V-shaped underside suggesting it was cast in this way rather than in an ingot mould as these all have U-shaped or flat-bottomed sections. This off-hand method was apparently acceptable for the relatively cheap base metals but more care was taken and permanent moulds were used when casting the smaller precious metal ingots. Indeed, Kruse (1988) has suggested silver ingots were cast to standard weights and thinks that an experienced craftsman could judge how much metal to pour into his mould.

Late Iron Age clay 'coin pellet moulds' (also known as 'coin blank moulds' and 'coin moulds') which were used to produce blanks to be struck as coins should also be considered as a type of ingot mould. They are clay slabs, 1-2 cm thick, with a regular array of flat-bottomed cylindrical hollows in them and are normally reduced fired. Complete examples are rare, perhaps because they often had to be broken to remove the solidified metal. All the ingot moulds listed in Table 2.1 with the exception of that from Glastonbury Lake Village and one piece from Thetford: Fison Way are coin pellet moulds as are those listed in Table 2.2 from Colchester: Sheepen, Gorhambury and Needham. The use of these objects has been described on numerous occasions (eg Clifford 1961) so it

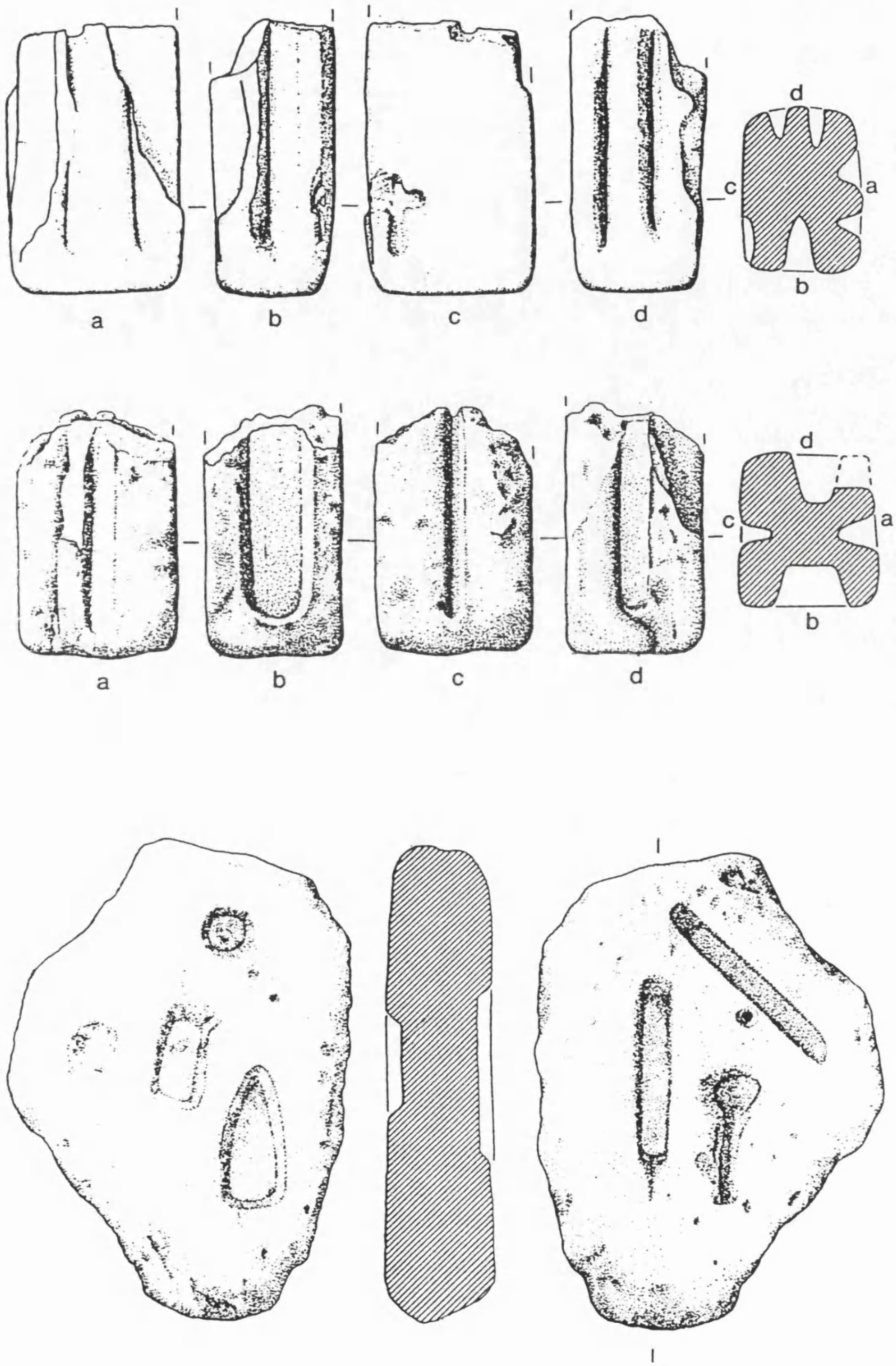

Figure 5.15 - **Ingot moulds from York: Coppergate. The top two are of soapstone and the bottom one of reused Roman brick/tile. Scale 1:2** (drawings by Eddie Moth, York Archaeological Trust)

would be superfluous to repeat the details here. It should be noted that the usage is in some ways analogous to that of crucibles and some vitrification is often produced. Analysis is therefore more likely to give positive results than is the case with object moulds. Results of analyses of metal traces on coin pellet moulds from a number of sites are summarised by Tournaire *et al* (1982).

The use implied by the name coin pellet mould has been questioned by some numismatists as they are concerned that the widespread find spots of these objects suggest multiple mints which they find difficult to accept. Experiments were reported by Sellwood (1976), purporting to show that the moulds could not be used as had been previously described. In these experiments molten copper was poured into moulds and solidified in irregular or cylindrical shapes, "proving" coin blanks could not have been made in them. However, earlier work by Tylecote (1962B) has shown that noble metals (those used in the Iron Age for struck coinage) make sounder castings and do not normally 'wet' clay moulds, even when heated under oxidising conditions (but note the debased (only 65-70%) silver found in one of these moulds from Old Sleaford (Jones *et al* 1976)). Tylecote (ibid) also showed that copper can produce usable blanks if melted under reducing conditions, which can be obtained by adding carbon to the clay of which the mould is made or by covering the mould with charcoal as it is heated. A further point was that weighing out metal clippings before they were melted gave far better size control than pouring molten metal ever could. A recent note (Collis 1985) presents the evidence on both sides of the debate and concludes that "... we cannot say definitely that 'coin moulds' were connected with coin production, but the present evidence, both analytical and circumstantial, suggests it is the best hypothesis we have at present ...".

Investment moulds

Moulds for investment (lost wax) casting must be made of clay as they are formed round a wax model of the object it is desired to make. Once the clay had dried, it was fired, the wax melted and tipped out and the molten metal poured in. It was necessary to break the mould to remove the casting so these moulds could only ever be used once. Most later Iron Age moulds such as those from Gussage All Saints (Spratling 1979, Foster 1980A) are of this type. In the Roman period piece moulds became the dominant type of object moulds but investment casting continued in use for one-off pieces. A good example is the statue mould found at Gestingthorpe (Draper 1985, Fig 38) which clearly shows the use of chaplets to support a clay core. Theophilus (Ch 30) describes making wax patterns, covering them with clay, melting out the wax, firing the mould to red heat, removing it from the fire and casting in it. He also gives instructions for making a far larger and more complex investment mould with a clay core which was buried in a trench before the metal was poured in to provide adequate support (Ch 61). Once the metal was no longer red hot the mould was unearthed but allowed to cool slowly (to avoid cracking the casting) before being removed. When casting tin or pewter (Ch 88) the mould was cooled so it could just be held before the molten metal was poured in.

Investment moulds were also used in late Saxon and medieval times for making large objects such as bells and cauldrons, eg the bell mould from Gloucester: St Oswald's Priory. In these cases the mould had to be very carefully prepared and had to contain enough vegetable matter to give it some porosity so gases were not trapped, producing blow-holes in the casting. The mould was normally positioned in a pit and molten metal run into it from a furnace as the quantities were too large for crucibles to be used. Theophilus (Ch 85) describes the process in detail. He uses tallow rather than wax for modelling large castings. Tylecote (1976) also describes the manufacture of these large castings.

Investment moulds (and piece moulds too) had to be carefully designed so separate streams of molten metal united before solidification was complete. The sprue cup had to be sufficiently large that the metal in it stayed liquid for long enough for it to be sucked down into the contracting casting to prevent voids forming. Tylecote (1987) quotes figures of 2-7% for the contraction on solidification of most metals. Vents were not normally provided in clay moulds as the fabric was sufficiently porous to make them superfluous. By pouring into an inclined mould, air and evolved gases escaped more readily, giving sounder castings (Coghlan 1968).

<u>Piece moulds</u>

Clay piece moulds were widely used in Roman and later times. Considerable numbers have recently been found at Compton Dando (AML 4639) and Castleford (Bayley and Sherlock 1986, Budd and Bayley 1988 and AML 161/87) and smaller numbers are known from other Roman sites (see Table 2.2). In the post-Roman period the only sites producing large numbers of piece moulds are in Ireland and Scotland, eg Garranes (Ó Ríordáin 1941-2) and Dunadd (Craw 1929-30 and AML 4237), but occasional fragments are known from a number of English sites (see Tables 2.3-2.6). The main reason for the change from investment to piece moulds was undoubtedly because the latter were labour-saving and permitted a far greater degree of mass-production. This was not because the moulds themselves could be reused but because one original pattern (see below) could be used to make many moulds, each of which was probably only used once. The main evidence against multiple use is that, on all the moulds examined, the clay luting the valves together appears to have been applied in one go whereas, if the mould had been reused, multiple applications would be expected. The only reason for having a mould that could be taken apart was so that the pattern could be removed for reuse.

The mould was made by taking a suitably-sized and shaped piece of clay, putting it on a flat surface and pressing the pattern into its slightly convex upper surface. Stab marks or cuts were made in the clay round the pattern to provide locating marks and a second piece of clay was pressed over the top, presumably after some sort of parting agent had been dusted on. This method of manufacture produces top and bottom valves that can easily be differentiated, even in a fragmentary state, as the upper part is concavo-convex while the lower part is plano-convex and usually carries a deeper impression. Once the clay had dried sufficiently the mould was taken apart, the pattern removed and the mould reassembled. The valves were sometimes tied together, and the joins were sealed with more clay. In some cases the sprue cup was integral with the mould valves but sometimes it was added after they had been luted together. None of these piece moulds had air vents, perhaps because the joint between the valves was not airtight even when luted or perhaps because the clay fabric itself was sufficiently permeable to make them unnecessary.

If the clay used for the mould was fine enough then very detailed ornamentation could be reproduced. Because the mould fabric was not strong the fine detail was usually damaged in removing the casting, one reason the mould was not normally reused. Examples of the detail possible can be seen on some of the moulds from Hartlepool: Church Close (Bayley 1988C). Here the mould piece bearing the design was not a complete valve but a block which was incorporated into a surround for casting. The decorative plaques being made were plain on the reverse so a flat sheet of clay without any registration marks was smoothed into position over the block and its surround and served as the second valve of the mould. Moulds made in this way have very different cross-sections from those already described.

Sometimes rather coarser detail such as fields to receive champlevé enamel were cast in. The examples from Compton Dando and Castleford show that both small triangular and lozenge-shaped fields as well as larger, more complex ones were cast into the metal rather than being cut from it when solid, although examination of enamelled objects suggests that the fields were often cleaned out or their bases roughened before the enamel was applied.

Piece moulds tend to survive better than investment moulds as they did not have to be broken as much to remove the casting. However, complete or nearly complete moulds often show no sign of having been used which probably explains their exceptional preservation. They were taken apart, the pattern removed and were reassembled, but then lost or discarded before they could be used, as happened to the Roman trumpet brooch mould from Prestatyn, Clwyd (AML 4685 and Blockley 1989, Fig 94). This mould had a left and right half rather than top and bottom, and incompletely removed casting flashes on a number of brooches of different types show this arrangement was quite general. Moulds for Roman brooches from continental Europe also show this arrangement (Drescher 1973). In contrast, the brooch moulds from Compton Dando had back and front valves, the fronts bearing the design of the enamel fields as has been mentioned above. It is the form of these T-shaped brooches and their decoration that make mould valves arranged in this way the obvious choice.

Most moulds are for single objects but some small things like pins were cast several at a time, radiating from the sprue cup like fingers on an outstretched hand. Examples are known from Dunadd and from Helgö, in Sweden (Lamm 1980). In other cases individual moulds were assembled into multiples for casting. An example is the Roman spoon moulds from Castleford where each spoon was made in a 2-piece mould but about 16 of these mould pairs were assembled into a roughly conical-shaped multiple with the bowls round the edge at the bottom and the handles pointing up to the apex where a sprue cup was added (AML 161/87). The molten metal ran from the sprue cup down the handles and into all the spoons at once (Fig 5.16). An unused multiple mould of a similar form is known from Mont Beuvray (Beck, Monthel and Rabeisen 1982/3) but there the units that were linked together are described as investment rather than piece moulds. In medieval times mass-production was taken further and moulds assembled from many pieces, stacked and luted together were used to cast such things as simple buckles (eg Armitage *et al* 1981, Bayley 1987A).

Most of the piece moulds that survive are simple two-piece moulds but multi-piece moulds were used for casting larger and more elaborate objects such as some of the enamelled vessels from Castleford (Budd and Bayley 1988). The moulds for the cylindrical pieces had inner and outer valves that had deliberately shaped lugs for ensuring their correct register and the outer valve was multi- (perhaps three-) piece so it could be removed from the pattern without damage. The dished, circular

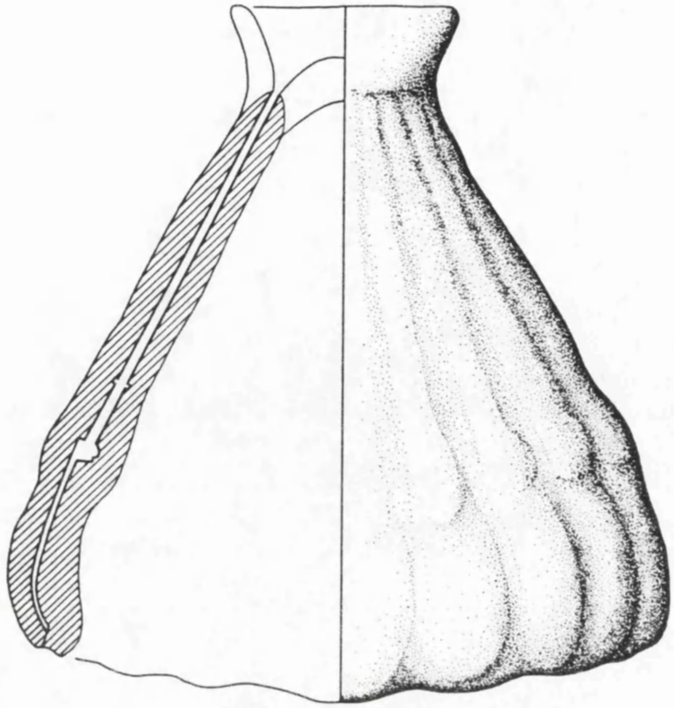

Figure 5.16 - Reconstruction drawing of a mould assembly from Castleford in which two-piece spoon moulds were luted together and about 16 spoons cast at one time. Scale 1:2 (drawing by Margaret Mahoney, English Heritage)

parts of these complex objects were however cast in two-piece moulds with locating knobs like more mundane objects (Figure 5.17).

Piece moulds made of fine-grained stone are rare but not unknown in the period covered by this study. Those that do exist are something of an enigma as they have no obvious registration marks and one must therefore question how the parts were correctly located or whether they were used open or with a flat back which would require no precise location. In contrast, later medieval stone trinket moulds had holes drilled in them to take locating pegs, often of lead, to ensure their correct register (eg Shoesmith 1985, Figs 12-15).

Models and trial pieces

Both investment and piece moulds are made round a pattern or model. This must be made of wax or some other easily melted material for investment casting but is normally of a more durable material where a piece mould is to be made.

The earliest record of honey bees in Britain is *c*.300 BC though this may indicate imported bee products (such as honey or wax) rather than live insects (Robinson 1984). Investment casting appears, in a highly developed form, at around the same time (Northover 1984). At

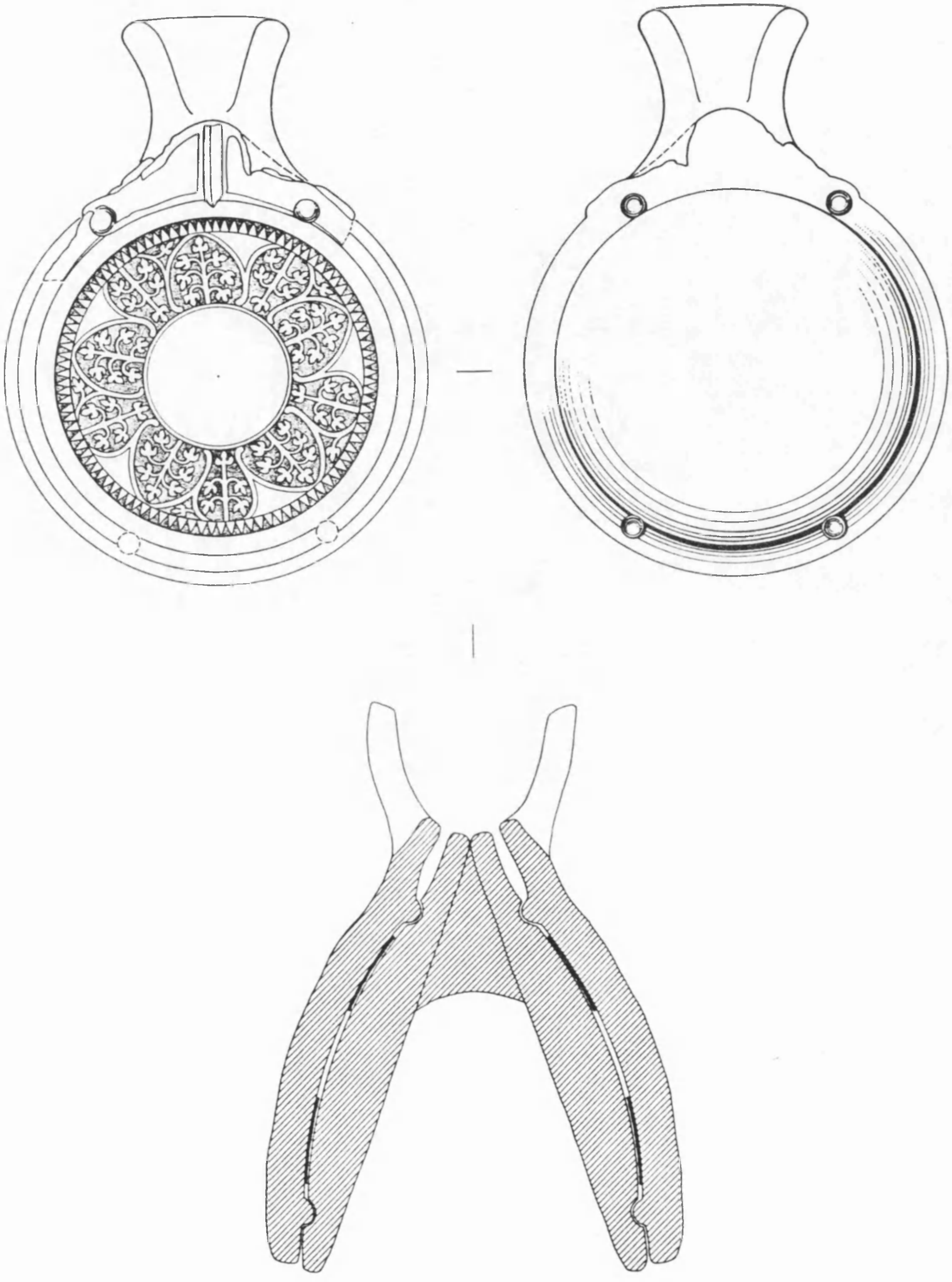

Figure 5.17 - Reconstruction of two-piece moulds for casting vessel parts with recessed fields to take enamel, found at Castleford. The locating knobs round the edge ensure correct registration of the concave, decorated front valve on the convex, plain back. Two of these metal parts were required for each vessel so they were cast in pairs, as shown in the lower sketch, with a spacing piece between the mould pairs and a single added sprue cup. Scale 2:5 (drawing by Miranda Schofield, English Heritage)

Gussage All Saints a number of bone modelling tools were found with the other workshop debris and had presumably been used for shaping the wax patterns round which the clay moulds were formed (Spratling 1979).

As has been noted above, piece moulds were made from patterns which could be reused many times so a more durable material was required. Clay moulds could faithfully reproduce fine detail so, to save work later on, the pattern would carry all the decoration and have the surface finish desired in the metal casting. In some cases suitably prepared castings could have been used as patterns but the majority of finds recorded as patterns have been in softer materials like lead or bone. Fine-grained wood could also have been used but no wooden patterns have yet been recognised in the archaeological record.

One problem with using existing objects as patterns for mould making is that vital, functional parts such as runners and sprue cups are missing. This difficulty could be got round by adding temporary extensions of clay or wax to the object or by carving the necessary shapes out of the green-hard mould before it was fired. A further problem is that castings were often subsequently worked so an existing object would not have exactly the same shape as the casting from which it was made. For example, the catch plate on Roman brooches was turned over at the edge to give a secure location for the pin.

Patterns have not always been recognised for what they are. An example is the three lead brooches from Poole's Cavern which Mackreth (1983) suggested had been used as brooches, though careful examination of the admittedly deeply corroded objects suggested they could not in fact have been so used (Bayley and Branigan 1989). Lead models are recorded from other Roman sites too (see Table 2.2); interestingly almost all are for brooches. Drescher (1973) illustrates several models of lead and "bronze" for a variety of Roman objects though the latter may just be partly cleaned-up castings - though they could have been used as models.

East (1986) has recorded a lead-tin alloy piece decorated with gripping beasts and thus dated to the 9th century which she suggests was a model for "bronze-casting".

It has been suggested that lead or lead-tin models could have been used as patterns for investment casting, ie 'lost lead' rather than 'lost wax' casting. While this is probably technically possible, there are no known investment moulds for objects for which lead patterns have been found. All the evidence is that piece moulds were normally used for making ordinary objects from the time of the Roman conquest onwards.

One class of object which is relatively common on Irish and Scottish metalworking sites of the later 1st millennium AD are the so called motif pieces made of bone which were used by the craftsmen to work out their designs (O'Meadhra 1987). Comparable objects are rare on English sites but examples are known from both London and York (MacGregor 1985); perhaps less durable organic materials or unfired clay were used in other places.

Metal waste

When molten metal is being poured into moulds of any sort it can accidentally be spilt, either because the mould is overfilled or because it splashes or misses the mould altogether. In all these cases droplets and larger, irregularly-shaped flows of metal result. Some molten metal may also find its way into the fire and become incorporated into the hearth lining and fuel ash slags. Most of this metal would have been collected and recycled but some escaped and is among the commoner finds on archaeological sites where non-ferrous metals were being worked. It is recorded in Appendix A as spillages and appears in Tables 2.1-2.6 under the heading "waste". It should be noted that metal waste of this sort on its own is not good evidence for metalworking as it can form anywhere that metal gets into a fire hot enough to melt it, eg metal objects in a cremation pyre or in a building that burnt down.

A second type of metal waste is that which solidifies in a mould but is not part of the object(s) being cast. It includes the runners and sprues as well as the flashes that form between the valves of a piece mould and is all removed from the casting when it is fettled. A failed casting, where the metal failed to fill the mould completely, is a further type of casting waste. This can result from inadequate temperature control of either the mould or the melt or from poor mould design. A casting with blowholes was also effectively a failed casting though some repairs were often made to large castings such as statues, either by letting in patches or by burning or running together, as Theophilus describes (Ch 61). These types of metal waste are listed in Tables 2.1-2.6 as either "scrap" or "waste". On sites I have recorded they appear under the "waste" heading but where published accounts do not differentiate between this casting waste and other forms of scrap metal they are all recorded as "scrap". (See Chapter 6 for further discussions of scrap metal.)

CHAPTER 6

WROUGHT METALWORKING

Many of the metal objects of antiquity were not cast but were made from one or more pieces of metal that had been hammered and cut to the desired shape. This was basically a two step process; first the cast metal was fabricated into sheet, rod, bar or wire and then these part manufactures were made into objects and decorated. Precious metals were often wrought rather than cast, as less metal was required which made economic sense. Many copper alloy objects were also wrought or had wrought metal added to a casting, for example the spring and pin on a cast Roman brooch. These composites were joined in a number of ways (see Chapter 7).

As noted in Chapters 4 and 5, the raw metal produced by smelting was refined and alloyed and then cast into ingots or blanks which were, in their turn, the raw material for wrought metalworking. Large ingots, the direct products of smelting, are not normally found on sites where metal was wrought. Some large pieces of metal like the massive sheet of well homogenised brass from Colchester: Sheepen (Musty 1975) would however have been suitable raw material for a wrought metalwork industry. Sometimes fragments of ingots of this general type are found complete with traces of the chisel cut which severed them.

Processes

Wrought metalworking is a general term covering a whole range of different processes. These can be considered in three main groups. Metals can be forged using a hammer; sheet metal can be cut to shape and dished and/or decorated and, finally, part manufactured sheet, rod or wire may be cut, bent and joined into composites.

Metal to be forged is placed on an anvil or in open or closed dies and hit with a hammer. Repeated blows are necessary unless using closed dies, such as those for striking coins, where a single blow is normal practice. Swages used to produce beading on wire are another type of closed die.

Sheet metalworking was really a subset of forging until the 16th century when rolling was introduced (Smith 1981). Sheet may be cut to shape, then dished and/or worked by local hammering or punching. The processes are described as sinking (hammering on the concave side on a wood block), raising (hammering on the convex side over a rounded stake or anvil) and embossing (using a punch and a die). Sheet metal may also be spun on a lathe to produce simple shapes. Repoussé work and chasing were used to decorate sheet metal and are considered further in Chapter 8.

Part manufactured metal stock was forged from ingots or blanks. Wire was produced by strip twisting, strip drawing and drawing down rods (Whitfield 1990). The earliest indisputable evidence for this last process is three Viking-period draw plates from Haithabu, Schleswig (Naumann 1971). To convert part manufactures into objects, the metal was cut to size and machined, ie metal was removed using tools. This term, anachronistic perhaps before mechanisation, covers sawing, turning, boring, drilling, reaming, grinding, filing and scraping. Engraving, a decorative technique, also removes metal (see Chapter 8). Lead in copper alloys is beneficial when these operations are performed as the metal comes away in small chips rather than long springy turnings, but it also confers less welcome properties (see Chapter 9).

All these mechanical working processes deform the metal plastically, permanently changing its external shape, and at the same time set up internal stresses which alter its crystal structure. This work hardening reduces the malleability of the metal, making it harder and stronger. This can be a beneficial change but if the metal is to be worked beyond a certain point the internal stresses have to be relieved by annealing, heating to above the metal's recrystallisation temperature (about 400°C for brass and bronze and 200°C for copper and silver). Hot working (above this temperature) is now normal industrial practice for copper alloys (Cairns and Gilbert 1967) and avoids the need for annealing but it is not a suitable process for all metals. There is some evidence it was used in antiquity (Unglik 1991 *contra* Hodges 1964) but works of art are rarely made this way (Smith 1981), perhaps because the surface quality is inferior. The working-annealing cycle can be repeated any number of times. Surface dirt and scale can be removed by quenching the metal after annealing though Drescher (1955) says brass should not be quenched. Tin and lead and their alloys recrystallise at room temperature and so do not have to be annealed but they are normally cast and not wrought.

Once an object had been formed, whether cast or wrought, it was filed and scraped, ground and polished to give an acceptable surface finish. Some of the many whetstones found in the course of archaeological excavations were certainly used in this way but they were necessary domestic tools too and so, in isolation, cannot be considered as evidence for metalworking. Loose abrasives like sand were used as well as lumps of stone. Theophilus (Ch 61) describes cleaning a brass casting with "sand and sticks whose ends are slightly shredded". Finer abrasives were used as polishes on a cushioned pad or wheel. Soft haematite (also known as jewellers' rouge) can be used in this way and faceted nodules have been found on the Coppergate site in York with other evidence for metalworking (Bayley forthcoming). An alternative method of finishing an object was to burnish the surface with a hard tool such as steel or agate (Theophilus Ch 26). This was particularly necessary when a surface coating of another metal had been applied and needed consolidation.

The archaeological evidence

The above description is far more detailed than the corresponding introduction to Chapter 6 as many of the processes of wrought metalworking leave little or no evidence in the archaeological record other than the objects that were produced. A workshop could be set up almost anywhere, tools were portable and only a small fire would be necessary to anneal the metal being worked.

The most commonly found evidence of metalworking is scrap metal, offcuts from machining operations. A number of Roman sites, eg Verulamium (Frere 1972) and St Mary Bishophill Senior in York (Ramm 1976), have produced boxes set into the ground, full of metal filings that were collected for recycling. Larger sheet metal offcuts are more widely found as are both small and larger pieces of part manufactured metal, such things as bars, rods and wires. Some of these may have had faults such as cracks which made them unsuitable for further working but others appear perfectly sound and were probably accidentally lost or mislaid. Some unassembled component parts of composite objects are also found which are further evidence for wrought metalworking. Baldock (Bayley 1986B) produced a part-made domed-headed rivet or stud and also rolled sheet metal rivets, both used and unused.

Tools

The only other finds which are indicators of metalworking are tools; Theophilus provides a detailed description of making and using a wide range (Ch 5-21). Many of these, such as hammers, files, awls, punches and chisels, could have been used in any number of trades so it is difficult to positively associate individual tools with metalworking. However, where a 'tool kit' is found together or tools are found with scrap metal the association is suggestive of the use to which the tools were put. An example is the file of 10th century date from York: Coppergate which had brass filings in its teeth (Bayley forthcoming).

Some tools such as the doming block and ball-headed punches from Poole's Cavern (Bayley and Branigan 1989) are far more specific, and there the association with both part manufactures and casting waste suggests metal working was carried out on site. Other tools which can be specifically associated with metalworking are dies. These were relatively common in early Saxon times when they were probably used by burnishing a metal foil into the die. Surviving examples are all made of copper alloys, but bone or wood could have been used also (Capelle and Vierck 1971). Roman examples are also known, eg from Oulton, though this was probably used as a punch on brass sheet. Coin dies such as those from York would also have been used to punch (strike) their design, in this case onto silver, though trial stamps on lead were also found (Pirie 1986).

Whetstones and abrasives have already been mentioned but a further form in which haematite is found is as a deposit of powder in a pot. This is usually interpreted as pigment, eg for wallpaintings (Davey and Ling 1981), and, while it is indeed a common pigment at all periods, it is possible that some of the single finds may have been polishes rather than paints. As with much of the evidence for wrought metalworking it is the context and associations that provide the only positive identifications.

CHAPTER 7
JOINING

Metal components were joined in a variety of ways. Mechanical joints could allow movement, eg hinges, or could be rigid if held by rivets. Other rigid joints were made by welding, brazing or soldering at elevated temperatures.

Welding and burning together

Welding fuses components but was not commonly used for non-ferrous metals. Gold can be welded once gentle heat has removed absorbed moisture but silver has an oxide film and so can only be hot welded; copper is not easily welded (Tylecote 1987). Although grains of gold were welded into larger pieces in prehistoric times (Eluère and Raub 1991), melting in a crucible seems to have been more commonly used in the periods covered by this study.

Roman lead pipes were made by bending a strip of sheet metal to shape, applying a temporary 'mould' and pouring in molten lead, a process known as autogenous welding (Tylecote 1987) or burning together (Maryon and Plenderleith 1954). Pieces of large bronze statues were assembled in a similar way by pouring in excess molten bronze which heated the castings and gap-filled. Additions to objects could be cast-on in a similar way (Hodges 1964). Burning together was often used to make repairs (Forbes 1964A).

Soldering

Hughes (1988, 80) defines soldering as "... uniting metal components by heating and fusing a metal or alloy filler which melts at a lower temperature than either metal to be joined." Brazing is an identical process but involves higher temperatures. In modern terminology soft soldering is carried out below 300^{o}C, hard or silver soldering in the range 300-800^{o}C and brazing above 800^{o}C (Cairns and Gilbert 1967). In all cases it is essential that the solder wets and flows over the surfaces to be joined so a flux is used to clean the metal and remove any oxide film. The solder can be applied as fragments, filings or in a paste with an organic binder. The components to be joined must be held close together and capillary action helps to draw the solder into the joint. Soft solders provide a weaker joint than hard solders, though in all cases the join is stronger than the strength of the solder because of surface tension effects and because some of the metal being joined dissolves in the solder, changing its composition (Cairns and Gilbert

1967).

A range of alloys with different lead-tin ratios were extensively used as soft solders from Roman times onwards (Hughes 1988). They were used on copper alloys and Theophilus (Ch 89) describes the use of a 2:1 tin-lead alloy (approximately the eutectic) with a resin flux for joining tin. A mid 10th century context on the Coppergate site in York has produced a 4 mm diameter rod of metal of similar composition which appears to have been used as solder as its tip has been melted (Bayley forthcoming).

The *Mappae Clavicula* describes the use of a 2:1 copper-tin alloy as a solder for copper and its alloys which would have a melting point of about 740^{o}C (Smith and Hawthorne 1974). Hard solders of this type do not seem to have been widely used on copper alloy objects though copper alloys were used to coat or join components of iron objects such as keys or barrel padlocks in Late Saxon and medieval times. These copper-rich coatings are sometimes described as brazing metal though there is seldom accurate compositional data which would indicate a melting point.

Most of the work on the solders of antiquity has been confined to those used on precious metals (Lang and Hughes 1984, Hughes 1988). Soft solders were used, but far commoner are a range of hard solders including silver-tin and silver-copper alloys. Tylecote (1987) suggests the latter are rare until the 11th century but Hughes' (1988) paper suggests otherwise. He describes a range of compositions with up to 28% copper which corresponds to the eutectic with a melting point of 779^{o}C. Theophilus (Ch 73) describes the preparation of 2:1 silver-copper and gold-copper solders which were used with an argol/salt flux for joining silver and gold respectively, and the use of copper oxides in a flux for joining gold (Ch 51). Pliny (33,93) describes the preparation of a similar mixture of copper compounds he calls santerna for joining gold.

Various factors such as colour, strength and fusion range may have affected the choice of solder. Where multiple joins were to be made on a single object the first would have been made with a higher melting point solder so subsequent work did not remelt it.

Mercury has been used to repair a Roman silver spoon. The broken edges were amalgamated with mercury, clamped together and the area then heated with a blowpipe causing the mercury to evaporate and a good join to form, though with several percent of mercury remaining (Hughes 1988). This is not strictly soldering, as defined above, but serves a similar purpose.

CHAPTER 8
DECORATION

The decoration applied to non-ferrous metal objects can be divided into three main groups. These are relief decoration of the metal surface, applied metal(s) and added non-metallic materials; they are considered in turn below. Often a single object has more than one type of decoration as can be seen from Appendix C, though relief decoration is not considered there.

The surface of an object may also have been coloured though post-burial corrosion normally obscures this. We do not know if metal objects were highly polished or allowed to develop a natural patina. The very reduced relief seen on some modern, highly polished objects such as brass name plates suggests this was not the way metalwork was treated in antiquity as corresponding rounding of profiles is not widely seen, though this too could be obscured by decay.

Hughes and Rowe (1982) provide examples of the whole range of colouring effects that may be obtained and, while not all the chemicals they employ were available in antiquity, at least some of their effects must have been possible. Some colouring effects require special alloy compositions and the best known of these are Japanese, such metals as *shakudo* which is a copper alloy containing a few percent of gold and can have a range of colours from aubergine to black after patination. Craddock (1982) equates this with Pliny's Corinthian metal which contains both gold and silver (Bk 9, 139) and has identified a Roman plaque as being treated in this way. More recently a ?bracelet from a sub-Roman cemetery at Cannington with an overall black patina has been identified as being a similar alloy; it was a tin-bronze with several percent of gold and low levels of silver (Bayley and McDonnell 1990B).

Relief decoration

Relief decoration can be cast in, but more commonly it is applied or enhanced once the metal has solidified. The decorative effect is achieved either by cutting away metal (engraving) or by moving or deforming it (chasing, repoussé, embossing). Both cast and wrought objects are decorated in this way but some of the techniques available (eg repoussé) are only applicable to thin sheet metal and are therefore only found on wrought work.

Applied metals

This broad group of decorative techniques includes metal platings, inlays, overlays and applied metal producing relief decoration such as filigree and granulation. Often the applied metal differs in composition and hence colour from that of the bulk metal of the object; sometimes it provides an overall cover but sometimes just parts are covered, giving a bichrome or polychrome effect.

Gilding

Gilding has been known since the middle of the 3rd millennium BC. The earliest examples are leaf gilded but by the Roman period an alternative technique known as mercury or fire gilding was also in use.

In leaf gilding the gold was beaten very thin making gold leaf which was then burnished onto a clean silver or base metal surface. The thinness of the leaf can be appreciated from Pliny's description (Bk 33, 61) which says that an ounce of gold would produce at least 750 gold leaves measuring four fingers each way, which Bailey (1929) calculates as an average thickness of 0.34 microns.

Mercury gilding was known from the middle of the 1st millennium BC but its use did not become widespread until the 3rd century AD (Oddy 1980). It must however have been an accepted if uncommon technology in the mid 1st century AD as Pliny notes that it was legal to gild copper using mercury (Bk 33, 64) and goes on to describe the preparation of the surface of the base metal and the application of the mercury and gold leaf (Bk 33, 100). There are two variants of mercury gilding. In the first the surface of the object to be gilded is amalgamated by rubbing with mercury and then the gold leaf is applied while, in the other, a gold-mercury amalgam is produced and then applied to the object. In both cases the object is then heated at about 350^{o}C to drive off the mercury, hence the name fire gilding. Oddy (1980) claims that the first technique, which equates to that described by Pliny, was more difficult, so it may be that mercury gilding did not become common until the use of a gold-mercury amalgam was adopted. It should be noted however that Pliny describes the dissolution of gold in mercury in the context of separating gold from other materials (Bk 33, 99) so the existence of gold-mercury amalgams was known in the 1st century even if their application in gilding was not.

Theophilus clearly used a gold-mercury amalgam (Ch 35-37) but also describes amalgamating the surface of silver before applying gilding to it (Ch 38). He notes that brass is more difficult to gild than unalloyed copper or silver and that it must therefore be more carefully amalgamated and more thickly gilded. He says that brass to be gilded should be pure and free of lead (Ch 62) and identifies gilding brass made from unrefined copper containing lead as a problem, as white [mercury-rich] spots would remain on its surface after heating (Ch 68) due to the greater affinity of mercury for the lead.

Craddock (1988) quotes Oddy *et al* (1979) to show that classical mercury gilded objects were almost invariably made of copper with about 1% of tin if cast, but were pure copper if wrought. Oddy *et al* (1986) analysed a collection of Romanesque metalwork and showed that the gilded cast pieces had more varied compositions. Most were brasses or gunmetals with low lead contents (mean = 1.4%) but the average level of additions was nearly 10% (see Figure 10.6). The gilded wrought metalwork was all pure copper.

All the gilded objects in Appendix C are late Roman or later in date. The majority appear, as expected, to be mercury gilded. For those Roman brooches that were analysed quantitatively, the results are comparable to the Romanesque metalwork in terms of overall level of additions (mean = 9.5%) and lead content (mean = 1.1%) but tin-rich rather than zinc-rich alloys predominate (cf Figure 10.31). If the qualitative analyses are considered too the proportion of brasses is higher, but bronzes are still found more frequently (see Table 8.1). Note that Theophilus' descriptions of mercury gilding refer only to brass, copper and silver while the majority of leaf gilded objects are bronzes.

It should be noted that the presence of mercury in a qualitative XRF analysis was the criteria used in describing objects as mercury gilded despite the comment by Lins and Oddy (1975) that mercury can occasionally be detected in gilding that was not applied using it. On some objects so little gilding survived that gold could not be detected analytically though it was just visible; in these cases it was not possible to say whether the object was or was not mercury gilded.

Table 8.1 - Gilded Roman brooches (data from Table C.3)

Alloy	with mercury	no mercury	? mercury	total
copper	3	-	1	4
bronze	11	7	1	19
gunmetal	2	-	1	3
brass	8	2	4	14
(leaded) gunmetal	-	1	-	1
Total	23	10	8	41

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Wilson (1981) notes that gilding was practised throughout the Saxon period but that silver is less commonly gilded in the 9th and 10th centuries.

Tinning

Tinning is used as a term to describe a very thin surface coating of tin or a tin-rich alloy which appears white or grey in colour. This appearance can be simulated by inverse segregation when casting a bronze (Tylecote 1976) but normally tinning was applied either by fluxing and dipping or by rubbing a hot object with a rod of tin or tin-lead alloy (Tylecote 1986, Oddy 1980). Thouvenin (1970) has suggested that electrochemical deposition of tin would also have been possible. Oddy (1980) considers the use of this technique unlikely as none of the early medieval manuscripts mention it though the necessary materials were well known. Some objects are 'parcel tinned' and this would be easier to execute using a resist and electrochemical plating than with hot metal.

The composition of layers of tinning is variable. Iron and copper alloys were coated with both tin and tin-lead alloys while the tinning on copper alloys is sometimes a tin-copper alloy with a far higher melting point than the 232^{o}C of pure tin. Oddy (1980) has argued that these copper-tin layers formed in situ by the interdiffusion of the two metals during prolonged heating in a reducing atmosphere below the melting point of tin. Tinning of this type is essential when mercury gilding is to be applied to the same object (Oddy 1980).

Tinning is known but uncommon in Iron Age times (Oddy 1980) but is found widely on Roman objects; nearly 10% of the brooches listed in Table C.3 had traces of tinning on them. Pliny (Bk 34, 160f) notes that copper vessels were tinned and states that a number of different alloys of varying value, mainly tin-lead alloys, were used for this purpose. He goes on to comment that "A method has been devised in Gaul for plating copper articles with pale lead [ie tin], so skillfully that they can scarcely be distinguished from silver." (Bailey 1932).

The confusion between tinning and silvering may originally have been a deliberate attempt to counterfeit and certainly Pliny's terminology is not always open to unambiguous translation. Modern archaeological nomenclature has an unfortunate tendency to call all white plating 'silvering' despite analytical results which show the vast majority to be tinning (AM Laboratory, unpublished data). There is confusion too between plated objects and high tin bronzes (speculum metal) that are white/grey all through.

Tinning continued in use in post-Roman times (eg Oddy 1980, Jope 1956) and in the later medieval period it is more common on iron than copper alloys; Theophilus (Ch 92) describes its application by dipping, though the discovery of a tin rod and a tin-lead bar with melted tips in 10th century contexts at York: Coppergate suggests they had been rubbed over heated objects to tin them (Bayley forthcoming).

Silvering

Silvering, meaning a thin surface coating similar in appearance to tinning, appears to be unknown in the Roman period except on coins which are sometimes described as 'silver washed'. The surface of a debased coin could be whitened by heating and pickling to remove copper (Smith 1981) but dipping and wrapping in silver sheet are also recorded (Tylecote 1976) though La Niece (1990) notes some of the problems with these last two methods. Close plating, where a thin sheet of silver was soft-soldered over a base metal object, was also used in Roman times (ibid) but more often the silver cover was only partial (see below).

The earliest known European mercury silvered object is an 8th century forged coin (ibid) but this method of silvering has otherwise been recognised only from the 13th century onwards (eg Wright 1987, 91) but is rare even then (La Niece 1990), though Theophilus (Ch 36) describes the preparation of silver amalgam which comprised five parts by weight of mercury with one part of silver.

Inlays

Inlays are small pieces of metal, often wires or multi-strand wire ropes, hammered into place in a groove engraved or traced in the surface of an object. They are of different colour to the bulk metal and it is this contrast which provides the decorative effect. Inlays are rare though not unknown in copper alloy objects (eg the six Roman brooches of Group 2 and 4 types listed in Table C.3) but are found more often in iron objects where copper, brass and silver were used individually or in combination. Typical inlaid objects are Roman styli, early Saxon buckles and belt plates (Evison 1955) and medieval knives with inlaid makers' marks (Beresford 1975).

Overlays

Overlays are, strictly speaking, where the surface of an object has been roughened and thin sheet metal is then laid on it and hammered, keying into the deliberately created surface irregularities. Salin (1957) describes the application of brass and silver to ironwork by this technique which he calls damascening, a term more commonly applied in Britain to the visible effect of pattern welding ferrous metals. Theophilus (Ch 91) describes both inlaying and overlaying on iron.

Some Roman copper alloy objects have an overlay attached with soft solder rather than mechanically. Most commonly the applied metal is silver, in the form of beaded wire or thin metal foils stamped with a relief design, and the decorated object is a brooch. Thin copper alloy sheets with repoussé decoration were also soldered onto brooches; where enough of this metal survives to be analysed, it is always brass. Overlays are not found on all types of brooches. Table 8.2 shows which typological groups (defined in Chapter 10) carry which types of overlay; those of unknown alloy are most likely to be brass, but in most of these cases only the solder with an impression of the repoussé decoration survived. Note the correlation of silver overlay with brass or gunmetal brooches and brass overlays on other alloys, especially leaded bronzes.

Table 8.2 - Overlays on Roman brooches (data from Table C.3)

	- - - - overlay - - - -				- - - - bulk metal - - - -		
Group	silver	copper alloy	?	Total No	brass or gunmetal	leaded bronze	other
2	1	2	1	4	4		
3		1		1		1	
7	1			) 2	1		
			tin	)		1	
8	24			24	22	2	
9	13			13	12	1	
plate	7			)	3	2	2
		16		) 27	4	7	5
			4	)	1	2	1
?	1			1	1		
Total	47	19	6	72	48	16	8

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The disadvantage of this method of overlay is that the juxtaposition of different metals provides, on burial, an electrochemical environment where the solder preferentially corrodes, often leading to the separation of the overlay from the object. Some of the objects in Table C.3 described as tinned may originally have had overlays which are now lost; this is particularly true of Group 8 and plate brooches of types where some examples have surviving overlays.

Decorative Roman military fittings which are normally made of brass (see Chapter 10) are also relatively often overlaid (close plated) with silver. Examples include studs from Sheepen (Niblett 1985, Fig 61,8) and phalerae from Xanten (Jenkins 1985).

Filigree and granulation

The final sort of applied metal decoration is filigree and granulation which are normally only used on precious metals, the applied metal being of (roughly) the same composition as the base to which it is soldered. There is a considerable literature on the use of these techniques at all periods (eg Wolters 1981) and they are not considered further here. Tylecote (1987) has pointed out that some granulation is applied without any solder and the heat used is below the melting point of the metal so the process is sintering, producing a solid-state weld.

Non-metallic materials

Both niello and enamel are inlaid into metal objects while 'gems' of glass or semi-precious stones are attached in a number of ways.

Niello

Niello has a black, slightly lustrous appearance and, in the period of this study, consisted mainly of copper and silver sulphides, used either separately or together. La Niece (1983) has published the results of a wide-ranging study of its composition and use and the comments below draw freely on her paper.

The earliest, positively identified niello is found on 1st century AD objects. The Romans used it to decorate tableware, jewellery and military fittings. Silver sulphide niello was used on silver and gold objects while copper alloy objects have copper sulphide niello, though there are exceptions. La Niece found that brass is the copper alloy that most frequently bears niello decoration and the same is true for the objects analysed here, where five of the eight brooches and two of the three other objects with niello decoration are brass (see Appendix C). On four of these brooches it is combined with tinning so perhaps in these cases the tinned copper alloy should be seen as mock silver, as silver is certainly the metal that is most often decorated with niello.

The single sulphide niellos used by the Romans decompose at temperatures below their melting points (861^{o}C for AgS and 1121^{o}C for Cu_2S) and so had to be softened and burnished into place at about 600^{o}C rather than being melted with a flux. From the 5th century, although silver sulphide was still used (though not copper sulphide), mixed silver-copper sulphides became the normal type of niello, and as this melts at about 680^{o}C it could be applied as a powder and then fused.

From the 10th century niello becomes far less common though Theophilus provides a good description of its manufacture and application (Ch 28-9 and 32). His recipe is however for a silver-copper-lead sulphide which was regularly used in later medieval times though the earliest surviving western European objects known to have this sort of niello are 13th century in date. The earlier surviving documentary references to niello are discussed by Oddy *et al* (1983) and illustrate the range of compositions found by La Niece (1983).

Enamel

Enamel was used to decorate copper alloy objects from the Iron Age onwards; two main techniques were used. The first was champlevé, where sunken fields to hold the enamel were cut or cast into the object to be decorated. The reserved metal between the fields was an integral part of the design and was sometimes decorated with tinning and/or applied silver wire or foils. The other technique was cloisonné where thin metal strips were bent to shape and soldered on edge to a backing piece of metal to form the fields. Cloisonné enamelwork only appeared in England in Saxon times and is used for high quality metalwork, usually of precious metals; examples are things such as the Alfred jewel (Backhouse *et al* 1984, Plate I) or plaques for reliquaries (Sherlock and Woods 1988, Fig 63,1). Most enamels, even at this period, are champlevé.

The enamel itself is a glass, often opaque but sometimes translucent, which was fused in situ so it adhered to the underlying metal. Bateson and Hedges (1975) suggest that lead, which is found almost universally in ancient enamels, was added to help them 'wet' the metal more effectively. Not all metals are equally easy to enamel; for instance Vargin (1967) states that brasses with over 10-13% zinc are hard to enamel. Despite this, high zinc brasses were enamelled - 24 enamelled brooches (of 180 with quantitative metal analyses) have zinc contents in excess of 13%. Table 8.3 summarises the alloy data for all the enamelled Roman objects in Appendix C and shows that every alloy was used, though leaded bronzes made up nearly half the total numbers. This is in contrast to Romanesque champlevé enamels which are fairly pure copper (Oddy *et al* 1986), though their composition may owe more to the fact that they are all gilded.

Champlevé enamel was applied in a number of ways. Each field could be filled with a single colour; juxtaposed blocks of enamel (often of two alternating colours) could be used; or blocks of millefiore could be used on their own, alternating with plain colours, or set into a field of a single colour of enamel. Some plain enamel fields also had spheres or cylinders of glass set in them to give the effect of spots, sometimes of one colour cased in a second one. Butcher (1977) describes and illustrates a range of typical Roman enamelwork, though with a bias towards larger and more unusual objects. The range of enamel colours used was quite large, but some weather so badly that the apparent colour can be misleading (Bayley 1987E). This can bias the recorded frequencies of different colours.

Over half the Group 7, 10 and plate brooches are enamelled as are a lower proportion of Groups 3, 8 and 9 (see Chapter 10 for brooch typology). Only occasional examples from other Groups carry enamel.

Table 8.3 - Enamelled Roman objects (data from Tables C.3-C.4)

Alloy	brooches	others	total	% total
bronze	80	3	83	14
leaded bronze	188	19	207	36
leaded gunmetal	47	6	53	9
gunmetal	51		51	9
brass	160		160	27
copper	6		6	1
other	20	2	22	4
Total	552	30	582	

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Applied 'stones'

Some jewellery was decorated with 'gems' made of either glass or semi-precious stones. Precious stones were occasionally used, but normally only on objects of precious metals.

A few Roman brooches of Groups 2 and 7 had glass beads (usually opaque red) riveted on to give a similar effect to an annular field of enamel (eg Bushe-Fox 1949, Plate 28, 34). More frequent were plano-convex glass 'gems', held in place by sheet metal soldered to a plate brooch (eg Niblett 1985, Fig 76, 41-2) or the conical glass 'gems' found on T270 and T271 plate brooches. Roman finger rings have inset 'gems' of glass or stone, either *en cabochon* or cut as cameos or intaglios. Banded stones such as onyx were popular for cut gems and the visual effect was often mimicked by black glass with a surface layer of opaque white through which the design was cut.

Garnets cut to flat, geometric shapes were used to decorate early Saxon jewellery such as saucer brooches where they were set in cloisons backed by cross-hatched gold foils (Avent 1975). Sometimes pieces of glass or white materials such as shell, bone or minerals were set in similar ways (La Niece 1988).

CHAPTER 9

METALS AND THEIR ALLOYS

In the period and area covered by this thesis, gold, silver, copper, lead, tin, mercury and iron were known as metals and objects were made of gold, silver, copper and its alloys with tin, zinc and/or lead, and lead and tin, both separately and together. Iron was also widely used but its working is not considered here. The uses made of these various metals and their alloys at different times are discussed in Chapter 10.

Nomenclature

The first points that need settling relate to the nomenclature to be adopted for the metals under discussion and the correlation of modern terminology with that used at various times in the past. The names are not important in themselves but provide a convenient shorthand when discussing alloys of different compositions. The use of alloy names is more than a convenience when dealing with qualitative analyses as they cannot, by definition, provide a specific composition but only an indication of a more general alloy type. Some modern alloys, even those containing only the elements known in antiquity, were not used then for one reason or another; other alloys, once commonly employed, have fallen out of use more recently so in some cases direct equivalents are hard to find. The conventions adopted here are as follows:

Gold: A metal looking like gold and in which gold is a major element. Natural contaminants and/or artificial additions may also be present at various levels. The colour depends on composition but in antiquity is normally yellow.

Silver: A white metal in which silver is a major component. It is often seriously debased with large quantities of copper or copper alloy and in a corroded state may look green, like a copper alloy.

Copper: Fairly pure copper with at most a percent or two of additions. The major contaminant in ingot copper is often copper oxide (Tylecote 1986A).

Bronze: A copper-tin alloy which may contain small amounts of other elements (often zinc and/or lead).

Speculum metal: A bronze which appears grey or white in colour and normally contains over 20% tin. In modern terminology many of these alloys would be described as bell metal as modern speculum metal has over 30% tin.

Leaded bronze: Bronze containing more than several percent of lead.

Brass: Copper alloyed with zinc. As zinc metal was virtually unknown in

Europe in medieval and earlier times, brass was made by the cementation process (see Chapter 4) and so has a maximum zinc content of around 30%, far lower than much modern brass. In modern terminology many ancient brasses are gilding metals. Much ancient brass contained minor amounts of tin and/or lead.

Leaded brass: Brass containing more than a few percent of lead.

Gunmetal: Copper alloyed with significant amounts of both tin and zinc. In modern terminology gunmetal usually has a more specific meaning, that of bronze with a few percent of zinc.

Leaded gunmetal: Gunmetal containing more than a few percent of lead.

Lead: Ancient lead is normally over 99% pure (eg Tylecote 1962A).

Tin: Elemental tin with no deliberate additions; often well over 95% pure (Hughes 1980).

Pewter: Lead-tin alloys with at most a few percent of other elements; the proportions of the two metals vary widely (see Chapter 10). Alloys from within this range of compositions were used as soft solders and to tin copper alloy and iron objects; in these cases the metal is usually described as solder rather than pewter. Modern pewter contains little or no lead and is often hardened by the addition of copper and/or antimony (Cox 1987); such alloys were not used in antiquity.

Alloy composition

With copper alloys there are often problems in deciding which name to apply to a metal of a particular composition. The name should indicate the deliberate additions and thus reflect the intention of the craftsman producing it. The major alloying elements are tin, zinc and lead and these are found in almost all proportions. Metal composition is thus a three dimensional continuum which can be shown graphically on a ternary diagram where the three corners represent the three alloying elements. The variables are the amounts of zinc, tin and lead expressed as a proportion of the total additions in the copper (ie, zinc+tin+lead) so the nearer a point in the diagram is to a corner, the higher the relative amount of that element in the alloy. Results plotting together on the diagram thus indicate similar compositions for the objects analysed, provided their copper content is roughly the same. Bayley and Butcher (1981) pioneered the use of diagrams of this type in discussing the alloy composition of Roman brooches. Figure 9.1 shows the relative positions of the different alloys on the ternary diagram but also the lack of any actual dividing lines between them. Thus in assigning alloy names to metals of intermediate compositions arbitrary criteria have to

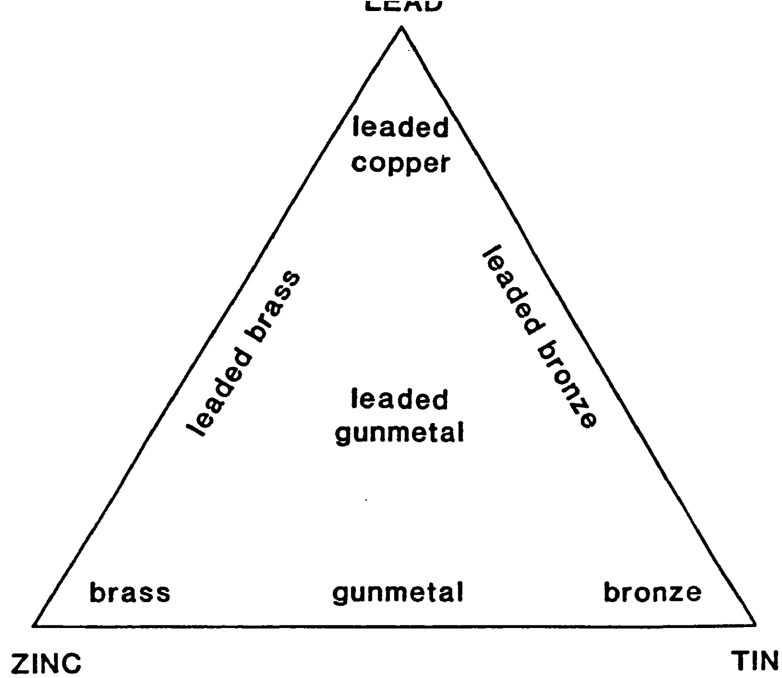

Figure 9.1 - Ternary diagram showing the relationships between composition and alloy name

be adopted. Consideration of the alloy properties (see below) does not help, as there is a gradual rather than step-wise change with composition for each property.

In an attempt to make these arbitrary divisions in a rational way, the whole range of compositions was examined and the lines then drawn in such a way that any clusters present were not split. This exercise was carried out using the quantitative analyses of Roman brooches from Richborough (343 analyses in Table C.3). These objects span a period of over 300 years and represent all the commonly occurring Roman copper alloys. The three histograms (Figures 9.2-9.4) show the range and frequency for each element and Figure 9.5 shows the relation between zinc and tin content.

The lead histogram is interpreted as three superimposed distributions. The first group (with lead under 4%) corresponds to 'unleaded' alloys where the lead present is an accidental contaminant rather than a deliberate addition. At the high lead end the 'leaded' alloys are those with large, and presumably deliberate, additions of lead (over 8%). Between are the '(leaded)' alloys which contain enough of the metal to affect their properties to some extent. Most of these are mixed alloys with significant amounts of both tin and zinc and probably represent poorly sorted recycled metal. See the section on properties of alloys (below) for further discussion of the levels at which additions of lead become significant. In some cases 'leaded' and '(leaded)' alloys are

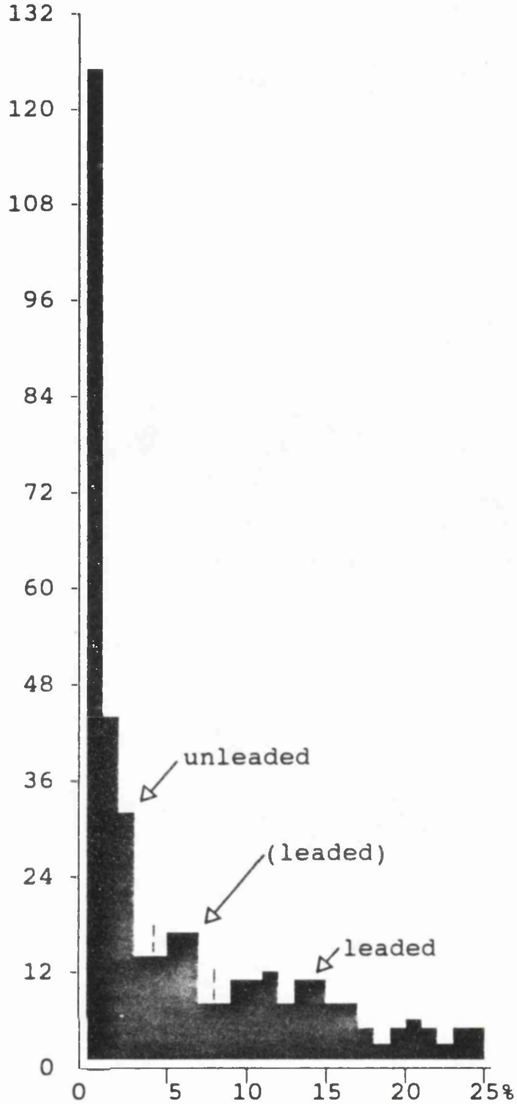

Figure 9.2 - Lead content

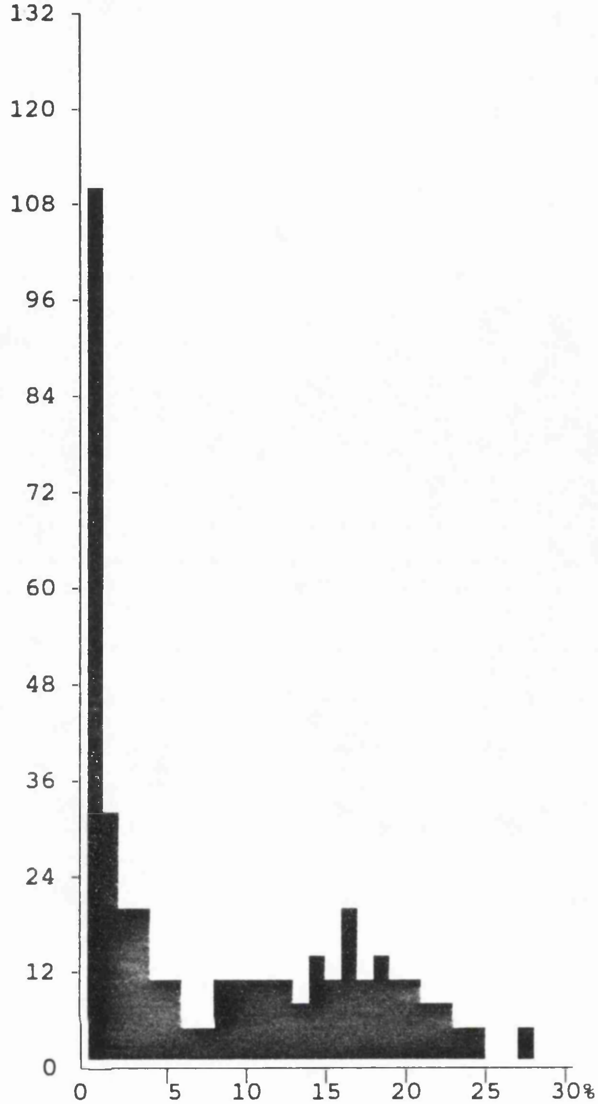

Figure 9.3 - Zinc content

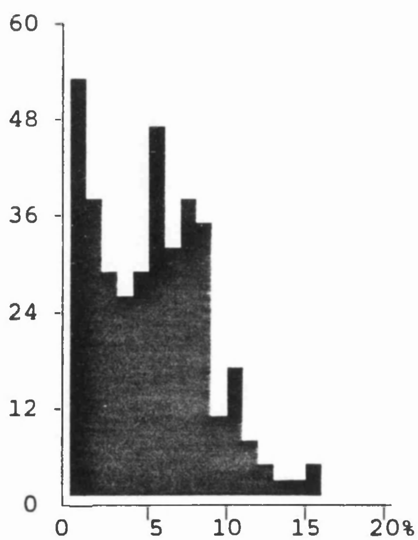

Figure 9.4 - Tin content

Figures 9.2-9.4 - Histograms of lead, zinc and tin contents for 343 Roman brooches from Richborough

considered together; when discussion mentions only leaded and unleaded alloys it is this usage which is meant.

The zinc and tin histograms (Figures 9.3 and 9.4) cannot be considered in isolation as there is an inverse relationship between the two elements; high tin goes with low zinc levels and vice versa (Figure 9.5). The two ends of this distribution are clearly brasses and bronzes while between lie the gunmetals.

The discontinuities on the zinc and tin histograms reflect the boundaries to the clusters on Figure 9.5. The low zinc (zinc under 6%) points are mainly bronzes, with over half of them having under 1% zinc. The high zinc (zinc over 14%) ones are, with two exceptions, brasses and the middle section mainly mixed alloys. Similarly the low tin (tin under 3%) points are mainly brasses (and include a fair number with under 14% zinc) while the high tin ones (tin over 7%) are almost all bronzes. The middle group are a mixture of bronzes and gunmetals. The boundary values for zinc are twice those for tin, as twice as much zinc as tin is required to produce the same changes in the micro-structure, and hence the working properties of a copper alloy. For this reason Figure 9.5 is not symmetrical about the line Zn=Sn. Although the values taken from Figures 9.3 and 9.4 provide reasonable discrimination between the different alloys present, there are some unresolved problems as the middle zone in each histogram represents a mixture of different alloys. For this reason an alternative way of dividing up the brass-gunmetal-bronze continuum was devised.

The divisions were made along lines with fixed zinc to tin ratios rather than at fixed zinc or tin percentages (Figure 9.6). The values of the ratios were arbitrarily chosen, being those which fell at the boundaries of the clusters of points. The brass and bronze clusters are defined by $Zn \geq 4Sn$ and $Sn \geq 3Zn$ respectively. Brasses now include some objects with under 14% zinc and bronzes include objects with 3-7% tin but low zinc; a better discrimination is achieved than by fixing the boundaries at Zn=14% and Sn=7%. The area between the two new boundaries covers a wide range of compositions and the analyses within it tend to cluster towards one side or the other with relatively few in the middle. This has led to a further subdivision with lines at $2Zn=5Sn$ and $3Zn=2Sn$ separating brass/gunmetals from gunmetals and bronze/gunmetals. These subdivisions indicate whether a mixed alloy is zinc-rich or tin-rich while still separating it from the purer brasses or bronzes.

The lines drawn on Figure 9.6 represent the boundaries which are used in this thesis in assigning alloy names to quantitative analyses. The alloy names applied to all the quantitative analyses in

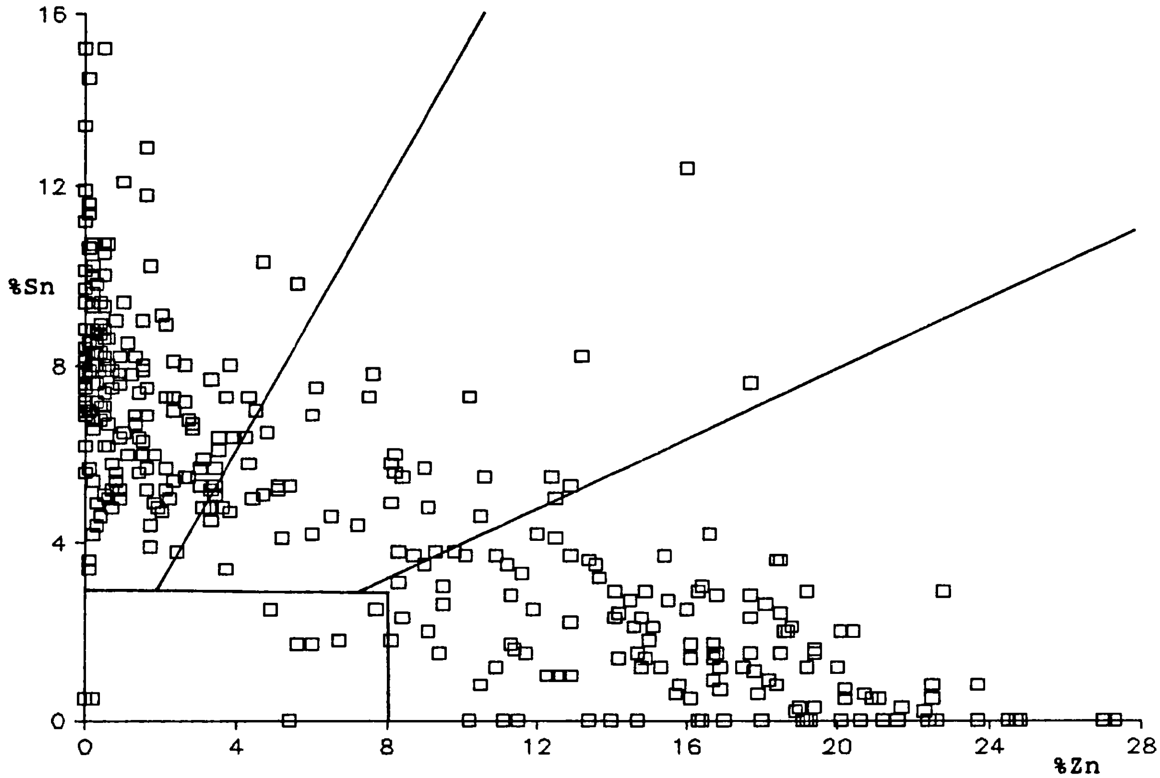

Figure 9.5 - Tin v. zinc content for 343 Roman brooches from Richborough with some boundaries from Figure 9.6 superimposed

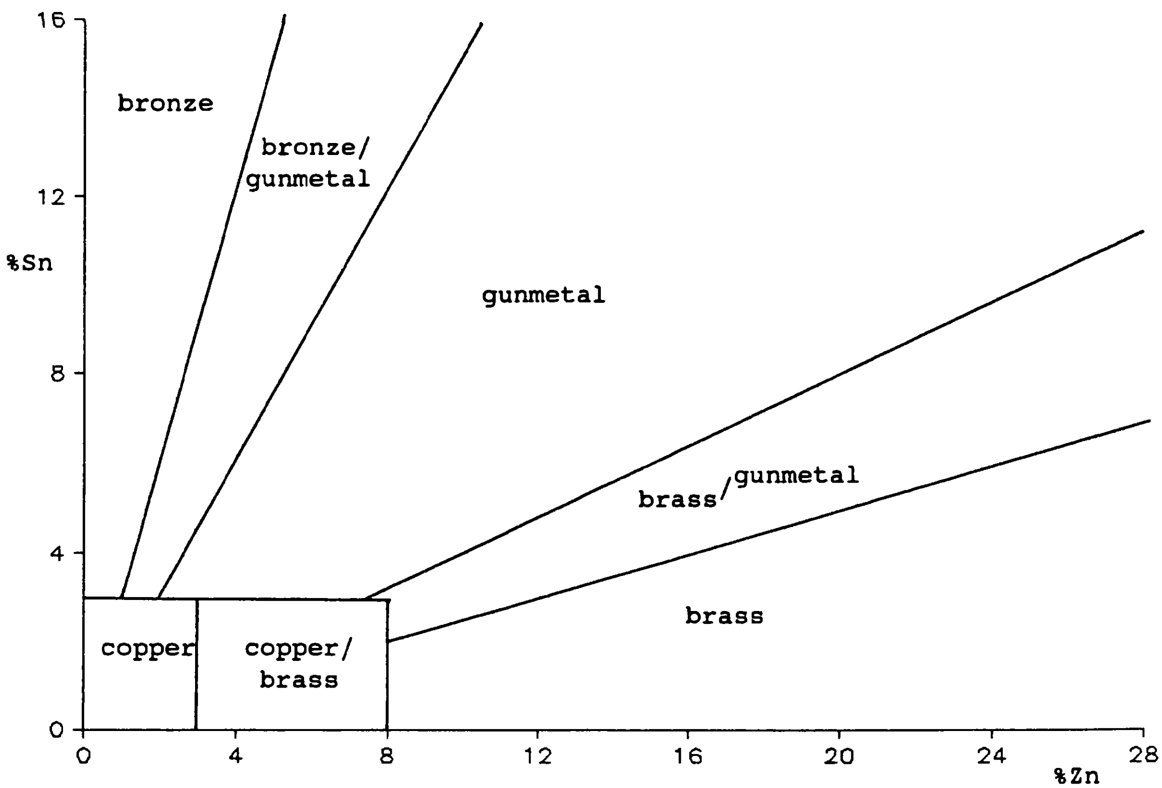

Figure 9.6 - Tin v. zinc content showing the boundaries as defined in Table 9.1 for each alloy name

Appendix C are as defined in Table 9.1. While the absolute positions of the boundaries are arbitrary, and hence debatable, they do produce useful and usable categories. If the dividing lines were moved, the number of objects that would be re-categorised is relatively small and hence of only minor importance when compared with overall trends.

Table 9.1 - Alloy composition: boundaries used in assigning alloy names

brass	Zn≥4Sn	Zn≥8%
brass/gunmetal	2.5 Sn≤Zn≤4Sn	Zn≥8% or Sn≥3%
gunmetal	0.67Sn≤Zn≤2.5Sn	Sn≥3%
bronze/gunmetal	0.33Sn<Zn<0.67Sn	Sn≥3%
bronze	Sn≥3Zn	Sn≥3%
copper		Zn<3% and Sn<3%
copper/brass		3%≤Zn<8% and Sn<3%
leaded alloys		Pb>8%
(leaded) alloys		8%≥Pb≥4%

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An added advantage of using Zn:Sn ratios as delimiters is that objects plotting together on the ternary diagram will have the same alloy name, as both procedures cluster objects with the same relative rather than absolute composition. Figure 9.7 shows a ternary diagram like Figure 9.1 with boundaries defined in Table 9.1 superimposed.

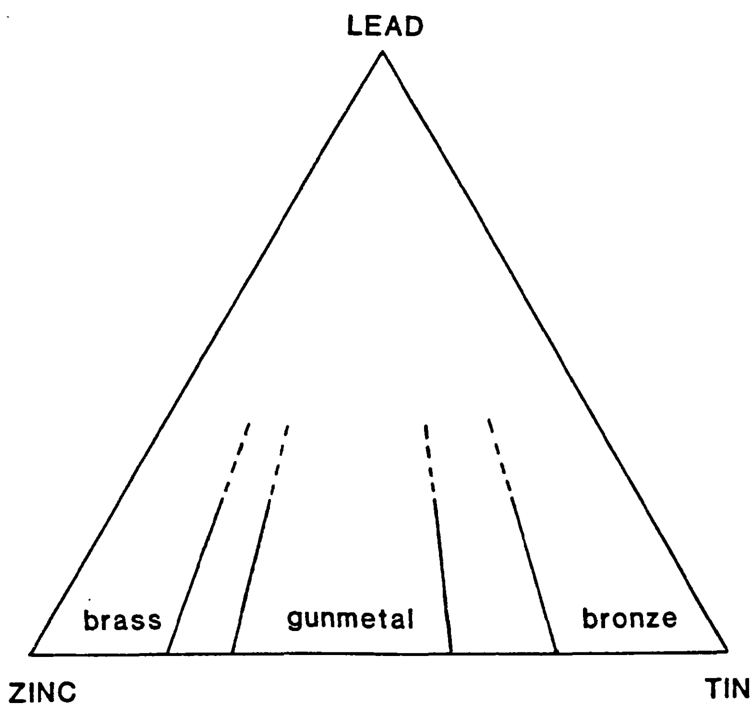

Figure 9.7 - Ternary diagram with the brass-gunmetal-bronze boundaries defined in Table 9.1 superimposed

Ancient names and recipes for alloys

An alternative nomenclature to that outlined above is to use the terminology of antiquity to describe the different copper alloys. There are, however, two main difficulties in this. The first is that different names were used in different periods, reflecting the languages of the time, and the other is the problem of specifically associating the names in use with particular compositions. The anachronism of using Roman terminology to describe medieval metals and vice versa is as great as that of using modern terminology. The second objection to ancient names is, however, a more serious one. In the past alloy names were not used consistently, and often a single name covered a range of compositions while, conversely, a single alloy could have a number of names, often depending on the use to which it was put or the place it was made.

In Latin literature *aes* was used as a generic term for copper and all copper-based alloys but it also specifically meant bronze (the alloy of copper and tin). Bailey (1932) suggests *aes* also included brass though the specific Latin term for brass was *aurichalcum.* Craddock (1988) discusses Pliny's terminology and recipes for copper alloys and suggests that, as Pliny is writing mainly about art history and only incidentally about metallurgy, the following translations are a context sensitive interpretation of the text and incidentally produce compositions that are known from chemical analysis of Roman metalwork:

aes: bronze (copper with about 7% tin, used for castings)
plumbum argentarium: lead (from the silver mines)
plumbum nigrum: 'black lead' = lead
plumbum album: 'white lead' = tin
argentarium: 50:50 tin-lead alloy

When these translations are applied to Pliny's recipes (Bk 34, 95-98) the following compositions emerge which Craddock equates with the range of compositions found in Roman statuary (1988, Fig 4):

1) Campanian, used for utensils and vessels, bronze with 10% added lead.
2) A similar alloy of bronze with 8% added lead.
3) Two-thirds new bronze and one-third scrap with one-eighth added lead which is used for tablets and statues.
4) A casting alloy of bronze with 10% lead and 5% *argentarium*, ie 12.5% lead and 2.5% tin.
5) 'Pot' bronze with 3-4% added lead.

Craddock's context sensitive translations could be thought of as a licence to read sense into an otherwise muddled text, but it is not unexpected that single words should have multiple meanings as the authors of these classical texts were not technicians and could thus only write what they were told, as has been mentioned in Chapter 2, above.

An example of an alternative translation being more appropriate occurs in Pliny's previous paragraph (Bk 33, 94) where he mentions *aes* from Cyprus and describes the metal as ductile and malleable, unlike *caldarium* which is brittle until it has been purified in the fire. This is more likely to refer to copper rather than bronze as oxidation was a standard method of refining (see Chapter 4).

Pliny also describes the use of *stagnum* and tin-lead alloys of various proportions for plating copper alloy vessels and other objects (Bk 34, 160-2). He says *tertiarium* was a 2:1 lead-tin alloy that was used to solder lead pipes; modern plumbers' solder used for the same purpose has the same composition. Lang and Hughes (1984) discuss possible interpretations of the term *stagnum* in the context of Roman soldering technology but cannot find a single translation that fits with the range of compositions they determined from analysis of antiquities; perhaps this is another example of a term with a generic meaning rather than a single specific one.

Both silver and gold were recognised as precious metals in antiquity. Pliny (Bk 33, 80) notes that all gold contains some silver but if the proportion is as high as one fifth the metal is called electrum. He says this alloy was also made deliberately by adding silver to gold.

In the medieval period Latin was still the main written language and so was used by Theophilus. He uses the terms *aes* and *aurichalcum* but it is clear that both refer to copper-zinc alloys, though the latter was purer than the former (Ch 66-7). In other places *aes* has other meanings so Hawthorne and Smith (1979) provide context sensitive translations. Agricola chose to write in Latin in the 16th century though he had to invent words for many of the technical terms he used (Hoover and Hoover 1950). However, an increasing number of English terms appear in later medieval documents (Blair *et al* 1986).

The words 'brass' and 'maslin' have Anglo-Saxon origins but 'latten' first occurs in the early 14th century (Blair and Blair 1991) and 'bronze' not until the 17th century (Blair *et al* 1986), when Dr Johnson defines it in his famous dictionary as brass! In late medieval usage 'brasse' could mean any copper alloy or, very rarely, copper alone with, if anything, a bias towards bronze (Blair *et al* 1986). Cameron (1974) mentions the mid 15th century instructions for the tomb of Richard Beauchamp, Earl of Warwick, which specify "the finest latten" should be used. By chance this monumental brass survives and has been analysed and shown to contain 8.2% zinc, 3.6% tin and 1.2% lead. On this basis Brownsword (1987) has suggested that the alloy known as 'latten' in medieval times was always of this or a similar composition. While neither the composition nor the medieval specification of this particular monument can be questioned, it is dangerous to build a whole nomenclature round a single example. However it does appear that maslin and latten were used to describe zinc-rich alloys and seem to represent similar compositions. They correspond roughly to impure brasses and zinc-rich gunmetals in the terminology adopted here and some contain enough lead to be classed as (leaded). Both terms may be used in the same document which suggests they were not exactly equivalent (Blair and Blair 1991); it may have been usage or source rather than composition that were being differentiated.

Properties of alloys

Modern metallurgy describes and explains the properties of metals and alloys in terms of their crystal structures and how these react to applied forces. It provides objective numerical measures of physical properties which can be used to gauge the suitability of different alloys for particular uses.

Some of these physical properties are tabulated for a range of modern copper alloys (Tables 9.2-9.5). Tensile strength and hardness are self explanatory; elongation is a measure of the ductility of the metal. The data are taken from Smithells (1955) and Miller (1941). The values given in the Tables for worked alloys refer to the most fully work-hardened conditions which can usually be achieved in modern commercial production. These figures are less extreme for rods and similar sections than for strip or sheet (the figures quoted) as they cannot be worked to such extremes. Where only one figure (rather than an annealed/worked pair) is given it is for the metal in an as-cast state.

Pure copper is not a very suitable metal for most applications as it is soft and has low tensile strength. However, it is ductile and hardens only slowly as it is worked and hence has a high working capacity and elongation. Trace levels of impurities (eg copper oxide, lead or antimony) severely affect its working properties. One element that is often found in ancient copper alloys is lead and this produces hot shortness and also affects the cold working properties of the metal.

Alloying other metals with copper greatly improves its mechanical properties, but these depend not only on the chemical composition of the metal but also on its previous treatment. For wrought alloys the degree of working, the temperature at which this was carried out and any subsequent annealing are important, while for cast alloys the temperature at which the metal was poured and the size and type of the mould all affect its properties. Cold working is the sole method of hardening and strengthening the copper-base alloys used in antiquity.

Within the range of compositions found in archaeological material, only a single phase is present in pure brasses as all European brass up to the 17th century was made by the cementation process which could produce a maximum zinc content of only just over 30% (Craddock 1978). These so called α brasses are solid solutions of copper and zinc (see Figure 9.8) so their properties tend to change only gradually with composition (see Table 9.2).

Table 9.2 - Physical properties of modern commercial brass strip and sheet

% Zinc	m.p. or liquidus (°C)	Tensile strength (tons/sq in)		Elongation (%)		Hardness (HV5)	
		annealed	worked	annealed	worked	annealed	worked
0	1083	14	24	55	4	50	110
3		15	28	50	4	55	130
5	1066	16	30	50	4	60	140
10	1044	18	33	55	4	60	150
15	1021	19	36	60	4	65	160
20	1000	20	40	65	5	65	170
30	954	21	45	70	5	65	185

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Bronzes of the compositions used in antiquity are often multi-phase systems as the wide temperature range over which solidification takes place promotes segregation (see Figure 9.9). Their properties change more rapidly than those of brasses but there are no sharp discontinuities. The sudden changes apparent in Table 9.3 reflect the differences between as-cast, wrought and annealed metal. Because the high-tin phases are hard and brittle, bronzes with over 8% tin have to be annealed at about 700°C for long enough to homogenise them before they can be cold worked (Kempster 1975).

Lead is almost completely insoluble in all copper alloys and so is always present as a separate phase, usually in the form of discrete droplets at the grain boundaries or as thin inter-granular films. It has relatively little effect on the strength of the metal, but because of its distribution it has a profound effect on its other properties (cf Tables 9.3 and 9.4). There seems to be no consensus as to the levels of lead that can be tolerated in alloys that are to be worked. Up to 2% of lead improves the machining qualities of the alloy but above this level it

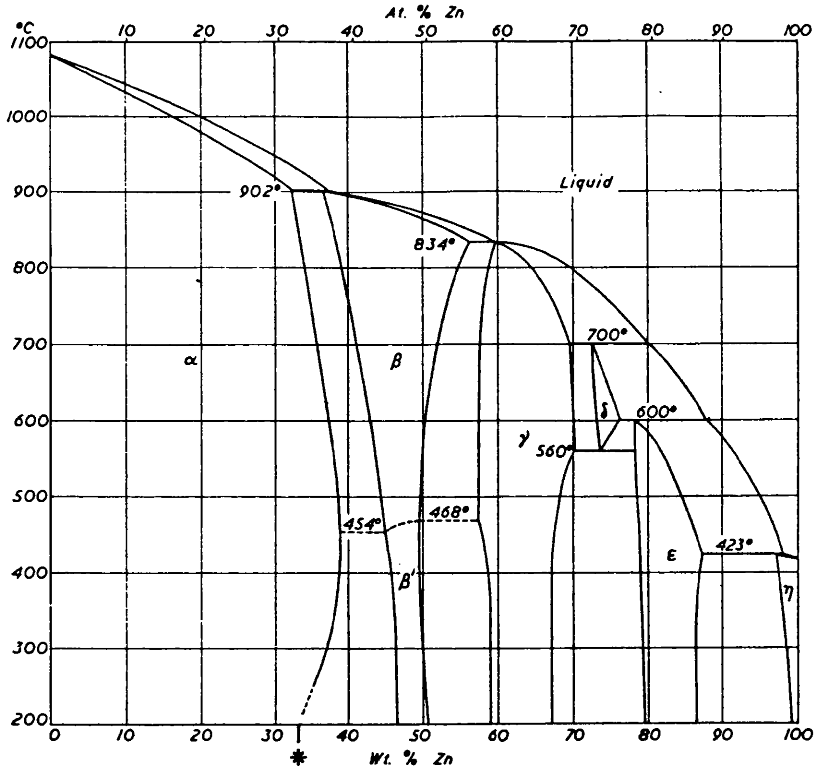

Figure 9.8 - Copper-zinc phase diagram (Smithells 1955)

* = maximum zinc content of cementation brass

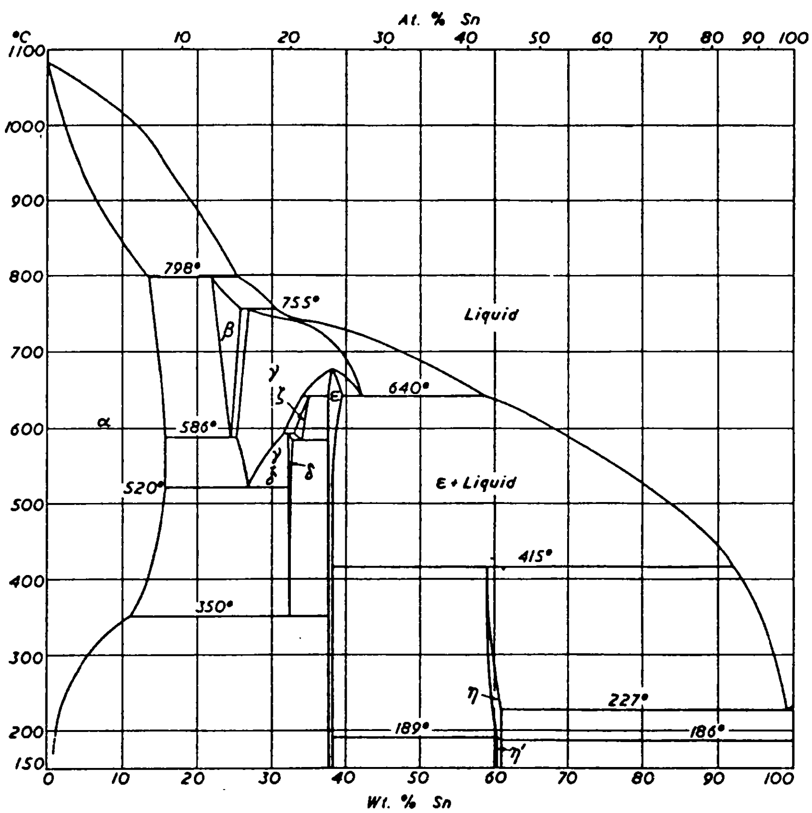

Figure 9.9 - Copper-tin phase diagram (Smithells 1955)

Table 9.3 - Physical properties of modern commercial bronzes

% Tin	m.p. or liquidus (°C)	Tensile strength (tons/sq in) annealed	Tensile strength (tons/sq in) worked	Elongation (%) annealed	Elongation (%) worked	Hardness (HV5) annealed	Hardness (HV5) worked
0	1083	14	24	55	4	50	110
3	1065						
3.75		22	48	65	5	60	210
5	1050						
5.25		23	52	65	5	65	230
6.75		24	55	65	5	65	260
7.5	1033						
10 *		15-20		10-20		70-90	
12 *		11-19		4-15		80-100	
14 *		12-16		1-3		100-120	
18 *		10-12		1-3			

Note - Almost all the above figures are for alloys containing 0.1% or more of phosphorus which acts as a deoxidant, giving a more fluid melt and castings free from pinholes and also improves tensile strength when compared to phosphorus-free bronze (which was the alloy of antiquity).

* These figures are for sand cast alloys

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Table 9.4 - Physical properties of modern leaded bronzes

% Tin	% Zinc	% Lead	Tensile strength (tons/sq in)	Elongation (%)	Hardness (HV5)
10	0	5	12-15	5-15	70
10	0	10	11-13	4-10	65
9	0	15	10-12	4-10	60
7	0	20	9-11	2-15	55
5	0	25	8-10	2-15	50
<2	0	20	*c.*9		45

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reduces both strength and ductility. Parkins (1968) notes that attempts to deform leaded alloys produces inter-granular fracture while Law (1919, 111) says that "copper or bronze containing ... [lead] cannot be worked to any appreciable extent". Bailey (1932, 161) however quotes Gowland as saying that "the tenacity of bronze is not seriously diminished by the presence of 5% lead". More recent experiments by Staniaszek and Northover (1983) have shown that alloys with even higher lead contents can be rolled, but the stresses imposed by forging are rather different so their conclusions should be treated with caution in considering what alloys could satisfactorily be wrought in antiquity. Certainly most wrought Roman brooches contain less than a few percent of lead (cf Chapter 10, eg Group 1 and earlier brooches).

Gunmetals are mixed alloys and therefore have some of the properties of both brasses and bronzes. Unless they have very low tin contents they will normally have more than one phase present unless they are well annealed. Zinc-rich leaded gunmetals are "good casting alloys capable of reproducing fine detail and largely used for ornamental purposes" (Miller 1941).

Table 9.5 - Physical properties of modern gunmetals and leaded gunmetals

% Tin	% Zinc	% Lead	Tensile strength (tons/sq in) annealed	worked	Elongation (%) annealed	worked	Hardness (HV5) annealed	worked
*3.5	13	0	25	40	70	8	70	175
*10	2	0	25	45	65	18	70	180
10	2	0	18-22		20		70-100	
8	4	0	17-21		20		70-100	
9	3	1	16-20		15		70-100	
7	3	3	15-18		15		60-70	
7	1	1	12-18		2-15		80-120	
5	5	5	12-16		15		60-70	
5	5	5	13-16		15-35		60-70	
4	7	6	13-17		15-27		55-65	
3	9	7	13-18		15-30		55-65	
3	15	6	13-18		20-35		55-65	
1	25	3	13-18		25-40		45-60	

* These are wrought alloys; the rest are cast

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Mixed alloys are preferable to binary alloys for some applications. For instance up to 2% of zinc in bronzes acts as a deoxidant and makes the molten metal more fluid and so gives castings free from pinholes (which are formed by the release of dissolved gases during solidification); many of the bronzes in Figure 9.5 have zinc present at these low levels. Above 2% though, the colour of the bronze is altered and the alloy will be harder but weaker (Law 1919). The addition of lead also produces a very fluid melt and, in moderate amounts, it can even be beneficial when machining castings as the metal is 'free cutting', producing small chips rather than long turnings. Figure 9.2 shows that many Roman copper alloys, even those described as unleaded, contain enough lead to affect their working properties.

The data in Tables 9.2-9.5 all refers to the properties of the solid metal but all copper alloys were initially molten and were cast, either direct into objects or into ingots or blanks which were then wrought, and their castability varies too. Pure copper can only be cast in an open mould as closed moulds produce very porous castings. Bronze is less viscous than copper and hence better to cast (Forbes 1954). Adding up to 2% lead to melts reduces viscosity further, but more lead than this just reduces the melting point (Craddock 1988). As lead is subject to gravity segregation the melt must be well stirred to avoid grossly inhomogeneous castings.

CHAPTER 10

METAL USAGE AND ALLOY SELECTION

Table 10.1 summarises the data on metals being worked, presented in Tables 2.1-2.6, and shows that a range of metals and alloys were being used to make objects. Conversely, if objects made of a particular alloy are found, it was clearly being worked. If there is no evidence of manufacture nearby, it is reasonable to suppose that the objects were imported from places or areas where there is manufacturing evidence. Because alloys have greatly improved qualities, pure metals were not widely used (see Chapter 9). The use of these alloys is not constant through time as new ones were introduced and old ones became less common or went out of use.

Table 10.1 - Summary of metals worked (data from Tables 2.1-2.6)

	Iron Age	Roman	Early Saxon	Middle Saxon	Late Saxon	Early Medieval	Total
No of sites	75	241	21	13	64	46	460
Metal:							
copper alloy	39	141	6	8	32	28	254
silver	12	47	-	5	31	12	107
gold	8	17	3	2	11	3	44
lead	1	56	-	2	8	6	73
tin	5	9	-	1	2	-	17
pewter	-	29	-	1	2	-	32

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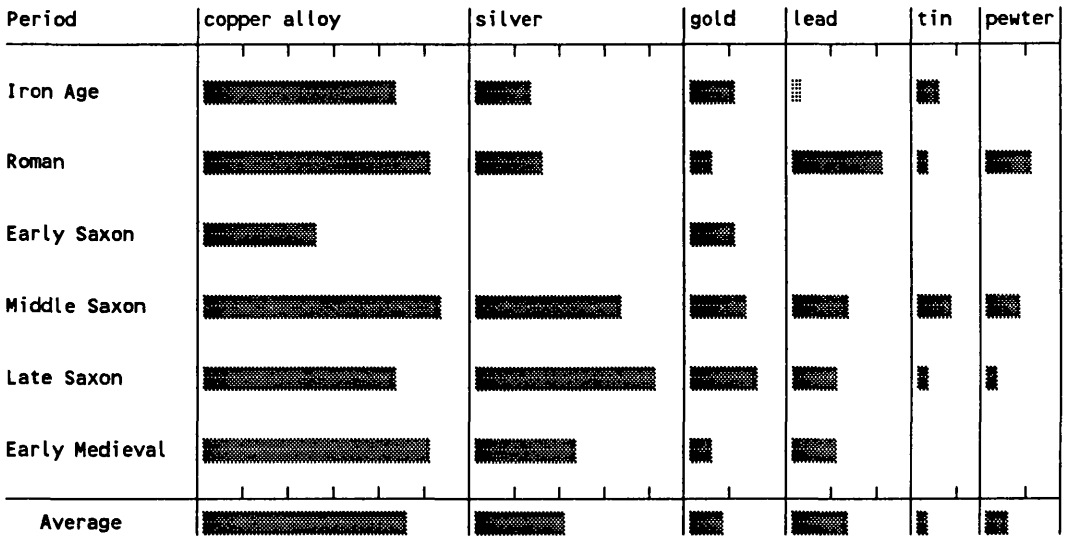
Figure 10.1 shows the data in Table 10.1 compared with the average figures for all periods, so significant divergence from this mean is apparent. However date is not the only factor that affects the metals used, as the type of object and the fabrication method employed are also important. The availability of supplies is a further factor, and one for which many different reasons can be suggested; some are included in the discussion below and others appear in Chapter 12.

Copper and its alloys were the most commonly worked metals at all periods. This is not surprising as they possess a range of properties and can perform functional and decorative roles in both cast and wrought form. Table 10.1 does not differentiate between the individual copper alloys though not all are equally common at each period. Their pattern of usage is described below.

At all periods silver and gold were precious metals though

Figure 10.1 - Percentage of metalworking sites of each period with evidence for the working of different metals



Note: The number of sites for the Early and Middle Saxon periods is far smaller than for other periods so the figures are not necessarily significant.

Key: =1% =3% =6% =9% etc

The divisions on the horizontal lines are spaced every 12%

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their values relative to each other and the base metals were not constant; Casey (1984) discusses the monetary relationships and metal content of Roman coinage and Spufford (1988) extends this into the medieval period. As well as being used for coinage, gold and silver were also used for display, the scale depending on the wealth and ostentation of the individual. Two alloys whose use the Romans developed, brass and pewter, can be thought of as substitutes for the two precious metals and metal colouring, by plating it with tin or gold, became common in Roman Britain, an additional poor man's alternative to precious metals.

Tin, lead and their alloys have only a limited range of uses which partly explains the limited evidence for their working.

<u>**Gold and silver**</u>

In the later Iron Age the same gold and silver alloys were used for both torcs and coinage (Burns 1971, Northover 1988) and traces of these metals are found on coin pellet moulds (eg Tournaire *et al* 1982) and gold on crucibles also. There is little evidence for the extraction, refining or working of silver on its own, though Norfolk has produced both a silver bar ingot (from Snettisham) and an ingot? mould from Thetford: Fison Way which has silver on it, while a similar fragment was associated with the coin pellet moulds at Old Sleaford.

The Roman period sees a full separation of gold from silver, the evidence for parting and cupellation shows that precious metals were refined. Both metals were used for coinage, gold was also used for high class jewellery and silver for jewellery, spoons and vessels (eg Kent and Painter 1977). The small number of silver items in Appendix C includes rings, spoons, a pin, a bracelet and 16 brooches. These are mainly penannulars and crossbows and related types though they also include a plate and a trumpet brooch. Crossbow brooches made of gold are also known (eg Kent and Painter 1977, nos 19-22) and, like the silver brooches, their forms can be paralleled among the copper alloy examples.

Silver and gold continued in use in the post-Roman period for jewellery and coinage. Gold predominated until the 7th century when Islamic movements in the Mediterranean disrupted supplies and silver then became the coinage metal and was also used for high quality jewellery. Gold did not completely disappear for these types of objects but was much less common (Hodges 1982, Hinton 1990). The Middle Saxon silver coinage (sceattas) was superseded by the 9th century by silver pennies which continued into the medieval period. In Saxony in the 10th century there was an upsurge in silver production and minting, and England's increased trade with the Continent at this period led to a rise in minting here, as foreign coinage was not allowed to circulate in England and so was reminted (Spufford 1988). Mints are documented in many English towns at this period (ibid, Map 10A) and the large numbers of silver-melting crucibles found in both Northampton and York may be physical evidence of this activity.

Lead

Objects made of lead are known, though uncommon, in the Iron Age (eg Bulleid and Gray 1911).

With the introduction of more substantial buildings in the Roman period, there was a demand for lead as plumbing and flashing. It was also used to make objects such as coffins. Increasing amounts of lead also went into other metal alloys but the plentiful and easily worked ores meant that Britain was accused of flooding the Roman Empire with cheap lead and protectionist measures were introduced (Pliny Bk 34, 164).

In the post-Roman period lead continued in use but was not very common. Few Saxon copper alloys contain the high lead levels used in Roman times. Late Saxon lead objects include trinkets which were also made in pewter (see below) and, from the 11th century, it was used to make sepulchral chalices (Hornsby *et al* 1989) as well as being used for weights, coffins, vats, cames, pipes and roofing (Homer 1991).

* The objects analysed include almost all Roman brooches coming to the AML or to Sarnia Butcher from 1977 to 1990. The other objects were deliberately selected from among those coming to AML, either to provide large groups of analyses from a few sites from all parts of the country, or to provide relatively large numbers of analyses of specific types of objects.

Tin and pewter

Pewter first appears in the Roman period, but it does not become common until the 3rd century when it was used mainly for vessels which may be seen as copies, in a less expensive material, of the high quality silverware then in fashion. The major Roman exploitation of Cornwall's tin resources began in the 3rd century (Davies 1935) and it is unlikely that these two things are unrelated. The composition of Roman pewter is very variable, running from virtually pure tin down to alloys with over 50% lead. Beagrie (1989A) has summarised the quantitative analyses and has shown that compositions approximating to 95%, 75% and 50% tin are commonest, though all intermediate compositions are known. Early Roman pewter is all very high in tin with only a few percent of additions (Jones 1983).

The Romans also used tin and tin-lead alloys as decorative or protective coatings on metalwork (see Chapter 8) and tinning is common in the post-Roman period too.

Pewter is not common in the immediate post-Roman period but Wilson (1981) notes its use in the 8th and 9th centuries and by the 10th century it was being used for mass-produced badges and brooches (AML 4352, Bayley forthcoming). Vessels appear a little later; the earliest English documentary reference is to a "tin" chalice in a letter of *c.*1006 AD but domestic pewterware is not mentioned before the 1290s (Homer 1991). In later medieval times pewter was widely used for both vessels and trinkets such as pilgrim badges (Hornsby *et al* 1989). Theophilus describes making both cast and wrought vessels from tin or pewter (Ch 88-90).

Copper and its alloys

Most of the discussion below is based on the data in Appendix C. Table C.3 contains the results of 3271 analyses of late Iron Age and Roman brooches which are summarised in Tables 10.8, 10.10 and 10.11, and Table C.4 lists the results obtained for 850 other objects, most of them Roman, the major groups of which are summarised in Table 10.2.* Alloy names were assigned to individual objects on the basis described in Chapter 9 for quantitative analyses though for qualitative XRF analyses the following caveats, discussed in more detail in Appendix B should be borne in mind:

1) Joint alloy names, eg bronze/gunmetal, indicate uncertainty as to the most appropriate name and may, but do not necessarily, imply an intermediate composition.

2) Alloys that are described as (leaded) may have lead contents outside

unlikely to be either heavily leaded or very low in lead.

3) The alloy name implies a composition which cannot be guaranteed to be exactly within the limits defined, but this is of little importance when considering overall trends in large data sets as random errors will cancel out. The chance of mis-describing the composition of an individual object is higher and is more likely with mixed alloys than with brasses, bronzes or heavily leaded bronzes, as the generally lower levels of additions present produce less clear-cut data.

Two main graph types are used for visual presentation of the numerical data. The first is a stacked bar graph which shows the proportions of the different alloys present in a particular group of objects and which allows comparisons to be made between groups of different sizes. The second is a ternary diagram of the type described in Chapter 9. Note that the whole diagram is shown in every case so the distribution of points can be compared between diagrams.

Iron Age and Roman copper alloys

Throughout the Iron Age bronze was the dominant alloy, though leaded bronzes were introduced towards the end of the period especially for larger, more intricate castings where the greater fluidity of the melt was an advantage. The results of analyses of objects from the temple site at Hayling Island show this pattern; about 80% were bronzes, over three-quarters of which were unleaded (Table 10.2 and Figure 10.2). Although the site was occupied from the 1st century BC, none of these contexts are sealed early enough to allow the presence of leaded bronzes to support or disprove Northover's (1988) thesis that their use was an early 1st century AD development. The few objects made of other copper alloys are mainly Roman ones, deposited during a later phase of use of the site.

In the early 1st century AD objects made of brass began to appear in southern Britain. These were initially imports from Gaul or beyond and there is no evidence that brass was made or melted here in the late Iron Age, though part manufactured brooches suggest it was wrought at Baldock (Stead and Rigby 1986). Pre-Conquest brass finds include a few 'ritual' objects from Hayling Island and the head-dresses and sceptres from Wanborough, Surrey (AML 204/87) though brooches are far more common on a number of sites, eg King Harry Lane, St Albans (Stead and Rigby 1989).

Table 10.2 - Summary of analyses of Iron Age and Roman objects other than brooches (data from Table C.4)

Site	bronze	leaded bronze	leaded gunmetal	gunmetal	brass	other	total
Hayling Island	195	54	8	13	26	16	312
Gloucester: Kingsholm	1	1		1	14	1	18
Colchester: Sheepen	3	8	6	4	27	7	55
Richborough	6	6			5	2	19
Uley	23	18	16	14	35	7	113
Ashton	23	4	3	10	16	3	59
Carlisle	7	22	10	4	12	5	60
Coleshill	15	13	3	4	4	1	40
Gorhambury	40	38	12	11	21	3	125
Heybridge	7	11	3	1	2		24
Total	320	175	61	62	162	45	825

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In the decade or so following the Roman conquest there was an enormous upsurge in the use of brass and evidence for this and its manufacture and working appears throughout the Romanised areas in Britain. The finds from the Sheepen site at Colchester (Nibblett 1985) illustrate this well; nearly 80% of the brooches and 50% of the other copper alloy finds are brass (see Table 10.2 and Figure 10.2 for the non-brooches). Much of this early Roman brass is military metalwork, coins and brooches (see below) with relatively few other civilian objects. The early military metalwork in Table C.4 is marked with an asterisk in the Type column; 80% of these objects are brass. Cowell (1990) found a similar pattern at Camerton where 62% were brass.

The data in Table 10.2 gives some idea of the overall pattern of copper alloy usage in Roman Britain throughout the three or four centuries of occupation. Brooches are considered in more detail below and show much more chronological variation than is apparent in the other objects; the overall proportions of alloys used is not very different (see Figure 10.2). The analysed objects from Ashton, Carlisle, Coleshill, and Heybridge comprised all the copper alloy objects from these settlement sites which span the mid 1st to 4th centuries. Those from Gorhambury were a cross-section designed to provide groups from well-dated contexts of all periods as well as larger numbers of several classes of everyday objects. The finds from Colchester: Sheepen were almost all the objects from the site, but as it had a very short-lived

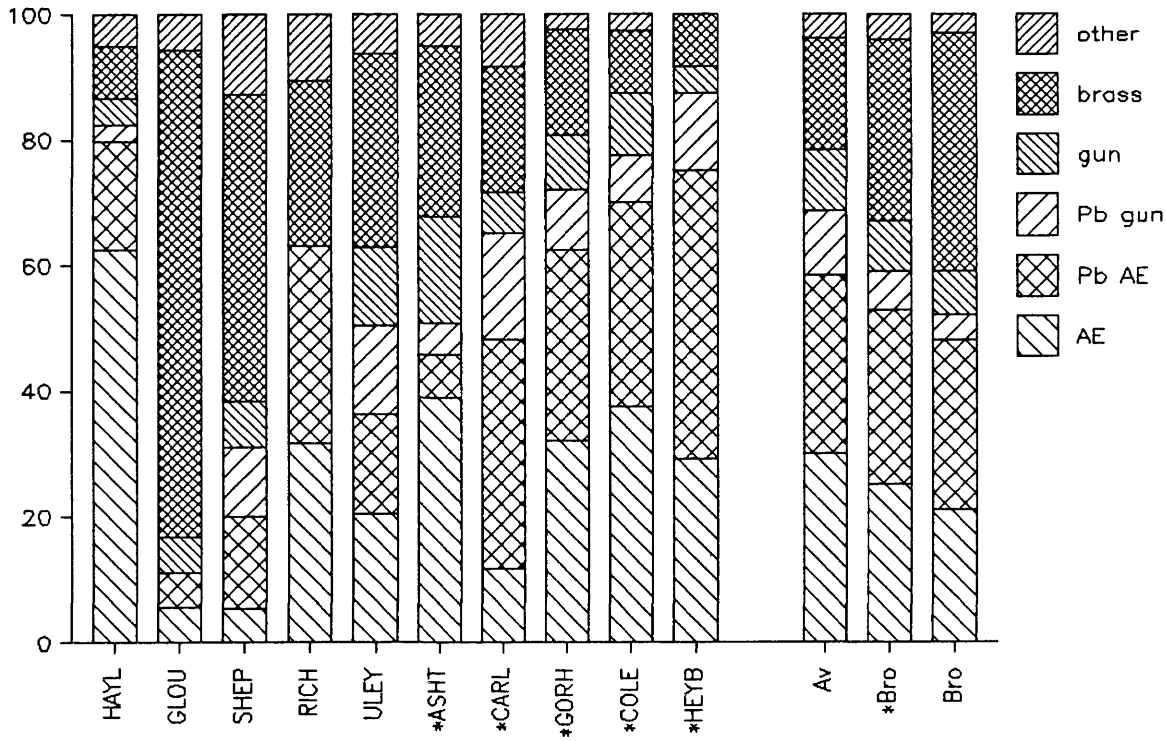

Figure 10.2 - Proportions of objects (other than brooches) made of different alloys from selected Roman sites

Notes to Figure:

Most of the Hayling Island objects are late Iron Age

Av = overall proportions for the sites marked *

*Bro = overall proportions for brooches from the sites marked *

Bro = overall proportions for all Roman brooches analysed

See Table C.1 for the key to the codes for sites

See Table 10.2 for total numbers of objects analysed from each site

Key to alloys (for Figures 10.2-10.3, 10.7-10.9, 10.34 and 10.37)

AE = bronze, Pb AE = leaded bronze,

gun = gunmetal, Pb G = leaded gunmetal,

brass = brass, other = other copper alloy or unalloyed copper and mostly military occupation in the mid 1st century AD they cannot be considered representative of Roman copper alloys in Britain. The same can be said of the objects from Gloucester: Kingsholm which were military metalwork from the early fortress. The Richborough and Uley objects may not be representative either as they were selected items of particular types.

The patterns from the five representative sites are similar, with the group average (Figure 10.2) showing that over half the objects analysed were bronzes or leaded bronzes and the rest were divided fairly evenly between brasses and gunmetals, the latter both with and without lead. The proportions of different alloys among the brooches from the same sites are shown for comparison. There are more brasses and thus fewer gunmetals and bronzes and, when all the brooches analysed here are considered, a further increase in the proportion of brass is seen. Craddock (1978) noted that 26 of 84 everyday objects he analysed (31%) contained over 4% zinc, and the figure for the non-brooch brasses and gunmetals here is comparable at 38%. Brasses were used mainly for decorative objects such as jewellery and for ritual or religious objects of various sorts where the golden appearance of the metal was doubtless appreciated. The higher than average proportion of brass at Uley (a temple site) arises because many of the objects analysed were either bracelets or 'votive' rings. Brass was also used where its mechanical properties were beneficial, eg for making decorative chains or domed-headed tacks and other wrought objects such as type Aa rat-tail spoons; the typologically similar Ab spoons were cast and so could be made of leaded alloys (see Table C.4). Most copper alloy spoons were tinned to avoid unpleasant tastes when eating, so the different colours of the alloys would have been hidden.

Neither leaded brass nor leaded copper were normally used in Roman Britain though a few objects made of lightly-leaded brass are found, particularly in the latter part of the period. Unalloyed copper is virtually unknown too; it is used only for such things as repoussé decorated sheet metal, eg the helmet cheek piece from Gloucester: Kingsholm, where its malleability would be an advantage. Virtually unalloyed copper, with tin its 'major' addition, was however used to make objects that were to be mercury gilded (see Chapter 8).

There was doubtless considerable recycling of both metalworking waste and broken or outdated objects. This scrap must have been carefully sorted as distinct brasses and bronzes were still in use as late as the 4th century. There is some evidence that the proportion of mixed alloys increased with time (see Table 10.3) and Cowell (1990) has noted the same trend which he puts down to design rather than accidental mixing. Data for the early Saxon period (see Table 10.4) shows this trend continuing.

Table 10.3 - Analyses of Gorhambury objects from closely dated contexts

Century	bronze	leaded bronze	leaded gunmetal	gunmetal	brass	other	total	% all gunmetals
1st	6	1	-	1	2	-	10	10
2nd	24	13	7	4	13	-	61	18
2nd/3rd	-	1	-	2	-	-	3)	) 20
3rd	1	4	-	-	1	1	7)	
3rd/4th	1	5	1	1	1	-	9	22
4th	1	4	2	2	-	1	10	40

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Post-Roman copper alloys

In the post-Roman period a picture of alloy usage is beginning to emerge though fewer analyses have been done. Some of these, summarised in Table 10.4, allow tentative interpretations to be made. Figure 10.3 shows that up to the 7th century most of the groups are characterised by high proportions of gunmetals. There appear to be distinct changes from the 8th century, though the small number of later sites with analysed metalwork means that it is not yet known if these are representative of their periods.

Mortimer (1991) has found that late 4th/early 5th century cruciform brooches were mainly made of bronzes or brasses, with the former being commoner, but that by the early 6th century a range of bronzes, gunmetals and brasses is found with the tin-richer alloys predominating; lead levels are typically 2-6% throughout. She argues this pattern of alloy use shows the continuing production of bronze "... since it occurs persistently ... but brass does not seem to have been made in any quantity ..." Continual recycling, the usual explanation offered for the growing preponderance of mixed alloys, would naturally lower the average zinc content of the metal pool as up to 10% of it is lost with each remelt (Caley 1964). Thus, if some sorting of scrap was practised, it is possible that relatively pure bronzes could have survived and the presumption of continued production from newly smelted metal is unnecessary. It is possible that distinctive trace element patterns may indicate the use of new metal but data of that type is not considered here.

Table 10.4 Summary of post-Roman analyses

Site	bronze	leaded bronze	leaded gunmetal	gunmetal	brass	other	total	% all gunmetals
Mucking	65	29	3	2	3	2	104	5
Portway	19	12	15	3		2	51	35
Watchfield	2	18	7	8	4	3	42	36
Avon valley	23	10	3	27	8	2	73	41
Finglesham	54	4	11	54	20	29	172	38
Morningthorpe	25	2	1	19	1	2	50	40
Hamwih other	44	26	8	3	13	18	112	10
Hamwih pins	5	65	9	2	16	16	113	10
Coppergate	23	21	7	21	98	52	222	12
Flaxengate	13	5	4	7	33	54	116	10
Romanesque-	4		1	5	13	1	24	25
Romanesque+	1	1		2	6	6	16	13
Romanesque*						33	33	0
Total	278	193	69	153	215	220	1128	

Sources of data:

Mucking - AML 178/88 Portway - Table C.6 (=Bayley 1985J)
Watchfield - Mortimer *et al* 1986
Avon valley - Brownsword *et al* 1984 (Most of the objects are brooches from Wasperton, Baginton and Stretton-on-Fosse)
Finglesham - AML 4434 Morningthorpe - AML 4724
Hamwih - AML 4334
York: Coppergate - AML 4354 Lincoln: Flaxengate - White (1982)
Romanesque - Oddy *et al* 1986 (* are wrought and gilded, + are gilded castings, - are ungilded: all except two of the bronzes are castings)

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The early 6th century finds from Watchfield include a wider range of objects but still show bronzes and gunmetals predominating (Figures 10.3 and 10.4). Over a third of these objects have lead contents of over 8%, and they include a belt set and two bindings with very high tin contents - from 20% up to over 30% (Mortimer *et al* 1986). Decorative bars attached to a brooch from Wasperton are of a similarly high tin bronze though they have low lead levels and contain considerable amounts of silver and gold (Brownsword *et al* 1984). Analyses of other brooches from sites in the valley of the Warwickshire Avon (Figure 10.5) present a similar picture to that from Watchfield, though there are fewer leaded alloys and the levels of additions are lower (see Table 10.5).

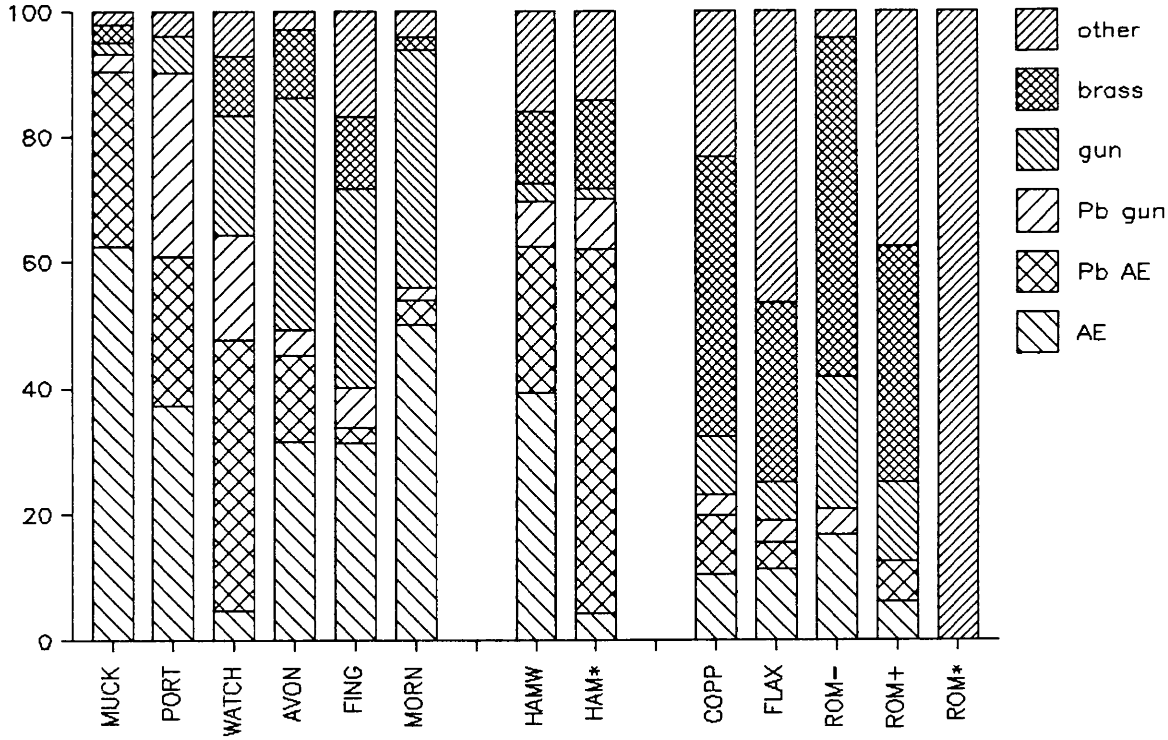

Figure 10.3 - Proportions of objects made of different alloys from selected post-Roman sites (data from Table 10.4)

The left hand group of sites are early Saxon (5th-7th century)

The centre pair, Hamwih, are middle Saxon (8th-9th century)
HAM* = Hamwih pins

The right hand group are late Saxon and early medieval (10th-12th century)

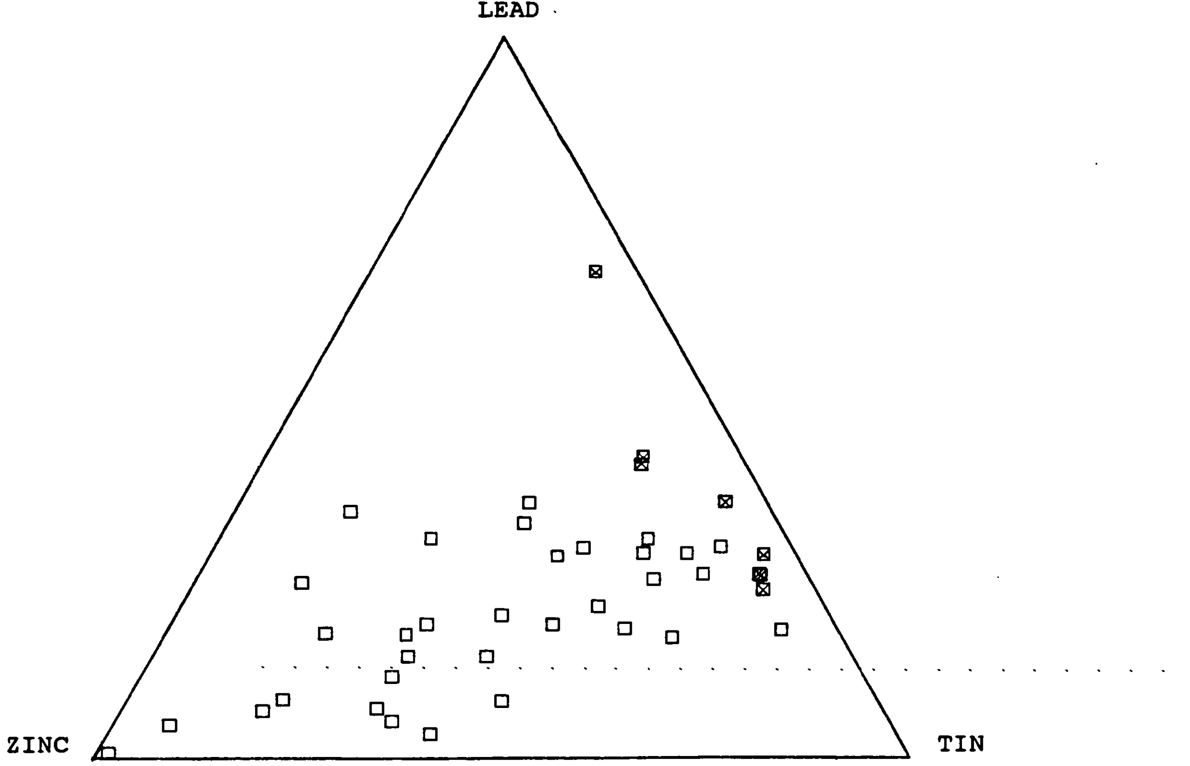

Figure 10.4 - Ternary diagram of analyses of 6th century objects from Watchfield, Oxfordshire (data from Mortimer *et al* 1986) Crossed symbols are speculum metal and bronzes with over 10% lead

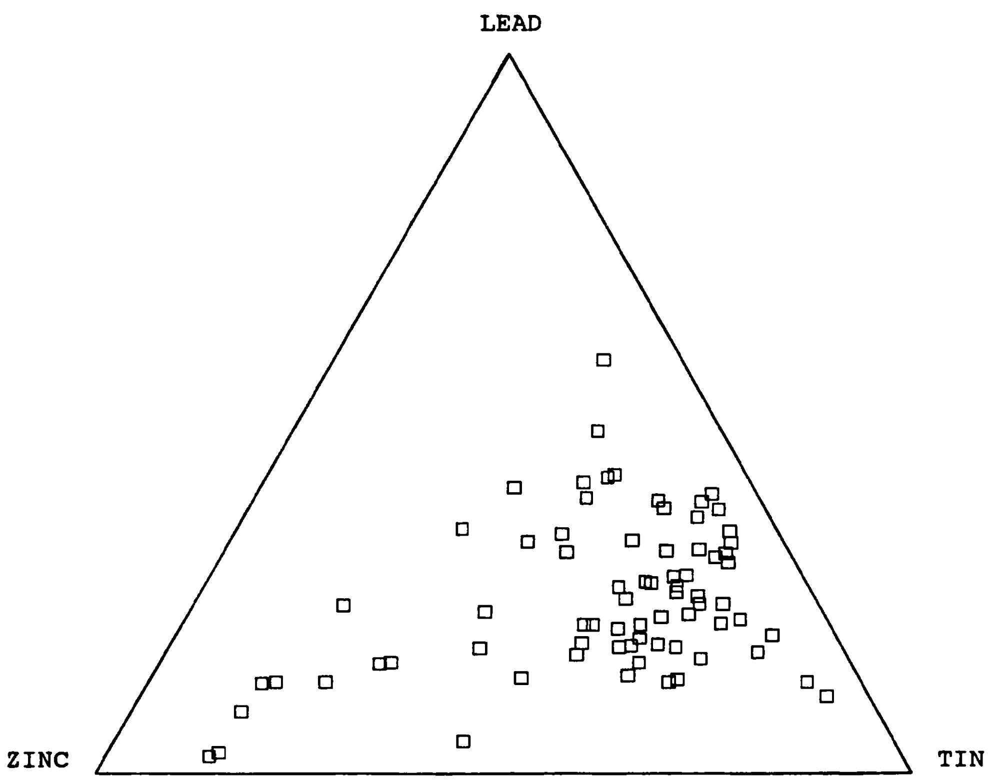

Figure 10.5 - Ternary diagram of analyses of early Saxon brooches from sites in the Avon valley, Warwickshire (data from Brownsword *et al* 1984)

Table 10.5 - Means and standard deviations for groups of quantitative analyses in Table 10.4

Site/group	sample size	Zn%	Sn%	Pb%
Watchfield	42	7.1 ± 5.4	10.9 ± 7.9	5.9 ± 4.3
Watchfield*	33	8.3 ± 5.4	7.8 ± 4.1	4.1 ± 2.2
Avon valley	73	3.3 ± 3.8	5.6 ± 1.7	2.9 ± 1.4
Romanesque+	16	5.8 ± 4.1	2.7 ± 3.0	1.4 ± 1.3
Romanesque-	22	12.6 ± 6.2	3.1 ± 2.7	4.0 ± 3.2

Notes: Watchfield* excludes the 6 speculum metal objects and 3 other bronzes with over 10% lead (shaded on Figure 10.4)
Romanesque+ are gilded, Romanesque- ungilded castings

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By the Middle Saxon period there is evidence of newly produced metal being used. Analyses of 225 objects from Hamwih (AML 4334) show that only about 10% are gunmetals, with bronze and leaded bronze making up two-thirds of the total. Towards the end of this period Gilmore (1987) has argued that the radical change in the composition of Northumbrian stycas in the early 9th century is due to the abandonment of a silver standard and the adoption of a brass coinage that, in its initial phases, was made from random proportions of pure, high-zinc brass (which must have been newly made) and the old coins.

Objects and metal scrap from York: Coppergate which are mainly of 10th/11th century date were also analysed and nearly half were found to be brasses with a further 10% of brasses that were (leaded) (AML 4354). Analyses by White (1982) of contemporary metalworking scrap and waste from the Lincoln: Flaxengate site show that just over a third of the material is copper with only a few percent of additions. Next commonest are brasses (28%) and leaded brasses (12%). Arrhenius (1982) presented similar results for Scandinavian metalwork: "during the Vendel period brass bronzes came back into fashion and in the Viking Age they held total dominance". Drescher (personal communication 1979) found tin absent from the copper alloys at Haithabu, Schleswig.

A group of Romanesque metalwork has been analysed by Oddy *et al* (1986). The results are not likely to be representative of the alloys in general use in the 12th century as they were all high quality decorative pieces, many of them mercury gilded and/or enamelled. The study did however show that many of the wrought pieces were virtually pure copper, while gilded castings had low but varied total additions and ungilded castings were almost all zinc-rich alloys, most with low lead contents (Tables 10.4-10.5 and Figure 10.6).

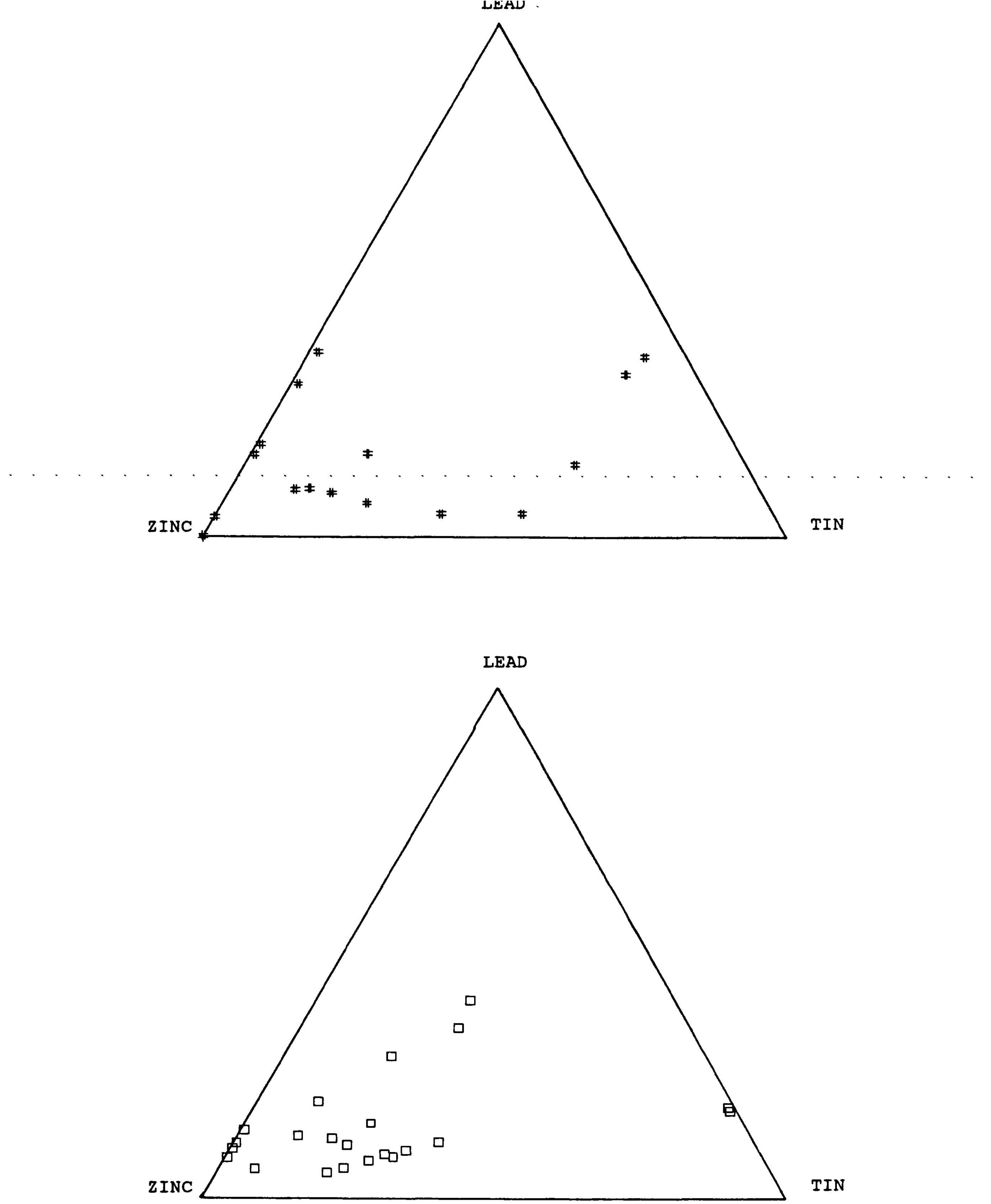

Figure 10.6 - Ternary diagrams of analyses of cast Romanesque metalwork in the British Museum (data from Oddy *et al* 1986)
The gilded objects (top diagram) contain an average of 90% copper while the ungilded ones (lower diagram) contain an average of only 80%

number of sites, those quoted above must stand alone and may or may not prove to be typical of their periods. It does seem that in them we have pointers to the position in the high medieval period where brass and zinc-rich gunmetals were commoner than bronze, and leaded brass and leaded copper were used as well as copper with little if any additions. The overall trend seems to be away from the distinct, well defined alloys of the Roman period towards those with lower levels of additions which gave compromise rather than specific alloy properties. However, craftsmen like Theophilus were still capable of careful selection and refining of metals where it was technically necessary (Hawthorne and Smith 1979).

Late Iron Age and Roman brooches

The alloys used to make Roman brooches have already been referred to above. Brooches were selected for this more detailed study of alloy usage as they are normally frequent finds on Roman sites, they are typologically diverse, many of these types are relatively well-dated, and most brooches are large enough so that the removal of a sample for AAS analysis presents no problems. In 1st century AD Britain the wearing of one or more brooches was almost essential as they were needed to hold clothes in place. Fashions changed and brooch wearing became progressively less common in the civilian population and far fewer brooches of later types are found. 3rd and 4th century types come mainly from sites with a military presence.

The late M R Hull devised a typology for these brooches based on his study of many thousands of them though unfortunately only the first part of it, which deals with pre-Roman bow brooches, has been published as yet (Hull and Hawkes 1987). Copies of galley proofs of an earlier attempt to publish Hull's corpus have been made available to myself and to Sarnia Butcher who used them to assign Hull's type numbers to the majority of the brooches listed in Table C.3. Hull's typology divides brooches into 14 groups (see Table 10.6), each of which is subdivided into a number of types. In general, higher numbered groups contain types of later date, though the large numbers and typological diversity of 1st century brooches mean that many Group 1, 2, 4 and 5 brooches are contemporary. Plate brooches and penannulars are found at all periods.

This typology is a useful and usable one though it does present some problems which have been highlighted by this programme of analytical work. In particular, the fantail brooches are an artificially created group as the brooches are closely paralleled in both form and

Table 10.6 - Summary of Hull's brooch typology

Group	
1	La Tène III and Roman brooches with no hook and no arms
2	Brooches with cylindrical spring cover
3	Fan-tailed brooches
4A	Eye brooches
4B	Early hinged brooches: Aucissa, Hod Hill and allied series
5	Early sprung brooches
6	Polden Hill series
7	T-shaped brooches
8	Trumpet-headed brooches
9	Knee brooches
10	Various enamelled bow brooches
11	Sheath-footed and crossbow brooches
plate	Plate and disc brooches
penan	Penannular brooches

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composition by types in Groups 2, 7 and 8. Group 10, the other small group (see Table 10.7), also presents problems as its types are either derivatives of Hod Hill types or are most closely related to some of the plate brooches despite having a bow brooch form. The group of plate brooches brings together a diverse range of types of all dates though the number of examples of each type is usually smaller than for the bow brooches (Groups 1-11). In some groups very fine sub-divisions were made by Hull and in others a whole range of variants were classed together under a single type. However, most types are well-defined and are distinct from adjacent types. Some brooches are of intermediate types, or of a type not known to Hull which creates problems. Where brooches are incomplete it is often difficult to assign a type number with any certainty, though it is possible to assign a Group to almost every fragment.

3271 brooches were analysed, 31% of them quantitatively by AAS and the rest qualitatively by XRF; the results of these analyses are presented in Table C.3 where alloy names have been allotted to each brooch as described in Chapter 9 and Appendix B. Where the pin is made separately, the analysis is for the main part of the brooch. The numbers of brooches from each group are shown in Table 10.7. 75 of these brooches were found outside England. These include the groups from Prestatyn in Wales (24) and Camelon in Scotland (16) which are considered together with the English examples. The rest (35) are from two sites in Belgium,

Table 10.7 - Summary of brooch analyses by Group

Group	XRF	AAS	Total	* = 10 AAS analyses - = 10 XRF analyses
1	291	57	348	******-----------------------------
2	111	59	170	******-----------
3	31	10	41	*---
4	308	108	416	***********-------------------------------
5	344	266	610	***************************----------------------------------
6	80	35	115	****--------
7	196	170	366	*****************--------------------
8	138	50	188	*****--------------
9	73	14	87	*-------
10	17	11	28	*--
11	72	98	170	**********-------
plate	310	83	393	********-------------------------------
penan	212	46	258	*****---------------------
other	70	11	81	*-------
Total	2253	1018	3271	

- - - - -

Oudenaarde and Velzeke, and were analysed in an attempt to show whether English alloy usage patterns also applied on the Continent. Reference is made to these results in the texts describing each Group and in the section below on analytical results for continental brooches.

The comments on the interpretation of XRF data given above apply as much to brooches as to other objects. Where there are larger numbers of any one brooch type, the range of alloy names can help define the range of compositions. For example, where there are many brasses and some gunmetals this is not usually because there are two distinct compositional groups but because a continuum of compositions exists that are all impure brasses with varying levels of added tin; the range of compositions has bridged the arbitrary divisions made in assigning alloy names.

In the early stages of this programme of analyses it became apparent that there was a significant correlation between brooch type and composition (Bayley *et al* 1980) and further work indicated that there was little if any variation between the same types of brooch from sites in different parts of the country (Bayley and Butcher 1981); the data in Table C.3 confirms these impressions. In the analysis of the data which follows, these two points are taken to be generally true though the few instances where divergence from them is seen are noted and possible explanations given.

Tables 10.8, 10.10 and 10.11 summarise the data in Table C.3 by brooch type and alloy. The intermediate compositions brass/gunmetal and bronze/gunmetal have been added to the brass and bronze totals respectively. The totals in these three Tables do not add up to the grand total shown in Table 10.7 as brooches without definite types and most single examples of an individual type have been excluded. Figures 10.7-10.9, 10.34 and 10.37 present graphs of alloy frequency for most brooch types where sufficient numbers of analyses exist. The high frequency of brass in the early period, referred to above in the general discussion of Roman alloys, is immediately obvious in Figure 10.7.

There are very variable numbers of brooches of particular types which means that discussion of the patterns of alloy use has to proceed at a number of levels, not all of which can be applied to all types. With only a few analyses of a particular type any inferences drawn must be tentative. With somewhat larger numbers of analyses, patterns of preferred alloy use begin to emerge and with large groups statistical intercomparisons become viable. There are no absolute numbers of analyses necessary for the different levels of discussion as the homogeneity of the group and the proportion of quantitative analyses both affect what can be said.

Table 10.8 - Summary of analyses of late Iron Age and Roman bow brooches (data from Table C.3)

Type	bronze	leaded bronze	leaded gunmetal	gunmetal	brass	other	total	AAS %
1-5	6	1			4		11	55
9	18				1		19	21
10-11	149	4	2	23	60	3	241	16
13-20	31	1	1	1	3	1	38	16
21-24				6	72	2	80	50
25-28	3		1	1	77		82	24
29-35	1	5	2	1	4		13	54
36	10	3	1	2			16	13
37	2	5	1	1	1		10	20
40-44	1	1		1	21		24	25
45-50.54	1				5		6	0
51				5	63		68	26
52	1				18		19	16
53	3				3		6	0
55-58	2				8		10	30
60-80	28	3	1	26	197	1	256	25

Table 10.8 (cont)

Type	bronze	leaded bronze	leaded gunmetal	gunmetal	brass	other	total	AAS %
84	1	1			10		12	42
88	4	1			1		6	33
89-91	22			2	225		249	52
92-93	37	168	18	6	2	1	232	47
94	45	29	3	8	4	1	90	28
95-103	19	67	6	4	5	2	103	29
112-117		1		1	6		8	63
104-111) 118-136) 138-142) 143B.144)	11	153	3	1			168	58
137.146	4	13	3	1	1	1	23	30
151-152	4	6			3	1	14	71
143A.145	1	4		2	4	1	12	50
147.148	5	1	4	7	28	2	47	21
149	21	16	3	2	18	2	62	27
153A/B/C	2				5		7	14
153D		3					3	67
154.159	1	25			1		27	63
157	1	2		1	12		16	25
158A	5	1	4		15	3	28	25
158C	7			2	7		16	6
158D/E/F		11					11	45
162-170	6	5	1	7	28	4	51	18
171	4	6		1	2	1	14	7
173A				5	14		19	11
173B	3	10	1		1		15	7
175-179	2	26	6				34	27
180.182-3		1	8		7	1	17	41
181		2					2	100
185	1	1			1		3	33
186	5	4		1	1	2	13	62
187		9	3	2	4	2	20	55
189		14	1			1	16	63
190	11	12	3	1		1	28	50
191	5	30	4	1	3	5	48	65
192	1	13	4		11	8	37	47
193-197		1			1	2	4	75
Total	460	658	84	122	952	48	2324	

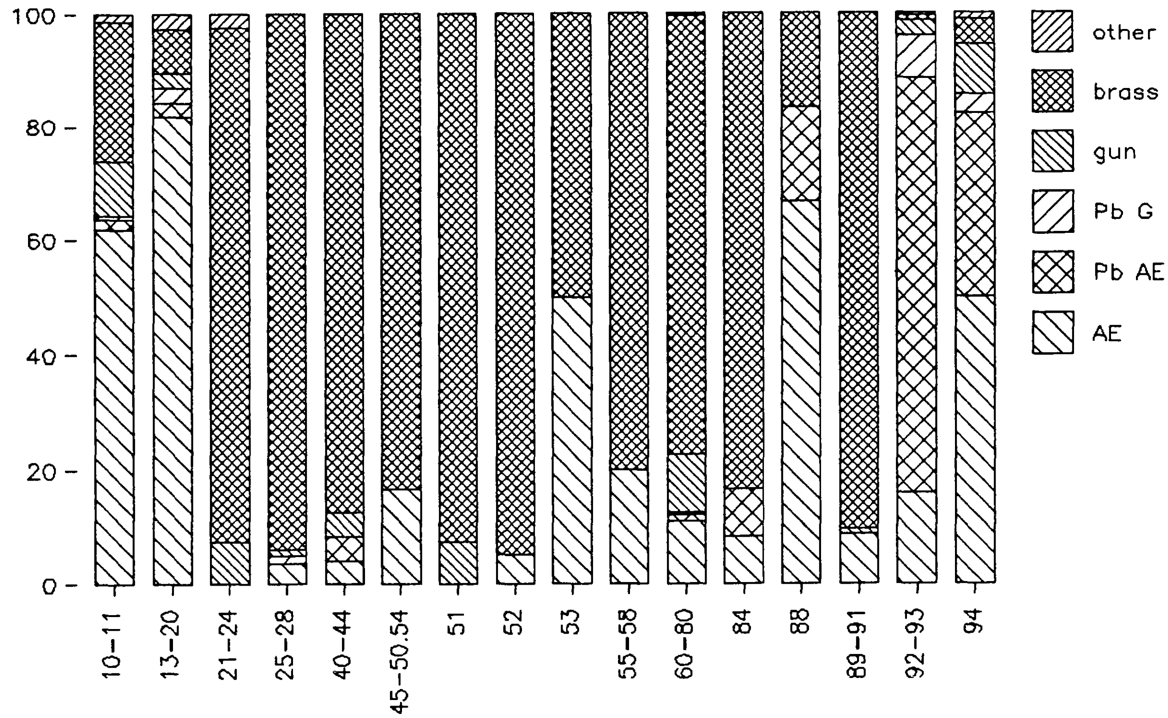

Figure 10.7 - Proportions of brooches of Groups 1, 2, 4 and 5 made of different alloys

The Hull type number(s) are written below each block

See Table 10.8 for total numbers of brooches of each type

Appendix D contains illustrations of late Iron Age and Roman brooches of the types discussed in this Chapter.

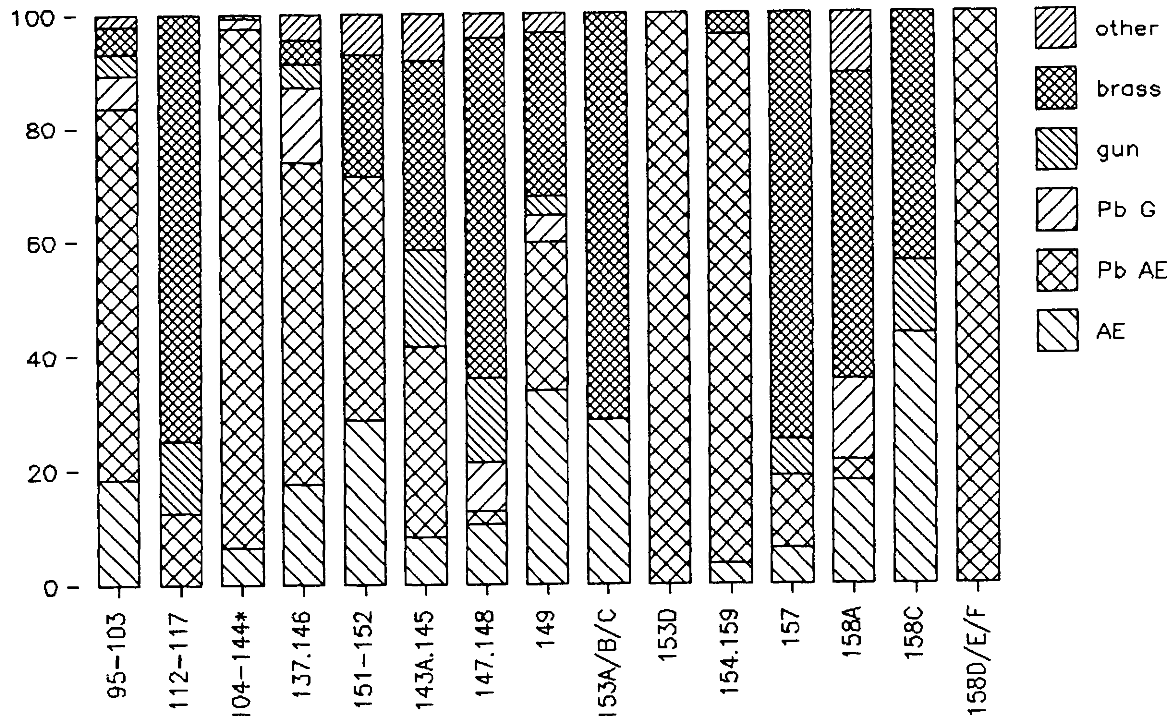

Figure 10.8 - Proportions of brooches of Groups 6, 7 and 8 (part) made of different alloys

The Hull type number(s) are written below each block

See Table 10.8 for total numbers of brooches of each type

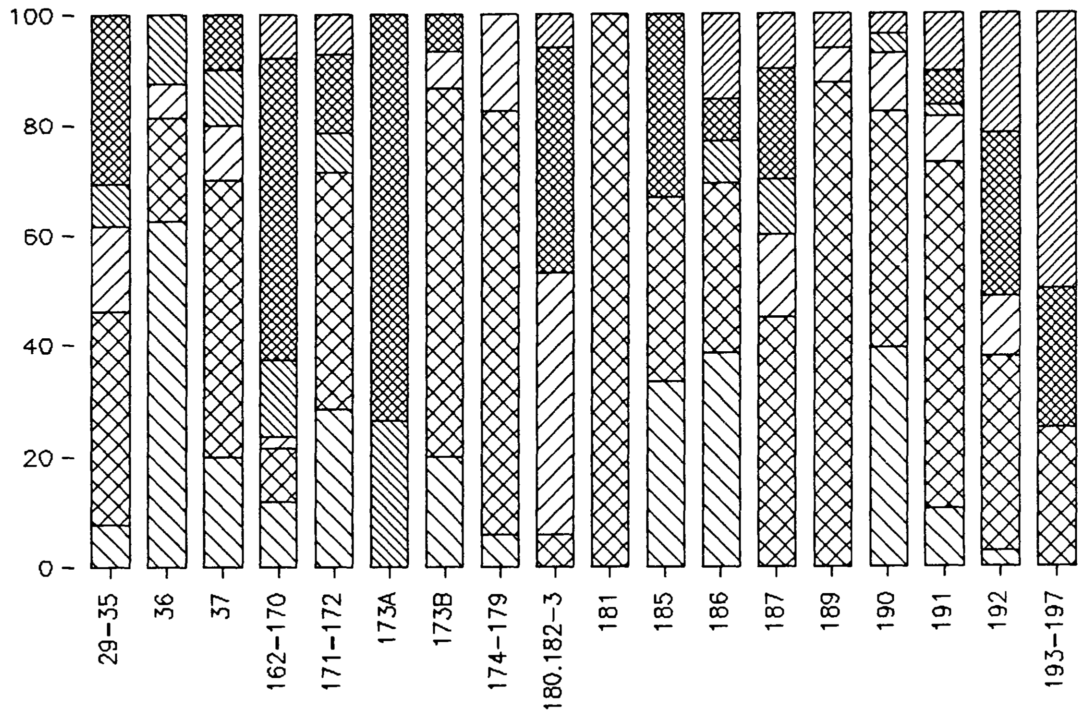

Figure 10.9 - Proportions of brooches of Groups 3, 8 (part), 9, 10 and 11 made of different alloys

The Hull type number(s) are written below each block

See Table 10.8 for total numbers of brooches of each type

Group 1 and earlier brooches (Types 1-20)

Hull's types 1-3 fall outside the group structure he set up; they belong before the 1st century AD. The analysed examples include two La Tène I (T1) and several La Tène II (T3) brooches; all are bronzes like other Iron Age objects. The three brass T3 brooches are pseudo La Tène II types which were made later, when brass was in general use. This is one case where Hull's typology is insufficiently detailed to separate the originals from the copies.

Group 1 contains small numbers of Nauheim brooches (T9) and hinged strip bows (T13-T20) which are almost all bronzes, suggesting they are products of a pre-Roman metalworking tradition. Note that the hinge of T13-T20 is formed by rolling the head of the bow under, round an axis bar, quite unlike the superficially similar hinges of the Group 4B brooches where the head is rolled forward over an axis bar.

The largest group of brooches are the so-called Nauheim derivatives (T10-T11) which are a long-lived 1st century AD type, in use both before and after the Roman Conquest. These are one-piece brooches with a four-turn spring and an internal chord, like T9. They all have solid catch plates, unlike the open ones in T9, and their bows vary from round or square-section wires or rods to strips of various widths. Hull defined T10 as having a reverse curve and T11 a simple curve to the bow. The two types are considered together here as they show the same range of compositions.

Figure 10.10 shows there are two distinct compositional groups, brasses and 'bronzes'. The former are a relatively tight cluster, most with a small tin content. The 'bronze' cluster is far less well-defined with higher average lead levels than the brasses. The gunmetals and leaded alloys are outliers to the bronze cluster, being part of the same continuum. There are few leaded alloys (only 3 out of 57 have over 4% lead) which is to be expected as these brooches were obviously hammered and bent to shape; the spring depended on the elasticity of the metal for its effectiveness.

T10-11 brooches from 37 sites have been analysed but over half of them came from just five sites in the south and south-east (Baldock, Hayling Island, London, Richborough and Wanborough) while very few came from the north and west. A quarter of the brooches are brass though in the five large groups this total varies from 17-35%. Attempts to find a correlation of composition with any typological trait has failed. At Baldock and Richborough more of the brooches with wire bows are brass and those with strip bows bronze, though the reverse is true at Hayling Island. Four of the five Belgian examples are bronze, one

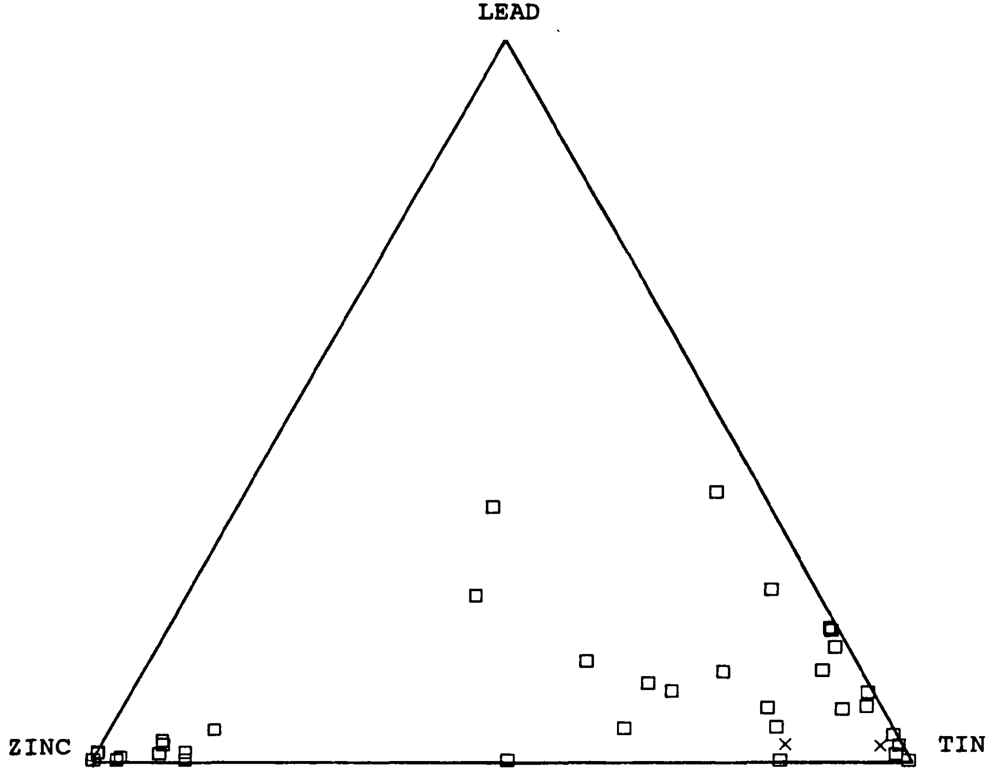

Figure 10.10 - Ternary diagram of AAS analyses of Nauheim derivative brooches (x = Continental example)

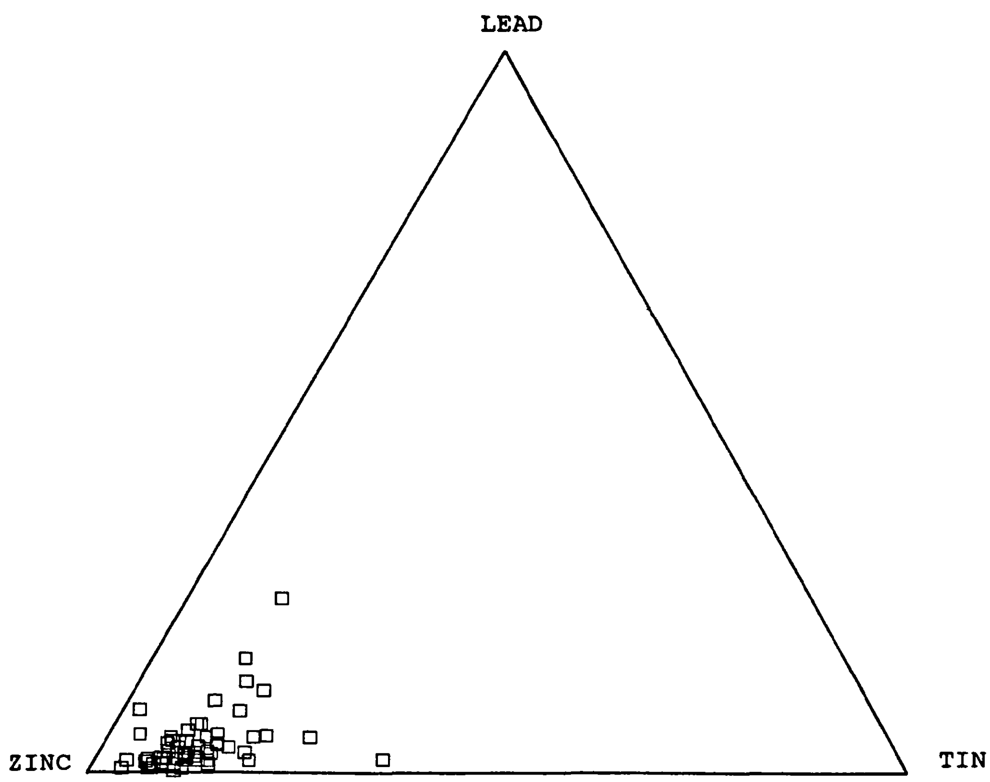

Figure 10.11 - Ternary diagram of AAS analyses of Group 2 brooches

gunmetal.

Group 2 (Types 21-28)

All these brooches have a head made of two flanges bent round into a cylinder holding a coiled spring which ends in the brooch pin. Two main varieties are recognised; Langton Down (T21) and its variants (T22), and thistle or rosette brooches (T25-27). There are a few brooches with an expanded foot (T23-24) and a few fantail brooches (T29A) with the same type of head. These brooches date to the mid 1st century and are found in pre-Conquest contexts but are almost certainly imports from the Continent where the same types are common.

All these brooches are brasses with minor amounts of tin (see Figure 10.11 and Table 10.12) but in a few cases the tin content is high enough to reclassify the alloy as a brass/gunmetal or a gunmetal. Lead content is mainly under 1.5% and only two brooches (out of 59) contain over 3% lead.

Group 3 (Types 29-38)

Although these brooches all have an expanded foot, other parts of the design of T29-T36 which demonstrate close parallels with types in other groups are of far greater significance. Figure 10.12 shows their compositions are dissimilar, which is because their grouping is only a modern classification and bears no relationship to design or production in Roman times. For this reason they are discussed together with related types in other Groups.

Table 10.9 - Group 3 brooch types

Type	Related group/type	
29A	2	T23-T24
29B	7	T121 etc
34	5	T94
35	8	
36	7	T146 mainly
37	-	T249?

\- - - - -

The one fantail brooch type with no obvious close relations is the Aesica brooch (T37) though its overall form may have derived from some of the simpler rosettes. The more highly decorated examples have elaborate Celtic style motifs showing a native British origin; some have soldered on metal foils carrying the decoration which is the tentative

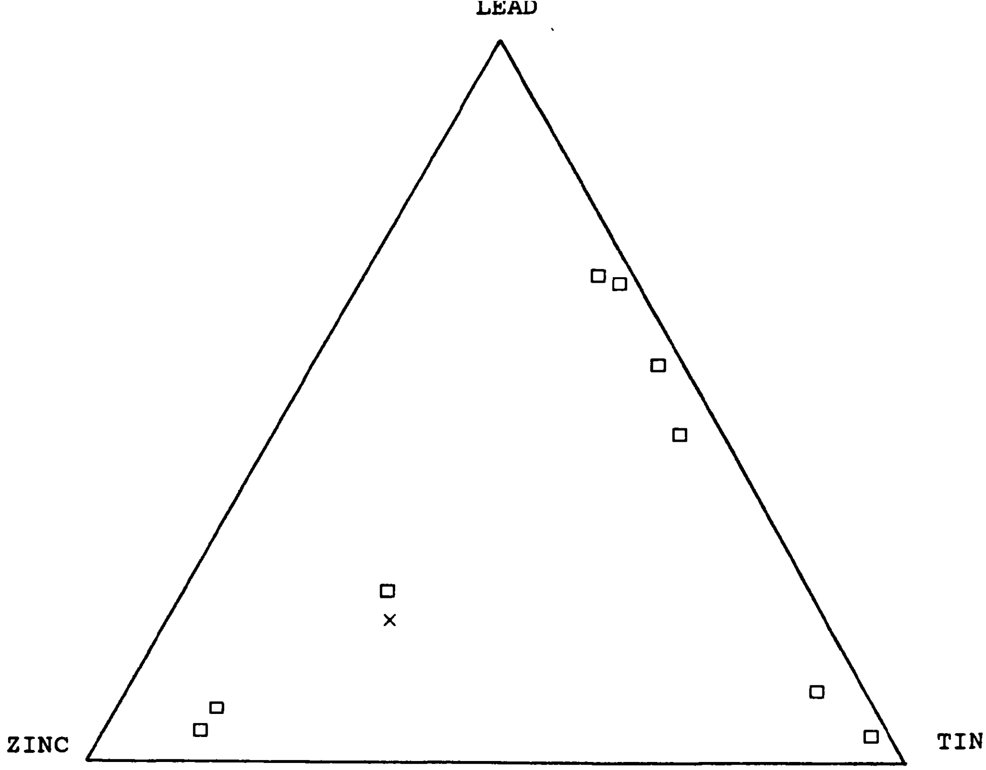

Figure 10.12 - Ternary diagram of AAS analyses of Group 3 brooches
(x = continental example)

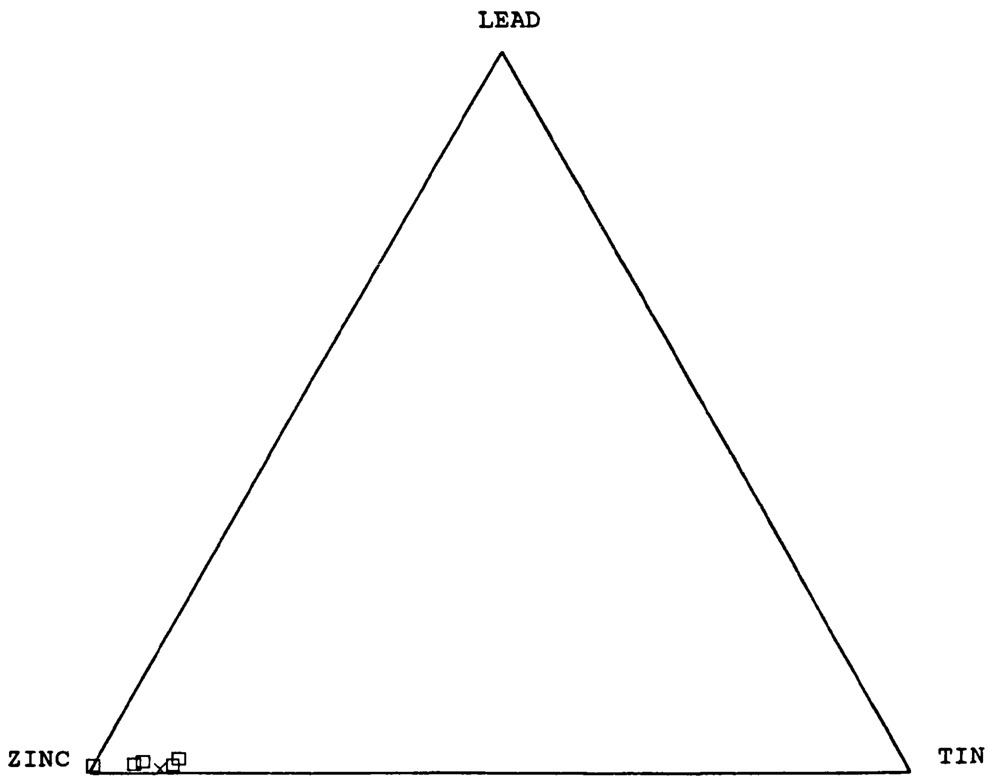

Figure 10.13 - Ternary diagram of AAS analyses of Group 4A (eye) brooches
(x = continental example)

link to T249. Most of these brooches are heavily leaded bronzes, an alloy that frequently occurs among British-made brooches (see below for fuller discussion).

<u>**Group 4A**</u> (Types 40-44)

The more decorated of these brooches have a pair of 'eyes' at the top of the head. They are one-piece brooches with the external chord of the spring held by a forward-facing hook. They are early 1st century AD continental types of which only a few have been found in Britain, mainly on sites occupied soon after the Conquest. All are high zinc brasses with low levels of tin (see Figure 10.13 and Table 10.12). The one Belgian example is compositionally indistinguishable from the rest.

<u>**Group 4B**</u> (Types 45-83)

These brooches all have the head rolled forward around an axis bar (often of iron) on which the pin is hinged.

Aucissas (T51) are, like the eye brooches, made of high zinc brass with minor amounts of tin though a few contain enough tin to be re-classified as gunmetals. Bagendon brooches (T52) are essentially Aucissa variants with divided bows and/or bows pierced by fine iron rods carrying copper alloy spheres; they too are brasses (see Figure 10.14). There are a few copies (T53) of these types which are as often made of bronze as brass; not all the copyists can have had access to the correct alloy.

Strip bows with the head rolled forward (T55-T58) are mainly brasses but do include two bronzes, a similar proportion of 'misfits' to those of the other strip bow types (T13-T20) which were mainly bronze with a few brasses. Two Belgian examples are a brass and a leaded bronze.

One of the largest groups of brooches in this study are the Hod Hills (T60-T80). They are typologically quite diverse, but with enough common features to show their coherence as a group. Many, perhaps even all, were once tinned all over or in part and a few were also decorated with niello or enamel. Compositionally they are far less uniform than the other Group 4 types with a spread of compositions from bronze to brass, but with a concentration at the zinc-rich end of the spectrum (see Figure 10.15). Here the gunmetals appear to be the outliers to the brass distribution while the bronzes are compositionally discrete. Despite the range of types and the range of compositions found, there is apparently no correlation between them. It would seem that the makers' intention was to produce a brass brooch but they were not always careful, or able, to use the right alloy; perhaps it was felt that if the brooch was to be tinned all over it did not matter as none of the bulk metal

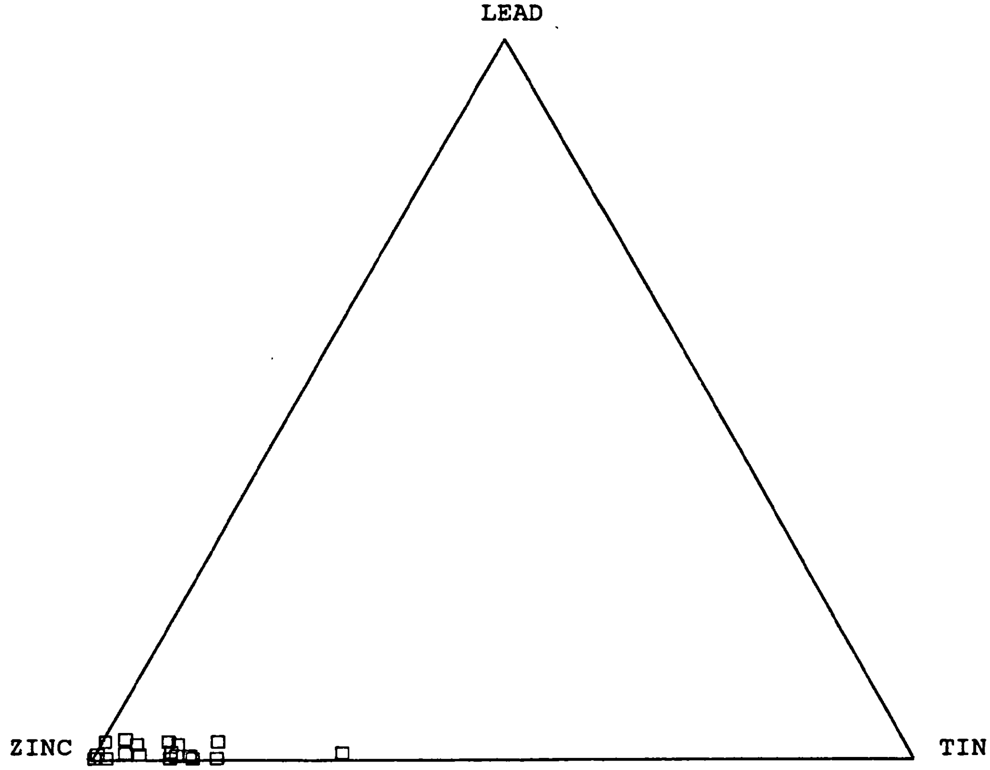

Figure 10.14 - Ternary diagram of AAS analyses of Aucissa and Bagendon brooches (T51-T52)

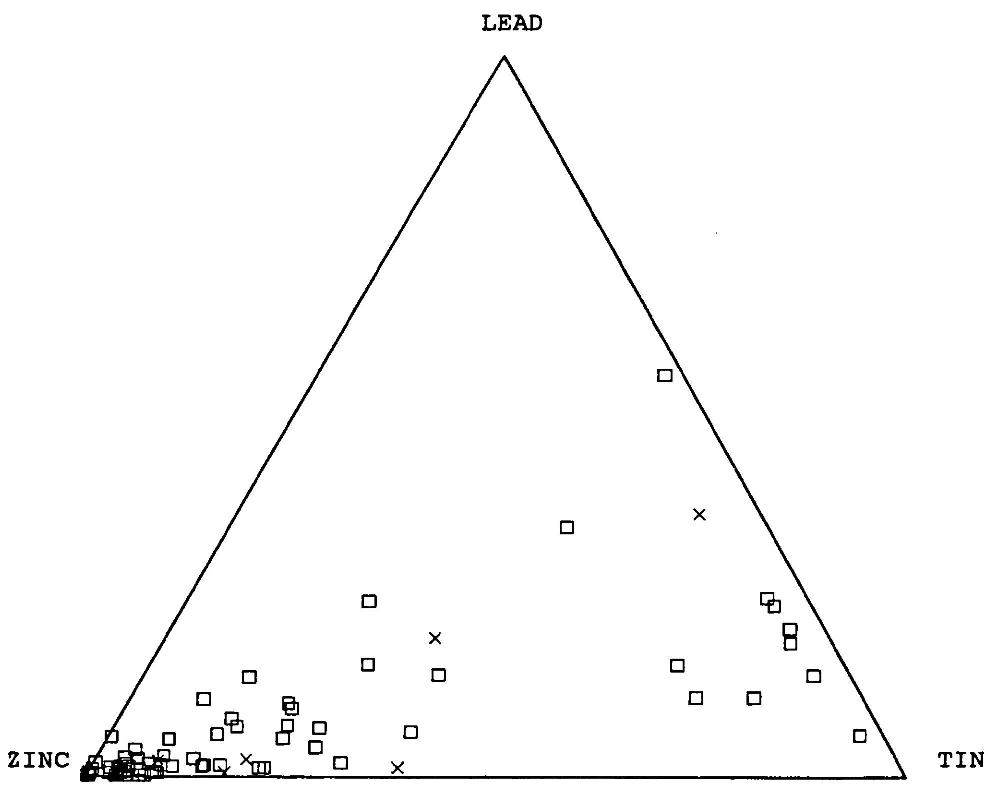

Figure 10.15 - Ternary diagram of AAS analyses of Hod Hill brooches (T60-T80) (x = continental example)

would show. A correlation of alloy composition with the presence of tinning cannot be reliably demonstrated, as when brooches are more than superficially corroded the tinning is often lost; Table C.3 records its survival, not its original presence. When new, many of these brooches must have had a quite striking bichrome effect; parcel-tinned brass would have looked as dramatic as parcel-gilt silver. Half the nine Belgian Hod Hill brooches are variants of types known in England but their compositions are typical for the group; all but one were brasses or gunmetals.

Group 5 (Types 84-94)

This group has the largest number of brooches, 20% of the total that can be identified to type. They have varied origins with kräftig-profilierte (T84) and Flügel Fibeln (T87) coming from south eastern Europe and Birdlip brooches (T88) being British copies of T87. The one-piece Colchester or Colchester A (T90) is a British type and both British (T91) and continental (T89) variants are also found. A later development is the so-called two-piece Colchester or Colchester B (T92) and its variants (T93) which were normally made of three pieces of metal, the main casting, a separate pin-spring whose chord went through a hole in the crest on the head of the brooch, and a thin rod which went through the coils of the spring and a second hole in the crest. The final type in this group is the Colchester derivative or dolphin brooch which had either a spring-pin held into the head of the brooch by one or more rearward-facing hooks (T94A) or a hinged pin (T94B).

The continental brooches are almost exclusively brass, like many of those types discussed above, but T88 are mainly bronze. Despite their British origin most of the Colchester A brooches are high zinc brass with a little tin; there are no significant differences between the brasses of the main type and the variants, but about 10% of T90-T91 are bronzes and gunmetals. These are not outliers to the main distribution but a discrete scatter (see Figure 10.16). T90-T91 brooches from 29 sites were analysed and non-brass examples were found from 12 of them. Figure 10.17 shows their distribution is not a random scatter; nearly half the total came from Richborough with only Hayling Island, Wroxeter and Gorhambury also producing more than a single example.

Nearly three quarters of T92-T93 are heavily leaded bronzes which make quite a tight cluster, though with a number of outliers containing enough zinc to reclassify them as leaded gunmetals. There are also unleaded bronzes in a separate group which make up 16% of the total, as well as a few gunmetals (see Fig 10.18). As with the bronze T90-T91,

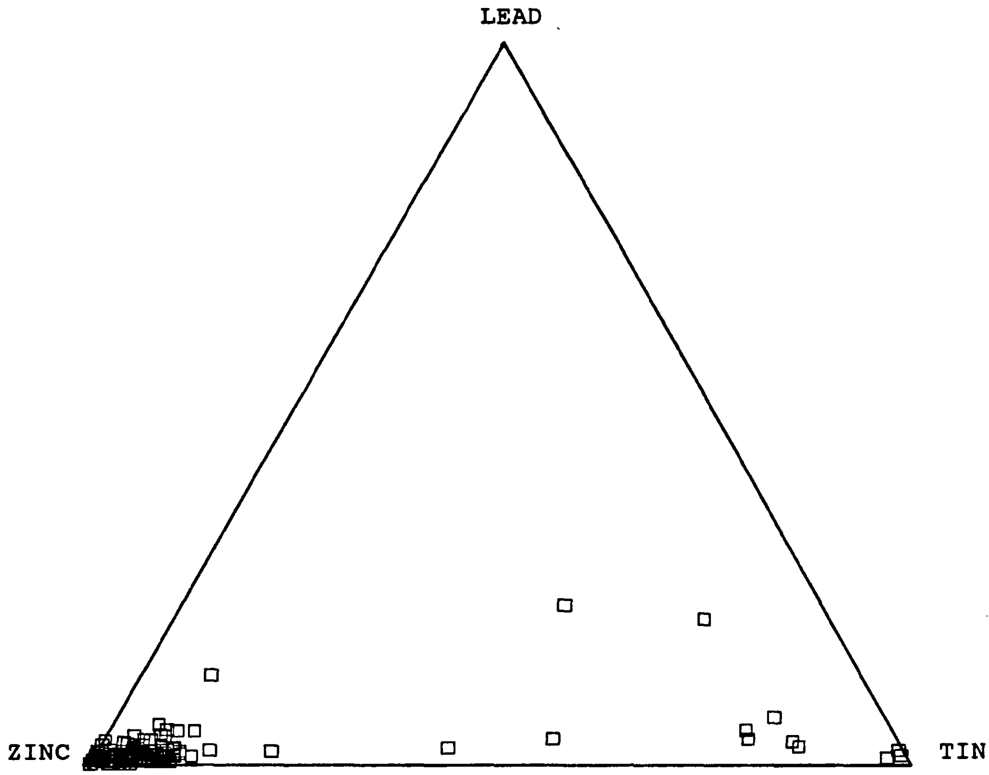

Figure 10.16 - Ternary diagram of AAS analyses of Colchester A brooches (T89-T91) (x = continental example)

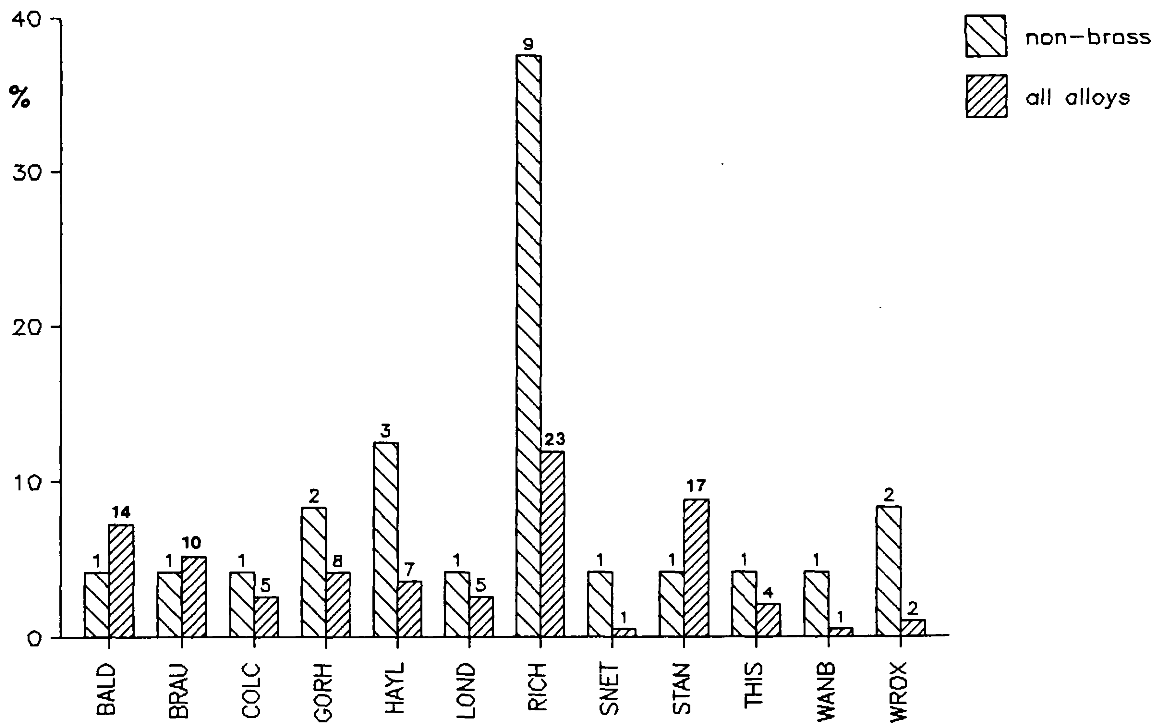

Figure 10.17 - Histogram showing the percentage of non-brass T90-T91 brooches from each site that produced examples, compared with the percentage of all T90-T91 brooches coming from that site. The number of brooches represented by each bar is written above it
See Table C.1 for the key to the codes for sites

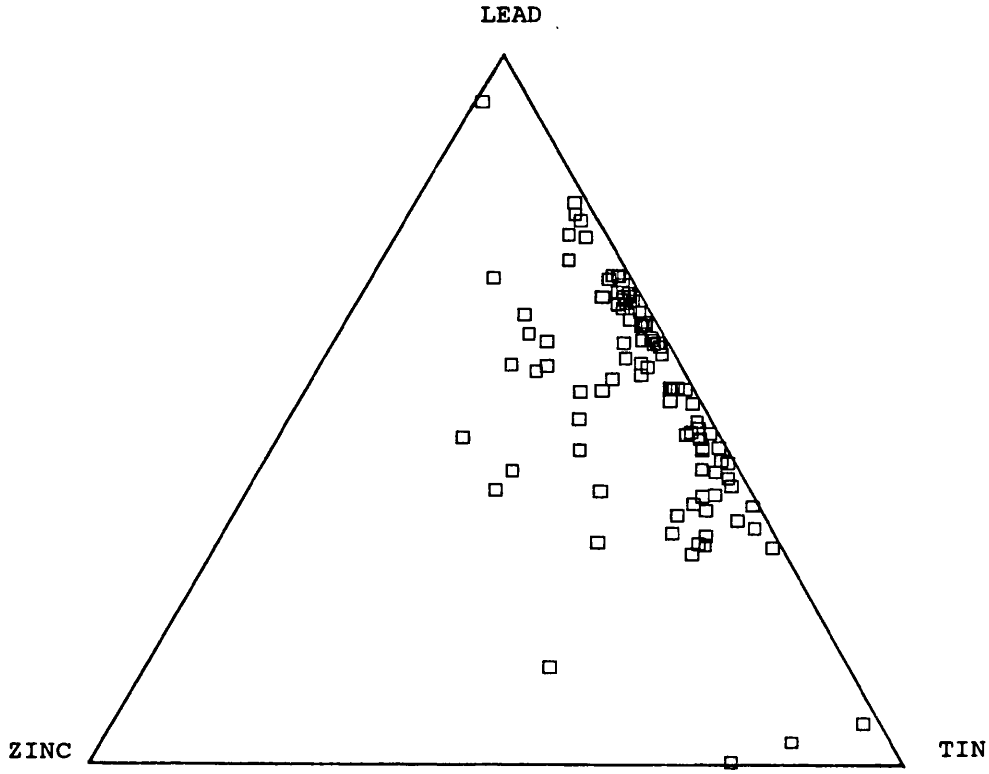

Figure 10.18 - Ternary diagram of AAS analyses of Colchester B brooches (T92-T93)

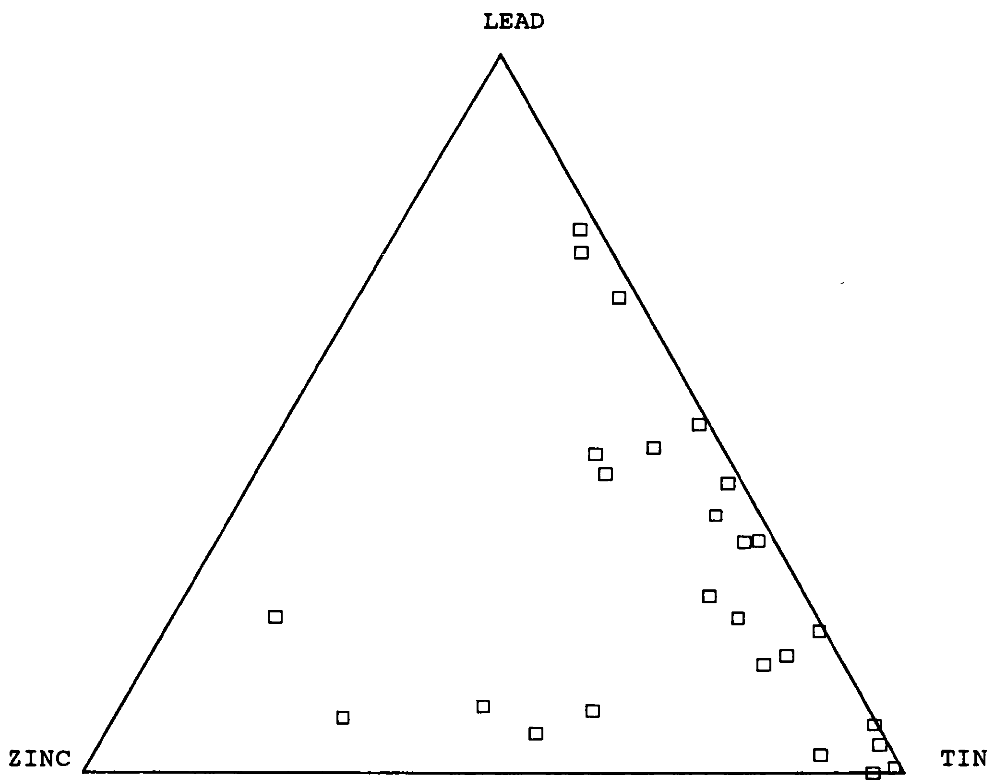

Figure 10.19 - Ternary diagram of AAS analyses of T94 (dolphin) brooches

the distribution among sites is not even; half the unleaded T92-T93 come from London though it produced less than 20% of the brooches of these types.

T92-T93 brooches developed from the earlier T89-T91 type in the third quarter of the 1st century. The only major difference is in the spring-pin mechanism which is made separately in the later type. It can be seen that this change in design went hand in hand with a major change in the alloy used. Leaded bronzes could not have been used for T89-T91 as it would have been impossible to form the metal into the spring-pin which was an integral part of the brooch. It is impossible to tell if a sudden lack of brass led to the new design or whether the new design came first and allowed the use of the leaded alloys. I believe the former explanation is more likely and that unleaded bronze examples of T90-T91 and T92-T93 belong to the change-over period; the concentration of bronzes on a few sites may be a clue to the source of these compositional variants though no evidence of manufacture has been found. The sequence of events may have run: with brass not available, use bronze; if using bronze, why not change the design to allow the use of leaded bronze; use leaded bronze (some mixed with a little brass) for the new design.

T94 is not a very uniform group, either typologically or compositionally. It developed around the same time as T92-T93 and represents alternative methods of attaching the pin to a body derived from that of the Colchester A brooch. About half have rearward-facing hooks holding the spring-pin in place behind the head, while the rest have a hinged pin. The former was not a very robust mechanism and does not appear to have had a long life. It may have been a local development as most examples come from the east Midlands and East Anglia. Half the brooches are bronzes and another third leaded bronzes, both part of a single group spanning a wide range of lead contents; there are also a few brasses and gunmetals (see Figure 10.19). There are no significant differences in the alloys used for brooches with different spring mechanisms.

<u>Group 6</u> (Types 95-103)

These so-called Polden Hill brooches represent a further group of Colchester derivatives with another, rather more effective, method of attaching the spring-pin. It is held securely inside the head by an axis bar passing through the coils of the spring and also through both ends of the head; in general appearance they are similar to T94.

Compositionally these brooches are similar to the T92-T93 ones (see Table 12.13) though there are virtually no leaded gunmetals.

Figure 10.20 shows that, in contrast to T94, there is a concentration at the lead-rich end of the bronze-leaded bronze continuum. The few brasses are rather purer than the T94 ones but are not associated with any particular type, though T97 brooches, classified as 'light and slender' by Hull, appear to be mainly unleaded and may be wrought rather than cast. The few gunmetals do not appear to be outliers of either the brasses or bronzes.

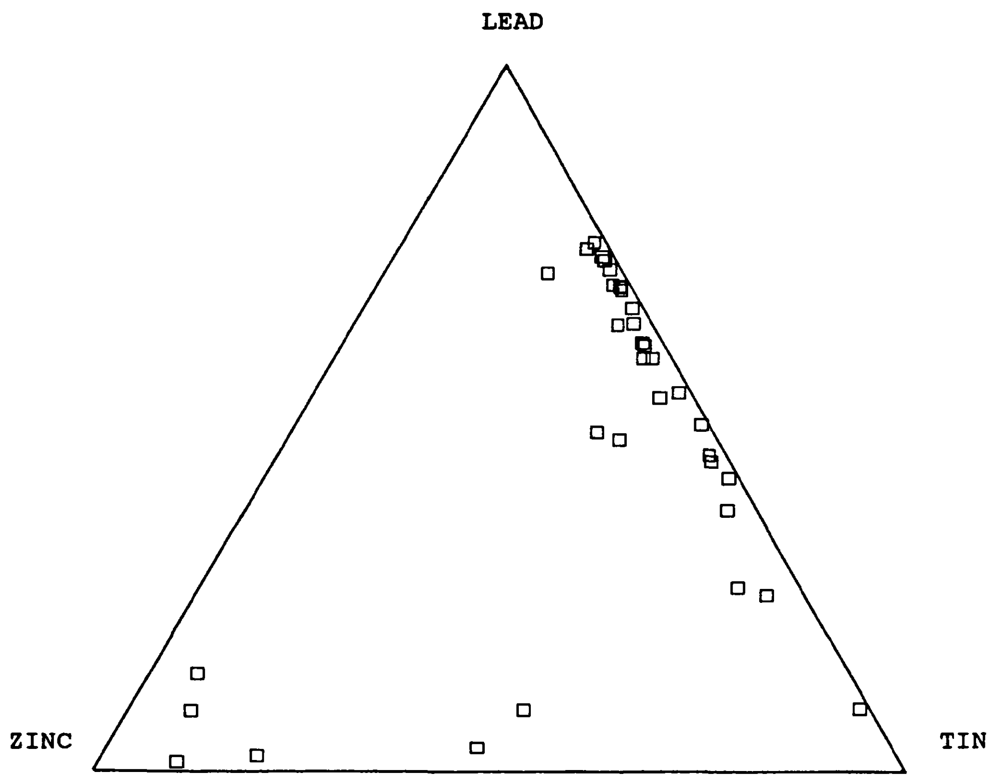

Figure 10.20 - Ternary diagram of AAS analyses of Group 6 (Polden Hill) brooches

Group 7 (Types 104-152)

The majority of these brooches are T-shaped and have hinged pins though a minority have a sprung mechanism. Many clearly derive from Colchester brooches but others show influences from Polden Hill and trumpet brooches. Sarnia Butcher (personal communication, 1991) has suggested that the many varieties represent cross-influences rather than an orderly typological development. This makes definite assignment to a particular type more difficult than for brooches in most other groups (cf the relatively large number of Group 7 brooches without a type number in Table C.3). She has also suggested that Group 7 be divided into a number of sub-groups which share common typological traits and distributions; these sub-groups correspond to compositional groups that have been identified.

The first sub-group is the Applied Hook series (T112-T117) which has a southerly distribution. The brooches mainly have very low lead contents and a range of brass to gunmetal compositions (Figure 10.21). Their method of construction is also quite different from that of the other T-shaped brooches, showing they have different origins despite some superficial similarities.

The T-shaped Colchester derivatives (T104, T118, T121, T123-T125, T130 and T133-T136) and the related but more developed types with Polden Hill and trumpet features (T105-T111, T119-T120, T122, T126-T129, T131-T132, T138-T142 and T144) are found almost exclusively in south-west England and Romanised south Wales and are thus thought to have been made in this region, a hypothesis supported by the discovery of moulds for making T-shaped brooches at Compton Dando, on the Mendips (AML 4639). Among a small group of the fragments were moulds for T111, T121B? and 149B. Although there is considerable typological variation in this group, they are compositionally very uniform; the vast majority are leaded bronzes (Figure 10.22). The T-shaped Colchester derivatives and T138-140 are not enamelled though many of the developed types are.

A few types are found mainly in the Midlands and north Wales; these include both Colchester derivatives (T137 and T146) and developed brooches (T150-T152). Although leaded bronzes predominate, lead levels are lower (see Table 10.13) and other alloys are used more frequently than for the south-western types. T151-T152 are not typical Group 7 brooches. Described by Hull as Wroxeter and Prestatyn types respectively they are compositionally and typologically diverse (see Figure 10.23) with no clear correlation between the two.

Other T-shaped brooches, which are all British-made types, appear to have a variety of origins on the basis of their find spots. Most of these other brooches have a headloop, either a loose one that is attached to or part of the hinge mechanism, or a fixed one that is part of the main brooch casting. These brooches are occasionally found in pairs, joined by a decorative chain attached to the headloops which thus seem to be more than purely decorative features. Some brooches have unperforated fixed headloops, suggesting they are later developments where the headloop is no longer a functional feature. This type of evidence helps provide relative dating though the difference may represent a changed quality of production as much as a later date. Brooches with loose headloops may have sprung or hinged pins while those with fixed headloops are invariably hinged.

The headstud series (T143A, T145, T147-T149) emerged towards the end of the 1st century though use continued into the 2nd century. The

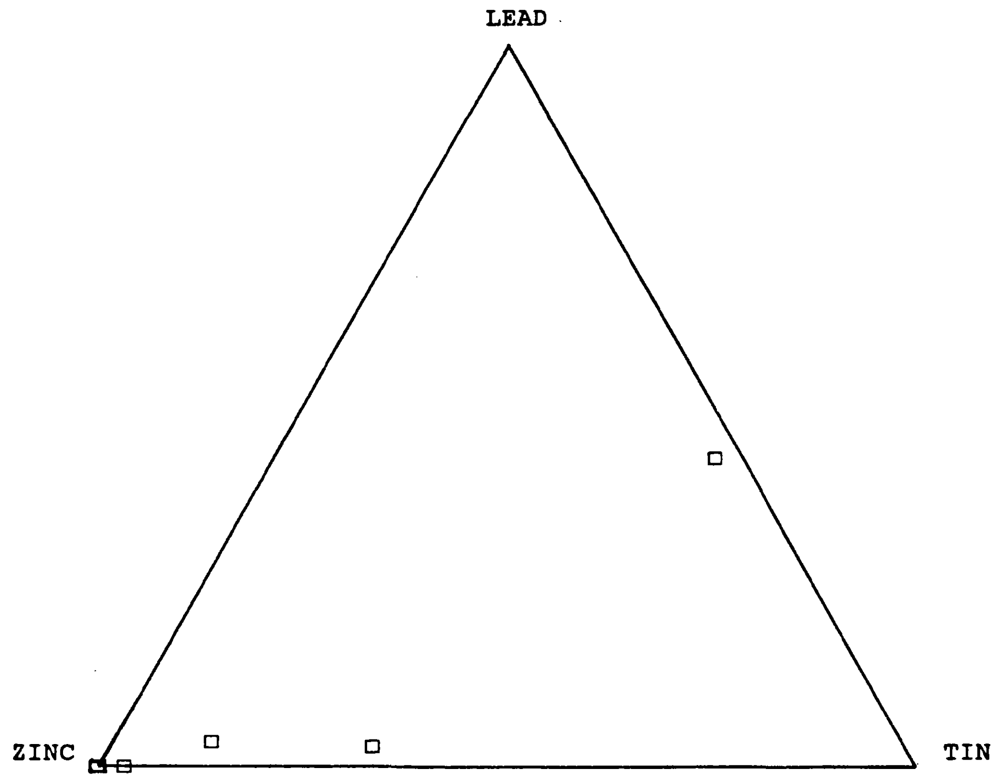

Figure 10.21 - Ternary diagram of AAS analyses of applied hook brooches (T112-T117)

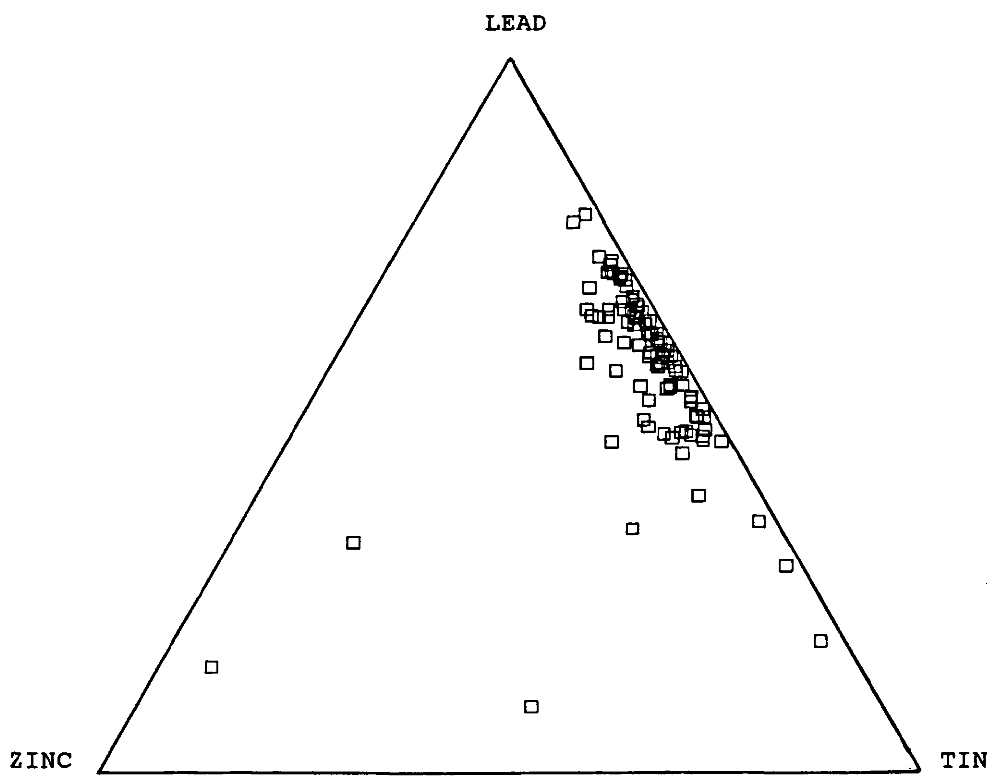

Figure 10.22 - Ternary diagram of AAS analyses of south-western T-shaped brooches

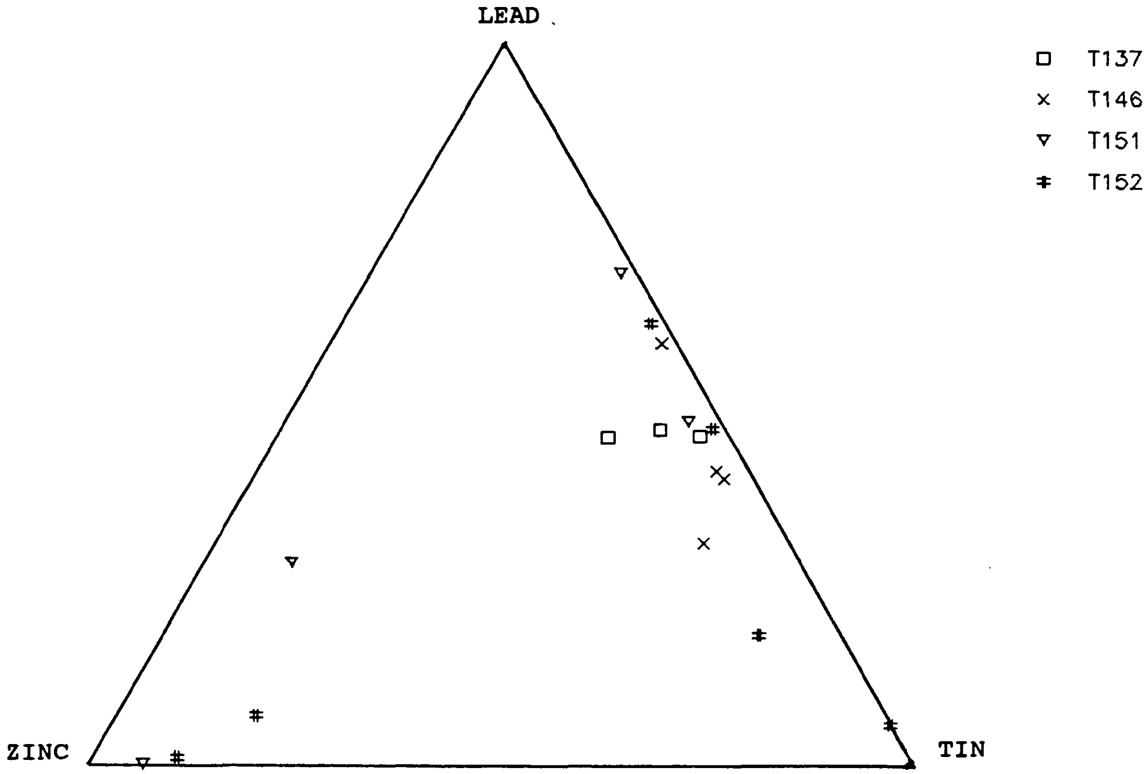

Figure 10.23 - Ternary diagram of AAS analyses of T-shaped brooches of types found mainly in the Midlands and North Wales

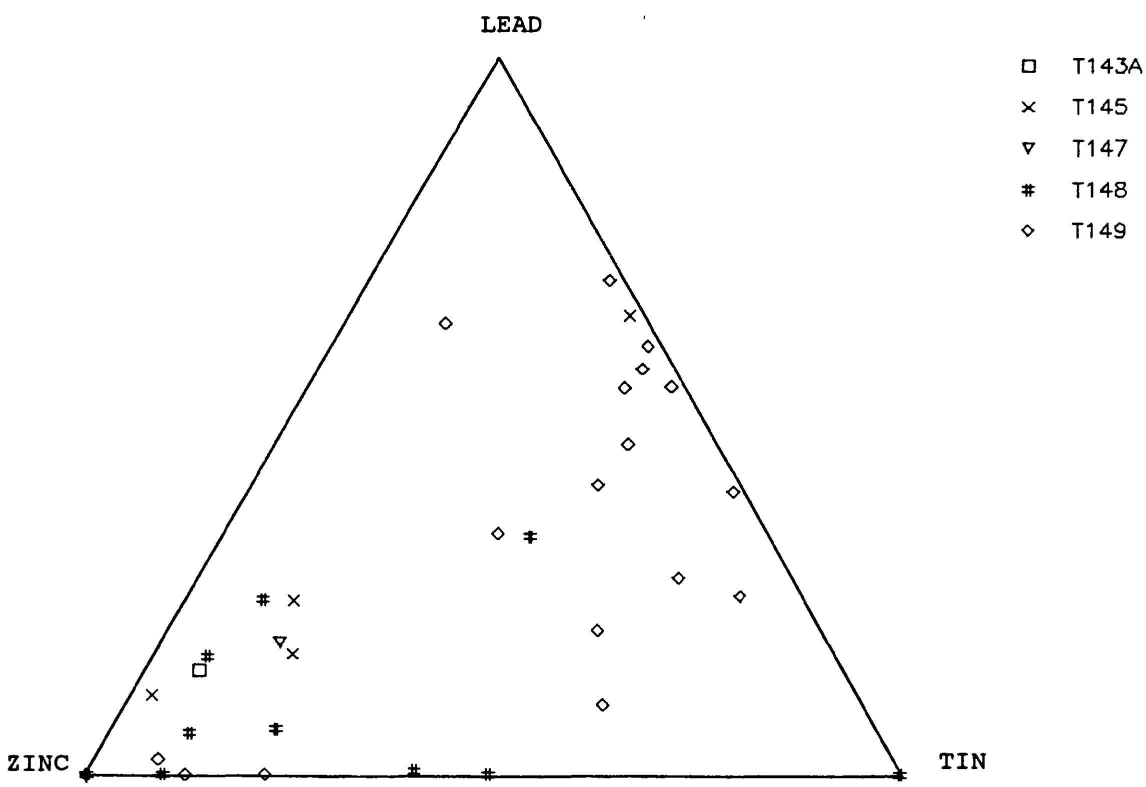

Figure 10.24 - Ternary diagram of AAS analyses of headstud brooches

(mainly) brasses and gunmetals of T147-T148, which have loose headloops, are generally considered earlier than T149 with fixed headloops which are predominantly bronzes and leaded bronzes. A related headstud type is T145 which was probably slightly earlier still, being produced in the third quarter of the 1st century; analysed examples are mainly brasses and gunmetals (see Figure 10.24).

The brass and gunmetal headstuds have higher lead contents than earlier brasses (see Table 10.12) while T149 brooches have less lead and more zinc than other Group 7 leaded bronzes (see Table 10.13); a few are even reclassified as gunmetals. The pairing of brass or gunmetal with loose headloops and leaded bronze with fixed headloops also occurs in Group 8 (see below).

<u>Group 8</u> (Types 153-170)

These brooches, distinctive products of Roman Britain, had developed fully by 75 AD (Boon and Savory 1975). They can be divided into the Backworth series of true trumpet brooches (T153-T160) and the related, trumpet-headed brooches (T161-T170).

Discussion with Sarnia Butcher has suggested that Hull's primary typological division, which depended on the nature of the moulding of the button in the middle of the bow, is not a helpful one in grouping like brooches together and discussing their development and use. Figure 10.8 shows, for example, that T153 contains two compositional sub-groups while T158 can also be sub-divided on the basis of distinct alloy compositions. It is therefore proposed that major divisions should be based on whether the headloop is loose or fixed, the pin hinged or sprung, and the waist moulding full-round or flat at the back.

A standard undecorated trumpet brooch (trumpet A) can then be defined with sprung pin, loose headloop and full-round waist moulding, which corresponds to Hull's T153A-C and T158A - most of these are brasses or gunmetals (see Figure 10.25). This would appear to be a long lived type with later 1st century origins but flourishing well into the 2nd century. It appears to be native to the northern, military areas of Britain.

A second group of trumpet brooches are the devolved plain ones with fixed headloops and half-round waist mouldings (trumpet B, Hull's T153D and T158D-F) which are leaded bronzes (see Figure 10.26). These have a more southern and western distribution.

A further group of devolved imitations (trumpet C, T154 and T159) are all leaded bronzes whether they have loose or fixed headloops. They have lower tin and higher lead contents on average than the trumpet

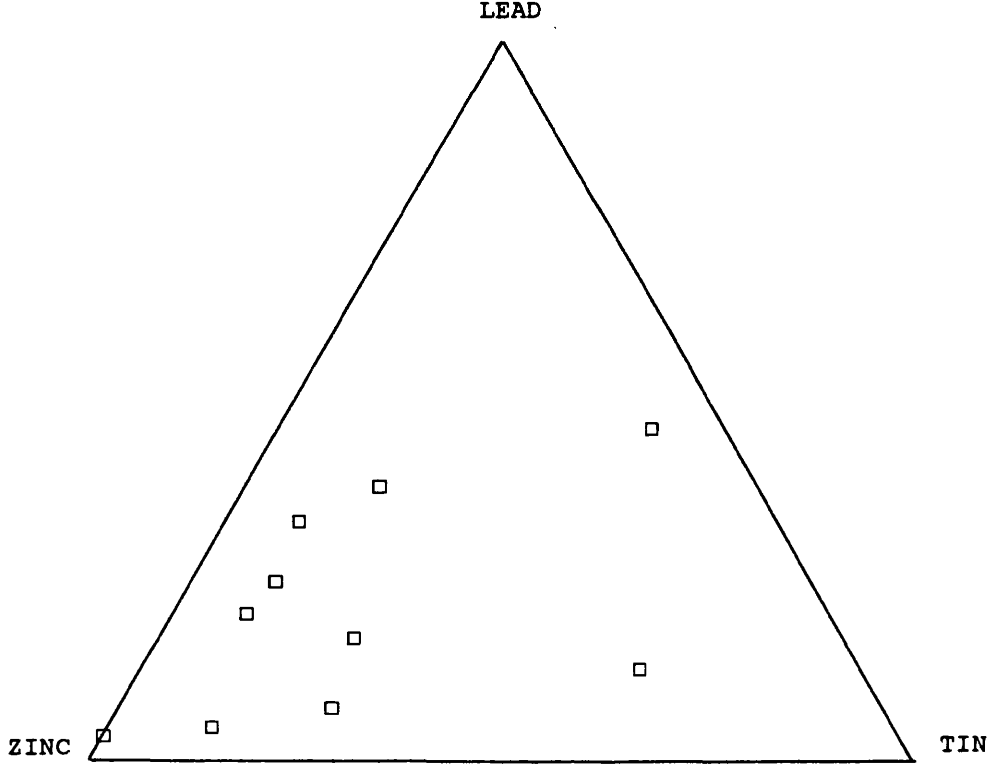

Figure 10.25 - Ternary diagram of AAS analyses of trumpet A brooches

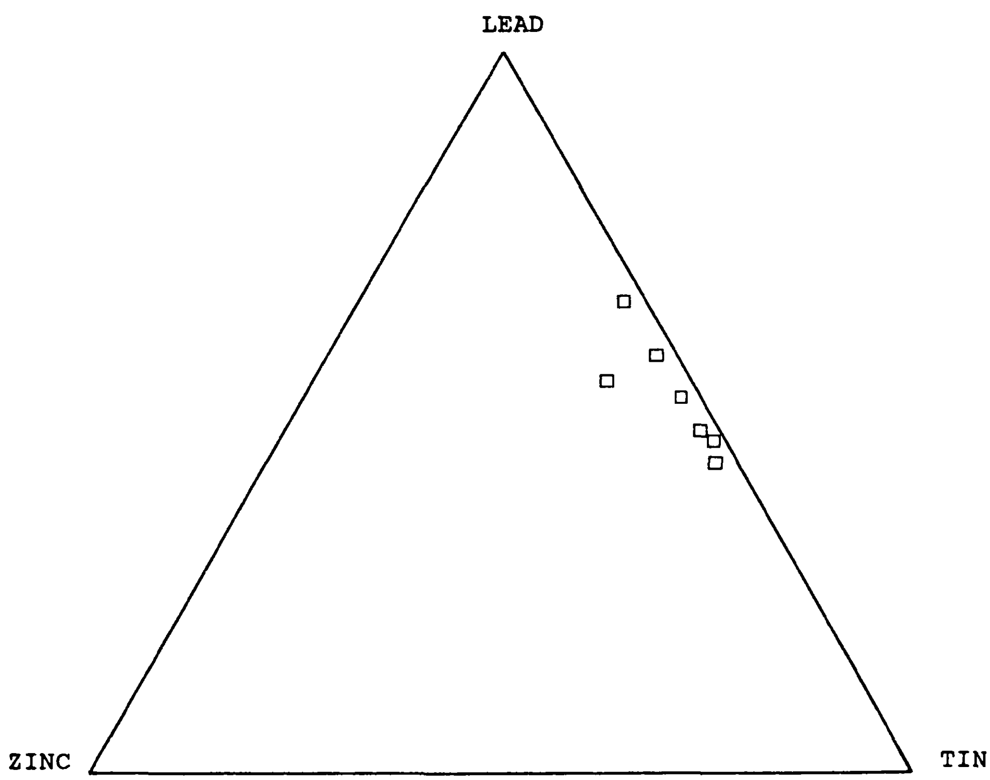

Figure 10.26 - Ternary diagram of AAS analyses of trumpet B brooches

B leaded bronzes (see Table 10.13) which explains the shift in the distribution of points towards the lead end of the tin-lead side in the ternary diagram (see Figure 10.27).

The decorated trumpets (trumpet D, T157) are a far smaller group which display a high degree of craftsmanship with a number of distinctive patterns of enamelling identified. Some of these patterns can be paralleled on the Group 7 headstuds as can the use of applied silver wire. Most are of unleaded alloys with brass predominating.

The assorted trumpet-headed brooches (trumpet E) mainly have low lead contents with zinc-rich alloys predominating, comparable to those used for T157 (Figure 10.28). The few quantitative results suggest this is not a tight compositional group but that the craftsmen making these decorative brooches favoured the golden colour that zinc-rich alloys provided. The use of enamel and, on T166-T168, applied silver wire is widespread. Some of the Group 3 brooches (T35) have T-shaped heads but are closely related when their decorative schemes are considered, though the two analysed examples are bronze and leaded bronze like a small proportion of the trumpet E brooches.

__Group 9__ (Types 171-179)

These knee brooches are mainly leaded bronzes with high lead contents; exceptions are T171 and T173A (see Figure 10.29). In the former unleaded or (leaded) bronzes predominate and brasses decorated with enamel and applied silver wires are also known. T173A are mainly brasses and are also often decorated with applied silver wire or foils in similar designs to some of the trumpet D and trumpet E brooches suggesting they may have been made in the same workshops. These Group 8 and 9 brasses all have much lower zinc contents than early brass brooches (see Table 12.12 and Figure 10.40).

__Group 10__ (Types 180-183)

These brooches sit between the Hod Hill types (T60-T79), from which they presumably derived, and the 'equal ended' plate brooches (T229-T233) with which they share decorative schemes though still retaining the hinged head of a bow brooch; all have a continental origin. The Group 10 brooches and the T229-T233 plate brooches show a similar compositional range which runs from impure brass to gunmetal and leaded gunmetal (Figure 10.30).

Eight of the Belgian brooches were of these types. Note the 'continental' points on Figure 10.30 are for T182, T227 and T229. In all cases they are compositionally similar to the English examples of the

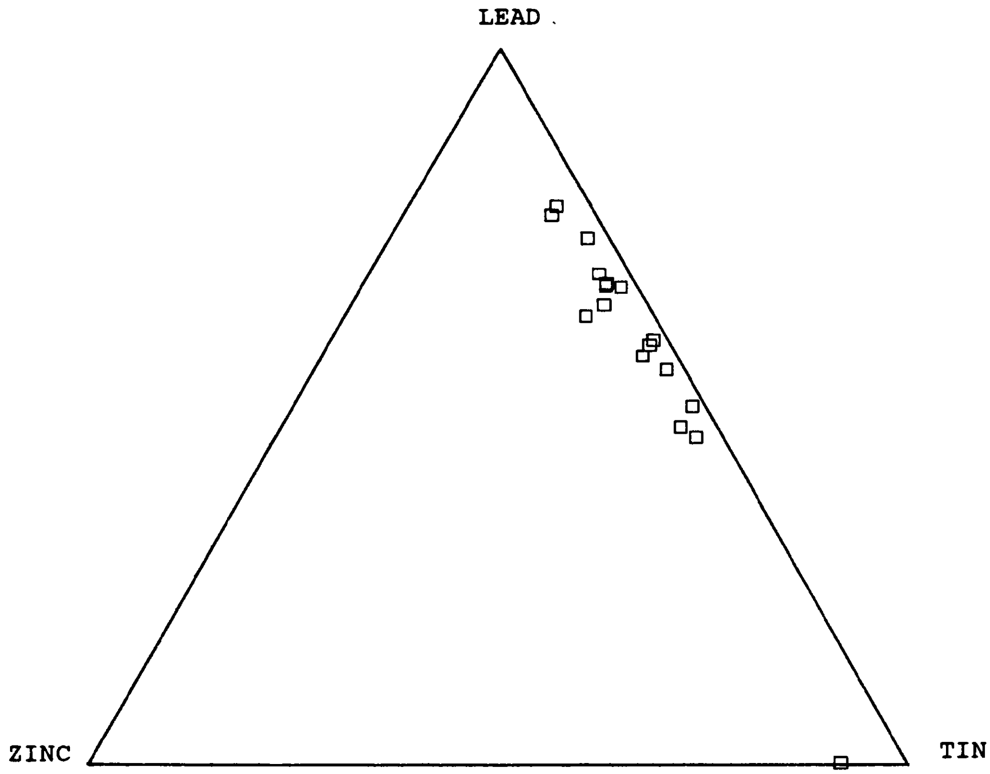

Figure 10.27 - Ternary diagram of AAS analyses of trumpet C brooches

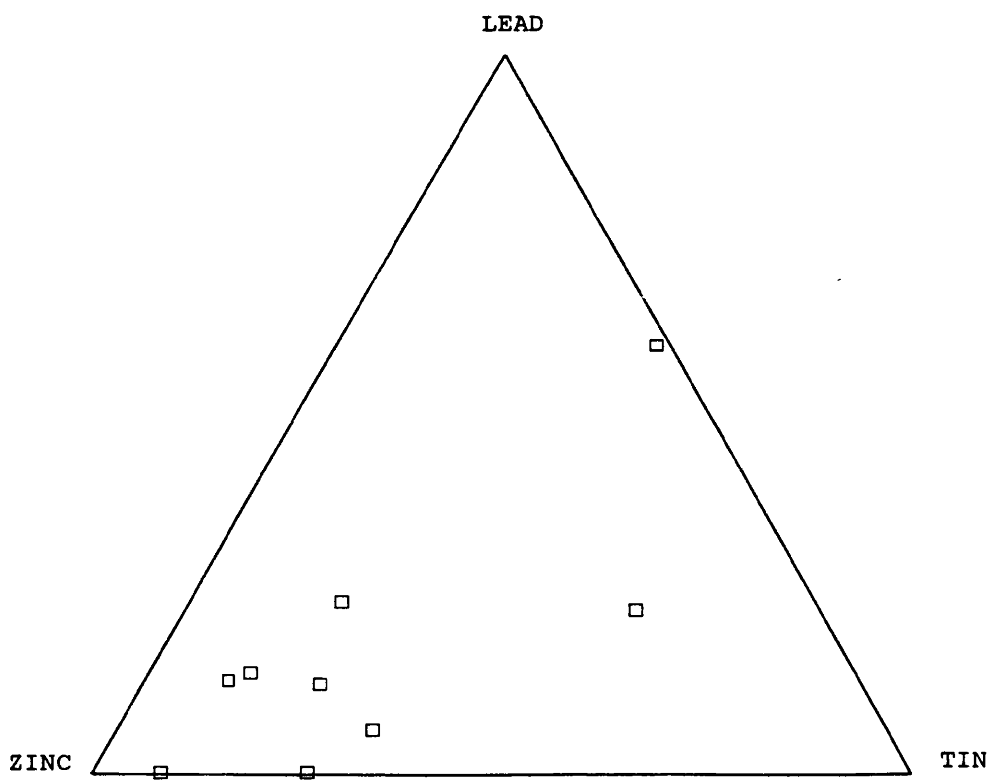

Figure 10.28 - Ternary diagram of AAS analyses of trumpet-headed (trumpet E) brooches

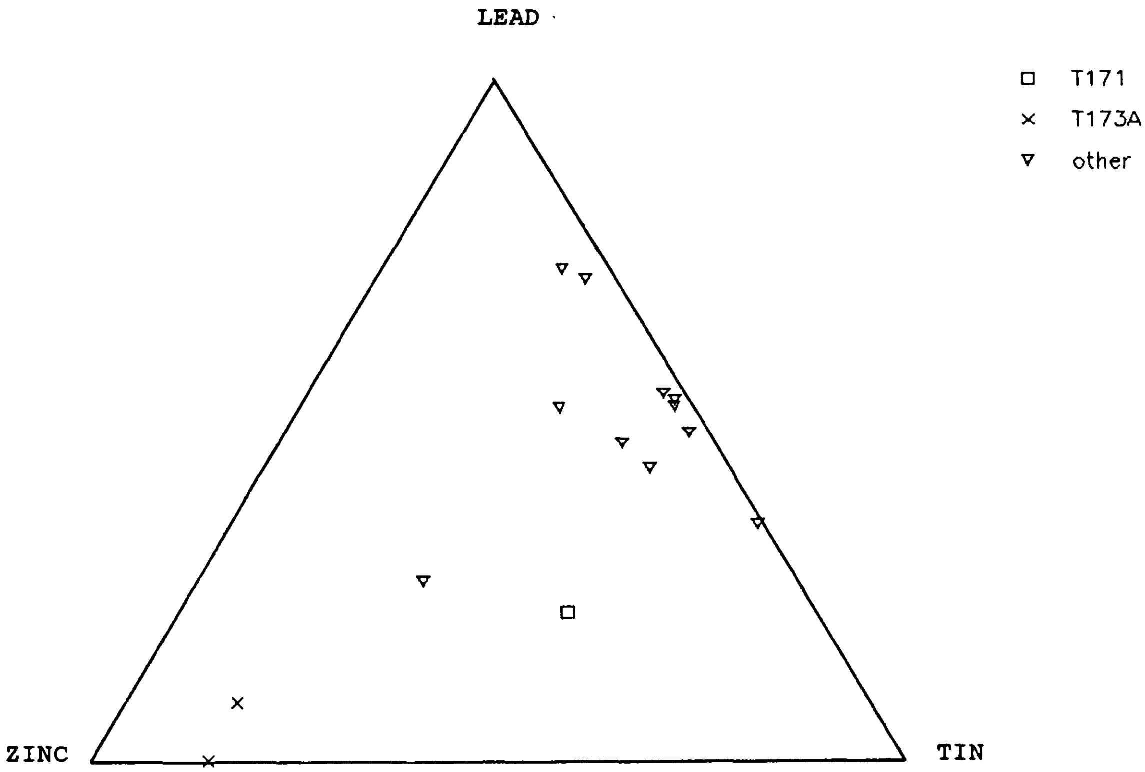

Figure 10.29 - Ternary diagram of AAS analyses of Group 9 (knee) brooches

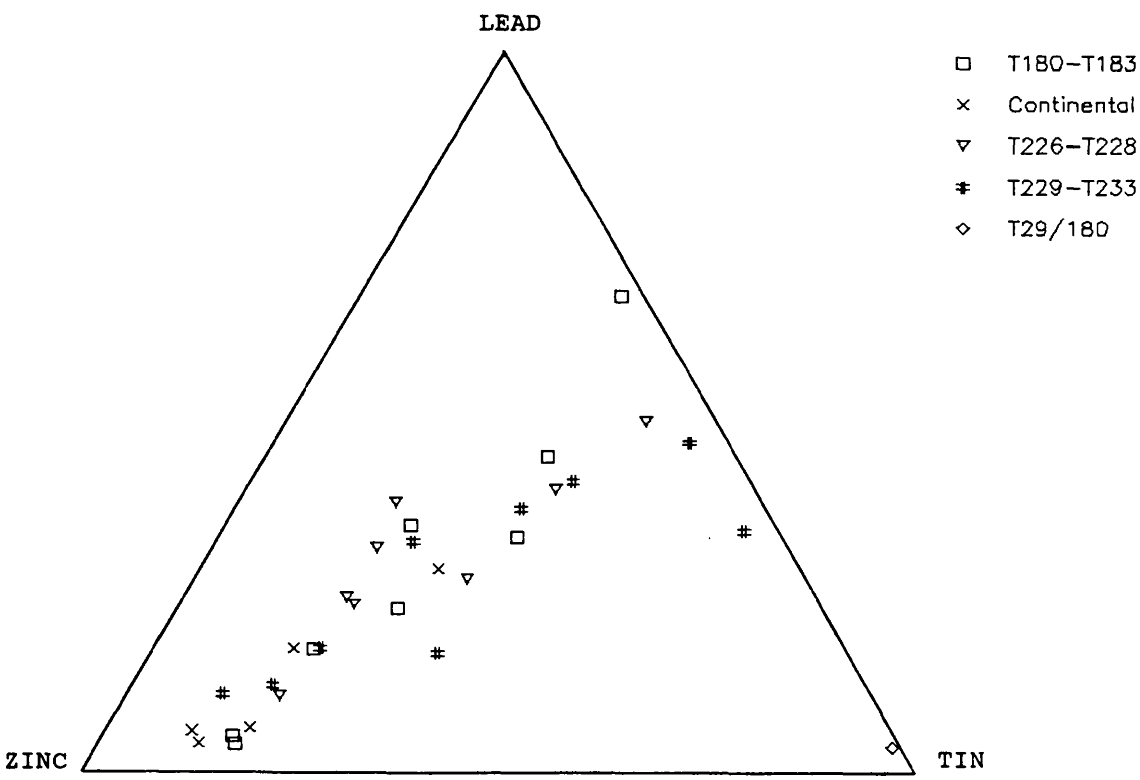

Figure 10.30 - Ternary diagram of AAS analyses of Group 10 and related plate brooches (T180-T183 and T229-T233)

same types.

<u>Group 11</u> (Types 184-198)

These brooches all belong to the 3rd and 4th centuries with the higher type numbers being later, though there appears to have been a considerable degree of overlap with different types being used concurrently. Many of these brooches were gilded and/or tinned and they include the only silver bow brooches seen in the course of this study. Solid gold examples of T192 are known (Kent and Painter 1977). The gilding all appears to be mercury gilding, where sufficient of it survives to tell, and these gilded objects are all low in lead and high in copper though otherwise of variable composition; parallels can be drawn with the gilded Romanesque castings (Figure 10.6). It is likely that many of the other unleaded brooches in this group were also originally gilded though no traces of it now survive.

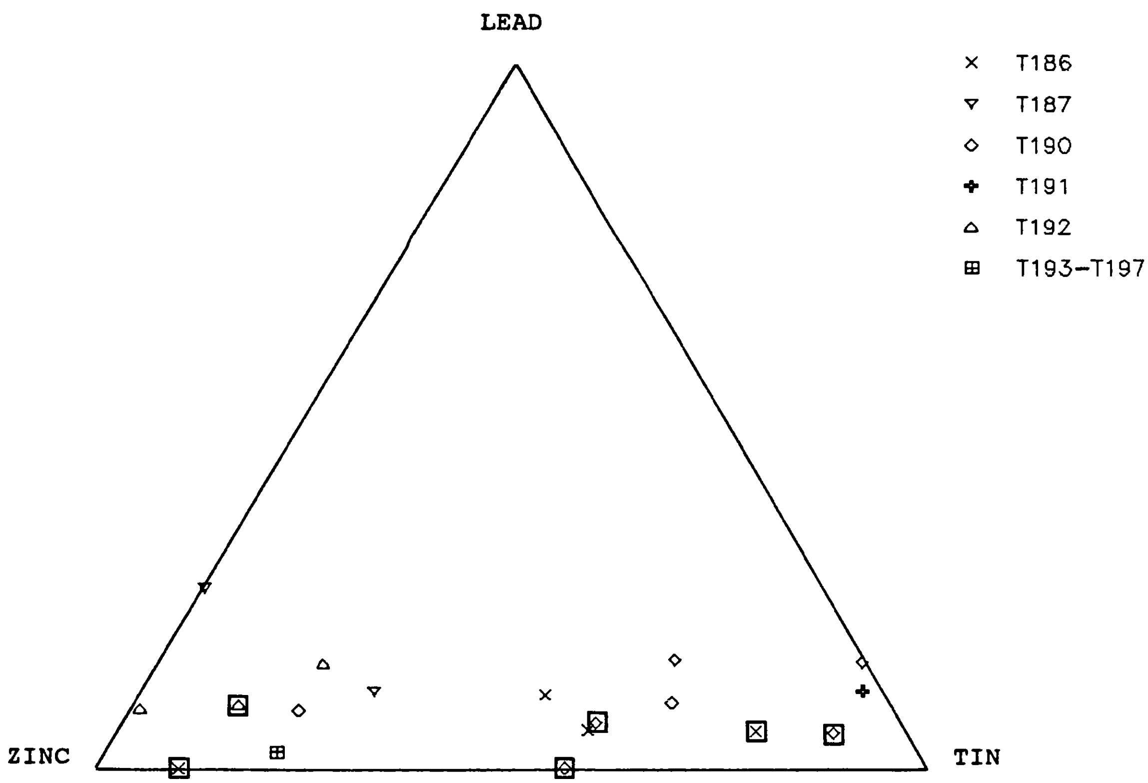

Figure 10.31 - Ternary diagram of AAS analyses of Group 11 brooches with lead <2% that are, or probably were, mercury gilded
(□ = gilding survives)

The majority of brooches (if the gilded and probably once gilded ones are excluded) are leaded bronzes. The only major exception to this are the T189 and T192 leaded brasses, a distinct late Roman alloy type (Figures 10.31-10.33). It appears that the necessity to provide a suitable alloy for gilding overrode any other consideration. The

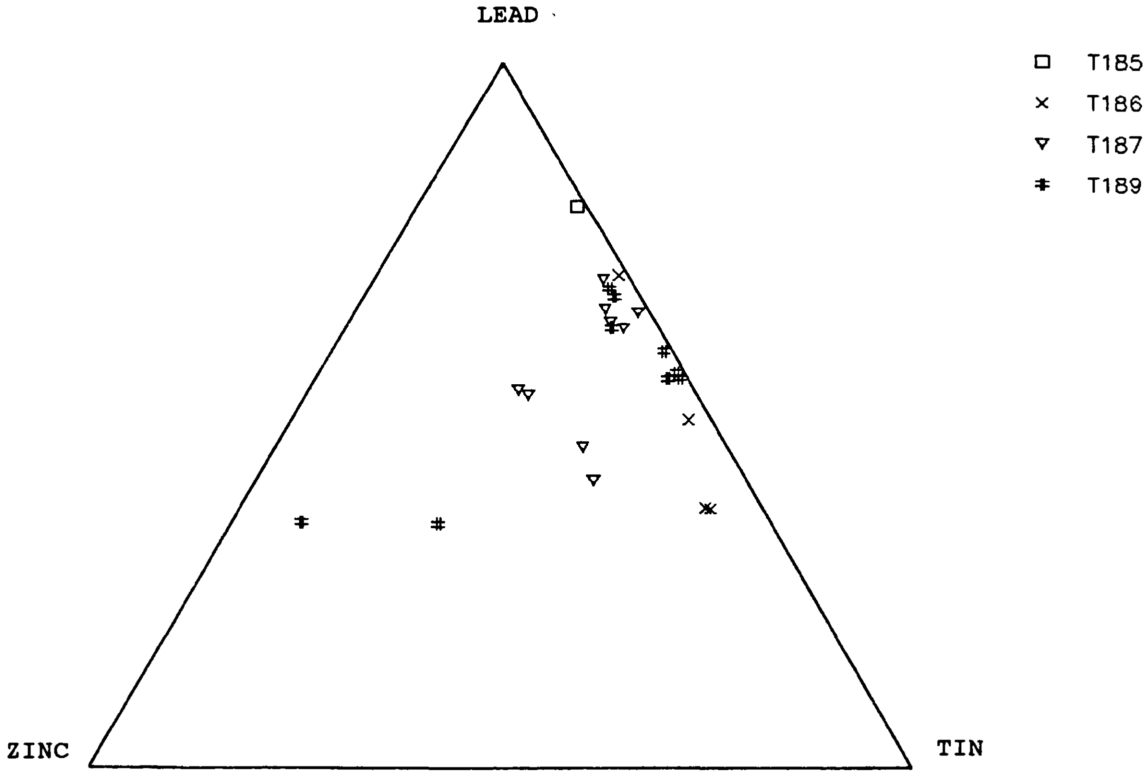

Figure 10.32 - Ternary diagram of AAS analyses of sheath-footed brooches (T185-T189) with lead >2%

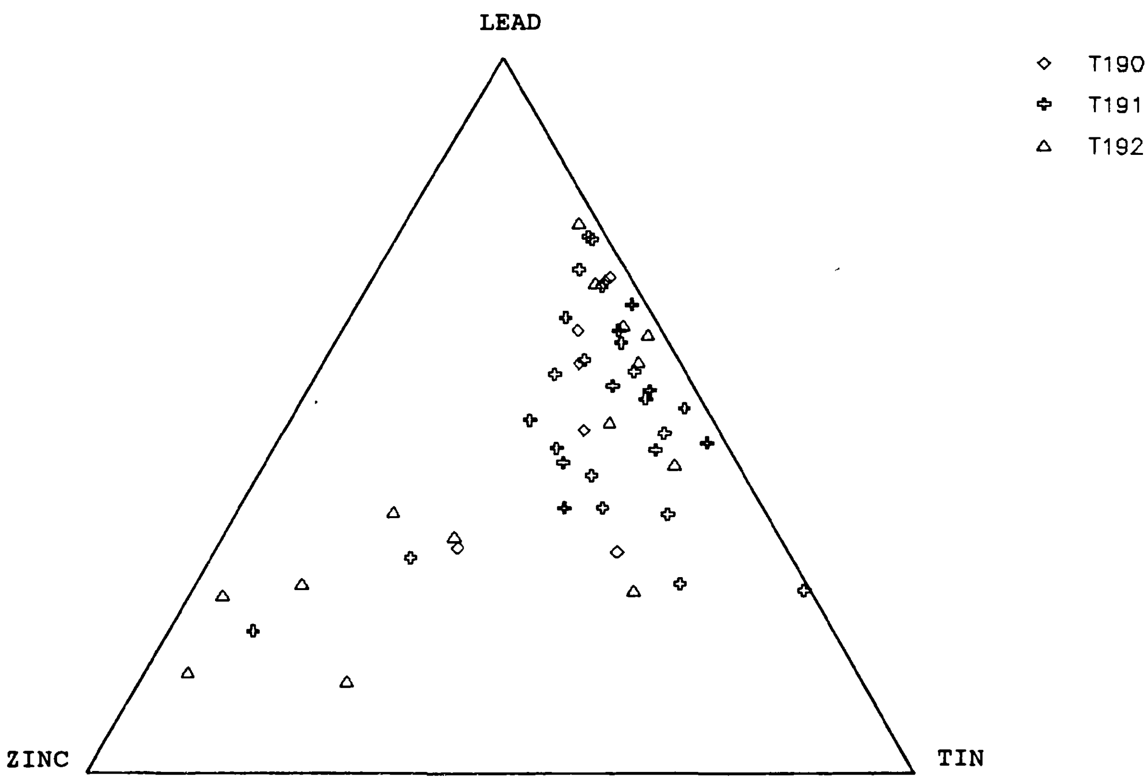

Figure 10.33 - Ternary diagram of AAS analyses of crossbow brooches (T190-T192) with lead >2%

compositional homogeneity of the ungilded ones is remarkable, given the long period of currency of these types.

The finds of fragments that can be assigned to T192 include a number of screw terminals with sheet metal knobs which were part of the pin-fixing mechanism. All were made of brass, presumably because of its malleability, and then gilded (as far as one can tell). They would have been used on any of the gilded brooches which are made of a wider range of low-lead alloys.

Plate brooches (T199-279)

This is not a group with a limited period of use like the individual bow brooch groups, nor is it homogeneous in terms of origins or composition (Table 10.10 and Figures 10.34-10.35). Some types have limited date ranges and their compositions can be compared with those of

Table 10.10 - Summary of analyses of Roman plate brooches (data from Table C.3)

Type	bronze	leaded bronze	leaded gunmetal	gunmetal	brass	other	total	AAS %
200	1	1	2		3		7	14
203-223	10	9	11	8	5	2	45	20
224	1		1		5	2	9	0
225				2	9		11	36
226-228	1	10	6	2	9	6	34	26
229					6	1	7	43
230-233		8	6	4	4		22	36
235-237	2				4		6	0
238	1	1			6		8	25
242				1	2		3	67
249	2	10	3	1	2		18	0
250-259	10	26	6	7	11	1	61	21
260		11	1	1			13	23
261-266	2	4	2	2	7		17	18
267-8.199	9	6		3	5	2	25	8
269	3	4	4	1	1	2	15	7
270	12			4	4		20	25
271			1		5		6	17
275	1	5	2	1	3		12	25
277-279	1			5	3		9	11
Total	56	96	47	42	93	14	348	

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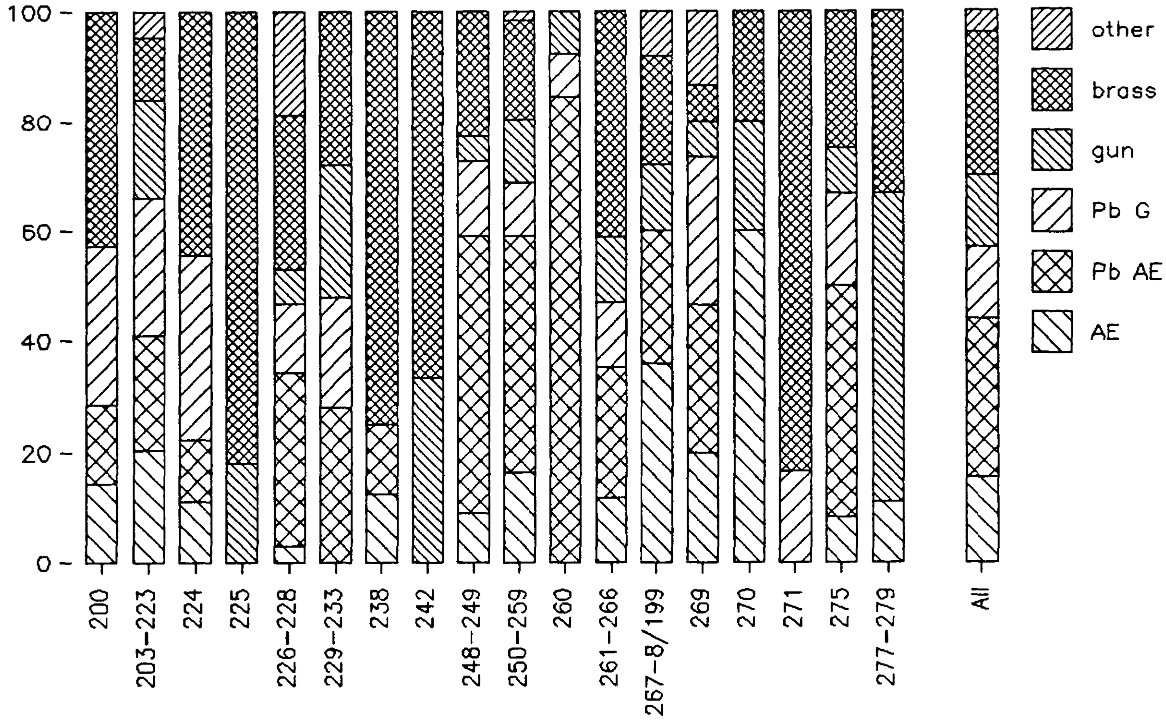

Figure 10.34 - Proportions of plate brooches of selected types made of different alloys

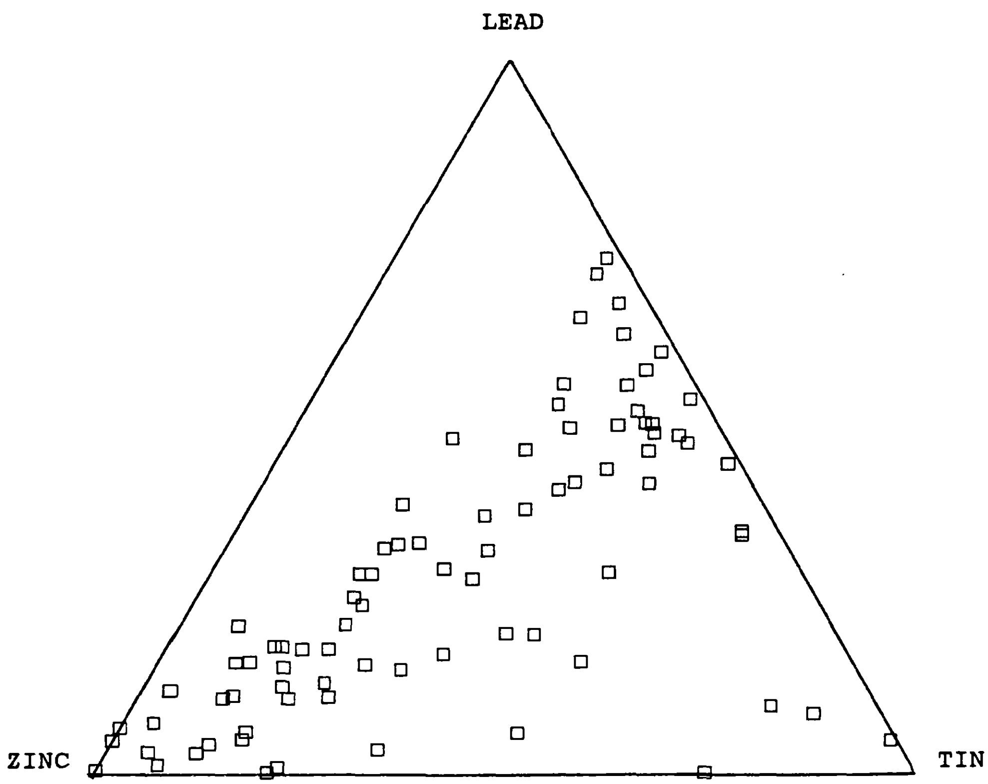

Figure 10.35 - Ternary diagram of all AAS analyses of plate brooches

contemporary bow brooches. The majority however are poorly dated and links to bow brooch types are based more on the decorative techniques used than on the overall appearance or form. Table 10.7 shows that a relatively low proportion of the plate brooches were analysed by AAS and this, combined with the small number of examples of individual types, means that the interpretations of analytical results offered below must be indicative rather than definitive.

A group of early plate brooches (T224-T225) date to the mid 1st century AD and are mainly brasses but with a lower zinc content than many contemporary bow brooches. Most are tinned like the Hod Hill brooches, and the plano-convex glass 'stones' on T224 are held in place by repoussé-decorated, openwork metal sheets soldered into place, which have parallels in the applied repoussé sheets found on some T23, T24 and T29A brooches. Less confidence than normal should be put in the XRF results for T224 brooches as their thinness means that de-zincification is likely to be significant while the presence of solder means that at least some of the detected tin and lead is likely to be adventitious. Other early plate brooches are T238 (which has the keyhole outline of T27) and T242 which again are mainly brasses. In many cases they have applied repoussé foils, glass 'stones' and/or tinning as found on T224-T225. One is also decorated with niello which is otherwise found mainly on Hod Hill brooches and contemporary military metalwork.

T249, a British type, also have applied repoussé plates. They are mainly leaded bronze (or leaded gunmetal), though the applied sheet, where it survives, is often brass. Perhaps this was a way of producing a 'brass' brooch though made mainly of the ?cheaper or less desirable leaded bronze. The designs on some repoussé sheets are Celtic though somewhat degenerate (Kilbride-Jones 1980) and have parallels on the more ornate Aesica brooches (T37) which are also leaded bronzes (and British).

Another group that has already been identified comprises the equal ended brooches (T229-T233) which are found far more commonly on the Continent than in Britain and are therefore considered to be of continental manufacture; the same comment applies to the bow brooch variants of these types (see Group 10, above). Most are mixed, zinc-rich alloys which seem typical of many continental brooches after the early to mid 1st century (see Figure 10.30). Apparently related to these equal ended brooches are the lozenge-shaped plates (T226-T228), particularly T228 with its zoomorphic lugs.

T250-T259 are all disc brooches decorated with enamel in a variety of designs. Traces of tinning often survive on the reserved metal between the enamel fields and in a few cases silver was detectable, most probably the remains of beaded wire or foils once soldered in place in a similar way to that on some of the Group 8 brooches. T260 are similar to T257 but are oval rather than round and once had a 'stone' of some sort in the centre. Half of these brooches are leaded bronze but all alloys are represented; Figure 10.36 shows something of this diversity. T262-T266 are also enamelled discs but here zinc-rich and unleaded alloys are more frequent.

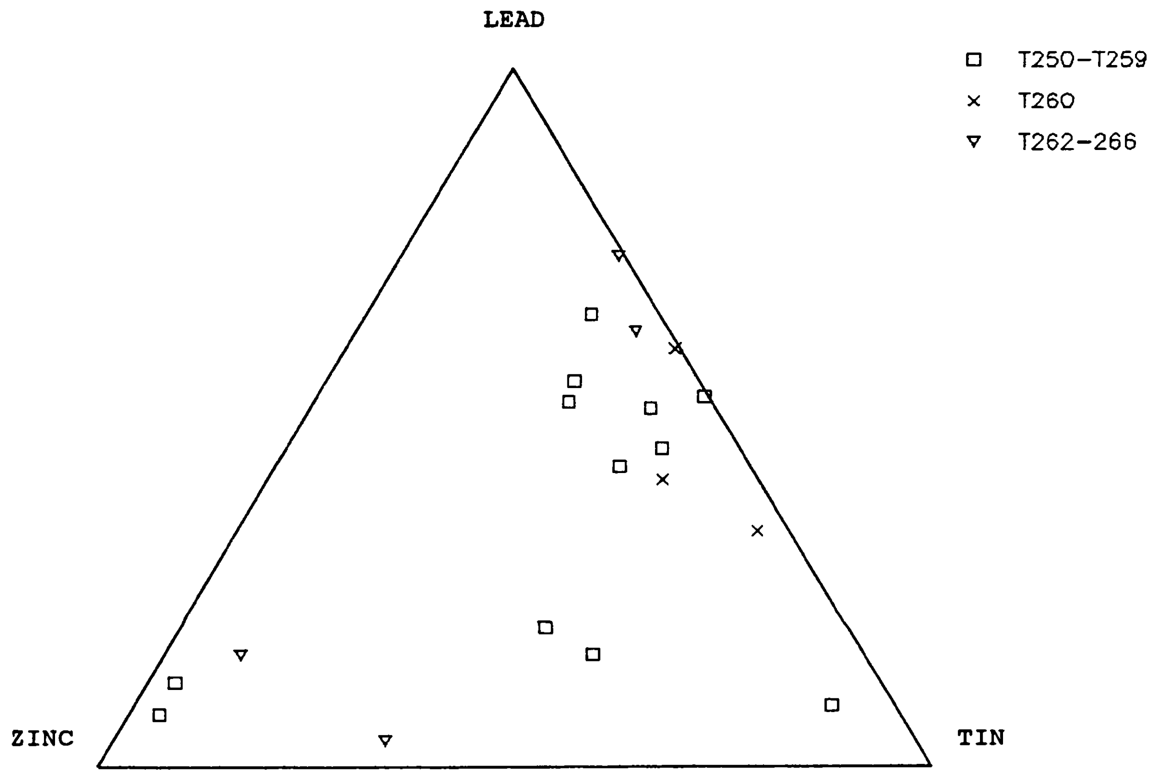

Figure 10.36 - Ternary diagram of AAS analyses of some enamelled disc brooches (T250-T266)

T267, T268 and T199 have a domed form with many small fields of enamel in contrast to the larger fields, often with juxtaposed blocks of different colours, of T250-T266. No trace of tinning survives on any of these examples which include bronzes (9 of 25), leaded bronzes (6 of 25) and brasses (5 of 25).

T269 are not enamelled and are made of all alloys, though with a preference for leaded tin-rich ones.

T270 and T271 are late plate brooches, respectively circular and oval, and all are (or were) gilded, and often tinned on the back. All had a central conical glass 'stone' or intaglio. T260 can thus be seen as a prototype for T271 though compositionally it is quite different. In T270-T271 the prime factor governing alloy choice was the ability to accept (mercury) gilding, and low lead alloys are therefore the norm; the quantitative analyses all show a lead content of under 1%. The range of alloys used was similar to that used for the gilded Group 11 brooches but somewhat surprisingly there appears to be a different preferred alloy for the two types; five (of 6) T271 are brass while 12 (of 20) T270 are bronze. Stylistically the two types are so closely related that it is difficult to see a reason for the different compositions, unless perhaps the metal available to the workshop where they were made changed with time and one type is a later development of the other.

None of the other plate brooch types are sufficiently numerous for any comment to be relevant. The types not discussed above include dragonesque brooches (T200), zoomorphic brooches (T203-223), and various representational plate brooches (T275-T279).

Penannular brooches (Types P1-P15)

Penannular brooches are fairly frequent finds but their simple form precludes much typological variation. Most are wrought and because of this and the stresses imposed on them in use, the vast majority are unleaded alloys. The leaded examples are mainly (leaded) and of relatively massive cross section. As Table 10.11 and Figures 10.37-10.38 show, there is no significant difference between the alloys used for different types. There is no distinct division into two groups as was seen with T10-T11 though, as there, tin-rich alloys predominate over zinc-rich ones. Other alloys include seven silver penannulars.

Table 10.11 - Summary of analyses of Roman penannular brooches (data from Table C.3)

Type	bronze	leaded bronze	leaded gunmetal	gunmetal	brass	other	total	AAS %
P2				1	3	1	5	20
P3	31	3	4	5	16	5	64	22
P4	33	3	2	9	18	6	71	17
P5-P7	36	4	3	9	12	4	68	10
P10-13	2		1		4		7	15
Total	102	10	10	24	53	16	215	16

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Continental brooches and other metalwork

The analytical results for the brooches from Velzeke and Oudenaarde have been discussed above, together with those for similar brooches from English sites. Most of them are comparable with the English results which adds support to the statements made, based on typological

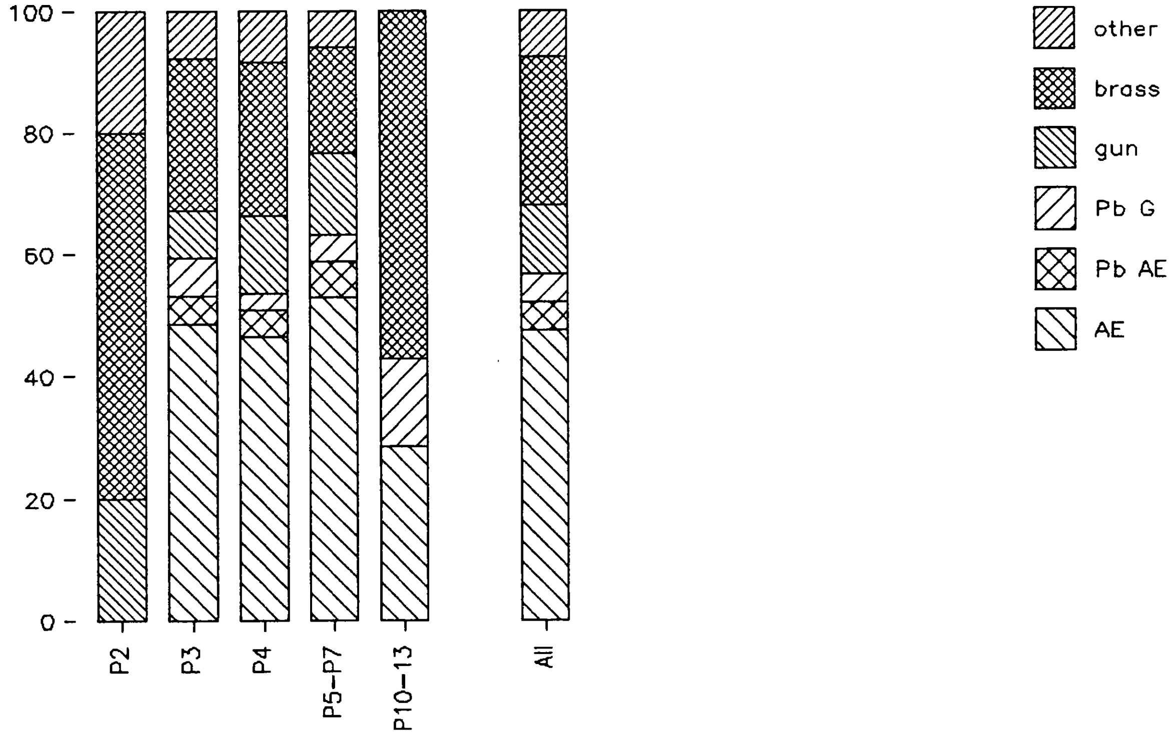

Figure 10.37 - Proportions of penannular brooches made of different alloys

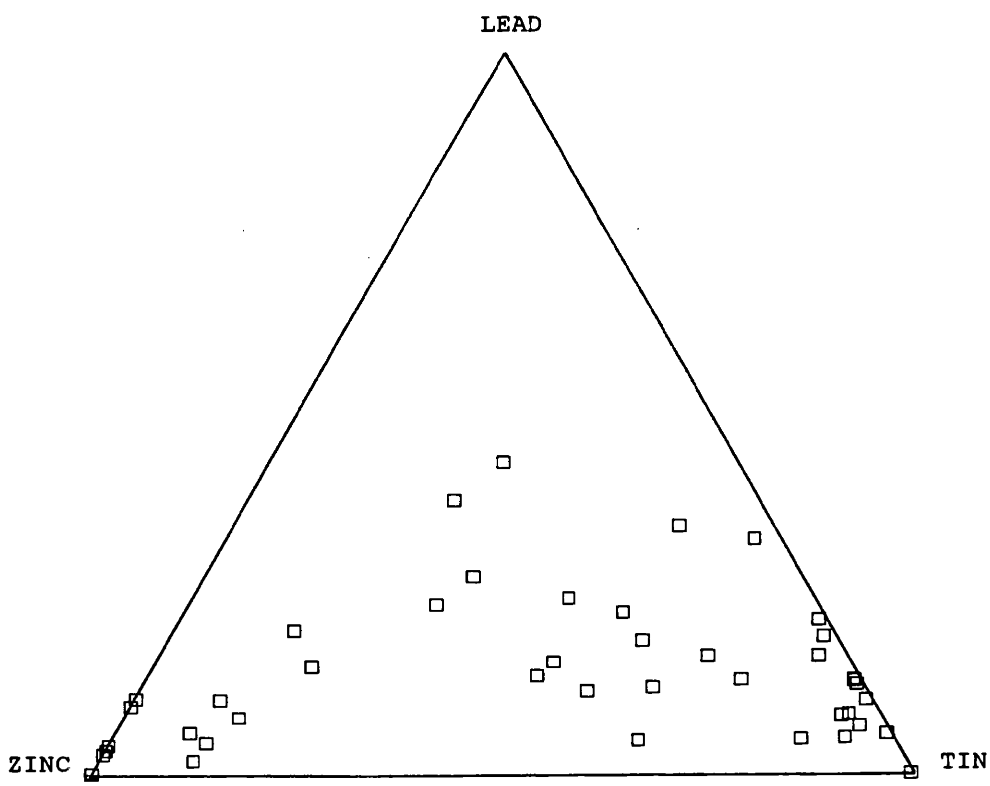

Figure 10.38 - Ternary diagram of AAS analyses of penannular brooches

studies, that certain types found in England were made on the Continent.

Guerra *et al* (1990) analysed 18 brooches from Argentomagus, in France. Only one of them, a Nauheim brooch (T9), was a bronze, the rest were brasses. These included T21, T25, T26, T51 and T89 which are all types that, when found in England, are normally also made of brass. Rabeisen and Menu (1985) analysed metalworking waste from Alesia dating to the first half of the 1st century AD which included failed castings for four brooches, all of them brass. Two were T26, the others were not described in sufficient detail to be identifiable to type. Again the alloy is the expected one.

Guerra *et al* (1990) comment that the production of bronze brooches seems to be interrupted by the Roman conquest of Gaul as after then no indigenous brooches contain more than 0.7% tin. If this statement is based solely on the analyses reported by them, which it appears to be, I would doubt its universal applicability as all the brooches analysed are of types in use around the time of Christ and so represent only a fraction of those in use in the following centuries. It is more likely to be true if it were just referring to the 1st century AD.

The small number of published analyses of brooches from the Continent makes it difficult to take this comparison further. Results from single sites are suggestive and it is reasonable to assume that, as in England, findspot is not a factor in determining the composition of a particular brooch but as yet this hypothesis has not been tested. There is also no comparative analytical data known to me for later Roman brooch types found on the Continent.

If objects other than brooches are considered then the numbers of analyses are larger, eg Beck *et al* (1985) analysed 465 objects, but work has concentrated on statuettes, vessels and votive objects rather than on small everyday ones so the data is not strictly comparable with that presented in Table C.4 and no detailed consideration of their results is therefore attempted here though a similar range and frequency of alloys to that shown in Figure 10.2 was found.

Comparing groups of analyses

Nearly 40% of the brooches analysed were brasses and over 25% leaded bronzes, blanket terms which both cover a wide range of compositions. Different brooch types do however have somewhat different compositions within these ranges as shown by the differing distributions of points on the ternary diagrams. In order to quantify and compare these differences a numerical measure of average value and dispersion is required.

The mean and standard deviation (SD) are commonly used measures but they assume a normal (Gaussian) distribution of the data which is unlikely with small numbers of samples, even assuming a normal distribution of the population from which they come. Inspection of graphical representations suggest the data may not be normally distributed even where samples are relatively large.

Alternative measures of average and dispersion are the median and interquartile range (IQR) which make no assumptions about the shape of the distribution from which the data is taken. The median is a robust measure of average value as it is little affected by outliers. The IQR ignores extreme values and at the same time indicates the tightness of the cluster. It also shows the skewness of the distribution as the upper and lower quartiles need not be equidistant from the median. Not all outliers are sufficiently obvious for them to be removed from data sets prior to calculating average values. Sometimes it is not clear which points should be considered as part of a loosely clustered group and which as outliers to it; either way, they will have little effect on the calculated median value.

An example of the robustness of medians and IQRs is provided by the Group 6 brooches (see Figure 10.20). The majority are heavily leaded bronzes but there are also both (leaded) and unleaded bronzes as well as gunmetals and brasses. Figure 10.39 shows the effect of progressively removing outliers from this data set. There are 35 analyses in total and both the mean +/- one SD and the median and IQR were calculated for all three alloying elements. The zinc mean is unrepresentative as there are a few high value outliers but the IQR shows the skewness of the distribution. Four brasses were removed from the data set leaving 31 analyses; the zinc IQR dropped though the median was little changed. Then two gunmetals, three bronzes and lastly three (leaded) bronze/gunmetals were removed giving a final total of 23 analyses, at which point the means and SDs were recalculated. All the analyses removed had lower lead contents than average so the median lead value slowly increased and the IQR reduced as the outliers were removed. At the end of the iteration the median lead value (17.8%) was higher than the mean (16.1%), showing the skewness of the distribution once low values had been removed. At this point the SD is comparable to the IQR as the data set has been reduced to a single cluster so the values approximate to a normal distribution.

For the reasons given above, medians and interquartile ranges are used as measures of average value and dispersion in the discussion that follows.

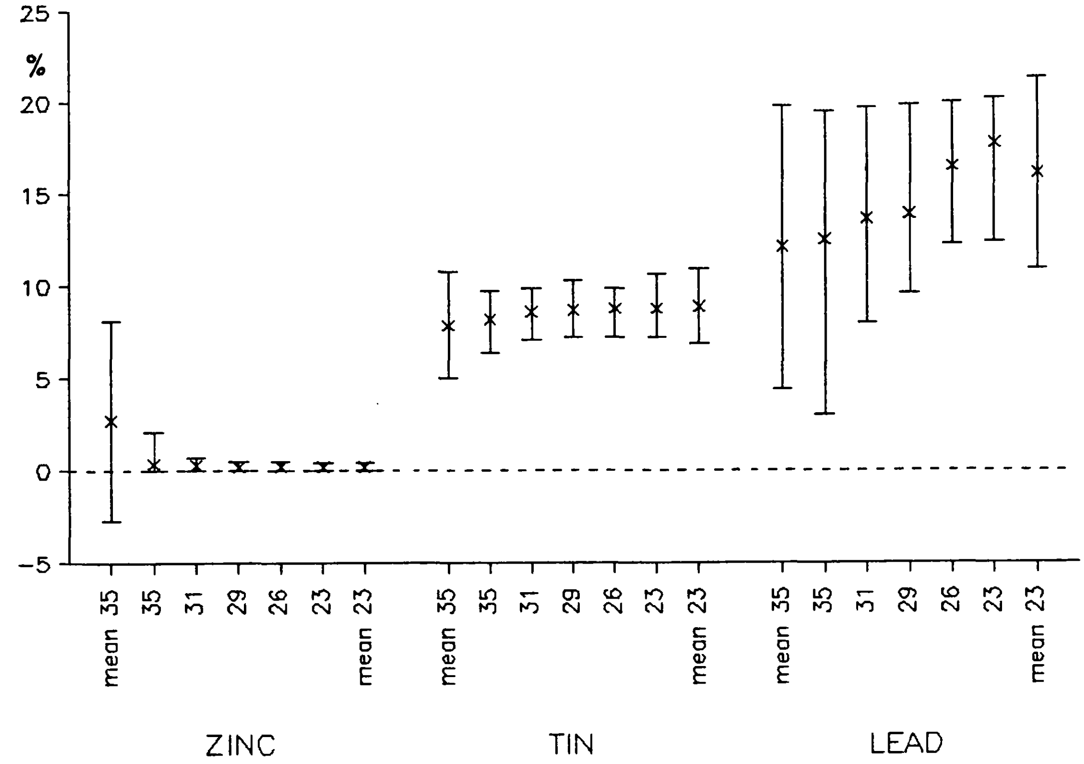

Figure 10.39 - Medians and interquartile ranges for Group 6 AAS analyses (see text for discussion)

Brass

Many different brooch types were preferentially made of brass but quantitative analyses show their median compositions are rather different, though all lie within the bounds defined as brass in Chapter 9. These values are given in Table 10.12 and plotted in Figure 10.40.

Table 10.12 - Medians, upper and lower quartile ranges for selected types of brass brooches

Type	sample size	Zn % med	Zn % upp	Zn % low	Sn % med	Sn % upp	Sn % low	Pb % med	Pb % upp	Pb % low
10-11 A	11	19.1	5.4	6.2	1.0	.7	1.0	.2	.1	.1
21	31	17.3	2.4	1.7	2.4	.4	.7	.5	.7	.2
26	20	18.6	.7	1.6	1.8	.4	.2	.4	.3	.2
Gp 2	59	17.5	1.9	1.3	2.0	.8	.3	.5	.6	.2
40.42	6	18.8	3.6	.2	1.5	.6	.4	.3	.0	.1
51-52	20	18.6	2.0	1.6	1.5	.7	1.2	.1	.3	.1
60-80	71	16.1	4.1	5.9	2.3	2.3	1.3	.4	1.0	.2
60-80xAE	59	17.1	4.0	3.5	1.5	1.8	.7	.3	.7	.1
89-91	128	19.1	1.1	2.2	1.1	.4	.5	.3	.0	.2
89-91xAE	116	19.5	1.0	2.0	1.0	.3	.5	.3	.0	.2
148	9	12.5	.2	4.8	1.7	4.6	.5	.7	3.2	.7
trumpet A	8	12.2	4.7	2.0	2.5	1.3	1.0	4.2	2.0	3.1
trumpet E	9	9.5	4.8	4.5	2.7	3.9	.5	2.6	.9	1.9
Gp 10++	30	9.2	3.3	3.9	4.2	2.5	1.0	5.0	2.8	2.9
Gp 11 Au	18	4.3	3.2	2.7	4.5	2.3	2.9	.9	.5	.5
190-192 A	9	12.5	3.2	2.7	4.6	1.1	3.3	6.5	1.2	3.4

Notes:

10-11 A = brass examples of T10-T11

Gp 2 = all Group 2 brooches, including T21 and T26

60-80xAE/89-91xAE = T60-80/T89-91 excluding the bronzes

Gp10++ = Group 10 and related plate brooches

Gp11 Au = Group 11 brooches which are, or probably were, gilded

190-192 A = brass and gunmetal examples of T190-T192 (left half of Figure 10.33)

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The compositions of the early to mid 1st century brass brooches are clearly different from the later brass types. Median values for zinc are high (17-20%), tin low (typically 1-2%) and lead very low (not more than 0.5%). Even within this group there is some variation, Group 2 brooches have higher median tin contents than other types,

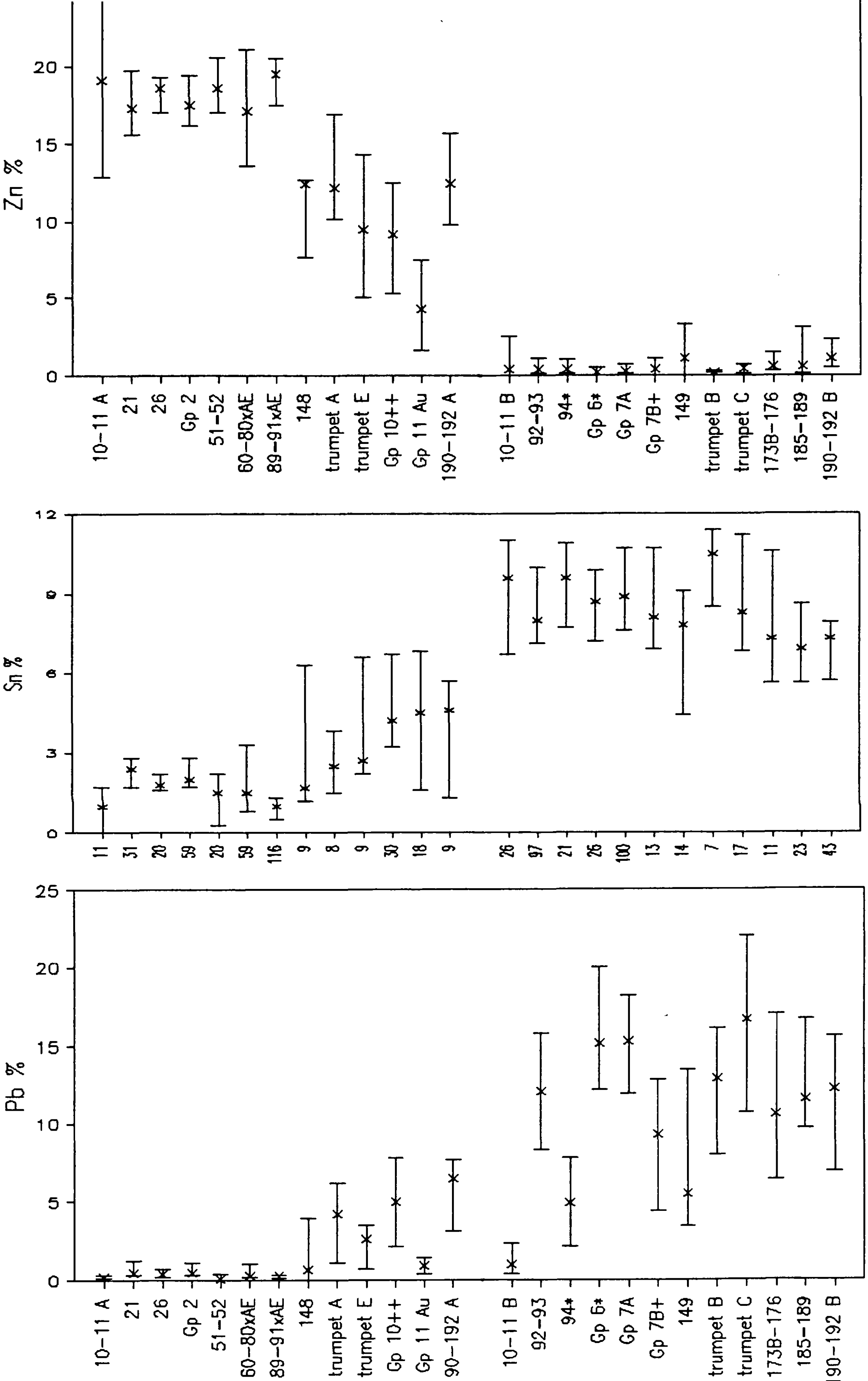

Figure 10.40 - Medians and interquartile ranges for groups of brooches made of brass (to the left) and leaded bronze (to the right)
The brooch types defined in Tables 10.12 and 10.13 appear below the zinc and lead graphs and the sample sizes below the tin graph

suggesting that the brass used for making brooches had multiple sources. Later brasses have lower median values for zinc (9-13%) coupled with higher tin and lead values (typically 2-5%). This change to less pure alloys mirrors the increasing proportion of mixed alloys noted in the contemporary objects other than brooches (see Table 10.3, above).

Most of the early to mid 1st century types are of continental origin so it is clear that brass was the normal brooch-making alloy in use on the Continent at this period. This is borne out by analyses of brooches of the same types from continental sites (eg Rabeisen and Menu 1985, Guerra *et al* 1990). The one piece Colchester brooches (T89-91) are an anomaly in this group as most of them are considered to be British-made as continental examples are rare. Part-made examples have been found at Baldock (Stead and Rigby 1986) which supports their British origin, and a pre-Conquest date seems certain for at least some examples. There is however no evidence for the manufacture or melting of brass in Britain before the Claudian Conquest so the metal for these (wrought) brooches is likely to have been imported even if they were fabricated here.

The brasses of the late 1st and 2nd centuries fall into two groups. One comprises the British-made brooches of Groups 7 and 8 and the other the Group 10 and related plate brooches of continental origin. As already noted, the average zinc content of both groups is lower than in earlier types suggesting the metal was not all newly made cementation brass but some, at least, was recycled metal. The continental brooches tend to have more varied compositions than the British ones (cp Figure 10.30 with Figures 10.25 and 10.28) but the number of quantitative analyses is too low for detailed comparison to be made.

The British-made brasses have a generally northern distribution which suggests a possible military link, either as a source of brass or because such customers were prepared to pay for quality brooches made of a less widely available alloy. This pattern continues with the later knee brooches where the only types which appear to be British products (T171 and T173A) come mainly from northern, military sites and are brasses.

The latest brooches in Figure 10.40 are the crossbows whose brasses and gunmetals (T190-T192 A) have comparable compositions to the Group 10 brooches, suggesting a continental origin is likely. These two groups are the only ones in which leaded brasses are normally found.

The 'gilded' crossbow brooches have, by definition, low lead levels (median 0.9%). Their zinc and tin medians cannot usefully be compared directly with those of other groups of brass brooches as they include brasses, bronzes and gunmetals. However, the maximum zinc content is 10.9% with the median down to nearly 4%. Average copper contents are higher than for most brooches, with some examples over 90%, so these brooches can be considered as impure coppers.

Leaded bronze

A similar intercomparison exercise can be undertaken with the leaded bronzes. The impression given by Figure 10.40 is of greater consistency than among the brasses though there are some noteworthy variations.

Table 10.13 - Medians, upper and lower quartile ranges for selected types of bronze and leaded bronze brooches

Type	sample size	Zn % med	Zn % upp	Zn % low	Sn % med	Sn % upp	Sn % low	Pb % med	Pb % upp	Pb % low
10-11 B	26	.4	2.1	.4	9.6	1.4	2.9	1.0	1.3	.6
92-93	97	.4	.7	.3	8.0	2.0	.9	12.1	3.7	3.8
94*	21	.4	.6	.3	9.6	1.3	1.9	4.9	2.9	2.8
Gp 6*	26	.2	.3	.2	8.7	1.2	1.5	15.2	4.8	3.0
Gp 7A	100	.3	.4	.2	8.9	1.8	1.3	15.3	2.9	3.4
Gp 7B+	13	.4	.7	.4	8.1	2.6	1.2	9.3	3.5	4.9
149+	14	1.1	2.2	1.1	7.8	1.3	3.4	5.5	8.0	2.1
trumpet B	7	.2	.1	.0	10.5	.9	2.0	12.9	3.2	4.9
trumpet C	17	.5	.2	.4	8.3	2.9	1.5	16.7	5.3	6.0
173B-176	11	.6	.9	.3	7.3	3.3	1.7	10.6	6.4	4.2
185-189	23	.6	2.5	.5	6.9	1.7	1.3	11.6	5.1	1.9
190-192 B	43	1.1	1.2	.6	7.3	.6	1.6	12.2	3.4	5.3

Notes:

10-11 B = bronze and gunmetal examples of T10-T11

Gp 7A = T104-T111 and T118-T144 (omitting T137 and T143A)

Gp 7B = T137, T146, T151-T152

trump B = trumpet B   trump C = trumpet C

190-192 B = leaded bronze examples of T190-192

* = brasses and gunmetals omitted   + = brasses omitted

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The T10-T11 bronzes (T10/11 B) are included as a typical example of unleaded bronzes for comparison; the relatively high zinc IQR indicates the presence of a few gunmetals in the group. In most cases the intention of the alloy maker probably was to produce a bronze with a roughly consistent tin content (8-10%) and then add to it 12-15% lead, though occasionally nearly twice this amount was added. The actual amount was not critical as the only effect of additional lead at these levels is to lower the melting point of the alloy. T94 has a markedly lower median lead content than the rest of the leaded bronzes because the distribution is a bronze-leaded bronze continuum (see Figure 10.19). The larger than average IQRs for T149 show the relative inhomogeneity of the type as, again, both leaded and unleaded bronzes are represented as well as a few zinc-rich alloys.

The Group 9 and 11 brooches show distinctly higher (though still low) zinc contents than the other leaded bronzes, coupled with rather lower tin contents, which may be a further manifestation of the drift towards more mixed alloys in the later Roman period.

Leaded bronzes are very characteristic British alloys in the later 1st and 2nd century, being used for Colchester B, Colchester derivative and T-shaped types as well as for some headstud and trumpet brooches. The Group 9 and 11 leaded bronzes however are unlikely to have all been made in Britain as these types are far commoner on the Continent, which is their most likely source. This implies that from the late 2nd century leaded bronze was being used on the Continent for brooch making though its introduction there appears to be a century or more later than in Britain. I know of no analyses of continental examples of these later brooches which could be used to confirm or refute this suggestion.

CHAPTER 11

THE NATURE AND DISTRIBUTION OF METALWORKING SITES

Sites that have produced evidence for metalworking are listed in Appendix A where the nature of the evidence is described briefly and references to the sources of information are given. The Appendix does not attempt to be a complete list of metalworking sites but includes data on all major sites and a representative cross section of other sites. Omitted sites would add more points to the distribution maps but are unlikely to alter the conclusions presented significantly.

In most cases the metalworking finds were an unexpected by-product of an excavation which was looking for other things such as a fort, settlement or cemetery. This accidental way in which data has been acquired and the summary way in which much of it has been published has been the subject of comment by two authors writing about the industries of the past. Cleere (1982) bemoaned the "... melancholy fact that industry, the centre of modern economy and society, has hitherto been given scant attention by archaeologists studying the Roman period" while Clarke (1984, 129) makes much the same point, commenting that "the crafts and industries which were the life-blood of medieval England have generally been poorly served by the archaeologist, who has until recently shown a peculiar lack of interest in this most important aspect of medieval life."

The choice of which sites to excavate is not a random one as it is dictated by development threats and research programmes. Some parts of the country and some types of site have attracted more attention than others so excavations and hence the sites with evidence for metalworking are not evenly or randomly distributed. However, at any one period differences in the distributions of individual classes of finds are real ones as each class has been randomly sampled by the excavations that have taken place. Comparisons between periods are on less firm ground as the types of sites excavated are often not the same.

The overall number of sites of each period is far from constant (see Table 11.1). Even when the varying timespans are taken into account and the figures are scaled, Roman sites are relatively more common and early and middle Saxon sites less common than average. It is settlements that produce most of the evidence for metal working and these are not common in the early Saxon period.

Although the Roman period has produced some large assemblages of metal working finds, the vast majority of sites of this period have produced only a few. Before dismissing these less productive sites,

Table 11.1 - Temporal distribution of metalworking sites

Period	Duration (approx)	No of sites (from Table 2.8)	Sites/century
Iron Age	300	75	25
Roman	400	242	60
Early Saxon	250	21	8
Middle Saxon	200	13	7
Late Saxon	200	64	32
Early medieval	200	46	23
All sites	1600	460	29

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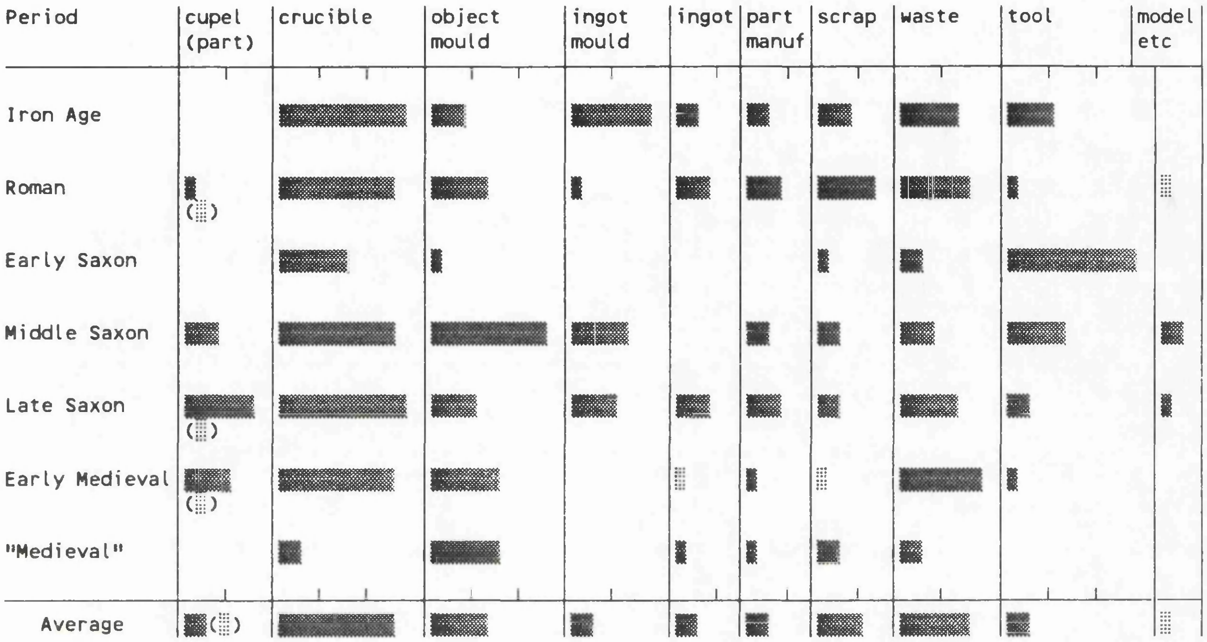
Lamm's (1980, 105) comment that "it is quite simply impossible to estimate the importance or extent of a workshop from the number of mould fragments discovered" should be noted. The proportion of sites with larger assemblages is higher in the late Saxon and early medieval periods, which may help explain the relative paucity of sites of these periods. Industry appears to have been concentrated into fewer larger units - and these were mainly in towns. This trend to greater centralisation gets more marked in later medieval times when London seems to become the major centre for a number of metal crafts (Hinton 1990).

The nature of metalworking finds

Not only the number but the nature of finds from metalworking sites vary with time. In Chapter 2 metalworking finds were divided into ten categories and reasons for the relative frequencies of each category were discussed. These frequencies are not the same at all periods; in some cases the differences are quite marked (see Table 2.8 and Figure 11.1). Some of these differences are the product of the small sample size for the Early and Middle Saxon periods, but others reflect real changes with time. They are due mainly to the varying type and scale of metal working practised. The nature of the metals being worked also varied with time (see Figure 10.1) and this too had an effect on the categories of finds present; for example, cupels are not found unless precious metals were being worked.

Even on settlement sites where more extensive remains might be expected, all that usually survives are portable finds which have been lost or discarded along with other rubbish. Although hearths are sometimes recorded, it is usually not possible to say whether their association with metalworking debris is more than fortuitous. There are very few structures that can be considered workshops at any period; those that have been identified are noted below.

Figure 11.1 - Percentage of metalworking sites of each period with examples of each category of metalworking finds



Note: The number of sites for the Early and Middle Saxon periods is far smaller than for other periods so the figures are not necessarily significant.

Key: =2.5% =5% =10% =15% etc

The ticks on the horizontal lines are spaced every 20%

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Workshops

Published reports identify buildings as workshops on the basis of the presence of metalworking finds, not necessarily in any great quantity; sometimes even the nature of the finds is not described (eg Fox 1971). Where the quantity and range of finds are more extensive, or features such as boxes to collect metal scrap are found, the identification of the structure as a workshop can be made with more confidence (eg Frere 1972). Buildings thus identified are normally no different from others around them so there is no criterion, other than the presence of metalworking finds or features, which can be used to identify workshops.

Some craftsmen were itinerant specialists, not permanently based on a single site, and their workplaces must thus have been either existing buildings, which normally had another use, or temporary structures erected to provide shelter for just as long as was needed. Evidence for metalworking is also found in places which originally had other, incompatible functions (eg the temple at Nettleton (Wedlake 1982) and the forum at Leicester (Wacher 1975)) and indicates secondary re-use of a disused or even derelict building. Where craftsmen worked in one place buildings were used as 'permanent' workshops though, as noted above, there are few features which specifically identify them.

A well-published and definite group of Roman workshops is that from Verulamium (Frere 1972) where a range of timber buildings in Insula XIV fronting onto Watling Street show five phases of construction and use for just over a century from 49 AD. In the first three phases, boxes or trays containing copper alloy scrap were found set into the floors in six rooms. Crucibles and metal scrap and waste found in these and other rooms of all phases show that precious as well as base metals were worked there. Strip buildings of this general type are commonly found lining the through roads in both large and small Roman towns where they are often identified as shops. In Roman Britain (and on into the late medieval period) there was no distinction between a shop where goods were sold and a workshop where they were manufactured; they were the same place. The shop-lined High Street of modern Britain is thus the descendant of an old tradition, though the manufacturing is nowadays usually carried out at another location.

On several military sites buildings have been identified as fabricae but normally metalworking evidence is limited to portable finds. At Exeter, Bidwell (1979) noted rectangular plank-lined troughs, dating to the period 55-75/80 AD, one containing copper alloy filings and others with slag, waste, offcuts and scrap objects in them. At Colchester: Culver Street the mid 1st century brass-making crucibles were associated with hearths in tribunes' houses, though they may represent colonial rather than military activity (Bayley 1984A).

In the post-Roman period no workshops have been positively identified before the 9th century. By then metalworking was becoming largely an urban craft or industry, probably carried on by full-time craftsmen who lived permanently in one place. The evidence to support this suggestion is both the relatively large quantities of debris found in restricted areas and its association with structures which can be identified as workshops. Examples are the timber buildings on Lincoln: Flaxengate (Perring 1981) and the wattle and plank built buildings on the Coppergate site in York (Hall 1984 and Bayley forthcoming). At Winchester: Lower Brook Street, Biddle (1990) has tentatively identified a 9th century stone building as a workshop as it was quite distinct from the timber buildings around it and was associated with evidence for goldworking.

Geographical distribution of sites

As has already been noted, the geographical distribution of sites with evidence for metalworking (Figures 11.2-11.7) is a reflection of the distribution of excavated sites. It is notable that the concentrations and lacunae show variation with time but without constructing distribution maps of all excavations on sites of each period it is difficult to be sure if these variations are significant. There are some areas which are mainly inhospitable upland or heath which not unexpectedly show little activity at any period. These include the Weald, Devon and adjacent parts of Cornwall, Dorset and Somerset, Cumbria and upland Lancashire. Activity in other upland areas is mainly related to metal extraction rather than fabrication of objects.

Chronological variations

In describing metalworking processes and their associated finds (Chapters 3-8), some details were given of the periods at which they were common and of the changes with time that can be identified. That detail will not be repeated here where it is the broader patterns of the industries and the reasons for them that are considered. The differences shown in Figure 11.1 will be discussed as will the geographical location of particular industries at each period. The detailed comments are restricted to the Iron Age, Roman and Late Saxon periods because of their relatively large number of sites.

Iron Age

Cunliffe (1974, 295) has noted that "archaeological evidence for bronze working in pre-first-century BC contexts is rare ..." and the sites listed in Appendix A bear this out with only Ancaster: Quarry, most of Beckford, Christon, the earlier phases at Danebury and Winnall Down definitely falling in the early or middle Iron Age, though the metalworking on many of the sites listed is not closely dated. The Iron Age is considered here mainly as the baseline from which Roman metalworking grew, so the concentration of evidence in the century or two before the Roman Conquest is not unhelpful. The metal being worked was normally bronze, though gold and silver alloys were used for coinage and occasional items such as torcs (see Chapter 10 for details).

Northover (1988), writing about the whole of the Iron Age, has identified two distinct types of metalworking assemblage. The first is casting debris, crucibles and investment moulds, which is found mainly on undefended lowland sites. One quarter of the sites listed in Table 2.1 have produced some evidence of this type; major groups are those from

Beckford, Gussage All Saints, Grimsby: Wheelsby Avenue and Thetford: Fison Way.

The second type comprises evidence for wrought industries where crucibles are rare but tools and scrap metal are commoner and finds such as bar ingot moulds, ingots and part manufactures are also known. Over a third of the Iron Age sites listed provide some evidence of this type though there are no large assemblages like those of clay moulds. These finds come mainly from hill forts such as South Cadbury though they are also known on lowland sites, especially in the 1st century AD. The higher than average proportion of sites with tools is surprising as wrought metalworking continued in subsequent periods but it may reflect the way finds of different periods are published as much as actual frequencies.

From around 80 BC coins began to be made in southern Britain (Harding 1974) and the main surviving evidence for this is coin pellet moulds which are found at over a third of the sites in Table 2.1 (where they are listed as ingot moulds - which explains the anomalously high frequency in Figure 11.1); dies too are noted at Bagendon. The use of these 'moulds' is described in Chapter 5, above. Collis (1985) argues that the frequency with which they are found outside major settlements demonstrates only that coin production was not always centralised, not that there must have been an alternative use for the moulds. This minting technology went out of use after the Roman Conquest so coin pellet moulds are a diagnostic 'type fossil' for the late Iron Age; where they are found in later contexts they are residual.

To these three types of metalworking sites must be added Hengistbury Head where a wide range of metallurgical processes including cupellation were carried out (Northover 1987). This activity belongs mainly to the period running from the mid 1st century BC to the Roman Conquest (Cunliffe 1987). Associated with the metalworking finds were a considerable number of Durotrigan coins and it is tempting to associate the precious metal working with the production of these coins though the link is unproven.

Table 2.1 also includes four Cornish sites (Chun Castle, Chysauster, Red Moor and Trevelgue) where tin extraction was probably the main metallurgical activity. The remainder of the sites are those where non-specific "bronze working" is claimed or where a few crucible fragments have been found without other evidence to show what was done with the molten metal. Crucibles on their own could be indicators of either investment casting where no moulds have survived, or of wrought metalworking where scrap was being remelted and cast into bar ingots or

Figure 11.2 - Iron Age sites with metalworking finds

blanks. Moulds are not essential for this; a temporary groove in the ground would serve, and leave no trace to be found.

Most areas of lowland Britain have a fairly even number of sites with evidence for metalworking of one sort or another, though the higher frequency of excavation in the south-eastern half of the country is reflected in the distribution (Figure 11.2). While this map indicates where craftsmen worked, and the finds show something of how they worked at a mechanical level, we know nothing of their relationships with the communities in which they operated. It is generally accepted that non-ferrous metalworking was a specialist craft and was not widely practised in the way that spinning, weaving and even iron smithing are thought to have been. Cunliffe (1974) has suggested that each large nucleated settlement was capable of supporting one or more full-time specialists, though whether the demand would have been sufficient to provide full-time employment is open to question. There is the evidence from sites like Gussage All Saints of a less permanent relationship between the craftsman and his customer. There the main group of metalworking debris was the product of a single episode of casting and it is suggested that an itinerant craftsman arrived, set up a temporary workshop, executed his commission and travelled on to his next customer (Spratling 1979). Similarities of style in the objects produced over considerable areas futher support the idea of itinerant craftsmen, though it could also be argued that centralised production and local trade would result in the same distribution of products, though not of metalworking debris. The existing evidence is so partial that a definitive interpretation is not possible; at present either hypothesis is tenable - and it is likely that both mechanisms operated at some times in some areas.

Roman

There is no single date at which England stopped having a native Iron Age culture and adopted a Roman one. The military conquest and ensuing romanisation proceeded gradually, so while towns in the south east showed changes early, smaller and remoter settlements were little affected for considerable periods. Both the date and degree of change were variable so, on minor settlement sites which date to the mid or late 1st century AD, it is difficult to discriminate between Iron Age and Roman activity when there is no break in occupation. In considering whether to class metalworking finds from these sites as Iron Age or Roman, the nature of the finds was considered and those sites that showed evidence of techniques or alloys which are not known on definite Iron Age sites were classified as Roman while those whose finds are typical of

Iron Age sites were classified as Iron Age. The co-existence of Iron Age and Roman metalworking traditions which these finds indicate is neatly described by Frere (1974, 325) who says "... the manufacture of bronze objects in Roman Britain was carried on at two distinct levels. On the one hand, we have craftsmen, no doubt based mainly on the towns and on the larger vici of the north, who manufactured objects in classical taste, though in provincial style. ... Distinct from these there still existed rural or itinerant craftsmen in the north and west trained in the old traditions of the native bronze industry of Celtic Britain ...".

Cleere, in his paper on 'Industry in the Romano-British countryside' (1982), discusses the difference between craft and industry: "... it is the systematic nature of a craft that qualifies it for the appellation of industry. Thus ... the work of an isolated rural or urban smith ... producing goods on demand for use in the immediate vicinity of his workplace should not be considered industry." Todd (1976, 106) comes to a similar conclusion; he says "Unfortunately, the term 'industrial' is too freely and loosely used by writers on Roman Britain. Often a building or an installation is labelled 'industrial' when in reality it was no more than the work-place of a local craftsman who was serving a very limited market. Many 'industries' of the province should with greater accuracy be termed local crafts."

Manning (1987, 586) accepts that "In modern usage there is a clear distinction between craft and industry [but] ... in the Roman world there was no such distinction". He argues that this was because of the lack of technical innovation and invention which meant "... production could be increased only by multiplying the number of units and not by changing to other processes ..." There was no mechanisation or mass-production as we would understand it in post-industrial revolution terms, and thus even relatively large scale production should be considered craft rather than industry.

In this thesis it is the processes used by craftsmen and the physical evidence for them which are of prime concern; the semantic debate as to whether their activities were craft or industry is only a distraction from this main theme. Both terms are used below, but in Manning's undifferentiated sense; neither should be equated with a particular scale of operation.

Romano-British metalworking is far more varied than that of the Iron Age as both new techniques and new alloys were introduced. These were not new discoveries but imports from other parts of the Empire; the Romans were renowned for their organising skills but not for their technical originality (Tylecote 1976). Hawkes (1951) believes the Roman

Figure 11.3 - Roman sites with metalworking finds

Conquest had more wide-ranging effects on metalworking than purely technical changes, as the style and types of objects were affected too. He also notes the changes in the cultural and economic structure within which the metals industry worked which Manning (1979) considers to be the more important change. Certainly improved communications and trade, and a functioning money economy must have had a significant effect.

Richmond (1966) expressed a widely-held belief that the market for craftsmen's products would have been a local one, so small towns probably had as many shops/workshops as larger ones. The distributed nature of Roman metalworking is well illustrated by the number of sites which have provided evidence for it (see Figure 11.3); they include sites of all types ranging from forts and their vici through coloniae, civitas capitals, small towns, roadside settlements and villas to native villages and farmsteads. In addition there are a number of primarily industrial settlements such as those in the Peak District and Mendips where lead was mined and smelted. Apart from this last group, the metalworking was normally incidental to, or at most just part of, the economic basis of the settlement. Even those sites which have produced relatively large quantities of metalworking finds are no exception here; the economic basis of Roman as of Iron Age Britain was essentially agrarian.

Because of the large number of Roman metalworking sites it is convenient when discussing them to subdivide them by the metal worked in order to identify any distribution patterns. On just over a tenth of the Roman sites in Appendix A the published reports do not specify the metal(s) worked, so those sites are effectively omitted from the discussion below, while nearly a quarter of the sites have produced evidence for the working of two or more metals and so are discussed more than once. There is no correlation of specific pairs of metals on these multi-metal sites if the processes where two metals are involved, ie parting and cupellation, are ignored. The correlation of settlement size with range of metals worked is not a strong one. However, if all the sites in a particular town are considered together, then the larger areas that have been excavated tend to produce larger numbers of metallurgical finds and thus evidence for more processes and/or the working of wider range metals. In plotting Figures 11.4-11.8 multiple sites in the same town with the same type of finds have been ignored for the sake of clarity.

Gold

A total of 17 sites has produced evidence for goldworking

Figure 11.4 - Roman sites with evidence of gold working

(Figure 11.4). Only the inscription from Norton, the ingot fragments from Wimborne and the scrap from the Snettisham jeweller's hoard tell us nothing further of the processes being undertaken. Of the other sites, which range in date from the mid 1st to the 4th century, six have fragments of parting vessels (see Table 4.2), seven have metal melting crucibles and four dishes or re-used sherds probably or definitely used for refining gold. Sometimes gold was refined by heating and/or fluxing it with little or no lead so there is then little if any difference between the residues left by melting and refining. The gold in one of the small type 4 crucibles from Chester: Hunter Street School (Figure 5.5, 3) was melted using a blowpipe, a method which was probably also used on the metal in the mini thumb pots from Verulamium (Figure 5.4, 6-7). This would produce localised heat and relatively oxidising conditions, suitable either for melting down a small collection of filings or refining a similar quantity of metal. Most of the crucibles containing gold are small; 20-30 mm is a typical diameter.

Parting, though only recently recognised on any scale, appears to be a Roman introduction to Britain as no pre-Conquest parting vessels are known and much of the precious metal in use in the immediate pre-Conquest period is far from pure (see Chapter 10). Three of the groups of parting vessels come from southern England, from mid-late 1st century contexts. There is no indication of the source of the metal that had been refined in them but it could have been Iron Age coins and torcs of the earlier 1st century which would have needed treatment before their absorbtion into the far purer Roman metal pool. The three groups of parting vessels from Lincoln are very similar to each other, they came from almost adjacent sites and are thus probably debris from the same campaign, be it a short or longer-term one. They can be dated to the 4th century. Although six of the ten sites with evidence for parting are Roman, it is a relatively less common process than in the late Saxon or early medieval periods as there are far more Roman metalworking sites.

The goldworking sites show no geographical concentrations but are unusual in one respect; all apart from Gorhambury and the three sites first mentioned are located in major towns; the army, with its regular cash income, does not appear to have been specifically targetted. This distribution can be interpreted in two ways - either goldworking was under official control of some sort and so was carried out in just a few centres or, alternatively, there were only a few goldsmiths who thus set up shop in places with relatively large and wealthy populations which also had good communications with a large hinterland and its potential customers. Cool (1986) subscribes to the latter opinion by stating that

"The number of workshops in Britain producing high-class jewellery must always have been much smaller than the number ... dealing in copper alloys and thus they must have commanded a more geographically extensive market for their wares." The few well-placed workshops could of course also have been under official control.

Silver

Scattered across the whole country, there are 47 sites which provide definite or possible evidence for silver working (Figure 11.5). The processes represented include parting (discussed above under gold), cupellation and melting. In the 4th century, payments to the army were sometimes made in stamped ox-hide shaped silver ingots rather than in coin and a number of these have survived. Although their use was monetary, complete ingots of this and other shapes could have been used as the raw material of a silversmithing industry. However, none of them or the pieces of scrap metal and part manufactures which are also known, except those from Snettisham and probably Wicklewood, have definite metalworking associations.

At four Mendip sites (Charterhouse, Chew Park, Green Ore and Herriott's Bridge) local argentiferous lead ores were processed. Finds of litharge suggest silver was being separated from lead by cupellation as part of the production cycle. Fairly large-scale cupellation is known or suggested at nine further sites which are far away from suitable ore sources (see Table 4.1); there it is most likely that silver of variable purity was refined before it was re-used. A cupellation furnace is recorded from Silchester and a hearth associated with lead-rich debris from Leicester, while at Exeter: near the South Gate a 1st or 2nd century find of heavily burnt animal bone with up to 1% of lead is said to be consistent with its use in cupellation. The other sites have produced litharge cakes or fragments of them. Dates for these range from 2nd to 4th century but most are not well dated. Smaller-scale cupellation is suggested by the lead- and silver-rich deposits found on some shallow crucibles (mostly of type 3) which are known from a further six sites which mainly date to either the late 1st century or to the 4th century.

Crucibles that were used for silver melting have been found on 16 sites. They include types 2?, 3, 4 and 6 but some sherds are too small for a type to be identified. Where crucibles are dated they are mainly from 1st or 2nd century contexts. Refining and melting have not been noted at the same site except at Verulamium, where different types of crucible were used for the two processes, and possibly London: Copthall Street. This initially appears surprising but may indicate

Figure 11.5 - Roman sites with evidence of silver working

considerable specialisation by Roman craftsmen.

Lead

Over 50 sites have evidence for lead working of some form (Figure 11.6). The sites that have produced lead pigs (ingots) are omitted from Figure 11.6 as those listed in Appendix A are only a small proportion of the total. Tylecote (1986A, Fig 29) illustrates the findspots of 87 of these ingots, about half of which come from in or close to the ore fields where they presumably originated. A further third were found at ports, en route to an unknown destination.

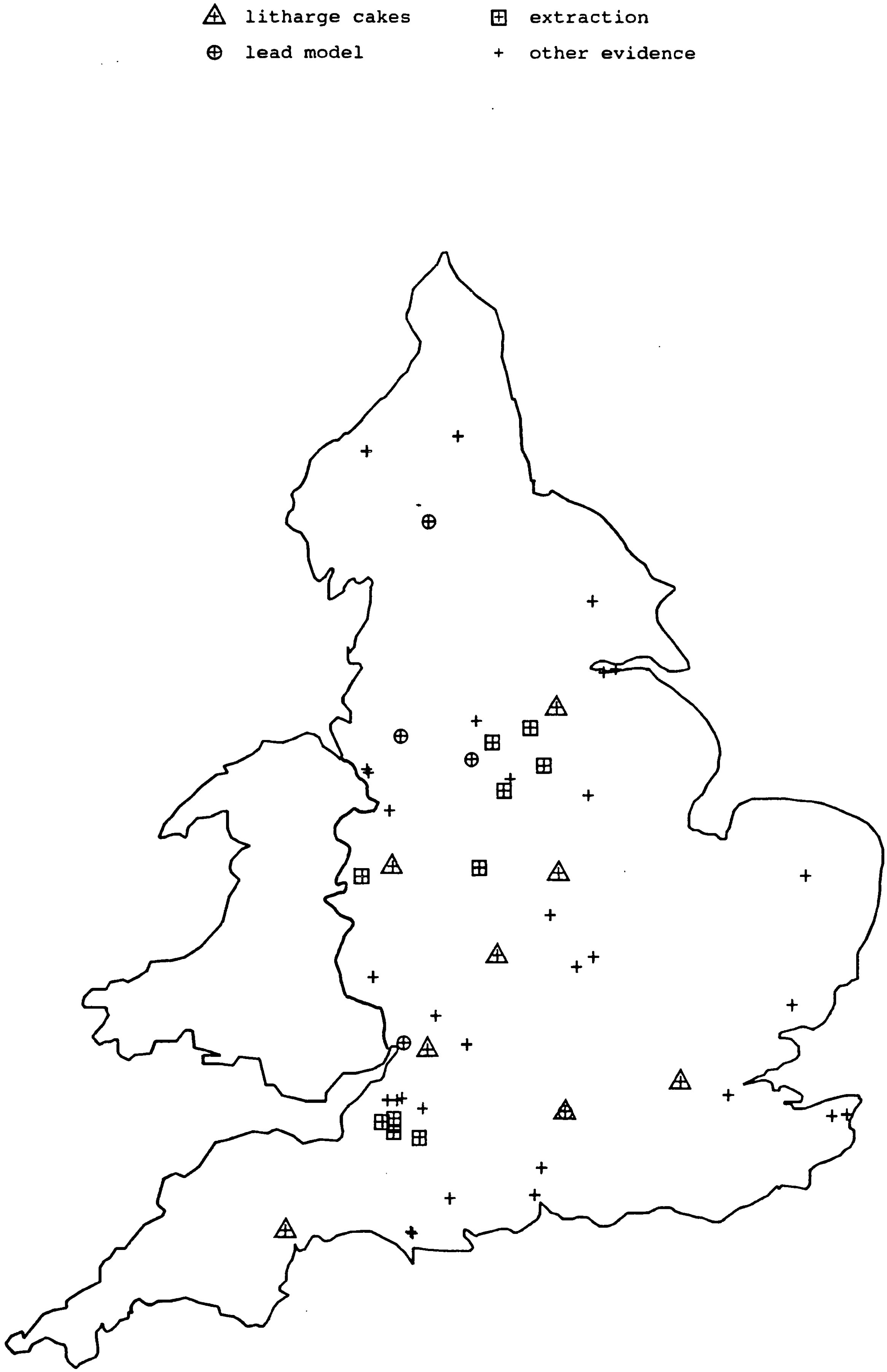
Sites in the orefields of Derbyshire, Shropshire and the Mendips provide evidence of metal extraction and, in the latter case, of the separation of siver from the argentiferous lead too; presumably the silver content of the Derbyshire lead was too low to make this worthwhile. Sites producing litharge cakes and evidence of large-scale cupellation are marked on Figure 11.6 (as well as on Figure 11.5) as lead was a major raw material for this process although it is normally considered as silver working rather than lead working.

Six sites have produced lead objects of types normally made of copper alloy and these are interpreted as models from which clay piece moulds were made. They are not strictly evidence for lead working as there is no proof most were made on those sites, but they do show the use of lead in the course of copper alloy working. One 3rd century lead ring from Silchester is unfinished and so is more definite evidence for lead working on site (Cool 1983).

The majority of the leadworking sites provide evidence of lead melting and/or cutting, usually with no indication of the end product, though the "plumbers' furnaces" in Cirencester are associated with rebuilding work. Much lead working may have been associated with its incorporation into the fabric of buildings, though leadworking evidence is not recorded on many of the sites of major buildings where it might reasonably be expected. Leadworking may not always have been recorded as much of the evidence left behind is ephemeral because of the relatively low temperatures involved.

Figure 11.6 shows a concentration of leadworking sites in the Midlands and Wessex with far fewer in the North and East. Even when the distortion introduced by production sites is ignored the division into two regions remains. It is possible that inclusion of the 'unrecorded' lead working mentioned above would even out the distribution as no obvious explanation for the observed pattern can be suggested.

Figure 11.6 - Roman sites with evidence of lead working



Tin and pewter

All but one of the finds indicative of tin working come from Cornwall (see Figure 11.7) which is not surprising when they are such things as cassiterite pebbles or smelting hearths. It is less obvious why all the tin ingots and all but one piece of tin metal should have been found there as alloys containing tin, such as bronze and pewter, were worked, and presumably made, more widely. This concentration is far more extreme than that shown by the lead ingots, discussed above.

Eighteen sites have produced moulds for casting pewter plates and vessels though only at Silchester was an ingot also found. A further nine sites have produced ingots and/or scrap, waste and part manufactures. Those pieces that have been analysed run from 98% tin down to under 50%, a range that is mirrored in Roman pewter vessels (Beagrie 1989A). Where these finds are dated they are 3rd century or later, though there is some suggestion of 2nd century working of impure tin from London: Walbrook. Pewter is an alloy that was effectively unknown in Britain in pre-Roman times. However, once it was introduced, it must have been commonly used as otherwise the effort of making reusable stone moulds would not have been worthwhile. The moulds are large and heavy and so are unlikely to have been transported far from where they were used.

There is a concentration of sites around Bath which have produced all the large groups of moulds, with most of the rest found to the south of a line from there to the Wash. One mould comes from St Just in west Cornwall and two from Yorkshire (Langton and York). The metal ingots and scrap/waste are also mainly from the South with isolated finds at Benwell and Corbridge on Hadrian's Wall. The concentration of finds near Bath, just to the north of the Mendips, can be explained as an industry using local lead together with tin 'imported' from Cornwall. There is no obvious reason for the distribution of the other sites. The metal finds, except perhaps the large ingots, could be considered as raw materials for tinning or soldering rather than as evidence for the manufacture of pewter vessels, though none pre-date the 3rd century which is odd if they do represent a separate industry.

Copper and its alloys

There are no ingots of unalloyed copper in England though examples of probable Roman date are known in Wales (Kelly 1976). This lack of copper away from known production areas is as surprising as the lack of tin, but ingots of copper alloys are known from a number of sites. Brass ingots have been recognised from Coppice Corner and 1 Alvin Street in Gloucester and from Claydon Pike, while the large brass sheet

Figure 11.7 - Roman sites with evidence of tin and pewter working

● tin working + pewter working

from Colchester: Sheepen must also be counted in this context though it is heavily worked and homogenised rather than being an as-cast ingot. The Sheepen site also produced a fragment cut from a bronze ingot while four copper-lead ingots and one of copper with 4% lead came from Lullingstone villa. Despite the lack of evidence for unalloyed copper it must have been available, as brass was being made by the cementation process in the 1st and 2nd centuries (see Chapter 4) at Colchester: Culver Street, Canterbury: 7 Palace Street and Canterbury: Cakebread Robey.

By far the commonest form of evidence for the working of copper and its alloys are crucibles, and analyses of the residues on them can be used to suggest the composition of the alloy melted. A high proportion of crucibles initially appear to have been used for melting gunmetals while analyses of metalwork (see Figure 10.2) suggest it was not commonly used. This contradiction is caused by the volatility and amphoteric nature of zinc which lead to its over-representation on crucibles and moulds, a problem discussed more fully in Appendix B, and means that analyses of crucible residues must be interpreted with caution if the results are not to be misleading. Taken as a whole, analyses show that a wide range of copper alloys were being worked in Roman Britain so it is likely that a high proportion of the objects found here were made here, or could have been made here.

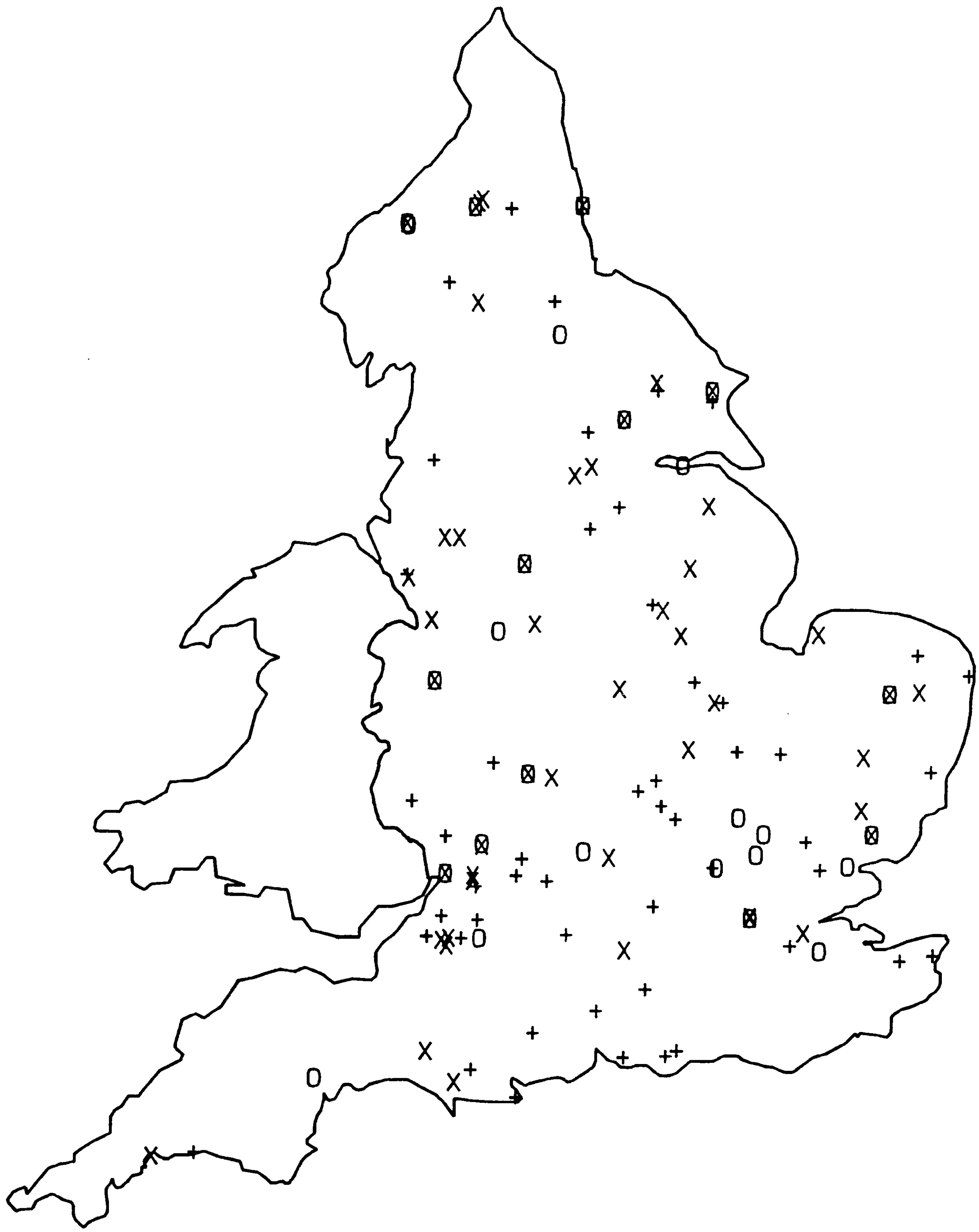
On about half the sites where there is evidence for the working of copper alloys, an end product can be identified with more or less certainty. This does not mean that only this type of object was being made; as always the negative evidence that archaeology provides must be treated with caution. The finds that indicate particular products include clay object moulds which show that castings were being made; if they survive well then the type of object can be identified, as at Castleford and Compton Dando, though the composition of the metal being cast is usually not determinable. Failed castings also indicate the intended product while sprues, like indeterminate mould fragments, are non-specific indiators of casting; metal waste allows the alloy being worked to be positively identified. There is positive evidence that objects were being cast on 48 sites all over the country (see Figure 11.8).

Evidence for wrought metalworking is less common (found on 30 sites) though the range of finds is as great. They include part manufactures such as the brooches and rivet from Baldock and tools like the doming block and ball-headed punch from Poole's Cavern. Hammers, chisels, punches and files are all possible, though non-specific, evidence for copper alloy working. The by-products of wrought

Figure 11.8 - Roman sites with evidence of copper alloy working

X casting objects O wrought metalworking

\+ non-specific metalworking



metalworking include sheet offcuts, which appear most commonly in 4th century contexts, and "boxes" of turnings or filings such as those from Catterick, Verulamium and York which all date to the 1st and 2nd centuries and are most likely to be the by-products of wrought work, though fettling castings could produce similar debris. Bar ingot moulds are a further indicator of wrought metalworking but the only Roman period finds are from the far north so it is not clear if they represent a Roman or native metalworking practice; the latter appears more likely, given that they are almost unknown in southern England.

One particular class of object for which there is good evidence of manufacture is counterfeit coins. The official mints provided a very intermittent supply of coin so there was a considerable, unfulfilled demand to be met and no law forbade the forgery of copper coin until the 4th century (Boon 1974). Cast counterfeit coins were in common use in the 3rd century; Boon (ibid) records finds of moulds from 25 sites, several of which are also noted in Appendix A. More recently a large group of coin moulds together with several mis-cast coins have been discovered in London (Jenny Hall, personal communication 1991). The smaller copper coins of the 4th century were also counterfeited, though in this case it appears discs were cut from a circular-section metal bar, flattened and struck; examples are known from Lydney Park and North Leigh villa.

Working of copper alloys was widespread on all types of sites all over the country; there are no significant differences between cast and wrought metalworking which share the same distribution. There is a similarly wide temporal range with evidence of both wrought and cast industries in contexts dating from mid 1st to 4th centuries.

Applied decoration such as gilding and tinning is found on Roman objects but there is no evidence of its application. Enamelling was also widely used but there is no good evidence for its application; Bateson (1981) summarises the evidence. It is easy to assume that if objects were being cast with ready-made fields for enamel, as was the case with some of the brooches from Compton Dando and the vessels from Castleford, then they would have been enamelled at the same place. So far this is an assumption rather than a proven fact. It is true that opaque glass has been found in crucibles at Chichester (Bayley 1978B) and Catsgore (Leech 1982) but in neither case was there any indication of the use made of the glass; bead-making is as likely as enamelling.

Early Saxon

Figure 11.9 shows the location of the few Early Saxon sites that have produced evidence for metalworking. Their mainly eastern distribution associates them with the Anglo-Saxon immigrants who came to these areas at this time. There is almost no evidence of contemporary British metalworking in England though Irish, Welsh and Scottish finds illustrate what might be expected (eg Youngs 1989). Despite their small number, the English finds demonstrate that both wrought working and casting were carried on.

The abnormally high proportion of finds classified as tools (cf Figure 11.1) include a number of dies from Lincolnshire, East Anglia and Kent which were used for decorating sheet metal. Touchstones, used for assaying gold, have been found in graves and are definitely tools but may not necessarily indicate their owners were craftsmen; traders too needed a method of assessing the purity of the metal they dealt in.

There are a few crucible and mould fragments from Mucking, including part of a square-headed brooch mould, which together with the failed castings from Cassington and Woodeaton provide positive evidence for casting. A crucible fragment from Spong Hill and two further crucibles from Glastonbury Tor are further evidence of metal melting. Though Glastonbury falls chronologically within this period, its cultural affinities are British rather than Saxon. However, the crucibles are not distinctive and the comparative data is inadequate so it is not possible to say if the cultural differences are reflected in technological ones.

The Yeavering crucibles may also belong here chronologically as occupation of the nearby palace site ended during the 7th century. They show a variety of fabrics and forms but their poor dating makes them an inappropriate group to use as comparative material for this period.

Middle Saxon

For the following two centuries there are more finds, but they come from only a dozen sites (Figure 11.10). Despite this they provide evidence for a range of different processes.

Gold was refined at Hamwih (Southampton) and that site has also produced the only archaeological evidence of any period for the manufacture of gold amalgam. A probable touchstone is among the finds from Whitby Abbey.

Silver was refined at Hamwih, Barrow on Humber and probably London: Jubilee Hall and was melted at the first two sites and at Hartlepool.

There are ingot moulds from York: Fishergate, Whitby and

Figure 11.9 - Early Saxon sites with metalworking finds

Figure 11.10 - Middle Saxon sites with metalworking finds

Hamwih which, together with the hoard of strap ends from Sevington, indicate wrought metalworking. Ingot moulds are far commoner in middle and late Saxon times than they are either earlier or later.

Evidence for casting includes a pewter model from Huntingdon (which adds that alloy to to the list of those being worked at this period) and clay piece moulds from six sites, an unusually high frequency; those from Hartlepool: Church Close are of a type for which no parallels are known to me (see Chapter 5).

As usual, the metals cast in the moulds cannot be determined though the same sites have produced crucible sherds with traces of a range of copper alloys and also, in three cases, silver. This is the only period when type 11 crucibles are found in England; there are examples from Wharram Percy and Hartlepool suggesting they are an Anglian rather than a Saxon type. York: Fishergate had no lidded crucibles but did produce one with a lug/handle which is also not a normal English form; the best parallels for that are from the contemporary settlement at Ribe in Jutland (Brinch Madsen 1984 and Figure 5.14, 3). Other York: Fishergate crucibles were thumb pots, some with a pointed base.

In several instances the metalworking has only been dated as middle Saxon by the designs preserved in the clay moulds. Although the object types have not always been identifiable, the style of the interlace or other designs are sufficiently specific even on small fragments. It may be that other metalworking finds of this period have not been dated correctly, or at all, as a result of the lack of specifically datable finds associated with them. If the proportion of sites with moulds were nearer the average for all periods, there should be about double the number of sites so far identified.

The metalworking evidence at this period comes from settlements of various types. That towns are among them is perhaps not surprising but it adds concrete support to Hodges' (1982, 144) comment that "many artefacts were either made or finished off in the emporia". Several of the sites (Jarrow, Whitby, Hartlepool and possibly Barrow-on-Humber) are monastic, which illustrates Dodwell's (1982) point that craftsmen were attached to monasteries permanently and for special commissions; Theophilus, working at a later period, is an example of this. Because of this association of metalworking and other specialised crafts with monasteries, some people are tempted to look on monastic or other 'high status' settlement as a necessary concomitant of craft activity. The finds from Wharram Percy are a rebuttal of this thesis and demonstrate that craftsmen were active, though not necessarily permanently resident, on sites of other types.

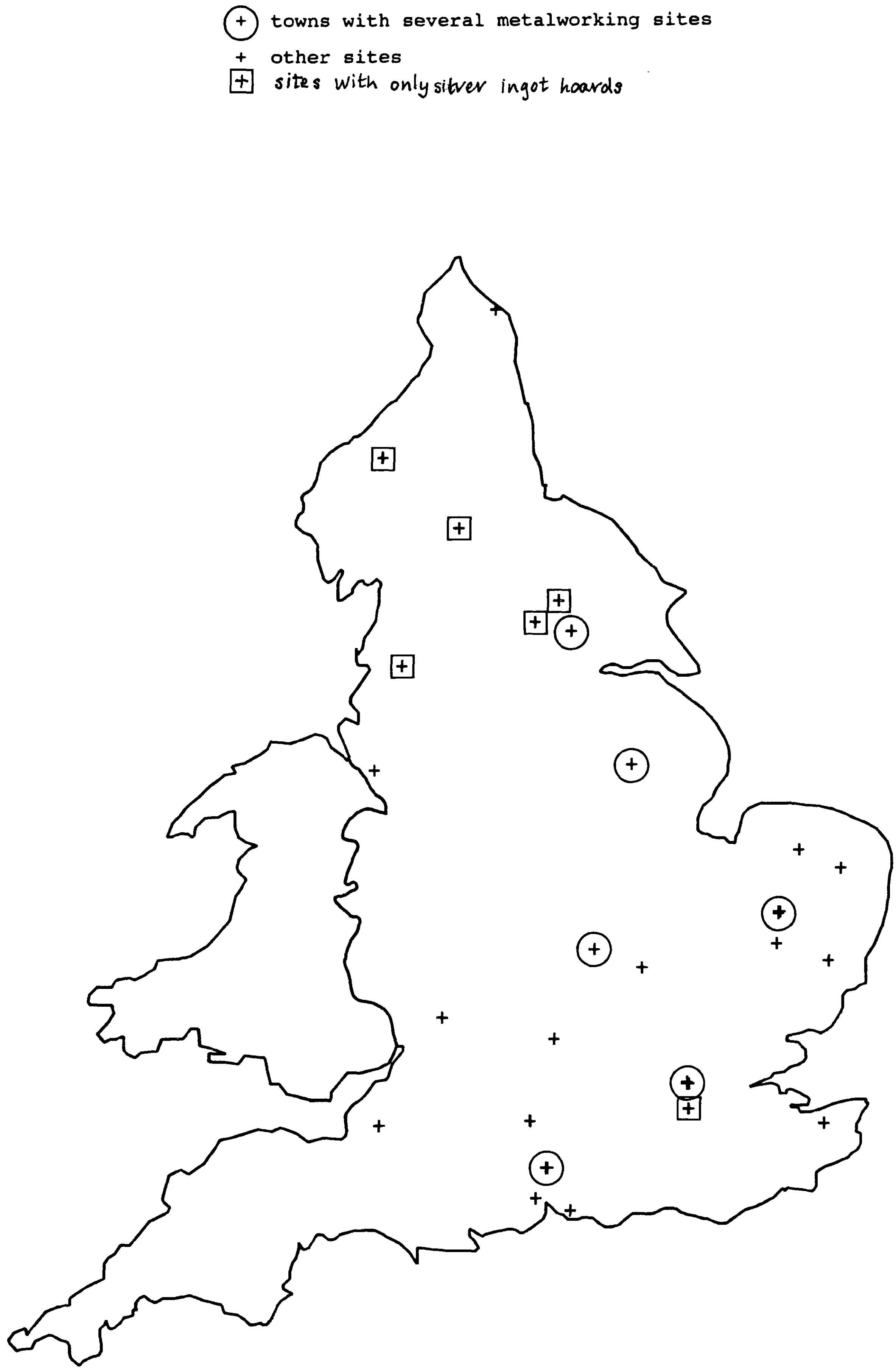
The geographical distribution of sites is rather different from those of earlier and later periods; there are more sites in the north than the south. This may be a result of the small sample size rather than any other factor.

Late Saxon

From the late ninth century onwards the number of sites with evidence for metalworking is larger. Most of these are urban and underlie medieval and later towns. Metalworking was not always an urban industry at this period but it is notable that 37 of the 64 sites lie in just 6 towns or cities and that finds are not common on small rural settlements, a completely different pattern from that found in the Roman period. At this period too the average quantity of finds on each site is also greater. These changed patterns can be used to advance the argument for more highly specialised craftsmen producing for a larger market than previously, reflecting the growing economic health and wealth of the country. Despite these changes, metalworking was essentially a local craft or industry and "the basis of the economy was [still] essentially agrarian" (Chibnall 1986). Late Saxon metalworking sites are widely scattered across the country, both in Wessex and in the Danelaw to the north-east (Figure 11.11). In some places the metalworking evidence is as early as the late 9th century but in other towns the earliest finds are 10th or 11th century, and in some there is evidence of continuity into the post-Conquest period.

There are some differences in the metalworking finds from the Danelaw and Wessex though the same range of processes and metals appear in both areas. Ingot moulds are common and are mainly made of fired clay or (relatively) local stone. However, nine (out of 12) examples from York: Coppergate are of soapstone which must have been imported from Shetland or Scandinavia; all but one of these is a purpose made mould block (like those illustrated in Figure 5.15) rather than a re-used vessel sherd. At the contemporary settlement at Haithabu, Schleswig the proportions are reversed with 91 of 109 ingot moulds made from sherds of soapstone vessels (Resi 1979). The thimble-shaped crucible from York: Parliament Street is of a Scandinavian form (Figure 5.14, 1) and it too suggests the presence of viking craftsmen, though most of the contemporary crucibles in York are English-made Stamford ware (Figure 5.10). Stamford ware crucibles are among those found throughout the Danelaw and even in London, but in Thetford similar forms were made in local Thetford ware while London and Winchester, in the heart of Wessex, have their own range of forms and fabrics (Figures 5.11 and 5.12).

Figure 11.11 - Late Saxon sites with metalworking finds



* The Viking bullion hoards comprising or including silver bar ingots that are listed in Table 2.5 and located in Figure 11.11 are, like the late Roman silver ingots, not evidence for metalworking at their findspot. Rather, they are examples of the products of metalworking and were potential raw material available to contemporary craftsmen.

Gold and silver

There is evidence of assaying, refining and melting gold. Touchstones have been found at Winchester and York, and in both cities there are also small (possibly assay) cupels with traces of gold on them. From the York: Coppergate excavations come blocks of fused quartz chips which appear to have been used in a similar way. Parting vessels have also been recognised on two sites in York (Figure 4.6) and two in Winchester. Crucibles used to melt gold have been found at Cheddar, Netherton, Ipswich and York and a gold droplet at Winchester.

On some of the sites a very high proportion of the finds suggest silver working, either melting or refining. Litharge cakes and cupels with traces of silver are common on sites in Lincoln, York and Winchester and cupels are known from other sites, eg in Northampton and Thetford too. On most of the sites where crucibles were found, the residues on them suggest that silver was among the metals melted, and those ingot moulds which retained traces of metal had mainly been used for casting silver. The product would have been silver bar ingots such as those found in hoards, an ideal raw material for making wrought silver items such as coins. Most ingots that have been analysed are of good quality silver (Kruse 1988), showing that refining had indeed been carried out.* Most of the sites with silverworking finds are in towns known to have had mints at this period (Spufford 1988). The York: Coppergate site has produced two coin dies and several lead trial stamps (Pirie 1986) which, when taken together with the large quantity of evidence for silver refining and melting (Bayley forthcoming), can be interpreted as indicating a possible physical location for a moneyer's workshop. It is tempting to extrapolate this data and suggest that the great upsurge in silver working at this period was directly related to the increase in the volume of coinage in circulation, an indicator not only of commerce but of English wealth.

Copper alloys

Many crucibles contain traces of copper alloys; brass appears to be common. This is in accord with the upsurge in the use of brass at this time (see Chapter 10). Bar ingots of brass and other copper alloys are known, though some are too long to have been cast in any surviving moulds which shows that other formers, even a temporary groove made in a workshop floor as has been suggested at earlier periods, could have sufficed for base metals. Bars, rods, wire and sheet metal offcuts are common on sites such as York: Coppergate and Lincoln: Flaxengate and provide further evidence for wrought metal industries. Object moulds are also known on several sites and finds such as sprues confirm casting. For the first time bell moulds make their appearance, a direct indicator of the liturgical changes that required large bells (Hinton 1990); there are examples from Gloucester: St Oswald's, Winchester: Cathedral Green and York: Coppergate. The former is well enough preserved for the size and profile to be reconstructable and suggests a form without the very flared mouth that is normal in later medieval times.

Lead, tin and pewter

In York there is some evidence of casting small objects in lead or pewter, a type of metalworking which showed a renaissance from the tenth century (Roesdahl et al 1981, Bayley forthcoming). The antler mould from Southampton is probably contemporary and was almost certainly used for lead or pewter as it could not have stood the higher temperatures of other molten metals (MacGregor 1980). A fine limestone mould from the Flaxengate site in Lincoln may also have been used for casting pewter. Unfinished pewter trinkets of early 11th century date have been found at London: Cheapside (Hornsby *et al* 1989).

There is direct evidence for tinning too; at York: Coppergate bars of pure tin and lead-tin alloy with molten tips were found showing that dipping was not a universal method of application.

At this period too, lead had other non-metallurgical uses. It was the basic raw material for glazes on pots and for making some types of glass (eg Mainman 1990, Bayley 1987C).

Early medieval

As was noted in Chapter 1, the Norman Conquest had little impact on the material culture of England so the division between late Saxon and early medieval is not a clear one where metalworking evidence is concerned. Figure 11.1 shows that the only significant difference between the frequencies of late Saxon and early medieval metalworking finds is the absence of ingot moulds and motif pieces in the later period. Some of the same pottery fabrics continue in use, so finds such as Stamford ware crucibles can belong to either period (eg Gilmour 1988). The nature of the urban sites which produce most of the metalworking finds also serves to blur the distinction as residuality of finds is often a problem. The range of metals worked appears reduced, with no evidence for tin or pewter working; precious metal working is less common than in the late Saxon period but the full range of processes continued.

Most of the sites in Table 2.6 do definitely belong to the early medieval period but some, eg those in Lincoln, are not yet fully

Figure 11.12 - Early medieval sites with metalworking finds

studied and the metalworking finds may eventually turn out to be late Saxon. The increase in object moulds is due to the larger number of bell moulds and other similar moulds found. The sites are scattered across the country, mainly in towns, with a concentration in the Midlands and South.

Later Medieval

The sites summarised in Table 2.7, most of which have no firm dating, mainly produced evidence for two processes, lead melting and bell casting; in other cases the published information referred only to "bronze working". The lack of detail and the poor dating mean that no further comment is warranted.

There is some evidence for metalworking in the later Middle Ages, but the quantity of both sites and finds is far lower than at earlier periods; perhaps the more geographically concentrated nature of the industries (suggested above) has provided archaeologists with a lower chance of locating these sites in their randomly located excavations.

SUMMARY AND CONCLUSIONS

This thesis has focused on the material evidence for metalworking and on the information this provides about the processes carried out by craftsmen in antiquity. Information on 479 sites where metalworking debris of one sort or another has been found has been assembled; in 135 cases the information is wholly or mainly the result of my own investigation of the material. In addition, the use of metals at each period has been surveyed and a special study made of the use of copper alloys in the Roman period. The data for this study was a total of over 4,000 analyses, including nearly 1,000 quantitative ones.

Metalworking

Prior to this work, most of Chapter 4 could not have been written as although it was known that the processes described had been carried out, material evidence for them had not been identified. 'Heating trays' had not been identified as a specific type of crucible nor had they been identified as cupels. Parting vessels were known from only a single site, and cementation brass was known to exist from metal analyses though not from manufacturing debris. Now that 'type fossils' for these processes have been recognised, it is likely that more evidence for them will be found among the residue of 'unidentifiable fragments' which have previously failed to get to the right specialist as the finds researcher could not guess what they might be.

Although crucibles and moulds were relatively well known, the diversity of types and their affinities set out in Chapter 5 had not been recorded. The frequency with which gold and, more particularly, silver is found on crucibles was unsuspected; most were considered as "bronze working" finds - and the range of copper alloys in use has been shown to be far wider than this over-simplification implies.

Chapter 6 serves only to show how little evidence there is for wrought working. Even this little is probably more than many might expect, as popular misconceptions see crucibles, moulds and the occasional tool as the only evidence for metalworking.

When the work that led to this thesis started in the mid 1970s it was common to find copper alloy objects catalogued in excavation reports as 'bronzes' and any white metal coating on them described as 'silvering'. The results presented in Appendix C show that these descriptions are respectively often and usually inaccurate. These facts are now noted by most of those who write finds reports. The information gathered together in Chapter 8 is mainly well known, but the data in Appendix C is a large enough set that the frequency of different types of decoration present can be taken to represent a norm for decorative though functional Roman objects. Table 8.1 shows that traces of gilding survive on only 41 (of 3346) brooches. Overlays of silver wire or foils were found on 47, while repoussé decorated copper alloy (usually brass) overlays were noted on up to 24 brooches. Tinning, without definite or possible overlays, was present on about 280 brooches, 40% of them Hod Hill types. Enamel was by far the commonest form of applied decoration with 552 examples, 16% of all brooches.

Chapter 11 attempts to present a balanced picture of metalworking at different times; it is based on the interpretation of the site specific data assembled in Appendix A.

The position of the metalworker in society was touched on in the discussion (in Chapter 10) of Iron Age metalworking, while in Roman times the debate seems to centre on whether his work should be considered a craft or an industry. Though there is little evidence from the early and middle Saxon periods, metallurgical activity then must surely have been on a craft scale; the status of metalworking sites appears very varied. In late Saxon England there is a suggestion of more organised activity which can be seen as the beginning of manufacturing industries, though still on a craft scale until mechanisation became significant in later medieval times.

Although a good outline of most of the metalworking processes carried out in antiquity can now be given, our understanding is still incomplete. More detailed investigations than those presented here, eg quantitative phase analyses using a scanning electron microscope with EDAX analyser, would add further detail and should thus clarify the position. Work of this sort would help confirm or refute my more speculative interpretations of apparently anomalous finds. Examples include the gold-refining cupels with low-lead vitreous deposits; it might be possible to prove whether they really were cupels or just atypical crucibles.

Metal usage and alloy selection

The changes in the metals and alloys used, which were identified in Chapter 10, can be interpreted to give information about the availability and supply of metals at different periods. Most of the new data assembled relates to the composition and use of late Iron Age and Roman copper alloys.

The influx of brass into southern England in the early to mid

1st century AD was a direct result of contact with, and conquest by, the Roman Empire. Brass was in general circulation as coinage in Gaul from the end of the Republic in the mid 1st century BC. Condamin and Boucher (1973) found little zinc in the alloys used to make figurines until later periods and put this down to a state monopoly leading to the exclusive use of brass for coinage. Analyses of a variety of objects from Alesia have shown that brass was in general use by the early 1st century AD (Rabeisen and Menu 1985), throwing doubt on Condamin and Boucher's interpretation. Pernot and Hurtel (1987) analysed wrought sheet metal from other French sites and found mainly bronzes but some brasses, including a Celtic figure of a 'god'. They note that the use of brass in Celtic metallurgy has been little studied and remains a controversial subject. A similar ambivalence marks the discovery of brass in definite pre-Conquest contexts in Britain, though import from the Continent is a convenient explanation here.

In Britain brass disappears (in a relative sense) during the third quarter of the 1st century AD. This is the point at which Colchester A brooches give way to Colchester B and Colchester derivative types (see Chapter 10 and Bayley 1985K). The timing of this change is interesting as from the reign of Vespasian (AD 69-79) the zinc content of the brass coinage fell steadily (Caley 1964) suggesting that from this date sufficient newly made brass ceased to be available and existing metal was being remelted. The state monopoly described by Condamin and Boucher (1973) may have led to the requisitioning of much of the brass then in use for objects other than coins, and thus to the change to other alloys by most brooch makers. The brass used to make later brooches has a lower zinc content than the mid 1st century types (see Figure 10.40), further evidence for the recycling of existing metal.

That brass was largely replaced by heavily leaded bronze is another observation for which an interpretation can be offered. The lead-silver mines of Britain were intensively exploited in the mid and late 1st century and Pliny recorded the glut of lead this produced. The economy of using some of this surplus to stretch the available bronze must have appealed to the new entrepreneurs of Roman Britain. The Mendip location of Compton Dando, one of the few sites with good evidence for brooch manufacture, must be more than a happy coincidence.

The trend towards higher proportions of objects of mixed alloys seen in the analyses of Roman objects other than brooches (Table 10.3) suggest that an increasing proportion of the metal used in later Roman Britain was recycled. If this is true it may provide a measure of the economic health or trading activity of Britain within the Roman

Empire, though there could be technical rather than economic explanations for the change. The trend appears to continue into the early Saxon period (Table 10.4), though the reasons for it may not be the same.

These are occasions when the metal analyses show clear patterns which can be linked to existing data and which can be interpreted to throw some light on the economy of the Roman Empire. At other periods the data set is too small or too diffuse to give definitive answers. Further quantitative analyses of specific types of objects should allow better understanding and perhaps even resolution of some of these outstanding problems.

Another query that the analytical results raise is that of brooches of atypical compositions for their type. While it is possible they are all 'Friday afternoon jobs', they could be material evidence for very small scale, local production or for temporary shortages of the preferred alloy. Although the work reported here provided a mass of data, it has only just begun to explore the reasons for the patterns within it.

Historical interpretation

Few of the changes identifiable in the material evidence can be linked directly to historically identified events, though the Roman Conquest does seem to have brought with it new processes, new forms of crucibles and new alloys. More specifically, the evidence for the manufacture of counterfeit coins in the 3rd century can be seen as a reflection of the disruptions to the economy of the Roman Empire at that period. The revival of the Cornish tin industry at much the same time would appear to be a direct response to the documented failure of the Spanish tin mines and coincides with the upsurge in the manufacture of pewter vessels in England.

At a later date the Viking influence on northern England is clearly seen in the occurrence of Scandinavian crucible forms and soapstone ingot moulds in York, perhaps material evidence of trading contacts. The ingot moulds from Whitby may show a craftsman was working at the monastery but may just be evidence of the better documented activities of the Vikings, their raids on rich, undefended settlements. The expansion of English trade in late Saxon times is well known as is the insistence than foreign coins were reminted before they were allowed to circulate in the country, so the large number of silver-melting crucibles from towns known to have mints can be interpreted as material evidence for this upsurge in the minting of silver pennies.

The points made above are all interpretations of, or inferences drawn from, the data presented here. The list could doubtless be expanded, but to do so I would need a more detailed knowledge than I possess of the historical background. By making the primary data available I hope that those who have this background will now be in a better position than before to substantiate or disprove their hypotheses. The whole area of the historical and archaeological interpretation of the data presented here is one where much further work is possible and would, in my opinion, be most rewarding.

APPENDIX A

GAZETTEER OF SITES WITH NON-FERROUS METAL WORKING FINDS

The entries are arranged in alphabetical order of site names. Sites within a town are listed by site name but in sequence under the town name. An asterisk after the site name indicates that the information about the technological finds is largely or totally my own work.

The information given under each entry is in the following form:

Site name.

County (as existing after 1974) and grid reference. Where no precise grid reference for the site was known the four figure reference from Bartholomew's Gazetteer (Mason 1977) or from the Ordnance Survey (1987) gazetteer is given.

Period and date. The period is a general indication of date but this is more closely defined where information is available. The date range given does not necessarily represent the whole life of the site in question but is the date assigned either to the finds described or to the contexts from which they came. All dates are AD unless otherwise indicated. All sites dated 13th century or later have been omitted, however some of the entries described solely as "Medieval" will be post 1200 AD in date. Little use has been made of these entries because of the uncertainty as to whether they relate to the period of this study.

Nature of site. (If known).

Description of finds. More detail is given for unpublished material and for major or important groups.

References which provided the information given. Much of my own work and that of others working for me is as yet unpublished. In these cases I have referred to the relevant Ancient Monuments Laboratory Report(s); these are available for consultation in the National Monuments Record which is maintained by the Royal Commission on Historical Monuments (England) and fiched copies of the new series reports (those with numbers in the form AML ***/**) are also available on demand from the Laboratory. Where the information comes from personal observations that are unpublished in any form "JB" is given as the reference.

Comments. These normally only appear where I question the published identification or interpretation of the finds.

Alcester * Warwks (SP 0857)

Roman: mid 2nd - late 4th century

Settlement with timber buildings like the shops/workshops known elsewhere. There is evidence for copper working including a mould for casting small button-like discs and six crucible sherds [one type 4/5 and two type 5] used to melt brasses and bronzes or gunmetals.

Refs: Hartley 1954, Crickmore 1984, AML 67/90

Alcester: 1-5 Bleachfield Street Warwks (SP 0857)

Roman: late 3rd - mid 4th century

Finds from a pit included 13 crucible sherds [types 4 and 6] and a possible crucible lid.

Refs: Booth *et al* forthcoming

Alcester: Gateway Supermarket (site AL 18) * Warwks (SP 0857)

Roman: 4th century

Finds include a crucible fragment [type 4], hearth lining, sheet metal clippings and blobs and dribbles of brass, gunmetal and leaded bronze.

Refs: JB

Ancaster: Gap Lincs (SK 983436)

Iron Age: late

Settlement

Finds include a coin pellet mould fragment.

Refs: Whitwell 1982

Ancaster: Quarry Lincs (SK 987432)

Iron Age: 4th - 2nd centuries BC

Settlement. Finds of slag suggest copper alloys could have been worked on this site.

Refs: May 1976

Ash Kent (TR 2857)

Saxon: 7th century

Grave 66 in Gilton-Town cemetery produced a tablet-shaped touchstone c.25 x 20 x 10 mm.

Refs: Moore and Oddy 1985

Bagendon Gloucs (SP 017062)

Iron Age: 20/25 - 43/45 AD

Settlement with more evidence for industry than domestic occupation. Finds include parts of well over 100 coin pellet moulds, many found in a group near the remains of a furnace. The holes in them are of two sizes (the larger is less common) and taper slightly. Emission spectroscopy detected copper, silver, gold, tin, lead and zinc in varying proportions. The analyses are said to show that most of metal in the moulds was copper-silver though some was thought to be brass.

The interpretation of the site as a mint is supported by the presence of four possible iron coin dies and a small anvil. Other sorts of metal working are indicated by several crucible fragments, a slab of bronze (20 x >20 x 3 mm), a black lydite pebble touchstone and an assortment of iron tools.

Refs: Clifford 1961, RCHM(E) 1976, Collis 1975

Comment: Zinc is almost universally detected in moulds used for non-ferrous metals, sometimes in relatively large amounts. The suggestion that brass may have been one of the metals melted in the coin pellet moulds should not therefore be given too much weight, particularly as the overall levels of metals found were so low.

Baldock * Herts (TL 2433)

Iron Age and Roman: early 1st century AD - 4th century

Oppidum with continued occupation throughout the Roman period; the settlement retained its native appearance in the post-conquest period. The dates given are all for the filling of the pits and ditches and as such represent a terminus ante quem for the objects in them.

The earliest metal working evidence is 3 brass blanks for one-piece Colchester brooches found in contexts dated c.25-50, 50-70 and 70-90 AD respectively. Also found were a part-made rivet/stud (dating 70-90), rolled sheet metal rivets (mainly 3rd-4th century) and some two dozen crucible fragments [type 4] from vessels with average volumes of c.200 ml. A concentration of crucible sherds dates to 150-180 and may indicate the location of a workshop though similar sherds come from contexts dating from 70-90 on into the late 4th century. The crucibles were used to melt a whole range of copper alloys, many containing significant amounts of zinc. Late 4th century finds include a pewter ?ingot fragment 50 x 48 mm and another smaller piece.

Refs: Stead 1975, AML 3604 and 3605, Stead and Rigby 1986, Bayley 1986B

Comment: The brooch blanks probably represent late Iron Age activity while the rest of the metal working is Roman, being late 1st century at the earliest.

Baldock: Upper Walls Common Herts (TL 250341)

Roman: mainly 1st-2nd century

Finds include a pit containing "bronze-working" debris.

Refs: Grew 1981

Barrow on Humber * Humberside (TA 0721)

Saxon: mid

Finds include fragments of both clay piece moulds and handmade crucibles [type 6?] used to melt brasses and gunmetals, mostly unleaded (7), and silver (2) as well as a cupel fragment with silver on it.

Refs: AML 4005

Barton on Humber Lincs (TA 032217)

Saxon: 7th century

Grave goods included a leaded bronze die for impressing sheet metal with style II ornament.

Refs: Wilson 1981, Youngs, Clark and Barry 1983, Capelle and Vierck 1971

Barton on Humber: St Peter's Church Lincs (TA 035219)

Medieval

Excavations found two bell casting pits and a plumber's workshop.

Refs: Webster and Cherry 1979 and 1980

Basingstoke: Viables Farm Hants (SU 63185020)

Iron Age/Roman

Finds include a triangular crucible [type 2].

Refs: Millet and Russell 1984

Bath Somerset (ST 7564)

Roman

Finds from the temple of Sulis Minerva include a mould for casting amulets, probably in pewter or lead, and a flan-shaped pewter ingot from the spring.

Refs: Beagrie 1989A

Bath: Abbey Green Somerset (ST 7564)

Roman: late 1st century

Sheet offcuts, droplets of lead and part of a tuyere were found. "The precise nature of the lead working is uncertain; it may have been connected with building activities, with the manufacture of objects, or even cupellation".

Refs: Greene 1975

Comment: There is no positive evidence for cupellation here; the other possibilities are more likely.

Bath: Citizen House Somerset (ST 74906477)

Medieval: 11th-13th century

Finds include a stone crucible.

Refs: Wilson and Moorhouse 1971

Beckford * Worcs (SO 984364)

Iron Age: 250-50 BC

Open settlement site. Finds include 44 fragments of triangular crucibles [type 1 or 2] used to melt bronze, scrap bronze (blobs, dribbles, lumps and sheet fragments), clay investment moulds and copper-rich hearth lining and fuel ash slag. Traces of zinc and lead were detected in some of the samples, suggesting the use of local, zinc-containing copper ores. Most of the finds date to the middle Iron Age but one nearly-complete mould from a different area is late Iron Age.

Refs: Britnell 1974, AML 3762, Northover (personal communication), Hurst and Wills 1987

Bedford: Empire Cinema Site * Beds (TL 048498?)

Saxon: late

The finds included a number of sherds of bag-shaped, ? Stamford ware vessels, at least some of which have been used as crucibles [type 7]. Some had an extra outer layer of less refractory clay. They were little vitrified and only three sherds showed any sign of metal; one contained silver droplets and two had traces of copper.

Refs: AML 3032

Benwell Tyne and Wear (NZ 2164)

Roman

Two lumps of pewter from this fort on Hadrian's Wall may be evidence for metal working. One was round and weighed c.100g and the other 70g. Analysis by Smythe found 97.7% Sn, 2.73% Pb.

Refs: Beagrie 1989A, Smythe 1937/38

Binham Priory * Norfolk (TF 982399)

Medieval: 12th century and later

The site museum contained a number of complete and fragmentary bag-shaped crucibles in a fairly fine fabric, similar to Stamford ware [type 7]. Most pieces were more or less deeply vitrified and showed some trace of copper or one of its alloys.

Refs: Fernie 1980, JB

Bletsoe * Beds (TL 0258)

Roman

Finds from this villa site include two fragments of clay piece moulds.

Refs: JB

Bodinar Cornwall (SW 4332)

Roman: late 3rd century

Finds included pieces of tin which Borlase claims were smelted here.

Refs: Davies 1935, Tylecote 1962A, Borlase 1873

Boscarne Cornwall (SX 0367)

Post Roman/ Saxon: 8th/9th century ?

Plano-convex, ovalish tin ingot in Bodmin Museum is said to come from here. A C-14 date from a wooden shovel in the tin works may be related.

Refs: Beagrie 1985A, Penhallurick 1986

Bottesford Lincs (SE 899069)

Iron Age

Fragment of a coin pellet mould found.

Refs: Whitwell 1982

Bowes: Old Spital Farm Durham (NY 9112)

Saxon: 10th century

Hoard included 17 fragments of bar ingots and three blobs/dribbles, all of silver.

Refs: Edwards 1985, Kruse 1988

Box Wilts (ST 8268)

Roman: late 3rd-4th century

Villa. Evidence for metalworking includes 2 crucible fragments with 'copper' deposits, some sheet metal clippings and a blob of gunmetal.

Refs: Hurst, Dartnall and Fisher 1987

Boxgrove Sussex (SU 921085)

Roman

Finds on this farmstead include a "crucible containing bronze slag" and fragments of coin pellet moulds.

Refs: Frere 1983A

Comment: Some of the excavated features are said to have possible Iron Age origins which may explain the presence of coin pellet moulds.

Brampton Norfolk (TG 224237)

Roman

Timber buildings used as "bronze workshops" found within the defences.

Refs: Knowles 1977, Goodall 1972, Beagrie 1989A

Comment: The "piece of limestone with curved grooves" is millstone grit and is not a mould.

Braughing Herts (TL 3925)

Iron Age: late

Coin pellet mould fragment found; XRF detected only silver.

Refs: Partridge 1979, Tournaire *et al* 1982

Braughing: Wickham Kennels Herts (TL 39052433)

Iron Age: 25 - 75 AD

Finds include a copper alloy bar and coin pellet moulds, four of which were analysed and had traces of gold and/or silver on them.

Refs: Partridge 1982

Braughing Herts (TL 3925)

Roman: early 2nd and 3rd centuries

Strip buildings along both sides of Ermine Street were associated with "bronze" working. The earlier phase produced three sherds from small copper alloys. The later phase had crucibles and slag associated with a "bowl of burnt clay, 1.2 m across, with a flue-like outer chamber" identified as a metal working hearth.

Refs: Partridge 1975, Potter and Trow 1988

Bredon Hill Hereford and Worcester (SO 960400)

Iron Age: 100 - 50 BC

Hill fort. Excavations found a "bronze smelting floor" with a furnace, round the base of which was a spread of ash, charcoal and "bronze" slag. Five hammers and other tools were also found.

Refs: Hencken 1938

Breedon on the Hill Leics (SK 4022)

Iron Age: 1st BC/AD or 2nd BC!

Finds include a triangular crucible [type 1].

Refs: Wacher 1964, Cunliffe 1974

Comment: Pottery from the site has parallels which are dated 4th/3rd century BC so occupation is more likely to be earlier than later.

Brislington Avon (ST 6270)

Roman

Villa. Two small limestone moulds for a decorated strip and a ribbed rod or handle are known, as well as lead scrap and sheet. These may possibly be considered as evidence for pewter working as seven pewter jugs were found in a well.

Refs: Branigan 1976, Beagrie 1989A

Bristol: Filwood Park Avon (ST 591692)

Roman: 2nd-4th century

Agricultural settlement with "plentiful evidence of metal-working". Finds include a trial casting in lead and cut and cast counterfeit coins.

Refs: Frere 1984

Bristol: Victoria St Avon (ST 5872)

Medieval

Several moulds for casting small "bronze" objects have been found as well as evidence for a "bronze" pin industry, possibly for making wool cards.

Refs: Schofield *et al* 1981

Brough on Humber Yorks (SE 9326)

Roman: 2nd-4th century

Finds include a crucible rim sherd [type 5?] and copper alloy scrap and sheet clippings. 5 lead pigs have also been found. They may be accidental losses during trans-shipment or stock retained for local use.

Refs: Ramm 1978, Wacher 1969

Brough on Noe Derbys (SK 184825)

Roman: later 2nd-3rd century

The fort acted as a control point for the Roman lead mines in Derbyshire. Finds of a furnace, hearths, slag, galena, lead offcuts and objects suggest metalworking on site.

Refs: Elkington 1976, Frere 1984 and 1985

Brough under Stainmore Cumbria (NY 7914)

Roman

Flawed and unfinished castings and a lead model of a brooch were found.

Refs: Bateson 1981, Collingwood 1931C

Comment: The illustrations of the supposedly flawed and unfinished objects are not very convincing.

Bury St Edmunds Suffolk (TL 8564)

Saxon:

Leaded gunmetal die found.

Refs: Meeks and Holmes 1985, Leeds 1936, Capelle and Vierck 1971

Comment: This is one of two dies from "Suffolk" published by Capelle and Vierck; cf Icklingham.

Bury St Edmunds Abbey Suffolk (TL 8564)

Medieval: ?early

Finds include a lead bar and dribbles and a fragment of a litharge cake with traces of silver on it.

Refs: AML 4135

The Caburn Sussex (TQ 444089)

Iron Age/Roman: *c*.200 BC - 100 AD

Hillfort. Four pits produced crucible fragments and an iron hammer head 3" long was also found.

Refs: Curwen 1927

Caister by Yarmouth * Norfolk (TG 517123)

Roman: late 2nd - late 4th/early 5th centuries

Finds include eight fragments of both hand made and wheel thrown crucibles, two used to melt silver and the rest (including two with an added outer layer) copper alloys, a sherd reused as a cupel, copper alloy waste and an antler hammer head.

Refs: Ellison 1966, AML 4150 and 4755

Comment: At least one of the crucible sherds with traces of copper alloy is late Saxon [type 7].

Caistor by Norwich Norfolk (TG 2303)

Roman: 1st century AD

Town. To the north-east of the town was found a "bronze-working furnace" and nearby were fragments of crucibles and moulds. None of the mould fragments showed any evidence of a parting line and are therefore thought to be from investment moulds. A wide range of copper alloy objects were being cast. The crucibles included 2 sherds of type 1 or 2 while the majority were from circular vessels [?type 6]. The fabrics were mainly very vesicular which shows their poor refractory qualities. 5 metal blobs were leaded bronzes, some with minor amounts of zinc.

Refs: [Mann] 1939, Tylecote 1969

Camerton Avon (ST 6857)

Roman: mid 3rd - late 4th century

Road-side settlement. Excavations in the north-east corner of the settlement found three furnaces and, lying near one of them, parts of three or four limestone moulds for pewter vessels. With the moulds was an iron clamp that may have been used to keep the valves of the moulds together while the molten metal was poured in.

Refs: Peal 1967, Wedlake 1958 and 1982, Beagrie 1989A

Canterbury Kent (TR 1457)

Roman: late 4th or early 5th century

A hoard of silver including four ingots, three ox-hide and one bar-shaped, was found. They are thought to have been bullion paid to soldiers and not therefore a craftsman's stock of raw material.

Refs: Painter 1965, Johns and Potter 1985

Canterbury: Cakebread Robey * Kent (TR 1457)

Roman: pre 75 AD

Finds include several dozen fragments of crucibles thought to have been used to make brass by the cementation process.

Refs: AML 3862 and 4644, Bayley 1984A

Canterbury: Marlowes IV and Marlowes Theatre * Kent (TR 1457)

Iron Age/Roman: 1st century AD

Finds include fragments of four triangular crucibles [type 1] used to melt bronze (2), ?copper and gold. One of these crucibles containing bronze and a fragment of a coin pellet mould predate c.70 AD, the other crucibles are from late 1st century contexts.

Refs: AML 3862

Comment: These finds are typical of the later Iron Age though the contexts they were found in date as late as 70-100 AD.

Canterbury: Marlowes III and Cakebread Robey * Kent (TR 1457)

Roman: mainly 290-350 AD

Parts of nine crucibles [type 5] were found, all but one hand-made and of a refractory fabric with abundant fine quartz temper. Most also had a very thin extra outer layer of less refractory clay. Most had been used to melt brass but tin was also detected on one sherd.

Refs: AML 3862

Canterbury: Cakebread Robey * Kent (TR 1457)

Saxon: mid

A small group of clay mould fragments, some at least probably from piece moulds, were found.

Refs: AML 4644

Canterbury: Marlowes IV * Kent (TR 1457)

Saxon: 8th - mid 11th century

Two clay mould fragments and a piece of copper alloy waste were found.

Refs: AML 3862

Canterbury: Cakebread Robey * Kent (TR 1457)

Medieval: mid 11th-12th century

Finds included scrap and waste metal and a bar ingot (46x12x10 mm) of copper with a little lead, tin and silver (see Table C.5).

Refs: AML 4644

Canterbury: 7 Palace St * Kent (TR 14955798)

Roman: 2nd century

Finds included a lidded crucible thought to have been used to make brass by the cementation process; its brimful volume was 25 ml. XRF detected copper and zinc.

Refs: AML 4139, Bayley 1984A and 1987B

Canterbury: St Augustine's * Kent (TR 154579)

Medieval: pre c.1300 AD

Excavations found a casting pit and in it a cylindrical bronze bar 25 x 200 mm, pieces of mould similar to bell mould but of different shapes, some with traces of bronze, and hearth lining rich in copper and tin.

Refs: AML 4647, Youngs, Clark and Barry 1984

Canterbury: 41 St George's Street Kent (TR 152576)

Medieval: late 12th century

Finds include debris from a metal melting furnace, probably used for casting bells, and about 30 crucible sherds [type 8] used to melt bronze(1), ?brass(10) and silver(3).

Refs: AML 37/87, Youngs, Clark and Barry 1986, Budd 1988

Canterbury: St John's Lane Kent (TR 1557)

Roman: c.54-100 AD

Finds include a crucible [type 8?] used to melt a copper alloy.

Refs: AML 18/88

Comment: The crucible form is more typical of the early medieval period.

Canterbury: St John's Lane Kent (TR 1557)

Medieval: 12th-14th century

Finds include two pieces of litharge cakes and lead waste.

Refs: AML 18/88

Canterbury: St Pancras * Kent (TR 1557)

Unstratified finds include part of a fired clay ingot mould. XRF detected traces of copper, zinc and lead.

Refs: AML 3490

Canterbury: 44 Watling Street Kent (TR 1557)

Iron Age: mid 1st century AD

"Bronze working" finds include crucible fragments, scrap and waste metal associated with two hearths.

Refs: Frere *et al* 1987

Carlisle Cumbria (NY 4056)

Roman

A complete crucible [type 4] with brimful volume of 540 ml (tidemark at 430 ml) and a thick extra outer layer of less refractory clay was found.

Refs: AML 4452

Carlisle: Annetwell Street * Cumbria (NY 4056)

Medieval: early

Finds include the base of a pot with an added outer layer that has been used for parting.

Refs: JB

Carlisle: Castle Street Cumbria (NY 4056)

Roman: c.100 AD

Annex to fort. Finds include many copper alloy offcuts "... clearly the residue of a recycling process ...". In Per 9 (late 2nd - mid 3rd century), after the fort went out of use, a lead 'ingot' 56 x 53 x 29mm with cut (?chisel) marks on the upper face was found.

Refs: Padley forthcoming

Carlisle: Fisher Street * Cumbria (NY 4056)

Roman

Finds include three crucible fragments [one type 6], hearth lining, copper alloy waste and lead scrap, mercury, a haematite pebble worn flat on one side and two fragments of galena.

Refs: JB

Carlisle: Keays Lane * Cumbria (NY 4056)

Roman

Finds include fragments of 2 crucibles used to melt copper alloys and bronze blobs and dribbles.

Refs: JB

Carlisle: The Lanes Cumbria (NY 4056)

Saxon: 9th century

Finds include 2 fragments of a two-piece mould for a strap-end decorated in the Trewhiddle style.

Refs: Taylor and Webster 1984

Carnanton Cornwall (SW 8765)

Roman: probably 4th century

Finds include a large, pure tin ingot.

Refs: Davies 1935, Tylecote 1962A, Beagrie 1985A

Carn Euny Cornwall (SW 4229)

Roman: 1st-5th century

Pieces of cassiterite and smelted tin found.

Refs: Tylecote 1962A

Carsington Derbys (SK 2553)

Roman: 2nd-4th century

Smelting of local lead ores carried out here. Two uninscribed lead pigs each weighing 120 lb were found in a pit.

Refs: Current Archaeology 1981, Frere 1985

Cassington: Purwell Farm Oxon (SP 4510)

Saxon: early

Finds included a failed casting for a saucer brooch.

Refs: Dickinson 1982

Castleford * Yorks (SE 4225)

Roman

About 25 crucible fragments have been found on a number of different excavations. Several different fabrics and types, all handmade, are represented. Most appear to have been used for copper working though silver was detected on three.

Refs: JB

Castleford * Yorks (SE 427257)

Roman: late 1st century

Hundreds of fragments of clay piece moulds for casting vessels were found. Relief decoration on the moulds produced champlevé fields in the castings to take enamel. At least 20 different designs have so far been identified.

Refs: Budd and Bayley 1988, JB

Castleford * Yorks (SE 427257)

Roman: late 3rd - 4th century

Excavations have produced about 800 fragments of clay piece moulds for casting purse-shaped spoons of two very similar patterns. The minimum number of spoons cast was 35. The two-piece moulds were luted together with clay and assembled into cone shaped multiple units with a single sprue cup so about 16 spoons were cast at a time by running molten metal down the handles towards the bowls.

Refs: Bayley and Sherlock 1986, AML 161/87, Budd and Bayley 1988

Castle Gotha * Cornwall (SX 02764964)

Roman: mainly 1st century

Finds include a stone mould for a penannular brooch or bracelet, copper alloy scrap and waste, a cassiterite pebble and two pieces of haematite.

Refs: AML 3515, Saunders and Harris 1982, Bayley 1982A

Castle Rising Norfolk (TF 666246)

Medieval: probably 12th century

Several dozen crucible fragments [?type 8], some with a pinched out lip and/or an added extra outer layer were found. They were probably used to melt copper alloys. A bell pit and associated bell mould fragments and bronze waste were found in the church.

Refs: AML 211/87 and 38/89

Castor Northants (TL 1298)

Roman

A crucible with a narrow neck was found and a late Roman "working floor with traces of metal-working or potting".

Refs: Tylecote 1962A, Wilson 1974

Catterick Yorks (SE 2397)

Roman: late 2nd century or later

Two wooden 'trays' 50 cm square, containing brass scrap and filings, and a fragment of a crucible used for melting gunmetal were found.

Refs: Wacher 1978, AML 215/88

Catterick: Bainesse Farm Yorks (SE 241973)

Roman

Finds include a shallow handmade crucible used to melt leaded gunmetal.

Refs: AML 72/86

Chalton Hants (SU 7316)

Saxon: 6th-8th century

Finds include an offcut of copper alloy sheet metal.

Refs: Addyman *et al* 1972

Charterhouse Somerset (ST 507564)

Roman: mid 1st-2nd and early 4th century

Mining settlement, exploiting the local argentiferous lead ores

Finds include two small crucibles [type 6] and about twelve inscribed lead pigs from 49-161/9 AD.

Refs: Bulleid and Gray 1911, Haverfield 1906

Charterhouse Somerset (ST 5055)

Medieval

Two crucibles, now in Taunton Museum, have been found here.

Refs: Tylecote 1962A

Cheddar Somerset (ST 4553)

Saxon: 10th - early 11th century

Finds include 59 fragments of crucibles [mainly type 6]. The deposits on them suggest that gold (3), silver (13) and copper alloys were being melted; three may have been used for enamelling. A copper alloy blank for making a strap end, copper-rich fuel ash slag and spillages as well as a stone mould, probably for a buckle of medieval or earlier date, were also found.

Refs: Biek 1979

Comment: The 'enamelling' crucibles may instead have been used as cupels.

Chedworth Gloucs (SP 0511)

Roman: 2nd century or later

Villa. Finds include crucibles and "bronze laminae".

Refs: Hartley 1954, Branigan 1976

Chelmsford: sites CHAA and CHN * Essex (TL 7006)

Roman: 2nd century

Finds include fragments of crucibles used to melt copper alloys and copper alloy blobs and dribbles.

Refs: AML 2657 and 74/86

Chester: Castle Esplanade Cheshire (SJ 4066)

Saxon: c. 965 AD

Silver hoard included 23 complete "ingots" and 75 fragments. Some pieces are unusually base.

Refs: Kruse 1988

Chester: Cuppin Street Cheshire (SJ 403660)

Saxon

Pit containing a broken ingot mould was less then 50 m from Castle Esplanade hoard find spot.

Refs: Youngs, Clark and Barry 1987

Chester: Hunter Street School * Cheshire (SJ 403664)

Roman: 4th century

Finds include 6 crucible sherds. Four came from small [type 4] vessels and had been used to melt gold containing up to 16% silver (analysis by Peter Northover), one was from a shallow dish c.140 mm in diameter which contained lead and silver as did the last fragment. Copper alloy and lead waste were also found. The gold in at least one of the crucibles had been melted with the aid of a blow pipe as the pattern of vitrification, which was inside rather than outside the vessel, indicates this.

Refs: AML 2915 and 4043, Grew 1980

Chester: Hunters Walk * Cheshire (SJ 4066)

Roman

Finds include a fragment of a small (c.40 mm diameter) crucible used to melt copper alloy and copper alloy waste.

Refs: AML 2915

Chester: Site GFC * Cheshire (SJ 4066)

Roman ?

Three crucible sherds were noted [one of type 4] which had traces of copper alloys on them.

Refs: AML 4091

Chester: Lower Bridge Street Cheshire (SJ 4066)

Saxon: 11th century

Finds include an ingot mould; no trace of metal survived.

Refs: Mason 1985

Chesterfield Derbys (SK 385711)

Roman: early - mid 2nd century

Fort. Final phase of occupation was "... marked by a number of ovens and furnaces connected with metal working". Finds include parts of four crucibles, two about 40 mm diameter with traces of silver and one conical in form.

Refs: Hart 1981, Ellis 1989

Chester-le-Street: Middle Chare Durham (NZ 2751)

Roman: probably 4th century

Finds include a crucible [type 7?], volume 35 ml.

Refs: Evans *et al* forthcoming

Chew Park Avon (ST 5759)

Roman: mainly 2nd century

Settlement. Galena was worked, primarily for its silver. The evidence for lead extraction includes many pieces of lead ore and dross, melted spillages, "extracted galena" (ie fragments of galena in a porous brown matrix) and litharge.

Refs: Rahtz and Greenfield 1977

Chichester: Chapel Street * Sussex (SU 8604)

Roman: 1st century

Finds are said to include hundreds of crucible fragments, scrap metal and unfinished brooches. 30 of the crucible sherds contained red enamel, but their presence presupposes the manufacture of objects to be enamelled. The other crucibles (21 sherds) were oxidised fired and had traces of silver in them and were used for parting silver from gold.

Refs: Wacher 1975, Cunliffe 1973, Bayley 1978B and 1991A, JB

Chichester: Greyfriars Sussex (SU 861050)

Roman: c.85-150 AD

Finds associated with timber buildings include a complete [type 4] crucible with a brimful capacity of 450 ml.

Refs: Frere 1985, AML 4451

Christchurch Priory Hants (SZ 161924)

Medieval

Finds include a soapstone mould.

Refs: Wilson and Hurst 1970

Christon * Avon (ST 3757)

Iron Age: early-mid

Finds included slag, a thick-walled crucible fragment of Bronze Age type with traces of leaded bronze and a clay ?mould or tuyere fragment.

Refs: AML 4634, Morris 1988

Chun Castle Cornwall (SW 405340)

Iron Age: 3rd or 2nd century BC

Leeds described finds of slag in and around a stone-built furnace and of slag and "tin dross" in an adjoining hut as evidence for tin smelting. A hemispherical stone mould said to be from here is "... generally considered to have been used for casting cakes of tin". Another find was a large block of "tin ore" described as having "... no resemblance to any naturally occurring tin ore, but having the appearance of being a smelted deposit such as would collect at the bottom of a cavity in which smelting had taken place". Tylecote considers the furnace may not have anything to do with tin smelting and that the "tin ore" is a deeply corroded oval, plano-convex tin ingot, 8"x6"x1.5" thick and weighing 11lb. Thomas suggests the furnace is post-Roman but the ingot probably prehistoric.

Refs: Leeds 1927, Tylecote 1962A and 1966, Thomas 1956

Chysauster Cornwall (SW 473350)

Iron Age: 100 BC-100 AD

Finds included mauls, rubbers and hammer stones as well as crude stone-built troughs and paving with large shallow depressions in it. The presence of a piece of tin metal is taken as confirmation that this was a "tin town".

Refs: Hencken 1928

Cirencester * Gloucs (SP 0202)

Roman

Six plumbers' furnaces associated with 4th century rebuilding were found around the basilica and two sites have produced four crucible fragments [type 4] with traces of gold (1) and copper alloys (2) and a sherd reused as a cupel with gold droplets on it.

Refs: Wacher 1962, 1975 and 1978, AML 3984

Cirencester: Bath Gate cemetery * Gloucs (SP 0202)

Roman: Per VI

Finds include four crucible sherds, two from small [type 4] vessels which have been used to melt brass and two from larger vessels used to melt silver and ?brass respectively.

Refs: AML 3416

Cirencester: St Mary's Abbey * Gloucs (SP 0202)

Medieval: 12th or 13th century

Finds include three sherds, one probably from a cupel with traces of silver, another from a conical based crucible [type 5] used to melt leaded bronze and the last from a pot used to melt lead.

Refs: AML 3420

Claydon Pike Gloucs (SU 190996)

Roman

Finds include a bun ingot of brass, bronze and gunmetal waste and two crucible fragments [one type 2].

Refs: Northover forthcoming

Colchester: Balkerne Lane * Essex (TL 993252)

Roman

Finds include three crucible fragments [one type 3, one type 4] used to melt copper alloys.

Refs: AML 3817, Bayley 1984C

Colchester: Castle * Essex (TL 998254)

Roman

Finds include a small hemispherical crucible [type 3] used to melt brass or gunmetal.

Refs: AML 3031, Bayley 1984D

Colchester: Culver Street * Essex (TL 995251)

Roman: mid 1st - 2nd/3rd centuries

Finds include hearth lining and fuel ash slag, some copper alloy lumps and spillages, and 36 crucible sherds. These crucibles are 2nd-3rd century with a few in later contexts. Most are type 4, have an extra outer layer of less refractory clay, and have been used to melt a whole range of different copper alloys of which the majority were leaded bronzes; rim diameters were 40-60 mm. Two sherds (one unstratified) had traces of gold. Also found were 27 fragments of crucibles thought to have been used to make brass by the cementation process (mainly from mid and late 1st century contexts, they came from tribunes' houses but they may be colonial rather than military). Sherds from two further crucibles [?type 2] used to melt silver, came from poorly stratified contexts; they are probably of 1st century date.

Refs: AML 3872 and 86/87, Bayley 1984A, Frere 1983A, Bayley and Budd forthcoming

Colchester: Gilberd School Essex (TL 9925)

Medieval

Evidence for the casting of bronze and leaded bronze included metal waste and mould fragments (similar to bell mould).

Refs: AML 86/87

Colchester: Lion Walk * Essex (TL 997251)

Roman: 1st century

Mid 1st century finds include pieces of hearth lining containing droplets of leaded bronze, some of which appear to be parts of tuyeres with abnormally large diameters (5-7 cm), lead and copper alloy waste and bits of lead-rich, glassy slag which also contained small amounts of copper. From later 1st century contexts came fragments of crucibles [type 4] used to melt leaded bronzes and gunmetals. Most were about 80-100 mm in diameter though some were considerably smaller; one of these having traces of silver in it came from a 4th century context.

Refs: AML 3817, Bayley 1984C

Colchester: Sheepen Essex (TL 9825)

Iron Age: 1st century AD

The site had a mint that was destroyed at the conquest. Finds included quantities of fired clay, partly vitrified by heat, a number of crucibles (which may belong in the post-Conquest phase) and many "... open pitted slab-moulds of highly baked clay". Silver was detected on about two-thirds of the 29 mould fragments analysed.

Refs: Hawkes and Hull 1947

Colchester: Sheepen * Essex (TL 9825)

Roman: 1st century

Finds from the military metalworking site (49-61 AD) include sheet clippings and shapeless lumps of copper alloys, remains of manufactured objects, slag, mould fragments, "furnace clay" and over 14 crucibles [at least four of type 3 and one probably type 4, used for leaded gunmetal?], some of them small, one "little bigger than a thimble". Pieces of red and blue frit were also noted, as evidence for enamelling. In another area with many crucibles, metalworking lasted to the end of the 1st century.

The more recent excavations produced fragments of 7 crucibles [most of them type 3, one type 4]; copper alloy scrap and waste including spillages, a casting sprue, pieces of part manufactures (eg rod and sheet) and the corner or end cut from a rectangular bronze ingot 13-15 mm thick; a large brass plate/sheet (910x150x5 mm) with a stamped inscription; a lump of soft haematite; five fragments of clay object moulds and two fragments of coin pellet moulds.

Refs: Hawkes and Hull 1947, AML 3199, Bayley 1985B, Musty 1975

Comment: The coin pellet moulds are probably residual in these Roman contexts.

Colchester: various sites * Essex (TL 9925)

Medieval: early

Six crucible sherds provide evidence for the melting of silver (2) and copper alloys (2): one was a possible cupel.

Refs: AML 112/88, Bayley 1988D

Combe Down Avon (ST 7662)

Roman

The site is described as a factory for making pewter where stone patterns were found.

Refs: Wacher 1978

Comment: The 'patterns' are probably moulds.

Compton Dando * Avon (ST 6464)

Roman

Hundreds of fragments of clay piece moulds for T-shaped and headloop brooches were found together with some pieces of handmade crucibles used to melt leaded bronze and leaded gunmetal. The moulds were of a fairly fine, even textured sandy clay. Some of the moulds had relief decoration to produce fields for champleve enamel on the brooches. The in-gates appear always to be at the foot end of the brooch. Three brooch fragments, including one with the remains of a casting flash were also found.

Refs: AML 4639, Frere 1986

Corbridge Northumberland (NY 983648)

Roman

Finds include a pewter 'ingot' of oblate spheroid form weighing c.450 g and containing 94.78% Sn, 5.37% Pb. An irregular lump contained 43.94% Sn, 56.30% Pb.

Refs: Hughes 1980, Smythe 1937/38

Corbridge: Red House site Northumberland (NY 971651)

Roman

Excavations in building 10, the fabrica, found three hearths and associated with one was a crucible used to melt copper alloys. Nearby was an area with other hearths and pits, two of which contained fragments of lead droppings.

Refs: Hanson *et al* 1979

Cottenham Cambs (TL 486691)

Roman

Finds from this settlement (? near a temple enclosure) included "molten bronze".

Refs: Grew 1981

Coventry: Much Park Street * W Midlands (SP 3379)

Medieval: 12th - early 14th century

Finds include parts of 6 crucibles [type 8?], two with traces of leaded gunmetal, and fragments of 7 clay piece moulds for casting buckles, blobs and dribbles of brass/gunmetal and leaded bronze and unfinished castings of buckles in leaded bronze and leaded copper.

Refs: AML 2953, Schofield *et al* 1981, Bayley 1987A

Cressingham Norfolk (TF 8501)

Iron Age

Coin pellet moulds found; silver was detected on one and silver and copper on another.

Refs: Tite *et al* 1985

Croft Ambrey Hereford and Worcester (SO 4465)

Iron Age: late

Finds include a few small crucible sherds and the end of a part-worked bar ingot.

Refs: Stanford 1974

Croydon Surrey (TQ 3365)

Saxon: c. 872 AD

Hoard includes three complete silver ingots and one fragment.

Refs: Kruse 1988

Cuerdale Lancs (SD 5729)

Saxon: c. 905 AD

Hoard included coins and hacksilver. There were over 183 complete silver "ingots" and more than 168 fragments which weighed over 12 kg. Most were bar ingots or part-worked metal but there were 16 'mark' ingots (average weight 256 g) and a fragment of a large, circular 'Gusskuchen' ingot.

Refs: Graham-Campbell 1987, Kruse 1988

Dalton Parlours Yorks (SE 402445)

Roman: mainly 3rd-4th century

Villa. Finds include crucibles with "bronze" residues.

Refs: Goodburn 1978

Danebury Hants (SU 3237)

Iron Age: 5th-2nd century BC

Evidence for metal working comprises 16 crucibles or fragments, three possible tuyeres or bellows guards, slag containing copper, probably hearth lining, and a bag of metal filings. The early (5th century) crucibles are thumb pots with a handle/lug, not the usual triangular Iron Age form of the 4th-2nd century examples. Among the iron tools were files, awls, small chisels and punches which may have been used to work copper alloys.

Refs: Cunliffe 1984, Northover 1988, Cunliffe and Poole 1991

Dewlish * Dorset (SY 768972)

Roman

Villa. Finds include a complete crucible [type 4/5?]

Refs: JB

Doncaster * Yorks (SE 5703)

Roman

Excavations produced fragments of five crucibles of a variety of fabrics. Three [one type 4?] were used to melt copper alloys, probably brass, and two [one type 3?] to melt silver.

Refs: AML 4185

Doncaster: Frenchgate and St Sepulchre Gate * Yorks (SE 5703)

Roman: probably 2nd century

Excavations outside the fort produced a hemispherical crucible [type 3] which had been used to melt silver. Also found was a sample of litharge with "some copper but little silver" suggesting silver may have been recovered from coins by lead soaking.

Refs: AML 3418, Bayley 1986A, Tylecote 1986B

Dorchester Dorset (SY 6990)

Roman

Finds include a lead working hearth.

Refs: Wacher 1975

Dorchester: Greyhound Yard * Dorset (SY 6990)

Roman: mostly early

Three crucible sherds with traces of copper alloys and the runner part of a large (?)investment mould were found. A later Roman context produced a single [type 4] crucible about 10 cm high.

Refs: AML 26/88

Dorchester: Greyhound Yard * Dorset (SY 6990)

Medieval: early

Finds included a partly vitrified clay "envelope" formed round a cloth-wrapped package (? of scrap metal).

Refs: AML 26/88

Dorchester: Methodist Chapel * Dorset (SY 6990)

Roman: early

Finds included a small [type 6] crucible.

Refs: AML 26/88

Dorchester: Wollaston House Dorset (SY 6990)

Roman

Finds include a small amount of copper alloy waste and scrap.

Refs: AML 3155

Dragonby Lincs (SE 905138)

Iron Age: 100 BC onward

Triangular crucibles are well represented among the finds.

Refs: May 1970

Droitwich Worcs (SO 8963)

Roman

This roadside settlement produced evidence for "bronzeworking".

Refs: Smith 1987

Duston Northants (SP 726607)

Iron Age

Coin pellet mould fragment found.

Refs: Whitwell 1982

Easingwold Yorks (SE 5269)

Saxon: probably late 9th-mid 10th century

A silver bar ingot 30 x 8 mm found by a metal detector. The date is from comparison with other bar ingots from hoards.

Refs: Blackburn and Bonser 1990

East Harptree Avon (ST 5655)

Roman

Five silver ingots were found. One was a small lenticular cake, the rest segments of flat cakes.

Refs: Painter 1965

Eccles Kent (TQ 7260)

Roman

Villa. Finds include what is described as an iron crucible.

Refs: Detsicas 1983

Edington Somerset (ST 3839)

Roman

Many moulds for counterfeit coins were found.

Refs: West 1931

Elmswell Humberside (SE 9958)

Roman

Crucible fragment found in pit 2.

Refs: Hartley 1954

Exeter: South St Devon (SX 9192)

Roman: 50-75 AD

Excavations found a workshop in a timber building with six pieces of crucibles [?type 3] "... containing an opaque glassy paste" and possibly used for "... enamelling or ... lead melting ..."

Refs: Fox 1952 and 1971

Comment: The vitreous material may be just a crucible slag, suggesting the vessels were used for metal melting.

Exeter: near South Gate inside walls Devon (SX 9192)

Roman: 55-150/160 AD

A furnace lined with heavily burnt animal bone containing up to 1% lead was found. This is consistent with it having been used for cupellation. The same stratum also produced several tuyeres.

Refs: Fox 1968

Exeter: Bartholomew East St Devon (SX 917925)

Roman: pre 80-85 AD

Excavations found hearths and furnaces (some at least were for iron working) as well as tuyeres and crucibles.

Refs: Fox 1971

Exeter: Trichay Street * Devon (SX 9192)

Roman: 55-75/80 AD

Site thought to be the fabrica of the fortress. In it were rectangular plank-lined troughs containing slag, waste, offcuts and scrap objects, mostly of brass. One trough contained copper alloy filings. Two crucibles [one type 8] probably used to melt brass were also found.

Refs: AML 54/89, Bidwell 1979

Exeter: Rack Street * Devon (SX 9192)

Roman: c.75-80 AD

A military demolition dump included brass waste and fragments of five crucibles [mostly type 6] probably used to melt copper alloys. Another find, from a late 2nd century dump, was a rim fragment from a melting hearth or very large shallow crucible with traces of gunmetal on it.

Refs: AML 54/89

Exeter: Frienhay Street * Devon (SX 9192)

Roman: mid - late 1st century

Finds include two crucibles [type ..] used for melting copper alloys and two [type 3] with silver and lead rich deposits, probably used for cupellation, which all came from military dumps. A late 1st century ditch contained seven fragments of oxidised-fired, hemispherical, lidded vessels 12 - 16 cm in diameter with c.15 mm walls and green exterior vitrified surfaces which had been used for parting.

Refs: AML 55/89

Exeter: Basilica Devon (SX 9192)

Roman: late 4th-5th century

In a large pit were found a piece of furnace lining, large lumps of slag and some sheet bronze clippings.

Refs: Bidwell 1979

Exeter: St Mary Major Devon (SX 9192)

Medieval: 12th century

Inside the tower is a bell pit.

Refs: Allan 1984

Exeter: various sites in the city Devon (SX 9192)

Medieval: 11th - early 13th century

Over 50 crucibles, slag and two unfinished moulds of fine grey limestone were found. There is also a mould of fine, soapy, calcareous stone for casting a costrel-shaped pilgrim badge in the museum.

Refs: Allan 1984, Allan *et al* 1984, Howard 1984

Exeter: 34-8 Bartholomew St East Devon (SX 91729253)

Medieval: 12th-13th century ?

A small group of clay cauldron mould fragments were found.

Refs: Youngs and Clark 1981

Faxfleet Yorks (SE 8624)

Roman

Lead pig found here.

Refs: Ramm 1978

Finglesham Kent (TR 3353)

Saxon

Die for impressing metal foil found.

Refs: Hawkes *et al* 1979, Meeks and Holmes 1985

Foxholes Farm Herts (TL 342125)

Iron Age: late

Finds include an atypical crucible fragment with a copper-rich deposit.

Refs: Tylecote 1989

Frocester Court Gloucs (SO 785029)

Roman

The stone floor of Building C in this villa complex had "droplets of bronze and fragments of moulds" on it.

Refs: Frere 1983A

Gatcombe Avon (ST 5369)

Roman: late 3rd and 4th century

Minor buildings on a villa estate, several of which produced some evidence of metal working. A pool of lead that solidified in a pot is cited as evidence for lead working. The evidence for the "probable" pewter workshop is a hearth with "nine pieces (weight 1600 g) of lead-tin alloy with about 50-60% lead..." in Building 21. Some "pewter dross" with 26.3% lead was found in Building 13/14 which also had an area of burning associated with a molten "bronze" lump. Buildings 5 and 9 had further slight evidence for lead working.

Refs: Branigan 1977

Comment: Branigan mentions Gatcombe in a number of his other publications where the impression is given that it is a considerable industrial centre. The excavation report is more modest in its claims but still makes as much as possible of the rather meagre evidence. All the evidence quoted above could have been produced by melting down metalwork taken from the villa when it was abandoned in 370/80 AD and could indicate looters rather than craftsmen at work.

Gatesbury Herts (TL 3924)

Iron Age: late

Analysis of six of the *c*.50 coin pellet moulds detected traces of silver.

Refs: Craddock and Tite 1981

Gestingthorpe Essex (TL 927388)

Roman: probably 3rd century or later

Villa and surrounding buildings. Evidence for copper alloy working was associated with building 2. The finds include scrap metal (of a wide range of copper alloys) and casting waste, including part-finished and miscast pieces. There were parts of 4 crucibles of two shapes, the larger form being wheel thrown with a volume of c.300 ml [type 5]; the other was a type 4/5 crucible. Most if not all of the clay mould fragments were from an investment mould with an integral pouring gate for casting a statuette. The mould fabric was the same all through though there was a sharp change in colour from black nearer the modelled surface to red-brown on the outside. The presence of chaplet holes indicate that the mould was for a hollow casting.

Refs: Draper 1985, Frere 1970

Glastonbury Lake Village Somerset (ST 4940)

Iron Age: 1st century BC

Settlement. A total of 37 crucibles were found, none of them complete. The fabric of many of them contained finely divided vegetable matter, probably introduced as animal dung. 24 of them were triangular in plan [type 1] and the rest globular thumb-pots and square or rectangular forms. Only the triangular crucibles showed much sign of use. Other evidence for metal working included a fired clay fragment which was almost certainly the in-gate of a mould, a stone object that may have been an ingot mould, quantities of copper alloy scrap and waste and "several small pieces of dark red-coloured stone ... showing facets from wear". An iron object described as "perhaps the guard of a dagger" has been identified by Hencken as a hammer head. There are also two bone and one antler modelling tools, perhaps for making wax originals for investment casting.

Refs: Bulleid and Gray 1911 and 1917, Hencken 1938

Comment: The non-triangular crucibles are all described as red (ie oxidised fired) and cannot therefore have been used as metal melting crucibles. The red-coloured stone is most probably haematite that had been used as jewellers' rouge to polish the metal objects being made.

Glastonbury Tor Somerset (ST 512385)

Post Roman: 5th-7th century

Finds included a bowl hearth and two crucibles containing "bronze".

Refs: Rahtz 1970, Laing 1975

Gloucester: 1 Alvin Street * Gloucs (SO 8318)

Roman: probably 2nd century

Finds from a pit alongside a masonry building included a rectangular brass ingot. Analysis by Duncan Hook found 20.3% Zn, 0.3% Sn.

Refs: JB

Gloucester: Coppice Corner * Gloucs (SO 8318)

Roman

Finds included part of a small rectangular brass ingot. ICPS analysis by Nigel Blades found 18.9% Zn, 0.2% Pb, Sn n.d., 0.2% Fe.

Refs: JB

Gloucester: Kingsholm * Gloucs (SO 8319)

Roman: 49-mid 60's AD

Military occupation. Finds include six handmade crucible fragments [?type 2] containing traces of brass (3), silver (1) and lead (2), non-ferrous slag, copper alloy waste and scrap of a wide variety of compositions and an unfinished sheet copper cheek piece for a helmet.

Refs: AML 4355, 4369 and 4475, Bayley 1985A

Gloucester: 10 Lower Quay Street Gloucs (SO 8318)

Roman: late 3rd - early 4th

Finds include part of a flat-bottomed crucible [type 4/5] containing gold.

Refs: Garrod and Heighway 1985

Gloucester: 63-71 Northgate Street * Gloucs (SO 8318)

Roman?

A complete valve from a 2-piece mould (with a separate sprue cup) for a small cylindrical object was found. XRF analysis failed to detect significant amounts of metals.

Refs: JB

Gloucester: St Oswald's Priory Gloucs (SO 8318)

Saxon: 10th century

Excavations in the church found a bellpit, mould fragments and "bronze" waste suggesting a bell with a diameter in the range 19-34 cm was cast.

Refs: Schofield *et al* 1981, Duncan and Wrathmell 1986, Heighway *et al* 1978

Gloucester: Westgate Street * Gloucs (SO 8318)

Roman: probably 4th

Three oolitic limestone moulds "for the casting of pewter vessels" were found as was a ?crucible [type 4] with traces of silver.

Refs: Blagg 1980, AML 2827, Heighway *et al* 1979

Comment: The crucible came from a 10th century context but was probably a residual Roman find.

Gloucester: Westgate Street * Gloucs (SO 8318)

Medieval: 11th-12th century

Finds include a reused sherd described as "a 'palette' to test the colour of a batch of molten glass".

Refs: AML 2827, Bayley 1979B

Comment: This piece was probably from a sherd used as a cupel.

Godmanchester Cambs (TL 2470)

Roman: late 1st/early 2nd century

"Bronze" droplets, scrap metal and crucibles were found in a workshop.

Refs: Green 1975

Goldsborough Yorks (SE 3856)

Saxon: c. 920 AD

Hoard includes one complete and one fragmentary silver ingot.

Refs: Kruse 1988

Gorhambury * Herts (TL 1107)

Roman: 1st - 2nd century

Villa with late iron age farmstead underneath. Finds include a fragment of a coin pellet mould, pieces of four handmade crucibles [type 6] used to melt leaded gunmetal, silver and gold (2) and some copper alloy blobs and dribbles.

Refs: AML 28/86, Bayley 1990B

Great Casterton Leics (Rutland) (TF 0008)

Roman

One conical crucible [type 5] is recorded from this villa site.

Refs: Hartley 1954, Tylecote 1962A

Great Dunmow Essex (TL 6221)

Roman

Finds include a crucible fragment and a blob of leaded gunmetal.

Refs: AML 3933

Great Witcombe Gloucs (SO 9114)

Roman

Moulds for pewter found.

Refs: Blagg 1980, Blagg and Read 1977

Green Ore Somerset (ST 5750)

Roman: 1st-2nd century

Lead mining and smelting settlement. Excavations produced evidence for lead smelting and cupellation in the form of hearths, clinker, slag, ore and much litharge and metallic lead, including four lead pigs produced during the reign of Vespasian (69-79 AD).

Refs: Ashworth 1961-2, Tylecote 1962A

Iron Age

An enclosure ditch contained many clay investment mould fragments "with tubular impressions, sometimes bossed. ...the moulds may have been for bossed terrets".

Refs: Whitwell 1982, Northover 1984

Grove Priory Beds (SP 923226)

Medieval

There is a small amount of evidence for lead melting.

Refs: Youngs, Clark and Barry 1983

Gunnerside Yorks (SD 9598)

Medieval ?

A lead smelting furnace, five feet in diameter, was found.

Refs: Tylecote 1962A

Gussage All Saints Dorset (SU 0010)

Iron Age: mainly 1st century BC

Enclosed settlement. The main evidence for bronze working was a large dump of triangular crucibles [type 1] and fragments of investment moulds, most from a single pit which can be dated to the 1st century BC. There was some evidence for bronze casting earlier and possibly later too. Other finds relating to the bronze working include bone modelling tools for working on the wax patterns for the moulds, a bronze billet (part worked bar ingot) and waste and scrap metal as well as pieces of vitrified clay hearth lining and tuyeres. The pit contained nearly 7300 fragments of moulds for a variety of objects including terrets, bridle bits, lynch pins, strap unions and button-and-loop fasteners. At least 33 crucibles are represented by the nearly 600 fragments found. The crucibles and moulds were made of different fabrics as different properties were required of them.

Refs: Spratling 1979, Wainwright and Spratling 1973, Foster 1980A and 1980B

Hacheston Suffolk (TM 3059)

Roman

Near a workshop floor was a pit containing a casting jet and pool of metal, composition 79% Pb, 13.8% Sn, 6.7% Cu. Beagrie considers the metal waste is unlikely to derive from pewter manufacture as the composition is anomalous. There was also some evidence for "bronze" working.

Refs: Peal 1967, Beagrie 1989A

Hadstock: St Botolph's Church Essex (TL 559447)

Medieval

Excavations inside the church found two lead melting hearths, an oval "bell furnace" and two bell pits.

Refs: Rodwell 1974, Webster and Cherry 1975

Halstock * Dorset (ST 533076)

Roman: 260 - 350 AD

Villa. Finds include about 12 fragments of clay piece moulds for a variety of objects including rings.

Refs: JB

Halton Chesters Northumberland (NY 9967)

Roman

Found in the ditch of the vallum near this fort was a shale slab 10 x 8 x 2 cm cut in intaglio with many designs on one face and one end. The lack of runners show it cannot have been used for casting; gold foil may have been pressed into the shapes and then filled.

Refs: Smith 1922

Hambleden Bucks (SU 7886)

Roman

Villa. Finds include a broken crucible, scrap "bronze" and also iron tools.

Refs: Cocks 1921, Branigan 1980

Ham Hill Somerset (ST 4817)

Iron Age

Finds include an iron hammer head.

Refs: Hencken 1938

Hamwih - see Southampton (Hamwih)

Harpham Yorks (TA 0961)

Roman

Villa. An ashy layer in a ditch produced copper alloy scrap (sheet, wire and parts of objects), four complete crucibles with an added outer layer of less refractory clay and a number of clay piece moulds for a variety of objects including a ring and three "composite moulds" for casting studs.

Refs: Goodall 1972, Ramm 1978

Comment: The crucibles are illustrated by Ramm as type 8 or 9 but the extra outer layers may, in some cases, be hiding type 4 crucibles.

Hartburn Northumberland (NZ 0886)

Iron Age

Unstratified finds include one bar ingot mould with two depressions.

Refs: Jobey 1973B

Hartlepool Cleveland (NZ 525337)

Medieval: probably 12th century

Town. Evidence for bronze working found near quayside.

Refs: Youngs, Clark and Barry 1983

Hartlepool: Church Close * Cleveland (NZ 5283 3373)

Saxon: c.700 AD

Fragments of clay piece moulds and crucibles were found. The moulds were not of normal piece mould form and some fragments were highly decorated. The lidded crucibles [type 11] had traces of silver, while bronze and gunmetal were noted on some of the other crucible sherds.

Refs: Youngs, Clark and Barry 1986, AML 157/87, Cramp and Daniels 1987, Bayley 1988C

Headington Wick Oxon (SP 5408)

Roman: mid 2nd - mid 4th century or later

Finds include crucibles [type 5] "fragments of which were very numerous".

Refs: Taylor 1939

Hengistbury Head Dorset (SZ 1791)

Iron Age: mainly c.50 BC - 43 AD but some earlier and ?later activity

Excavations have produced evidence for a number of industries including non-ferrous metal working. The finds include two bun ingots of copper (2.5 kg) and argentiferous copper (nearly 9 kg), two copper matte cakes, slags from refining or smelting copper ores or matte, cupellation hearths, waste and scrap bronze (including a casting sprue), silver and gold, a touchstone and over 20 crucible fragments, most of which are triangular [type 2?].

Refs: Cunliffe 1978, 1980 and 1987, Gowland 1915, Northover 1987 and 1988

Hereford: Bewell House Hereford (SO 508402)

Medieval

Features include a pit used as a furnace which "... must be associated with metal-working, probably of one of the copper alloys".

Refs: Webster and Cherry 1976

Heronbridge Cheshire (SJ 4163)

Roman: 90-140 AD

At least ten crucibles [one type 6?, 2 type 6A?], clay piece moulds for box or casket fittings and "bronze" slag were found in a workshop. Kelly claims indirect evidence for lead working in the 2nd-3rd centuries.

Refs: Hartley 1954, Kelly 1976, Smith 1987

Herriott's Bridge Somerset (ST 5758)

Roman: mainly 2nd century

Excavations produced evidence for lead smelting and cupellation. Finds associated with hearths included galena and "part-melted galena", lead lumps, metal spillages, strip and sheet and litharge. Two crucible fragments [type 6] were also found.

Refs: Rahtz and Greenfield 1977

Heybridge * Essex (TL 8508)

Roman: late 1st - 4th century

Finds included sheet offcuts, bars, blobs and a ?casting sprue, mainly of bronze and leaded bronze.

Refs: AML 3464

Hockwold Norfolk (TL 7388)

Roman: mainly late 2nd - late 4th century

Among the finds from this temple site are 3 hoards of pewter which include a "molten ingot of some 3 lbs weight and some other drops of molten metal ... obviously a tin/lead alloy" as well as a partly finished plate with the base perforated by the chuck, some sheet fragments and irregular lumps and ? manufacturing waste.

Refs: Peal 1967, Gurney 1986

Hod Hill Dorset (ST 855105)

Iron Age

Hillfort. Finds include one possible coin pellet mould fragment but it is, atypically, very rough and unused.

Refs: Richmond 1968

Holy Island Northumberland (NU 123436)

Saxon: ?10th century

Finds from dry stone buildings include "lead working waste".

Refs: Youngs, Clark and Barry 1985

Housesteads Northumberland (NY 790688)

Roman

Fort and vicus. Finds include a crucible and a coin mould.

Refs: Environment and Transport World (DoE staff newspaper) 1981

Hunsbury Northants (SP 7358)

Iron Age

Finds include many tools.

Refs: Cunliffe 1984

Huntingdon Cambs (TL 2472)

Saxon: ?early 9th century

River dredging produced a small lead-tin alloy piece decorated on one side with Gripping Beasts and thought to have been produced as a model for "bronze-casting".

Refs: East 1986

Ickham Kent (TR 231591)

Roman

Pewter and military buckles and fittings made here. Much of the material appears to be cut or semi-molten fragments.

Refs: Wilson 1975, Detsicas 1983, Beagrie 1989A, JB

Comment: Actual finds are complete copper and lead alloy objects and scrap and waste lead/lead alloy.

Icklingham: Mitchell's Hill Suffolk (TL 7772)

Saxon: 7th century ?

Leaded gunmetal die for impressing metal foil found.

Refs: Hawkes 1987, Capelle and Vierck 1971

Comment: This is one of two dies from "Suffolk" published by Capelle and Vierck; cf Bury St Edmunds.

Ilchester Somerset (ST 5222)

Iron Age: 1st century BC/AD

Finds include one valve of a mould of limestone or chalk used to cast a highly decorated ring. There was evidence for the working of both lead and "bronze".

Refs: Leach 1982

Ilchester Somerset (ST 5222)

Medieval: 12th century

Five vessels [type 8] are identified as crucibles.

Refs: Pearson 1982

Comment: The descriptions suggest they have been used as lamps rather than crucibles.

Ipswich: Buttermarket * Suffolk (TM 1644)

Saxon: later 9th - 10th century

Finds include crucibles of a variety of forms [including types 6 and 9?] with traces of copper alloys and gold, about 20 fragments of decorated clay piece moulds and many sherds from large vessels reused as cupels. Another site produced a fragment of a brass bar ingot.

Refs: JB

Jarrow * Northumberland (NZ 3265)

Saxon: late 7th-mid 9th century

Three crucible fragments, one a knob or handle from the side of a vessel, and two possible tuyere pieces, all used for melting gunmetals were found.

Refs: Cramp 1975, AML 4317

Kelvedon Essex (TL 8518)

Roman

Evidence for metal working found.

Refs: Schofield *et al* 1981

Kenchester Hereford (SO 4343)

Roman

Small scale metal working is indicated by the discovery of a furnace together with molten lead, slag, crucible fragments containing "bronze" and part of a stone mould. A folded lead sheet bearing impressions of a coin of Titus (AD 79-81) was also found.

Refs: Crickmore 1984, Hartley 1954, Goodburn 1978, Shoesmith 1986

Keynsham Avon (ST 6568)

Roman

"A small crucible and a mould for casting a pendant or ornament" were found on this villa site.

Refs: Bulleid and Horne 1926

Keynsham: Manor Woods Avon (ST 668617)

Roman?

Finds include 2 coin moulds.

Refs: Frere 1986

Kingscote Gloucs (ST 80659608)

Roman

Several ovens, all with traces of "bronze" working, were found in a building.

Refs: Goodburn 1979

Kingsdown Camp Somerset (ST 8167)

Iron Age (and Roman): continued into 2nd century

"...some fragments, perhaps of a funnel ... [and] maybe part of a mould" were found in a pre-Roman ditch. Two pieces of "bronze slag" were also found.

Refs: Gray 1930

Comment: The "funnel" may be a mould in-gate.

Kingston Down Kent (TR 1951)

Saxon: early 7th century

Grave 50 contained a pebble 38 x 26 x 18 mm used as a touchstone.

Refs: Moore and Oddy 1985

Kirkby Thore Cumbria (NY 6325)

Roman: 2nd century ?

The site has been described as "... a centre of the local bronze-working industry" and traces of the manufacture of trumpet brooches are said to have been found here.

Comment: The evidence for brooch manufacture has been queried by Savory and Boon (1975).

Langridge Avon (ST 7270)

Roman

A pewter mould was found associated with building remains.

Refs: Branigan 1976

Langton Yorks (SE 7967)

Roman: 3rd - 4th century

Villa succeeding native farmstead. Finds included a stacking limestone mould for pewter plates and five conical crucibles [type 5], probably used to melt copper or one of its alloys. Lead may also have been cast here.

Refs: Goodall 1972, Ramm 1978

Lansdown Avon (ST 7268)

Roman: mid 2nd - late 4th century

Finds include about 40 limestone moulds for decorated and plain vessels, 7 of which have been repaired in antiquity with lead (alloy) clamps, and white lias moulds for casting 15 smaller items including mirror handles, spoons, strips and pendants. Some moulds may have been finished on site.

Refs: Bush 1908, Hartley 1954, Beagrie 1989A

Lechlade: Rough Ground Farm Gloucs (SU 2199)

Roman

Finds include a crucible [type 1/2] without metal traces.

Refs: Allen forthcoming

Leicester Leics (SK 5804)

Roman: mid 1st - 4th century

Town. Finds include crucibles and "a fine stone mould for thin ornamental bronze plates". A late 4th century hearth was associated with lead-rich debris from cupellation which contained 15% copper, 55% lead and a trace of silver. The Jewry Wall excavations produced one valve of a stone mould for a small medallion.

Refs: Wacher 1975, Kenyon 1948

Comment: The "fine stone mould" is more likely to have been for pewter than bronze.

Leicester: Blackfriars Street Leics (SK 58130459)

Iron Age: probably 1st century AD

Finds included three small fragments of coin pellet moulds.

Refs: Clay and Mellor 1985

Leicester: The Shires Leics (SK 5804)

Roman: pre late 2nd century

Finds include mould fragments for objects including spoons.

Refs: Leicester Museums 1989

Lincoln Lincs (SK 9771)

Roman: early 3rd century

Outside the walls to the east of the lower colonia were found considerable numbers of clay moulds for counterfeit denarii of the House of Severus.

Refs: Esmonde Cleary 1987

Lincoln: Bailgate Lincs (SK 9771)

Late Saxon: 10th-11th century

Evidence for copper working found.

Refs: Schofield *et al* 1981

Lincoln: Dane's Terrace * Lincs (SK 9771)

Medieval: mainly early

About 20 crucible sherds [mainly type 7] were found.

Refs: JB

Lincoln: Flaxengate * Lincs (SK 977715)

Late Saxon: 9th-12th century

Workshops for metal and glass working were discovered as well as many related finds including hundreds of sherds of crucibles used to melt silver, copper alloys and lead. Most were Stamford ware [type 7] but some were handmade [type 6]. Also found were a number of cupels, five stone ingot moulds (3 of them demonstrably used to cast silver) and one stone object mould (probably used for casting lead or pewter), fragments of clay piece moulds and many pieces of scrap and part-manufactured metal of a variety of copper alloys. Other finds include fragments of litharge cakes and parting vessels, the latter almost certainly of Roman date.

Refs: Perring 1981, AML 2208, 2998 and 4163, Foley 1981, White 1982, Gilmour 1988, Bayley 1991A, JB

Lincoln: Grantham Place * Lincs (SK 976715)

Medieval: early

Finds include 10 crucible fragments [mainly type 7], two fragments of ?parting vessels, some slag and a fragmentary stone ingot mould.

Refs: Youngs and Clark 1982, JB

Lincoln: Holmes Grain * Lincs (SK 9771)

Medieval: early ?

Two ingot moulds, one of stone and the other of reused tile were among the finds. Analyses are inconclusive; they could have been used to

Refs: AML 4163

Lincoln: Hungate * Lincs (SK 9771)

Medieval: early

Finds include about 20 crucible sherds [mainly type 7] and 27 bags of copper working hearth/mould.

Refs: JB

Lincoln: The Lawn Lincs (SK 974719)

Medieval: 12th century?

Finds include a bell-casting pit

Refs: Youngs *et al* 1988

Lincoln: Lucy Tower * Lincs (SK 9771)

Medieval: early

Finds include 5 crucible sherds and a clay mould fragment, possibly for a tripod pitcher foot.

Refs: JB

Lincoln: Michaelgate * Lincs (SK 975716)

Medieval: ?11th-12th century

About 70 crucible fragments, mainly of Stamford ware [type 7] found.

Refs: Youngs, Clark and Barry 1986, JB

Lincoln: The Park * Lincs (SK 9771)

Medieval: early

Finds include a Stamford ware sherd reused as a cupel with gold droplets trapped in the vitrified surface and a clay mould fragment of bell-mould type.

Refs: JB

Lincoln: St Mary's Guildhall Lincs (SK 973704)

Roman: early 3rd-4th century

Finds include scrap "bronze" and pieces of clay moulds.

Refs: Frere 1983A, Esmonde Cleary 1987

Lincoln: Silver Street/Saltergate * Lincs (SK 9771)

Medieval: early

Finds include over 200 crucible fragments, mostly of Stamford ware [type 7] used for melting copper alloys, silver and gold. Also found were fragments of hearth lining with bronze traces, 11 fragments of litharge cakes, parting vessel fragments similar to those from Lincoln: Flaxengate, and a soapstone vessel sherd reworked as an ingot mould.

Refs: AML 3987, JB

Lincoln: Spring Hill * Lincs (SK 9771)

Medieval: early

Finds include two cupel sherds and a crucible used for metal melting.

Refs: JB

Lincoln: Swan Street * Lincs (SK 9771)

Medieval:

Finds include two fragments of clay mould (of bell-mould type), one with attached copper alloy.

Refs: JB

Lincoln: West Parade * Lincs (SK 9771)

Medieval: early

Finds include 23 crucible sherds.

Refs: JB

Lingwell Gate (nr Wakefield) Yorks (SE 3320)

Roman: *c*.200 AD

A narrow-necked crucible [?type 5] and moulds for casting coins are thought to have come from here.

Refs: Brailsford 1964, Faull and Moorhouse 1981

Littlecote Park Wilts (SU 301705)

Roman: late 3rd century

A room immediately N of the villa contained a sequence of three bronze-working furnaces.

Refs: Frere 1984B

London: S of Cannon Street (TQ 3180)

Roman: *c*.70-85 AD

Cut into levelling below the palace was found a pit containing pots with lids which had been luted into place which had been used to refine (part) gold and a small [type 6] gold melting crucible. A sprinkling of gold dust was found nearby in a contemporary well.

Refs: Wacher 1978, Marsden 1975, Guildhall Museum 1969, Bayley 1991A

London: Aldersgate Street (TQ 32168151)

Late Saxon: 11th century

Finds include a lead disc, multiple struck with a die, apparently for the obverse of an Edward the Confessor penny.

Refs: Youngs, Clark and Barry 1985

London: Battersea/River Thames (TQ 2777)

Roman: 4th century

Ten ingots were found in the river. Six have been analysed and shown to be binary lead-tin alloys containing from 94.0% down to 50.4% Sn.

Refs: Hughes 1980, Beagrie 1989A, C Jones 1983

London: Cheapside (TQ 3281)

Late Saxon: early 11th century

Hoard of pewter beads, rings and brooches in various stages of manufacture found.

Refs: Hedges 1964, Hornsby *et al* 1989

London: Copthall Avenue * (TQ 3281)

Roman: mainly 2nd-3rd century

Finds include 6 crucible sherds [one type 4] with traces of silver (3), gold (1) and ?brass (1) on them and three small crucibles with traces of lead with gold (1) or silver (2) on them. The small crucibles may be purpose-made cupels.

Refs: AML 3949 and 80/88, Malony 1990

London: Crosby Square (TQ 3381)

Roman

"Copper" dribble and copper ore found.

Refs: London Museum 1930

London: Jubilee Hall (TQ 3080)

Saxon: mid

Finds include fragments of 2 small crucibles used to melt gunmetal, and a lead-rich lump - probably a fragment of a litharge cake.

Refs: AML 70/86 and 21/89

London: 85 London Wall (TQ 3281)

Roman: mid-late 3rd century

Over 700 moulds for making counterfeit coins and a few miscast coins were found dumped in the city ditch.

Refs: Jenny Hall (personal communication)

London: Milk Street * (TQ 3281)

Saxon: late

Ten crucible fragments [?type 7 or 8] were found, two with traces of silver, the rest probably used to melt various copper alloys. An ingot mould was also found; no trace of metal survived on it.

Refs: AML 4487 and 11/87, Bayley *et al* 1991

London: Newgate Street (TQ 3281)

Roman: mid-late 3rd century

Two mould fragments for making counterfeit coins were found.

Refs: Jenny Hall (personal communication)

London: St Helen's Place (TQ 3381)

Roman

Crucible [type 8 or 6] containing copper alloy found.

Refs: London Museum 1930 (Museum of London accession no A27895), JB

Comment: This form looks more post-Roman.

London: St Mary at Hill, Lower Thames Street (TL 333806)

Medieval: *c*.1075

Crucible found with a hoard of coins.

Refs: Clark 1991

London: Tenter Street (TQ 3381)

Roman: late

Finds include a crucible base with traces of gunmetal.

Refs: AML 70/86

London: Tower of London (TQ 3380)

Roman: 4th century

Finds include a silver ingot, dated 373 AD from inscription.

Refs: Tylecote 1962A

London: Walbrook (TQ 3180)

Roman

Finds of lead-tin alloy scrap and objects suggest tin and lead may have been worked nearby from the 2nd century or earlier but pewter was not used until the mid 3rd century.

Refs: Beagrie 1989A, C Jones 1983

London: various sites in the city * (TQ 3280)

Saxon: 10th - 11th century

16 complete crucibles from the Museum of London collections and 116 sherds from recent excavations were assigned to one of 3 fabric groups; Stamford ware [type 7], London ware and early medieval coarse ware [type 8]. Silver and a whole range of copper alloys were identified on 39 sherds and crucibles while most of the rest had been used, though the alloy could not be positively identified. Stamford ware was used mainly for melting silver, London ware for both silver and copper alloys while EMCW was used mainly for copper alloys. The vessel diameter also correlates with the alloy melted; Stamford ware crucibles are typically 30-70 mm in diameter with some examples up to 90 mm. The London ware comes in two sizes, 40-80 m which were used for silver, and about 150 mm which was normally used for copper alloys. The EMCW crucibles are 70-150 mm in diameter with the unleaded alloys more common in the smaller sizes. Some of these crucibles had an added extra outer clay layer and in two cases it was continued upwards over the rim of the vessel to make a bar across the top, just behind the lip, presumably to keep back any crucible slag or charcoal when pouring the molten metal.

Refs: AML 11/87, Bayley *et al* 1991

Long Bennington Lincs (SK 829472)

Roman: 1st-mid 3rd century

Finds include fragments of two crucibles with added outer layers [one is type 4] used to melt copper alloys, and a possible in-gate fragment from a clay mould.

Refs: Leary forthcoming

Longthorpe Cambs (TL 164975)

Roman: mid 1st century ?

An industrial area adjacent to the fort mainly produced pottery but finds included a crucible and some copper alloy scrap.

Refs: Dannell and Wild 1987

Comment: The crucible does not look very convincing.

Long Wittenham Oxon (SU 5493)

Iron Age: early

Finds include a vessel identified as a crucible "... because its hard and rough walls are exceptionally thick in proportion to its size".

Refs: Savory 1937

Looe Island Cornwall (SX 257513)

Prehistoric, Roman or Medieval

An oxhide shaped ingot of 15% tin bronze weighing c.14 kg was found by a diver.

Refs: Beagrie 1985B

Louth Lincs (TF 3287)

Saxon: 7th-8th century

A copper alloy ?die for making foil mounts was found with much Anglo-Saxon and Viking style metalwork on a deserted medieval village.

Refs: Youngs 1989

Lullingstone Kent (TQ 5465)

Roman: end of 1st and mid 4th century

Late finds from this villa include the base of a conical crucible [type 5], containing traces of gunmetal and a second, unused, example. Also found were four rectangular copper-lead ingots and one plano-convex circular one of copper with 4% lead which were deposited at the end of the 1st century.

Refs: Meates *et al* 1950, Meates 1987

Lullingstone Kent (TQ 5465)

Saxon: 7th century

Die found.

Refs: Capelle and Vierck 1975

Lydney Park Gloucs (SO 6303)

Roman: 2nd and 4th century

The evidence for the earlier phase of metal working comprises a hearth, scrap metal, molten blobs and a leaden die (model) for a brooch. It is thought that brooches were made on the site. In the 4th century coin blanks were cut from a copper alloy bar.

Refs: Wheeler and Wheeler 1932, Tylecote 1962A

Lyveden Northants (SP 984861)

Medieval

Finds from this deserted settlement include a clay mould "for casting small objects of pewter or bronze".

Refs: Bryant and Steane 1969

Magiovinium * Bucks (SP 9033)

Roman

Settlement. Finds included four crucible fragments from vessels 50-60 mm diameter. All were of fairly fine textured, highly tempered fabrics and two had traces of an extra outer layer of less refractory clay. XRF analysis suggested the crucibles had been used to melt brass and leaded gunmetal. Also found was a ?tuyere with traces of bronze on it.

Refs: AML 3541

Maiden Castle Dorset (SY 6688)

Iron Age: late 1st century BC and early 1st century AD

Hill fort with areas of pits and huts inside the rampart where major parts of four crucibles, one triangular [type 1/2] and the others circular, were found. More recent excavations found a few further crucible fragments and spilt molten metal as well as a large concentration of small sheet scraps and rivets.

Refs: Wheeler 1943, Northover 1988

Comment: At least one of the round vessels cannot have been used as a crucible as it is described as being of "brown ware", ie it is not reduced fired. Traces of metal are noted only on one of the other round crucibles.

Malton Yorks (SE 7871)

Roman: later 1st to 4th century

Finds from the settlement outside the fort include two complete small conical crucibles and fragments of other larger ones [all type 5] as well as part of a piece mould for casting a ring with a diameter of about 8 cm and copper alloy scrap, both sheet metal and large blobs and lumps.

Refs: Ramm 1978, Robinson 1978, JB

Matlock Moor Derbys (to N of SK 2960)

Roman ?

Lead smelting hearths found

Refs: West 1931

Meare Somerset (ST 4442)

Iron Age: later 1st century BC to early 1st century AD

Settlement. Finds included "part of what may be the remains of a tuyere" and a number of complete and fragmentary crucibles [type 2], some with traces of "bronze" on them. All are triangular in plan but of varying sizes and wall thicknesses. They are relatively deeper than the crucibles from Glastonbury Lake Village.

Refs: Bulleid and Gray 1953, Avery 1968

Melandra Derbys (SK 089950)

Roman

In civil settlement outside this fort was found evidence for lead working.

Refs: Grew 1981

Milton Keynes (MK 636) * Bucks (SP 8738)

Medieval

Finds include a sandstone ingot mould with the area near the three grooves blackened; no metals were detected.

Refs: JB

Milton Keynes: Bancroft villa (MK 105) * Bucks (SP 827403)

Roman: 4th century

Crucible [?type 4] used to melt a mixed copper alloy found in a midden.

Refs: JB

Mingies Ditch Oxon (SP 3706)

Iron Age

Finds include a possible mould fragment and two pieces of crucible [type 1].

Refs: Salter forthcoming

Minsterley Salop

Roman

Lead smelting hearth(s)

Refs: Salzmann 1913

Mucking * Essex (TQ 6881)

Iron Age

Triangular crucible [type 2] found.

Refs: M Jones 1980, JB

Mucking * Essex (TQ 6881)

Saxon: early

Two mating fragments from the front and back of an unused? clay piece mould for a great square-headed brooch were found in a hut fill. A possible mould fragment came from another hut and a few crucible sherds were also found.

Refs: M Jones 1975, M Jones 1980, JB

Murton High Crags Northumberland (NT 9649)

Roman: probably late 1st century onwards

Finds include part of a sandstone bar ingot mould with a single U-shaped groove 20 mm x 15 mm x 100 mm (to the break).

Refs: Jobey and Jobey 1987

Nanstallon Cornwall (SX 034670)

Roman: c.65 - c.80 AD

Short-lived fort "... yielded evidence of the exploitation of local tin" and crucible fragments, including one with silver-rich slag adhering, from around a hearth.

Refs: Branigan 1980, Fox and Ravenhill 1972

Neatham Hants (SU 7441)

Roman: 3rd - 4th century

There is evidence of "bronzeworking" at this roadside settlement. The finds include slag, crucible fragments and metal spillages. A 4th century well produced a fragment of siltstone mould with traces of red ?ochre used for casting pewter.

Refs: Smith 1987, Beagrie 1989A, Millett and Graham 1986

Needham Norfolk (TM 2281)

Roman: mid 1st century

Coin pellet mould fragment with parts of 9 holes was found in the fill of a ditch dated by other finds to 43-61 AD.

Refs: Frere 1941

Netherton Hants (SU 374575)

Late Saxon: 10th century

Crucibles, both dish and thimble-shaped [type 6], possible mould fragments, slag and metal waste and scrap were found in and around a series of small pits, 60 cm in diameter and 30 cm deep. Preliminary analyses have demonstrated the working of leaded and unleaded copper alloys, gold and silver. There is some evidence of mercury gilding and possibly silver inlay work. The dish-shaped crucibles (heating trays) were heated from above and used both to melt silver and gold alloys and for cupellation.

Refs: Webster and Cherry 1979 and 1980, Tite *et al* 1985

Nettleton Wilts (ST 8178)

Roman: c.340 AD on

The pagan shrine fell into disuse and was adapted for metal working. Around a furnace built of limestone were found six moulds of oolitic or lias limestone for casting pewter vessels as well as many other stone fragments which may have been parts of other moulds (which Beagrie considers "very dubious"). One complete crucible [type 6] and three "double walled" fragments from integral lidded crucibles used for melting copper alloys were also found.

Refs: Wedlake 1982, Beagrie 1989A

Comment: The furnace may not be associated with the non-ferrous metal working as large quantities of iron slag are also recorded. The "double walled" crucibles probably have an extra outer layer of less refractory clay over the crucible proper.

Northampton: Black Lion Hill * Northants (SP 7560)

Late Saxon

Finds included a sherd of a crucible [type 10] used to melt copper or one of its alloys.

Refs: AML 4302, Bayley 1985H

Northampton: Chalk Lane * Northants (SP 7560)

Late Saxon

Nearly 100 crucible fragments were found. The majority were apparently of one fabric and form [type 10] and were used for melting silver and copper alloys. Four cupel fragments of vegetable-tempered fabrics and one refractory potsherd reused as a cupel, all with lead-rich vitreous surfaces and three with trapped silver droplets, were also found. Copper-rich fuel ash slags and some greasy, off-white material shown by XRD to be $CaPO_4.2H_2O$ - possibly weathered bone ash ($Ca_3(PO_4)_2$) were also noted.

Refs: AML 3099 and 3100, Bayley 1981

Northampton: Marefair * Northants (SP 7560)

Late Saxon

About a dozen crucible sherds [type 10], used to melt silver and possibly copper alloys too were found as well as a single cupel sherd and copper alloy dribbles, scrap sheet and metal turnings.

Refs: AML 2730, Bayley 1979A

Northampton: St Peter's Gardens * Northants (SP 7560)

Late Saxon: early 10th century

Nine sherds of crucibles [type 10] used to melt silver (5), copper alloys (3) and lead (1) and a sherd from a cooking pot in the same fabric reused as a cupel were found as well as a potsherd with haematite on it.

Refs: AML 4302, Bayley 1985D

Northampton: St Peter's Street Northants (SP 750604)

Late Saxon

Finds include a crucible [type 10], a part worked copper alloy strip and lead lumps and dribbles.

Refs: Williams 1979

Northampton: The Green * Northants (SP 7560)

Late Saxon ?

Finds include sherds from 2 crucibles [one type 8] used to melt copper alloys.

Refs: AML 4486

North Elmham Norfolk (TF 9820)

Saxon: 10th-12th century

Finds include a crucible [type 6] with traces of copper in it.

Refs: Rigold 1962-3

North Leigh Oxon (SP 397154)

Roman: mid-late 4th century

Finds from this villa included a hoard of irregular coins together with a few metal blobs, two cylindrical metal bars and 62 discs cut from them with a chisel. These blanks may have been intended to be struck to pass as coins.

Refs: AML 4407, Goodburn 1978

Norton Yorks (SE 7971)

Roman

An inscription refers to a goldsmith's shop.

Refs: Wacher 1978

Norwich Norfolk (TG 2354 0915)

Medieval: 11th century

"House and bronze smithy" found.

Refs: Webster and Cherry 1973

Norwich: Bacon's House Norfolk (TG 2309)

Medieval

Bell mould but no pits found.

Refs: Margeson forthcoming

Norwich: Castle Mall * Norfolk (TG 2309)

Medieval: early

Finds include copper-rich fuel ash slags, copper alloy waste and fragments of clay moulds for large objects such as bells. A bell pit of uncertain date was also found.

Refs: Gaimster, Margeson and Hurley 1990, JB

Norwich: Fishergate Norfolk (TG 2309)

Medieval: 10th-11th century

Finds include a cupel with traces of silver on it.

Refs: AML 143/87

Norwich: Magdalen Street Norfolk(TG 23150957)

Medieval

A "bronze-smith's workshop" found.

Refs: Webster and Cherry 1974

Norwich: Pottergate Norfolk (TG 2309)

Medieval

Copper alloy offcuts found.

Refs: Margeson forthcoming

Norwich: 73 St Benedict's Street Norfolk (TG 2309)

Medieval: 12th - 13th century

Finds include a crucible with copper-rich deposits.

Refs: Margeson forthcoming

Norwich: World's End Lane Norfolk (TG 2309)

Medieval: probably late 12th - 13th century

Bell mould and metal waste was found as well as two bell pits.

Refs: Atkin and Evans forthcoming

Nottingham: Lace Market area Notts (SK 5740)

Medieval: 12th century

"Isolated examples of bronze working" found.

Refs: Schofield *et al* 1981

Oare Wilts (SU 1563)

Iron Age: early 1st century AD

Finds include a hammer head and a small chisel.

Refs: Cunnington 1909

Oldcroft Gloucs (SO 6406)

Roman: 4th century

Four cut pieces of silver bar ingots were deposited with a large hoard of copper alloy coins dated to 354/9 AD. The silver appears to have been hammered rather than being 'as cast'.

Refs: Blackburn and Bonser 1990, Rhodes 1974

Old Sarum Wilts (SU 1332)

Medieval: Norman

Finds include two crucibles [type 8], one containing fairly pure copper, and a cross-pein hammer head.

Refs: Stone and Charlton 1935, Musty and Rahtz 1964

Old Sleaford Lincs (TF 078462 and TF 076458)

Iron Age: late

Open settlement. Over 3000 fragments of coin pellet moulds with holes of three sizes were found. In one was a pellet of base silver. Other mould fragments had traces of silver on them. Also found was a silver droplet on a crucible or ingot mould fragment.

Refs: Whitwell 1982, M Jones *et al* 1976, AML 220/87, Frere 1985, JB

Oulton Staffs (SJ 9135)

Roman

Die of lightly leaded bronze for making rosette bosses found.

Refs: Jackson forthcoming

Owmby Lincs (TA 0704)

Roman

Unfinished Roman brooch found.

Refs: Whitwell 1982

Oxford Oxon (SP 5106)

Late Saxon: late 10th/early 11th - late 11th century

Fragments of bag-shaped crucibles [type 7] and an oolitic limestone ingot mould used for casting silver have been found.

Refs: Jope 1952/53 and 1958

Ozengell Kent

Saxon: late 7th century

Grave in a cemetery produced a touchstone 32 x 22 x 12 mm.

Refs: Moore and Oddy 1985

Pakenham Suffolk (TL 9367)

Roman: 1st century AD and possibly later

Finds include spillages, sprues, runners and failed castings, most of bronze but including other copper alloys and silver too. Other finds are parts of five crucibles [?type 3] and an investment mould.

Refs: JB

Par Beach, St Martin's Scilly Isles (SV 932153)

Roman: 3rd/4th century ?

Plano-convex tin ingot 90 mm across found in hut on the shoreline.

Refs: Tylecote 1966, Beagrie 1985A

Piddington Northants (SP 79655400)

Roman: mid-late 4th century

Lead scrap and waste and a small furnace used for copper alloy working have been found.

Refs: Grew 1981, Beagrie 1989A

Piercebridge * Durham (NZ 213157)

Roman: mostly 4th century

Finds from workshops to the east of Dere Street include a fragment of a clay piece mould and 10 fragments of crucibles, mostly handmade [type 6], which had been used to melt a range of copper alloys. There was also one small cupel with traces of silver in it and two fragments, from a multi-part, possibly brass-making crucible.

Refs: Wilson 1975, AML 118/88

Pilsdon Pen Dorset (SY 4199)

Iron Age: late

A crucible fragment with traces of gold on it was found in association with two hearths.

Refs: Current Archaeology 1969, Branigan 1980

Polden Hills Somerset (ST 3838)

Iron Age/Roman: mid 1st century

This hoard was mainly decorated metalwork but also contained a few other objects, amongst which were a "bronze" hammer head and two iron "toggles".

Refs: Brailsford 1975

Comment: The iron "toggles" may also be hammer heads.

Poole's Cavern * Derbys (SK 0572)

Roman

The metal finds from the site include evidence for both casting and smithing of copper alloys; a casting jet and other metal waste, scrap metal sheet and bars and rods, two doming punches and a block. An unfinished brooch casting is recorded as well as several lead brooches.

Refs: AML 4737, Mackreth 1983, Bayley and Branigan 1989

Comment: The lead brooches are published as such but I think they were used not as finished objects but as patterns to make clay piece moulds. The pottery from the site has yet to be catalogued so crucibles and/or clay moulds may yet be discovered.

Portchester Castle Sussex (SU 625045)

Roman

Finds include the base of a crucible [?type 6] with some 'bronze' in a crack.

Refs: Cunliffe 1975

Portchester Castle Sussex (SU 625045)

Saxon

Incomplete crucible [type 6] found.

Refs: Cunliffe 1976

Comment: The "vertically set lug rising above the rim" is probably an accidental slag attachment and not part of the crucible proper.

Porthmeor Cornwall (SW 4337)

Roman: 2nd - 5th century

Occupation was associated with two hearths used for iron or tin smelting. Finds included several pieces of haematite, one abraded on one side, and two pieces of smelted tin, one weighing 1 kg.

Refs: Fox 1973, Penhallurick 1986

Poundbury * Dorset (SY 685911)

Iron Age

Finds include two crucible sherds with bronze on them.

Refs: AML 3355, Green 1987

Poundbury * Dorset (SY 685911)

Roman

Finds include lead scrap, dribbles and offcuts.

Refs: AML 3732, Bayley 1987D

Prah Sands Cornwall (SW 580279)

Post Roman:7th-8th century ?

Four plano-convex tin ingots, one circular and the others oval, weighing a total of 8.5 kg were found washed out from the bottom of a submerged forest which gave the C-14 date.

Refs: Beagrie 1985A, Penhallurick 1986

Rampton * Notts (SK 7978)

Iron Age/Roman: 1st century

Two crucible fragments [type 2] containing bronze and ?gunmetal and a hearth were among the finds.

Refs: AML 3989

Ravensden Beds (TL 078544)

Medieval: mid 12th century

"Bronze smithy" found under the first church.

Refs: Wilson and Hurst 1970

Red Moor, Lanlivery Cornwall (SX 0858)

Iron Age: mid

The pieces of slag found are interpreted as evidence for tin smelting.

Refs: Clark 1952, Penhallurick 1986

Richborough Kent (TR 3260)

Roman: late 1st - early 2nd century

There is evidence for the working of "bronze", possibly also lead and silver. This activity may be in connection with the building of the Monument or could belong, in part at least, to the later civil settlement. Several furnaces were found as well as slag, copper alloy blobs and dribbles and pieces of small crucibles. Part of a lead pig dating to 96-98 AD and two silver ox-hide ingots, which are probably later, were also found.

Refs: Bushe-Fox 1926, Cunliffe 1968, Painter 1965

Comment: Recent conservation work has shown the "unfinished" brooch, quoted as part of the metalworking evidence, to be enamelled and fully complete.

Ringstead Norfolk (TF 7040)

Iron Age

This founder's hoard included a cast disc, part worked into sheet metal.

Refs: Clarke 1951

Rocester Staffs (SK 111395)

Roman: early 2nd century

Mould fragments in a hard sandy creamy-white to grey-black fabric were found. About 70 had no distinguishing features but 20 appeared to be from 2-piece moulds for openwork mounts, studs and ?rings.

Refs: Frere 1987

Rochester * Kent (TQ 7468)

Iron Age

Ten coin pellet mould fragments found; not all the holes were the same size. Some of the fragments had traces of silver(3), copper(2) and lead(1).

Refs: AML 2811, AML 4541

Rochester: 30 High Street Kent (TQ 7468)

Saxon: mid 7th century

Gunmetal die for impressing metal foil found in 12th century pit.

Refs: Tatton-Brown 1984, Hawkes 1987, Capelle and Vierck 1971

Rockbourne: West Park Villa Hants (SU 1217)

Roman

Finds include two crucible fragments with copper-rich deposits on them and a lump of corroded tin c.30 x 30 x 60 mm.

Refs: RCHM(E) 1983, Beagrie 1989B

Romsey Abbey Hants (SU 3521)

Medieval: ?Norman

Finds include a few pieces of clay mould, possibly for a bell, and metal waste, both bronze and gunmetal.

Refs: AML 122/87

Rudston * Yorks (TA 0967)

Roman: Probably 2nd century

Finds from this villa include three clay mould fragments, one an ingot mould, a possible tuyere, parts of eight crucibles used for melting copper alloys and scrap and spilt metal.

Refs: Stead 1980

Rushmore Dorset (SU 0812)

Roman

An anvil "of a type used by goldsmiths" found.

Refs: Liversidge 1968

St Albans (Verulamium) Herts (TL 1307)

Iron Age: end of 1st century BC - mid 1st century AD

Many fragments of coin pellet moulds were found on two sites, including some with traces of gold and/or silver, together with a few fragments from three further sites and some crucibles.

Refs: Richards and Aitken 1959, Branigan 1980, Tournaire *et al* 1982, Frere 1983B

St Albans (Verulamium) * Herts (TL 1307)

Roman: mid 1st - mid 2nd century

Town. Excavations found several phases of workshops with a total of 12 boxes let into the floors of six rooms, to collect copper alloy turnings and filings for reuse. Nearly 50 crucibles were also found. These included three [type 3] used for refining silver, a coarse sherd reused for melting or refining gold and at least 14 small shallow thumb pots [cf type 6] used for melting scrap gold (5) and silver (4); the metal solidified in them rather than being poured. Copper alloys had been melted in other crucibles [four of type 6, three of type 6A and 17 of type 4] and traces of silver (3) and gold (1) were found in further type 4 crucibles. Other finds include a copper alloy coin die for a Hadrianic denarius (134-8 AD).

Refs: Frere 1972, Wheeler and Wheeler 1936, AML 68/91

St Just in Penwith Cornwall (SW 3731)

Roman

Two stacking moulds made of greisen, a soft, highly micaceous, altered granite were found. They were used to cast bowls or plates, most probably of pewter.

Refs: Brown 1970, Beagrie 1989A

St Mawgan in Pyder Cornwall (SW 874654)

Iron Age: c.25 - 50/70 AD

Settlement with metalworking in Hut A. Finds included tin ore, slag, crucibles, droplets, folded scrap and a 2" long bar ingot of "bronze".

Refs: Murray-Threipland 1956

Salisbury Wilts (SU 1429)

Saxon: early?

Die said to be from here has a "late Celtic" design for decorating sheet metal. Analysis showed it to be a lightly leaded brass.

Refs: Capelle and Vierck 1971

Salmonby Lincs (TF 332731)

Saxon: 7th century

Finds include a metal worker's die.

Refs: Wilson 1981, Capelle and Vierck 1971

Saltersford Lincs (SK 926334)

Roman

Waste "bronze" and a chisel were cited as evidence for enamel working. More recently field walking has produced an incompletely finished buckle and brooch. Crucibles were found in early excavations.

Refs: Bateson 1981, Frere 1983A, Preston 1917

Santon Norfolk (TL 837873)

Iron Age (and Roman): c.60 AD

The hoard includes a small "bronze" anvil, a "bronze" modelling tool and two formers or dies for making repetitive patterns in sheet metal as well as scrap metal, offcuts and unfinished objects.

Refs: Spratling 1970 and 1975, Wainwright and Spratling 1973

Scarcliffe Derbys (SK 4968)

Roman: c. 120 AD

There are hearths for lead smelting, probably using local ores.

Refs: Whitwell 1982

Scotby Cumbria (NY 4454)

Saxon: c. 935 AD

Hoard includes one complete silver ingot and five fragments, two of which join.

Refs: Kruse 1988

Scotton Humberside (SK 8899)

Iron Age

A fragment from a circular coin pellet mould was found. Emission spectrography failed to detect any metals on it.

Refs: Tournaire *et al* 1982, Whitwell 1982

Sevington Wilts (ST 8678)

Saxon: 9th century

A jeweller's hoard included strap-ends in all stages of manufacture from roughly cut ingot to finished object.

Refs: Wilson 1981

Sewingshields * Northumberland (NY 813702)

Roman: 4th century

Hearths were found in association with a hand-made crucible [type 5], a possible tuyere and some clay mould fragments.

Refs: AML 3782, Bayley 1984B

Silchester Hants (SU 6262)

Iron Age: early-mid 1st century AD

Finds include fragments of coin pellet moulds, some with traces of silver, and a number of handmade crucibles [some of type 3] used for melting metal and glass as well as clay moulds.

Refs: Boon 1954 and 1969, Fulford 1985A, Northover 1988, Frere 1987

Silchester Hants (SU 6262)

Roman

Town. Finds include cupellation furnaces, slag and waste bronze and lead, a pewter/solder ingot fragment (38% tin) weighing *c*.2.5 kg, crucibles [type 3 and type 5], some used to melt brass and/or gunmetal, oolitic limestone moulds for pewter vessels and half mould for making counterfeit coins of Tetricus (c.270 AD) as well as tools, an as-cast silver blank for a 3rd century finger ring and a lead finger ring of late 2nd/3rd century type, possibly a pattern for mould making.

Refs: Gowland 1900, Boon 1969, Blagg and Read 1977, AML 3407, Wacher 1975, Grew 1981, Hughes 1980, Beagrie 1989A, Fulford 1985B, Cool 1983

Snailbeach Salop (SJ 3702)

Roman

Lead smelter

Refs: West 1931

Snettisham Norfolk (TF 6834)

Iron Age: 1st century BC

Finds include a bar ingot of silver alloy (originally thought to be tin) and a precious metal torc with casting jets still in position.

Refs: Northover 1988, Burns 1971

Snettisham Norfolk (TF 6834)

Roman: 1st century AD

Finds include about 50 crucible sherds [probably all from type 1/2] and about 30 piece mould fragments. Bronze and ?gunmetal were being cast.

Refs: JB

Snettisham Norfolk (TF 6834)

Roman: 2nd century

A jeweller's hoard included silver sheet, wire and bars of various sizes, scrap gold, a quartz burnishing tool and a "copper" blade.

Refs: Frere 1986

Snodland * Kent (TQ 70756203)

Roman: 4th century ?

Finds from this villa site include a complete crucible [type 4/5] used to melt brass and sheet brass offcuts. Volume of crucible 240 ml (135 ml to tidemark = c.1 kg metal).

Refs: JB

Southampton (Clausentum) Hants (SU 4413)

Roman: 69-79 AD

Two lead pigs of Vespasian found.

Refs: Holdsworth 1984

Southampton (Hamwih) * Hants (SU 427118)

Saxon: c.700 - late 9th century

Town with trading and manufacturing functions. Over 50 complete crucibles and sherds [mostly type 6, some with a pinched out lip] were found in excavations on a number of sites. Most have a diameter of 30-40 mm with a brimful volume of 10-15 ml and are of not very refractory fabrics. They were used to melt bronzes, brasses and gunmetals, most without significant amounts of lead, and 2 contained silver. Some crucibles are rather larger and a few were wheel-thrown [type 4/5] in a coarser and more refractory fabric; they were used exclusively to melt silver. Six cupels with traces of silver (2) or gold (2) and a litharge cake fragment were also found, as was a stone mortar used for preparing amalgam for mercury gilding, at least two stone and two brick ingot moulds and six clay piece mould fragments.

Refs: Addyman and Hill 1969, Holdsworth 1976, Keen 1975, AML 3934 and 2/86, JB

Southampton: Brewhouse Lane (Site E) Hants (SU 419112)

Saxon: late

Finds include the base of a red deer antler, sawn off and used as a mould. There are the eroded traces of a decorated, disc-shaped depression 37 mm in diameter and an in-gate.

Refs: MacGregor 1980

South Cadbury Somerset (ST 620250)

Iron Age: 1st century BC or AD

Smiths' workshop found with furnaces, iron and bronze tools, scrap metal, whetstones and a gold bar.

Refs: Spratling 1970, Alcock 1970, Spratling 1973

Comment: Spratling later said the association of the tools with metalworking was probably incorrect.

South Shields Tyne and Wear (NZ 366679)

Roman: c 125 - early 5th century

Finds included an unfinished casting of a trumpet brooch, a clay mould for a "bronze" tag and two crucibles [one type 9?] as well as much copper alloy scrap including bars, rods and a possible bar ingot fragment.

Refs: Bateson 1981, Allason-Jones and Miket 1984

Comment: The "crucibles" are atypical for this period and may not have been used as such.

Southwark: Arcadia Buildings (TQ 32527966)

Roman: 50-70 AD

Finds include a number of crucibles [one type 3, vol 54 ml] containing traces of bronze and brass and possible clay mould fragments. In an adjacent building was a feature identified as a bowl hearth.

Refs: Dean 1980

Southwark: 107-115 Borough High Street * (TQ 3260 8005)

Roman: later 3rd century

Fragment of a litharge cake, a by-product of cupellation, was found.

Refs: AML 3714, Yule 1982

Southwark: 201-211 Borough High Street (TQ 3251 7983)

Roman: Flavian

Near a hearth were spillages and a part worked block/bar of "bronze".

Refs: Bird *et al* 1978

Southwark: Cathedral Crypt (TQ 32668032)

Roman

Fragments of plano-convex cakes of litharge from cupellation were found.

Refs: AML 142/87

Southwark: District Heating Scheme * (TQ 3280 8033)

Roman

A ditch filled in during the mid 4th century or later, but with many residual finds, produced a sherd from the rim of a small crucible [type 4] used to melt leaded gunmetal and a body sherd from a larger crucible used to melt silver; both have added outer layers.

Refs: Bayley in Hinton 1988

Southwark: Bonded Warehouse, Montague Close (TQ 3271 8034)

Roman

Copper alloy spillage (late Flavian) and "bronze melting slag" (late 2nd century) were found.

Refs: Bird *et al* 1978

Southwark: 1-7 St Thomas Street (TQ 3274 8019)

Roman: early-mid 2nd century

Finds include most of a crucible [type 4] with extra outer layer used to melt copper-rich alloy.

Refs: Bird *et al* 1978

Southwark: Tooley Street (TQ 331802)

Saxon: later 10th century

An ox mandible used as a motif piece was found.

Refs: Cottrill 1935

Southwark: Toppings Wharf (TQ 3286 8034)

Roman: Flavian

Finds include copper alloy offcut and sprue with runner as well as copper-rich slag.

Refs: Sheldon 1974

Spong Hill * Norfolk (TF 9919)

Saxon: early

Crucible fragment [type 6?] found. No metal survived on it.

Refs: AML 4521

Springhead Kent (TQ 617725)

Roman: 1st - 5th century

Associated with a group of temples were industrial remains suggesting that copper alloys and lead were worked here. Finds include an possible unfinished brooch.

Refs: Penn 1957, Jessup 1970, Detsicas 1983

Stanmore Middx (TQ 1792)

Roman: after 408 AD

Inscribed silver ingot found.

Refs: Painter 1965

Stanwick Northants (SP 9771)

Roman

Finds include a clay mould fragment.

Refs: AML 72/86

Stanwick Yorks (NZ 185120)

Iron Age: early - mid 1st cent AD

Fragment of a mould gate and possible tuyere found. The hoard of metalwork includes copper alloy scrap and faulty castings. More recent excavations have found hearths associated with a "bronze" ingot, fragments of crucibles for copper alloy melting and moulds.

Refs: Spratling 1981, Frere 1986, JB

Stanwix Cumbria (NY 3957)

Roman: 2nd quarter of 2nd century

Fort on Hadrian's Wall. Unfinished and flawed castings, scrap metal and part manufactures (bar, wire etc) found. They were apparently redeposited and not in situ.

Refs: Collingwood 1931A and 1931B

Comment: In the smudgy illustrations some of the supposedly unfinished objects appear quite normal.

Stoke Gifford Avon (ST 616800)

Roman: c.270-350

Finds include crucibles and copper alloy scrap and droplets.

Refs: Goodburn 1979

Studland Dorset (SZ 0382)

Roman: 1st century, some pre 60 AD

Finds include a stone bar ingot mould and three crucible fragments [type 2 or 3] with traces of copper alloys on them.

Refs: Field 1965, Bidwell 1985

Comment: The mould was not originally published as such; it is probably not one.

Sutton Courtenay Oxon (SU 5093)

Saxon: ?5th century

Crucible found.

Refs: Leeds 1923

Comment: The crucible is described as being of a "dirty greenish-buff colour" which is not a colour normally found on reduced-fired crucibles.

Sutton Walls Hereford (SO 5246)

Iron Age: 1st century AD

Iron anvil (c.25 AD) and crucible [type 1] (60-75 AD) found.

Refs: Kenyon 1953

Swallowcliffe Down Wilts (ST 9627)

Iron Age

"Bronze" slag and waste metal were found as well as several "awls" of iron and "bronze".

Refs: Clay 1925

Swarling Kent (TR 1252)

Iron Age

Evidence was found for bronze casting and enamelling.

Refs: Detsicas 1983

Roman

Lead working is suggested at this villa by a hearth filled with charcoal and lead waste.

Refs: Wilson 1974

Tattershall Thorpe Lincs (TF 237608)

Saxon

Burial found with smith's tool kit including "... snips, tongs, punches, files and bags of scrap metal..."

Refs: Rankov 1982

Templebrough Yorks (SK 4191)

Roman: mid 1st century onwards

A lead smelter is recorded as well as several crucibles [some type 6?], scrap bronze, slag and waster castings.

Refs: May 1922, Hartley 1954, West 1931

Thetford: Fison Way * Norfolk (TL 8683)

Iron Age: early - mid 1st century AD

Evidence for metalworking includes over 100 fragments of coin pellet moulds, some with traces of silver, nearly 50 pieces of clay investment moulds and 240 fragments of triangular crucibles [type 2] of a range of sizes used to melt bronze as well as a clay ?ingot mould fragment with traces of silver. The coin pellet moulds date to the 40's - 60's AD while the bronze casting is pre-Conquest. Also found were parts of two copper alloy bar ingots.

Refs: AML 3761, Wilthew and Bayley forthcoming

Thetford: Sites 1 and 2 * Norfolk (TL 865826)

Late Saxon: 10th-11th century

Town. Finds include 35 crucible sherds, one handmade [type 6] and the rest of Stamford ware [type 7], mainly used for melting brass or maybe other copper alloys; about half had an added outer layer. Two sherds with traces of silver had probably been reused as cupels. Also found were two chalk ingot moulds, a limestone mould for a pendant, copper alloy and lead scrap, unfinished garment hooks and tools including a file, a chisel and a bar with recessed rosettes, possibly a matrix for forming sheet metal.

Refs: Rogerson and Dallas 1984, Bayley 1984E, AML 3114

Thetford: Site 4 * Norfolk (TL 866826)

Late Saxon: 10th-11th century

Town. Finds include two handmade crucibles [type 6], used for melting silver and brass, and a cupel with traces of silver on it.

Refs: Bayley 1984E, AML 3114 and 3282

Thetford: Star Lane * Norfolk (TL 868829)

Late Saxon ?

Stray finds include one Stamford ware crucible sherd.

Refs: Bayley 1984E, AML 3114

Thetford: Site 1092 * Norfolk (TL 869822)

Late Saxon: 10th-11th century

Finds include two crucible sherds [type 7], a chalk ?ingot mould and unfinished garment hooks.

Refs: Bayley 1984E, AML 3114

Thetford: Red Castle Norfolk (TL 860830)

Saxon

Finds include three crucible sherds [types 7 and 8].

Refs: Knocker 1967

Comment: Descriptions suggest they may have been used as lamps.

Thetford: Redcastle Furze Norfolk (TL 8683)

Saxon: 11th century

Finds include four iron punches, a few crucible fragments (including two of Stamford ware) and a shelly limestone bar ingot mould.

Refs: Andrews forthcoming

Thetford: Brandon Road (Site 5756) Norfolk (TL 863830)

Late Saxon: 10th-11th century

10th century finds include fragments of clay moulds for large objects such as bells or vessels, one with an adhering failed casting for a leaded bronze vessel, as well as bronze waste. Fragments of two crucibles from 11th century contexts had traces of silver and brass respectively.

Refs: AML 24/86

Thetford: Minstergate * Norfolk (TL 8783)

Saxon: mostly early 11th century

Finds include 13 crucible sherds, mostly Stamford ware [type 7], one of which was used to melt silver.

Refs: AML 15/91

Thetford: Guildhall (Site 25296) * Norfolk (TL 8783)

Medieval: Late 12th or 13th century

Finds from a single pit included 20 kg of litharge cake fragments, nine crucible sherds [including type 8] used to melt silver (1) and copper alloy (1), six sherds reused as cupels and one sherd from a parting vessel.

Refs: AML 126/91

Thetford: Site 5759 Norfolk (TL 870823)

Medieval: late 12th century

Evidence for bell founding from the church in Trench 2 includes two possible bell pits, mould fragments (with a rim diameter of 300-350 mm) and bronze dribbles. Trench 1 produced a crucible with silver on it, probably of 11th century date.

Refs: AML 23/86 and 25/86

Thistleton * Leics (SK 9117)

Roman

Finds include parts of two crucibles [type 4].

Refs: JB

Thornton: St Peter's Church Leics (SK 468076)

Medieval

Bell pit found.

Refs: Webster and Cherry 1976

Thorpe Notts (SK 7650)

Roman

This roadside settlement produced evidence for "bronze" and lead working. Finds include the side of an unfinished lead coffin.

Refs: Smith 1987

Thorpe Thewles Cleveland (NZ 4025)

Iron Age: late

Finds included eleven fragments from at least six crucibles [type 2] and two stone bar-ingot moulds.

Refs: Heslop 1987

Thurgarton Notts (SK 6949)

Medieval: mid 12th century or later

Foundations with remains of clay mould for a bell of over 40 cm diameter and a furnace were found together with pieces of high tin bronze (22-26% Sn).

Refs: Tylecote 1976, Duncan and Wrathmell 1986

Thurleigh Beds (TL 052585)

Medieval: ? 12th century

Bell pit found.

Refs: Webster and Cherry 1972

Tiddington Warwks (SP 216555)

Roman

Settlement. Finds include "bronze" wasters or unfinished castings, dribbles and lumps of copper alloy and crucible fragments. "Ten billets of lead indicate that cupellation had been carried out". Recent finds include a litharge cake fragment with traces of silver.

Refs: Hartley 1954, Fox 1968, Palmer 1981, AML 4750

Comment: More recent work (eg Palmer 1981) tends to refute the earlier claims that Tiddington was a major industrial centre.

Tintagel * Cornwall (SX 0489)

Post Roman: 5th - 6th century

Finds include an unstratified crucible fragment, a possible clay mould fragment and leaded bronze and gunmetal spillages. A motif piece is probably also from here.

Refs: AML 195/88, O'Meadhra 1987

Towcester Northants (SP 6948)

Roman: mid 4th century

Workshops south-west of the town were used for the manufacture and/or repair of pewter and lead objects. Finds include a pewter vessel, a lump of lead and at least one stone mould for a pewter vessel.

Refs: Schofield *et al* 1981, Esmonde Cleary 1987, Smith 1987

Towcester: St Lawrence's Church * Northants (SP 694487)

Roman: 3rd century ?

Finds include copper alloy waste and fragments of several wheel thrown crucibles with maximum diameters of c.100 mm used to melt leaded gunmetals.

Refs: AML 4509

Tower Knowe Northumberland (NY 700871)

Roman

Finds at this native settlement include a sandstone bar ingot mould.

Refs: Jobey 1973A

Trereife Cornwall (SW 4532)

Medieval or later

A furnace that may have been used for smelting tin was found and above it was a large inscribed block of pure tin, 16.5" x 8" x 2" weighing 29.5lb.

Refs: Tylecote 1962A and 1966, Penhallurick 1986

Trethurgy * Cornwall (SX 035556)

Roman: mid/late 3rd - late 5th century or later

A large, badly decayed, plano-convex tin ingot, originally measuring 30 x 21 x 7 cm and weighing over 10 kg, was among the finds from this settlement site.

Refs: AML 3724, Miles and Miles 1973, Beagrie 1985A, Todd 1987

Trevelgue Cornwall (SW 8263)

Iron Age

Finds included a furnace pit containing copper and tin slag.

Refs: Davies 1935

Tripontium (N of Rugby) Warwks (SP 5379)

Roman: early/mid 2nd century

Finds include a lead pig from the Peak District.

Refs: Crickmore 1984

Uley * Gloucs (ST 789996)

Roman:

Excavations on this temple site produced copper alloy blobs and dribbles, sheet offcuts and part manufactures as well as unfinished castings of rings. A fired clay fragment may possibly have come from the in-gate of a mould. Also found were two fragments of litharge cakes, by-products of the refining of debased silver.

Refs: AML 25/87

Verulamium - see St Albans

Vindolanda * Northumberland (NY 771664)

Roman: 270-350 AD

Vicus and fort. Evidence of "bronze" working includes three crucibles, one with a bar of clay across the pouring lip, five or six ingot moulds, a casting sprue and a flawed casting of a 2nd or 3rd century military buckle. XRF analysis failed to detect any metals on the ingot moulds which may be post-Roman in date.

Refs: Birley 1977A and 1977B, AML 3727, Bidwell 1985

Wadsley Yorks (SK 3290)

Medieval

Crucible [type 5/7] found.

Refs: Tylecote 1962A

Waldringfield Suffolk (TM 283443)

Iron Age: mid 1st century AD

Finds include over 30 fragments of clay moulds for terret rings and strap-union plates.

Refs: Frere 1987

Wall (Letocetum) Staffs (SK 1007)

Roman

Lead smelting on a small scale is recorded.

Refs: Crickmore 1984

Wallingford: St Michael's Church Oxon (SU 6089)

Medieval

Bell pit found.

Refs: Schofield *et al* 1981

Walton-le-Dale * Lancs (SD 5528)

Roman

Finds include fragments of three crucibles, one [type 6] used to melt a copper alloy and the others [type 3] to melt or refine silver. All were heated from above.

Refs: AML 93/88

Ware Herts (TL 3514)

Roman

There is evidence for "bronze" working at this roadside settlement. "Coin forgery is indicated by coin blanks and irregular coins".

Refs: Smith 1987

Water Newton Cambs (TL 1197)

Roman: early 3rd century

Moulds for casting counterfeit denarii of the House of Severus found.

Refs: Esmonde Cleary 1987

Wattisfield Suffolk (TM 0274)

Roman: early 4th century

Twelve fragments of piece moulds for casting "knife blades" were found.

Refs: Wacher 1961

Weekley Northants (SP 8881)

Iron Age: 2nd-1st century BC

Finds include a fragment of a triangular [type 1] crucible with sides of c.90 mm. No metals were detected on it.

Refs: Jackson and Dix 1986-7

West Stow Suffolk (TL 8170)

Saxon: early 5th - mid 7th century

Pottery includes "... vessels that may be crucibles".

Refs: West 1969

Westbury Wilts (ST 8751)

Roman

Mould for small [pewter] bowl found.

Refs: Goodall 1972

Weston-under-Penyard Hereford (SO 6323)

Roman

Scrap and waste "bronze" found.

Refs: Hartley 1954

Wetwang Slack Yorks (SE 94676071)

Iron Age: 1st century AD

Finds included at least 16 fragments from triangular crucibles used to melt bronzes and gunmetals together with one round crucible used to melt brass. Also found were a number of mould fragments, probably from investment moulds.

Refs: AML 4873, Grew 1981

Comment: Late 1st and 2nd century Roman finds were noted on the site and the brass-melting crucible is likely to belong with them rather than with the rest of the metalworking debris.

Wharram Percy * Yorks (SE 8564)

Saxon: 8th century

15 fragments of clay piece moulds, some of which can be dated from the designs on them, were found together with sherds from five crucibles used for melting bronzes or gunmetals, at least two of them lidded. Associated finds included five further fragments of crucible/mould and parts of up to five tuyere blocks.

Refs: Gaimster, Margeson and Hurley 1990, AML 26/91

Whatley Somerset (ST 7347)

Roman

Finds from this villa site include lead slag.

Refs: Davies 1935

Whitby Abbey Yorks (NZ 8911)

Saxon: 7th-9th century

Finds include two stone ingot moulds and a probable touchstone 54 x 14 x 6 mm.

Refs: Foote and Wilson 1970, Wilson 1967 and 1976, Graham-Campbell 1980, Moore and Oddy 1985

Whitchurch Salop (SJ 5441)

Roman: 2nd century

Finds from the civilian settlement include waste "bronze" and lead.

Refs: Jones and Webster 1968

Comment: One find described as a "... base, presumably of an ornament" looks like a casting sprue.

Whitchurch Avon (ST 6167)

Roman: later 3rd century

A total of 350 coin moulds and fragments for casting counterfeit antoniniani of 260-74 AD were found. Most of the mould fragments were double-sided as a number would have been stacked together in use. Grass-tempered casing material survived on some of the pieces. Four small crucibles [?type 6] were also found.

Refs: Boon and Rahtz 1965

Comment: The larger crucibles mentioned could not have been used as such as they are described as being oxidised fired.

Wick Avon (ST 7072)

Roman

19th century excavations of this villa found at least one lias mould for casting pewter which had been mended in antiquity.

Refs: Beagrie 1989A

Wicklewood * Norfolk (TG 0702)

Roman

Systematic metal detector use has found quantities of metal objects and scrap and waste metal; blobs, dribbles, casting sprues, a failed casting and fragments of objects and bar ingots. The whole range of copper alloys, lead, pewter and silver are represented in the scrap metal.

Refs: AML 4646

Wilderspool Cheshire (SJ 6186)

Roman: 2nd century mainly

Hearths were found associated with scrap "bronze" and lead, crucibles used to melt copper alloys, clay mould fragments and a lead brooch.

Refs: May 1904, Tylecote 1962A, G Jones 1968, Frere 1977

Comment: The lead brooch was probably a model from which clay piece moulds would have been made.

Wilderspool: Loushers Lane Cheshire (SJ 697868)

Roman

Finds include a crucible [type 6A] and clay mould fragments.

Refs: Frere 1977, Tylecote 1986A

Wimbourne Dorset (SZ 0199)

Roman ?

Gold ingot fragments found.

Refs: Painter 1965

Winchcombe: North Street Gloucs (SP 02512837)

Medieval: early

Crucible fragment found.

Refs: Saville forthcoming

Winchester Hants (SU 4829)

Iron Age

A crucible with traces of copper in it and a coin pellet mould fragment found as well as spillages of molten bronze and copper-rich slag.

Refs: Collis 1978, AML 4114

Winchester Hants (SU 4829)

Roman

A hearth in a house was associated with cakes of "bronze". Eleven sherds of crucibles were found on the Cathedral Car Park site.

Refs: Wacher 1975, AML 4668, Bayley and Barclay 1990

Winchester: Assize Courts * Hants (SU 4829)

Late Saxon and Medieval

A scatter of 37 crucible sherds [one type 6, mainly type 8] were found, four in pre-Conquest contexts. One had been used to melt silver and one ?brass. Other finds included one sherd reused as a cupel and two sherds from cupels, one with traces of silver.

Refs: AML 4668, Bayley and Barclay 1990

Winchester: Castle Yard * Hants (SU 4829)

Saxon: mainly late 10th - late 11th century

Finds included 23 crucible sherds [?mainly type 8], two with traces of silver, and three cupel sherds with traces of silver.

Refs: AML 4668, Bayley and Barclay 1990

Winchester: Cathedral Car Park * Hants (SU 4829)

Saxon: 9th - 10th century

A fragment of a large cupel? (diameter 100 mm) and one from a parting vessel were found in the New Minster occupation deposits.

Refs: AML 4668, Bayley and Barclay 1990

Winchester: Cathedral Green * Hants (SU 4829)

Saxon: mainly mid 10th - mid 12th century

Late 10th century bell casting pits were found together with metal waste and bell mould fragments. From the same areas came a sherd reused as a cupel and 12 crucible sherds, three used for copper alloys. Other areas produced a fragment of a large cupel (diameter 90 mm) and 22 further crucible sherds [one type 7], three used for melting silver and five for brass and other copper alloys.

Refs: AML 4668, Bayley and Barclay 1990, Biddle 1965, Tylecote 1976

Winchester: Lower Brook Street * Hants (SU 4829)

Saxon: 9th - 11th century

Finds included 17 crucible sherds (XRF detected silver (1), bronze (1), gunmetal (1) and "copper" (3)), one sherd reused as a cupel, four fragments from parting vessels, a gold droplet and two touchstones. All probably predate c.900 AD and are residual in later contexts.

Refs: AML 4668, Bayley and Barclay 1990, Bayley 1991A, Moore and Oddy 1985

Winchester: Lower Brook Street * Hants (SU 4829)

Medieval: 12th - 14th century

Houses X and XI produced most of the 145 crucible sherds [mainly type 8, some with a lip] which were used for melting copper alloys, including leaded and unleaded bronze. The eight fragments of cupels (diameters 60-80 mm) and the four litharge cake fragments came mainly from 12th/13th century contexts.

Refs: AML 4668, Bayley and Barclay 1990

Winchester: Staple Gardens Hants (SU 47862959)

Roman: mainly late

Finds include six fragments from crucibles used to melt silver(1) and a range of zinc-containing copper alloys.

Refs: AML 4780

Winchester: Staple Gardens Hants (SU 47862959)

Medieval: 9th - 14th century

Hearths and associated litharge cakes indicate the refining and possible working of silver.

Refs: Youngs, Clark and Barry 1985

Winchester: Victoria Road Hants (SU 4729)

Roman

Finds include a litharge cake fragment.

Refs: JB, Bayley and McDonnell 1990A

Winchester: western suburbs Hants (SU 4729)

Saxon: late 9th-11th century

Finds include 18 crucible fragments, the majority used to melt brass [type 6 and/or 8] and copper-containing hearth lining.

Refs: AML 4249

Winchester: western suburbs Hants (SU 4729)

Medieval: mid/late 12th - 14th century

Finds include 27 crucible fragments with rim diameters in the range 40-70 mm [type 8?], most with traces of copper, lead and zinc but some with tin too. Also found was one shallow crucible with silver in it and a fragment of a litharge cake, evidence of metal refining.

Refs: AML 4249

Winchester: Wolvesey Palace * Hants (SU 4829)

Saxon: late 10th - early 12th century

A total of 27 crucible and 12 cupel sherds were found. The crucibles [mainly type 8] were used for melting copper alloys. One cupel had traces of gold on it, the rest were far larger (diameters 90-130 mm) with central depressions of a size that matches the diameter of many of the litharge cakes. Also found was an unidentified object, perhaps a fragment of luting clay.

Refs: AML 4668, Bayley and Barclay 1990

Windlesham Surrey (SU 927627)

Iron Age (late) and Roman

Evidence of "bronzeworking" found.

Refs: Frere 1986

Winklebury * Hants (SU 6152)

Iron Age: possibly 3rd - 1st century BC

Finds include a crucible fragment and a piece of a bronze bar ingot.

Refs: Bayley 1977, AML 2138

Winnall Down * Hants (SU 498303)

Iron Age: early

Finds include four crucible fragments, two of which may be residual in Roman contexts.

Refs: AML 2849, Bayley 1985C

Winterbourne Monkton Down Wilts (SU 1072)

Iron Age

Crucible fragment [type 2] found in a pit.

Refs: Cunnington *et al* 1913

Witcombe Gloucs (SO 899144)

Roman

Stone mould for casting pewter vessels found at this villa.

Refs: Beagrie 1989A

Wolsty Hall Cumbria (NY 105511)

Iron Age/Roman

From a hut came a broken sandstone ingot mould, thought to have been used for casting small "bronze" bars.

Refs: Trump 1958, Blake 1959

Woodeaton Oxon (SP 535127)

Roman

Evidence for bronze working included a sprue with three runners, probably from a piece mould, and three bars 7-16 cm long, described as ingots.

Refs: Bateson 1981, Kirk 1949

Woodeaton Oxon (SP 535127)

Saxon: early?

Failed casting for a pendant found with Roman metalwork.

Refs: Dickinson 1982, Kirk 1949

Woodmancote: The Ditches Gloucs (SO 996095)

Iron Age

This hillfort has yielded evidence of gold working and minting including a fragmentary coin mould.

Refs: Frere 1983A and 1985

Wookey Hole Cavern Somerset (ST 5145)

Iron Age/Roman

Crucible found here.

Refs: Bulleid and Gray 1911

Wroxeter Salop (SJ 5608)

Roman: late 1st century onward

Town. Evidence has been found indicating that copper alloys, lead and silver were worked here and that cupellation was carried out. Finds include fragments of crucibles containing both copper alloys and silver [including type 6 and 6A], a casting sprue with 2 runners, an unfinished and a faulty casting (the first from a two-piece mould and the other from an investment mould), waste metal, a fragment of a (counterfeit) coin mould, a possible mould for casting pewter vessels and an iron die.

Refs: Bushe-Fox 1913 and 1916, AML 3153 and 3182, Kelly 1976, Hartley 1954, Beagrie 1989A

Yeavering * Northumberland (NT 9330)

Saxon ?

Finds include 13 crucible sherds from vessels of different sizes, fabrics and forms used to melt both bronze and ?brass.

Refs: AML 150/88

Comment: Occupation of the nearby "palace" site ended during the 7th century (Hinton 1990) which may suggest a date for these finds.

York: [Yorkshire Museum] * Yorks (SE 6051)

Roman

Four complete crucibles used to melt brass and gunmetal were noted [types 4: vols 360 and 245 ml and 6: vols 17 and 19 ml].

Refs: AML 4432

Comment: The type 6 crucibles could be post-Roman.

York: Aldwark Yorks (SE 607521)

Roman: c.200 AD

Counterfeit coin moulds found.

Refs: Schofield *et al* 1981, Wilson 1975

York: Bedern Yorks (SE 60515208)

Medieval: c.1200

A furnace, hearths, lined pits and clay moulds are evidence for bronze founding, the products being mainly small bells. Also found were 2 stone moulds for casting counters.

Refs: Webster and Cherry 1977, Ransome 1977, Tweddle 1986

York: 9 Blake Street Yorks (SE 6051)

Late Saxon:

Part of a mould for a trefoil brooch and some crucible sherds were found.

Refs: MacGregor 1978

York: Castle Yorks (SE 6051)

Saxon: mid 10th century

Long bone (?tibia) used as a motif piece found.

Refs: Grove 1940

York: Church Street Yorks (SE 6051)

Roman: 2nd-early 3rd century

Finds include a crucible sherd.

Refs: MacGregor 1976

York: 16-22 Coppergate * Yorks (SE 604516)

Saxon : late 9th - 11th century

The site has produced considerable quantities of evidence for the working of copper and lead alloys, gold and silver. Over a thousand crucible fragments [mainly type 7] were used for melting silver (80%), gold (9%) and copper alloys (11%). The evidence for metal refining includes nineteen cupels of three types used for both gold and silver; purpose made dishes, reused sherds and blocks of fused quartz chips. There are also parts of nine litharge cakes and fifteen fragments of parting vessels. Other finds from the site include twelve ingot moulds, a few clay mould fragments, much scrap and waste metal, part manufactures, unfinished objects, pieces of galena and haematite, bone motif pieces, assorted tools, two coin dies and trial stamps.

Refs: AML 3214 and 3465, Hall 1984, Roesdahl *et al* 1981, JB, Bayley 1991A and forthcoming

York: Feasegate Yorks (SE 6051)

Medieval: 12th - 13th century

Crucible (Roman or medieval) found.

Refs: Tylecote 1962A, Dyer and Wenham 1958

York: 46-54 Fishergate * Yorks (SE 606511)

Saxon : 8th-early 9th century

Finds include an ingot mould and 36 crucible sherds [mainly type 6, including some with a pointed base]. One sherd was a knob/handle from the side of a crucible. Most were from vessels used to melt bronzes or ?gunmetals but silver was found on five. About 100 deeply vitrified sherds, probably of some metallurgical function, were also found.

Refs: Youngs, Clark and Barry 1986, AML 118/90

York: Goodramgate Yorks (SE 6051)

Medieval

Evidence for bell founding discovered.

Refs: Schofield *et al* 1981

York: Hungate * Yorks (SE 6051)

Saxon: 10th - 11th century

Finds included eleven crucible fragments [type 7], seven of which had traces of silver surviving on them.

Refs: Richardson 1959, JB

York: 1 Kings Square Yorks (SE 60435196)

Saxon ?

Finds include a stone ingot mould.

Refs: Youngs *et al* 1988

York: Parliament Street Yorks (SE 6051)

Roman

Fragment of a limestone mould for a dish or bowl found, probably for casting pewter.

Refs: Tweddle 1986

York: Parliament Street * Yorks (SE 6051)

Late Saxon:

One complete crucible [type 9] found.

Refs: AML 3539, Bayley in Tweddle 1986

York: 22 Piccadilly * Yorks (SE 605516)

Medieval: 11th century

Finds include 65 fragments of cuboid vessels with luted on lids used for parting silver from gold.

Refs: Youngs *et al* 1988, Bayley 1991A and forthcoming

York: Rougier Street Yorks (SE 6051)

Roman: 4th century ?

Sherds of three crucibles used to melt copper alloys (?leaded gunmetal) found.

Refs: AML 82/87

York: St Mary Bishophill Senior Yorks (SE 6051)

Roman: late 2nd century

Metal workshops contained two superimposed boxes containing 'bronze' working scrap and a crucible.

Refs: Wacher 1975, Ramm 1976 and 1978

York: 34 Shambles Yorks (SE 6051)

Medieval

Finds include a group of copper alloy rods, wires and sheet metal offcuts. The sheet metal has uniform lead (c.1%) and tin (c.4%) contents but zinc ranges from 5-15%.

Refs: Caple in Tweddle 1986

York: Tanner Row Yorks (SE 6051)

Roman: late 2nd-early 3rd century

Finds include the base of a crucible [type 4] used to melt copper alloy and a possible clay mould fragment as well as a reused sherd, half a small [type 4] crucible and 2 fragments of a shallow dish all with traces of gold and apparently used as cupels.

Refs: AML 18/87 and 82/87

York: Tanner Row Yorks (SE 6051)

Medieval: early

Sherds of three crucibles [one ?type 7] used to melt various copper alloys found.

Refs: AML 18/87

APPENDIX B

ANALYTICAL METHODS

Two main analytical techniques were used to obtain the results presented here. Atomic absorption spectrophotometry (AAS) gave quantitative results for about 1000 copper alloy objects, mainly late Iron Age and Roman brooches, using methods based on those described by Hughes *et al* (1976). Qualitative X-ray fluorescence (XRF) was used to analyse further metal objects and metalworking debris of all sorts.

AAS was the preferred method for analysing metal objects as the quantitative results it provides permit more detailed interpretation than is possible with qualitative XRF data. XRF analyses were normally carried out on objects that had been conserved but where a patinated surface remained. XRF was used for four reasons:

1) The object was too small or thin for a sample to be taken
2) The object was too deeply mineralised for an uncorroded metal sample to be obtainable
3) Permission to sample had not been given
4) Sufficient time was not available to carry out AAS analyses

Where some objects from a single site were analysed by AAS and some by XRF, it was normally for reasons 1 and/or 2. In these cases some of the objects analysed by AAS were normally reanalysed by XRF and used as approximate 'standards' to give greater confidence when interpreting the other XRF results (see below).

Sampling for AAS

The samples for analysis were drilled from the back of each object with a No 60 high speed steel bit driven by a 12V electric drill. This was mounted in a stand with a movable table below so the area to be sampled could be carefully controlled and the minimum stresses placed on the object to avoid unnecessary damage. The first metal turnings, from the corroded surface layers, were always discarded so the sample collected would represent, as far as possible, metal of the original composition used to manufacture the object. The metal turnings were collected on sheets of cellophane (a fresh one for each sample) and then transferred to a numbered gelatine capsule. Care was taken not to drill right through objects as the metal sample would then be contaminated with corroded surface metal and the resulting hole would be seen as unacceptable damage. If the object was too thin for a single drill hole to provide sufficient sample, a second hole was made, usually close to the first. A total of about 20 mg of metal was removed from each object except where they were not large or thick enough, when as large a sample as possible was taken.

In the course of taking samples, it was noticeable that a number of different alloys were represented as the bright metal turnings showed a variety of colours from yellow to brown, pink and white. There was also considerable variation in hardness (as judged by the difficulty in removing turnings) and in the form of the turnings which ranged from long coherent spirals to chips and powder. Sometimes an object could be seen to be deeply corroded as the turnings lacked a bright metallic lustre; in these cases the analytical results would only approximate to the original composition. No attempt was made to correlate the appearance of the sample with the analytical results except where the sample was obviously corroded which could be used to explain the low analytical total obtained.

The samples were stored in their gelatine capsules in sealed boxes with silica gel in an attempt to minimise corrosion before they were analysed. Normally analysis followed within a few weeks of sampling.

AAS sample preparation

About 10 mg of each sample was weighed out into a 25 ml beaker. The beaker was weighed empty, the sample was added without handling the beaker, and the beaker + sample was then reweighed. The sample weight was obtained by difference.

The sample was dissolved in 1 ml freshly prepared aqua regia (3:1 hydrochloric:nitric) made using analar grade concentrated acids. If dissolution was slow the beaker was warmed on a hot plate but not allowed to boil. When the metal turnings had dissolved a further 1 ml concentrated hydrochloric acid was added to prevent precipitation of the tin in a metastannate complex on dilution. The dissolved sample was then transferred to a 25 ml volumetric flask which was made up to the mark with distilled water. The samples were transferred to 30 ml polythene bottles for storage. They were approximately 10 mg in 25 ml, ie 400 ppm total metals in solution.

The standards for calibrating the spectrophotometer were made up from bought 1000 ppm standard solutions obtained from BDH. They were stored in polythene bottles.

AAS analytical procedure

The elements sought were copper, tin, zinc, lead, silver and, initially, arsenic and antimony but it soon became clear that these last two elements were not reliably detectable at the levels present, so they

* The use of the concentration readout corrects for the curvature of the calibration as the samples (and standards) were above the linear range for the elements of interest.

were not sought in most of the samples.

The machine used was a Pye Unicam SP 1900 double beam instrument fitted with either a 10 cm or 5 cm burner. The normal flame used was air-acetylene but nitrous oxide-acetylene was sometimes used for tin. As there was a six position lamp turret, warming up problems were minimised by keeping all the lamps in use switched on. The instrument was set up according to the manufacturer's instructions and the concentration readout was used except when analysing for copper.* The display on the machine was calibrated directly in ppm, avoiding errors in conversion and transcription. This required just two standards and a blank for each element (The standards used are given in Table B.1). With copper the concentrations used to match those in the sample solutions were too high for the machine to correct for the curvature of the calibration, so a graph of read-out against ppm was plotted from the standards each time the machine was used. The sample readouts were then converted to ppm using this graph. With both copper and zinc the concentrations present in the sample solutions meant the absorbance was beyond the normal range of the instrument. To avoid dilution of the samples, the analytical sensitivity was reduced by using an alternative wavelength (for copper) and by rotating the burner (for zinc). All calibrations were checked before, during and after each run to make sure no drift had occurred and, when necessary, samples were re-run.

Table B.1 - AAS standards used

Element	Concentrations (ppm)
Cu	100, 200, 300, 400, 500
Sn	50, 100
Zn	50, 100
Pb	50, 100
Ag	5, 10

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<u>Errors in AAS analyses</u>

Both systematic and random experimental errors affect the overall reliability of the analytical results obtained. If all possible sources of errors are identified, steps can be taken to minimise them.

It was assumed (after Craddock 1976) that the sample taken from each object was large enough to be representative of the original metal. The collection and storage methods used were designed to minimise contamination. Errors at these stages are random and unquantifiable. As a check on macro-segregation of lead, one brooch was multiple sampled along its length. The results (Table B.2) show no gross systematic variation and the random error (as measured by the standard deviation of these small number of figures) is no higher than the estimate of overall errors (see below).

Table B.2 - Multiple analyses of a crossbow brooch

AAS reading (ppm Pb)	lead content (Pb %)	error (as % of Pb%)
25.5 ± 0.2	6.85	0.8
17.7 ± 0.2	6.70	1.1
35.3 ± 0.2	7.00	0.6
26.4 ± 0.2	6.70	0.8
23.4 ± 0.3	6.29	1.3
28.4 ± 0.2	6.70	0.7
	mean = 6.71	

standard deviation = 0.216 (=3.2%)

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The sample preparation was subject to two main random errors. The first was in weighing out the sample. The graduations on the balance scale were every 0.2 mg so weights could be read to ± 0.1 mg. When weighing out 10 mg as described above the random error in sample weight was thus ± 2% as both weighings were subject to an uncertainty of ± 0.1 mg. With samples significantly lighter than 10 mg the percentage error on weighing them out is larger so where possible sample weights in the range 9.5-11.5 mg were used. The second random error was due to the use of 'B' grade volumetric glassware (certified as accurate to ± 0.06 ml, ie ± 0.24%). On top of these are the errors produced by incomplete dissolution and/or transfer of the sample and inaccurate making up of the solution to 25 ml.

Making up the calibration solutions was also subject to random errors due to the glassware used; the errors depended on the dilutions used but averaged ± 0.65% for 50 and 100 ppm standards; errors were over 1% for some of the copper and silver standards.

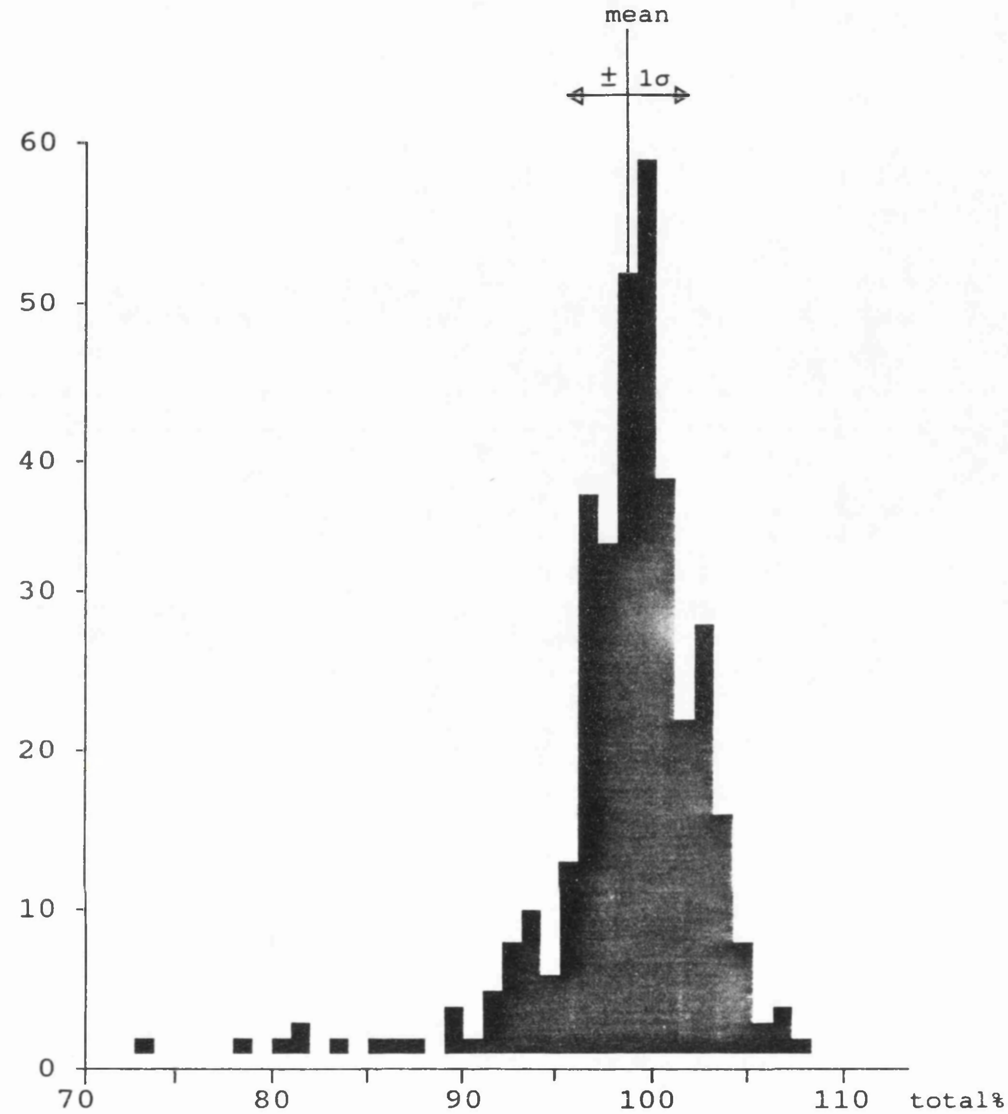
Hughes et al (1976) reported enhancement of 8 or 10% in the zinc, tin and lead signals when copper was present in quantity and thus recommended adding copper to calibration standards for these elements. However Slavin (1968) says that if the total solid in solution is less than 0.1%, the standards need contain only the element of interest in the same solvent as the sample. The samples analysed here were typically 400 ppm = 0.04%, well below this limit. Because of these conflicting views, attempts were made to observe the reported enhancement (AML 2677) but no difference was found so single element standards were used for all analyses from 1978 onwards (ie, all samples other than those from Richborough). The earlier analyses had been made with about 400 ppm copper added to the calibration solutions of elements other than copper.

Cooke (1973) identifies a number of effects which contribute to uncertainty in the final signal displayed by the spectrophotometer. Correct adjustment of the instrument minimises most of these but normally the digital display is not completely steady so it too introduces an error that needs to be considered. The absolute fluctuation in the display is roughly constant for each element but when expressed as a percentage it varies widely, depending on the magnitude of the signal registered. Of the elements analysed, tin has a far higher detection limit than the others and so gave a far lower signal to noise ratio, resulting in larger errors than for the other elements. This variation makes it difficult to give generalised estimates of errors due to the spectrophotometer and its display but they were not negligible and were probably of the order of 1%. Note that it has been assumed that using the concentration readout from the spectrophotometer introduced no significant errors into the results. The readability of the copper calibration graph was typically ± 1 ppm.

The random errors in preparing the sample solutions were just over 2%. When the calibration and other machine errors are included the overall precision is around 4%. The results presented in Appendix C are given to one place of decimals but it can be seen from the above discussion that they are not all accurate to this level. Because of the known experimental errors, divisions of the data set based on absolute values have been avoided where possible. See Chapter 9 for a discussion of how and where divisions were made.

In all the above it has been assumed that numbers have been correctly read and written down, and that any arithmetic operations performed on them were done without error. The only check on the results produced was whether the analytical total was acceptably close to 100%. So this check could be made, copper was analysed for directly rather than calculated by difference. Figure B.1 shows the distribution of analytical totals for the brooches from Richborough. It is approximately normal with a mean value of 98.5% and a standard deviation of 4.1%. If the outliers to the distribution are ignored (ie totals < 89% which comprise 2.6% of cases), the mean is 98.9% and the standard deviation 3.0%. The asymmetry of the distribution suggests that corrosion rather than operator error is the main source of these outliers.

Figure B.1 - Frequency histogram of the analytical totals for the brooches from Richborough



The difference between the mean and 100% is due to systematic errors such as the presence of corrosion products and elements not analysed for. Intergranular corrosion can penetrate deeply into apparently unaltered metal and means not all the sample weight is metals. Iron is normally considered a trace element but is a significant omission in these analyses as Craddock and Meeks (1987) have shown it has a mean value of 0.27% in Romano-British metalwork, and Craddock (1985) notes that cementation brass often contained higher amounts.

The standard deviation, whether the 3.0% or the 4.1% figure is used, indicates that the predicted analytical precision of ± 4% is an underestimate. Unquantified factors such as using the concentration readout on the spectrophotometer must have introduced errors that were not negligible, and it is possible that other errors associated with the spectrophotometer are underestimated.

XRF analysis

The XRF spectrometer used was a Link Systems MECA 10-42 energy dispersive system fitted with a rhodium X-ray tube and a lithium drifted silicon detector. Analytical conditions were a tube voltage of 35 kV and current of 0.03 mA, an air path for the X-rays and, typically, a detector live time of 10 or 20 seconds. The range of the detector was 0-40 keV with a channel width of 20 eV. In many cases when analysing the bulk metal of copper alloy objects, windows three channels wide were set over each peak of interest and counting terminated when either 20,000 or 30,000 counts had accumulated in the Cu K_α window. At other times, especially when analysing applied decoration on metal objects and metalworking debris, individual peak heights were recorded (as in Table B.4).

Table B.3 - X-ray lines used

Element	Line
Cu	K_α (8.02 keV) and K_β (8.90 keV)
Zn	K_α (8.63 keV)
Au	L_α (9.71 keV)
Hg	L_α (9.99 keV)
Pb	L_α (10.55 keV)
Ag	K_α (22.10 keV)
Sn	K_α (25.19 keV)

Background was measured at 10.0 keV unless mercury was present when it was recorded at 11.0 keV.

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There are many factors that affect the strength of the signal (peak height) produced by each element when analysing a particular object. These include the shape, size and surface texture of the object, the concentration and distribution of the element of interest, the major element composition of the object and the analytical conditions used. In addition, some elements fluoresce more strongly than others; this is a function of the voltage applied to the X-ray tube. Analytical conditions were standardised but little if any control of the other variables was possible as no sampling or surface preparation was attempted.

Analyses of samples of known composition suggest the detection limits under the operating conditions used were under 1% in the bulk metal.

The system is set up to analyse a large area (about 1 cm^2) and provides qualitative or at best semi-quantitative results. There are both advantages and disadvantages to this which are discussed in the sections below.

XRF analysis of metal objects

XRF analyses the surface of objects, the penetration of the X-ray beam depending both on its energy and on the composition of the object. Where an object is deeply corroded the surface will have a very different composition to that of the core of the object. Normally corrosion increases the proportion of less electropositive elements; the magnitude of this effect depends on the burial environment of the object. High proportions of heavy elements tend to depress the signal levels for lighter elements as some of the fluorescent X-rays are re-absorbed before they leave the object. Both of these effects have to be taken into consideration when interpreting the XRF spectra obtained (see below).

Most of the copper alloy objects of the period of this study contain detectable amounts of zinc, tin and lead in addition to copper so XRF is not very helpful when used purely as a qualitative analyser, ie on a presence/absence basis. However, peak heights are very variable, from barely more than background levels up to a couple of orders of magnitude greater than this. The relative heights of peaks, ie semi-quantitative analyses, can thus often be interpreted to suggest a broad alloy type, but further sub-divisions are not considered reliable.

In order to get a feel for the relative peak heights to be expected, a number of metal standards of known composition were analysed by XRF and four groups of brooches from different sites that had been analysed by AAS were reanalysed by XRF; the data are given in Table B.4. The metal standards were smooth polished discs while the brooches were

Table B.4 - Data used to plot Figs B.2 - B.5

AA No	Cu_α	Cu_β	Zn	Pb	Sn	Zn%	Sn%	Pb%
	XRF peak heights					AAS results		
Caister by Yarmouth (symbol = x)								
689	7818	1499	216	2780	251	.7	7.8	15.4
692	10136	1783	2313	284	33	16.5	1.0	2.9
693	10005	1624	70	81	83	.1	8.5	16.1
687	8897	1434	571	883	37	12.5	6.5	8.5
688	11317	1940	204	156	51	2.4	6.7	1.7
691	10597	1828	1129	475	43	14.8	3.0	6.6
683	9826	1696	377	1369	91	3.0	7.7	3.8
690	10882	1919	693	1073	69	10.2	3.6	9.0
684	3113	679	398	1859	182	2.1	5.8	11.4
686	9804	1628	nd	277	46	.9	8.1	5.4
685	17590	2991	763	2319	306	2.2	8.0	9.6
851	8438	1417	874	140	76	1.9	2.3	.5
850	11775	1894	769	176	nd	14.0	4.1	3.3
Uley (symbol = ∇)								
751	3428	607	nd	1349	174	.7	11.0	16.9
695	20170	3130	485	4063	355	.6	4.9	13.2
696	11219	1882	nd	841	375	.2	11.2	13.0
749	4427	755	151	1580	184	1.4	9.9	18.3
1468	6205	1021	146	1358	275	.0	7.1	30.5
750	16517	2705	nd	988	212	.6	13.2	20.6
694	18978	3130	nd	2017	319	.1	3.9	12.9
698	6435	1120	295	92	128	1.3	5.7	.4
697	6262	1051	nd	2781	189	.1	8.4	11.3
1470	10300	1645	nd	2862	107	.2	9.8	17.1
747	2688	485	81	1059	82	1.2	5.8	13.3
748	20634	3329	nd	501	179	.6	11.7	4.0
704	21080	3233	2737	67	nd	19.6	.9	.2
902	2449	386	nd	1632	139	.0	6.6	16.3
908	20744	3399	634	413	293	1.9	5.7	.0
909	17920	2802	989	69	155	8.3	2.2	.0
901	4259	711	nd	806	150	.0	9.4	19.5
Piercebridge (symbol = #)								
965	7699	1379	694	208	68	16.7	1.7	.0
966	7501	1288	nd	7327	451	.0	5.9	9.3
967	11088	1877	751	6038	914	2.1	7.8	9.9
968	13492	2234	1337	443	93	14.3	1.3	.0
969	9171	1476	1864	2417	87	14.2	2.0	8.9
970	31541	5069	783	1572	444	3.1	6.8	8.5
971	10391	1847	1062	392	149	12.5	2.1	.0
972	12682	2228	1577	244	286	6.1	1.7	.0
973	9024	1616	214	994	441	.2	8.6	1.1
974	11426	1895	410	1171	228	5.2	6.8	.0
975	10519	1795	300	2430	414	1.0	6.2	3.4
976	13618	2281	212	1058	191	3.0	7.3	4.8
978	9772	1720	nd	5377	879	.0	8.5	12.6
979	14296	2258	214	544	112	3.8	4.6	10.1
980	17693	3057	1156	77	nd	12.5	.0	.0
981	11242	1859	nd	3957	193	.0	6.7	16.7
982	11769	1955	231	2371	333	.8	7.9	5.2
988	9024	1518	1391	952	59	16.4	2.0	4.9

Table B.4 (continued)

AA No	Cu_α	Cu_β	Zn	Pb	Sn	Zn%	Sn%	Pb%
	XRF peak heights					AAS results		
Tiddington (symbol = ◇)								
1354	3315	581	52	808	142	.2	8.3	6.8
1355	18373	2902	2159	193	127	16.9	2.1	.5
1356	15206	2671	2728	207	68	15.9	2.4	1.5
1357	9716	1593	188	271	260	.2	13.0	1.3
1358	17571	2696	nd	2003	76	.5	9.9	6.4
1359	5943	991	804	115	314	9.3	8.3	.6
1360	13801	2304	1402	nd	183	11.0	7.4	.1
1361	15163	2391	1019	199	125	4.4	8.2	1.4
1362	4082	644	77	1111	187	.3	11.4	24.8
1363	6839	1182	nd	1151	343	.0	15.6	16.7
1364	3712	651	1636	1802	248	8.3	7.2	9.1
1365	11425	1841	675	296	159	14.3	7.1	1.4
1389	7965	1357	nd	1026	104	.1	10.6	8.0
1390	5795	1000	380	66	74	3.5	6.8	.5
1391	5869	1005	nd	1458	186	.6	9.2	24.2
1392	12130	2014	nd	1864	120	.4	8.9	13.3
1393	4671	848	221	531	132	3.2	8.5	8.5
1394	5211	921	363	1585	102	.2	8.0	20.0
1395	21883	3507	258	1836	262	.7	13.7	14.3
1396	6521	1144	nd	634	218	.1	12.3	12.5
1397	12342	2033	nd	1984	149	.2	12.6	12.4
1398	10606	1780	183	1219	271	.4	12.9	20.2
1399	3575	607	133	3367	252	.6	7.7	19.6
1400	3159	557	161	76	273	2.1	14.5	.5
1401	9344	1534	338	4041	160	.0	8.2	18.5
1402	18504	2939	1231	951	49	12.5	2.0	6.0
Metal standards (symbol = □)								
B6	13144	2014	5318	nd	nd	23.3	.0	.0
B2	13182	2114	6807	64	nd	35.0	.0	.0
B4	8914	1572	5203	nd	nd	35.0	.0	.0
B1	11187	1800	4939	38	nd	29.5	.8	2.0
D4	15404	2495	nd	130	98	.5	10.0	5.0
D3	19813	3149	1367	157	46	5.0	5.0	5.0
D2	16513	2692	811	63	98	4.0	8.0	.5
D1	19601	3238	nd	nd	91	.5	10.0	.0
D6	17142	2727	262	nd	104	.5	10.0	.0
D5	21221	3330	nd	nd	66	.5	5.0	.0
B3	12834	2024	8248	101	22	40.0	.8	2.0

Notes to Table:

Percentage figures for the metal standards are quoted compositions rather than AAS analyses

nd = no peak visible on spectrum

irregular shapes and had varied surface finishes; some had only a thin patinated surface while others were more deeply corroded.

The data in Table B.4 are plotted in Figures B.2 - B.6. In all cases the XRF peak heights are scaled to copper so they can be compared. Scaling in this way minimises the variability in signal strength due to the size and shape of the objects. It assumes that copper is present at a constant level in each object, which is approximately true.

Figure B.2 shows the zinc data. The gradient of the best fit line for the polished metal standards is shallower than for the unprepared archaeological objects, suggesting that the latter are suffering from varying degrees of de-zincification of their surfaces as might be expected. Low values of the ratio (below 0.3) indicate zinc in the bulk metal at levels below 4% (with one exception), while higher values mainly equate to significant amounts of the metal though there is some overlap. Within the two groups the value of the ratio is little guide to the actual percentage of zinc present in the uncorroded metal though all ratios over 0.8 do correspond to over 8% zinc in the alloy.

The tin data (Figure B.3) is less clear cut. Here the best fit line for the modern metal standards is far steeper than any line that might be drawn through the points representing the archaeological objects, indicating enhanced tin levels in the surfaces of the latter, as expected. There is good, though not absolute, correlation of high values of the ratio (over about 10) with significant tin levels but lower values of the ratio can correspond to almost any bulk metal tin content.

Consideration of the peak height ratios can thus usually indicate if tin and/or zinc is present in significant amounts, but no reliable estimate of the actual quantities present can be obtained. This is not the disaster it might seem as it is the relative amounts of tin and zinc that define the name given to the alloy (see Chapter 9). The zinc and tin ratios must first be considered separately, but a more helpful indicator of the alloy of which an object is made is the zinc:tin ratio. Figure B.4 shows the correlation of XRF and AAS results for this ratio. A log-log plot has been used as there is a wide range of values.

Not all the samples in Table B.4 can be plotted because of zero values. There are nine samples where the zinc content determined by AAS was zero and a further 17 samples had zinc not detectable by XRF. These samples are all bronzes and would lie off-scale to the bottom left of Figure B.4. Assigning arbitrary small but non-zero values would just produce clusters of points whose location depends on the value chosen. A smaller group of samples cannot be plotted because the tin content is zero and/or tin was undetectable by XRF. They are brasses and would lie

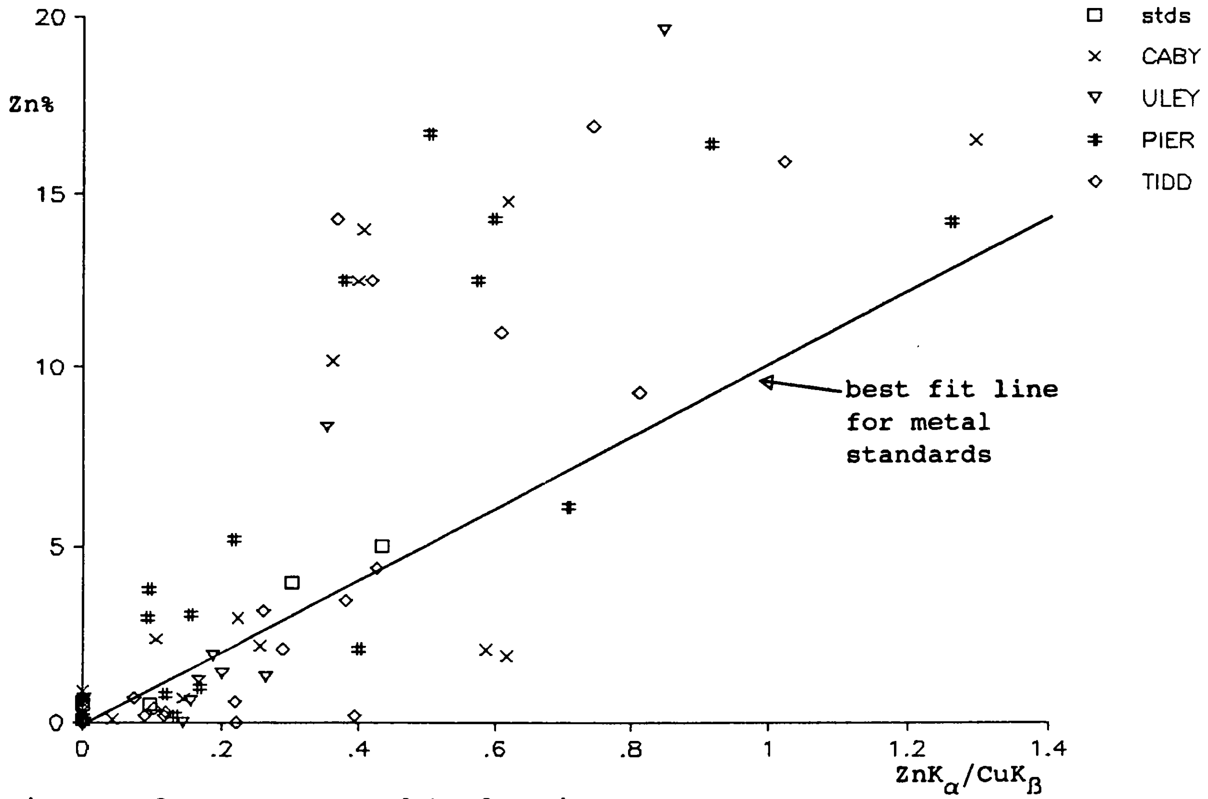


Figure B.2 - AAS v. XRD data for zinc

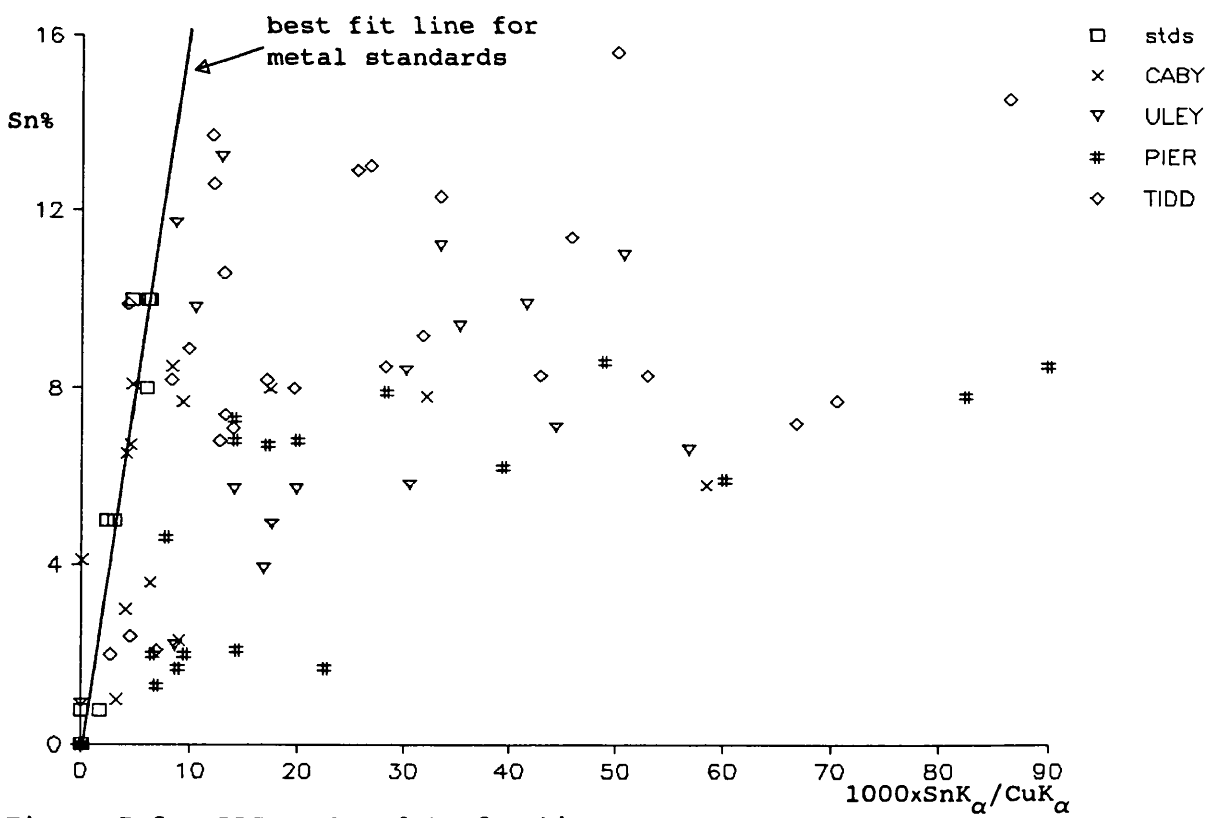


Figure B.3 - AAS v. XRF data for tin

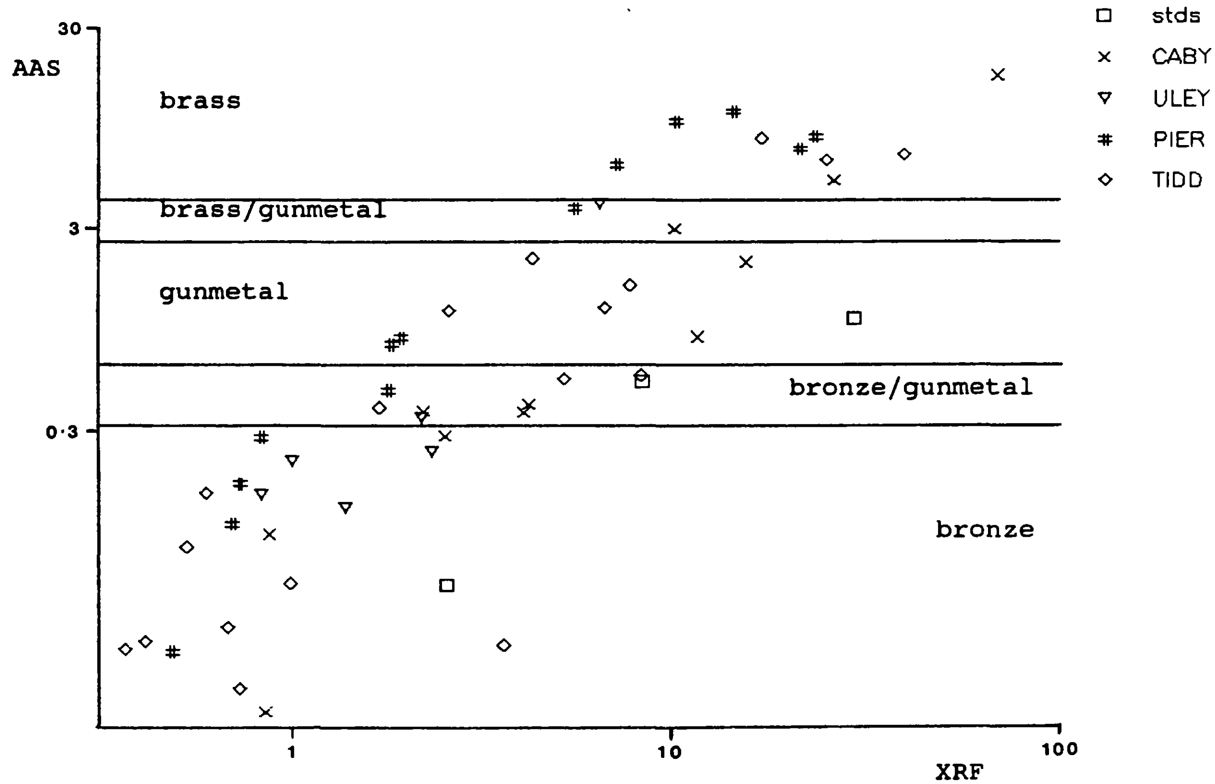


Figure B.4 - AAS data (Zn%/Sn%) v. XRF data ($ZnK_{\alpha}/SnK_{\alpha}$) with the alloy name boundaries superimposed

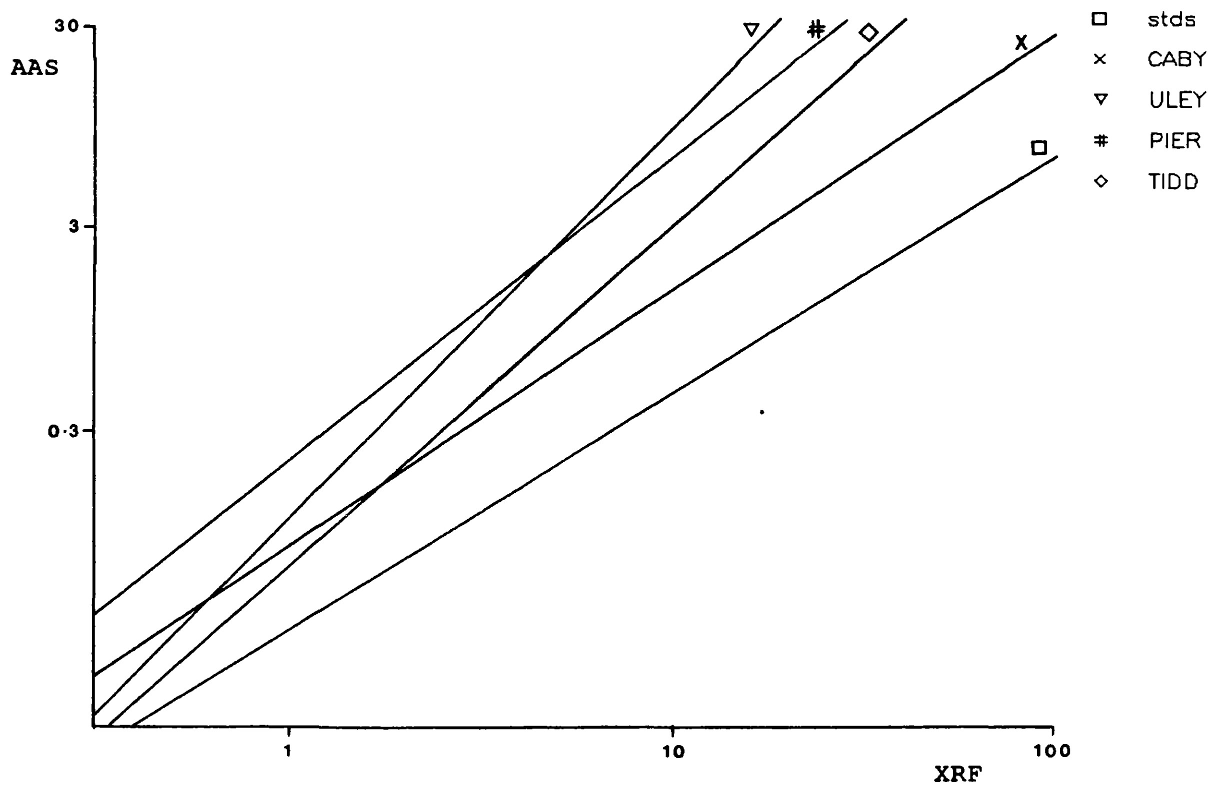


Figure B.5 - Regression lines of XRF data ($ZnK_{\alpha}/SnK_{\alpha}$) on AAS data (Zn%/Sn%) showing inter-site variability

off-scale to the top right of figure B.4. One modern brass sample with a higher zinc content than was attainable in antiquity (B3) is not plotted in the figure as it lies just off-scale to the top right (XRF ratio = 375 AAS ratio = 50). Figure B.4 shows a positive correlation of AAS and XRF zinc:tin ratios with bronzes to the bottom left and brasses to the top right; the boundaries within the brass-gunmetal-bronze continuum defined in Chapter 9 are superimposed. It can be seen that almost all bronzes have zinc:tin peak height ratios of under 1.5 while for brasses the ratio is over about 8; the bronze/gunmetals, gunmetals and brass/gunmetals lie in between. It should be noted that when joint alloy names, eg bronze/gunmetal, are assigned on the basis of XRF data they indicate uncertainty as to the true composition rather than the specific intermediate compositions defined for AAS data, accepting the reality of the overlapping distributions in Figure B.4.

On closer examination it can be seen that the results from different sites show slight differences in distribution. When the regression lines for the data from individual sites are drawn they are found to lie roughly parallel but not all superimposed. The offset is produced by the variable degree of de-zincification and tin enrichment caused by corrosion. The two effects go hand-in-hand and both decrease the zinc:tin ratio of the surface relative to the bulk metal. The more aggressive soil conditions are represented by the upper calibration lines on Figure B.5; note the line for the metal standards is well below the rest. Because of this inter site variation it is dangerous to set absolute values for the zinc:tin peak height ratio which correspond to the boundaries of the different alloy groups. With objects from any one site the range of values found needs to be assessed and boundaries then assigned which produce sensible divisions within that data set.

Figure B.6 shows the lead content (determined by AAS) plotted against the lead:copper XRF peak height ratio. It bears some resemblance to the tin plot (Figure B.4) as high values of the ratio (over about 0.9) usually correspond to leaded alloys (those with over 8% lead), but here low values of the ratio (under 0.2) generally indicate insignificant lead levels (below 4%). Values of the ratio between these boundaries can correspond to almost any lead content though it is usually above a few percent. Most objects with lead ratios in the intermediate range are described as '(leaded)' though their lead contents do not necessarily fall within the range defined for the AAS analyses (see Chapter 9).

The results of these exercises are quite encouraging, but show that any attempt to get more from these XRF results than a rough indication of alloy type would have no firm foundation. While the alloy

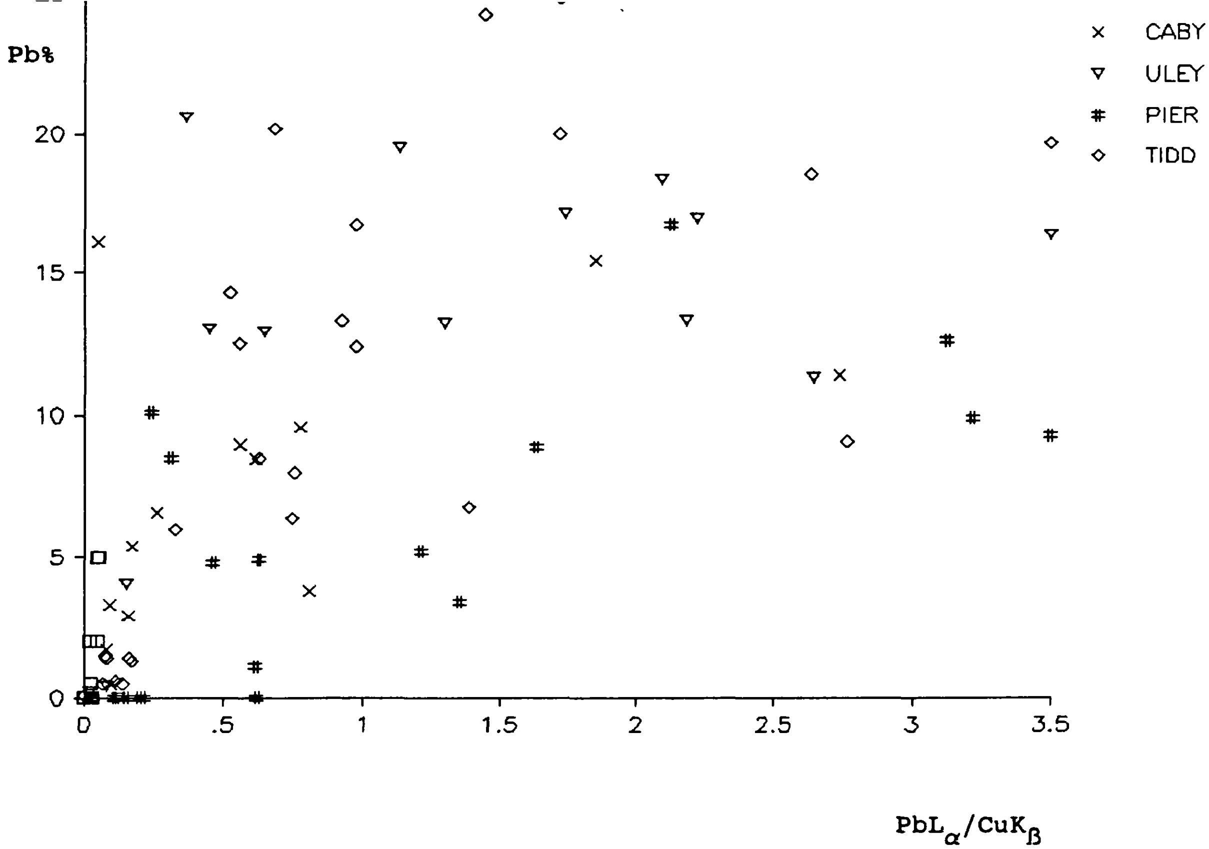


Figure B.6 - AAS v. XRF data for lead

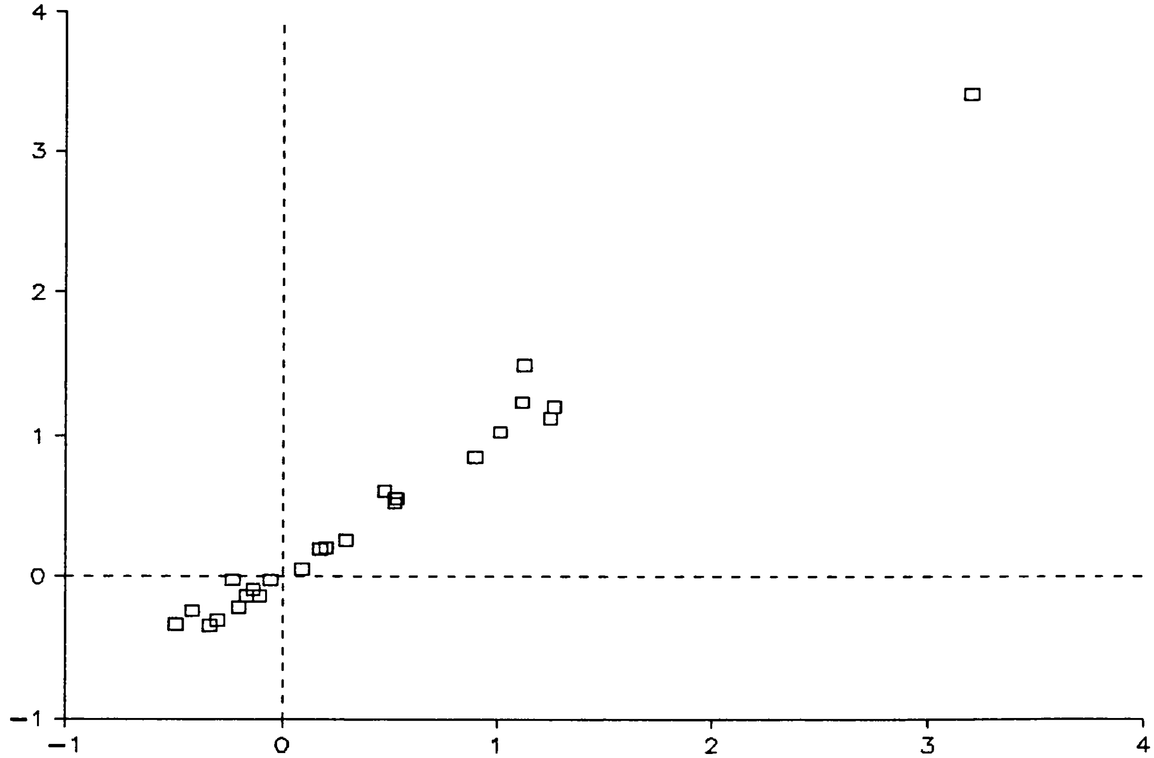
name assigned on the basis of XRF analysis is likely to fairly represent the composition of the majority of the objects, it can be seen from Figures B.2-B.5 that there are outliers to the main distributions so the composition implied by the assigned alloy name cannot be guaranteed to be correct in every case. This matters when describing individual objects, but when considering overall trends in alloy use (see Chapter 10) it is of little importance.

Replicate XRF analyses are generally in reasonable agreement. One group of 25 brooches from Chelmsford were analysed twice, several months apart (see Table B.5 and Figure B.7). It is unlikely that exactly the same area was selected for analysis on both occasions and this will account for some of the variation found. In over half the cases the peak height ratios were within 15% of their original values and only 8% of the results were over 50% different (see Table B.5 and Figure B.8). The reproducibility of the lead/copper ratio was less good than for zinc/tin and for the former, variability was higher on average for lower values. Although the these percentage variation figures may appear large, the alloy names assigned to the objects on the basis of the peak height ratios was the same in all cases, showing the robustness of the measures used.

XRF analysis of applied decoration

Applied surface decoration can normally be positively detected by XRF where the applied material contains elements not present in the underlying bulk metal. A good example of this is gilding as gold is not normally present in copper alloys. Applied silver can normally also be detected as silver is not present in the copper alloys at detectable levels. Sometimes only slight traces of the applied metal survive. This is usually in corners or crevices that are not easy to analyse, given the geometry of the XRF system, and may comprise only a small proportion of the area being analysed and hence not be detectable, even when extended analysis times are used.

Where the applied decoration comprises metals present in the bulk metal of the object, eg 'tinning' on a leaded bronze, it is not normally possible to positively identify the decoration although the absence of, eg silver, can be demonstrated. The tinning was normally a very thin layer that is often partly or nearly completely abraded away and may originally only have covered selected areas of the object. In this case the large area analysed is a drawback as coated and uncoated areas cannot be separated and the averaging effect of the analysis camouflages the variations in composition. Analyses of tinning on iron



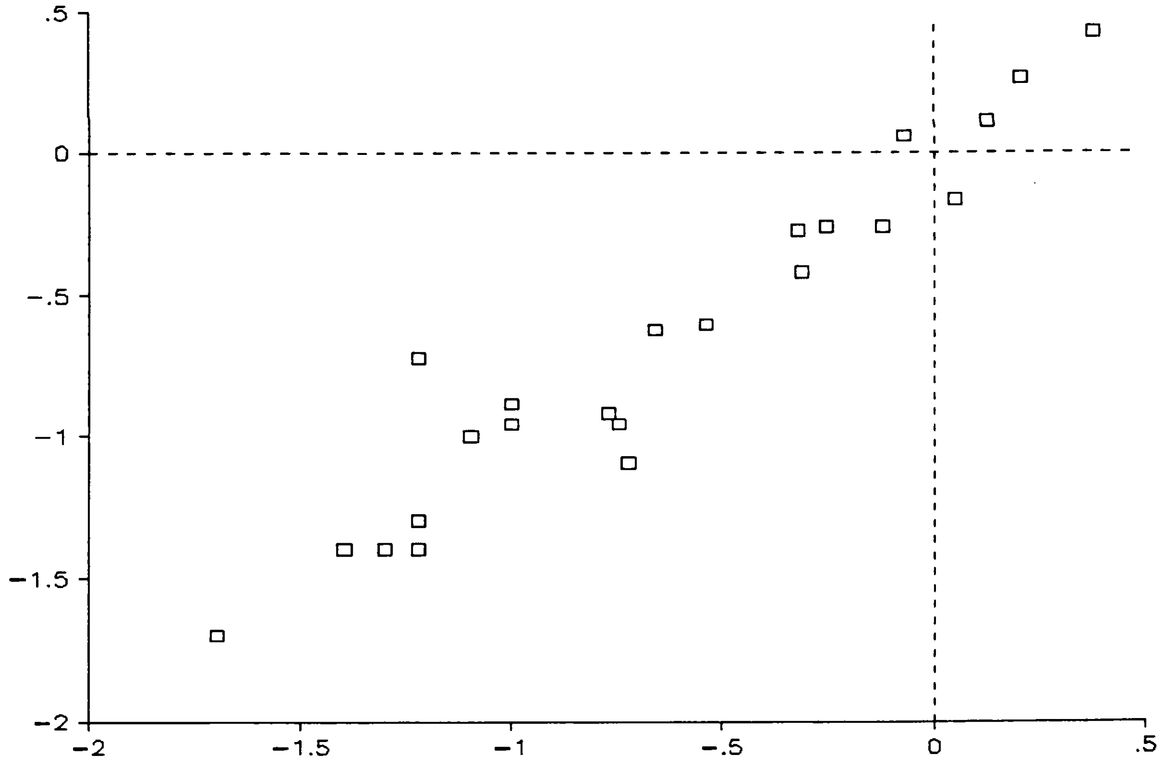


Figure B.7 - Duplicate XRF analyses of 25 Roman brooches from Chelmsford. Upper graph shows correlation of zinc/tin peak height ratios (units = $\log_{10}(ZnK_\alpha/SnK_\alpha)$) and lower graph shows correlation of lead/copper peak height ratios (units = $\log_{10}(PbL_\alpha/CuK_\beta)$)

Table B.5 - Duplicate XRF analyses of 25 Roman brooches from Chelmsford

Site No	Zn/Sn A	Zn/Sn B	Zn/Sn % var	Pb/Cu A	Pb/Cu B	Pb/Cu % var
1	.88	.94	6.59	.10	.11	9.52
3	1.23	1.12	9.36	.04	.04	.00
14	.38	.57	40.00	1.12	.68	48.89
57	.46	.45	2.20	1.34	1.29	3.80
59	.73	.8	9.15	1.61	1.83	12.79
60	18.46	16.13	13.47	.02	.02	.00
68	1.59	1.6	.63	.48	.53	9.90
88	.78	.72	8.00	.00	0	.00
89	3.40	3.61	5.99	.05	.04	22.22
90	.32	.46	35.90	.76	.55	32.06
91	.59	.94	45.75	.06	.05	18.18
102	.63	.6	4.88	.56	.55	1.80
106	3.34	3.56	6.38	.49	.38	25.29
107	13.32	31.37	80.78	.18	.11	48.28
110	10.34	10.7	3.42	.06	.19	104.00
134	1.49	1.57	5.23	.17	.12	34.48
148	.68	.72	5.71	2.39	2.67	11.07
151	1588.87	2541.85	46.14	.01	0	200.00
155	3.32	3.34	.60	.29	.25	14.81
158	17.78	13.28	28.98	.08	.1	22.22
162	13.03	17.21	27.65	.06	.04	40.00
164	.50	.49	2.02	.85	1.14	29.15
168	2.96	4.09	32.06	.19	.08	81.48
216	1.96	1.8	8.51	.10	.13	26.09
?	7.88	7.11	10.27	.22	.24	8.70

Note: Zn/Sn=$ZnK_{\alpha}/SnK_{\alpha}$ and Pb/Cu=PbL_{α}/CuK_{β} peak height ratios

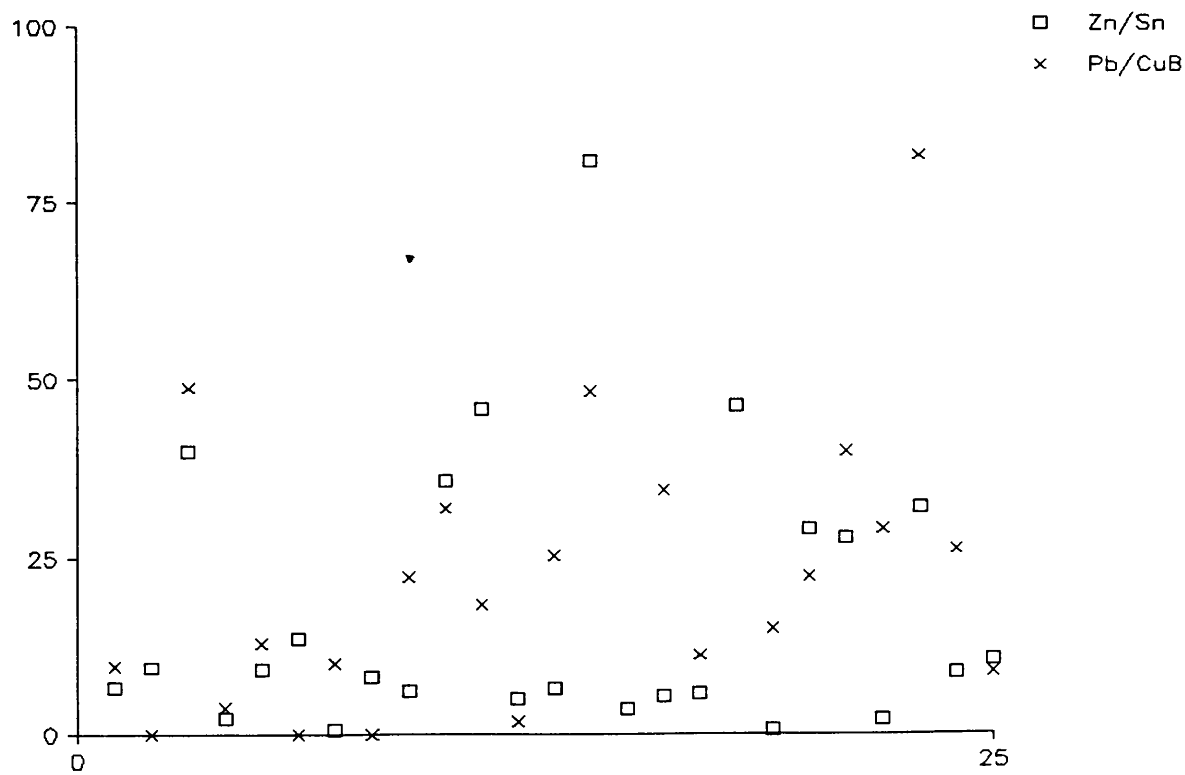


Figure B.8 - Percentage variability (y-axis) for each brooch (data from Table B.5)

objects has shown that both tin and tin-lead alloys were used.

Niello is also difficult to positively identify by XRF as single sulphides were widely used (see Chapter 8). Even if sulphur is sought (by evacuating the sample chamber) its presence may be obscured by the lead M peaks and, even when positively identified, it may be present in metal corrosion products rather than niello.

XRF analysis of metalworking debris

All the crucibles examined as part of this study had the metalliferous slag deposits on them analysed qualitatively by XRF. These results can be interpreted to suggest what metal or alloy was melted in the crucible.

The ultimate aim is to identify the composition of the metal that was melted in the crucible. The available evidence is sometimes corroded metal droplets trapped in the slag layer but more usually just the crucible slag itself. The relationship between the composition of this surviving material and that of the original metal is very complex so the imprecision introduced by qualitative analysis is only one of several approximations that have to be made in interpreting the XRF results. In practice, qualitative XRF results are a positive advantage as they prevent spurious precision being attached to their interpretation.

The proportions of the various non-ferrous metals present in crucible slags depends not only on their original concentrations in the metal melt but also on their chemical nature. Elements like gold which are unreactive are not detected unless they are present as discrete metal droplets trapped in the slag. At the other end of the scale the concentrations of lead and particularly zinc are enhanced as they can act as glass-forming elements and so are chemically bound into the crucible slag. Zinc has a very high vapour pressure and so tends to diffuse into the crucible walls so it is well represented when the crucible is analysed, even if it was only present in minor amounts in the metal melt. ~~Figure B.5 shows the relative peak heights recorded for a metalworking slag and an included metal droplet, showing the sort of enhancement that can be expected.~~ The shape of the crucible may also affect the amounts of more volatile elements detected as a deep or lidded form will tend to contain the metal vapour while with an open form it will quickly be lost to the atmosphere and so be present in lower concentrations as the crucible slag forms.

The XRF system used is an advantage when dealing with crucible slags as they are far from homogeneous. An analysis of a relatively large area is thus more likely to detect all the metals present and give average values for their relative amounts than an individual spot analysis could do. If the metal traces are very slight or scattered the chances of them being detected increase with the size of the area analysed. The system is also very fast to use so large numbers of sherds can easily be processed.

When analysing crucibles, iron was normally sought as well as non-ferrous metals. The iron is present in the clay fabric of the crucible and so provides a very approximate internal standard against which the other elements may be compared. Where overall levels of non-ferrous metals are very low (relative to iron) though still detectable, the crucible is described as 'used' with no attempt made to identify the metal or alloy being melted. Where copper is the only element detected this may be because 'pure' copper was being melted or because the overall levels of metals detected are so low that alloying elements would not show above the background.

With moulds there is far less likelihood than with crucibles that high levels of metals will survive both burial and rediscovery. A good mould was not 'wetted' by the metal cast in it and its temperature was not normally high enough for long enough to produce any significant slagging of the surface in contact with the metal. Thus the only metal normally entering the fabric of the mould was that in the vapour in equilibrium with the melt, ie mainly zinc and, to a lesser extent, lead. For these reasons XRF analyses of clay object moulds do not normally produce useful results. Occasionally metal ran into a crack in the mould and remained and corroded there, providing good evidence of the alloy being cast.

Ingot moulds on the other hand can provide evidence of the metals cast in them as they were used repeatedly over a period of time, allowing detectable levels of metals to build up. Volatile elements are not so great a problem here as the open moulds allow their escape to the atmosphere. Even in ingot moulds the levels of metals are far lower than in crucibles and they are less firmly bound to the surface so vigorous washing removes all trace of them. The only positive results were obtained from unwashed ingot moulds.

Scrap and waste metal can also be analysed. The results obtained are interpreted as for metal objects.

APPENDIX C
ANALYTICAL RESULTS

The analyses presented in Tables C.3 and C.4 were carried out by myself and by others working either with or for me. Many of the AAS samples were taken by myself though they were analysed by others. The earliest work was done in 1975/6 and over the years since then all the individuals listed below have, with varying degrees of supervision, analysed groups of finds by AAS and/or XRF. Their initials appear in Table C.2 beside the sites for which they carried out analyses. All the interpretation of the results and presentation of the data is my own work.

Individuals who carried out analyses:

AM - Averil Martin-Hoogewerf
FM - Fiona Macalister
GM - Gerry McDonnell
IC - Ian Cross
JB - Justine Bayley
JW - Jonathan Webb
MH - Mike Heyworth
ML - Moira Laidlaw
NP - Neil Pratt
PB - Paul Budd
PW - Paul Wilthew
RL - Ruth Linton
SW - Susan Wilthew

Table C.1 lists the codes used to identify individual sites in Tables C.2-C.6 and provides references where some or all of the analyses have already been written up or published.

The non-brooches ('others') listed in Table C.2 are only a sample of the many objects that have been analysed to determine their bulk composition and/or the nature of the applied decoration. This sample is made up of relatively large groups of finds from a limited number of sites and includes objects from sites of a range of Iron Age/Roman dates in various parts of the country. The analytical results for them are given in Tables C.4-C.5. Chapters 8 and 10 summarise and discuss not only this data but the information derived from many other, smaller groups of finds too.

Considerable numbers of objects from a few post-Roman sites have, at my suggestion, also been analysed in the Ancient Monuments Laboratory but the bulk of this work is not mine so the AML Reports containing these results are quoted when referring to the information they contain, rather than reproducing it here. The exception is Portway, where the analyses are my own work and the results are reproduced in Table C.6.

All AAS analyses were completed by the end of 1986. About two thirds of the XRF results had been obtained by the same date; the remainder are more recent work.

Table C.1 Sites providing objects for analysis

ALDB Aldeborough, Yorks (SE 4066)

ASHT Ashton, Northants (TL 0588)

BALD Baldock, Herts (TL 2433)
Refs: AML 3278, 3322, 3781, Bayley 1986B

BANT Bantham, Devon (SX 6643)

BEES Beeston Castle, Cheshire (SJ 5458)

BRAN Brancaster, Norfolk (TF 7743)

BRAU Braughing, Herts (TL 3925)
Refs: AML 3895, 2/87, Bayley 1988B

BROU Brougham, Cumbria (NY 5328)
Refs: AML 40/86

CABY Caistor-by-Yarmouth, Norfolk (TG 518125)
Refs: AML 4125

CAME Camelon, Central Region (NS 8680)
Refs: AML 3847

CANT Canterbury: Cakebraed Robey (TR 1457)
Refs: AML 4644

CARL Carlisle, Cumbria (NY 3955)
Refs: AML 3634, Bayley 1990E

CARV Carvossa, Cornwall (SW 9148)
Refs: Butcher 1987B

CAST Castleford, Yorks (SE 427257)

CATS Catsgore, Somerset (ST 5025)
Refs: AML 2766, Bayley 1982D

CATT Catterick, Yorks (SE 241973)

CHEL Chelmsford, Essex (TL 7006)
Refs: AML 2826, 4845, 124/89

CHES Chesterfield, Derbys (SK 3871)

CHIC Chichester, Sussex (SU 8604)

CIRE Cirencester, Gloucs (SP 0202)

CLEE Cleeve Abbey, Somerset (ST 047407)

COLC Colchester, Essex (TL 9925)
Refs: AML 4257, 95/87

COLE Coleshill, Warwks (SP 195905)

CORB Corbridge, Northumb (NY 983648)
Refs: AML 4465, Bayley 1989C

COSG Cosgrove, Northants (SP 7942)
Refs: AML 3283

DEEP Deepdale, Derbys (SK 1669)
Refs: AML 4737

DERB Derby, Derbys (SK 3536)

DODD Dodderhill, Hereford & Worcester (SO 9063)

Table C.1 (continued)

DORC	Dorchester, Dorset (SY 6990)
	Refs: AML 3094, 3790, Bayley 1982C
DOVE	Dover, Kent (TR 3141)
DRAG	Dragonby, Humbers (SE 905138)
	Refs: AML 86/90
GARD	Garden Hill, Sussex (TQ 444319)
	Refs: AML 4287
GDUN	Great Dunmow, Essex (TL 6222)
	Refs: AML 3147
GEST	Gestingthorpe, Essex (TL 927388)
	Refs: Bayley 1985F
GLOU	Gloucester, Gloucs (SO 8318)
	Refs: AML 4355, 4369, 4684, Bayley 1985A
GORH	Gorhambury, Herts (TL 117078)
	Refs: AML 34/86, 37/86, Bayley 1990C and 1990D
HAYL	Hayling Island, Hants (SZ 7303)
	Refs: AML 2783, 3217
HENL	Henley Wood, Avon (ST 4365)
	Refs: AML 4398
HEYB	Heybridge, Essex (TL 8508)
	Refs: AML 3464, Bayley 1986C
HOUS	Housesteads, Northumb (NY 790688)
	Refs: AML 4466
ICKH	Ickham, Kent (TR 231591)
	Refs: AML 125/89
ILCH	Ilchester, Somerset (ST 5222)
	Refs: AML 4933
INWO	Inworth, Essex (TL 8817)
KEST	Keston, London (TQ 4164)
KILH	Kilhallon, Cornwall
LAMY	Lamyatt Beacon, Somerset (ST 669363)
	Refs: AML 3217
LANC	Lancaster, Lancs (SD 4762)
LECH	Lechlade, Gloucs (SU 2199)
	Refs: AML 3682
LEIC	Leicester: various sites, Leics (SK 5804)
	Refs: AML 4777
LOND	London: various sites (TQ 3281)
LULL	Lullingstone, Kent (TQ 5465)
MAGI	Magiovinium, Bucks (SP 9033)
	Refs: AML 4298, Butcher 1987A
MAXE	Maxey, Cambs (TF 1208)

Table C.1 (continued)

NORN	Nornour, Cornwall (SV 9515)
	Refs: AML 4153, Bayley and Butcher 1981
OLDW	Old Windsor, Berks (SU 9874)
OPEN	Old Penrith, Cumbria (NY 5130)
OUDE	Oudenaarde, Belgium
PAPC	Papcastle, Cumbria (NY 1031)
	Refs: AML 68/90
PIER	Piercebridge, Durham (NZ 2115)
	Refs: AML 116/88
POOL	Poole's Cavern, Derbys (SK 0572)
	Refs: AML 4737, Bayley and Branigan 1989
PORT	Portway, Hants (SU 344463)
	Refs: AML 3704, Bayley 1985J
POUN	Poundbury, Dorset (SY 685911)
PRES	Prestatyn, Clwyd (SJ 0682)
	Refs: AML 4685, 28/87, Bayley 1989D
REDC	Redcliff, Humbers (SE 9925)
	Refs: AML 8/87
RICH	Richborough, Kent (TR 3260)
	Refs: AML 4304, Bayley *et al* 1980, Bayley and Butcher 1981
SEAM	Sea Mills, Avon (ST 5576)
	Refs: AML 4900
SEAT	Seaton, Devon (SY 2490)
SEWN	Sewingshields, Northumb (NY 813702)
SHEP	Colchester: Sheepen, Essex (TL 9825)
	Refs: AML 3188, 3286, 3425, Bayley 1985F and 1985G
SHOR	Shortlanesend, Cornwall (SW 805475)
	Refs: Butcher 1980
SNET	Snettisham, Norfolk (TF 6834)
STAL	St Albans, Herts (TL 1307)
	Refs: AML 138/88, Bayley 1989B
STAN	Stanwick, Northants (SP 9871)
SWIN	Swindon Hill, Wilts
	Refs: AML 3901
TARH	Tarrant Hinton, Dorset (ST 927118)
	Refs: AML 4716
TATT	Tattershall Thorpe, Lincs (TF 237608)
THIS	Thistleton, Leics (SK 9117)
	Refs: AML 72/91
THOR	Thorpe-by-Newark, Notts
TIDD	Tiddington, Warwks (SP 216555)
	Refs: AML 85/89
TRET	Trethurgy, Cornwall (SX 035556)

Table C.1 (continued)

ULEY	Uley, Gloucs (ST 789996)
	Refs: AML 65/87, 85/87, 117/88
VELZ	Velzeke, Belgium
VIND	Vindolanda, Northumb (NY 769663)
WAKE	Wakerley, Northants (SP 9599)
	Refs: AML 2181, Bayley 1978A
WALL	Walls, Dorset
	Refs: AML 4703
WANB	Wanborough, Wilts (SU 2082)
	Refs: AML 3943
WEEK	Weekley, Northants (SP 8880)
	Refs: AML 3760, Bayley 1986-7
WELT	Welton Wold, Lincs (SE 974279)
	Refs: AML 4827
WHIT	Whitcombe, Dorset (SY 7188)
	Refs: AML 4333
WICF	Wickford, Essex (TQ 7493)
	Refs: AML 4062
WICL	Wicklewood, Norfolk (TG 0702)
	Refs: AML 4646
WIGG	Wigginton
WILD	Wilderspool, Cheshire (SJ 6186)
WINC	Winchester, Hants (SU 4829)
	Refs: AML 34/89
WITC	Witcombe, Gloucs (SO 9114)
	Refs: AML 4932
WNEW	Water Newton, Cambs (TL 1097)
WORC	Worcester, Hereford & Worcester (SO 8554)
WPER	Wharram Percy, Yorks (SE 8564)
	Refs: AML 3113, Bayley et al 1981
WROX	Wroxeter, Salop (SJ 5608)
XXXX	Other/unknown
YORK	York: various sites, Yorks (SE 6051)
	Refs: AML 4042, 4321

Table C.2 - Summary of late Iron Age and Roman analyses included in Tables C.3-C.5

Site	Brooch analyses AAS	analyst	XRF	analyst	total	Other analyses AAS	analyst	XRF	analyst	total	Grand total
ALDB	0		40	JB	40	0		0		0	40
ASHT	0		34	JB	34	0		58	JB	58	92
BALD	52	RL	92	JB	144	0		8	JB	8	152
BANT	0		1	JB	1	0		0		0	1
BEES	1	SW	1	JB	2	0		0		0	2
BRAN	0		1	JB	1	0		0		0	1
BRAU	33	NP+SW	43	JB+NP	76	0		0		0	76
BROU	0		4	JB	4	0		0		0	4
CABY	13	NP+RL	7	NP	20	0		0		0	20
CAME	3	SW	13	JB	16	0		0		0	16
CARL	0		29	JB	29	0		54	JB	54	83
CARV	6	RL	11	JB	17	0		0		0	17
CAST	0		98	JB	98	0		0		0	98
CATS	22	AM	13	JB	35	0		0		0	35
CATT	0		19	JB	19	0		0		0	19
CHEL	18	SW+AM	47	JB	65	0		1	JB	1	66
CHES	0		1	JB	1	0		0		0	1
CHIC	0		10	JB+ML	10	0		0		0	10
CIRE	0		2	JB	2	0		0		0	2
CLEE	0		1	JB	1	0		0		0	1
COLC	0		61	JB+PB	61	0		0		0	61
COLE	0		29	NP	29	0		40	NP	40	69
CORB	0		22	JB	22	0		0		0	22
COSG	0		2	JB	2	0		0		0	2
DEEP	0		3	JB	3	0		0		0	3
DERB	0		5	JB	5	0		0		0	5
DODD	0		7	JB	7	0		0		0	7
DORC	0		19	JB	19	0		0		0	19
DOVE	0		2	JB	2	0		0		0	2
DRAG	0		96	JB	96	0		0		0	96
GARD	0		3	JB	3	0		0		0	3
GDUN	0		2	JB	2	0		0		0	2
GEST	0		12	JB	12	0		0		0	12
GLOU	0		7	JB	7	0		18	JB	18	25
GORH	20	SW	27	JB	47	0		124	SW	124	171
HAYL	33	RL	89	RL+JB	122	44	RL	268	RL	312	434
HENL	0		23	JB	23	0		0		0	23
HEYB	0		2	NP	2	0		24	FM	24	26
HOUS	3	SW	17	JB	20	0		0		0	20
ICKH	0		13	JB	13	0		0		0	13
ILCH	0		7	JB	7	0		0		0	7
INWO	0		1	JB	1	0		0		0	1
KEST	0		12	JB	12	0		0		0	12
KILH	0		1	JB	1	0		0		0	1
LAMY	0		3	JB	3	0		0		0	3
LECH	3	NP	6	JB	9	0		0		0	9
LEIC	4	?	7	JB	11	0		0		0	11
LOND	0		341	JW+JB	341	0		0		0	341
LULL	0		1	JB	1	0		0		0	1
MAGI	5	SW	15	JB	20	0		0		0	20
MAXE	0		5	PW	5	0		0		0	5
NORN	124	AM	15	JB	139	2	AM	0		2	141
OLDW	0		1	MH	1	0		0		0	1
OPEN	0		18	JB	18	0		0		0	18
OUDE	4	SW	3	JB	7	0		0		0	7

Table C.2 (continued)

Site	Brooch analyses AAS	analyst	XRF	analyst	total	Other analyses AAS	analyst	XRF	analyst	total	Grand total
PAPC	0		11	JB	11	0		0		0	11
PIER	18	SW	29	JB	47	0		0		0	47
POOL	0		28	JB	28	0		7	JB	7	35
POUN	0		5	JB	5	0		0		0	5
PRES	18	SW	6	JB	24	0		0		0	24
REDC	0		5	JB	5	0		0		0	5
RICH	341	JB+IC	96	JB+NP	437	3	JB	19	JB	22	459
SEAM	0		12	JB	12	0		0		0	12
SEAT	0		3	JB	3	0		0		0	3
SEWN	0		2	JB	2	0		0		0	2
SHEP	22	FM	20	JB	42	0		55	JB	55	97
SHOR	1	RL	0		1	0		0		0	1
SNET	0		33	JW+JB	33	0		0		0	33
STAL	107	FM+NP	69	JB	176	0		0		0	176
STAN	0		89	JW+JB	89	0		0		0	89
SWIN	2	NP	5	JB	7	0		0		0	7
TARH	8	SW	20	JB	28	0		0		0	28
TATT	0		1	JB	1	0		0		0	1
THIS	19	NP	51	JB	70	0		0		0	70
THOR	0		2	JB	2	0		0		0	2
TIDD	26	SW	43	JB	69	0		0		0	69
TRET	0		2	JB	2	0		0		0	2
ULEY	18	NP+RL+SW	19	JB	37	0		113	JB	113	150
VELZ	16	SW	12	JB	28	0		0		0	28
VIND	0		6	JB	6	0		0		0	6
WAKE	0		9	JB	9	0		0		0	9
WALL	0		12	JB	12	0		0		0	12
WANB	45	SW	91	JB+RL	136	0		0		0	136
WEEK	0		17	JB	17	0		0		0	17
WELT	4	SW	7	JB	11	0		0		0	11
WHIT	2	SW	1	JB	3	0		0		0	3
WICF	9	SW	16	JB	25	0		0		0	25
WICL	0		49	JB	49	0		0		0	49
WIGG	0		1	JB	1	0		0		0	1
WILD	0		1	JB	1	0		0		0	1
WINC	0		23	JB	23	0		0		0	23
WITC	0		5	JB	5	0		0		0	5
WNEW	0		1	JB	1	0		0		0	1
WORC	0		31	JW+GM	31	0		0		0	31
WROX	18	SW	57	JB+JW	75	0		0		0	75
XXXX	0		1	JB	1	3	JB	0		3	4
YORK	0		15	JB	15	0		0		0	15
	1018		2253		3271	52		789		841	4112

(arranged in typological order)

Notes and key to the Table:

The Site is identified by the four letter code defined in Table C.1.

The Site No is usually the finds number assigned by the excavator but is sometimes the catalogue number used in publishing the finds.

The AML No is the accession number given to the object by the Ancient Monuments Laboratory.

The Group and Type numbers are based on the corpus of brooches drawn up by M R Hull (Hull and Hawkes 1987 and forthcoming) and most of them have been assigned to the analysed brooches by Sarnia Butcher. A Type number followed by + means the brooch is only similar to that Type and thus may have been misclassified. Question marks denote uncertainty.

Where elemental percentages are given, the brooches have been analysed by AAS and the alloy name has been assigned as explained in Chapter 9. Where there are no percentage figures the alloy name has been derived from XRF analyses as outlined in Appendix B.

The letters in the column headed Decor describe the nature of any applied decoration; they have the following meanings:

A = applied metal foil

> = silver

< = copper alloy

ˆ = tin alloy

B = applied bone plate

E = enamel; (E) = was enamelled but none survives

G = gilding (with or without mercury)

I = metal inlay (metal identified as for applied metal foil)

N = niello

S = glass 'stone'; (S) = glass 'stone' now lost

W = white metal coating (tinning)

+ = unidentifiable rivetted-on decoration now lost

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
KEST	841269		1	1	bronze						
THIS		THZ624	1	1B	bronze						
RICH	7350293		1	3	brass		77.5	19.2	1.2	0.2	0.0
RICH	7351547		1	3	brass		82.3	17.7	2.8	0.3	0.0
HAYL		145b	1	3	bronze		86.5	1.1	14.0	1.7	0.1
HAYL		2356	1	3	(leaded) bronze		83.3	0.1	11.4	6.7	0.0
HAYL		1960	1	3	bronze						
SWIN	770328	112	1?	3?	bronze						
ILCH		17	1	3A	bronze						
DODD	8515510		1	3B	brass						
RICH	7351753		1	3C	brass		79.5	16.7	1.5	0.3	0.0
HAYL		3388	1	5	bronze		79.2	0.2	9.7	0.6	0.3
LECH		1959-9	1	9	bronze						
HAYL		1420	1	9	bronze						
HAYL		1729	1	9	bronze		81.3	0.2	13.1	0.2	0.1
HAYL		1023	1	9	bronze						
HAYL		3325	1	9	bronze						
HAYL		825	1	9?	bronze		76.3	0.0	7.4	0.2	0.1
HAYL		2813	1	9?	bronze		77.7	0.0	10.6	0.1	0.1
HAYL		2029	1	9?	bronze		97.7	0.0	14.1	0.7	0.1
HAYL		30	1	9?	bronze/gunmetal						
HAYL		93	1	9?	bronze						
HAYL		530	1	9?	bronze						
HAYL		1662	1	9?	bronze						
HAYL		3014	1	9?	bronze						
HAYL		3222	1	9?	bronze						
HAYL		2909	1	9?	bronze						
BALD		Cat 1	1	9A	bronze						
WANB		Cat 1	1	9A	brass/gunmetal						
TARH		259	1	9C	bronze						
TARH		197	1	9/10/11	bronze						
WEEK	781378	21	1	10	bronze						
WEEK	781396	76	1	10	bronze						
MAGI		Pub 15	1	10	bronze						
SHEP		Rep 1	1	10	brass						
GEST	777260	Pub 1/BR 59	1	10	bronze						
WANB		Cat 2	1	10	brass?						
WANB		Cat 5	1	10	bronze						
WANB		Cat 6	1	10	gunmetal						
WANB	707353	Cat 7	1	10	gunmetal						
WANB		Cat 9	1	10	bronze						
WANB		Cat 10	1	10	(leaded) bronze						
WANB		Cat 12	1	10	bronze						
WANB		Cat 21	1	10	(leaded) bronze						
WANB		Cat 24	1	10	brass						
WANB	684356	Cat 25	1	10	brass						
WANB	692708	Cat 26	1	10	brass						
HAYL		1400	1	10	bronze		81.0	0.0	10.4	0.4	0.2
HAYL		87	1	10	gunmetal		82.8	5.5	4.7	3.2	0.1
ASHT	835122	542	1	10	gunmetal						
ASHT	835108	680	1	10	brass						
THIS	610986	BH760	1	10	brass						
THIS	610987	BH761	1	10	brass						
THIS	610990	BH794	1	10	brass						
HAYL		5	1	10	brass						
HAYL		65	1	10	brass						
HAYL		68	1	10	brass						
HAYL		1932	1	10	brass						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
CARL		Ae138	1	10	gunmetal						
RICH	7351873		1	10	bronze						
RICH	7351883		1	10	bronze						
LOND		GPO 188	1	10	brass						
LOND		LCT 1302	1	10	gunmetal						
WEEK	781382	30	1?	10?	bronze						
WANB		Cat 16	1	10?	bronze						
GORH	820266	2338	1	10?	bronze						
GORH	820031	26	1	10?	bronze						
HAYL		378	1	10?	bronze						
HAYL		1996	1	10?	bronze						
WEEK	781401	87	1	10A	bronze						
BALD		Cat 19	1	10A	bronze/gunmetal						
WANB	681065	Cat 8	1	10A	bronze						
RICH	7351501		1	10A	bronze		86.4	0.0	10.1	2.4	0.1
RICH	7351581		1	10A	bronze		88.8	0.0	11.2	2.6	0.1
WINC		VR-449	1	10A	bronze						
STAN	8700352		1	10A	bronze/gunmetal						
WEEK	781411	190	1	10B	gunmetal						
OUDE		6	1	10B	gunmetal						
RICH	7350559		1	10B	brass/gunmetal						
RICH	7350077		1	10B	gunmetal		84.3	5.1	5.3	0.0	0.0
RICH	7350068		1	10B	bronze		90.2	0.3	4.4	3.0	0.0
RICH	7350092		1	10B	bronze/gunmetal		85.3	2.8	6.7	1.2	0.0
RICH	7350094		1	10B	brass		70.9	24.5	0.0	0.3	0.1
RICH	7351548		1	10B	bronze		91.5	1.7	10.2	1.0	0.1
STAL	670417	A1	1	10B	bronze						
ICKH	746632	388	1	10B	bronze						
LOND		97	1	10B	gunmetal?						
STAL	670468	A4	1	10B?	brass						
BALD		Cat 25	1	10C	bronze						
BALD		Cat 32	1	10C	bronze						
BALD		Cat 33	1	10C	bronze						
BALD		Cat 40	1	10C	brass						
BALD		Cat 41	1	10C	brass						
TIDD		82-236	1	10C	bronze						
TIDD		82-200	1	10C	bronze						
COLE		1018	1	10C	(leaded) bronze						
COLE		1088	1	10C	bronze						
RICH	7351038		1	10C	bronze						
RICH	7350096		1	10C	brass		87.2	12.3	1.0	0.3	0.1
RICH	7351525		1	10C	brass		80.6	19.1	0.0	0.2	0.0
RICH	7351751		1	10C	brass		72.5	27.3	0.0	0.0	0.1
BALD	7211100	Cat 23	1	10C	bronze		83.8	2.5	11.0	2.0	0.1
BALD	7211230	Cat 39	1	10C	brass		73.5	27.7	0.9	0.1	0.0
ASHT	835123	638	1	10C	bronze						
ALDB	78108256	jb1	1	10C	bronze/gunmetal						
CARL		Ae217	1	10C	gunmetal						
STAL	670523	A3	1	10C	bronze						
STAL	682695	A2	1	10C	gunmetal						
CAST		15-680	1	10C	gunmetal						
LOND		A28337	1	10C	bronze						
ULEY		3605	1	10D	brass						
ULEY		3717	1	10D	bronze	W					
ULEY		6062	1	10D	bronze/gunmetal						
DRAG		DR 68 VG	1	10D	bronze						
STAN	8701776		1	10D	bronze						
WROX	721368		1	10F	brass		84.5	15.1	1.9	0.0	0.1

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
CAST		1-508	1	10F	brass						
LOND		A22346	1	10F+	bronze						
OUDE		9	1	10G	bronze?						
OUDE		10	1	10G	bronze?						
RICH	7351529		1	10G	bronze						
OUDE		7	1	10G	bronze		87.8	1.8	11.0	0.3	0.1
OUDE		8	1	10G	bronze		87.9	0.4	17.0	0.4	0.1
WINC		VR-1030	1	10G	bronze						
LOND		98	1	10G	bronze						
LOND		13861	1	10G	brass/gunmetal						
LOND		19280	1	10G	brass/gunmetal						
LOND		A28562	1	10G	brass						
BRAU		496	1	10H	brass						
SWIN	770764	92	1	10/11	bronze						
MAXE		M80-41-2740	1	10/11	bronze/gunmetal						
WANB		Cat 11	1	10/11	bronze						
WANB		Cat 13	1	10/11	brass						
WANB		Cat 27	1	10/11	brass						
RICH	7350776		1	10/11	bronze						
RICH	7351506		1	10/11	bronze						
RICH	7350772		1	10/11	bronze						
RICH	7350071		1	10/11	gunmetal						
RICH	7350074		1	10/11	brass		76.2	20.7	0.6	0.0	0.1
RICH	7350107		1	10/11	bronze		90.4	0.0	8.8	0.2	0.1
GORH	820348	3295	1	10/11	bronze						
THIS		THZ2233	1	10/11	bronze/gunmetal?						
DRAG		DR 65 EG	1	10/11	brass						
RICH	7351884		1	10/11	bronze						
RICH	7351885		1	10/11	bronze/copper						
LOND		CASS 61	1	10/11	bronze						
LOND		GPO 105	1	10/11	bronze						
LOND		GPO 3758	1	10/11	bronze						
LOND		LEA 320	1	10/11	brass						
LOND		18158	1	10/11	bronze						
LOND		0.1817B	1	10/11	bronze						
STAN	8701531		1	10/11	brass						
STAN	8612948		1	10/11	bronze						
WORC		3899-7004	1	10/11	gunmetal						
MAXE		2800/7658	1	10/11?	bronze						
HAYL		3030	1	10/11?	brass						
HAYL		KP4	1	10/11?	gunmetal						
STAN	8800722		1	10/11?	bronze						
BALD		Cat 20	1	10/11A	gunmetal						
BALD		Cat 22	1	10/11A	bronze						
BRAU		106	1	11	bronze/gunmetal						
BRAU		225	1	11	bronze						
BRAU		356	1	11	bronze						
DORC		Rep 4	1	11	brass						
MAGI	779208	Pub 3	1	11	bronze						
WICF		259	1	11	bronze						
WANB		Cat 3	1	11	bronze						
WANB		Cat 4	1	11	brass						
WANB		Cat 14	1	11	brass						
WANB		Cat 15	1	11	copper						
WANB		Cat 17	1	11	copper						
WANB		Cat 18	1	11	bronze/gunmetal						
WANB		Cat 19	1	11	bronze						
WANB		Cat 22	1	11	(leaded) gunmetal						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
WANB		Cat 23	1	11	gunmetal						
KEST	841268		1	11	bronze						
KEST	841237		1	11	bronze						
KEST	841270		1	11	bronze						
BRAU		1036	1	11	brass						
BRAU		453	1	11	bronze						
BRAU		433	1	11	bronze						
BRAU		774	1	11	bronze						
BRAU		564	1	11	brass						
BRAU		904	1	11	brass						
BRAU		1025	1	11	bronze						
RICH	7350050		1	11	bronze/gunmetal		91.5	2.6	7.2	1.1	0.0
RICH	7350063		1	11	brass		77.5	19.4	1.6	0.2	0.0
RICH	7351048		1	11	bronze		84.5	1.1	6.0	0.0	0.3
HAYL		1398	1	11	bronze		51.9	0.0	6.4	0.7	0.0
HAYL		2975	1	11	bronze		84.1	0.1	9.6	0.1	0.0
WROX	721365		1	11	bronze		89.6	0.4	8.3	1.3	0.5
GORH	811385		1	11	bronze		83.9	0.2	16.2	1.4	0.1
GORH	811389		1	11	bronze		88.3	0.0	12.5	0.0	0.1
TIDD		81-644	1	11	bronze/gunmetal		87.7	3.5	6.8	0.5	0.0
GORH	820284	2514	1	11	bronze						
GORH	820227	1546	1	11	bronze						
GORH	820334	2967	1	11	bronze						
WITC	732331	bz93	1	11	bronze						
HAYL		1	1	11	brass						
HAYL		159	1	11	bronze						
HAYL		223	1	11	bronze						
HAYL		562	1	11	bronze						
HAYL		1006	1	11	bronze/gunmetal						
HAYL		2068	1	11	bronze						
HAYL		2303	1	11	bronze						
HAYL		2386	1	11	bronze						
HAYL		2927	1	11	bronze						
HAYL		2953	1	11	bronze						
HAYL		58	1	11	bronze						
CHEL		CHAG 29	1	11	bronze						
CHEL		CHN 14	1	11	brass						
CHEL		CHK Ae207	1	11	gunmetal						
CHEL		CHM Ae275	1	11	bronze						
CHEL		CHK Ae206	1	11	bronze						
CHEL		CHK Ae209	1	11	bronze						
LOND		GPO 325	1	11	brass						
LOND		LCT 1154	1	11	bronze						
LOND		LYD 793	1	11	brass						
LOND		MC 20	1	11	brass						
LOND		3422	1	11	bronze						
SNET		Cat 28	1	11	bronze						
GORH	811365	924	1	11+?	bronze						
HAYL		1015	1	11?	bronze						
HAYL		2152	1	11?	bronze						
HAYL		3443	1	11?	bronze						
CHEL		CHAG 33	1	11?	bronze						
CHEL		CHV 7	1	11?	bronze						
BALD		Cat 15	1	11A	bronze						
BALD		Cat 16	1	11A	bronze/gunmetal						
BALD		Cat 17	1	11A	bronze						
BALD		Cat 18	1	11A	bronze						
RICH	7351585		1	11A	bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7351178		1	11A	brass		89.6	11.3	1.7	0.6	0.0
WINC		VR-1013	1	11A	bronze/gunmetal						
LOND		A24066	1	11A	bronze						
LOND		16978	1	11A	bronze						
LOND		16980	1	11A	bronze						
LOND		16979	1	11A	brass						
STAN	8700812		1	11A?	gunmetal						
BALD		Cat 29	1	11B	bronze						
BALD		Cat 37	1	11B	brass						
BALD		Cat 38	1	11B	bronze/gunmetal						
BALD	715557	Cat 31	1	11B	bronze		92.8	0.0	5.6	1.3	0.3
TARH		795	1	11B	bronze						
COLC		1.81-229	1	11B	brass						
COLC		1.81-2298	1	11B	bronze						
COLC		1.81-2619	1	11B	bronze/gunmetal						
DRAG		DR 66 JL	1	11B	brass						
WINC		VR-1043	1	11B	bronze/gunmetal						
WINC		VR-3176	1	11B	gunmetal						
ICKH		2039	1	11B	gunmetal						
LOND		20372	1	11B	bronze						
LOND		19559	1	11B	bronze/gunmetal						
LOND		13091	1	11B	gunmetal						
STAN	8516932		1	11B	bronze						
STAN	8612939		1	11B	(leaded) bronze						
STAN	8700404		1	11B	brass/gunmetal						
BALD		Cat 28	1	11C	bronze						
BALD		Cat 34	1	11C	bronze						
HEYB		Ae 405	1	11C	bronze						
RICH	7351503		1	11C	brass		84.1	15.0	1.8	0.2	0.1
RICH	7351510		1	11C	bronze		95.1	0.4	8.3	0.7	0.1
RICH	7351758		1	11C	brass		89.0	12.9	1.0	0.4	0.1
BALD	7210306	Cat 26	1	11C	bronze		84.6	1.7	10.2	0.6	0.5
BALD	715590	Cat 24	1	11C	copper		87.6	0.9	1.5	0.4	0.6
BALD	7210363	Cat 35	1	11C	bronze		86.8	0.1	11.6	2.3	0.1
BALD	7210420	Cat 27	1	11C	bronze		87.3	0.4	6.6	2.3	0.1
BALD	7211174	Cat 36	1	11C	leaded gunmetal		78.7	7.3	6.9	8.2	0.1
TARH		216	1	11C	brass						
COLC		1.81-5092	1	11C	bronze/gunmetal						
COLC		1.81-4186	1	11C	brass						
COLC		1.81-595	1	11C	brass/gunmetal						
COLC		1.81-620	1	11C	bronze						
DRAG		DR 63 HQ	1	11C	gunmetal						
DRAG		DR 70 BZP	1	11C	brass						
STAN	8516930		1	11C	bronze						
HENL	734858	711	1	13	bronze						
BRAU		974	1	13	bronze						
HAYL		3007	1	13	bronze		90.0	0.1	11.4	0.9	0.2
BRAU		886	1	13	bronze		85.7	0.8	9.3	0.7	0.2
GORH	820259	2149	1	13	bronze						
TARH		743	1	13	bronze						
CARV		33	1	13?/17?	copper						
DORC	7816092		1	14?	bronze						
TIDD		82-242	1	14?	brass						
LOND		WIV 525	1	16?	bronze						
DORC		Rep 12	1	17	bronze						
BALD		Cat 126	1	17	brass						
HENL	734859	712	1	17	bronze						
CLEE	830090		1	17	bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
WANB		Cat 41	1	17	brass						
WANB		Cat 42	1	17	bronze						
TARH		803	1	17	bronze						
TARH		380	1	17	bronze						
TARH		874	1	17	bronze						
POUN		Ae 18	1	17	gunmetal						
TARH		127	1	17?	(leaded) gunmetal						
WALL		5	1	17A	bronze						
WALL		6	1	17A	bronze/gunmetal						
WROX	721374		1	17A?	bronze		89.7	0.0	7.6	1.3	0.0
WALL		8	1	17A?	bronze/gunmetal						
TIDD		M600	1	17B	bronze						
WALL		2	1	17B	bronze/gunmetal						
WALL		7	1	17B	bronze						
DORC	7816710		1	17B?	bronze						
BRAU		71/342	1	18	bronze		76.4	0.1	10.2	0.4	0.0
BALD		Cat 13	1	18?	bronze						
BALD	7211214	Cat 14	1	18?	(leaded) bronze/gunmetal		81.1	2.0	5.6	6.7	0.1
WEEK	781374	12	1	19	bronze						
WEEK	781376	19	1	19	bronze						
LOND		81.279/1	1	19	bronze						
ICKH	746476	1616	1	20	bronze						
HAYL		3167	1	20?	bronze						
BRAU		341	1	?	bronze						
BRAU		954	1	?	bronze						
BALD		Cat 3	1	?	bronze						
BALD		Cat 2	1	?	brass						
BALD		Cat 4	1	?	bronze						
BALD		Cat 5	1	?	bronze						
BALD		Cat 6	1	?	bronze						
BALD		Cat 7	1	?	bronze						
BALD		Cat 8	1	?	bronze						
BALD		Cat 9	1	?	bronze/gunmetal						
BALD		Cat 10	1	?	bronze/gunmetal						
BALD		Cat 11	1	?	bronze						
BALD		Cat 12	1	?	bronze						
BALD		Cat 21	1	?	bronze						
BALD		Cat 30	1	?	bronze						
BALD		Cat 42	1	?	bronze						
BALD		Cat 43	1	?	brass						
WICF		351	1	?	bronze						
WICF		283	1	?	bronze						
MAXE		2680/7667	1	?	bronze						
WANB		Cat 20	1	?	bronze/gunmetal						
WANB		Cat 61	1?	?	brass						
BRAU		276	1?	?	bronze						
BRAU		1103	1	?	bronze						
RICH	7350081		1?	?	bronze/gunmetal		89.8	5.6	9.8	0.2	0.1
RICH	7350102		1	?	bronze		86.1	1.8	6.0	3.5	0.1
CHEL		CHAA 2	1	?	(leaded) bronze		87.8	2.6	8.6	4.4	0.1
GORH	820150		1?	?	bronze		85.9	0.2	12.1	1.3	0.1
ASHT	835148		1	?	bronze						
WALL		4	1?	?	bronze						
STAL	670495	A6	1	?	brass						
STAL	670453	A5	1	?	bronze						
RICH	7351876		1	?	bronze						
RICH	7351887		1	?	bronze						
LOND		WIV 233	1?	?	bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
BALD		Cat 88	2	21	brass						
BALD		Cat 91	2	21	brass	W					
BALD		Cat 92	2	21	brass/gunmetal						
BALD		Cat 93	2	21	brass	W					
BALD		Cat 94	2	21	brass						
BALD		Cat 95	2	21	brass						
MAGI	7711196	Pub 2	2	21	brass/gunmetal						
WAKE	745074	124	2	21	gunmetal	W					
TIDD		82-73	2	21	(leaded) brass						
TIDD		M18	2	21	brass/gunmetal						
WANB		Cat 43	2	21	brass						
BRAU		396	2	21	brass						
BRAU		921	2	21	gunmetal						
SHEP		Rep 13	2	21	brass		75.0	18.1	4.0	0.6	0.0
SHEP		Rep 15	2	21	brass		81.5	14.3	2.6	1.6	0.1
SHEP	722212	Rep 14	2	21	brass		78.6	14.5	2.4	0.7	0.1
SHEP	722214	Rep 16	2	21	brass		71.2	18.9	1.5	0.1	0.0
THIS		THZ1179	2	21	brass		66.3	15.6	2.6	0.7	0.0
HAYL		674	2	21	brass						
HAYL		182	2	21	brass/gunmetal	W	67.9	10.3	3.6	0.7	0.0
BALD	7211143	Cat 87	2	21	brass		71.2	17.1	1.9	0.2	0.1
BALD	707054	Cat 90	2	21	brass		73.5	24.5	0.5	2.4	0.0
BALD	7211139	Cat 89	2	21	brass		72.9	21.8	3.5	0.4	3.0
TIDD		M589	2	21	brass		76.1	16.9	2.1	0.5	0.2
GORH	811383		2	21	brass		79.1	17.3	2.8	0.5	0.2
GORH	820252		2	21	brass		77.7	17.5	2.7	0.6	0.1
BRAU		824	2	21	brass	W	82.5	16.3	2.0	0.3	0.2
BRAU		514	2	21	brass		72.1	17.9	2.6	0.3	0.1
BRAU		1045	2	21	brass		79.2	20.8	1.4	0.3	0.1
BRAU		434	2	21	brass		78.0	22.9	0.9	0.1	0.1
BRAU		1069	2	21	brass		87.5	15.3	1.7	0.3	0.1
PRES		1924	2	21	brass						
REDC	8650620	1007	2	21	brass	W					
REDC	8650619	1000	2	21	brass/gunmetal	I					
THIS	611047	BH1665	2	21	brass						
STAN	8800718		2	21	brass						
WICL		46	2	21?	gunmetal						
STAL	682718	E18	2	21?	brass						
STAL		E27	2	21?	brass						
WAKE	745080	136	2	21A	gunmetal	W					
STAL	670491	F19	2	21A	brass		75.3	22.6	0.9	1.3	0.1
STAL	670296	E2	2	21A	brass		82.6	12.4	1.7	0.3	0.0
STAL	670420	E1	2	21A	brass		81.9	16.6	3.1	0.7	0.1
STAL	670490	E13	2	21A	brass		79.6	16.1	2.0	1.3	0.1
STAL	670439	E14	2	21A	brass		76.7	20.7	1.9	1.0	0.0
DRAG		DR 67 PY	2	21A	brass						
STAL	682724	E6	2	21A/B	brass		78.1	19.7	2.4	0.5	0.0
STAL	670421	E19	2	21A/B	brass		76.0	19.4	0.8	0.3	0.1
STAL	682676	E29	2	21A/B	gunmetal		85.6	11.0	6.1	0.3	0.0
STAL	682671	E15	2	21A/B	brass		77.9	16.4	3.5	2.6	0.0
STAL	4520	E8 or E9	2	21A/B	brass		77.8	18.9	3.0	1.2	0.7
STAL	682673	E23	2	21A/B	brass						
STAL	682711	E25	2	21A/B	brass						
STAL	670487	E17	2	21A/B	brass						
STAL	4520	E8 or E9	2	21A/B?	brass		77.0	16.3	2.8	2.8	0.1
STAL	682682	E24	2	21A/B?	brass						
STAL	670426	E7	2	21B	brass		79.3	19.7	2.3	1.6	0.1
STAL	682684	E4	2	21B	brass		89.7	10.2	2.4	0.2	0.0

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
STAL	4535	E11	2	21B	brass		76.1	20.7	1.9	0.4	0.0
STAL	682678	E28	2	21B	brass						
STAL	682688	E26	2	21B	brass						
STAL	682677	E16	2	21B	brass						
STAL	4579	E10	2	21B	brass						
DRAG		DR 67 TA	2	21B	brass	W					
STAN	8800687		2	21B	brass						
STAL	670484	E21	2	21B?	brass						
STAL	4518	L3	2	22	brass	I<					
GEST		Pub 3	2	22?	gunmetal						
RICH	7351522		2	22A	brass/gunmetal		78.4	16.6	4.2	1.1	0.0
STAL	4542	J1	2	22A	brass		79.8	19.5	2.2	1.0	0.0
BALD	777938	Cat 86	2	22A	brass		74.8	17.9	1.8	0.9	0.1
WANB		44	2	22A	brass		79.0	14.7	1.7	0.0	0.0
STAL	670637	J2	2	22A?	brass		80.4	16.0	1.7	1.1	0.1
STAL	682708	K2	2	22C	brass		75.6	19.2	2.4	0.1	0.0
STAL	670485	L4	2	22C	brass						
STAL	670434	K1	2	22C?	brass						
STAL	4531	L6	2	23	brass	A<					
SHEP		Rep 17	2	23/24/29A	brass		73.9	15.3	2.3	3.4	0.0
BALD	7210439	Cat 102	2	23?	(leaded) brass	W	78.5	15.7	2.7	6.1	0.1
SHEP	722333	Rep 18	2	24/29A?	brass	W					
BALD		Cat 96	2	25	brass						
BALD		Cat 97	2	25	brass						
HAYL		1843	2	25	brass						
LOND		84.306/11	2	25	brass						
RICH	7351886		2	25/26?	brass	A<					
DRAG		DR 70 ZE	2	25B	brass						
SNET		Cat 27	2	25C	brass						
SHEP	722336	Rep 21	2	26	brass						
GORH	820084		2	26	brass		74.3	19.0	2.7	1.1	0.1
GORH	820106	626	2	26	bronze/gunmetal?						
HAYL		145a	2	26	brass	W					
HAYL		2677	2	26	brass						
WINC		VR 5105	2	26/27	brass						
HAYL		2837	2	26/27?	brass/gunmetal						
STAL	4552	F16	2	26A	brass						
STAL	4553	F12	2	26A	brass						
STAL	4554	F17	2	26A	brass						
STAL	4581	F5	2	26A	brass						
STAL	4582	F14	2	26A	brass						
BALD		Cat 98	2	26A	brass						
SHEP	722203	Rep 19	2	26A	brass						
GEST	777258	Pub 4/BR 6	2	26A	bronze and gunmetal						
SHEP	722215	Rep 20	2	26A	brass		76.1	18.6	1.5	0.2	0.1
STAL	682689	F21	2	26A	brass		78.1	16.3	2.2	0.7	0.0
STAL	682696	F20	2	26A	brass		78.5	16.5	2.1	2.1	0.1
STAL	670462	F8	2	26A	brass		76.7	17.1	2.0	0.5	0.1
STAL	670520	H6	2	26A	brass		81.8	17.0	2.8	0.2	0.0
STAL	670652	F25	2	26A	brass		78.2	18.2	2.3	0.4	0.0
STAL	670653	F13	2	26A	brass		80.7	21.0	4.8	1.3	0.0
STAL	682672	F23	2	26A	brass		73.6	19.8	1.7	1.1	0.1
STAL	682669	F9	2	26A	brass		79.8	19.3	1.8	0.6	0.0
STAL	682707	F7	2	26A	brass		74.0	18.6	1.7	0.2	0.1
STAL	682680	F22	2	26A	brass		77.1	18.9	1.8	0.4	0.0
STAL	682655	F6	2	26A	brass		79.8	19.8	1.7	0.9	0.0
STAL	4541	F1	2	26A	brass		81.7	16.2	1.5	0.2	0.0
STAL	4532	H5	2	26A	brass		79.0	16.4	2.2	0.5	0.1

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
BRAU		1059	2	26A	brass		77.8	18.2	1.9	0.7	0.1
STAL	670488	F 3	2	26A	brass						
STAL	682705	H1	2	26A	brass						
STAL	682706	H3	2	26A	brass						
STAL	682713	F24	2	26A	brass						
STAL	682683	F29	2	26A	brass						
STAL	682698	F11	2	26A	brass						
STAL	4556	F28	2	26A	brass						
STAL	682701	H2	2	26A	brass						
DRAG		DR 71 TD	2	26A	brass						
DRAG		DR 70 APM	2	26A	brass	I^					
LOND		A17718	2	26A	brass						
STAL	4583	F4	2	26A?	brass						
STAL	670489	F19	2	26A?	brass		74.7	17.3	1.6	0.2	0.0
STAL	682714	F15	2	26A?	brass		75.9	21.8	1.5	0.4	0.0
STAL	670515	F2	2	26A?	brass						
STAL	670512	H4	2	26A?	brass						
WAKE	745055	1	2	26B	brass?						
WICL		10	2	26B	gunmetal						
STAL	4526	F31	2	26B	brass		75.9	22.4	1.7	0.1	0.1
LOND		C990	2	26B	brass						
STAL	4561	F30	2	26B?	brass		77.5	18.6	1.6	0.4	0.1
BALD		Cat 100	2	27	brass	W					
SHEP	722201	Rep 22	2	27	brass?						
SHEP	722205	Rep 23	2	27	brass						
THIS		THZ650	2	27	brass						
THIS	610743	TH2	2	27	brass						
HAYL		1648	2	27	brass	W(A)					
COLC		GBS-965	2	27	brass						
STAL	682693	G4	2	27	brass	(S)					
STAL	682694	G3	2	27	brass	(S)					
STAN	8701480		2	27+	brass						
STAL	4521	G2	2	27?	brass	(S)					
STAL	4521	G1	2	27?	brass	S					
SHEP	722332	Rep 24	2	27?	leaded gunmetal?						
HAYL		1564	2	27?	brass						
BALD		Cat 99	2	27A	brass						
ASHT	835150	673	2	27A	brass						
ULEY		5839	2	27A	brass	E					
DRAG		DR 66 KK	2	27A	brass						
DRAG		DR BG	2	27A?	brass						
LOND		440	2	27B	brass						
LOND		439	2	27B	brass	W					
DRAG		DR 70 AG	2	27B?	brass	W					
HAYL		799	2	28?	brass						
DRAG		DR 66 BC	2	28A	bronze						
STAL	4521	L1	2	?	brass	WA>					
ASHT	835073		2	?	brass						
COLC		1.81-4971	2	?	brass						
STAL	682664	F33	2	?	brass						
STAL	4530	H7	2	?	brass						
STAL	670298	G5	2	?	brass	(S)					
STAL	670514	L2	2	?	brass						
HAYL		KP12	2	?	brass						
TIDD		81-1059	3	29	brass	W	77.0	15.9	2.4	1.5	0.2
TIDD		82-154	3	29?	leaded gunmetal						
STAL	670461	L5	3	29A	brass		78.4	15.8	2.2	0.8	0.0

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
GORH	820113	678	3	29A	brass						
STAN	8612947		3	29A	brass	W					
WICL		20	3	29B	leaded bronze						
VELZ		2	3	29B	gunmetal	E	77.2	10.3	5.3	4.0	0.0
THIS	611046	BH1664	3	29B	(leaded) bronze						
SNET		Cat 23	3	29B	(leaded) bronze						
NORN	733396		3	29B?	(leaded) gunmetal	E	75.0	9.9	4.8	4.8	0.0
SNET		Cat 11	3	34	(leaded) bronze						
WICL		50	3	34+	gunmetal						
NORN	620654	48	3	35	bronze		84.1	0.2	10.2	0.4	0.0
NORN	621139	49	3	35?	leaded bronze		94.1	0.2	7.0	9.7	0.0
LULL		Brooch 56	3	36	leaded gunmetal	W					
MAXE		M80-1638-27	3	36	leaded bronze	W					
RICH	7350906		3	36	bronze		91.0	0.3	4.9	0.6	0.1
GORH	820104		3	36	leaded bronze	W	70.6	1.0	13.7	13.2	0.1
ALDB	78108243	jb16	3	36	gunmetal?	E					
THIS		THZ326	3	36	bronze						
OPEN	7815599		3	36	bronze	E					
CAST		1-40	3	36	bronze/gunmetal?	(E)					
CAST		1-402	3	36	bronze	E					
CAST		1-514	3	36	bronze	(E)					
CAST		1-515	3	36	bronze	E					
CAST		10-1350	3	36	bronze	E					
CAST		10-120	3	36	bronze?	E					
CAST		10-962	3	36	(leaded) bronze	E					
CAST		16-264	3	36	bronze	E					
RICH	7351917		3	36+	gunmetal						
WICL		33	3	37	bronze						
WANB		Cat 45	3	37	leaded bronze	A<					
TIDD		81-857	3	37	leaded bronze		71.3	0.6	7.7	19.6	0.0
TIDD		M12	3	37	leaded bronze		73.3	0.0	8.2	18.5	0.2
TIDD		M13	3	37	leaded bronze						
THIS		THZ2122	3	37	leaded bronze/gunmetal	?					
THIS		THZ2706	3	37	leaded gunmetal	W					
CAST		12-37	3	37	bronze						
DRAG		DR 67 TY	3	37+?	gunmetal						
HAYL		1848	3	37?	brass						
TIDD		82-260	2/3	?	gunmetal						
BALD		Cat 48	4	40	brass						
BALD	7210433	Cat 49	4	40	brass		75.6	23.7	1.2	0.3	0.0
THIS		THY66	4	40	brass						
HOUS	811591		4	40?	(leaded) bronze						
LOND		13048	4	40A	brass						
LOND		453	4	40A	brass						
LOND		A24941	4	40B	brass						
TIDD		82-82	4	40C	gunmetal						
RICH	7350742		4	40C	brass		78.1	18.6	2.0	0.2	0.0
RICH	7351745		4	40C	brass		78.2	17.8	1.1	0.3	0.0
RICH	7351582		4	40C	brass		82.0	18.8	2.1	0.4	0.0
THOR	852996	17	4	40C	brass/gunmetal						
DRAG		DR 65 CU	4	40C	brass						
LOND		A2406	4	40C	brass						
RICH	7351574		4	42	brass		74.0	22.4	0.0	0.2	0.0
VELZ		3	4	42	brass		82.6	18.7	1.7	0.1	0.0
LOND		CS 1	4	42	brass						
LOND		106	4	42	brass						
LOND		105	4	42	brass						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
LOND		104	4	42	brass						
DODD	8515485		4	43	brass						
CAST		9-1396	4	43	brass/gunmetal						
COLC		1.81-2493	4	43?	brass						
DRAG		DR 65 ABV	4	44+	bronze						
PAPC		84-012	4	44?	brass						
LOND		0.1800	4	45	brass						
LOND		81.629/1	4	45+	bronze						
LOND		0.1813	4	46?	brass						
LOND		84.240/2	4	48	brass	W					
LOND		0.1814	4	50	brass						
SHEP	722216	Rep 25	4	51	brass						
WROX	787180		4	51	brass						
WANB		Cat 46	4	51	brass						
WANB		Cat 47	4	51	brass						
WANB		Cat 48	4	51	brass						
COLE		595	4	51	brass						
COLE		93	4	51	gunmetal						
RICH	7350070		4	51	brass						
RICH	7351030		4	51	brass						
RICH	7351403		4	51	gunmetal						
RICH	7351507		4	51	brass						
BRAU		862	4	51	brass						
BRAU		625	4	51	brass						
RICH	7351771		4	51	brass		82.1	19.4	0.3	0.2	0.3
SHEP		Rep 26	4	51	brass		67.0	20.6	0.5	0.6	0.0
BRAU		512	4	51	brass		77.6	17.6	0.0	0.1	0.0
ASHT	835113	551	4	51	brass						
ASHT	835117	536	4	51	brass						
SEAM		67-90	4	51	brass						
ILCH		75	4	51	brass						
THIS		THVbag81	4	51	brass						
THIS	610969	BH705	4	51	brass						
THIS	611005	BH822	4	51	brass						
COLC		1.81-3800	4	51	brass						
COLC		GBS-761	4	51	brass						
COLC		GBS-696	4	51	brass						
LOND		LCT 1391	4	51	brass						
LOND		TRM 52	4	51	brass						
WANB		Cat 49	4	51?	brass						
BALD		Cat 105	4	51A	brass						
BALD		Cat 106	4	51A	brass/gunmetal	W					
STAL	4540	M1	4	51A	brass						
STAL	4573	M2	4	51A	brass						
STAN	8700410		4	51A/52D	brass						
STAN	8701138		4	51A/52D	brass						
CATS		158	4	51B	brass						
RICH	7350890		4	51B	brass						
RICH	7350901		4	51B	brass						
RICH	7350972		4	51B	brass		80.5	18.4	0.8	0.4	0.0
RICH	7351097		4	51B	brass		77.6	20.1	2.0	0.0	0.1
RICH	7351098		4	51B	brass		81.2	15.5	2.7	0.0	0.0
RICH	7351386		4	51B	brass		83.6	16.7	0.9	0.1	0.0
RICH	7351515		4	51B	brass		78.1	20.6	0.0	0.0	0.0
RICH	7351584		4	51B	brass		78.5	20.4	2.0	0.2	0.1
RICH	7351521		4	51B	brass		77.2	22.8	2.9	0.1	0.1
RICH	7351541		4	51B	gunmetal		74.5	17.7	7.6	0.2	0.0
RICH	7351516		4	51B	brass		80.1	21.7	0.3	0.0	1.4

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7351176		4	51B	brass		75.0	16.7	1.7	0.4	0.1
RICH	7351715		4	51B	brass		73.9	23.7	0.8	0.2	0.1
STAL	670457	M3	4	51B	brass		77.7	18.6	2.0	0.1	0.0
BALD	7211175	Cat 104	4	51B	brass		73.5	24.1	3.1	0.1	0.4
WROX	721370		4	51B	brass		79.5	17.0	2.3	0.0	0.0
GORH	820365	2387	4	51B	brass						
TARH		415	4	51B	brass						
ALDB	78108251	jb2	4	51B	brass						
DODD	8515479		4	51B	gunmetal						
DRAG		DR 70 BEM	4	51B	brass						
DRAG		DR 72 BWS	4	51B	brass						
DRAG		DR 68 KO	4	51B	brass						
WROX	7410181		4	51B	brass						
LOND		442	4	51B	brass						
LOND		3427	4	51B	brass						
LOND		TRM 52	4	51B	brass						
LOND		29.201/1	4	51B	brass						
GORH	820234	1717	4	51B?	brass						
RICH	7350214		4	51C	brass		80.4	19.3	0.0	0.0	0.0
WORC	907219	3899-c17889	4	51C	brass						
CARL		Ae226	4	51C?	gunmetal						
WEEK	781385	35	4	52	brass						
SHEP		Rep 30	4	52	brass						
TIDD		M15	4	52	brass/gunmetal						
RICH	7351763		4	52++	bronze		87.6	0.6	5.0	0.7	0.1
LOND		0.1816	4	52/54	brass						
SHEP	722210	Rep 29	4	52A	brass						
HAYL		193	4	52A	brass		83.3	13.5	2.2	0.4	0.1
LEIC		316-135	4	52A	brass						
DRAG		DR 66 OL	4	52A	brass						
STAN	8700055		4	52A	brass	W					
WORC		3899-8505	4	52A	brass						
STAN	8612496		4	52B	brass						
RICH	7350066		4	52C	brass		72.9	17.7	1.5	0.5	0.0
HAYL		1655	4	52C	brass		69.7	19.2	0.0	0.5	0.1
ASHT	835101	303	4	52D	brass	?					
ASHT	835067	53	4	52D	brass						
GORH	820326	2907	4	52D	brass						
HAYL		264	4	52D	brass						
ICKH	746630	833	4	52D/60	brass						
CAST		15-140	4	51/53	bronze						
ILCH		69	4	53	bronze						
ICKH	741690	2867	4	53	brass						
ILCH		LP65/57	4	53?	bronze						
DRAG		DR 65 LR	4	53A	brass						
DRAG		DR 73 MW	4	53A	brass	I˙					
GORH	820129	987	4	54	brass						
VELZ		17	4	55	brass						
LOND		A13821	4	55	brass	W					
OUDE		5	4	56	leaded bronze		79.1	1.9	10.4	9.5	0.0
WROX	721375		4	56+?	brass		80.5	14.4	3.2	0.0	0.0
MAGI	7711042	Pub 1	4	56/57	brass						
TIDD		81-944	4	57	brass						
WANB		Cat 50	4	58	brass	I˙					
SEAM		65-108	4	58	brass						
ULEY		5732	4?	58/59?	bronze	W					
LOND		A13824	4	58A	brass						
LAMY		409	4	58B	bronze	W					

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7351754		4	58B	brass		77.8	16.8	2.8	1.7	0.0
BALD		Cat 107	4	60	brass	W					
BALD		Cat 108	4	60	brass	W					
BALD		Cat 109	4	60	brass	W					
BALD		Cat 110	4	60	bronze	W					
BALD		Cat 111	4	60	brass	W					
MAGI	7711176	Pub 14	4	60	brass/gunmetal	W					
CARV		28	4	60	bronze						
GEST	777257	Pub 5/BR 60	4	60	gunmetal	W					
VELZ		1	4	60	gunmetal?						
TIDD		82-54	4	60	brass	WN					
TIDD		81-648	4	60	brass	W					
CORB	831205		4	60	brass						
WINC			4	60	gunmetal	W					
WANB		Cat 51	4	60	bronze	W					
WANB		Cat 55	4	60	brass	W					
RICH	7351650		4	60	brass/gunmetal						
BRAU		556	4	60	brass	W					
BRAU		401	4	60	gunmetal						
RICH	7350504		4	60	bronze		80.8	2.1	7.3	1.2	0.1
RICH	7350099		4	60	brass		79.5	14.8	2.3	1.1	0.1
RICH	7350506		4	60	bronze		89.2	0.2	7.6	0.5	0.2
RICH	7351544		4	60	(leaded) bronze/gunmetal		78.5	3.5	6.1	5.4	0.1
RICH	7351572		4	60	brass/gunmetal		85.5	9.5	2.6	1.4	0.1
RICH	7351583		4	60	brass		85.7	21.1	0.5	0.1	0.1
RICH	7351737		4	60	brass		85.7	14.8	1.2	0.9	0.0
BALD	7211075	Cat 117	4	60	brass		68.2	26.8	1.4	0.7	0.0
WROX	721376		4	60	brass		81.9	17.7	1.3	0.0	0.0
BRAU		64	4	60	brass	W	82.2	18.0	1.1	0.2	0.2
ASHT	835075	166	4	60	brass	W					
TIDD		81-856	4	60	brass/gunmetal						
THIS		THVbag182	4	60	bronze						
THIS		THVbag183	4	60	brass						
THIS	611070	BH1792	4	60	gunmetal						
HAYL		598	4	60	brass	W					
COLC		1.81-3535	4	60	brass						
COLC		GBS-414	4	60	brass	W					
COLC		GBS-534	4	60	gunmetal	W					
COLC		GBS-469	4	60	brass						
HAYL		726	4	60	brass	WI<&Fe					
COLC		1.81-1219	4	60	brass/gunmetal						
CHEL		CHK Ae216	4	60	brass	W					
CHEL		CHK Ae239	4	60	brass						
DRAG		DR 68 LB	4	60	brass	W					
DRAG		DR 65 AAH	4	60	bronze						
HAYL		KP9	4	60	brass/gunmetal	W					
CAST		10-2167	4	60	brass/gunmetal	WN					
CAST		16-323	4	60	brass						
LOND		ATR 267	4	60	gunmetal	W					
LOND		FEN 192	4	60	brass						
LOND		GPO 263	4	60	brass/gunmetal						
LOND		GPO 3626	4	60	gunmetal						
LOND		GPO 5669	4	60	gunmetal						
LOND		LCT 1381	4	60	brass						
LOND		LEA 29	4	60	brass/gunmetal						
LOND		447	4	60	brass						
LOND		448	4	60	brass	W					
LOND		446	4	60	brass						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
LOND		445	4	60	brass						
LOND		20084	4	60	brass						
LOND		84.453/3	4	60	brass	W					
LOND		81.282/7	4	60	brass						
STAN	8610966		4	60	brass	W					
STAN	8612504		4	60	bronze/gunmetal	W					
LOND		21047	4	60	brass	W					
LOND		454	4	60	brass	W					
LOND		19754	4	60	brass	W					
WORC		3899-c17042	4	60	brass						
SNET		Cat 29	4	60	brass						
SNET		Cat 30	4	60	brass/gunmetal	W					
SNET		Cat 31	4	60	bronze/gunmetal						
TARH		887	4	60+	brass	W					
WINC		VR 9734	4	60/61	gunmetal						
RICH	7350474		4	60/61?	brass						
RICH	7351874		4	60/62?	brass	W					
CHEL		CHV 3	4	60/63	bronze/gunmetal						
CHEL		CHAL 12	4	60/63	brass						
THIS	611026	BH872	4?	60/63?	brass	W					
CHEL		CHK Ae243	4	60/71B	brass						
WANB		Cat 53	4	60/74	brass						
WANB		54	4	60/74	leaded bronze	?	80.8	0.1	9.5	13.3	0.1
WANB		Cat 52	4	60?	brass/gunmetal						
WANB		Cat 56	4	60?	brass						
CHEL		CHAG 25	4	60?	brass						
CHEL		CHAJ 17	4	60?	brass						
CHEL		CHD Ae308	4	60?	brass	W					
DRAG		DR 69 IN	4	60?	gunmetal						
DRAG		DR 66 FM	4	60?	brass	W					
HAYL		KP1	4	60?	brass	W					
HAYL		KP6	4	60?	brass						
CAST		10-1756	4	60?	gunmetal						
RICH	7351877		4	60?	brass						
DORC		Rep 9	4	61	bronze	W					
BALD		Cat 112	4	61	brass	W					
BALD		Cat 113	4	61	gunmetal	W					
BALD		Cat 114	4	61	bronze	W					
BALD		Cat 115	4	61	brass/gunmetal						
WICF		252	4	61	brass	W					
WICL		25	4	61	gunmetal?						
TIDD		M16	4	61	bronze?	W					
TIDD		82-149	4	61	brass	W					
WANB		Cat 57	4	61	brass	W					
RICH	7351768		4	61	bronze?	W					
RICH	7350065		4	61	brass/gunmetal		83.1	13.4	3.6	0.2	0.1
RICH	7350329		4	61	brass		76.0	22.5	0.8	0.3	0.2
RICH	7350691		4	61	bronze	W	88.9	0.5	8.8	2.2	0.0
RICH	7350770		4	61	bronze		88.5	0.5	10.7	1.9	0.0
RICH	7350909		4	61	brass	W	77.6	20.2	0.7	0.0	0.0
RICH	7350978		4	61	brass		77.9	12.9	2.2	2.5	0.0
RICH	7351538		4	61	brass		77.6	21.2	0.0	0.4	0.0
RICH	7351586		4	61	brass		70.5	16.0	2.5	0.3	0.0
ULEY		5723	4	61	(leaded) bronze	W	79.7	0.6	11.7	4.0	0.1
BALD	7211202	Cat 116	4	61	brass	W	70.8	28.3	0.0	1.7	0.0
THIS		THZ2214	4	61	brass	W					
THIS		THZ2707	4	61	brass/gunmetal	W					
HAYL		2306	4	61	brass	W					

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
COLC		GBS-33	4	61	brass/gunmetal						
CHEL		CHV 4	4	61	brass	W					
DRAG		DR 72 SV	4	61	brass	W					
WINC		VR-1018	4	61	brass						
LOND		OLC 40	4	61	gunmetal						
LOND		26393	4	61	brass/gunmetal						
STAN	8612487		4	61	brass						
LOND		449	4	61	brass						
COSG		217	4	62	brass	W					
SHEP	722204	Rep 32	4	62	brass	W					
SHEP		Rep 33	4	62	brass						
SHEP		Rep 34	4	62	brass						
BRAU		697	4	62	brass						
RICH	7350773		4	62	brass/gunmetal	W	79.7	13.6	3.5	0.2	0.0
RICH	7351724		4	62	brass		80.5	19.2	0.0	0.2	0.0
SHEP	722219	Rep 31	4	62	brass		75.9	22.2	1.0	0.3	0.0
BALD	7211119	Cat 120	4	62	brass	W	75.3	21.1	0.8	0.1	0.0
BALD	7210336	Cat 119	4	62	brass	W	73.7	28.3	0.0	0.1	0.2
GORH	811371	1090	4	62	brass						
GORH	820112	675	4	62	brass/gunmetal?						
STAN	8516944		4	62	brass						
COLC		GBS-837	4	62	brass	W					
CHEL		CHV 22	4	62	brass	W					
DRAG		DR 69 HE	4	62	brass	W					
DRAG		DR 66 HR	4	62	brass						
DRAG		DR 70 BBQ	4	62	bronze?						
CATT	8310557		4	62	brass	W					
WROX	743350		4	62	bronze?						
LOND		452	4	62	brass						
LOND		24764	4	62	gunmetal	W					
RICH	7350296		4	63	bronze		84.2	1.6	5.2	1.3	0.2
BALD	7211122	Cat 118	4	63	brass	W	71.1	28.4	1.2	0.2	0.0
BRAU		659	4	63	brass		76.7	18.2	1.2	0.0	0.0
BRAU		585	4	63	brass		80.1	18.9	2.9	0.3	0.3
THIS	610742	TH11	4	63	brass						
ULEY		77	4	63	brass	W					
COLC		1.81-3948	4	63	brass						
COLC		GBS-836	4	63	brass	W					
COLC		GBS-455	4	63	brass	W					
HAYL		1976-18	4	63	brass	W					
LOND		3425	4	63	brass	W					
BRAU		348	4	63?	bronze	W					
LOND		A13820	4	63A	brass						
RICH	7351757		4	63B	brass						
RICH	7351792		4	63B	gunmetal?						
RICH	7350279		4	63B	brass		80.9	17.9	0.6	0.5	0.2
RICH	7350093		4	63B	brass		81.4	16.1	1.4	0.5	0.1
RICH	7350210		4	63B	brass		76.9	23.7	0.0	0.0	0.1
RICH	7351708		4	63B	brass		75.3	18.7	2.0	0.3	0.1
SHEP	722207	Rep 35	4	63B	brass	W	78.0	21.3	1.9	0.1	0.0
SHEP	722211	Rep 36	4	63B	brass	W	76.7	17.1	1.5	0.3	0.1
DODD	8515494		4	63B	brass						
DRAG		DR 69 EL	4	63B	brass						
DRAG		DR 69 ADK	4	63B	brass						
LOND		FEN 406	4	63B	brass						
LOND		FMO 244	4	63B	brass						
RICH	7350384		4	64	brass		79.2	20.9	0.5	0.1	0.0
RICH	7351096		4	64?	brass						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
BALD		Cat 121	4	65	brass	W					
RICH	7350340		4	65	brass		81.3	16.7	1.4	0.1	0.1
BALD		Cat 122	4	66	brass	W					
DRAG		DR 72 ID(2)	4	67	brass	W					
RICH	7350060		4	70	gunmetal		79.7	9.0	5.7	1.0	0.1
WELT		SF7	4	70	brass	?	75.4	23.0	0.9	0.4	0.0
LOND		GPO 308	4	70	brass						
RICH	7351738		4	70C	brass		75.7	16.4	3.0	0.3	0.0
LOND		20.085	4	70C	brass	W					
LOND		3426	4	70D	brass						
RICH	7350211		4	70E	brass		81.8	14.5	2.7	1.3	0.1
VELZ		33	4	70E	(leaded) bronze		79.5	1.0	9.0	6.1	0.3
WALL		9	4	70E	brass/gunmetal						
VELZ		32	4	70E+	(leaded) gunmetal		80.4	13.5	9.2	5.6	0.3
WANB		Cat 58	4	70E/78	bronze	W					
BALD		Cat 123	4	71	brass						
BALD	7211121	Cat 124	4	71	brass	W	75.0	23.9	1.1	0.0	0.0
ILCH		27	4	71	brass	W					
COLC		1.81-4814	4	71	gunmetal?	W					
VELZ		29	4	71+	brass		76.1	18.7	0.7	0.2	0.2
RICH	7350509		4	71/79	bronze	W	86.0	0.4	8.9	2.5	0.1
HAYL		475	4	71?	brass	W					
RICH	7351546		4	71B	brass						
RICH	7350062		4	71B	brass		81.5	14.2	2.4	1.5	0.1
RICH	7350560		4	71B	brass		72.0	22.6	0.0	0.1	0.1
RICH	7351726		4	71B	brass		78.5	16.9	0.7	0.7	0.0
ASHT	835094	274	4	71B	bronze	W					
SEAM		65-135	4	71B	brass						
LOND		BWB 276	4	71B	brass	W					
LOND		GPO 244	4	71B	brass						
LOND		ORG 108	4	71B	gunmetal						
LOND		A16572	4	71B	brass	N					
LOND		456A	4	71B	bronze						
LOND		18.121	4	71B	brass						
GEST		Pub 6/BR 124	4	71B+	gunmetal						
RICH	7350900		4	71B?	brass						
WICF		260	4	73	brass	?					
WORC	907218	3899-c17727	4	73	gunmetal	E+					
DORC		Rep 2	4	73/75	brass	?					
HAYL		KP11	4	73/75	brass/gunmetal	W					
HAYL		3147	4	73?	brass	W					
DORC		Rep 5	4	74	brass	W					
TIDD		82-246	4	74	brass						
RICH	7350277		4	74	brass	W	79.0	16.1	1.7	2.2	0.1
HAYL		312	4	74	brass	W					
WINC		VR-3245	4	74	brass						
LOND		LCT 1045	4	74	brass	W					
LOND		19603	4	74	brass						
WORC		3899-7018	4	74	brass						
SNET		Cat 32	4	74	brass/gunmetal	W					
DORC		Rep 6	4	74/71	brass	W					
SWIN	770498	105	4	74?	brass	W					
VELZ		27	4	75	brass						
WANB		Cat 59	4	75	brass	W					
RICH	7350204		4	75	brass/gunmetal	W	84.3	12.9	3.7	1.3	0.1
HAYL		3121	4	75	brass/gunmetal	W	77.6	13.6	3.9	1.0	0.0
LOND		18122	4	75	brass	N					
LOND		21067	4	75	brass	W					

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7351891		4	75?	brass						
HAYL		263	4	76	bronze	W					
MAGI	7711088	Pub 17	4	77	brass/gunmetal	W					
RICH	7351076		4	77	brass		80.2	16.9	1.2	0.3	0.0
BRAU		1105	4	77	brass	W	83.7	17.9	2.4	0.5	0.0
LOND		19179	4	77	brass						
RICH	7350103		4	78	(leaded) gunmetal		80.9	9.3	3.8	4.4	0.1
RICH	7350206		4	78	brass		79.2	18.5	1.5	0.1	0.1
VELZ		28	4	78	brass		75.8	18.3	3.6	0.1	0.0
HAYL		1505	4	78	brass	W					
DRAG		DR 70 BOR	4	78	gunmetal	W					
VELZ		26	4	78+	brass		77.0	16.0	1.3	0.4	0.1
TARH		295	4	78+	brass	W					
HAYL		3476	4	78/79	brass	W					
SHEP		Rep 37	4	78?	brass		77.5	26.4	0.6	0.3	0.0
BRAU		943	4	78?	brass/gunmetal		80.2	12.7	4.6	1.3	0.0
RICH	7350473		4	79	brass/gunmetal	W	81.4	11.6	3.3	1.6	0.1
RICH	7350744		4	79	bronze	?	82.1	0.6	10.7	3.9	0.0
RICH	7350977		4	79	brass/gunmetal		80.7	10.1	3.7	0.6	0.0
RICH	7351580		4	79	gunmetal		82.3	10.2	7.3	3.0	0.1
WROX	721379		4	79	gunmetal		81.3	10.4	4.7	2.9	0.3
LOND		84.279/2	4	79	brass						
LOND		456B	4	79	brass	W					
VELZ		14	4	79+	brass		80.0	13.6	3.1	0.4	0.2
VELZ		30	4	79+	gunmetal		75.2	9.4	5.7	0.2	0.2
COLC		1.81-5122	4	79+	bronze	W					
LOND		435	4	79+	brass	E					
LOND		85.108/7	4	79+?	brass	W					
COLC		1.81-1640	4/10?	79+?	gunmetal	WN					
WANB		Cat 60	4	80	brass	EN					
RICH	7351093		4	80	gunmetal		85.1	10.5	4.6	0.3	0.1
BRAU		409	4	80	brass	W	71.6	21.4	0.7	0.2	0.0
PRES		1585	4	80	bronze		93.8	1.0	6.0	0.9	0.0
SHEP	722331	Rep 28	4?	?	bronze						
COLC		CF-63	4	?	brass	W					
RICH	7351778		4?	?	brass/gunmetal						
RICH	7351791		4	?	gunmetal						
RICH	7350505		4	?	bronze		85.4	2.6	8.0	3.9	0.1
RICH	7350802		4	?	(leaded) gunmetal		75.0	8.1	5.8	6.1	0.1
RICH	7351512		4	?	brass		85.5	13.4	0.0	0.0	0.1
RICH	7351764		4	?	brass		81.2	14.7	1.5	0.4	0.1
BALD	7211191	Cat 125	4	?	brass	W	73.1	25.5	0.6	0.2	0.0
ASHT	835145		4	?	brass						
ASHT	835086		4	?	brass						
COLC		1.81-364	4	?	bronze						
POUN		Ae50	4	?	brass	W					
STAL	670511	M4	4	?	brass						
LOND		WIV 325	4?	?	brass						
STAL	682648	N1	4??	?	brass		71.6	24.9	1.5	0.1	0.0
COLC		GBS-1026	5	84	brass						
LOND		A2388	5	84A	brass						
LOND		A2390	5	84A	brass						
LOND		A11962	5	84A	brass						
LOND		A2389	5	84A	brass						
RICH	7350386		5	84B	brass		80.9	14.2	1.4	0.1	0.0
RICH	7350695		5	84B	brass		84.7	16.1	0.5	0.1	0.0
RICH	7350804		5	84B	brass		79.3	18.0	0.0	0.1	0.0

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7350971		5	84B	brass		76.9	19.0	0.3	0.1	0.0
LOND		92	5	84B	brass						
CABY		948?	5	84C	leaded bronze		70.3	0.1	8.5	16.1	0.1
LOND		A21462	5	84C+	bronze						
LOND		A22303	5	85	gunmetal						
HAYL		444	5	87?	brass		83.0	13.9	1.4	1.2	0.1
CAST		10-2340	5?	88?	leaded bronze						
RICH	7351449		5	88B	brass		82.1	20.1	0.0	0.9	0.0
THIS		THZ1178	5	88B	bronze		79.5	0.1	10.2	0.1	0.0
DRAG		DR 68 OH	5	88B	bronze						
DRAG		DR 68 AAL	5	88B	bronze						
LOND		90	5	88B	bronze						
BALD		Cat 51	5	89	brass						
BALD		Cat 52	5	89	brass						
BALD		Cat 53	5	89	brass						
BRAU		1099	5	89	brass						
BRAU		1027	5	89	brass						
BRAU		1117	5	89	brass						
BRAU		1029	5	89	brass						
RICH	7350299		5	89	brass		85.8	14.7	0.0	0.0	0.1
STAL	670294	B10	5	89	brass		76.7	18.2	0.7	0.3	0.0
STAL	670423	B8	5	89	brass		78.1	18.9	0.4	0.1	0.1
STAL	682659	B9	5	89	brass		78.7	16.3	1.3	0.5	0.0
STAL	682644	B2	5	89	brass		77.2	21.0	1.1	0.2	0.0
STAL	670469	B1	5	89	brass		76.8	23.3	1.3	0.4	0.1
STAL	4576	B5	5	89	brass		78.3	19.5	1.7	0.1	0.1
BRAU		1052	5	89	brass		68.8	20.0	0.7	0.2	0.2
HAYL		1838	5	89	brass						
COLC		GBS-676	5	89	brass						
HAYL		2981	5	89	brass						
STAL	4588	B6	5	89	brass						
BRAU		114	5	89/90	brass		70.3	19.4	0.0	0.1	0.0
BRAU		388	5	89/90	brass		73.9	21.6	0.0	0.4	0.0
HAYL		2656	5	89/90	brass		66.0	18.9	2.1	0.4	0.0
BRAU		1043	5	89/90	brass		83.4	16.4	0.8	0.4	0.2
STAL	670274	B4	5	89?	brass		78.8	19.1	1.5	0.2	0.0
STAL	682717	B3	5	89?	brass		82.9	21.3	2.1	0.3	0.0
HAYL		2824 & 2982	5?	89?	brass						
LECH		1959-10	5	90	brass						
WEEK	781418	222	5	90	brass						
WEEK	781500	204	5	90	brass						
BALD		Cat 57	5	90	brass						
MAGI	779004	Pub 8	5	90	brass						
MAGI	7711152	Pub 10	5	90	brass						
MAGI	779377	Pub 11	5	90	brass						
MAGI		Pub 12	5	90	brass	?					
SHEP	722202	Rep 7	5	90	brass						
WICF		249	5	90	brass						
WICF		251	5	90	brass						
TIDD		M608	5	90	brass						
GORH	811381		5	90	bronze						
KEST	841233		5	90	brass						
BRAU		1030	5	90	bronze						
RICH	7350477		5	90	bronze		83.9	1.3	8.2	0.7	0.2
RICH	7350387		5	90	brass		80.6	16.8	1.5	0.1	0.1
RICH	7350274		5	90	brass		77.9	19.4	1.5	0.3	0.5
RICH	7351573		5	90	brass/gunmetal		78.7	8.4	2.3	0.2	0.0
SHEP		Rep 5	5	90	brass		72.9	22.6	0.3	0.5	0.1

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
SHEP		Rep 4	5	90	brass		75.7	25.6	0.4	0.3	0.0
SHEP		Rep 3	5	90	brass		77.3	16.8	0.9	0.5	0.1
SHEP		Rep 2	5	90	brass		75.9	23.7	0.1	0.3	0.0
SHEP	722217	Rep 8	5	90	brass		75.3	19.1	0.6	0.6	0.1
SHEP	722209	Rep 11	5	90	brass		63.8	22.7	1.4	0.2	0.0
STAL	670463	B7	5	90	brass		79.7	16.9	1.4	0.4	0.0
ULEY		5824	5	90	brass		74.3	19.6	0.9	0.2	0.0
THIS		THZ1755	5	90	brass		71.4	17.7	0.6	0.8	0.0
THIS		THY9	5	90	brass		74.5	15.3	1.2	0.7	0.0
HAYL		200	5	90	brass		82.5	19.4	0.0	0.7	0.1
HAYL		1824	5	90	bronze		88.0	2.3	10.4	0.5	0.1
BALD	7210449	Cat 54	5	90	brass		81.6	21.9	1.4	0.3	0.1
BALD	7211079	Cat 56	5	90	brass		71.1	20.5	0.6	0.1	0.0
BALD	7211239	Cat 61	5	90	brass		81.9	14.2	1.7	0.8	0.4
BALD	7210313	Cat 62	5	90	brass		71.3	20.7	1.6	0.2	0.0
BALD	7210361	Cat 60	5	90	brass		78.4	19.1	0.0	0.0	0.0
BALD	7210448	Cat 55	5	90	brass		80.3	18.9	0.0	0.2	0.0
GORH	811382		5	90	brass		76.9	22.8	0.6	0.3	0.1
GORH	811374		5	90	brass		73.3	16.6	1.5	0.3	0.0
GORH	820264		5	90	bronze		89.2	1.8	13.0	0.4	0.0
GORH	820225		5	90	brass		78.8	20.3	0.0	0.0	0.0
BRAU		1166	5	90	brass		73.6	25.0	0.6	0.0	0.0
BRAU		874	5	90	brass		78.1	22.6	0.4	0.1	0.1
BRAU		369	5	90	brass		79.9	19.7	0.7	0.0	0.2
ASHT	835130	444	5	90	brass						
ASHT	835076	178	5	90	brass						
ASHT	835137	481	5	90	brass						
ASHT	835119	535	5	90	brass						
ASHT	835120	537	5	90	brass						
ASHT	835134	473	5	90	brass						
GORH	826326	4030	5	90	brass/gunmetal						
GORH	820300	2675	5	90	brass						
GORH	820125	927	5	90	brass						
REDC	8650618	75	5	90	brass						
REDC	8650616	46	5	90	brass						
LEIC		316-41	5	90	brass						
LEIC		316-92	5	90	brass						
THIS		THZ701	5	90	brass						
THIS	610737	TH27	5	90	bronze?						
HAYL		2446	5	90	brass						
COLC		GBS-662	5	90	bronze						
COLC		GBS-713	5	90	brass						
COLC		GBS-1012	5	90	brass						
CHEL		CHV 5	5	90	brass						
BALD		Cat 160	5	90	brass						
BALD		Cat 161	5	90	brass						
BALD		Cat 162	5	90	brass						
LOND		LCT 1317	5	90	bronze						
STAN	8612473		5	90	brass						
STAN	8612481		5	90	brass						
WEEK	781422	231	5	90 or 92	brass						
TARH		744	5	90/117	brass/gunmetal						
BALD		Cat 65	5	90/91	brass						
HAYL		2758	5	90/91	gunmetal		71.4	6.7	8.9	0.6	0.2
HAYL		1672	5	90/91	bronze						
BALD	715549	Cat 58	5	90/91?	bronze		82.5	0.0	9.7	0.2	0.2
STAL	682729	C75	5	90/91?	brass						
STAL	670513	C74	5	90/91?	brass						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
STAL	4538	C62	5	90/91?	brass						
STAL	4522	C72	5	90/91?	brass						
WANB		Cat 63	5?	90/92?	bronze						
COLC		0874 CEH	5	90?	brass						
STAL	4524	C21 or C30	5	90?	brass		81.2	18.5	1.6	0.2	0.1
STAL	4524	C21 or C30	5	90?	brass		83.8	14.9	1.6	0.2	0.0
BRAU		272	5	90?	brass		73.0	22.1	0.4	0.1	0.1
BRAU		798	5	90?	brass		81.8	18.9	1.9	0.5	0.1
RICH	7350280		5	90A	brass		80.7	17.5	1.2	0.4	0.2
RICH	7350051		5	90A	brass		78.6	22.3	0.2	0.2	0.0
RICH	7351505		5	90A	brass		85.3	17.0	0.0	0.3	0.0
RICH	7351524		5	90A	gunmetal		70.9	16.0	12.4	0.7	0.1
RICH	7351513		5	90A	brass		78.4	24.8	0.0	0.0	0.0
RICH	7351705		5	90A	brass		76.6	22.5	0.5	0.0	0.1
SHEP	722206	Rep 10	5	90A	brass		77.4	27.2	0.3	0.1	0.0
STAL	682653	C12+	5	90A	brass		77.1	29.9	0.3	0.2	0.0
STAL	670451	C15+	5	90A	brass		77.9	20.6	0.6	0.3	0.0
STAL	670436	C18+	5	90A	brass		77.2	21.1	1.4	0.3	0.0
STAL	682697	C23+	5	90A	brass		75.6	17.2	1.6	0.2	0.0
STAL	682668	C14+	5	90A	brass		74.6	21.1	0.0	0.6	0.1
STAL	682662	C19+	5	90A	brass		78.2	18.0	0.2	0.1	0.0
STAL	682642	C9+	5	90A	brass		76.2	24.1	0.6	0.3	0.0
STAL	4557	C16+	5	90A	brass		79.9	19.0	1.4	0.1	0.0
STAL	670486	C13+	5	90A	brass		80.0	20.2	1.0	0.1	0.0
STAL	4574	C11+	5	90A	brass		77.8	23.2	1.0	0.1	0.0
STAL	4575	C10+	5	90A	brass		72.6	23.5	1.5	0.1	0.0
STAL	670447	C17+	5	90A	brass		77.2	16.9	1.6	0.2	0.0
STAL		C25	5	90A	brass						
DRAG		DR 71 BHB	5	90A	brass						
DRAG		DR 66 IP	5	90A	brass						
DRAG		DR 70 RE	5	90A	brass						
ICKH	746660	1227	5	90A	brass						
LOND		A28330	5	90A	brass						
STAN	8516915		5	90A	brass						
LOND		100	5	90A	brass						
SNET		Cat 1	5	90A	bronze						
RICH	7350109		5	90A/92	bronze		86.8	0.2	8.3	0.5	0.1
STAL	682712	C22+	5	90A?	brass		72.2	23.9	0.9	0.1	0.1
STAL	670483	C20	5	90A?	brass						
STAL	4527	C55+	5	90B	brass						
RICH	7350902		5	90B	bronze						
RICH	7351539		5	90B	brass/gunmetal						
RICH	7350091		5	90B	brass		74.2	20.0	1.2	0.8	0.1
RICH	7350800		5	90B	bronze		87.7	1.4	6.4	2.1	0.0
RICH	7350807		5	90B	bronze		88.6	0.2	10.2	0.1	0.1
RICH	7351577		5	90B	bronze		93.9	0.0	6.9	0.1	0.1
RICH	7351766		5	90B	bronze/gunmetal		93.9	3.1	4.8	2.4	0.1
RICH	7351664		5	90B	bronze		75.0	2.0	9.1	0.6	0.0
STAL	682704	C38+	5	90B	brass		76.6	18.3	0.8	0.1	0.0
STAL	682660	C43+	5	90B	brass		80.2	18.2	0.1	0.2	0.1
STAL	670452	C31+	5	90B	brass		75.4	19.8	0.3	0.2	0.0
STAL	670440	C34+	5	90B	brass		81.3	16.8	0.7	0.5	0.0
STAL	670506	C42+	5	90B	brass		78.7	18.6	0.8	0.4	0.0
STAL	670504	C7+	5	90B	brass		78.9	17.6	1.3	0.3	0.1
STAL	670649	C53+	5	90B	brass		74.3	23.1	1.1	0.2	0.1
STAL	670466	C36+	5	90B	brass		70.7	21.3	1.0	0.3	0.0
STAL	670435	C27+	5	90B	brass		81.3	17.5	0.7	0.2	0.0
STAL	670464	C57+	5	90B	brass		78.5	22.1	0.8	0.2	0.0

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
STAL	682661	C44+	5	90B	brass		77.4	17.5	1.2	0.1	0.0
STAL	682654	C32+	5	90B	brass		79.1	17.8	1.0	0.3	0.0
STAL	682700	C58+	5	90B	brass		80.8	20.5	1.2	0.2	0.0
STAL	682685	C3+	5	90B	brass		82.0	17.8	1.8	0.5	0.1
STAL	682686	C4+	5	90B	brass		79.8	15.8	2.5	0.4	0.3
STAL	4516	C65+	5	90B	brass		81.6	16.7	1.0	0.3	0.2
STAL	4551	C28+	5	90B	brass		82.4	17.4	1.5	0.2	0.1
STAL	670443	C5+	5	90B	brass		78.9	19.3	1.2	0.1	0.1
STAL	670444	C39+	5	90B	brass		78.2	18.6	1.3	0.9	0.1
STAL	4545	C40+	5	90B	brass		79.0	19.6	1.6	0.1	0.0
STAL	4567	C8+	5	90B	brass		79.8	19.3	1.3	0.1	0.0
STAL	682702	C59+	5	90B	brass		79.2	18.8	1.5	0.3	0.0
STAL	4544	C29+	5	90B	brass		80.5	17.5	1.6	0.2	0.0
STAL	670458	C54+	5	90B	brass		77.2	21.7	2.9	0.3	0.0
COLC		1.81-4048	5	90B	brass						
STAL	4533	C6	5	90B	brass						
STAL	4527	C55	5	90B	brass						
DRAG		DR 66 HV	5	90B	brass						
DRAG		DR 67 NX	5	90B	brass						
DRAG		DR 66 EE	5	90B	brass						
DRAG		DR 68 GL	5	90B	brass						
DRAG		DR 65 YS	5	90B	brass						
DRAG		DR 67 AFC	5	90B	brass						
DRAG		DR 72 KH	5	90B	brass						
DRAG		DR 70 AAK	5	90B	brass						
DRAG		DR 71 BFJ	5	90B	brass						
DRAG		DR 72 AJA	5	90B	brass						
LOND		122	5	90B	brass						
LOND		A22966	5	90B	brass/gunmetal						
STAN	8516903		5	90B	brass						
STAN	8516931		5	90B	brass						
STAN	8516937		5	90B	brass						
STAN	8516938		5	90B	brass						
STAN	8612544		5	90B	brass						
STAN	8612936		5	90B	brass						
STAN	8612994		5	90B	brass						
STAN	8700575		5	90B	brass						
STAN	8701457		5	90B	brass						
STAN	8800681		5	90B	brass/gunmetal						
STAN	8800685		5	90B	brass						
STAN	8800762		5	90B	brass						
LOND		20369	5	90B	brass						
STAL	682727	C51+	5	90B/91	brass		78.2	18.2	0.4	0.2	0.0
STAL	670275	C24+	5	90B/91	brass		84.3	15.1	0.9	1.0	0.0
STAL	682667	C52+	5	90B/91	brass		73.9	22.1	1.1	0.0	0.0
STAL	682666	C56+	5	90B/91	brass		76.0	21.3	0.5	0.1	0.0
STAL	4534	C50+	5	90B/91	brass		73.9	23.6	1.0	0.0	0.1
STAL	4571	C68	5	90B/91	brass						
STAL	670419	C33	5	90B/91	brass						
STAL	4539	C64+	5	90B/91?	brass		84.0	17.1	1.2	0.3	0.2
STAL	670507	C49+	5	90B/91?	brass		71.9	16.8	1.9	0.3	0.0
STAL	670521	C59+	5	90B/91?	brass		76.3	21.9	1.0	0.3	0.0
STAL	670449	C1+	5	90B?	brass		79.9	19.5	0.6	0.4	0.1
STAL	670467	C37+	5	90B?	brass		76.2	20.7	1.9	0.3	0.3
STAL	682687	C2+	5	90B?	brass		81.0	17.5	1.6	0.4	0.1
STAL	670427	C26+	5	90B?	brass		71.4	27.3	1.3	0.3	0.0
WROX	721364		5	90B?	bronze		85.1	1.4	9.7	0.4	0.0
BRAU		26	5	91	brass						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
BRAU		511	5	91	brass/gunmetal						
BALD		Cat 64	5	91	brass/gunmetal						
RICH	7350786		5	91	brass						
BRAU		541	5	91	brass						
STAL	682703	C70+	5	91	brass		73.4	20.1	0.5	0.7	0.1
STAL	670505	C48+	5	91	brass		78.9	20.4	1.2	0.2	0.0
STAL	670518	C61+	5	91	brass		89.6	20.1	2.1	0.1	0.0
STAL	670437	C45+	5	91	brass		81.0	19.6	1.8	1.1	0.0
STAL	682670	C63+	5	91	brass		76.8	20.2	0.8	0.3	0.0
STAL	682675	C47+	5	91	brass		78.7	18.5	0.3	0.3	0.1
STAL	682690	C46+	5	91	brass		78.1	19.6	1.3	0.2	0.0
BRAU		516	5	91	brass		73.8	14.5	1.5	2.4	0.4
HAYL		1529	5	91	brass		81.3	20.7	0.0	0.3	0.0
BALD	715561	Cat 63	5	91	brass		85.4	20.0	2.1	0.3	0.0
STAL	670481	C35	5	91	brass/gunmetal						
STAL	4562	C66	5	91	brass						
STAL	682731	C69	5	91	brass						
STAL	670438	C60	5	91	brass						
WINC		VR-309	5	91	brass						
WROX	7410166		5	91	bronze						
STAL	682652	C73+	5	91?	brass		76.6	17.6	1.7	0.1	0.1
STAL	670650	C71+	5	91?	brass		78.6	18.3	0.6	0.2	0.0
STAL	670519	C77+	5	91?	brass		73.2	19.5	1.0	0.4	0.0
HAYL		484	5	91?	brass						
STAN	8610963		5	91A	bronze						
STAN	8612538		5	91A	brass						
RICH	7350291		5	91B	brass		87.2	10.5	0.8	0.6	0.2
RICH	7351526		5	91B	brass		81.9	15.8	0.8	0.6	0.1
RICH	7351533		5	91B	brass		79.3	27.0	0.0	0.0	0.1
LECH		1959-5	5	92	(leaded) gunmetal						
LECH		1982(1438)	5	92	(leaded) bronze						
WEEK	781370	2	5	92	leaded gunmetal						
BALD		Cat 69	5	92	brass						
MAGI	7711177	Pub 4	5	92	leaded bronze						
GEST		Pub 7/BR 157	5	92	leaded gunmetal						
WICF		27	5	92	leaded bronze						
WICF		102	5	92	leaded bronze						
WICF		253	5	92	leaded bronze						
WICF		348	5	92	leaded bronze						
GARD		ME 11	5	92	leaded bronze						
COLC		CF-54	5	92	leaded gunmetal						
WANB		Cat 70	5	92	leaded bronze						
WANB		Cat 65	5	92	(leaded) bronze?						
WANB		Cat 66	5	92	leaded bronze						
WANB	692664	Cat 74	5	92	(leaded) bronze						
WANB		Cat 78	5	92	leaded bronze						
RICH	7351527		5	92	leaded bronze/gunmetal						
KEST	841234		5	92	leaded bronze						
KEST	841267		5	92	leaded gunmetal						
KEST	841271		5	92	leaded bronze						
KEST	841238		5	92	leaded bronze						
BRAU		368	5	92	leaded bronze/gunmetal						
RICH	7350503		5	92	leaded bronze		74.1	0.0	7.1	16.0	0.2
RICH	7350105		5	92	gunmetal		85.5	4.8	6.5	1.8	0.2
RICH	7350205		5	92	(leaded) gunmetal		79.9	5.4	5.3	7.0	0.0
RICH	7350076		5	92	(leaded) bronze		81.9	0.5	8.0	7.7	0.2
RICH	7350106		5	92	leaded bronze		77.6	0.0	8.1	16.9	0.1
RICH	7350741		5	92	leaded bronze		72.3	0.8	5.4	20.1	0.2

Table C.5 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7350328		5	92	leaded bronze		83.8	0.2	6.8	8.3	0.1
RICH	7350100		5	92	(leaded) bronze		80.7	0.2	10.7	7.6	0.1
RICH	7350095		5	92	leaded bronze		76.2	0.8	9.0	13.4	0.1
RICH	7350298		5	92	leaded bronze		78.8	0.0	10.1	9.2	0.1
RICH	7350290		5	92	leaded gunmetal		75.3	3.3	4.8	14.9	0.1
RICH	7350213		5	92	leaded bronze		77.2	0.0	7.8	13.7	0.1
RICH	7350501		5	92	leaded bronze		73.7	0.5	7.1	14.9	0.1
RICH	7350743		5	92	leaded bronze/gunmetal		78.4	3.3	7.7	10.9	0.1
RICH	7351036		5	92	(leaded) bronze		83.2	0.5	7.4	5.0	0.0
RICH	7351078		5	92	leaded bronze		77.2	0.9	8.2	11.6	0.1
RICH	7351094		5	92	(leaded) bronze		82.1	0.1	11.6	5.3	0.1
RICH	7351519		5	92	(leaded) bronze		87.6	0.1	7.9	6.2	0.0
RICH	7351571		5	92	leaded bronze		76.1	0.4	8.7	14.3	0.0
RICH	7351575		5	92	leaded bronze		77.5	0.5	8.6	10.0	0.1
RICH	7351520		5	92	leaded bronze		82.7	0.2	10.0	9.6	0.1
RICH	7351523		5	92	leaded bronze/gunmetal		79.8	3.1	5.9	14.0	0.1
RICH	7351570		5	92	leaded bronze		81.9	0.9	7.6	13.1	0.1
BRAU		459	5	92	leaded bronze		72.2	0.2	6.7	13.7	0.1
BRAU		251	5	92	(leaded) bronze		76.8	0.2	8.8	4.6	0.1
SWIN	770237	57	5	92	leaded bronze	W	76.9	0.7	10.3	8.1	0.1
THIS		THZ2705	5	92	(leaded) bronze		80.5	0.5	10.6	6.0	0.1
HAYL		1362	5	92	bronze		91.9	0.1	4.7	3.2	0.1
HAYL		1039	5	92	(leaded) bronze		74.7	2.0	12.5	6.7	0.1
HAYL		2	5	92	leaded bronze		63.7	0.2	7.7	16.3	0.1
HAYL		3041	5	92	leaded bronze		73.1	0.2	12.5	12.4	0.0
BALD	715586	Cat 77	5	92	leaded bronze		78.5	0.1	6.4	11.2	0.0
BALD	7211150	Cat 68	5	92	leaded bronze/gunmetal		74.5	4.0	8.7	10.5	0.1
BALD		Cat 70	5	92	leaded bronze		78.4	0.3	9.1	8.3	0.6
BALD	7210432	Cat 72	5	92	leaded gunmetal		74.5	7.5	5.4	11.5	0.9
BALD	7211141	Cat 76	5	92	leaded bronze		77.3	1.8	8.0	12.2	0.1
BALD	7211120	Cat 73	5	92	leaded bronze		75.0	0.5	9.6	17.9	0.1
BALD	715558	Cat 79	5	92	(leaded) bronze		85.5	0.7	5.0	8.0	0.0
WICF		255	5	92	leaded bronze		78.4	0.0	12.1	11.0	0.0
WICF		254	5	92	leaded bronze		73.6	0.4	12.4	26.0	0.0
WICF		258	5	92	leaded bronze		83.7	0.0	6.7	10.1	0.0
WICF		256	5	92	leaded bronze/gunmetal		82.5	3.8	6.8	14.2	0.1
WANB		71	5	92	leaded bronze		84.5	0.0	7.7	13.3	0.0
WANB	707303	77	5	92	leaded bronze		68.9	0.0	8.9	18.6	0.1
WANB		73	5	92	leaded bronze		65.9	0.0	12.5	19.3	0.1
WANB		72	5	92	(leaded) bronze		82.3	0.0	11.0	6.5	0.0
WANB		68	5	92	leaded bronze		73.3	0.5	12.3	10.6	0.0
WANB		75	5	92	(leaded) bronze		90.1	1.1	11.3	7.8	0.1
WANB	684102	83	5	92	leaded bronze		80.8	0.4	7.3	14.8	0.1
WANB		88	5	92	leaded bronze		75.6	0.2	8.1	19.9	0.0
WANB		85	5	92	leaded bronze		75.9	0.1	9.8	15.8	0.1
WANB	684373	84	5	92	leaded bronze		76.8	0.5	13.1	16.0	0.1
WANB		69	5	92	leaded bronze		80.5	0.4	9.6	11.8	0.1
WANB		80	5	92	leaded bronze		78.3	0.2	9.0	15.7	0.1
WANB		64	5	92	leaded bronze		72.7	1.0	8.4	19.4	0.1
WANB		87	5	92	leaded bronze		79.7	0.7	15.3	14.7	0.1
WANB		79	5	92	leaded bronze		72.3	0.2	11.1	13.4	0.1
MAGI	7711248	Pub 9	5	92	leaded bronze/gunmetal		76.9	4.3	10.5	9.6	0.0
CHEL		CHAK 7	5	92	(leaded) bronze		80.6	1.7	7.8	4.7	0.1
CHEL		CHS 73	5	92	(leaded) bronze/gunmetal		83.9	3.4	7.3	5.0	0.1
GORH	820030		5	92	leaded bronze		82.2	0.5	13.1	9.9	0.1
GORH	820073		5	92	leaded bronze		73.8	0.0	7.6	18.2	0.1
GORH	820037		5	92	(leaded) bronze		81.1	1.8	12.4	6.5	0.1
GORH	811373		5	92	(leaded) bronze		76.9	2.4	12.9	6.6	0.0

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
GORH	820270		5	92	(leaded) bronze		87.9	1.3	9.6	5.3	0.1
GORH	811384		5	92	leaded bronze		76.5	0.0	8.7	16.3	0.2
CHEL		CHD Ae333	5	92	leaded bronze		71.1	1.4	6.4	20.8	0.0
CHEL		CHM Ae288	5	92	leaded bronze		68.4	0.0	12.3	9.4	0.0
CHEL		CHK Ae232	5	92	(leaded) bronze		82.7	1.0	7.7	5.2	0.0
CHEL		CHK Ae267	5	92	(leaded) bronze		86.5	1.4	7.6	5.0	0.0
CHEL		CHK Ae247	5	92	leaded bronze		80.3	0.3	6.9	15.4	0.0
CHEL		CHK Ae238	5	92	leaded bronze		78.1	0.1	4.7	17.6	0.0
CHEL		CHK Ae241	5	92	(leaded) bronze		88.1	0.0	8.0	6.7	0.1
CHEL		CHK Ae217	5	92	leaded bronze/gunmetal		67.9	5.0	7.5	20.4	0.0
CHEL		CHK Ae196	5	92	(leaded) bronze		84.9	0.9	8.5	5.4	0.1
CHEL		CHK Ae246	5	92	leaded bronze		65.6	0.0	10.1	20.4	0.0
ASHT	835146	402	5	92	bronze						
GORH	811379	1851	5	92	leaded bronze						
GORH	820305	2718	5	92	leaded bronze						
GORH	820368	3973	5	92	leaded bronze						
SEAM		67-104	5	92	bronze						
SEAM		66-59	5	92	leaded bronze						
WITC	673591	bz50	5	92	leaded bronze						
THIS		THZ1451	5	92	leaded bronze						
THIS		THZ3993	5	92	(leaded) bronze						
THIS		THVbag53	5	92	bronze/gunmetal						
THIS		THVbag83	5	92	gunmetal						
THIS	610967	BH699	5	92	bronze						
COLC		GBS-1093	5	92	bronze						
COLC		GBS-714	5	92	bronze						
COLC		1.81-686	5	92	leaded bronze						
COLC		1.81-1703	5	92	leaded bronze						
CHEL		CHV 1	5	92	leaded bronze						
CHEL		CHV 6	5	92	leaded gunmetal						
CHEL		CHV 21	5	92	leaded bronze						
CHEL		CHAG 30	5	92	bronze						
CHEL		CHN 15	5	92	bronze/gunmetal						
CHEL		CHAG 27	5	92	leaded bronze						
CHEL		CHAG 28	5	92	leaded bronze						
CHEL		CHK Ae213	5	92	bronze						
CHEL		CHK Ae190	5	92	leaded bronze						
STAL	670525	D1	5	92	bronze						
ICKH		2080	5	92	leaded bronze						
HAYL		KP10	5	92	bronze?						
CAST		10-1778	5	92	(leaded) bronze						
OLDW	886270		5	92	leaded bronze/gunmetal						
LOND		A12034	5	92	leaded gunmetal?						
LOND		A21461	5	92	bronze						
LOND		3423	5	92	bronze						
LOND		130	5	92	bronze						
LOND		89	5	92	bronze						
LOND		81.629/3	5	92	bronze						
LOND		12665	5	92	leaded bronze						
LOND		A10375	5	92	leaded bronze						
LOND		18130	5	92	(leaded) gunmetal						
STAN	8612486		5	92	(leaded) bronze						
STAN	8611728		5	92	bronze						
STAN	8611730		5	92	bronze						
STAN	8610972		5	92	leaded gunmetal						
LOND		20371	5	92	brass						
LOND		19228	5	92	bronze						
LOND		20761	5	92	bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
LOND		3424	5	92	gunmetal						
SNET		Cat 5	5	92	bronze						
SNET		Cat 17	5	92	leaded bronze						
BRAU		987	5	92+	leaded bronze						
WANB		Cat 67	5	92+	leaded bronze						
WANB		89	5	92+	leaded bronze	W	67.4	0.2	10.2	22.2	0.1
WROX	721371		5	92+	leaded bronze		81.8	0.0	5.9	12.5	0.3
GARD		ME 12	5	92/93	leaded bronze						
TIDD		M2	5	92/93	leaded bronze/gunmetal						
COLC		CF-55	5	92/93	leaded gunmetal						
COLC		CF-33	5	92/93	leaded bronze						
BALD	7210429	Cat 75	5	92/93	leaded gunmetal		78.1	6.0	6.8	9.4	0.1
RICH	7351870		5	92/93	leaded bronze/gunmetal						
RICH	7351889		5	92/93	bronze						
RICH	7351911		5	92/93	bronze						
LOND		ACE 78	5	92/93	bronze/gunmetal						
LOND		ALG 29	5	92/93	leaded bronze						
LOND		AST 137	5	92/93	bronze						
LOND		CRU 47	5	92/93	(leaded) bronze						
LOND		DMT 185	5	92/93	leaded bronze						
LOND		ER 702-1	5	92/93	bronze						
LOND		FEN 222	5	92/93	leaded bronze						
LOND		GPO 419	5	92/93	(leaded) bronze						
LOND		GPO 1003	5	92/93	leaded bronze						
LOND		GPO 4366	5	92/93	leaded bronze						
LOND		GPO 3934	5	92/93	bronze						
LOND		GPO 4660	5	92/93	(leaded) bronze						
LOND		LCT 1294	5	92/93	leaded bronze						
LOND		LCT 1383	5	92/93	leaded bronze						
LOND		LCT 1384	5	92/93	leaded bronze						
LOND		LCT 1494	5	92/93	bronze						
LOND		LCT 1517	5	92/93	(leaded) bronze						
LOND		MGT 135	5	92/93	leaded bronze						
LOND		OPT 650	5	92/93	bronze						
LOND		ORG 87	5	92/93	(leaded) bronze						
LOND		OST 89	5	92/93	leaded bronze						
LOND		POM 610	5	92/93	(leaded) bronze						
LOND		SLO 87	5	92/93	leaded bronze						
LOND		18649	5	92/93	gunmetal						
SNET		Cat 18	5	92/93	leaded bronze						
BALD		Cat 78	5	92/93?	leaded bronze						
BALD		Cat 80	5	92/93?	leaded bronze						
BALD	263	Cat 71	5	92/93?	leaded gunmetal		80.9	4.2	4.9	12.3	0.1
LOND		ORG 91	5	92/93?	bronze						
WICF		301	5	92?	leaded bronze						
WANB	684375	Cat 90	5?	92?	(leaded) bronze						
WANB		Cat 95(1)	5?	92?	leaded bronze						
WANB		Cat 95(2)	5?	92?	leaded bronze						
WANB		93	5	92?	leaded bronze		76.5	0.0	9.9	11.6	0.0
TIDD		TA1	5?	92?	bronze		87.8	2.1	14.5	0.5	0.1
HAYL		179	5	92?	(leaded) bronze						
CHEL		CHAG 26	5	92?	leaded bronze						
CATT	8310556		5	92?	leaded bronze						
WICF		187	5	92??	leaded bronze						
WEEK	781371	3	5	93	bronze						
WICL		39	5	93	leaded bronze/gunmetal						
RICH	7350479		5	93	(leaded) bronze						
RICH	7350476		5	93	leaded bronze		78.3	0.2	8.8	15.5	0.1

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7351075		5	93	leaded bronze		76.7	2.3	8.1	12.1	0.2
RICH	7351091		5	93	leaded bronze		81.1	0.0	8.4	9.1	0.2
RICH	7351092		5	93	leaded bronze		83.0	0.1	7.0	10.9	0.1
RICH	7351578		5	93	leaded gunmetal		79.9	3.7	3.4	16.7	0.1
RICH	7351759		5	93	(leaded) bronze		81.9	0.3	7.6	6.6	0.1
WANB		81	5	93	bronze		89.8	2.5	9.3	0.0	0.1
WANB		82	5	93	leaded bronze		76.4	0.4	7.7	18.8	0.1
COLC		1.81-4968	5	93	leaded bronze						
COLC		1.81-965	5	93	leaded gunmetal						
LOND		101	5	93	gunmetal						
ULEY		2286	5/7	93?	leaded bronze		58.1	0.0	7.1	30.5	0.1
RICH	7350288		5	93A	leaded bronze		69.0	0.1	11.4	16.5	0.1
RICH	7350073		5	93A	leaded bronze		86.4	0.6	8.0	11.5	0.1
RICH	7351767		5	93A	leaded bronze		80.0	0.2	4.2	14.0	0.1
RICH	7351579		5	93A	leaded bronze/gunmetal		81.9	3.4	5.3	11.3	0.1
SHEP	722338	Rep 38	5	93A	leaded bronze/gunmetal		82.6	2.4	6.2	9.9	0.1
BALD	7210333	Cat 74	5	93A	leaded bronze		61.3	0.3	7.5	30.0	0.0
LOND		81.370/1	5	93A	bronze						
LOND		20655	5	93A	bronze						
LOND		20779	5	93A	bronze						
RICH	7350385		5	93B	leaded bronze		75.9	0.1	8.5	13.5	0.1
RICH	7351545		5	93B	leaded bronze		74.8	0.2	8.0	15.7	0.1
WROX	721363		5	93B	(leaded) copper		89.9	0.3	0.0	7.2	0.0
LOND		LCT 1132	5	93B	leaded bronze						
WEEK	781389		5	93C	gunmetal						
WAKE	745063	50	5	93C	leaded bronze						
GEST	777259	Pub 8/BR 110	5	93C	leaded bronze						
RICH	7351773		5	93C	leaded bronze		73.1	0.0	7.5	17.8	0.0
STAN	8516926		5	93C	leaded gunmetal						
WEEK	781402	90	5	94	leaded bronze						
TRET		118	5	94	leaded bronze						
TIDD		M3	5	94	bronze/gunmetal						
TIDD		81-226	5	94	(leaded) bronze						
CARV		19	5	94	bronze		82.0	1.5	12.5	2.6	0.1
SHEP	722337	Rep 40	5	94	bronze		74.4	0.0	10.9	2.8	0.1
LECH		1957-2	5	94	(leaded) bronze		74.8	0.9	12.3	7.8	0.1
BALD	7210426	Cat 82	5	94	gunmetal		87.5	6.0	7.5	0.8	0.1
MAGI	779678	Pub 7	5	94	(leaded) bronze		85.1	2.3	13.5	5.4	0.0
BRAU		610	5	94	bronze		90.8	0.0	10.6	0.8	0.1
BRAU		685	5	94	bronze		88.1	1.0	7.7	2.5	0.2
BRAU		655	5	94	bronze		87.5	0.7	9.6	2.1	0.0
ASHT	835070	66	5	94	leaded bronze						
REDC	8650617	83	5	94	bronze/gunmetal						
HAYL		1779	5	94	(leaded) bronze						
COLC		1.81-5195	5	94	bronze/gunmetal	W					
COLC		1.81-2415	5	94	bronze						
PRES	851058	76	5	94+	(leaded) brass		77.3	12.6	2.3	4.3	0.3
PRES		61	5	94+	bronze		86.7	1.0	10.3	0.3	0.0
PRES		204	5	94+	leaded gunmetal						
PRES	851060	148	5	94/152	(leaded) bronze/gunmetal		84.3	2.3	6.2	7.2	0.2
WICL		7	5	94?	leaded bronze/gunmetal						
ASHT	835138	666	5	94?	leaded bronze						
SNET		Cat 12	5	94A	gunmetal						
WICL		8	5	94A	bronze						
WICL		36	5	94A	bronze						
WICL		47	5	94A	leaded bronze						
WICL		48	5	94A	bronze/gunmetal						
SHEP		Rep 39	5	94A	(leaded) bronze/gunmetal		75.9	1.7	4.8	4.9	0.1

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
THIS	611004	BH817	5	94A	gunmetal		81.1	9.1	3.9	1.1	0.0
THIS	610975	BH718	5	94A	leaded bronze	W	73.8	0.1	4.8	17.7	0.1
THIS		THZ328	5	94A	leaded bronze		83.3	0.1	5.4	12.0	0.1
THIS		THZ2104	5	94A	bronze	W	83.6	0.1	13.6	0.1	0.0
THIS		THZ4117	5	94A	gunmetal		81.8	5.4	5.1	1.1	0.1
WANB		96	5	94A	leaded bronze		83.3	0.0	10.4	10.4	0.0
WANB		98	5	94A	bronze		93.8	0.4	10.7	0.0	0.1
WANB		Cat 97	5	94A	bronze/gunmetal		95.6	2.6	4.5	0.7	0.1
THIS		THZ2704	5	94A	brass?						
DRAG		DR 65 VG	5	94A	brass						
DRAG		DR 67 MU	5	94A	bronze						
CAST		16-337	5	94A	bronze						
LOND		WIV 234	5	94A	gunmetal						
LOND		C985	5	94A	bronze						
LOND		26374	5	94A	bronze						
LOND		26379	5	94A	(leaded) bronze						
LOND		7001	5	94A	leaded bronze						
LOND		26399	5	94A	bronze						
LOND		26406	5	94A	brass?						
STAN	8516905		5	94A	(leaded) bronze						
SNET		Cat 2	5	94A	bronze						
SNET		Cat 3	5	94A	bronze						
SNET		Cat 4	5	94A	bronze						
SNET		Cat 6	5	94A	bronze						
SNET		Cat 7	5	94A	bronze						
SNET		Cat 9	5	94A	(leaded) bronze						
SNET		Cat 10	5	94A	bronze						
SNET		Cat 14	5	94A	bronze						
SNET		Cat 15	5	94A	bronze						
WICL		9	5?	94A?	bronze						
STAN	8700083		5	94A?	bronze						
SNET		Cat 8	5	94A?	bronze						
WICL		18	5	94B	leaded gunmetal	W					
WICL		19	5	94B	leaded bronze						
WICL		32	5	94B	bronze	W					
WICL		51	5	94B	leaded gunmetal						
RICH	7350061		5	94B	(leaded) bronze		87.3	0.4	9.4	4.9	0.1
RICH	7350276		5	94B	leaded bronze		78.2	0.4	4.6	15.0	0.1
THIS	611018	BH855	5	94B	(leaded) bronze		84.9	0.1	8.0	4.1	0.0
THIS		THZ1557	5	94B	bronze		83.7	0.1	11.4	0.5	0.0
CHEL		CHK Ae189	5	94B	(leaded) bronze		84.5	0.1	9.3	6.7	0.1
WALL		12	5	94B	bronze						
CHEL		CHAF 10	5	94B	bronze						
CHEL		CHAF 11	5	94B	bronze						
DRAG		DR 68 HC	5	94B	gunmetal						
DRAG		DR 69 LX	5	94B	bronze						
DRAG		DR 69 YH	5	94B	brass						
DRAG		DR 67 BQ	5	94B	bronze						
DRAG		DR 67 XL	5	94B	bronze						
DRAG		DR 66 FC	5	94B	gunmetal						
WINC		VR-9676	5	94B	bronze						
STAN	8800704		5	94B	(leaded) bronze						
SNET		Cat 19	5	94B	leaded bronze						
SNET		Cat 20	5	94B	bronze						
SNET		Cat 21	5	94B	(leaded) bronze						
SNET		Cat 22	5	94B	bronze						
CAST		15-511	5	94B?	bronze						
TIDD		82-230	5	94C	leaded bronze/gunmetal						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
DRAG		DR 68 QF	5	94C	bronze/gunmetal	E					
DRAG		DR 66 BH	5	94C	gunmetal	E					
YORK		M831	5	94C	leaded bronze	E					
CHEL		CHAJ 18	5	92/94?	leaded bronze						
CHEL		CHAJ 19	5	92/94?	(leaded) bronze						
RICH	7351890		5	92/94?	brass						
RICH	7351875		5/6	92/94?	(leaded) bronze						
SEAM		65-276	5	92/95?	gunmetal?						
CHEL		CHAG 31	5	92/96?	brass?						
SWIN		387	5?	?	leaded bronze	W					
TIDD		81-165	5	?	leaded bronze/gunmetal						
RICH	7351517		5	?	leaded bronze						
RICH	7351777		5?	?	leaded bronze/gunmetal		67.8	2.6	5.5	23.6	0.2
THIS		BH37	5	?	leaded bronze	W	75.0	0.1	9.8	12.7	0.1
BALD	7211125	Cat 67	5	?	leaded bronze		78.1	1.7	7.6	10.2	0.1
ASHT	835142		5	?	brass						
ASHT	835077		5	?	gunmetal						
LOND		FNC 43	5?	?	bronze?						
LOND		ABS 407	5?	?	(leaded) bronze						
LOND		LCT 2214	5	?	bronze						
SNET		Cat 13	5?	?	bronze						
SNET		Cat 25	5?	?	(leaded) bronze						
SNET		Cat 16	6	95	(leaded) bronze						
TIDD		M8	6	95	(leaded) bronze?						
COLE		1087	6	95	leaded bronze						
TIDD		M9	6	95	bronze		89.6	0.2	13.0	1.3	0.3
TIDD		M588	6	95	leaded bronze		86.3	0.1	10.6	8.0	0.1
COLC		1.81-2197	6	95	leaded bronze						
DODD	8515472		6	95	(leaded) bronze						
LOND		0.1811	6	95	leaded bronze						
LOND		79.16/2	6	95	leaded bronze						
COLE		461	6	95/100C	leaded bronze						
POOL		5137	6?	95?	gunmetal						
CARV		21	6?	95A	bronze						
THIS		THV178	6	95A	bronze		84.5	0.7	6.4	2.6	0.1
THIS		THV17	6	95A	leaded bronze		68.1	0.8	8.7	17.8	0.1
ULEY		8222	6	95A	leaded bronze		70.5	0.0	9.4	19.5	0.0
THIS		THVbag185	6	95A	(leaded) bronze	W					
LOND		29.94/2	6	95A	bronze						
STAN	8516955		6	95A	bronze						
THOR	852995	13	6	95B	bronze						
CARL		Ae238	6	95B	leaded bronze						
WORC		774	6	95B	(leaded) bronze						
COLE		850	6	95C	bronze						
COLE		791	6	95C	leaded bronze						
LECH		1957-1	6	95C	leaded bronze		69.4	0.1	10.9	13.6	0.1
GORH	820253		6	95C	leaded bronze		74.4	0.4	12.0	20.3	0.1
THIS		THVbag184	6	95C	leaded bronze						
THIS		THVbag35	6	95C	leaded bronze/gunmetal						
STAN	8611856		6	95C	bronze						
WORC		784	6	95C	(leaded) bronze						
COLE		1085	6	96	bronze						
COLE		91	6	96	leaded bronze						
RICH	7350692		6	96	leaded bronze		67.5	0.4	7.1	23.8	0.0
WANB		101	6	96	leaded bronze		75.7	0.0	7.6	17.9	0.1
WROX	721380		6	96	leaded bronze		72.1	0.0	6.8	18.5	0.3
WITC	635032	bz32	6	96	leaded bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
LEIC		316-17	6	96	leaded gunmetal						
OPEN	7814429		6	96	leaded bronze						
LOND		84.341/4	6	96	leaded bronze						
WORC		620	6	96	leaded bronze						
SEAM		65/6-4	6	96/103	leaded gunmetal						
WANB		102	6	96?	leaded bronze		81.1	0.0	5.2	12.4	0.1
WROX	781666		6	96?	leaded bronze						
PRES	851059	231	6	97	leaded bronze		64.7	0.0	8.6	25.0	0.0
LOND		128	6	97A	brass						
CAST		14-340	6	97B	brass						
LOND		A7733	6	97B	bronze						
CORB	831173		6	98	leaded bronze						
LOND		ABC 165	6	98/100?	(leaded) bronze						
COLE		1086	6	98?	copper						
COLE		110	6	98?	leaded bronze						
WROX	840568		6	98?	bronze						
BALD	715556	Cat 83	6	99	brass	N	81.8	19.6	1.8	2.0	0.1
TIDD		M10	6	99	(leaded) bronze		79.9	0.5	9.9	6.4	0.2
DORC	8212384		6	99	bronze						
CAST		10-416	6	99	(leaded) bronze						
CAST		1-763	6?	99??	brass						
WORC		783	6	99A	leaded gunmetal						
WORC		3899-c11977	6	99B	gunmetal						
WORC		3899-c17407	6	99B	leaded bronze						
GLOU		69/49-49	6	99C	leaded bronze						
WROX	80000320		6	99C	(leaded) bronze						
LOND		18128	6	99C	(leaded) gunmetal						
RICH	7350502		6	100	gunmetal		91.2	4.4	5.0	0.9	0.1
RICH	7350694		6	100	leaded bronze		76.0	0.0	11.9	12.2	0.1
POOL		5166	6	100	bronze						
WROX	801377		6	100?	(leaded) bronze						
LOND		LCT 1520	6	100?	bronze						
NORN	620703	2	6	100A	leaded gunmetal	E					
WORC		3899-7002	6	100A	leaded bronze	E					
COLE		967	6	100B	leaded bronze						
NORN	621169	3	6	100B	(leaded) bronze		79.5	0.2	8.8	7.7	0.0
WROX	721372		6	100B	leaded bronze		75.2	0.3	11.0	9.3	0.3
WROX	781660		6	100B	(leaded) bronze						
DERB		035/1270	6	100B?	leaded bronze						
RICH	7350209		6	100C	leaded bronze		73.7	0.0	6.9	20.6	0.1
RICH	7351518		6	100C	brass		84.4	15.4	3.7	0.4	0.1
RICH	7351706		6	100C	leaded bronze		81.9	0.5	8.2	13.2	0.1
RICH	7351774		6	100C	leaded bronze/gunmetal		71.4	2.1	5.2	19.4	0.2
NORN	733378		6	100C	leaded bronze		72.9	0.7	9.7	12.5	0.0
WROX	721373		6	100C	leaded bronze		71.3	0.0	5.9	19.7	0.0
WROX	721378		6	100C	bronze		85.2	0.5	8.2	3.0	0.3
LEIC		316-138	6	100C	leaded bronze/gunmetal		74.8	3.2	9.0	12.0	0.0
NORN		243	6	100C	(leaded) bronze/gunmetal						
WROX	814477		6	100C	leaded bronze						
WROX	856848		6	100C	leaded bronze						
LOND		A11063	6	100C	leaded bronze						
WORC		901	6	100C	leaded bronze						
WORC	907221	3899-c18181	6	100C	(leaded) bronze						
TIDD		82-203	6	100C?	leaded bronze						
CABY		2808	6	101	leaded bronze		73.6	2.2	8.0	9.6	0.1
LOND		3428	6	102	bronze						
WORC		3899-c17035	6	102	bronze						
WORC		3899-c16867	6	102	bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
TARH		50	6	102/94	brass		81.7	13.8	1.0	2.4	0.0
WICL		26	6	103	bronze	W					
TIDD		M17	6	103	leaded gunmetal						
RICH	7350217		6	103	leaded bronze		77.7	0.3	8.8	15.2	0.1
NORN	650094	262	6	103	leaded bronze		70.6	0.2	7.2	13.9	0.0
WANB		103	6	103	leaded bronze		66.2	0.0	9.4	22.7	0.0
TIDD		82-98	6	103	gunmetal		70.6	9.3	8.3	0.6	0.0
TIDD		M11	6	103	leaded bronze		69.2	0.2	8.0	20.0	0.2
LOND		PIC 31	6	103	leaded bronze						
WANB		Cat 104	6	103?	(leaded) bronze						
LECH		1957-6	6	?	leaded bronze						
HOUS	811554		6?	?	gunmetal						
COLE		1008	6?	?	leaded bronze						
COLE		87	6?	?	leaded bronze						
COLE		2012	6?	?	leaded bronze						
LECH		1957-21	6	?	brass		74.5	16.4	1.8	0.2	0.1
TIDD		TA2	6?	?	leaded bronze		73.2	0.4	12.9	20.2	0.1
POOL		5255	6?	?	bronze						
CAST		1-738	6?	?	brass						
LOND		BRL 897	6?	?	bronze/gunmetal						
LOND		LCT 1312	6	?	?						
WORC		3899-c20425	6?	?	brass						
LAMY		160	7	104	bronze						
NORN	621099	4	7	104	leaded bronze		44.7	0.1	5.3	13.4	0.0
NORN	621107	5	7	104	leaded bronze		67.6	0.4	9.2	18.2	0.0
PIER		3557	7	104	leaded bronze		77.5	0.0	8.5	12.6	0.0
GORH	811369		7	104	leaded bronze		72.4	0.0	12.6	17.0	0.2
GORH	811393	2921	7	104	leaded bronze						
HOUS	803051		7	104	leaded bronze						
LOND		20738	7	104	bronze						
TARH		635	7	104-133	(leaded) bronze	W	82.1	0.5	7.6	7.6	0.1
TARH		637	7	104-133	leaded bronze		81.0	0.0	6.6	11.3	0.1
WINC		VR-9912	7	104?	bronze	W					
DORC	7816057		7	105	leaded bronze	E					
CARV		27	7	105	leaded bronze	E					
CATS		850	7	105/126	leaded bronze						
CATS		264	7	105/141	leaded bronze	E					
CATS		668	7	105/141	leaded bronze	(E)	77.9	1.0	8.6	8.1	0.1
SEAT		1	7	105?	leaded bronze	E					
NORN	620693	6	7	106	leaded bronze		75.0	0.3	8.9	17.9	0.0
SEAM		65-380	7	106	leaded gunmetal						
STAN	8701137		7	106	leaded bronze						
HAYL		3460	7	106?	leaded bronze		60.8	0.1	9.2	21.7	0.1
NORN	620704	9	7	108	leaded bronze	E	71.7	1.1	5.5	15.3	0.0
ULEY		5683	7	108	leaded bronze	W	78.6	1.2	5.8	13.3	0.1
ULEY		2276	7	108	leaded bronze	E	61.5	1.4	9.9	18.3	1.0
ULEY		2339	7	108	leaded bronze	W	69.4	0.6	13.2	20.6	0.1
NORN	621100	10	7	109	leaded bronze	E	64.9	0.6	10.1	16.2	0.0
NORN	620723	11	7	110	leaded bronze	E	66.6	1.8	8.4	17.2	0.0
WANB		107	7	110	leaded bronze	EW	73.9	0.0	7.5	18.3	0.0
TIDD		81-631	7	110	leaded bronze	E	78.8	0.4	8.9	13.3	0.1
WROX	781663		7	110	leaded bronze	E					
LOND		84.272/3	7	110	bronze	E					
WORC		828	7	110	leaded bronze	E					
WORC		3899-7001	7	110	leaded bronze	E					
WANB		Cat 109	7	111	leaded bronze	E					
WANB		Cat 111	7	111	leaded bronze/gunmetal	E					

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
NORN	621137	28	7	111	leaded bronze	E	0.0	0.4	15.1	16.2	0.0
NORN	620714	18	7	111	leaded bronze	E	93.7	0.1	10.9	23.9	0.0
NORN	620647	31	7	111	(leaded) bronze	E	38.9	0.5	6.5	6.7	0.0
NORN	620682	32	7	111	leaded bronze	E	0.0	0.7	16.3	31.9	0.0
NORN	620733	29	7	111	leaded bronze	E	68.4	0.1	9.9	15.4	0.0
NORN	620705	21	7	111	leaded bronze	E	55.0	0.4	3.2	13.8	0.0
NORN	620720	19	7	111	leaded bronze	E	65.4	0.8	9.2	18.4	0.0
NORN	620725	24	7	111	leaded bronze	E	82.5	0.2	7.7	13.4	0.0
NORN	620718	14	7	111	leaded bronze	E	65.7	0.1	7.4	18.8	0.0
NORN	621112	13	7	111	leaded bronze	E	73.9	0.6	8.8	14.0	0.0
NORN	621097	12	7	111	leaded bronze	E	72.2	0.5	9.1	11.9	0.0
NORN	620727	22	7	111	leaded bronze	E	67.1	2.0	10.7	12.5	0.0
NORN	620700	26	7	111	leaded bronze	E	68.9	0.2	8.9	16.4	0.0
NORN		273	7	111	leaded bronze	E	63.8	0.3	10.8	16.4	0.0
NORN	733357		7	111	leaded bronze	E	73.1	0.8	9.1	15.7	0.0
WANB	692728	110	7	111	leaded bronze	E	63.4	0.1	8.9	25.1	0.1
LOND		POM 483	7	111	(leaded) bronze	E					
CATS		669	7	113	brass		73.5	18.3	0.0	0.0	0.1
WALL		1	7	116	brass						
NORN	621114	33	7	117	brass		81.9	15.5	2.2	0.7	0.0
WANB		100	7	117	brass		78.5	8.9	0.3	0.0	0.0
CATS		691	7	117	gunmetal		77.5	11.3	5.6	0.5	0.0
LOND		A2466	7	117	brass						
WALL		10	7	117+	leaded bronze	E					
WANB		99	7	117?	brass		75.6	19.8	0.0	0.0	0.0
CARV		16	7	118	leaded bronze						
ALDB	78108254	jb3	7	118	leaded bronze						
HAYL		3	7	118	leaded bronze/gunmetal						
HENL	734860	713	7	118++	leaded bronze						
BALD	680508	Cat 81	7	118B	gunmetal		87.6	5.0	5.7	1.1	0.0
LOND		441	7	119	(leaded) bronze						
CATS		492	7	120	leaded bronze	E	74.5	1.4	8.7	19.2	0.1
CATS		1046	7	120	leaded bronze		70.0	1.8	12.4	16.3	0.1
TARH		839	7	120	(leaded) bronze/gunmetal	E	82.2	2.9	8.1	5.9	0.1
TARH		656	7	120	leaded bronze	E	80.8	0.1	7.7	9.1	0.1
DORC	8212380		7	120	leaded bronze						
TARH		837	7	120(?+)	bronze		85.6	0.3	10.9	2.6	0.1
ILCH		36	7	121	leaded bronze/gunmetal						
DORC		Rep 7	7	121?	leaded bronze						
STAN	8612520		7	121A	bronze						
WICL		29	7	121B	leaded bronze						
WICL		38	7	121B	leaded bronze/gunmetal						
WICL		41	7	121B	leaded gunmetal						
WHIT		2	7	121B	(leaded) bronze		85.3	0.2	12.2	5.2	0.0
CATS		156	7	121B	leaded bronze		66.5	0.5	7.5	23.0	0.1
STAN	8611712		7	121B	leaded bronze						
STAN	8612534		7	121B	bronze						
STAN	8612929		7	121B	leaded bronze						
STAN	8701503		7	121B	leaded bronze						
STAN	8800689		7	121B	leaded bronze						
CARV		24	7	122	leaded bronze	E					
NORN	620721	40	7	122	leaded bronze	E	79.5	0.7	11.6	17.1	0.0
NORN	621084	43	7	122	leaded bronze	E	0.0	0.2	15.6	18.4	0.0
NORN	620699	37	7	122	leaded bronze	E	63.9	0.5	7.5	20.5	0.0
NORN	620702	38	7	122	leaded bronze		70.0	0.5	7.8	15.0	0.0
NORN	620711	39	7	122	leaded bronze	E	68.2	0.4	8.5	16.1	0.0
NORN	733374		7	122	leaded bronze	E	61.4	0.1	7.2	30.0	0.0
CATS		929	7	122	leaded bronze	E	72.3	0.0	10.4	16.0	0.0

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
CATS		322	7	122	leaded bronze	(E)	63.8	0.3	7.1	19.2	0.1
ULEY		5444	7	122	leaded bronze	E	68.0	0.2	9.8	17.1	0.0
WALL		3	7	122	leaded bronze	E					
NORN		297	7	122	leaded bronze	E					
LOND		GPO 134	7	122	leaded bronze						
NORN	620712	47	7	123	leaded bronze		74.3	0.1	13.2	13.8	0.0
DORC		Rep 1	7	124	leaded bronze						
NORN	733361		7	124/125	leaded bronze	W	70.4	1.6	10.5	15.1	0.0
CATS		719	7	125	leaded bronze						
TIDD		82-182	7	125	(leaded) bronze						
WANB		Cat 108	7	125	leaded bronze						
HOUS	803051		7	125	leaded bronze		66.1	0.7	10.4	13.6	0.0
HAYL		KP7 and 13	7	125	leaded bronze						
CARV		18	7	125?	leaded bronze	W					
NORN		64	7	126	(leaded) bronze	E	34.3	0.0	4.0	7.4	0.0
NORN	621081	66	7	126	leaded bronze	E	61.9	0.3	6.7	14.0	0.0
NORN	621135	68	7	126	leaded bronze	E	72.9	0.2	6.8	19.0	0.0
NORN	620735	94	7	127	leaded bronze		72.8	0.2	11.0	14.0	0.0
NORN	620646	116	7	128	leaded bronze	E	68.5	0.1	7.7	16.1	0.0
NORN	620706	117	7	128	leaded bronze	E	70.5	1.8	7.3	17.4	0.0
NORN	620722	69	7	129	leaded bronze	E	30.4	0.1	4.5	11.3	0.0
NORN	620683	71	7	129	leaded bronze	E	75.0	0.1	9.6	19.1	0.0
NORN	620649	70	7	129	leaded bronze	E	0.0	0.4	13.1	23.1	0.0
NORN	733379		7	129	leaded bronze	S	73.1	0.3	11.9	12.7	0.0
CARV		17	7	129	leaded bronze	E	81.7	0.0	11.5	10.4	0.1
NORN	620695	72	7	130	leaded bronze		65.6	0.1	11.3	15.6	0.0
NORN	621119	77	7	130	leaded bronze		76.8	0.5	10.9	21.8	0.0
NORN	620701	73	7	130	leaded bronze		67.0	0.1	8.6	17.6	0.0
WROX	840600		7	130	bronze						
SEAT		2	7	131	leaded bronze/gunmetal	?					
NORN	620692	80	7	131	leaded bronze		76.9	0.1	6.2	11.7	0.0
NORN	621134	83	7	131	leaded bronze		71.7	0.1	8.7	14.6	0.0
NORN	621148	82	7	131	leaded bronze		77.0	0.1	5.3	11.5	0.0
NORN	733354		7	131	leaded bronze		73.9	0.1	11.3	13.4	0.0
HAYL		835 & 3472	7	131	leaded bronze		69.4	0.0	7.1	18.1	0.1
DORC		Rep 8	7	131+	leaded bronze						
NORN	733350		7	131/134	leaded bronze		69.1	2.0	7.6	19.1	0.0
WANB	684391	Cat 112	7	132	leaded bronze	E					
NORN	620650	84	7	132	leaded bronze	E	72.7	0.1	8.1	13.4	0.0
NORN	620684	85	7	132	leaded bronze	E	68.5	0.2	9.9	15.1	0.0
NORN		242	7	132	leaded bronze	E					
CATS		24	7	132A	leaded bronze	?					
NORN	621120	87	7	132A	leaded bronze	E	67.5	0.6	8.0	17.2	0.0
NORN		232	7	132A	(leaded) bronze	E	65.4	1.1	8.8	6.5	0.0
NORN	621078	88	7	132B	leaded bronze	E	70.1	0.2	9.3	16.1	0.0
NORN	620698	59	7	135	leaded bronze		73.0	0.5	8.2	12.3	0.0
NORN	621141	58	7	135	leaded bronze		77.8	0.4	10.2	9.9	0.0
NORN	620716	53	7	135	(leaded) bronze		63.9	0.2	10.5	6.0	0.0
CATS		877	7	135	leaded bronze		72.7	1.2	13.3	13.8	0.1
NORN	620730	98	7	135+	leaded bronze	E	73.1	0.2	10.2	9.0	0.0
TRET		13	7	135/136	leaded bronze						
NORN	620743	50	7	136	leaded bronze		81.0	1.3	6.8	8.3	0.0
HENL	734845	578	7	136+	(leaded) bronze						
CARV		20	7	137	leaded bronze		74.0	0.5	11.5	10.9	0.1
THIS	610988	BH764	7	137	leaded bronze/gunmetal		75.6	2.6	7.6	9.2	0.1
HENL	730943	484	7	137?	(leaded) bronze						
THIS	611053	BH1679	7	137?	leaded bronze						
THIS		THZ1756	7	137A	leaded bronze		76.2	1.3	9.0	9.7	0.1

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
ASHT	835110	679	7	137A	bronze						
ASHT	835115	557	7	137A	bronze						
TIDD		M14	7	137A	(leaded) gunmetal						
STAN	8516894		7	137A	leaded gunmetal						
STAN	8701636		7	137A	leaded gunmetal						
STAN	8800232		7	137A	leaded bronze						
WEEK	781400	86	7	137B	leaded bronze						
STAN	8516848		7	137C	(leaded) bronze						
STAN	8701382		7	137C	leaded bronze						
CATS		186	7	138	leaded bronze		73.4	1.9	8.4	14.0	0.1
CATS		718	7	138/139	leaded bronze		71.6	0.3	7.5	19.8	0.1
CATS		154	7	138/139	leaded bronze		67.2	1.4	9.7	22.2	0.1
CATS		153	7	138/139	leaded bronze/gunmetal		69.6	3.0	8.4	16.3	0.1
SEAM		65-267	7	138/140?	bronze						
TARH		169	7	139	bronze						
TARH		877	7	139	(leaded) bronze						
HENL	642035	113	7	139	leaded gunmetal						
CATS		926	7	139	leaded bronze		74.3	0.2	9.1	13.3	0.1
TARH		170	7	139	leaded bronze/gunmetal						
TARH		16	7	139	leaded bronze/gunmetal						
CATS		339	7	139+	leaded bronze						
CATS		141	7	139+	leaded bronze						
DORC		Rep 3	7	139++	leaded bronze						
CATS		344	7	139+?	leaded bronze						
CATS		566	7	139?	bronze						
HENL	734841	503	7?	139?	leaded bronze						
TARH		838	7	139?	(leaded) bronze						
HAYL		1014	7	139?	leaded bronze/gunmetal						
DORC	8212339		7	139?	leaded bronze						
CATS		70	7	140	leaded bronze		65.7	0.5	7.8	17.4	0.1
THIS		THV52	7	143A	brass	E	76.0	15.6	1.2	3.0	0.0
NORN	733343		7	143B	leaded bronze	E	77.7	0.4	8.2	10.8	0.0
NORN	733397		7	143B	leaded bronze	E	73.0	0.1	12.1	19.7	0.0
NORN	650093	261	7	143B	leaded bronze	E	68.3	0.1	11.1	15.6	0.0
ULEY		2272	7	144	leaded bronze	E	66.9	0.2	11.2	13.0	0.1
WANB		105	7	144	leaded bronze		74.4	0.1	7.4	18.8	0.1
MAGI	779677	Pub 18	7	144	leaded bronze	E	71.0	0.2	10.2	22.1	0.0
CHEL		CHK Ae208	7	144	leaded bronze	E	76.6	0.0	10.9	11.9	0.1
WIGG	681207	154	7	144	leaded bronze	E					
WANB	684121	106	7	144?	leaded bronze	WE	72.3	1.2	9.8	10.2	0.0
RICH	7350101		7	145	(leaded) bronze		83.9	0.2	8.0	7.9	0.1
NORN		231	7	145	leaded bronze		64.9	0.0	8.0	15.8	0.0
LOND		LCT 1499	7	145	gunmetal	E					
WICL		6	7	145+	brass	E					
RICH	7350203		7	145A	brass	E	79.3	20.2	0.5	2.7	0.0
RICH	7351747		7	145A	brass/gunmetal	E	80.4	11.3	2.8	3.0	0.0
THIS		THZ2101	7	145A	(leaded) brass	E	74.8	10.3	2.1	4.2	0.0
DRAG		DR 66 DN	7	145A	gunmetal	WE					
DRAG		DR 68 CY	7	145A	bronze/gunmetal	WE					
CAST		10-1640	7	145A	leaded bronze	E					
STAN	8800195		7	145B	(leaded) bronze/gunmetal	E					
RICH	7351090		7	146	(leaded) bronze		87.4	0.3	7.2	5.3	0.1
CAME		76-94	7	146	(leaded) bronze		88.3	0.4	8.1	6.3	0.0
PIER		4814	7	146	leaded bronze		83.0	0.0	5.9	9.3	0.1
PIER		2367	7	146	bronze		87.6	1.0	6.2	3.4	0.0
ALDB	78108252	jb14	7	146	leaded bronze						
ALDB	78108253	jb15	7	146	gunmetal						
POOL		5167	7	146	bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
DRAG		DR 68 VK	7	146	brass/gunmetal						
CAST		1-117	7	146	?						
LOND		83	7	147	brass	E					
LOND		A10123	7	147	gunmetal	E					
CORB	822130		7	148	gunmetal						
WELT		205	7	148	bronze	E					
ALDB	78108232	jb5	7	148	gunmetal	E					
COLE		64	7	148A	(leaded) gunmetal	E					
RICH	7350098		7	148A	gunmetal		85.6	7.5	7.3	0.0	0.0
PIER		2357	7	148A	brass		88.1	12.5	0.0	0.0	0.0
ALDB	78108255	jb8	7	148A	brass/gunmetal	E					
DRAG		DR 71 APZ	7	148A	brass	E					
DRAG		DR 69 SL	7	148A	brass						
CAST		1-524	7	148A	bronze						
CAST		10-2287	7	148A	gunmetal						
CAST		14-455	7	148A	brass	E					
CAST		14-299	7	148A	brass						
CAST		10-1666	7	148A+	bronze	+					
LOND		32.2/13	7	148A+?	brass						
CAST		1-605	7	148A?	brass/gunmetal						
COLE		860	7	148B	leaded bronze	E					
TIDD		80-61	7	148B	gunmetal	E	78.9	11.0	7.4	0.1	0.0
PRES	851071	404	7	148B	copper/brass	E	87.5	7.8	2.1	0.7	0.0
CAST		14-98	7	148B	brass	E					
CAST		14-311	7	148B	brass	E					
CAST		16-195	7	148B	brass	E					
LOND		GPO 4291	7	148B	brass	E					
LOND		25871	7	148B	brass	E					
LOND		87	7	148B	brass	E					
WORC		786	7	148B	brass	E					
SNET		Cat 26	7	148B	bronze	E					
COLE		284	7	148C	(leaded) gunmetal	E					
RICH	7351716		7	148C	brass	E	82.1	12.6	1.0	2.8	0.1
NORN		235	7	148C	brass	E	80.1	12.5	1.4	0.9	0.0
HAYL		3129	7	148C	(leaded) brass	WE+	79.5	12.7	1.7	4.9	0.1
PIER		4273	7	148C	brass	E	80.4	16.7	1.7	0.0	0.1
HOUS	79208026		7	148C	(leaded) gunmetal	E	93.3	4.1	5.4	5.0	0.0
ALDB	78108230	jb4	7	148C	brass	E					
ALDB	78108226	jb7	7	148C	brass	E					
ALDB	78108231	jb9	7	148C	brass	E					
ALDB	78108228	jb10	7	148C	brass						
ALDB	78108227	jb11	7	148C	brass	E					
ALDB	78108229	jb12	7	148C	brass	E					
CARL		Ae148	7	148C	brass	E					
CAST		10-1916	7	148C	gunmetal	E+					
HOUS	79208026		7	148C	(leaded) gunmetal	E+					
WROX	743369		7	148C	brass	E(S)					
LOND		3418	7	148C	brass	EA>					
CATS		913	7/8	148C/159	bronze	E	85.9	0.0	10.2	0.0	0.0
ULEY		2162	7	148/149	(leaded) bronze	E					
CARV		31	7	149	bronze	?					
HENL	684631	364	7	149	leaded gunmetal	?					
CARV		22	7	149	leaded gunmetal	E	85.9	6.0	2.9	16.7	0.0
PIER		1903	7	149	copper/brass	E	89.6	6.1	1.7	0.0	0.0
TIDD		81-814	7	149	bronze/gunmetal	E	83.2	4.4	8.2	1.4	0.1
TARH		159	7	149	brass		83.0	11.9	1.0	0.3	0.1
ULEY		2165	7	149	bronze	?	90.2	0.9	4.1	2.0	0.0
CARL		Ae264	7	149	brass	E					

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
CARL		Ae268	7	149	bronze	E					
COLC		1.81-893	7	149?	brass	E					
COLE		285	7	149A	leaded bronze						
RICH	7350208		7	149A	bronze/gunmetal		84.4	3.7	7.3	2.9	0.2
NORN	733366		7	149A	bronze		82.7	0.9	9.1	3.5	0.0
CAST		1-396	7	149A	bronze	(E)					
CAST		15-30	7	149A	brass	?					
LOND		A25083	7	149A	(leaded) bronze						
WORC		710	7	149A	bronze						
WORC		747	7	149A	bronze	(E)					
WICL		11	7	149B	brass	E					
WICL		13	7	149B	bronze	E					
WICL		30	7	149B	bronze	E					
WICL		34	7	149B	brass	(E)					
RICH	7350475		7	149B	copper	E					
RICH	7350089		7	149B	(leaded) bronze/gunmetal	E	88.9	1.7	4.4	4.4	0.1
NORN	620707	104	7	149B	(leaded) bronze	E	72.4	1.3	5.9	6.6	0.0
NORN	621170	99	7	149B	leaded bronze	E	63.3	0.5	8.5	12.8	0.0
NORN	620713	103	7	149B	leaded bronze	E	64.5	0.0	9.2	11.8	0.0
NORN	620651	101	7	149B	leaded bronze	E	63.7	0.0	10.8	17.6	0.0
CAME		76-78	7	149B	brass	E	75.9	18.5	2.5	0.0	0.0
WHIT		4	7	149B	leaded bronze	E	77.8	1.4	9.2	13.5	0.1
PRES	851070	438	7	149B	bronze	E	89.6	0.0	4.9	3.4	0.0
CHEL		CHK 2/60	7	149B	gunmetal	E	91.7	3.3	3.4	3.6	0.1
ASHT	835093	332	7	149B	brass	E					
WELT		507	7	149B	bronze	(E)					
ALDB	78108233	jb13	7	149B	bronze	E					
NORN	620713	105	7	149B	(leaded) gunmetal	E					
DRAG		DR 65 MW	7	149B	bronze	E					
DRAG		DR 65 HG	7	149B	bronze	E					
CIRE		StMF 20	7	149B	(leaded) bronze	E					
CAST		1-637	7	149B	brass/gunmetal	E					
CAST		1-551	7	149B	(leaded) bronze	(E)					
CAST		10-2071	7	149B	brass	E					
CAST		10-1985	7	149B	(leaded) bronze	E					
CAST		10-1601	7	149B	leaded bronze	E					
CAST		10-1409	7	149B	bronze	E					
CAST		10-2078	7	149B	bronze	(E)					
CAST		10-2135	7	149B	bronze/gunmetal	E					
CAST		10-1232	7	149B	bronze	E					
CAST		12-9	7	149B	bronze/gunmetal	E					
CAST		13-139	7	149B	leaded bronze	E?					
CAST		16-213	7	149B	brass/gunmetal	E+					
LOND		RAG 99	7	149B	leaded bronze	E					
LOND		32.2/10	7	149B	gunmetal/brass	E					
LOND		79.351	7	149B	brass	E					
LOND		81-282/6	7	149B	brass	E					
LOND		A20599	7	149B	brass	E					
LOND		19925	7	149B	brass	E					
LOND		84	7	149B	brass	E					
LOND		86	7	149B	brass	E					
LOND		A1263	7	149B	brass	E					
NORN	620689	106	7	149B?	leaded bronze	E	62.9	0.0	8.5	21.3	0.0
ASHT	835111	510	7	151	bronze	E					
LOND		LBT 68	7	151	leaded bronze	E					
WROX	721377		7?	151?	brass		80.1	18.4	1.3	0.0	0.2
POOL		5205	7/8	151?	lead						
TIDD		M6	7	151C	(leaded) brass	+	79.8	12.5	2.0	6.0	0.3

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
ULEY		7669	7?	151D	leaded bronze	E	73.5	0.0	6.6	16.3	0.1
TIDD		81-757	7	151D	leaded bronze	EA^	75.9	0.7	13.7	14.3	0.1
POOL		5099	7	151D	lead						
DODD	8515493		7	151D	leaded bronze	E					
DRAG		DR 68 BS	7	151D	bronze	E					
POOL		5206	7	151D?	lead						
WROX	721381		7	152	bronze		86.1	1.2	9.2	2.4	0.0
PRES	851066	93	7	152	leaded bronze	E	77.4	0.0	7.9	14.0	0.3
PRES	851068	427	7	152	brass	E	85.3	11.0	2.4	1.0	0.0
PRES	851086	284	7	152	bronze	E	89.3	0.0	9.8	0.6	0.0
PRES		1316	7	152	leaded bronze	E	76.0	0.0	12.1	11.5	0.0
PRES	851069	437	7	152++	brass	E	76.7	20.0	2.3	0.2	0.0
COLC		0862 CEH	7?	?	brass						
RICH	7351142		7	?	leaded bronze						
RICH	7350745		7	?	(leaded) bronze		82.6	1.2	7.8	7.9	0.2
NORN	620691	52	7	?	leaded bronze		68.6	0.0	10.6	12.7	0.0
NORN	621151	57	7	?	(leaded) bronze		80.7	1.1	8.0	4.9	0.0
NORN		34	7	?	bronze	E	80.2	0.0	9.4	3.6	0.0
NORN	620731	51	7	?	leaded bronze		66.0	0.6	10.1	24.7	0.0
NORN	620690	55	7	?	leaded bronze		70.3	0.3	10.2	15.7	0.0
NORN	621128	60	7	?	leaded bronze		68.1	0.1	6.9	21.8	0.0
NORN	620652	120	7	?	leaded bronze	E	71.9	0.7	10.3	13.8	0.0
NORN	620744	229(CREST)	7	?	(leaded) bronze		84.4	0.1	5.6	4.7	0.0
NORN	620744	229(BOW)	7	?	bronze		85.6	0.1	4.2	3.8	0.0
NORN	621146	228	7	?	leaded bronze	E	73.3	0.7	5.7	16.7	0.0
NORN	620729	119	7	?	leaded copper	E	76.7	0.0	2.7	10.1	0.0
NORN	621103	96	7	?	leaded bronze		68.2	0.3	10.2	13.1	0.0
CARV		25	7	?	leaded bronze		67.7	0.1	12.1	16.5	0.1
HAYL		3449	7	?	leaded bronze						
WANB		Cat 113	7	?	bronze	E	81.0	0.6	9.5	1.4	0.1
CATS		579	7?	?	leaded bronze		65.3	1.5	12.0	15.8	0.1
VELZ		24	7?	?	brass	E	75.0	12.3	2.3	0.8	0.2
TIDD		M21	7	?	leaded bronze	E	75.7	0.1	12.3	12.5	0.2
ASHT	835126		7	?	leaded bronze						
SEAM		66-55	7	?	leaded bronze	E					
THIS		BH415	7	?	leaded bronze						
DORC	8212370		7?	?	bronze						
DRAG		DR 67 AAY	7	?	bronze/gunmetal						
DRAG		DR 68 NV	7	?	bronze						
DRAG		DR 70 ABI	7?	?	bronze						
CIRE		StMF 200	7	?	leaded bronze	EW					
WILD	761066		8	153A	bronze	N					
POOL		5102	8?	153A/B/C	gunmetal						
POOL		5140	8	153A/B/C	gunmetal						
POOL		5258	8	153A/B/C	bronze						
COLE		120	8	153B	leaded bronze						
COLE		303	8	153B	leaded bronze						
WROX	843006		8	153B	brass	A>					
WROX	842998		8	153B	bronze	G					
BEES	819158		8	153C	brass		81.1	16.9	0.0	0.6	0.0
CORB	868601		8	153C	brass						
DRAG		DR BF	8	153C	brass/copper ?						
CAST		9-1214	8	153C	brass						
TIDD		M1	8	153D	(leaded) bronze		81.4	0.2	8.3	6.8	0.2
TIDD		M20	8	153D	leaded bronze		63.6	0.3	11.4	24.8	0.0
STAN	8612518		8	153D	leaded bronze						
COLE		460	8	154	leaded bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
COLE		810	8	154	leaded bronze						
RICH	7351709		8	154	bronze		59.2	1.0	12.1	0.0	0.1
WANB	707308	115	8	154	leaded bronze		89.6	0.5	8.1	8.2	0.1
WANB		114	8	154	leaded bronze		70.8	1.2	6.1	28.6	0.1
LEIC		316-47	8	154	leaded bronze		68.0	0.7	5.5	26.3	0.0
LEIC		316-34	8	154	leaded bronze		76.6	0.0	7.6	17.1	0.1
WANB	684167	116	8	154/159	leaded bronze		76.8	0.5	8.2	19.8	0.1
ULEY		3607	8	154A	leaded bronze	W	77.0	0.1	3.9	12.9	0.1
ULEY		5327	8	154A	leaded bronze		71.7	0.1	8.4	11.3	0.1
SWIN	770871	117	8	154A	leaded bronze		71.3	1.7	7.5	17.0	0.1
WROX	721367		8	154A	leaded bronze		75.2	0.0	9.3	14.8	0.0
GLOU		69/49-21	8	154A	leaded bronze						
YORK		M710	8	154B	leaded bronze						
RICH	7350207		8	154B	leaded bronze		75.7	0.2	9.3	14.6	0.1
NORN	621138	108	8	154B	leaded bronze		78.5	0.5	4.5	10.0	0.0
TIDD		81-949	8	154B	leaded bronze		69.1	0.6	9.2	24.2	0.0
PIER		16B 7	8	155?	leaded gunmetal						
RICH	7350212		8	157	brass	E	76.2	18.1	2.6	1.3	0.0
WANB		117	8	157	leaded bronze	E	69.4	0.1	9.2	21.4	0.0
PRES	851061	286	8	157A	bronze	?	88.2	0.1	8.2	0.2	0.0
CAST		R Jeffries	8	157A	brass	A>					
LOND		A11925	8	157A	brass						
LOND		A23484	8	157B	brass	E					
CAST		10-2180	8?	157B?	brass/gunmetal	A>					
LOND		82	8	157C	brass	E					
LOND		32.2/12	8	157C	brass	E					
CAST		15-141	8	157C/E	gunmetal	E					
LOND		A1264	8	157D	brass	E					
TIDD		81-209	8	157E	leaded bronze/gunmetal	E	82.5	3.2	8.5	8.5	0.1
ALDB	78108234	jb21	8	157E	brass	E					
CAST		15-592	8	157E	brass/gunmetal	E					
CAST		1-737	8	157E?	brass	E					
LOND		A20228	8	157F	brass	E					
WORC		3899-1048	8	157F	gunmetal	E					
WELT		435	8	158	(leaded) brass		78.5	10.3	1.5	6.2	0.0
OPEN	7815770		8	158	gunmetal						
PAPC		84-132	8	158	bronze						
POOL		5096	8	158+?	brass						
WICF		248	8	158A	leaded gunmetal						
CORB	831676		8	158A	bronze						
CATT	723733		8	158A	brass/gunmetal						
RICH	7350472		8	158A	brass/gunmetal		82.7	9.8	3.8	1.1	0.0
RICH	7350976		8	158A	bronze/gunmetal		91.7	2.0	4.7	1.0	0.0
CABY		836	8	158A	leaded brass/gunmetal		70.1	10.2	3.6	9.0	0.1
PIER		4323	8	158A	(leaded) brass		78.9	16.4	2.0	4.9	0.0
PRES	851064	434	8	158A	(leaded) brass		77.0	11.8	1.8	4.7	0.3
WELT		162	8	158A	(leaded) bronze		86.1	0.8	5.0	5.3	0.1
WELT		420	8	158A	brass/gunmetal		78.7	12.5	5.0	3.7	0.0
WPER	7310666		8	158A	brass/gunmetal						
ALDB	78108235	jb20	8	158A	brass						
ALDB	78108236	jb23	8	158A	brass						
CHEL		CHV 20	8	158A	brass						
CATT	8111875		8	158A	bronze/gunmetal						
CATT	8111931		8	158A	brass						
CATT	8111280		8	158A	brass						
CATT	8111866		8	158A	brass?						
CATT	8111900		8	158A	bronze						
OPEN	7710108		8	158A	brass/gunmetal						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
CAST		10-1600	8	158A	bronze						
CAST		12-5	8	158A	brass						
CAST		15-580	8	158A	brass						
LOND		C995	8	158A	gunmetal						
LOND		18648	8	158A	brass						
COLE		2013	8	158A(+)	leaded gunmetal						
CAST		14-238	8	158A/C	bronze						
CAST		14-230	8	158A/C	brass						
CARL		Ae222	8	158A?	leaded gunmetal						
CARL		Ae178	8	158A?	leaded gunmetal						
OPEN	7813570		8	158B	leaded bronze/gunmetal						
RICH	7350388		8	158C	brass		77.0	19.2	2.9	1.1	0.0
ALDB	78108237	jb22	8	158C	bronze						
OPEN	7814431		8	158C	copper/bronze						
DRAG		DR 70 AF	8	158C	gunmetal						
CAST		1-409	8	158C	gunmetal						
CAST		10-2148	8	158C	brass						
CAST		10-1849	8	158C	bronze						
CAST		10-1277	8	158C	bronze						
CAST		10-1486	8	158C	brass/gunmetal						
CAST		10-1319	8	158C	brass						
CAST		15-159	8	158C	brass						
CAST		15-294	8	158C	bronze						
CAST		16-284	8	158C	bronze						
CAST		16-329	8	158C	bronze						
LOND		RAG 155	8	158C	brass						
WROX	78000527		8	158C	brass						
THIS		THVbag179	8	158D	leaded bronze						
GLOU		69/49-66	8	158D	leaded bronze						
CARL		Ae13	8	158D?	leaded bronze						
HENL	684638	406	8	158D?	leaded bronze						
HAYL		2348	8	158E	leaded bronze		72.1	0.2	10.8	12.9	0.1
WANB		118	8	158E	leaded bronze	E	75.2	0.2	10.5	16.1	0.1
CATT	8111060		8	158E	leaded bronze						
CATT	8413512		8	158E	leaded bronze/gunmetal						
NORN	620694	109	8	158F	leaded bronze		76.5	0.0	8.8	8.0	0.0
CATS		363	8	158F	leaded bronze		76.1	2.1	8.5	13.7	0.1
TIDD		81-780	8	158F	leaded bronze		75.0	0.2	12.6	12.4	0.1
ILCH		21	8	158F	(leaded) bronze						
BALD		Cat 85	8	159+	brass/gunmetal	E					
NORN	621142	110	8	159+	(leaded) bronze	E	77.4	0.3	8.3	7.7	0.0
DERB		026/649	8	159+	leaded bronze	E					
WORC		709	8?	159+?	leaded bronze						
POOL		5139	8	159?	(leaded) bronze						
ULEY		378	8	159A	leaded bronze		73.7	0.7	11.0	16.9	0.0
WICF		186	8	159A	leaded bronze		68.9	0.6	11.4	27.7	0.0
TIDD		80-96	8	159A	leaded bronze		59.9	0.0	15.6	16.7	0.0
WROX	842998		8	159A	leaded bronze						
LOND		0.1815	8	159A	leaded bronze						
CATS		692	8	160	bronze						
TARH		756	8	160	leaded bronze		75.4	0.1	10.5	11.6	0.1
CORB	868598		8	162	brass	WA>					
LOND		RIV 40	8	162	brass	A>					
CAST		10-1303	8	162A	bronze/gunmetal	(E)					
WROX	840545		8	162A	brass	A>					
RICH	7350805		8	162B	brass	W	80.9	14.1	2.3	2.8	0.0
CATS		716	8	162C	brass	W	84.5	15.5	2.0	2.7	0.1
OPEN	7813157		8	162C	brass	WA>					

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
TIDD		82-229	8	163	brass	E					
LEIC		365-95	8	163	brass	E					
ALDB	78108244	jb17	8	163	brass	E					
THIS		THZ2212	8	163	brass	E					
OPEN	7815488		8	163	bronze/gunmetal	E					
DRAG		DR CX	8	163A	brass						
DRAG		DR 70 BEM	8	163A	brass	E					
CAST		16-322	8	163A	gunmetal	E					
GLOU	751162	sf102	8	163A	brass	E					
CAST		1-112	8	163B	gunmetal	E					
CORB	831211		8	164	bronze	E					
CORB	822128		8	164	(leaded) bronze	E					
PRES		1291	8	164	leaded bronze		74.6	0.0	9.5	15.3	0.2
CAST		10-1585	8	164	gunmetal	E					
CAST		10-326	8	164	brass	E					
CAST		15-408	8	164	gunmetal	E					
LOND		432	8	164+	brass	I¯orN					
PIER		(66)	8	166	brass	E					
WICL		37	8	166	gunmetal						
COLE		145	8	166	(leaded) gunmetal						
WANB		119	8	166	bronze/gunmetal	EWA>	87.1	2.4	6.1	2.6	0.0
WANB		120	8	166	copper/brass	EWA>	82.0	7.6	2.7	0.0	0.0
LOND		CRU 8	8	166	brass	A>					
RICH	7351701		8	166A	(leaded) brass/gunmetal	E	78.3	9.5	3.0	4.1	0.1
WROX	80000311		8	166B	bronze/gunmetal	E					
NORN	620717	111	8	166C	leaded bronze/gunmetal	EWA>					
LOND		19229	8	166C	brass	A>					
RICH	7351734		8	166D	copper/brass	E	80.0	7.7	2.5	1.5	0.0
WROX	781667		8	166D	gunmetal						
LOND		A10124	8	166E	(leaded) bronze	EA>					
CORB	822108		8	167	brass/gunmetal	E					
WORC		3899-6312	8	167	brass	WA>					
PIER		TF-16-A	8	167A	brass	WA>	82.1	14.3	1.3	0.0	0.0
LOND		19227	8	167A	brass	A>					
WORC		760	8	167B	base silver						
CAME		79-8	8	167C	brass/gunmetal	EWA>					
HAYL		1367	8	167C	brass	WEA>					
WANB		Cat 121	8	168	brass	E					
TIDD		81-497	8	168	gunmetal	E	80.4	14.3	7.1	1.4	0.0
ULEY		3880	8	168	leaded bronze	WE					
LOND		A27196	8	168A	brass	EA>					
WROX	743370		8	168A?	brass	E					
LOND		ASQ 8	8	168B	brass	A>E					
LOND		HTP 10	8	168B	brass	EA>					
DERB		DLC79EXH111	8	?	bronze						
DERB		CHB/EO 122	8	?	leaded bronze						
DERB		DLC79AYA49	8	?	leaded bronze						
RICH	7350696		8	?	leaded bronze		71.2	0.0	6.2	21.0	0.0
WALL		11	8	?	leaded bronze						
ALDB	78108229	jb6	8	?	brass	E					
POOL		5101	8	?	gunmetal						
POOL		5212	8	?	bronze/gunmetal						
CAST		10-2129	8?	?	bronze						
LOND		79-16/3	8	?	gunmetal						
STAN	8701128		8	?	brass/gunmetal	WA>					
CORB	831185		9	171	brass	W(E)					
SEWN	810678		9	171	leaded bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
MAGI	7711243	Pub 19	9	171	(leaded) bronze/gunmetal	EA>	75.2	7.3	11.7	5.4	0.0
ALDB	78108249	jb19	9	171	(leaded) bronze/gunmetal						
POOL		5138	9	171	bronze	E					
CARL		Ae86	9	171	copper						
CARL		Ae133	9	171	bronze						
DRAG		DR 67 SY	9	171	bronze						
CAST		10-523	9	171	leaded bronze						
CAST		15-673	9	171	leaded bronze						
PIER		77	9	171	bronze						
LOND		PIC 436	9	171	leaded bronze						
LOND		82.345	9	171	brass	WEA>					
CORB	868612	75-3917	9	171?	gunmetal	E					
LOND		A23483	9	172	(leaded) bronze						
BALD		Cat 103	9	173	brass/gunmetal	W					
POOL		5095	9	173	brass	?					
HAYL		1446	9	173	brass	EWA>					
LOND		ELD 17	9	173	brass						
CAME		75-4	9	173?	(leaded) bronze	W					
WROX	840630		9	173?	bronze						
CAME		76-44	9	173A	brass/gunmetal	WA>					
CAME		76-109	9	173A	brass/gunmetal	WA>					
CAME		76-85	9	173A	brass	WA>					
CAME		76-49	9	173A	gunmetal?	WA>					
CATS		696	9	173A	gunmetal	E					
PIER		2625	9	173A	brass	WE	86.8	12.5	2.1	0.0	0.0
CHEL		CHAD	9	173A	brass		83.7	10.8	1.9	1.2	0.0
ALDB	78108248	jb18	9	173A	brass?	E					
PAPC		PC84-038	9	173A	gunmetal	EWA>					
PAPC		84-547?	9	173A	gunmetal	EWA>					
WINC		VR-5263	9	173A	brass						
WROX	743487		9	173A	brass	WA>					
WROX	781659		9	173A	brass	WA>					
WROX	781662		9	173A	brass	WA>E					
STAN	8701116		9	173A	gunmetal	WA>					
CAME		76-15	9	173B	brass						
CAME		76-250	9	173B	leaded bronze						
CAME		76-141	9	173B	leaded bronze						
CAME		75-27	9	173B	leaded bronze						
HENL	734844	511	9	173B	leaded bronze						
CORB	831688		9	173B	leaded bronze						
CAME		75-21	9	173B	(leaded) bronze	W	88.7	0.0	7.3	4.0	0.0
GORH	820076	491	9	173B	bronze						
CARL		Ae176	9	173B	bronze						
CARL		Ae205	9	173B	leaded gunmetal						
OPEN	7814948		9	173B	leaded bronze						
PAPC		84-074	9	173B	leaded bronze						
WROX	80000340		9	173B	bronze						
WROX	781661		9	173B	(leaded) bronze	W					
CAME		76-162	9	173B?	leaded bronze						
VIND	819169		9	175	leaded bronze						
PIER		BB79 1	9	175A	leaded bronze	W					
RICH	7351736		9	175A	leaded bronze		77.6	0.3	8.5	10.9	0.0
PIER		CVW	9	175A	leaded bronze						
NORN	640017	115	9	175B	leaded bronze		70.5	0.3	11.5	13.5	0.0
NORN	733382		9	175B	leaded bronze		65.2	0.2	14.1	17.0	0.0
ULEY		4767	9	175B	leaded bronze						
VIND	819188		9	176	leaded gunmetal						
HOUS	811550		9	176	leaded bronze		74.8	1.4	6.6	22.8	0.0

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
COLC		1.81-4842	9	176	leaded gunmetal						
OPEN	7813594		9	176	leaded bronze	W					
OPEN	7813581		9	176	leaded bronze/gunmetal	W					
PAPC		84-055	9	176	leaded bronze	W					
PIER		4766	9	176A	leaded bronze	W					
RICH	7350908		9	176A	(leaded) bronze		79.8	1.5	7.9	7.4	0.1
RICH	7351743		9	176A	leaded bronze	W	75.9	0.6	6.2	18.0	0.1
WROX	78000174		9	176A	(leaded) bronze						
LOND		24670	9	176A	bronze						
RICH	7351741		9	176B	leaded bronze/gunmetal		81.1	2.7	5.5	9.3	0.0
CHEL		CHT 1	9	176B	leaded bronze		73.9	0.3	10.6	10.6	0.1
HOUS	811550		9	176B	leaded bronze	W					
LANC		sf3306	9	177	leaded bronze						
GORH	820349	3310	9	177+	leaded bronze						
PAPC		84-051	9	177+	leaded bronze						
LOND		ACW 30	9	177++	bronze	W(E/N)					
VIND	819174		9	178	leaded bronze						
OPEN	7813569		9	178	leaded gunmetal						
RICH	7351713		9	178A	(leaded) gunmetal		62.6	8.1	4.9	4.8	0.0
RICH	7351719		9	178A	(leaded) bronze		84.1	1.4	5.6	6.4	0.1
THIS		THVbag25	9	178A	leaded gunmetal						
HOUS	855040		9	178A	leaded bronze						
PIER		HS77 22-3AP	9?	178A?	leaded bronze						
LOND		SM 73	9	178D	bronze/gunmetal	E					
WROX	82000239	537	9	179	leaded bronze	WE					
WROX	811092		9	?	leaded bronze						
BRAU		88	9?	?	brass						
SHOR		107.ZE 13	3/10	29/180	bronze	E	26.9	0.1	10.6	0.4	0.1
VELZ		13	10	180	(leaded) brass	E					
VELZ		23	10	180	brass	E					
WICL		12	10	180	leaded gunmetal	E					
RICH	7350218		10	180	brass	E	81.4	14.1	2.9	0.7	0.0
RICH	7350788		10	180	brass	E	74.1	18.5	3.6	1.2	0.0
RICH	7351576		10	180	(leaded) gunmetal	E	71.1	10.6	5.5	5.0	0.0
RICH	7351748		10	180	(leaded) gunmetal	E	76.7	6.0	6.9	6.6	0.0
LOND		TRM 13	10	180	(leaded) brass	E					
LOND		84.453/4	10	180	(leaded) gunmetal						
LOND		C988	10	180	brass	E					
VELZ		19	10	180+	(leaded) bronze	E					
BRAU		687	10	180/183	(leaded) gunmetal		80.6	9.5	4.8	7.9	0.0
RICH	7351769		10	181	leaded bronze/gunmetal	W	77.5	4.5	7.0	9.6	0.0
NORN	621136	128	10	181	leaded bronze	E	64.4	0.3	8.9	20.1	0.0
COLC		1.81-991	10	182	leaded gunmetal	E					
WANB		122	10	182	brass/gunmetal	E	75.3	12.5	3.7	3.5	0.1
VELZ		11	10	182	brass	E	76.6	14.5	3.2	1.2	0.4
VELZ		34	10	182	brass	E	81.7	14.1	1.7	1.0	0.3
MAGI		Pub 16	10	183	(leaded) gunmetal	E					
VELZ		22	10	183	(leaded) brass	E					
VELZ		21	10	183	brass	E					
LOND		A17716	10	183	brass	E					
LOND		84.240/1	10	183	brass	(N)?					
LOND		84.382	10	183 (cf230)	brass/gunmetal	E					
VELZ		20	10	183+	gunmetal	E					
LOND		MLK 399	10	183+	leaded gunmetal	E					
WROX	82000239		10?	?	leaded bronze	E					

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
HOUS	803024		11	185	brass						
RICH	7351731		11	185	leaded bronze		68.8	0.0	5.6	24.4	0.0
BROU	671681	236	11	185	bronze						
HEYB		Ae 415	11	186	gunmetal						
PIER		1646	11	186	bronze	W					
WANB	684123	124	11	186	(leaded) bronze	W	82.6	0.3	7.4	7.8	0.0
YORK		M775	11	186+	bronze/gunmetal						
ULEY		4955	11	186/190	bronze	WG	80.5	1.3	5.7	0.4	0.1
PIER		3854	11	186?	bronze						
RICH	7350287		11	186?	copper/brass		92.5	6.7	1.8	0.2	0.1
CABY		540	11	186?	copper		86.1	1.9	2.3	0.5	0.4
RICH	7350283		11	186A	bronze/gunmetal		87.5	3.4	5.1	0.5	0.1
CABY		2298	11	186A	(leaded) bronze		81.6	0.9	8.1	5.4	0.1
PIER		45	11	186A	(leaded) bronze	W	82.6	0.8	7.9	5.2	0.0
RICH	7350286		11	186B	brass	GW	86.1	10.9	1.2	0.0	0.2
PIER		-	11	186B	leaded bronze	W	73.6	0.0	6.7	16.7	0.0
TATT		338 82	11	187	gunmetal						
VIND	819168		11	187	brass/gunmetal?	WG					
RICH	7350698		11	187	gunmetal		82.6	8.3	3.8	1.5	0.0
WICF		257	11	187	leaded bronze/gunmetal	W	76.3	4.6	10.4	10.6	0.6
PIER		1	11	187	leaded bronze/gunmetal	W	80.0	3.1	6.8	8.5	0.0
PIER		2310	11	187	leaded gunmetal		78.3	3.8	4.6	10.1	0.0
ALDB	78108245	jb25	11	187	(leaded) gunmetal						
PIER		-	11	187	(leaded) bronze						
PIER		2B 113	11	187	leaded bronze						
LOND		BWB 3513	11	187	brass?						
CARL		81ANN Ae311	11	187/189	copper	WG					
RICH	7351772		11	187/9	leaded bronze		65.9	0.5	5.1	9.8	0.3
CARL		81ANN Ae552	11	187?	brass	WG					
RICH	7350108		11	187A	leaded bronze	W	77.8	0.9	6.4	14.4	0.1
RICH	7351174		11	187A	copper/brass	W	85.9	5.4	0.0	1.9	0.1
RICH	7351744		11	187A	leaded bronze	W	73.8	0.5	6.2	16.1	0.1
WICF		250	11	187A	leaded bronze	W	75.7	0.1	9.8	19.1	0.0
RICH	7350215		11	187B	leaded bronze		81.2	0.8	5.6	11.6	0.0
RICH	7351742		11	187B	leaded gunmetal		76.0	4.3	5.8	11.8	0.1
ALDB	78108246	jb27	11	187B	brass						
RICH	7350284		11	189	leaded bronze		78.9	0.0	8.2	10.6	0.0
RICH	7350699		11	189	leaded bronze	W	68.2	0.6	8.6	19.8	0.1
RICH	7350907		11	189	leaded bronze	W	78.3	0.3	8.7	11.6	0.0
RICH	7351500		11	189	leaded bronze	W	70.5	0.0	13.4	17.9	0.2
RICH	7351511		11	189	leaded bronze	W	76.0	0.0	9.4	14.3	0.1
RICH	7351775		11	189	leaded bronze		73.6	0.5	6.9	16.8	0.2
RICH	7351752		11	189	leaded gunmetal		66.4	13.2	8.2	11.6	0.1
PIER		4123	11	189	leaded brass	W	74.8	14.2	2.0	8.9	0.0
ALDB	78108242	jb24	11	189	(leaded) bronze	W					
ALDB	78108247	jb26	11	189	(leaded) bronze	W					
OPEN	7815806		11	189	leaded bronze	W					
CATT	8310110		11	189	leaded bronze						
LOND		LCT 208	11	189	leaded bronze						
RICH	7351718		11	189+	leaded bronze	W	69.0	0.7	5.8	20.7	0.2
PIER		3364	11	189?	leaded bronze	W					
RICH	7350905		11	189G	leaded bronze		81.4	0.7	4.8	9.7	0.1
PIER		4818	11	190	bronze						
XXXX		K810035	11	190	leaded gunmetal						
RICH	7350470		11	190	bronze/gunmetal	GW	91.6	3.3	5.2	0.6	0.0
RICH	7350080		11	190	leaded bronze	W	73.1	0.3	8.0	20.7	0.0
RICH	7350508		11	190	bronze/gunmetal	GW	87.4	2.7	6.8	1.0	0.1
RICH	7351079		11	190	copper/brass	?	93.1	6.0	1.7	0.7	0.1

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7351703		11	190	bronze	G	97.1	0.5	5.1	0.3	0.1
RICH	7351725		11	190	(leaded) bronze/gunmetal	W	82.7	2.3	5.4	7.5	0.0
CABY		2643	11	190	leaded bronze/gunmetal		76.0	2.1	5.8	11.4	0.1
CABY		128	11	190	bronze/gunmetal		82.9	2.4	6.7	1.7	0.1
PIER		44	11	190	gunmetal		86.0	5.2	6.8	0.0	0.0
PIER		3653	11	190	(leaded) bronze/gunmetal	W	81.5	3.0	7.3	4.8	0.0
BROU	671676	95	11	190	bronze						
CARL		Ae59	11	190	leaded bronze						
CAST		10-190	11	190	bronze						
LOND		ER 1168-2	11	190	bronze						
LOND		24467	11	190	leaded bronze	W					
LOND		36.132/4	11	190	leaded gunmetal						
LANC		sf4449	11	190	bronze						
RICH	7350471		11	190/191	leaded bronze		70.8	0.5	7.9	20.5	0.1
RICH	7350806		11	190/191	bronze		90.2	0.0	7.2	1.3	0.0
RICH	7351894		11	190/191	leaded bronze						
RICH	7351895		11	190/191	bronze						
RICH	7351912		11	190/191	leaded bronze						
RICH	7351914		11	190/191	leaded bronze						
RICH	7350904		11	190/191A	leaded bronze		72.4	2.3	7.3	16.9	0.1
RICH	7350618		11	190/191B	(leaded) gunmetal		75.6	8.2	6.0	6.8	0.2
WICF		112	11	190?	leaded bronze						
RICH	7350297		11	191	(leaded) bronze/gunmetal	W	85.7	3.4	5.7	5.6	0.1
RICH	7350069		11	191	leaded bronze/gunmetal		76.5	4.3	7.3	10.2	0.2
RICH	7350294		11	191	leaded bronze		71.1	1.6	12.9	13.9	0.1
RICH	7350219		11	191	leaded bronze		72.0	0.9	7.8	15.3	0.1
RICH	7350272		11	191	leaded bronze		83.0	0.1	3.6	12.7	0.1
RICH	7351549		11	191	leaded bronze		80.1	1.1	8.5	13.2	0.1
RICH	7351765		11	191	(leaded) bronze		82.1	0.9	5.2	5.3	0.1
RICH	7351689		11	191	leaded bronze		68.8	0.2	9.6	8.9	0.1
CABY		3185	11	191	leaded gunmetal		66.8	12.5	6.5	8.5	0.2
PIER		3127	11	191	bronze	W	88.5	0.2	8.6	1.1	0.3
WROX	721382		11	191	silver						
BROU	676810	6	11	191	silver						
ICKH	7411767	1756	11	191	leaded bronze						
ICKH		2579	11	191	leaded bronze						
RICH	7351892		11	191	gunmetal						
RICH	7351893		11	191	(leaded) bronze						
RICH	7351915		11	191	leaded bronze						
LOND		13860	11	191	leaded bronze						
LOND		85.108/2	11	191	copper	G					
CARL		Ae65	11	191/192	leaded gunmetal						
RICH	7350278		11	191A	leaded bronze		74.2	2.3	7.0	13.7	0.1
RICH	7350270		11	191A	silver		28.9	3.7	0.6	0.8	64.9
RICH	7350104		11	191A	leaded bronze		74.0	1.1	8.5	15.7	0.1
RICH	7350271		11	191A	(leaded) bronze/gunmetal		87.5	2.2	5.0	5.4	0.4
RICH	7350777		11	191A	leaded bronze		70.4	0.7	7.5	19.3	0.1
RICH	7350775		11	191A	leaded bronze		73.3	1.0	9.4	12.8	0.1
RICH	7350903		11	191A	leaded bronze		65.6	0.1	10.6	22.2	0.4
RICH	7351095		11	191A	bronze		90.1	1.5	6.0	2.8	0.3
RICH	7351502		11	191A	(leaded) bronze/gunmetal		86.8	2.8	6.6	5.8	0.2
RICH	7351077		11	191B	bronze	W					
RICH	7350500		11	191B	leaded bronze		75.7	0.1	5.7	19.4	0.4
RICH	7350285		11	191B	leaded gunmetal		81.7	3.6	4.8	8.7	0.2
RICH	7350690		11	191B	(leaded) bronze		86.2	1.6	7.5	5.4	0.3
RICH	7350693		11	191B	(leaded) bronze/gunmetal		87.8	3.0	5.3	6.7	0.1
RICH	7350292		11	191B	leaded bronze/gunmetal		80.3	3.0	5.7	11.8	0.1
RICH	7350052		11	191B	leaded bronze		68.5	1.4	7.4	24.8	0.0

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7350075		11	191B	(leaded) bronze		88.7	0.7	5.2	6.9	0.1
RICH	7350273		11	191B	bronze		90.3	0.0	7.6	2.7	0.1
RICH	7350281		11	191B	leaded bronze		75.2	2.1	8.9	13.9	0.2
RICH	7350975		11	191B	leaded bronze/gunmetal		75.0	2.1	5.7	14.9	0.1
RICH	7351206		11	191B	brass		84.2	11.4	1.6	3.3	0.2
RICH	7351702		11	191B	leaded bronze	W	83.3	0.9	5.0	15.6	0.1
RICH	7351704		11	191B	leaded bronze		79.2	0.3	9.8	11.2	1.0
RICH	7351879		11	191B	brass						
LOND		438	11	191B	(leaded) gunmetal						
LOND		85.108/3	11	191B	bronze?						
LOND		85.108/1	11	191B	silver and brass						
LOND		0.1812	11	191B	brass						
RICH	7351335		11	192	copper						
RICH	7351353		11	192	brass/gunmetal						
RICH	7351793		11	192	(leaded) gunmetal						
RICH	7350072		11	192	brass						
RICH	7350348		11	192	brass	G					
RICH	7350478		11	192	leaded bronze		84.7	0.6	6.2	9.9	0.1
RICH	7350697		11	192	(leaded) brass		71.2	18.2	0.9	6.5	0.0
RICH	7350090		11	192	leaded gunmetal		71.8	12.9	5.3	10.9	0.2
RICH	7350097		11	192	brass/gunmetal		84.2	12.5	5.0	2.6	0.0
RICH	7350275		11	192	leaded bronze		76.2	0.2	5.4	21.6	0.1
RICH	7350970		11	192	leaded bronze		77.3	0.1	7.0	12.2	0.1
RICH	7351227		11	192	copper/brass		93.8	5.6	1.7	1.3	0.1
RICH	7351700		11	192	brass		76.1	18.9	0.2	1.8	0.0
RICH	7351723		11	192	brass	G	87.1	9.4	1.5	1.1	0.1
RICH	7351707		11	192	leaded bronze		66.3	1.6	11.8	10.7	0.1
RICH	7351790		11	192	(leaded) gunmetal		85.0	6.5	4.6	5.7	0.1
CABY		2301	11	192	bronze/gunmetal		81.9	3.0	7.7	3.8	0.3
CABY		2386	11	192	leaded bronze		65.7	0.7	7.8	15.4	0.1
CABY		980	11	192	(leaded) brass		69.9	14.8	3.0	6.6	0.1
CABY		1039	11	192	brass		76.2	16.5	1.0	2.9	0.0
ULEY		1219	11	192	leaded bronze		75.2	0.6	4.9	13.2	0.1
WICF		28	11	192	leaded bronze		73.3	0.1	6.0	27.6	0.2
WANB	692714	125	11	192	leaded bronze		82.4	2.2	7.3	9.7	0.2
ULEY		1156	11	192	brass						
CARL		Ae165	11	192	leaded bronze						
ICKH	746273	51	11	192	leaded bronze						
RICH	7351919		11	192	brass	G					
WROX	781665		11	192	leaded bronze						
WROX	78000943		11	192	leaded bronze						
WROX	781664		11	192	copper/bronze						
WROX	78000942		11	192	copper/bronze	G					
LOND		13073	11	192	bronze	G					
LOND		15083	11	192	leaded bronze						
LOND		10372	11	192	brass						
LOND		84.451	11	192	silver						
LOND		451	11	192	(leaded) brass	N?					
LOND		458	11	192	brass						
RICH	7350282		11	193	base silver		62.5	8.1	1.8	0.4	29.4
HENL	730948	454	11	194?	silver						
RICH	7351018		11	196	brass		76.0	16.3	0.0	0.1	0.1
WICF		44	11	197	leaded bronze		71.6	0.7	9.1	22.0	0.0
DOVE		K810254	11	?	copper	G					
WANB		Cat 126	plate	199	bronze	E					
CHES		T1	plate	199	gunmetal						
CAST		9-1221	plate	200	brass	E					

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
CAST		16-51	plate 200	bronze?	?					
WINC		VR 7312	plate 200?	leaded gunmetal	E					
WINC		VR 7381	plate 200?	leaded gunmetal	E					
RICH	7351712		plate 200B	brass	E	62.1	15.3	1.2	0.2	0.0
CATT	723730		plate 200B	leaded bronze	(E)					
LOND		81	plate 200D	brass	E					
CATT	8111962		plate 201	gunmetal	?					
PIER		1520	plate 202	bronze						
RICH	7350295		plate 203	bronze		85.3	0.0	10.1	0.5	0.1
RICH	7351528		plate 203	leaded gunmetal	E	64.1	6.1	7.5	11.8	0.1
RICH	7351711		plate 203	(leaded) brass	E	60.8	14.9	1.4	4.4	0.1
RICH	7351749		plate 203	leaded gunmetal		71.2	12.4	5.5	8.8	0.2
NORN	620624	130	plate 203	leaded bronze	E	76.3	1.2	8.3	9.6	0.0
HAYL		3454	plate 203	brass	E	77.8	14.2	2.1	3.1	0.1
TIDD		82-80	plate 203	leaded gunmetal	E	70.3	8.3	7.2	9.1	0.0
LOND		431	plate 203	(leaded) gunmetal						
LAMY	4774		plate 204	leaded gunmetal	E					
WICL		42	plate 204	leaded bronze	WE					
DOVE		K831206	plate 204	bronze	W					
HAYL		3316	plate 204	(leaded) bronze	EW	86.5	0.9	5.9	6.5	0.1
HAYL		2077	plate 204	leaded gunmetal	E					
HAYL		172	plate 204	leaded gunmetal	EW					
GDUN		Cat 621	plate 205	leaded bronze/gunmetal	E					
YORK		H 1396	plate 205	bronze	E					
WNEW	5421		plate 205	bronze/gunmetal	WE					
LOND		LEA 9	plate 206	leaded gunmetal	E					
THIS	610982	BH747	plate 210	leaded bronze/gunmetal	E					
LOND		3419	plate 210	gunmetal ?	E					
CATT	8111834		plate 211	leaded gunmetal						
RICH	7351735		plate 211	gunmetal	EW	82.4	8.7	3.7	2.3	0.1
LOND		A21459	plate 211	brass/gunmetal	EW					
LOND		CO ˆ308	plate 211	leaded gunmetal	NW					
CHIC		CHW88-84	plate 211	bronze	E					
WANB		Cat 127	plate 211+	bronze	EW					
CORB	868600		plate 211+	bronze	E					
LOND		20382	plate 212	brass	E					
YORK		H 31	plate 213	gunmetal	E					
YORK		H 31	plate 213	gunmetal	E					
YORK		B 3. H139a	plate 214	gunmetal	E					
ASHT	835074	159	plate 214	gunmetal	E					
CAST		16-220	plate 214	bronze	E					
LOND		A16426	plate 214	bronze	E					
STAN	8700072		plate 214	leaded bronze/gunmetal	E					
CAST		10-857	plate 216	gunmetal	E					
WANB		Cat 128	plate 216?	leaded bronze/gunmetal	E					
LOND		19230	plate 219	brass	WE					
TIDD		M7	plate 220	leaded bronze						
YORK		H 139c	plate 222	brass/gunmetal	E					
HENL	730941	469	plate 222	(leaded) brass/gunmetal	E					
NORN	620615	133	plate 222	gunmetal	EW					
CHIC		82/EP 234	plate 223	leaded gunmetal	E					
CHIC	800131	79/CM 583	plate 223	leaded bronze	?					
LOND		A19537	plate 223	bronze	EA>					
BALD		Cat 144	plate 224	brass	W					
BALD		Cat 145	plate 224	brass	W					
BALD		Cat 146	plate 224	bronze/gunmetal	WSA<					
RICH	7351321		plate 224	brass/gunmetal	S					
RICH	7351587		plate 224	(leaded) brass	S					

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
HAYL		1795	plate 224	brass	S					
HAYL		3313	plate 224	leaded brass/gunmetal	(S)WA<					
HAYL		1078	plate 224	brass	WSA<					
SHEP	722218	Rep 41	plate 224?	(leaded) gunmetal	SA					
BRAU		149	plate 225	brass	W					
BRAU		646	plate 225	gunmetal	W					
RICH	7350803		plate 225	brass/gunmetal		81.1	12.5	4.1	2.5	0.0
RICH	7350898		plate 225	brass/gunmetal		77.8	12.0	4.2	2.0	0.0
RICH	7351318		plate 225	brass		83.2	11.7	1.5	1.6	0.0
RICH	7351349		plate 225	brass		86.8	11.5	0.0	0.8	0.0
COLC		1.81-5046	plate 225	brass/gunmetal	WE					
COLC		1.81-5045	plate 225	brass/gunmetal	WE					
DRAG		DR 68 OD	plate 225	gunmetal						
CAST		14-453	plate 225	brass	W(E)					
BRAU		606	plate 225/227	brass	W					
TIDD		M599	plate 226	leaded bronze	?E					
WANB		Cat 129	plate 226	brass	E					
NORN		253	plate 226	(leaded) brass/gunmetal	E	76.4	9.7	3.3	4.4	0.0
NORN	621144	140	plate 226	(leaded) brass/gunmetal	E	73.5	11.4	4.5	7.6	0.0
WROX	840612		plate 226	leaded bronze	A<					
LOND		11631	plate 226	gunmetal	E					
STAN	8700080		plate 226	leaded bronze	WA<					
SWIN	771823	50	plate 227	leaded bronze	E					
CARV		23	plate 227	leaded bronze	E					
PIER		4795	plate 227	leaded gunmetal	E					
WANB		Cat 130	plate 227	leaded bronze	E					
COLE		520	plate 227	bronze	W					
RICH	7350067		plate 227	leaded bronze	E	79.5	1.5	9.0	10.7	0.0
NORN	621154	145	plate 227	leaded gunmetal	E	70.6	9.2	3.9	8.3	0.0
NORN	621150	143	plate 227	(leaded) bronze/gunmetal	E	69.5	3.9	6.3	7.0	0.0
NORN		151	plate 227	(leaded) brass/gunmetal	E	71.1	10.5	3.9	4.6	0.0
NORN	620633	146	plate 227	(leaded) gunmetal	E	72.6	8.0	6.5	5.6	0.0
OUDE		4	plate 227	(leaded) gunmetal	E	78.8	9.1	6.0	6.3	0.0
ASHT	835072	165	plate 227	copper						
HAYL		2750	plate 227	brass	E					
POUN		Ae34	plate 227	leaded bronze	E					
ICKH		2589	plate 227	brass						
LOND		A17717	plate 227	brass	E					
CHEL		CHK Ae215	plate 227+	gunmetal						
LOND		84.341/2	plate 227/267B	brass	(E)					
SEAT		20	plate 227?	leaded gunmetal	E					
HAYL		3322	plate 227?	brass	N					
VELZ		18	plate 228	(leaded) bronze	E					
RICH	7351319		plate 228	copper						
NORN	621089	152	plate 228	brass	E	48.0	7.8	2.0	1.2	0.0
LOND		A10127	plate 228	brass	E					
LOND		88	plate 228	leaded brass/gunmetal	E					
LOND		20126	plate 228	brass	E					
RICH	7351087		plate 228?	leaded gunmetal	E					
VELZ		25	plate 229	(leaded) brass	E					
VELZ		15	plate 229	brass	E					
WANB		Cat 123	plate 229	brass	(E)					
RICH	7350892		plate 229	brass	E	79.3	13.7	3.2	2.4	0.0
VELZ		12	plate 229	brass/gunmetal	E	78.4	12.5	3.1	3.4	0.3
VELZ		16	plate 229	brass	E	77.3	16.3	2.3	0.8	0.2
LOND		WIV 216	plate 229	brass	E					
GLOU		81/73-76	plate 230	leaded gunmetal	E					
RICH	7351357		plate 230	brass?						

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7351085		plate 230	brass	(E)	80.6	14.6	2.1	2.1	0.0
NORN	733364		plate 230	leaded gunmetal	E	76.4	6.1	7.3	8.2	0.0
NORN	733360		plate 230	(leaded) bronze/gunmetal	(E)	77.5	3.8	7.2	7.9	0.0
NORN	621126	168	plate 230	leaded bronze	E					
LOND		BWB 1329	plate 230	leaded bronze	E					
LOND		450	plate 230+	brass	(E)(N)					
HAYL		1936	plate 231	gunmetal	W+					
WANB		Cat 131	plate 231+	leaded bronze						
RICH	7351669		plate 231A	brass/gunmetal	E	81.7	11.2	3.5	3.2	0.1
NORN	620635	171	plate 231A	leaded gunmetal	E					
NORN	620636	172	plate 231A	leaded bronze	E					
COLC		1.81-616	plate 231B	leaded bronze	EN					
RICH	7350893		plate 231B	(leaded) gunmetal	E	75.8	9.1	4.8	6.9	0.0
NORN			plate 231B	(leaded) gunmetal	?					
LOND		MLK 176	plate 231B	gunmetal	(E)					
CHIC		80/CM 1188	plate 232	gunmetal	(E)					
RICH	7351542		plate 232	(leaded) bronze	E	81.3	0.5	10.0	5.6	0.1
NORN	621122	156	plate 232	leaded bronze	E	71.5	0.8	11.6	11.2	0.0
MAGI		Pub 21	plate 233	leaded gunmetal	E					
RICH	7350789		plate 233	gunmetal	E	79.2	6.0	4.2	2.1	0.5
RICH	7350891		plate 234	leaded gunmetal	E	74.1	7.2	4.4	10.8	0.0
NORN	733358		plate 234	leaded bronze	E	77.5	0.7	8.6	8.8	0.0
CHEL		CHK Ae245	plate 235C	brass						
BALD		Cat 149	plate 236	bronze	E					
YORK			plate 236	brass	E					
LOND		29.59/1	plate 236B	brass	E					
LOND		A16844	plate 236B	bronze	E					
CAST		10-1239	plate 237	brass/gunmetal	E					
BALD		Cat 142	plate 238	brass	WSA<					
RICH	7350801		plate 238	brass		73.1	18.4	3.6	1.4	0.0
RICH	7351082		plate 238	brass		77.8	21.6	0.0	0.1	0.0
CHEL		CHAG 32	plate 238?	bronze	SA<					
STAL	4563	P1	plate 238	brass						
DRAG		DR BH	plate 238	brass/gunmetal	W					
CHEL		CR 10	plate 238+	brass	WN					
SHEP	722335	Rep 42	plate 238?	leaded bronze/gunmetal	SAW					
CAST		14-97	plate 239	bronze/gunmetal	B					
BALD		Cat 151	plate 240	brass	E					
RICH	7350347		plate 241	leaded bronze	W	69.4	0.6	6.7	18.8	0.1
HAYL		1859	plate 242+	brass	W					
RICH	7351181		plate 242A	brass	(E)	80.8	14.9	2.9	0.9	0.0
RICH	7351342		plate 242A	gunmetal		76.5	7.6	7.8	3.9	0.1
SHEP	722347	Rep 43	plate 246	brass	B					
HAYL		3489	plate 246	leaded gunmetal	W+					
CAST		1-675	plate 246?	leaded brass	E					
OPEN	7826162		plate 247	leaded bronze/gunmetal						
COLC		GBS-254	plate 247?	bronze	W					
RICH	7351300		plate 248	(leaded) bronze/gunmetal	W	72.4	4.7	10.3	6.1	0.1
ASHT	835125	650	plate 248	brass						
SEAM		67-541	plate 248	brass/gunmetal	W					
WANB		Cat 133	plate 248?	brass/gunmetal						
COSG		233	plate 249	leaded bronze	?					
WICF		119	plate 249	leaded gunmetal						
HENL	734847	523	plate 249	leaded bronze						
VIND	819165		plate 249	leaded bronze/gunmetal	?					
HAYL		1402	plate 249	(leaded) gunmetal	WA<					
HAYL		141	plate 249	leaded bronze	W(A)					
CORB	868628		plate 249	bronze/gunmetal	W					

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
CHEL		CHV 2	plate 249	leaded gunmetal	WA<					
NORN	621111	184	plate 249	leaded bronze	WA<					
BALD		Cat 147	plate 249?	brass						
HOUS	79208989		plate 249?	bronze						
SEWN	810666		plate 249?	leaded bronze						
WANB		Cat 132	plate 249?	leaded bronze	W(A<)					
RICH	7351209		plate 249?	(leaded) bronze/gunmetal	W					
THIS	610979	BH751	plate 249?	(leaded) bronze	?					
STAL	682679	P3	plate 249?	brass	A<					
RICH	7351733		plate 249A	gunmetal	A<					
PAPC		84-105	plate 249C	(leaded) bronze	A<					
YORK		B 2	plate 250	brass						
RICH	7351727		plate 250	leaded gunmetal	E					
WROX	843142		plate 250	leaded gunmetal	E					
RICH	7350899		plate 252	brass	E	75.6	15.7	0.6	2.2	0.0
WANB		Cat 134	plate 252+/270+	brass/gunmetal	EW					
RICH	7351543		plate 252/6	leaded bronze		83.6	1.6	5.7	14.0	0.1
CHIC		78/CM 115	plate 252B	brass	E					
WICL		43	plate 252B	leaded bronze	E					
RICH	7350088		plate 252B	(leaded) bronze	WE	84.1	1.3	6.7	6.9	0.3
POOL		5257	plate 252B	gunmetal	E					
LOND		CAP 68	plate 252B	bronze	E					
WROX	78000529		plate 252B	leaded bronze	(E)A>					
CATT	8111064		plate 252B/259	(leaded) brass/gunmetal	WA>(E)					
WICL		49	plate 252C	leaded gunmetal	E					
RICH	7351746		plate 252C	bronze	WE	86.8	0.7	7.9	0.8	0.0
ULEY		2046	plate 252C	brass	WE					
WICL		16	plate 252C+	leaded bronze	E					
WICL		17	plate 252C+	leaded bronze	E					
WICL		40	plate 252C+	leaded gunmetal	E					
PIER		(63)	plate 253	leaded bronze	WE					
WICL		14	plate 253	leaded bronze	EWA>					
HOUS	816576		plate 253	leaded bronze/gunmetal	?					
WANB		Cat 135	plate 253	bronze	E					
KEST	841247		plate 253	leaded bronze	WE					
TARH		211	plate 253	gunmetal	E					
PIER		3249	plate 253	leaded bronze	E					
GLOU		69/49-22	plate 253	leaded bronze	EW					
GLOU		81/73-79	plate 254	bronze	E					
THIS		THZ2213	plate 254	bronze	E					
NORN	621088	298	plate 254	bronze	E					
WANB		Cat 136	plate 255	brass	EW					
NORN		257	plate 255	(leaded) bronze	E	77.6	0.0	5.6	6.5	0.0
HAYL		3096	plate 255	brass	EWA>					
OPEN	7813885		plate 255	bronze	WE					
YORK		B 1	plate 255+	brass/gunmetal	E					
TIDD		M591	plate 256	gunmetal	E					
RICH	7350086		plate 256	(leaded) bronze/gunmetal	W	84.1	1.8	4.9	5.2	0.1
RICH	7351728		plate 256	leaded bronze/gunmetal	E	71.5	3.5	6.4	11.2	0.0
HOUS	825165		plate 257	leaded bronze	E					
WANB		Cat 137	plate 257	leaded bronze	EW					
NORN	733359		plate 257	leaded bronze/gunmetal	E	75.3	3.2	6.6	12.5	0.0
STAN	8516942		plate 257	bronze/gunmetal	EW					
WINC		VR-223	plate 257	leaded bronze	WE					
WROX	78000518		plate 257	bronze	E					
WROX	775220		plate 257	leaded bronze	E					
LOND		84.261/1	plate 257	brass	E					
LOND		PIC 42	plate 257+	brass	E					

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
WICL		22	plate 257A	leaded bronze	E					
WICL		45	plate 257A	leaded gunmetal	E					
CORB	831686		plate 257A	gunmetal	E					
HOUS	811565		plate 257A	gunmetal						
POOL		5092	plate 257A	bronze	EWA>					
CORB	868604	75-3916	plate 257A	gunmetal	E					
HENL	730937	452	plate 257B	leaded bronze/gunmetal	E					
NORN	620601	194	plate 257B	bronze/gunmetal	E	69.6	4.8	7.7	2.4	0.0
HOUS	753011		plate 257B	leaded bronze	E					
NORN	620608	187	plate 257C	(leaded) gunmetal	E	57.7	8.7	10.6	4.8	0.0
NORN	621109	200	plate 258	brass	E	70.1	14.6	0.6	1.2	0.0
HAYL		(none)	plate 259	leaded bronze	E	73.4	1.5	8.5	10.9	0.1
ULEY		1569	plate 259	leaded bronze	E					
BANT		82	plate 259?	leaded bronze	E					
HOUS	79208643		plate 260	leaded bronze	E					
WANB		Cat 138	plate 260	gunmetal	(E)W					
WANB		Cat 139	plate 260	leaded bronze	EW					
BRAU		283	plate 260	leaded gunmetal	E					
RICH	7351080		plate 260	(leaded) bronze	WE	79.0	0.5	9.3	5.1	0.0
RICH	7351081		plate 260	(leaded) bronze	?	82.6	1.6	6.9	6.1	0.0
NORN	621132	196	plate 260	leaded bronze	E	71.0	0.0	7.3	11.3	0.0
THIS	610736	TH13	plate 260	leaded bronze	E					
WINC		VR77-5461	plate 260	leaded bronze/gunmetal						
WINC		VR-5461	plate 260	leaded bronze	E					
STAN	8800141		plate 260	leaded bronze	WES					
CHIC		ES90-2742	plate 260	leaded bronze	E					
WINC		VR 225	plate 260?	leaded bronze	WE					
YORK			plate 262	brass/gunmetal	E					
NORN	620620	199	plate 262	gunmetal	E					
THIS		THZ1752	plate 262+	brass	WEN					
LOND		PIC 42	plate 262+	brass	E					
WAKE	745075	125	plate 263	leaded gunmetal	E					
NORN	620612	204	plate 263	leaded bronze	E	75.6	0.6	5.8	11.0	0.0
ALDB	78108250	jb28	plate 263	brass	E					
HAYL		2976	plate 263	leaded bronze/gunmetal	E					
CAST		1-665	plate 263	brass/gunmetal	E					
WICL		31	plate 263+	brass	WA>					
BALD		Cat 148	plate 266	bronze?	E					
GEST		Pub 9/BR 76	plate 266	leaded bronze	E					
NORN	620600	205	plate 266A	gunmetal	E	72.5	9.3	4.8	0.5	0.0
WANB	692162	178	plate 266A	leaded bronze		78.9	0.0	5.5	15.8	0.0
BRAU		120	plate 266A	brass	E	83.3	15.5	1.9	3.3	0.0
POOL		5169	plate 266B	bronze/gunmetal?						
POOL		5090	plate 266B	leaded gunmetal						
CARL		Ae227	plate 267	leaded bronze	E					
WICL		21	plate 267B	leaded bronze	E					
RICH	7351714		plate 267B	(leaded) bronze	E					
RICH	7351730		plate 267B	bronze?	E					
NORN	621153	206	plate 267B	copper	E	91.1	0.0	2.0	1.6	0.0
STAN	8516921		plate 267B	bronze	E					
LOND		LCT 1304	plate 267B	bronze	E					
LOND		12538	plate 267B	brass/gunmetal	E					
LOND		A1918	plate 267B	bronze	E					
THIS		THZ4600	plate 267C	bronze	E					
CAST		1-541	plate 267C	bronze	E					
CAST		1-420	plate 267C	bronze	E					
LOND		A17331	plate 267C	brass?	EW					
LOND		81.629/2	plate 267C	gunmetal?	E					

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
LOND		A26490	plate 267C	brass/gunmetal	E					
WICL		15	plate 268	brass/gunmetal	E					
RICH	7350083		plate 268	leaded bronze?	E					
RICH	7351739		plate 268	leaded bronze	E					
RICH	7351201		plate 268	(leaded) brass/gunmetal	E	85.9	10.9	3.7	4.0	0.0
LEIC		316-193	plate 268	brass	E					
CAST		9-895	plate 268	bronze	E					
LOND		26538	plate 268/199	gunmetal?	E					
CARL		Ae146	plate 268?	leaded bronze	E					
WAKE	745057	29	plate 269	bronze						
WICL		23	plate 269	leaded gunmetal						
HENL	684636	375	plate 269	(leaded) brass/gunmetal						
CORB	822060		plate 269	leaded gunmetal						
POOL		5308	plate 269	leaded gunmetal						
POOL		5168	plate 269	bronze/gunmetal						
DEEP		3631	plate 269	(leaded) bronze						
DEEP		3632	plate 269	leaded gunmetal						
DEEP		3853	plate 269	leaded bronze						
NORN	620602	296	plate 269	bronze	G					
OPEN	7815595		plate 269	gunmetal						
RICH	7350525		plate 269A	(leaded) brass/gunmetal	E	79.2	8.3	3.1	4.6	0.3
WROX	743478		plate 269B	leaded bronze						
STAN	8611866		plate 269B	leaded bronze						
LOND		85.108/5	plate 269B+	brass						
WICL		5	plate 270	bronze	G					
WICL		24	plate 270	bronze	G					
HENL	642023	1	plate 270	gunmetal	GW					
HOUS	79208663		plate 270	bronze	WGS					
HOUS	811598		plate 270	bronze	WG					
MAXE	801274	2892/7732	plate 270	bronze	GS					
WANB		Cat 140	plate 270	bronze	GS					
WANB		Cat 141	plate 270	bronze	GSW					
RICH	7351086		plate 270	gunmetal	G(S)	85.7	4.7	5.1	0.6	0.0
RICH	7351717		plate 270	bronze	WGS	88.5	1.0	6.5	0.8	0.1
RICH	7351729		plate 270	brass	WGS	85.4	10.2	0.0	0.5	0.0
ULEY		7810	plate 270	bronze	GS	92.3	1.9	5.7	0.0	0.0
ULEY		7814	plate 270	brass/gunmetal	GS	85.4	8.3	2.2	0.0	0.0
ULEY		5270	plate 270	bronze	G					
HOUS	855044		plate 270	bronze	WG					
WROX	78000516		plate 270	bronze	G					
LOND		23479	plate 270	brass	G(S)					
CHIC		ES88-6	plate 270	gunmetal	GWS					
INWO		(1971)	plate 270+?	brass	GW					
WROX	743499		plate 270?	gunmetal	W					
WICL		28	plate 271	brass	WG					
WICL		52	plate 271	brass	G					
HENL	642026	36	plate 271	(leaded) gunmetal	GS					
NORN		237	plate 271	brass/gunmetal		87.5	9.2	2.6	0.1	0.0
WINC		VR-5381	plate 271	brass	GSW					
WINC		VR-5577	plate 271	brass	GSW					
WINC		VR-9700	plate 274	brass	WE					
GDUN		Cat 837	plate 275	leaded gunmetal	E					
KILH			plate 275	leaded bronze	A<					
CHIC		79/CM 332	plate 275	gunmetal	E					
NORN	621090	218	plate 275	(leaded) bronze	E	74.1	0.8	4.5	6.7	0.0
NORN	620679	217	plate 275	leaded bronze	E	67.6	0.4	7.4	16.4	0.0
NORN	621115	219	plate 275	leaded bronze/gunmetal	E	73.6	2.8	5.6	8.3	0.0
CAST		10-1731	plate 275	leaded gunmetal	E					

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
LOND		RAG 92	plate 275	brass	E					
LOND		RAG 92	plate 275	brass	E					
LOND		MSL ˆ684	plate 275	leaded bronze	E					
LOND		20780	plate 275	bronze/gunmetal	E					
CHIC		CH86-31	plate 275	brass	E					
GEST		Pub 10/BR108	plate 277	bronze	E					
CAST		1-240	plate 277	gunmetal	E					
LOND		POM 269	plate 277	brass	E					
LOND		POM 269	plate 277	brass ?	EW					
LOND		19108	plate 277	gunmetal						
RICH	7351776		plate 278	gunmetal?						
NORN	621133	210	plate 279	gunmetal	E	74.3	8.1	4.4	2.2	0.0
LOND		3429	plate 279	gunmetal	W					
LOND		19839	plate 279+?	brass	(E)					
MAGI		Pub 20	plate 280+	brass	E	78.7	17.9	1.0	0.6	0.0
GORH	811388		plate 280+	brass	E	76.7	15.1	2.8	4.0	0.2
BRAU		760	plate 300+	brass	B					
BALD	7210447	Cat 152	plate ?	brass	WN					
SHEP		Rep 44	plate ?	gunmetal						
PIER		2375	plate ?	leaded bronze	W					
HENL	730947		plate ?	silver						
COLC		CF-34	plate ?	(leaded) bronze	W					
COLC		CF-53	plate ?	leaded gunmetal	W					
NORN		201	plate ?	leaded bronze	E	67.9	0.7	8.6	12.9	0.0
NORN		236	plate ?	(leaded) gunmetal	E	77.3	5.8	5.2	5.2	0.0
NORN	620637	173	plate ?	(leaded) brass/gunmetal	E	72.3	8.0	2.7	4.3	0.0
NORN	620626	150(STUD)	plate ?	brass	E	74.3	12.2	2.7	2.7	0.0
NORN	620626	150(PLATE)	plate ?	brass	E	69.6	13.4	2.7	3.6	0.0
BALD	7211096	Cat 150	plate ?	brass		73.7	21.4	2.7	0.7	0.0
PIER		122-R10	plate ?	leaded bronze	W	79.8	2.1	7.8	9.9	0.0
PRES	851067	381	plate ?	leaded gunmetal	E					
GORH	820294	2626	plate ?	brass/gunmetal						
PAPC		84-078	plate ?	bronze	E					
DRAG		DR 68 ABO	plate ?	bronze						
CAST		1-676	plate ?	(leaded) brass/gunmetal	E					
CAST		1-395	plate ?	brass	E					
PIER		RSS 6	plate ?	leaded bronze	A<?					
WROX	78000103		plate ?	bronze						
LOND		84.193/2	plate ?	brass	E					
STAN	8800686		plate ?	brass	E					
WORC		3899-8509	plate ?	bronze	A					
RICH	7350895		penan P2	gunmetal		88.7	3.8	4.7	1.4	0.0
LOND		464	penan P2	brass						
LOND		A20819	penan P2	copper						
LOND		A13830	penan P2	brass						
LOND		460	penan P2	brass						
WEEK	781416	216	penan P3	bronze						
BALD		Cat 153	penan P3	bronze						
BALD		Cat 154	penan P3	bronze						
MAGI	7711300	Pub 23	penan P3	(leaded) gunmetal						
SHEP	722208	Rep 45	penan P3	brass						
WAKE	745058	33	penan P3	brass						
WAKE	745059	34	penan P3	bronze						
WAKE	745069	87	penan P3	copper						
GEST		Pub 11/BR	penan P3	brass						
GARD		ME 13	penan P3	bronze						
RICH	7350964		penan P3	leaded gunmetal						

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7351083		penan P3	silver						
RICH	7351419		penan P3	silver						
RICH	7351760		penan P3	brass/gunmetal						
RICH	7351762		penan P3	silver						
RICH	7350974		penan P3	silver						
RICH	7350082		penan P3	bronze		92.7	0.0	7.0	2.0	0.0
RICH	7350084		penan P3	bronze		89.1	1.3	6.9	1.3	0.1
RICH	7350507		penan P3	brass		80.1	16.4	0.0	2.0	0.1
RICH	7351070		penan P3	bronze		86.1	0.0	9.7	1.5	0.6
RICH	7351072		penan P3	(leaded) gunmetal		75.3	8.4	5.5	4.5	0.1
RICH	7351074		penan P3	bronze		92.6	0.1	3.4	1.8	0.0
RICH	7351299		penan P3	brass		88.2	9.1	2.0	2.9	0.0
RICH	7351732		penan P3	brass		80.7	14.0	0.0	0.6	0.1
RICH	7350550		penan P3	bronze/gunmetal		87.9	2.4	3.8	2.1	0.4
RICH	7351099		penan P3	brass		76.1	21.6	0.0	2.3	0.0
RICH	7351720		penan P3	bronze		90.5	1.5	6.3	1.6	0.1
RICH	7351722		penan P3	bronze/gunmetal		87.2	3.9	6.4	1.4	0.1
RICH	7351756		penan P3	brass		88.5	15.1	2.1	0.8	0.0
CABY		106A	penan P3	brass/gunmetal		75.6	14.0	4.1	3.3	0.5
ASHT	835116	556	penan P3	bronze						
WITC	615021	bz1	penan P3	bronze						
TIDD		80-7	penan P3	leaded gunmetal						
CABY		1470	penan P3	gunmetal						
CABY		2268	penan P3	bronze						
THIS		THZ10	penan P3	brass						
THIS		THZ351	penan P3	bronze/gunmetal						
THIS		THZ356	penan P3	bronze/gunmetal						
THIS		THVbag180	penan P3	bronze						
THIS	611021	BH863	penan P3	leaded bronze						
ULEY		5853	penan P3	gunmetal						
STAN	8516895		penan P3	(leaded) bronze						
DRAG		DR 66 HR	penan P3	brass						
DRAG		DR 70 AX	penan P3	bronze/gunmetal						
DRAG		DR 69 WS	penan P3	bronze						
DRAG		DR 70 AC	penan P3	bronze/gunmetal						
DRAG		DR 70 AB	penan P3	gunmetal						
DRAG		DR 67 LN	penan P3	brass						
DRAG		DR 72 KI	penan P3	gunmetal						
DRAG		DR 72 ALJ	penan P3	bronze						
DRAG		DR 70 BBP	penan P3	bronze/gunmetal						
DRAG		DR (I)	penan P3	bronze						
RICH	7351880		penan P3	bronze						
RICH	7351881		penan P3	bronze						
LOND		A5749	penan P3	bronze						
STAN	8800118		penan P3	bronze						
STAN	8701793		penan P3	(leaded) bronze						
STAN	8701777		penan P3	brass						
STAN	8700801		penan P3	bronze/gunmetal						
STAN	8700084		penan P3	brass/gunmetal						
STAN	8612987		penan P3	bronze						
STAN	8612988		penan P3	brass						
STAN	8612492		penan P3	bronze						
LOND		467	penan P3	gunmetal ?						
SNET		Cat 33	penan P3	brass/gunmetal						
DORC		Rep 28	penan P4	bronze						
BALD		Cat 155	penan P4	brass/gunmetal						
HENL	642037	130	penan P4	gunmetal						
HENL	734862	446	penan P4	copper						

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
HENL	734846	518	penan P4	gunmetal						
TIDD		M587	penan P4	brass						
TIDD		82-65	penan P4	brass						
TIDD		82-147	penan P4	bronze/gunmetal						
CORB	822079		penan P4	(leaded) gunmetal						
WANB		Cat 142	penan P4	brass						
WANB		Cat 143	penan P4	copper						
WANB		Cat 144	penan P4	leaded bronze						
WANB		Cat 145	penan P4	bronze/gunmetal						
COLE		771	penan P4	bronze						
COLE		395	penan P4	copper						
KEST	841257		penan P4	brass						
BALD	715540	Cat 156	penan P4	brass		81.7	17.3	1.8	1.2	0.1
WROX	760638		penan P4	bronze		90.8	0.0	4.7	0.7	0.0
PRES	851065	655	penan P4	(leaded) gunmetal		76.2	9.2	7.6	6.7	0.0
PRES	851063	433	penan P4	bronze						
PRES	851062	426	penan P4	bronze						
WITC	615026	bz6	penan P4	bronze						
LEIC		316-48	penan P4	gunmetal						
ALDB	78108240	jb31	penan P4	brass						
TIDD		81-863	penan P4	copper						
POOL		5259	penan P4	(leaded) bronze						
POOL		5171	penan P4	gunmetal						
ULEY		292	penan P4	brass						
ULEY		3647	penan P4	bronze						
ULEY		5858	penan P4	gunmetal						
CARL		Ae266	penan P4	gunmetal						
DRAG		DR 72 AA	penan P4	bronze						
DRAG		DR 70 AD	penan P4	brass						
DRAG		DR 69 DV	penan P4	bronze						
RICH	7351882		penan P4	gunmetal						
RICH	7351910		penan P4	brass						
RICH	7351913		penan P4	bronze/gunmetal						
WROX	82000288		penan P4	bronze						
WROX	78001037		penan P4	bronze						
WROX	7312123		penan P4	bronze						
WROX	8405523		penan P4	bronze						
WROX	775296		penan P4	brass						
LOND		3431	penan P4	gunmetal						
LOND		A123	penan P4	bronze						
LOND		463	penan P4	bronze						
LOND		3430	penan P4	bronze						
LOND		20384	penan P4	bronze						
LOND		20383	penan P4	bronze						
LOND		A5087	penan P4	bronze						
LOND		461	penan P4	brass						
STAN	8612547		penan P4	gunmetal						
STAN	8611716		penan P4	brass						
HENL	734863	474	penan P4?	bronze/gunmetal						
WANB		Cat 149	penan P4?	bronze						
RICH	7351918		penan P4?	bronze/gunmetal						
CATS		401	penan P4A	brass						
CARV		67	penan P4A	bronze						
RICH	7350598		penan P4A	bronze		89.0	0.3	8.3	0.8	0.1
RICH	7350894		penan P4A	brass		77.9	16.3	2.9	1.7	0.1
RICH	7350897		penan P4A	bronze/gunmetal		70.6	3.8	8.0	0.6	0.0
RICH	7351089		penan P4A	brass		88.0	11.1	0.0	0.4	0.0
RICH	7351589		penan P4A	bronze/gunmetal		86.2	1.7	3.9	1.7	0.1

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
RICH	7351710		penan P4A	(leaded) bronze		70.4	1.5	8.0	5.3	0.1
RICH	7351750		penan P4A	silver						
CARV		61	penan P4A	bronze						
CATS		91	penan P4A	bronze		95.1	0.0	5.4	0.0	0.1
CATS		155	penan P4A	brass		75.7	13.6	0.0	0.0	0.1
DRAG		DR 68 OY	penan P4A	brass						
LOND		LCT 1309	penan P4A	bronze						
RICH	7351588		penan P4B	silver						
RICH	7351740		penan P4B	bronze		87.8	0.5	10.5	1.0	0.0
PIER		4433	penan P5	silver						
PIER		4451	penan P5	bronze						
HENL	684633	369	penan P5	bronze						
ALDB	78108238	jb30	penan P5	bronze/gunmetal						
BRAN	774116	3227	penan P5	bronze?	W					
DORC	7816535		penan P5/P4A	bronze						
GEST		Pub	penan P6	gunmetal						
PIER		3151	penan P6	brass						
PIER		2363	penan P6	bronze/gunmetal						
PIER		225	penan P6	bronze						
PIER		3780	penan P6	gunmetal	E					
CORB	834922		penan P6	gunmetal						
HOUS	803032		penan P6	bronze?						
RICH	7351084		penan P6	leaded gunmetal		79.2	5.1	5.2	8.4	0.0
PRES	851067	1708	penan P6	bronze		89.3	0.0	9.8	0.6	0.0
ALDB	78108240	jb32	penan P6	brass						
CORB	868624		penan P6	brass/gunmetal						
LOND		11308	penan P6	brass/gunmetal						
PIER		60	penan P6/P7	leaded gunmetal						
RICH	7351073		penan P6A	bronze		84.8	0.1	14.5	3.6	0.1
OPEN	7813684		penan P6A	bronze						
YORK		M204	penan P6B	bronze						
CAME		76-10	penan P6C	bronze						
CORB	831684		penan P6C	bronze/gunmetal						
WANB		Cat 146	penan P6C	copper						
RICH	7351376		penan P6C	bronze		95.0	0.4	6.8	0.4	0.1
WELT		SF34	penan P6C	bronze						
ALDB	78108240	jb33	penan P6C	bronze						
ALDB	78108240	jb34	penan P6C	gunmetal						
ALDB	78108240	jb35	penan P6C	gunmetal						
ALDB	78108240	jb36	penan P6C	copper/bronze						
ALDB	78108240	jb37	penan P6C	bronze						
ALDB	78108240	jb38	penan P6C	copper/bronze						
POOL		5141	penan P6C	bronze						
CHEL		CHV 23	penan P6C	brass/gunmetal						
CARL		Ae256	penan P6C	leaded gunmetal						
CATT	8111013		penan P6C	brass/gunmetal						
OPEN	7815332		penan P6C	bronze						
PAPC		84-064	penan P6C	bronze						
PAPC		84-102	penan P6C	bronze/gunmetal ?						
WROX	7312364		penan P6C	bronze						
LOND		459	penan P6C	bronze						
LOND		A2393	penan P6C	bronze						
LOND		A2392	penan P6C	brass						
STAN	8612556		penan P6C	bronze/gunmetal						
CARL		Ae127	penan P6C?	bronze						
CARL		Ae132	penan P6C?	gunmetal						
CARL		Ae145	penan P6C?	gunmetal						
CARL		Ae202	penan P6C?	bronze						

Table C.3 (continued)

Site	AML No	Site No	Group Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
WROX	80000243		penan P6C?	bronze/gunmetal						
ALDB	78108240	jb39	penan P6D	leaded bronze/gunmetal						
MAGI	7711346	Pub 24	penan P7	(leaded) bronze/gunmetal						
CATS		455	penan P7	bronze						
YORK		M367	penan P7	bronze						
TIDD		M5	penan P7	bronze/gunmetal						
TIDD		83-1	penan P7	bronze/gunmetal						
RICH	7350774		penan P7	bronze		91.5	0.2	6.6	0.5	0.0
BALD	7211149	Cat 157	penan P7	bronze		81.2	1.5	11.8	0.7	0.0
PRES		1238	penan P7	leaded bronze						
WELT		468	penan P7	brass						
WELT		2	penan P7	gunmetal						
WELT		212	penan P7	gunmetal						
THIS		THZ1323	penan P7	brass						
CHEL		CHAG 24	penan P7	bronze						
WROX	78001000		penan P7	leaded bronze						
LEIC		316-202	penan P7?	brass		79.8	17.3	0.0	0.5	0.0
WANB		Cat 147	penan P9	brass						
ALDB	78108239	jb29	penan P9	brass						
TIDD		82-119	penan P10	bronze						
RICH	7351770		penan P11C	brass		78.1	24.7	0.0	0.0	0.1
PIER		2335	penan P12	brass						
PIER		4694	penan P12	brass						
WELT		416	penan P12	bronze						
DRAG		DR 71 AUG	penan P12	brass						
SEAM		?-105	penan P13	leaded gunmetal						
BRAU		914	penan ?	gunmetal						
BALD		Cat 159	penan ?	bronze						
YORK		M451	penan ?	leaded gunmetal						
WHIT		I	penan ?	bronze						
RICH	7350595		penan ?	copper						
BRAU		72/342	penan ?	bronze						
RICH	7350601		penan ?	copper		102.0	0.0	0.5	0.0	0.1
RICH	7350778		penan ?	bronze	E	81.9	0.5	15.2	3.2	0.1
RICH	7350896		penan ?	brass		77.0	17.7	2.3	0.4	0.0
RICH	7350984		penan ?	gunmetal		86.6	3.3	4.5	1.5	0.1
RICH	7351071		penan ?	bronze/gunmetal		83.2	1.9	4.8	1.6	0.1
RICH	7351163		penan ?	leaded gunmetal		69.4	8.2	5.6	9.0	0.1
RICH	7351004		penan ?	bronze		82.4	0.0	15.2	2.4	0.1
RICH	7351623		penan ?	brass		70.2	18.5	2.4	2.5	0.1
RICH	7351755		penan ?	copper		99.0	0.2	0.5	0.1	0.0
BALD	7211176	Cat 158	penan ?	bronze	W	82.5	0.0	10.9	1.3	0.1
ALDB	78108240	jb40	penan ?	copper/bronze						
CABY		1933	penan ?	gunmetal						
CABY		182	penan ?	brass						
CABY		2709	penan ?	brass						
CABY		470	penan ?	bronze						
POOL		5093	penan ?	leaded bronze						
POOL		5226	penan ?	bronze						
STAN	8516873		penan ?	(leaded) bronze						
COLC		1.81-3699	penan ?	copper/brass?						
COLC		GBS-736	penan ?	bronze						
COLC		1.81-459	penan ?	brass						
COLC		1.81-790	penan ?	brass						
ULEY		5526	penan ?	brass						
ULEY		4662	penan ?	brass						
POUN		Ae52	penan ?	bronze						
CATT	8111151		penan ?	bronze						

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
CATT	8111613		penan	?	bronze						
DRAG		DR 73 LM	penan	?	bronze						
ICKH			penan	?	brass/copper						
ICKH	746396	910	penan	?	gunmetal?						
CATT	8111233		penan	?	gunmetal						
RICH	7351916		penan	?	brass						
LOND		LCT 1133	penan	?	bronze						
STAN	8611738		penan	?	bronze						
WORC		740	penan	?	gunmetal						
WROX	78000944		4/5	?	brass						
LOND		CASS 141	5/6	?	(leaded) bronze						
LOND		FCS 56	5/6	?	?						
LOND		FEN 151	5/6	?	?						
LOND		FEN 269	5/6	?	bronze						
LOND		GPO 3933	5/6	?	bronze						
LOND		GPO 3759	5/6	?	(leaded) bronze						
LOND		GPO 4292	5/6	?	leaded bronze						
LOND		LCT 1501	5/6	?	bronze						
WORC		3899-c17035	5/6	?	bronze						
WORC	907217	3899-c11453	5/6	?	brass						
SNET		Cat 24	5/6	?	(leaded) bronze						
LOND		WIV 520	5/6/7	?	brass						
STAN	8516840		5/6/7	?	leaded bronze						
STAN	8516877		5/6/7	?	leaded bronze						
STAN	8611706		5/6/7	?	leaded bronze						
LOND		LCT 1175	5/6?	?	bronze						
LOND		LCT 2009	5/6?	?	(leaded) bronze?						
DRAG		DR 68 HF	5/7?	?	bronze						
TIDD		M4	7/8	?	leaded bronze						
TIDD		82-148	7/8	?	leaded bronze						
CORB	831672		7/8	?	bronze						
CATS		500	7/8?	?	leaded bronze	?	74.2	0.0	9.8	19.0	0.1
VELZ		31B	7/8?	?	(leaded) brass/gunmetal		75.4	12.6	3.6	6.9	0.2
VELZ		31A	7/8?	?	(leaded) brass/gunmetal		74.7	12.6	3.7	6.6	0.3
PRES		1376	7/8?	?	bronze/gunmetal	E	84.2	3.0	6.9	1.0	0.0
LECH		1958-1	?	?	bronze						
BALD		Cat 45	?	?	bronze						
BALD		Cat 46	?	?	bronze						
BALD		Cat 101	?	?	leaded bronze	W					
BALD		Cat 143	?	?	brass/gunmetal	W					
CAME		76-237	?	?	leaded bronze	W					
CARV		29	?	?	bronze						
WICL		27	?	?	leaded gunmetal						
WICL		35	?	?	leaded bronze						
WICL		53	?	?	leaded bronze						
WICL		54	?	?	brass						
VIND	819177		?	?	gunmetal?	WA>					
WANB	684406	Cat 35	?	?	bronze						
WANB		Cat 36	?	?	bronze/gunmetal						
WANB		Cat 37	?	?	bronze						
WANB		Cat 150	?	?	bronze						
KEST	841266		?	?	bronze						
CHIC	794756	79/CM 579	?	?	leaded gunmetal?						
BRAU		359	?	?	brass						
RICH	7350085		?	?	brass	E	78.5	11.9	2.5	3.4	0.1
SHEP	722213	Rep 27	?	?	bronze		78.1	0.2	14.3	0.8	0.0
BRAU		361	?	?	bronze/gunmetal		78.5	4.2	8.5	0.1	0.0

Table C.3 (continued)

Site	AML No	Site No	Group	Type	Alloy	Decor	Cu %	Zn %	Sn %	Pb %	Ag %
BALD	7211083	Cat 50	?	?	brass		71.9	23.0	1.3	0.1	0.0
BALD	7211183	Cat 84	?	?	bronze		90.3	0.4	14.6	0.0	0.1
BALD	7210319	Cat 47	?	?	brass		73.5	23.5	0.7	1.0	0.1
BROU	671624	36	?	?	bronze						
TARH		228	?	?	bronze						
CABY		871	?	?	bronze/gunmetal						
POOL		5129	?	?	gunmetal	E					
CHEL		CHV 9	?	?	brass						
CHEL		CHV 8	?	?	brass						
CHEL		CHM Ae277	?	?	bronze						
CARL		Ae209	?	?	brass						
CARL		Ae265	?	?	bronze						
STAL	682663	N2	?	?	brass						
POUN		Ae 16	?	?	bronze						
CAST		15-779	?	?	bronze						
RICH	7351871		?	?	brass						
PIER		106D 189	?	?	leaded bronze/gunmetal						
LOND		DMT 134	?	?	leaded bronze						
LOND		GPO 4364	?	?	bronze						
LOND		LCT 587	?	?	leaded bronze/gunmetal						
LOND		RAG 49	?	?	(leaded) bronze						
WROX	78001024		?	?	(leaded) bronze						
WROX	78001170		?	?	leaded bronze	W					

Table C.4 - Analytical results for late Iron Age and Roman objects other than brooches

Notes and key to the Table:

The Site is identified by the four letter code defined in Table C.1.

The AML No is the accession number given to the object by the Ancient Monuments Laboratory.

The Site No is usually the finds number assigned by the excavator but is sometimes the catalogue number used in publishing the finds.

The nature of the objects is described in the column headed Object. The codes that appear in the Type column refer to object typologies which are defined as follows:

Spoons:
- A = small round bowl with rat-tail handle
  - Aa = handle springs from rim of bowl
  - Ab = handle continues into rib running across back of bowl
- B = similar to A but with small oval or pear-shaped bowl
- C = 'mandolin' or 'purse'-shaped bowl; handle can be offset and/or collared
- D = large oval or pear-shaped bowl; handle usually offset and can be plain or twisted

Bracelets: The typology follows that defined by Crummy (1983)
- 1 = wire
- 2 = cable
- 3 = plain
- 4 = notched, toothed, crenelated
- 5 = transverse grooves
- 6 = diagonal grooves
- 7 = punched or raised dots
- 8 = hatched
- 9 = bead-imitative
- 10 = multiple motifs
- 11 = other

Ring/tokens:
- 1 = sheet metal shaped and filled with solder
- 2 = cast in ?open moulds
- 3 = sheet metal 'washers'
- 4 = other

* = early military metalwork

The Date is the date of the context in which the object was found and is therefore a *terminus ante quem* for its production and use.

The alloy name has been derived from XRF analyses as outlined in Appendix B except for those objects from Hayling Island marked $ which were analysed by AAS where the alloy names are as defined in Chapter 9; these AAS results are given in Table C.5.

The letters in the column headed Decor describe the nature of any applied decoration; they have the same meanings as in Table C.3.

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
ASHT	835139		'crab' casting			bronze	
ASHT	835078		balence arm			gunmetal	
ASHT	835064		bar, 2-piece			gunmetal	
ASHT	835100		bar, part-made			bronze	
ASHT	835071		bracelet			brass	
ASHT	835089		bracelet			bronze	
ASHT	835098		bracelet			bronze	
ASHT	835099		bracelet			bronze	
ASHT	835103		bracelet			bronze	
ASHT	835106		bracelet			brass	
ASHT	835144		bracelet			leaded gunmetal	
ASHT	835162		bracelet			silver	
ASHT	835063		fitting			brass	
ASHT	835082		lid			brass	
ASHT	835087		ligula			leaded gunmetal	
ASHT	835135		ligula			bronze	
ASHT	835149		ligula			bronze	
ASHT	835084		nail cleaner			gunmetal	
ASHT	835088		nail cleaner			bronze	
ASHT	835090		nail cleaner			leaded bronze	
ASHT	835091		nail cleaner			bronze	
ASHT	835133		nail cleaner			bronze	
ASHT	835141		nail cleaner			bronze	
ASHT	835147		nail cleaner			leaded bronze	
ASHT	835124		needle			bronze	
ASHT	835140		object, compound			copper	
ASHT	835081		pin			brass	
ASHT	835085		pin			brass	
ASHT	835104		pin			bronze	
ASHT	835107		pin			leaded bronze	
ASHT	835112		pin			gunmetal	
ASHT	835118		pin			brass	
ASHT	835127		pin			leaded bronze	
ASHT	835155		pin			bronze	
ASHT	835128		plate, decorated			gunmetal	
ASHT	835095		ring			bronze	
ASHT	835102		ring			leaded gunmetal	
ASHT	835160		ring				S
ASHT	835161		ring			silver	
ASHT	835096		ring, spiral			gunmetal	
ASHT	835083		seal box base			brass	
ASHT	835129		sheet cap			brass	
ASHT	835152		sheet cylinder			bronze	
ASHT	835066		sheet object			brass	
ASHT	835097		sheet object			bronze	
ASHT	835154		sheet object			brass	
ASHT	835080		sheet, repousse			bronze	
ASHT	835121		spatula probe			bronze	
ASHT	835151		spoon bowl			bronze	W
ASHT	835143		strip, decorated			gunmetal	
ASHT	835105		strip, part-made			brass	
ASHT	835065		strip, perforated			brass	
ASHT	835131		strip, rivetted			brass	
ASHT	835114		tack, domed head			brass	
ASHT	835069		terminal, knobbed			gunmetal	
ASHT	835079		terminal, loop			gunmetal	
ASHT	835092		tweezers			gunmetal	
ASHT	835132		tweezers			bronze	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
ASHT	835136		tweezers			bronze	
BALD	7210240		lump/ingot ?			pewter	
BALD	801910		mirror			bronze/speculum	
BALD	801911		mirror			bronze/speculum	
BALD	801912		mirror			bronze/speculum	
BALD	7210248		sheet fragment			pewter	
BALD	7210247		vessel rim			leaded gunmetal	
BALD	7210238		vessel, dish			pewter	
BALD	7210239		vessel, dish			pewter	
CARL		AE 68	?		4th	bronze ?	
CARL		AE 252	?		late1st/e2nd	leaded gunmetal	
CARL		AE 119	belt fastener		3-4th	bronze	
CARL		AE 72	belt fitting		Saxon	gunmetal ?	
CARL		AE 146	belt fitting		3rd/4th	brass ?	
CARL		AE 168	belt fitting ?		3rd	leaded bronze	E
CARL		AE 160	buckle		2-4th	bronze	
CARL		AE 259	buckle		late1st/e2nd	brass	
CARL		AE 128	chain		3rd	brass	
CARL		AE 114	dress fastener		12th	leaded bronze	
CARL		AE 231	figurine ?		Roman	brass	
CARL		AE 103	figurine head/mask		12th	bronze	
CARL		AE 249	fitting, annular		2nd	leaded gunmetal	
CARL		AE 82	handle		12th	leaded bronze	
CARL		AE 121	handle of bucket		3-4th	bronze ?	
CARL		AE 255	hook/strap end ?		2nd	bronze	
CARL		AE 240	key ?		late1st/e2nd	leaded gunmetal	
CARL		AE 135	knob		2nd	brass ?	
CARL		AE 52	knob		12-16th	brass	
CARL		AE 262	ligula		late1st/e2nd	gunmetal	
CARL		AE 118	loop		late 4th	leaded ?	
CARL		AE 149	mirror		2nd	bronze/speculum	
CARL		AE 124	mount, openwork		12th	leaded bronze	
CARL		AE 198	pendant		2nd	leaded gunmetal	
CARL		AE 79	pin		medieval	gunmetal	
CARL		AE 246	pin		late1st/e2nd	gunmetal	
CARL		AE 193	ring, finger		3rd	leaded bronze	E
CARL		AE 2	saucepan handle			leaded bronze	
CARL		AE 143	scabbard slide		3rd	leaded bronze	
CARL		AE 58	seal box		13-16th	leaded bronze	E
CARL		AE 156	seal box		late 4th	leaded bronze	
CARL		AE 218	seal box		Roman	leaded gunmetal	E
CARL		AE 107	seal box base		4th	leaded gunmetal	
CARL		AE 164	seal box lid		4th	leaded bronze	E
CARL		AE 192	seal box lid		3rd	leaded bronze	E
CARL		AE 244	seal box lid			leaded bronze	E
CARL		AE 245	seal box lid		2-4th	leaded bronze	E
CARL		AE 155	seal box lid ?		late 4th	leaded bronze	E
CARL		AE 272	sheet boss			brass/gunmetal	
CARL		AE 113	sheet object		4th	brass	
CARL		AE 253	sheet object		2-4th	brass	
CARL		AE 186	skillet handle		3rd	leaded bronze	
CARL		AE 267	skillet handle		late1st/e2nd	leaded bronze	
CARL		AE 237	spoon	Aa	late1st/e2nd	brass	
CARL		AE 247	spoon	Ab	late1st/e2nd	leaded bronze	W
CARL		AE 166	strap end			brass	
CARL		AE 117	strapping		saxon ?	leaded bronze/gunmetal	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
CARL		AE 250	strip + dome		Roman	copper	
CARL		AE 123	stud		3-4th	leaded gunmetal	E
CARL		AE 195	stud		3rd	leaded bronze	E
CARL		AE 201	stud		2nd	leaded bronze	
CARL		AE 191	stud, equal-ended		3rd	leaded gunmetal	E
CARL		AE 261	terret ?		late1st/e2nd	leaded bronze	
CARL		AE 235	vessel, bowl		late1st/e2nd	leaded bronze	
CHEL			votive bar		late 1st	brass	
COLE		618	amulet?			bronze	
COLE		95	attachment loop			bronze	
COLE		90	bracelet	2		bronze	
COLE		487	bracelet	1		brass	
COLE		558	bracelet	2		bronze	
COLE		872	bracelet	11		bronze	
COLE		2004	dress fastener			leaded bronze	E
COLE		629	earscoop			bronze	
COLE		113	fitting			leaded bronze	
COLE		66	ligula			gunmetal	
COLE		890	nail			copper	
COLE		67	nail cleaner			bronze	
COLE		605	nail cleaner			leaded bronze	
COLE		161	nail?			leaded bronze	
COLE		92	needle			bronze	
COLE		114	pin			bronze	
COLE		586 or 588	pin			bronze	
COLE		612	pin			gunmetal	
COLE		637	pin			bronze	
COLE		679	pin			leaded bronze	
COLE		1001	pin			bronze	
COLE		290	pin shaft			leaded bronze	
COLE		776	pin?			leaded bronze	
COLE		195	ring: finger			gunmetal	
COLE		13	rod			leaded bronze	
COLE		1003	seal box lid			leaded bronze	E
COLE		1000	steelyard			leaded bronze	
COLE		7	strip			leaded gunmetal	
COLE		51	strip			leaded gunmetal	
COLE		467	strip			leaded bronze	
COLE		667	strip			brass	
COLE		215	strip: decorated			gunmetal	
COLE		352	stud			leaded bronze	E
COLE		2001	terret?			leaded gunmetal	
COLE		324	tweezers			bronze	
COLE		521	tweezers			bronze	
COLE		824	tweezers			bronze	
COLE		2007	tweezers?			leaded bronze	
COLE		318	vessel fragment?			brass	
COLE		18	wire loop			brass	
GLOU		Cat 7	baldric mount	*		brass	
GLOU		Cat 17	belt loop	*		bronze	
GLOU		Cat 9	belt strip	*		brass	
GLOU		Cat 14	belt strip	*		brass	
GLOU		Cat 10	belt strip terminl	*		brass	
GLOU		Cat 8	belt terminal	*		gunmetal	
GLOU		Cat 12	buckle	*		brass	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
GLOU		Cat 13	buckle	*		leaded bronze	
GLOU		Cat 11	buckle & plate	*		brass	
GLOU			cheek piece	*		copper	
GLOU		Cat 4	dolabra sheath ftg	*		brass	
GLOU		Cat 16	mount	*		brass	
GLOU		Cat 1	pendant	*		brass	
GLOU		Cat 2	pendant	*		brass	W
GLOU		Cat 3	pendant	*		brass	
GLOU		Cat 18	spindle from stool	*		brass	
GLOU		Cat 5	strap junction	*		brass	
GLOU		Cat 6	terminal & rivet	*		brass	
GORH	820051	152	binding		1st	bronze	
GORH	826469	2884	binding, strap		2nd	bronze	
GORH	811399	3141	boss, ?mount		3rd/4th	(leaded) gunmetal	
GORH	820352	3394a	bracelet		3rd	(leaded) bronze/gunmetal	
GORH	820353	3394b	bracelet		3rd	(leaded) bronze	
GORH	820354	3458	bracelet	2	4th	gunmetal	
GORH	820299	2648	bracelet		4th	(leaded) bronze	
GORH	820068	427	bracelet			brass	
GORH	820020	27	bracelet			brass	
GORH	826341	4209	bracelet		2nd	bronze	
GORH	822163	2854	bracelet			brass	
GORH	820062	364	buckle		1st	gunmetal	
GORH	820035	101	casting, fragment		1st	bronze	
GORH	820138	1124	chain		1st	brass	
GORH	820324	2901	chain		2nd	brass	
GORH	822160	2761	cosmetic implement		2nd	bronze	
GORH	820111	662	disc		1st	bronze	
GORH	820342	3067	disc		3rd/4th	(leaded) bronze	
GORH	820336	2979	dress fastener		2nd	bronze	E
GORH	820330	2930	drop handle		2nd	brass	
GORH	820331	2947	drop handle		2nd	bronze ?	
GORH	820130	988	ear scoop		1st	bronze	
GORH	820319	2863	ear scoop		2nd	leaded bronze	
GORH	820325	2905	ear scoop		2nd	(leaded) gunmetal	
GORH	811370	1041	figurine fragment		2nd	(leaded) bronze/gunmetal	
GORH	820340	3034	file (cosmetic)		2nd	bronze	
GORH	820261	2233	fitting, cockerel		2nd	(leaded) bronze	W
GORH	820338	2976	folding knife		2nd	brass	
GORH	811376	1213	foot, ?from vessel		4th	gunmetal	
GORH	811394	2982	harness pendant		2nd	gunmetal	W
GORH	811378	1510	head escutcheon			leaded bronze	
GORH	820339	2983	key		2nd	brass	
GORH	820332	2964	ligula		2nd	bronze	
GORH	826474	2946	link		2nd	brass/gunmetal	
GORH	820321	2888	lock bolt		2nd	leaded gunmetal	
GORH	820065	388	lock bolt		2nd	leaded gunmetal	
GORH	820083	532a	lock pin		2nd	bronze/gunmetal	
GORH	820361	3730	mount		4th	leaded gunmetal	
GORH	820360	3547	mount		2nd	brass	
GORH	820268	2347	mount		2nd	brass/gunmetal	
GORH	820287	2536	mount		2nd	brass/gunmetal	W
GORH	811375	1208	mount		2nd	brass	A>
GORH	811366	853	mount, pelta			(leaded) gunmetal	
GORH	820267	2341	mount, pelta		4th	leaded bronze/gunmetal	
GORH	811392	2759	mount, vine-leaf		2nd	brass/gunmetal	
GORH	820139	1128	nail cleaner		1st	(leaded) bronze	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
GORH	820325	2905	nail cleaner		2nd	bronze	
GORH	820337	2981	needle		2nd	gunmetal	
GORH	820314	2810	needle		2nd	brass/gunmetal	
GORH	820322	2897	needle		2nd	bronze/gunmetal	
GORH	820329	2929	needle		2nd	bronze	
GORH	826473	2919	needle		2nd	brass	
GORH	826470	2885	needle		2nd	bronze	
GORH	820351	3372	needle		3rd/4th	bronze/gunmetal	
GORH	820036	130	pin		1st	brass	
GORH	820064	385	pin		mid 2nd	(leaded) gunmetal	
GORH	820323	2900	pin		2nd	bronze/gunmetal ?	
GORH	826471	2899	pin		2nd	bronze/gunmetal	
GORH	820269	2349	pin		2nd	bronze	
GORH	820074	483	pin		2nd	bronze	
GORH	820114	415	pin		2nd	(leaded) bronze	
GORH	820152	1191	pin		2nd	(leaded) bronze	
GORH	820108	632	pin		2nd	bronze	
GORH	826330	4085	pin		2nd	bronze	
GORH	820091	573	pin		2nd/3rd	gunmetal	
GORH	820140	1131	pin		3rd/4th	(leaded) bronze/gunmetal	
GORH	820134	1112	pin		3rd	bronze	
GORH	820128	968	pin		3rd	(leaded) bronze/gunmetal	
GORH	811396	3066	pin		3rd	brass/gunmetal	
GORH	820056	212	pin		4th	(leaded) bronze	
GORH	820008	4	pin			bronze	
GORH	820296	2630	pin			bronze	
GORH	820297	2632	pin			bronze	
GORH	820271	2373	pin		2nd	(leaded) gunmetal	
GORH	820280	2429	pin			bronze	
GORH	820013		pin			gunmetal	
GORH	811395	3012	plate		2nd	bronze	
GORH	811400	3142	razor handle		3rd	brass	
GORH	820310	2720	ring		2nd	leaded bronze	
GORH	820318	2862	ring		2nd	bronze ?	
GORH	820346	3249	ring		3rd/4th	leaded bronze	
GORH	820343	3088	ring		3rd/4th	leaded bronze/gunmetal	
GORH	820013		ring			leaded bronze/gunmetal	
GORH	820369	3974	ring		3rd	(leaded) bronze	E
GORH	820358	3523	ring (bent strip)		4th	bronze	
GORH	820345	3186	ring key		4th	leaded gunmetal	
GORH	826350	2294	rivet/pinhead		2nd	gunmetal	
GORH		369	rivet/pinhead		2nd	bronze	
GORH	820241	1850	scabbard runner		2nd	(leaded) gunmetal	
GORH	811397	3112	seal box		3rd/4th	(leaded) bronze/gunmetal	E
GORH	821589	494	seal box base			(leaded) bronze/gunmetal	
GORH	826340	4207	seal box lid		2nd?	(leaded) bronze	E
GORH	811377	1456	seal box lid		2nd/3rd	leaded bronze	E
GORH	820335	2978	spatula		2nd	gunmetal	
GORH	811386	2980	spoon	Aa	2nd	brass	W
GORH	811387	2911	spoon	Ab	2nd	leaded gunmetal	W
GORH	820052	164	spoon	Ab		(leaded) bronze	
GORH	811390	2417	spoon	Ab		leaded bronze/gunmetal	
GORH	811367	859	spoon bowl	Ab		bronze	W
GORH	811368	961	spoon bowl		3rd	base silver	
GORH	826477	2962	strip		2nd	bronze	
GORH	811398	3140	strip, decorated		3rd/4th	bronze	
GORH	820320	2887	stud		2nd	brass	WN
GORH	820236	1770	stud			(leaded) gunmetal	E

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
GORH	820082	531	stud		2nd	bronze	E
GORH	811380	1976	stud		2nd	(leaded) bronze	E
GORH	811402	3434	stud			(leaded) brass ?	E
GORH	820363	3779	stud, lion-headed		4th	(leaded) brass/gunmetal	
GORH	820026	11	stud/mount			bronze ?	E?
GORH	820121	856	stylus/pin shaft			leaded bronze	
GORH	820147	1194	tweezers		1st	bronze	
GORH		893	tweezers		1st	bronze/gunmetal	
GORH	820328	2924	tweezers		2nd	(leaded) bronze	
GORH	826478	2966	tweezers		2nd	(leaded) bronze	
GORH	820325	2905	tweezers		2nd	bronze	
GORH	820350	3347	tweezers		2nd/3rd	gunmetal	
GORH	820344	3089	tweezers		3rd/4th	brass	
GORH	811401	3329	tweezers		3rd/4th	gunmetal	
GORH	820265	2295	weight (disc)		2nd	leaded bronze	
GORH	820327	2922	weight (disc)		2nd	leaded bronze	
GORH	822161	2794	weight (disc)		2nd	(leaded) bronze	
GORH	820234	1773	weight (disc)		4th	leaded bronze	
GORH	820055	184	weight (disc)			leaded bronze	
GORH	820244	1958	weight (disc)			(leaded) bronze	
GORH	811364	8	wing, from eagle			(leaded) bronze	
HAYL		24	amulet?			(leaded) brass $	
HAYL		3345	apron mount	*		brass	WA>N
HAYL		537	arrow?			bronze	
HAYL		430	belt hook		recent	leaded copper $	
HAYL		36	belt hook, winged		1stBC-E 3rd?	(leaded) bronze $	
HAYL		29	binding		1stBC-E 3rd?	bronze	
HAYL		54	binding		1stBC-E 3rd?	bronze	
HAYL		60	binding		1stBC-E 3rd?	bronze	
HAYL		81	binding		IIV	bronze	
HAYL		106	binding		1stBC-E 3rd?	bronze	
HAYL		206	binding		3rd-4th	bronze	
HAYL		209	binding		1stBC-E 3rd?	bronze	
HAYL		451	binding		1stBC-M 1st	silver	
HAYL		508	binding			bronze	
HAYL		517	binding			bronze	
HAYL		518	binding		1stBC-E 3rd	bronze	
HAYL		521	binding		1stBC-E 3rd	bronze	
HAYL		523	binding		1stBC-E 3rd	bronze	
HAYL		539	binding			(leaded) bronze	
HAYL		564	binding			bronze	
HAYL		887	binding		1stBC-M 1st	bronze	
HAYL		1026	binding		1stBC-M 1st	bronze	
HAYL		1102	binding			leaded bronze	
HAYL		1338	binding		1stBC-E 3rd	bronze	
HAYL		1339	binding		1stBC-E 3rd	bronze	
HAYL		1456	binding		L 1st-E 3rd	bronze	
HAYL		1472	binding		1stBC-E 3rd	bronze	
HAYL		1650	binding		1stBC-E 3rd	bronze	
HAYL		1873 & 1883	binding		1stBC-E 3rd	bronze	
HAYL		2094	binding		1stBC-M 1st	bronze	
HAYL		2404	binding		3rd-4th	gunmetal	
HAYL		2641	binding		3rd-4th	(leaded) bronze	W?
HAYL		449	binding		1stBC-M 1st	bronze $	
HAYL		540	binding		1stBC-E 3rd	bronze $	
HAYL		413	binding?		1stBC-M 1st	bronze	
HAYL		7	bracelet		recent	bronze	W

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
HAYL		89 & 439	bracelet		1stBC-E 3rd?	bronze	W
HAYL		252	bracelet			bronze	
HAYL		260	bracelet		60's-E 3rd	bronze	
HAYL		308	bracelet		1stBC-E 3rd?	leaded bronze	
HAYL		338	bracelet		60's-E 3rd	bronze	
HAYL		344	bracelet		1stBC-M 1st	bronze	
HAYL		355	bracelet		L 1st-E 3rd	bronze	
HAYL		379	bracelet		L 1st-E 3rd	bronze	
HAYL		384	bracelet		1stBC-E 3rd?	bronze	
HAYL		391	bracelet		1stBC-E 3rd?	bronze	
HAYL		406	bracelet		1stBC-M 1st	bronze	
HAYL		409	bracelet		1stBC-E 3rd?	leaded gunmetal	
HAYL		437	bracelet		1stBC-M 1st	bronze	
HAYL		438	bracelet		1stBC-M 1st	bronze	
HAYL		503	bracelet			bronze	
HAYL		525B	bracelet		1stBC-E 3rd	bronze	
HAYL		526	bracelet		1stBC-E 3rd	(leaded) bronze	
HAYL		535	bracelet			bronze	
HAYL		589	bracelet		recent	(leaded) bronze	
HAYL		590	bracelet		recent	bronze	
HAYL		509 & 603	bracelet		recent	copper $	
HAYL		634	bracelet		60's-E 3rd	bronze	
HAYL		669	bracelet		1stBC-M 1st	bronze	
HAYL		935	bracelet		recent	bronze	
HAYL		1060	bracelet		1stBC-M 1st	bronze	
HAYL		1083	bracelet		60's-E 3rd	bronze	
HAYL		1469	bracelet		1stBC-E 3rd	bronze	
HAYL		1493	bracelet		1stBC-M 1st	bronze	
HAYL		1783	bracelet		3rd-4th	bronze	
HAYL		1797	bracelet		3rd-4th	bronze	
HAYL		1990	bracelet		3rd-4th	(leaded) bronze	
HAYL		3287	bracelet		1stBC-E 3rd	bronze/gunmetal	
HAYL		3409	bracelet		60's-E 3rd	bronze	
HAYL		3431	bracelet		1stBC-E 3rd	bronze	
HAYL		1450	bracelet		1stBC-E 3rd	bronze $	
HAYL		314	bracelet			bronze $	
HAYL		404	bracelet		1stBC-M 1st	bronze $	
HAYL		3363	bracelet			bronze $	
HAYL		1471	bracelet?		1stBC-E 3rd	bronze	
HAYL		3245	bracelet?		L 1st-E 3rd	bronze $	
HAYL		55	bridle bit		recent	bronze $	
HAYL		233	buckle		L 1st-E 3rd	(leaded) gunmetal	W
HAYL		33	button		3rd-4th	brass/gunmetal	
HAYL		250	clip		1stBC-M 1st	gunmetal	
HAYL		892	disc, conical		1stBC-E 3rd	brass	
HAYL		154	droplet		1stBC-M 1st	bronze	
HAYL		606	droplet		recent	brass/gunmetal	
HAYL		1390	droplet		L 1st-E 3rd	bronze	
HAYL		2744	droplet		3rd-4th	bronze	
HAYL		188	droplet		1stBC-E 3rd?	bronze $	
HAYL		2858	droplet		L 1st-4th	bronze $	
HAYL		3456	ear-ring			bronze	W
HAYL		1642	escutcheon		L 1st-E 3rd	bronze $	
HAYL		2759	fastener			(leaded) bronze	
HAYL		739	fitting		recent	brass	
HAYL		1841	fitting		recent	bronze $	
HAYL		279	foot, off vessel?		60's-E 3rd	leaded bronze	W
HAYL		3120	handle (knife)			brass	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
HAYL		97	handle, tankard		L 1st-E 3rd	bronze	
HAYL		28	handle, tankard		1stBC-E 3rd?	leaded bronze $	
HAYL		893	handle?		3rd-4th	brass	W
HAYL		251	harness ring		3rd-4th	leaded bronze	
HAYL		302	harness ring		1stBC-E 3rd?	leaded bronze	
HAYL		527	harness ring		1stBC-E 3rd	leaded bronze	
HAYL		619 & 625	harness ring		1stBC-M 1st	leaded bronze	
HAYL		654	harness ring		1stBC-M 1st	leaded bronze	
HAYL		1178	harness ring		L 1st-E 3rd	(leaded) bronze	W
HAYL		1757	harness ring		recent	bronze	W
HAYL		1758	harness ring		recent	leaded bronze	
HAYL		3119	harness ring			leaded bronze	
HAYL		3270	harness ring			silver	
HAYL		3375	harness ring		1stBC-E 3rd	leaded bronze	
HAYL		3106	harness ring			bronze $	
HAYL		3241	harness ring		1stBC-E 3rd	bronze $	
HAYL		3108	hinge			bronze	
HAYL		1050	hook		1stBC-M 1st	bronze	
HAYL		555	hook, fish			bronze	
HAYL		1901	lock plate		1stBC-E 3rd?	bronze	
HAYL		433	mount, lion headed		recent	leaded bronze/gunmetal	
HAYL		802	nail		3rd-4th	copper	
HAYL		3473	nail			bronze	
HAYL		3340	nail			copper $	
HAYL		1740	nail		recent	copper $	
HAYL		2992	object			bronze $	
HAYL		82	pin		1stBC-E 3rd?	brass	
HAYL		800	pin		60's-E 3rd	brass	
HAYL		1034	pin		3rd-4th	bronze	
HAYL		2279	pin		3rd-4th	bronze/gunmetal	
HAYL		3113	pin			silver	
HAYL		3178	pin		L 1st-E 3rd	bronze	
HAYL		3446	pin			brass	
HAYL		3465	pin			bronze	
HAYL		3314	pin		L 1st-E 3rd	bronze $	
HAYL		586	purse mount		1stBC-E 3rd	bronze	
HAYL		278	ring		1stBC-M 1st	leaded bronze	
HAYL		393	ring		1stBC-E 3rd?	bronze	
HAYL		485	ring			bronze	
HAYL		506	ring			bronze/gunmetal	
HAYL		559	ring			bronze	
HAYL		688	ring		60's-E 3rd	bronze	
HAYL		765	ring		60's-E 3rd	bronze	
HAYL		1730	ring		recent	leaded bronze	
HAYL		2804	ring		3rd-4th	silver?	
HAYL		3307	ring		recent	leaded bronze	
HAYL		1785	ring		3rd-4th	bronze $	
HAYL		107	ring, finger		1stBC-E 3rd	gunmetal	
HAYL		211	ring, finger		3rd-4th	bronze	
HAYL		242	ring, finger		3rd-4th	bronze	
HAYL		270	ring, finger		1stBC-M 1st	bronze	
HAYL		283	ring, finger		60's-E 3rd	bronze	
HAYL		307	ring, finger		1stBC-M 1st	(leaded) bronze	
HAYL		317	ring, finger		1stBC-M 1st	bronze	
HAYL		353	ring, finger		60's-E 3rd	(leaded) bronze	
HAYL		375	ring, finger		1stBC-M 1st	(leaded) bronze	
HAYL		405	ring, finger		1stBC-E 3rd?	bronze	
HAYL		420	ring, finger		1stBC-M 1st	bronze	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
HAYL		422	ring, finger		1stBC-M 1st	bronze	
HAYL		445	ring, finger		1stBC-M 1st	bronze	
HAYL		538	ring, finger			(leaded) bronze	
HAYL		703	ring, finger		L 1st-E 3rd	bronze	
HAYL		717	ring, finger		3rd-9th	brass/gunmetal	
HAYL		841	ring, finger		1stBC-M 1st	bronze	
HAYL		995	ring, finger		1stBC-M 1st	(leaded) bronze	
HAYL		1108	ring, finger		1stBC-E 3rd	bronze	
HAYL		1215	ring, finger		1stBC-E 3rd	bronze	
HAYL		1393	ring, finger		1stBC-E 3rd	brass	
HAYL		1434	ring, finger		1stBC-E 3rd	bronze	
HAYL		1444	ring, finger		1stBC-E 3rd	bronze	
HAYL		1572	ring, finger		L 1st-E 3rd	bronze	
HAYL		2098	ring, finger		recent	bronze	
HAYL		2791	ring, finger		3rd-4th	brass	
HAYL		2907	ring, finger		L 1st-4th	(leaded) brass	S
HAYL		3240	ring, finger		1stBC-E 3rd	bronze/gunmetal	
HAYL		3334	ring, finger		recent	(leaded) bronze/gunmetal	
HAYL		3378	ring, finger		1stBC-M 1st	bronze	
HAYL		3442	ring, finger		1stBC-M 1st	bronze	
HAYL		3471	ring, finger			leaded gunmetal	(S)
HAYL		511 & 1760	ring, finger?			(leaded) bronze/gunmetal	
HAYL		287	ring/weight		1stBC-E 3rd?	leaded bronze/gunmetal	
HAYL		328	ring/weight		60's-E 3rd	(leaded) bronze	
HAYL		414	ring/weight		1stBC-M 1st	(leaded) bronze	
HAYL		836	ring/weight		1stBC-M 1st	leaded bronze	
HAYL		1571	ring/weight		L 1st-E 3rd	leaded bronze	
HAYL		2570	ring/weight		3rd-9th	bronze	
HAYL		3477	ring/weight			(leaded) bronze	
HAYL		374	ring/weight		1stBC-M 1st	bronze $	
HAYL		3154	ring/weight			leaded bronze $	
HAYL		3461	ring/weight		1stBC-E 3rd	(leaded) bronze $	
HAYL		2872	ring/weight		3rd-4th	leaded bronze $	
HAYL		132	rivet		1stBC-E 3rd?	bronze	
HAYL		531	rivet			bronze	
HAYL		952	rivet		3rd-4th	bronze	
HAYL		3195	rivet		3rd-4th	bronze	
HAYL		3475	rivet			bronze	
HAYL		602	rivet		L 1st-4th	brass $	
HAYL		376	rod		1stBC-E 3rd?	gunmetal	
HAYL		1416	rod, bracelet?		1stBC-E 3rd	(leaded) bronze	
HAYL		14	sheet		recent	bronze	
HAYL		38	sheet		1stBC-E 3rd?	bronze	
HAYL		63	sheet		1stBC-E 3rd?	bronze	
HAYL		277	sheet		3rd-4th	bronze	
HAYL		411	sheet			bronze	
HAYL		459	sheet			copper	G
HAYL		483 & 573	sheet		1stBC-M 1st	bronze	W
HAYL		741	sheet		60's-E 3rd	bronze	
HAYL		744	sheet		1stBC-E 3rd	bronze	
HAYL		1056	sheet		1stBC-M 1st	bronze	
HAYL		1061	sheet		1stBC-M 1st	bronze	
HAYL		1593	sheet		1stBC-E 3rd	bronze	
HAYL		2496	sheet		3rd-4th	copper	
HAYL		2658	sheet		3rd-4th	bronze	
HAYL		2987	sheet		1stBC-E 3rd	bronze	
HAYL		3341	sheet			bronze	
HAYL		552	sheet, tube			brass	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
HAYL		629	sheet, vessel?		60's-E 3rd	bronze	
HAYL		280	spatula		60's-E 3rd	brass	
HAYL		650	spatula		c120	bronze	
HAYL		769	spatula		1stBC-M 1st	leaded bronze/gunmetal	
HAYL		2173	spatula		recent	leaded bronze	
HAYL		2794	spatula			gunmetal	
HAYL		1666	sphere		L 1st-E 3rd	brass	
HAYL		3097	sphere			copper	
HAYL		3080	sphere			brass $	
HAYL		6	strap end		L 1st-4th	bronze	
HAYL		49	strap end		1stBC-E 3rd?	bronze	
HAYL		71	strap end		1stBC-E 3rd	bronze	
HAYL		978	strap end		1stBC-M 1st	bronze	
HAYL		1103	strap end		1stBC-E 3rd	(leaded) bronze	
HAYL		2078	strap end			(leaded) bronze	
HAYL		3488	strap end			leaded gunmetal	N
HAYL		446	strap union		1stBC-M 1st	leaded bronze	
HAYL		460	strap union		recent	leaded bronze $	
HAYL		2887	strip		8th-9th	gunmetal	
HAYL		1111	strip, offcut?		1stBC-M 1st	gold	
HAYL		4	stud		recent	bronze	
HAYL		44	stud		1stBC-E 3rd?	bronze	
HAYL		101	stud		1stBC-E 3rd?	bronze	
HAYL		108	stud		1stBC-E 3rd?	gunmetal	
HAYL		180	stud		1stBC-E 3rd?	bronze	
HAYL		194	stud		L 1st-E 3rd	gunmetal	
HAYL		225	stud		L 1st-4th	bronze	
HAYL		226	stud		L 1st-4th	bronze	
HAYL		232	stud		L 1st-4th	bronze	
HAYL		256	stud		L 1st-4th	bronze	
HAYL		261	stud		L 1st-4th	bronze	
HAYL		271	stud		1stBC-M 1st	bronze	
HAYL		274	stud		60's-E 3rd	bronze/gunmetal	
HAYL		316	stud		1stBC-E 3rd?	bronze	
HAYL		321	stud		1stBC-E 3rd?	bronze/gunmetal	
HAYL		363	stud		c120	bronze	
HAYL		367	stud		L 1st-E 3rd	bronze	
HAYL		388	stud		L 1st-E 3rd	bronze	
HAYL		474	stud			bronze	
HAYL		481	stud			bronze	
HAYL		494	stud			bronze	
HAYL		594	stud		recent	gunmetal	
HAYL		604	stud		recent	bronze	
HAYL		616	stud		3rd-4th	gunmetal	
HAYL		643	stud		60's-E 3rd	bronze?	
HAYL		649	stud		60's-E 3rd	bronze	
HAYL		696	stud		60's-E 3rd	bronze	
HAYL		750	stud		60's-E 3rd	gunmetal	
HAYL		794	stud		60's-E 3rd	leaded bronze	
HAYL		927	stud		3rd-4th	brass/gunmetal	
HAYL		931	stud			(leaded) gunmetal	
HAYL		1097	stud		L 1st-E 3rd	bronze	
HAYL		1101	stud		M 2nd-E 3rd	bronze/gunmetal	
HAYL		1133	stud		L 1st-E 3rd	bronze	
HAYL		1140	stud		L 1st-E 3rd	bronze/gunmetal	
HAYL		1159	stud		L 1st-E 3rd	bronze	
HAYL		1241	stud		L 1st-E 3rd	(leaded) gunmetal	
HAYL		1464	stud		L 1st-E 3rd	leaded bronze	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
HAYL		1502	stud		L 1st-E 3rd	bronze	
HAYL		1565	stud		1stBC-E 3rd	bronze	
HAYL		1628	stud		1stBC-M 1st?	bronze	
HAYL		1691	stud		L 1st-4th?	bronze	
HAYL		1769	stud		recent	bronze	
HAYL		1778	stud		3rd-4th	brass	
HAYL		1988	stud		recent	brass	
HAYL		2006	stud		L 1st-E 3rd	bronze	
HAYL		2024	stud		L 1st-E 3rd	bronze	
HAYL		2027	stud		8th-9th	bronze?	
HAYL		2072	stud			bronze	
HAYL		2327	stud			copper	I>
HAYL		2360	stud		L 1st-4th	(leaded) bronze	
HAYL		2559	stud		3rd-4th	bronze	
HAYL		2660	stud		3rd-4th	bronze	
HAYL		2852	stud		L 1st-4th	bronze	
HAYL		2947	stud		L 1st-4th	bronze	
HAYL		3016	stud		L 1st-E 3rd	bronze	
HAYL		3155	stud		recent	bronze/gunmetal	
HAYL		48	stud		1stBC-E 3rd?	bronze $	
HAYL		3162	stud		recent	bronze $	
HAYL		248	stud		60's-E 3rd	bronze $	
HAYL		2500	stud		3rd-4th	gunmetal $	
HAYL		1728	stud?		recent	brass/gunmetal $	
HAYL		222	terminal		60's-E 3rd	bronze	
HAYL		394	terminal		1stBC-M 1st	bronze	
HAYL		2301	terminal			brass	
HAYL		3384	terminal, Janus			leaded bronze	W
HAYL		570 & 3247	terminal/binding		3rd-4th	bronze	
HAYL		105	terret		L 1st-E 3rd	bronze $	
HAYL		13	tweezers		recent	gunmetal	
HAYL		333	tweezers		1stBC-E 3rd?	(leaded) bronze	
HAYL		1481	tweezers		3rd-4th	bronze/gunmetal	
HAYL		1542	tweezers		L 1st-E 3rd	brass/gunmetal	
HAYL		1587	tweezers		L 1st-E 3rd	bronze	
HAYL		1660	tweezers		L 1st-E 3rd	brass	
HAYL		2043	tweezers		1stBC-E 3rd	bronze	
HAYL		25	votive offering?		recent	leaded gunmetal	W
HAYL		452	wire		1stBC-M 1st	bronze	
HAYL		1616	wire		1stBC-E 3rd	bronze	
HAYL		2074	wire			copper	
HAYL		2382	wire		3rd-4th	leaded gunmetal	
HAYL		865	wire		3rd-4th	(leaded) bronze $	
HAYL		3236	yoke pommel		1stBC-E 3rd	leaded bronze $	E
HEYB		403	apron strap	*	med or later	brass	
HEYB		402	disc: convex			bronze	
HEYB		407	finial: cast		Saxon?	leaded gunmetal?	
HEYB		408	hook/bent rod		later 3rd	leaded bronze	
HEYB		418	knob/terminal			leaded bronze	
HEYB		395	ligula		later 3rd	leaded bronze	
HEYB		410	needle		4th or later	leaded bronze	
HEYB		2/24	needle		Saxon	leaded bronze	
HEYB		406	pin		late 2nd-225	leaded bronze	
HEYB		411	pin		late 1st/2nd	gunmetal	
HEYB		2/27	pin		later 3rd	leaded bronze	
HEYB		2/6	pin/wire		early 3rd	leaded bronze	
HEYB		2/28	ring		Saxon	leaded gunmetal	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
HEYB		400	ring: finger		later 3rd	leaded gunmetal	S
HEYB		416	ring: finger		early 3rd	bronze	
HEYB		2/30	ring: finger		later 3rd	leaded bronze	
HEYB		2/31	sheet binding		later 3rd	bronze?	
HEYB		2/34	sheet binding			bronze	
HEYB		404	spoon	C	later 3rd	leaded bronze	
HEYB		397	stud (thin sheet)		later 3rd	brass	
HEYB		398	stud/nail		4th	bronze	
HEYB		413	tweezers		4th	bronze	
HEYB		2/21	tweezers		later 3rd	leaded bronze	
HEYB		2/42	tweezers		later 3rd	bronze	
POOL		4056	bracelet ?			bronze/gunmetal	
POOL		34a	doming block			leaded gunmetal	
POOL		6a	doming punch			bronze	
POOL		1006	doming punch			leaded gunmetal	
POOL		1269	mount			bronze	
POOL		4174	pin ?			leaded gunmetal	
POOL		1010	sheet hemisphere			brass	
RICH	7350452		spoon	Aa		brass	
RICH	7350455		spoon	Aa		brass	
RICH	7350457		spoon	Aa		brass	
RICH	7350760		spoon	Aa		copper/gunmetal	W
RICH	7350923		spoon	A?a		brass	
RICH	7350053		spoon	Ab		(leaded) bronze	
RICH	7350055		spoon	Ab		leaded bronze	
RICH	7350200		spoon	Ab		bronze/gunmetal	
RICH	7350202		spoon	Ab		(leaded) bronze	
RICH	7350458		spoon	Ab		leaded bronze	W
RICH	7350768		spoon	Ba		brass	
RICH	7350453		spoon	Bb		leaded bronze/gunmetal	
RICH	7351213		spoon	B/D		bronze	
RICH	7350450		spoon	C		(leaded) bronze	
RICH	7351316		spoon	C		silver	
RICH	7350054		spoon	D		bronze	
RICH	7350087		spoon	D		bronze	
RICH	7350456		spoon	D		bronze	
RICH	7350720		spoon	D		bronze	
SHEP		no 101	baldric clip	*		brass	
SHEP		no 52	belt hinge	*	48-60 AD	brass	
SHEP		no 43	boss		54-60 AD	gunmetal	
SHEP		no 4	buckle	*	44-49 AD	brass	
SHEP		no 76	buckle plate?	*	later 1st	brass	
SHEP		no 23	buckle plates	*	48-60 AD	brass	
SHEP		no 63	chatelaine		c.60 AD	bronze	
SHEP		no 31	cuirass hinge	*	48-60 AD	brass	
SHEP		no 48	cuirass hinge	*	48-60 AD	brass	
SHEP		no 49	cuirass hinge	*	48-60 AD	brass	
SHEP		no 50	cuirass hinge	*	48-60 AD	brass	
SHEP		no 51	cuirass hinge	*	48-60 AD	brass	
SHEP		no 68	dice		c.60 AD	leaded bronze	
SHEP		no 67	dice-box		c.60 AD	leaded bronze	W
SHEP		no 29	dress fastener	*	54-60 AD	brass	
SHEP		no 102	harness clip	*		gunmetal	N
SHEP		no 73	helmet ear-piece	*	c.60 AD	gunmetal?	W
SHEP		no 37	helmet flange	*	54-60 AD	bronze and brass	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
SHEP		no 18	hinge	*	44-60 AD	brass	
SHEP		no 30	hinge	*	54-60 AD	brass	
SHEP		no 15	hinge	*	44-60 AD	brass	
SHEP		no 58	hinge	*	48-60 AD	brass	
SHEP		no 64	hinge?		c.60 AD	leaded bronze	
SHEP		no 21	jug handle		44-60 AD	leaded copper	
SHEP		no 47	lorica fitting	*	48-60 AD	brass?	
SHEP		no 22	mount		54-60 AD	leaded bronze	W
SHEP		no 40	mount		48-60 AD		S
SHEP		no 42	mount		54-60 AD	leaded gunmetal	
SHEP		no 60	mount, circular		c.60 AD	brass	
SHEP		no 44	mount: S-shaped		54-60 AD	leaded gunmetal	W
SHEP		no 69	object		c.60 AD	leaded gunmetal	
SHEP		no 1	pendant		44-49 AD	gunmetal	
SHEP		no 91	pendant/amulet			leaded bronze	
SHEP		no 2	ring		44-49 AD	(leaded) brass	
SHEP		no 62	ring: finger		c.60 AD	copper	G
SHEP		no 62 bis	ring: finger		c.60 AD	(leaded) copper	G
SHEP		no 16	rod		44-60 AD	bronze	
SHEP		no 19	sheath binding	*	44-60 AD	brass	
SHEP		no 3	sheet		44-49 AD	copper	
SHEP		no 11	sheet		44-60 AD	copper	
SHEP		no 65	sheet		c.60 AD	copper	
SHEP		no 85	sheet binding?			(leaded) bronze	
SHEP		no 59	sheet, ribbed		48-60 AD	brass	
SHEP		no 17	shield binding	*	44-60 AD	brass	
SHEP		no 74	shield binding	*	c.60 AD	brass	
SHEP		no 108	spur?	*		brass	
SHEP		no 61	stamp		c.60 AD	leaded gunmetal	
SHEP		no 6	strap buckle	*	44-49 AD	brass	
SHEP		no 5	strap hinge	*	44-49 AD	brass	
SHEP		no 33	strap hinge	*	48-60 AD	brass	
SHEP		no 34	strap hinge	*	48-60 AD	brass	
SHEP		no 104	strap junction	*		leaded gunmetal	
SHEP		no 40	strapping		48-60 AD	leaded bronze	
SHEP		no 53	strapping	*	48-60 AD	leaded gunmetal	
SHEP		no 8	studs		44-60 AD		A>
SHEP		no 111	studs	*		brass	N
SHEP		no 13	weight		44-60 AD	leaded bronze	
ULEY		45	bracelet	4		brass	
ULEY		224	bracelet	10	390-420	brass	
ULEY		341	bracelet	4	390-420	brass	
ULEY		577	bracelet	4		leaded bronze/gunmetal	
ULEY		723	bracelet	4	360-390	leaded gunmetal	
ULEY		779	bracelet	5	360-390	bronze	
ULEY		951	bracelet	4	post-Roman	brass	
ULEY		1117	bracelet	4	360-390	brass/gunmetal	
ULEY		1295	bracelet	2		brass	
ULEY		1468	bracelet	4	390-420	brass	
ULEY		1622	bracelet	2	390-420	brass	
ULEY		1793	bracelet	6	390-420	leaded bronze/gunmetal	
ULEY		1810	bracelet	11	360-390	leaded brass	
ULEY		2062	bracelet	2	c100-310/17	brass	
ULEY		2230	bracelet	4	390-420	brass	
ULEY		2237	bracelet	4	390-420	leaded gunmetal	
ULEY		2318	bracelet	2	c100-310/17	brass	
ULEY		2392	bracelet	4		leaded gunmetal	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
ULEY		2426	bracelet	10		brass	
ULEY		3314	bracelet	2	390-420	brass	
ULEY		3741	bracelet	5		brass	
ULEY		3759	bracelet	4		brass	
ULEY		3762	bracelet	4		brass	
ULEY		3801	bracelet	4		brass	
ULEY		4094	bracelet	4	post-Roman	brass	
ULEY		4145	bracelet	5	post-Roman	bronze	
ULEY		4146	bracelet	5	post-Roman	bronze	
ULEY		4359	bracelet	4	post-Roman	leaded bronze	
ULEY		4524	bracelet	4	post-Roman	brass	
ULEY		4630	bracelet	4	post-Roman	brass	
ULEY		4742	bracelet	2	post-Roman	bronze	
ULEY		4883	bracelet	8	post-Roman	brass	
ULEY		4884	bracelet	10	post-Roman	brass	
ULEY		6010	bracelet	2		bronze	
ULEY		6383	bracelet	3		bronze	
ULEY		6531	bracelet	2		bronze/gunmetal	
ULEY		6750	bracelet	10	post-Roman	gunmetal ?	
ULEY		7000	bracelet	2	310-420	bronze	
ULEY		7254	bracelet	9	post-Roman	leaded gunmetal	
ULEY		2289	bracelet ?	4	c100-310/17	leaded gunmetal	
ULEY		3733	bracelet ?	1	c100-390	brass	
ULEY		5248	bracelet ?	1	post-Roman	bronze	
ULEY		260	bucket mount			leaded bronze/gunmetal	
ULEY		305	disc			leaded gunmetal	E
ULEY		3195	disc			leaded bronze	E
ULEY		407	face mask			brass+lead fill	
ULEY		5209	mount			(leaded) brass/gunmetal	E
ULEY		21	ring/token	1		brass + lead fill	
ULEY		39	ring/token	2		brass/gunmetal	
ULEY		100	ring/token	4		leaded brass/gunmetal	
ULEY		185	ring/token	2		bronze/gunmetal	
ULEY		222	ring/token	2	390-420	leaded gunmetal	
ULEY		287	ring/token	2	390-420	brass/gunmetal	
ULEY		288	ring/token	2	390-420	brass	
ULEY		377	ring/token	2	390-420	bronze/gunmetal	
ULEY		389	ring/token	4	390-420	leaded brass/gunmetal	
ULEY		416	ring/token	4	390-420	leaded gunmetal	
ULEY		542	ring/token	2	390-420	gunmetal	
ULEY		628	ring/token	1	390-420	bronze + lead fill	
ULEY		689	ring/token	4		leaded bronze/gunmetal	
ULEY		740	ring/token	2?	360-390	gunmetal ?	
ULEY		988	ring/token	2	390-420	leaded gunmetal	
ULEY		1057	ring/token	1	360-390	brass	
ULEY		1430	ring/token	2	390-420	leaded bronze	
ULEY		1486	ring/token	2	390-420	bronze/gunmetal	
ULEY		1542	ring/token	2	390-420	leaded bronze/gunmetal	
ULEY		1595	ring/token	2	390-420	bronze	
ULEY		1720	ring/token	4		leaded gunmetal	
ULEY		1791	ring/token	3	390-420	bronze	
ULEY		1831	ring/token	1	390-420	bronze + ?lead fill	
ULEY		1917	ring/token	4	310-390	leaded bronze	
ULEY		2205	ring/token	2	c100-310/17	leaded bronze/gunmetal	
ULEY		2553	ring/token	2?		leaded bronze	
ULEY		3364	ring/token	2	390-420	bronze/gunmetal	
ULEY		3552	ring/token	1	390-420	bronze	
ULEY		3737	ring/token	2		brass	

Table C.4 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
ULEY		3764	ring/token	2		gunmetal	
ULEY		3808	ring/token	2		gunmetal	
ULEY		4068	ring/token	2		gunmetal	
ULEY		4297	ring/token	2		gunmetal	
ULEY		4496	ring/token	2		bronze/gunmetal	
ULEY		4552	ring/token	4		gunmetal	
ULEY		4621	ring/token	2	post-Roman	leaded bronze/gunmetal	
ULEY		4663B	ring/token	4	post-Roman	leaded bronze	
ULEY		4780	ring/token	2	post-Roman	leaded bronze	
ULEY		4830	ring/token	4	post-Roman	leaded brass/gunmetal	
ULEY		4859	ring/token	2	post-Roman	gunmetal	
ULEY		4885	ring/token	2	post-Roman	bronze/gunmetal	
ULEY		4900	ring/token	2	post-Roman	leaded gunmetal	
ULEY		5602	ring/token	2	1st	gunmetal ?	
ULEY		6021	ring/token	2		leaded gunmetal	
ULEY		6050	ring/token	2		gunmetal	
ULEY		6318	ring/token	2?		gunmetal	
ULEY		6771	ring/token	2	post-Roman	bronze	
ULEY		6808	ring/token	1	post-Roman	brass+?lead fill	
ULEY		7054	ring/token	4	310-420	leaded brass/gunmetal	
ULEY		7773	ring/token	4	310-360	brass	
ULEY		7818	ring/token	1	310-360	brass+solder fill	
ULEY		7853	ring/token	3	post-Roman	bronze	
ULEY		143	statuette			leaded bronze	
ULEY		395	statuette			leaded gunmetal	
ULEY		1417	statuette			leaded bronze/gunmetal	
ULEY		1427	statuette			gunmetal	
ULEY		1567	statuette			leaded gunmetal	
ULEY		1749	statuette			copper/bronze	
ULEY		1949	statuette			leaded bronze	
ULEY		5542	statuette			brass	
ULEY		7248	statuette			gunmetal	
ULEY		8066	statuette			leaded gunmetal	
ULEY		933	statuette wing			bronze	
ULEY		36	statuette/bust			brass	
ULEY		709	statuette/bust			leaded bronze	
ULEY		3875	stud			leaded gunmetal	E

Table C.5 - AAS results for objects other than brooches

Site	AML No	Site No	Cu %	Zn %	Sn %	Pb %	Ag %	Alloy
CANT		783	95.2	0.0	1.4	2.6	0.8	copper
HAYL		105	89.8	0.0	10.2	1.2	0.0	bronze
HAYL		1450	87.5	0.0	10.3	2.3	0.9	bronze
HAYL		1642	88.9	0.0	10.8	0.2	0.0	bronze
HAYL		1728	69.3	18.0	5.7	0.2	0.1	brass/gunmetal
HAYL		1740	99.0	0.0	0.0	0.2	0.0	copper
HAYL		1785	86.5	0.0	10.5	0.4	0.0	bronze
HAYL		1841	88.5	0.0	3.8	3.2	0.0	bronze
HAYL		188	81.6	0.1	8.3	0.4	0.0	bronze
HAYL		24	77.9	12.6	0.0	6.9	0.0	(leaded) brass
HAYL		248	75.9	0.6	8.2	1.3	0.0	bronze
HAYL		2500	85.2	6.6	3.4	2.0	0.1	gunmetal
HAYL		28	65.0	0.0	7.3	21.6	0.0	leaded bronze
HAYL		2858	89.4	0.0	8.8	0.1	0.2	bronze
HAYL		2872	69.4	0.0	11.6	9.2	0.0	leaded bronze
HAYL		2992	83.0	0.0	6.3	3.9	0.0	bronze
HAYL		3037	74.7	0.0	12.5	0.3	0.1	bronze
HAYL		3080	82.5	14.8	0.0	0.0	0.0	brass
HAYL		3106?	81.9	0.0	10.3	2.9	0.0	bronze
HAYL		314	87.5	0.0	10.4	0.6	0.0	bronze
HAYL		3154	73.5	0.1	10.0	13.0	0.0	leaded bronze
HAYL		3162	89.3	0.4	8.9	1.3	0.0	bronze
HAYL		3236	71.9	0.0	5.4	19.4	0.1	leaded bronze
HAYL		3241	84.5	0.0	9.8	0.4	0.0	bronze
HAYL		3245	89.8	0.0	6.8	0.2	0.0	bronze
HAYL		3265	75.0	0.6	8.8	10.9	0.0	leaded bronze
HAYL		3314	82.4	0.0	10.7	1.3	0.2	bronze
HAYL		3340	96.9	0.0	0.0	0.1	0.0	copper
HAYL		3363	79.2	0.0	16.7	4.0	0.0	bronze
HAYL		3461	76.9	0.0	12.0	5.4	0.1	(leaded) bronze
HAYL		36	74.2	0.0	11.9	5.5	0.0	(leaded) bronze
HAYL		374	89.8	0.0	4.6	2.9	0.1	bronze
HAYL		404	93.0	0.0	3.8	0.1	0.2	bronze
HAYL		430	60.2	0.0	0.9	37.7	0.5	leaded copper
HAYL		449	87.5	0.0	13.7	0.0	0.0	bronze
HAYL		460	63.7	0.0	4.2	24.2	0.0	leaded bronze
HAYL		48	85.0	2.5	8.3	3.3	0.1	bronze
HAYL		509	96.0	0.0	2.2	0.1	0.2	copper
HAYL		540	70.6	0.0	11.5	1.2	0.0	bronze
HAYL		55	80.3	0.0	12.9	3.0	0.1	bronze
HAYL		602	77.8	19.6	0.0	0.1	0.0	brass
HAYL		687	78.9	0.0	10.4	1.7	0.1	bronze
HAYL		746	84.6	0.0	9.7	0.2	0.0	bronze
HAYL		865	78.4	0.0	10.8	4.0	0.1	(leaded) bronze
HAYL		94	87.2	0.0	12.8	0.3	0.0	bronze
NORN		REPORT 22	74.1	1.8	7.5	11.4	0.0	leaded bronze
NORN		1370	66.7	12.5	4.2	8.3	0.0	leaded brass/gunmetal
RICH	7350643		89.4	4.9	2.5	5.1	0.1	(leaded) copper/brass
RICH	7350393		85.7	4.2	6.4	4.3	0.1	(leaded) bronze/gunmetal
RICH	7350683		79.8	9.0	3.5	6.9	0.1	(leaded) brass/gunmetal

Table C.6 - Analytical results for post-Roman objects

Site	AML No	Site No	Object	Type	Alloy	Decor
Early Saxon (6th century)						
PORT		33-10	binding		(leaded) gunmetal	
PORT		67-6	binding		bronze	
PORT		1-1	brooch	disc	(leaded) bronze	W
PORT		1-2	brooch	disc	(leaded) bronze	W
PORT		2A-1	brooch	disc	(leaded) gunmetal	
PORT		16-2	brooch	disc	bronze	W
PORT		19-1	brooch	small long	(leaded) gunmetal	
PORT		19-2	brooch	small long	(leaded) gunmetal	
PORT		22-1	brooch	disc	bronze	
PORT		22-2	brooch	disc	leaded bronze	W
PORT		25-1	brooch	small long	bronze	W
PORT		25-2	brooch	small long	bronze/gunmetal	W
PORT		31-1	brooch	small long	(leaded) bronze	W
PORT		32-1	brooch	disc	(leaded) gunmetal	W
PORT		32-2	brooch	disc	(leaded) gunmetal	
PORT		35-1	brooch	saucer	bronze	G
PORT		35-2	brooch	saucer	bronze	G
PORT		38-1	brooch	disc	bronze/gunmetal	W
PORT		38-2	brooch	disc	(leaded) bronze	W
PORT		41-1	brooch	saucer	bronze	G
PORT		41-2	brooch	saucer	(leaded) bronze/gunmetal	G
PORT		42-1	brooch	disc	leaded gunmetal	W
PORT		48-2	brooch	saucer	bronze	G
PORT		48-3	brooch	saucer	bronze	G
PORT		50-1	brooch	small long	(leaded) bronze	
PORT		52-1	brooch	disc	leaded gunmetal	
PORT		52-2	brooch	disc	(leaded) gunmetal	
PORT		59-1	brooch	small long	leaded bronze	
PORT		67-2	brooch	quoit	bronze	W
PORT		SF 5	brooch	saucer	(leaded) bronze	
PORT		50-2	bucket		gunmetal	
PORT		35-3	buckle loop		bronze/gunmetal	
PORT		48-4	buckle loop		(leaded) bronze	
PORT		35-3	buckle plate		bronze	
PORT		48-4	buckle plate		bronze	
PORT		48-112	handle, brush		(leaded) gunmetal	
PORT		44-44	loop		leaded gunmetal	
PORT		1-3	pin		gunmetal	
PORT		44-44	pin		leaded gunmetal	
PORT		52-3	pin		leaded bronze	
PORT		54-9	ring, finger		silver	
PORT		44-44	scoop		copper	
PORT		33-9	sheet		gunmetal	
PORT		12-6	sheet cylinder		leaded bronze	
PORT		13-1	sheet cylinder		(leaded) gunmetal	
PORT		13-2	sheet cylinder		(leaded) gunmetal	
PORT		11-3	strip		(leaded) gunmetal	
PORT		61-15	strip		bronze	
PORT		61-19	strip		bronze	
PORT		26-4	tweezers		bronze	
PORT		53-1	tweezers		bronze	

Table C.6 (continued)

Site	AML No	Site No	Object	Type	Date	Alloy	Decor
Medieval							
ASHT	835153		buckle			brass	
CARL		AE 67	buckle		13-16th	leaded gunmetal/brass	
CARL		AE 66	buckle ?		13-16th	leaded brass	
GORH	820070	444	padlock			(leaded) bronze	
CARL		AE 44	seal matrix		post-med	leaded brass	
CARL		AE 20	strip, engraved			brass	
CARL		AE 62	stud		13-16th	copper	

APPENDIX D

ILLUSTRATIONS OF SELECTED TYPES OF LATE IRON AGE AND ROMAN BROOCHES

The illustrations are arranged in the order of the analytical results in Table C.3. The number below each illustration is the Hull type number. The list below shows the sites the brooches come from and the source of the illustrations which are 1:1.

Baldock

Illustrations from Stead and Rigby (1986):

Hull Types 21, 51, 100, 173A, 224, 226, P4, P6, P12.

Braughing

Illustrations from Potter and Trow (1988):

Hull Types 26, 89, 90, 94, 225, 260, 266.

Cirencester

Illustration from Hull and Hawkes (forthcoming):

Hull Type 158D.

Nornour

Illustrations from Dudley (1967):

Hull Types 35, 111, 123, 131, 149, 154B, 255, 257, 271.

Old Wintringham

Illustrations from Stead (1976):

Hull Types 36, 88.

Richborough

Illustrations by Judith Dobie, English Heritage:

Hull Types 3, 10, 40, 42, 58, 60, 79, 92, 145, 146, 148, 158A, 162B, 166, 176B, 178, 180, 181, 186, 187, 189, 190, 191, 192, 227, 229, 233, 238, 249, 252, 252C, 256, 267, 270, P3.

Illustrations from Cunliffe 1968:

Hull Type 157.

Salisbury Museum collections

Illustration from Mackreth (1973):

Hull Type 37.

Verulamium: King Harry Lane

Illustrations from Stead and Rigby (1989):

Hull Types 168, 263, 268, 269.

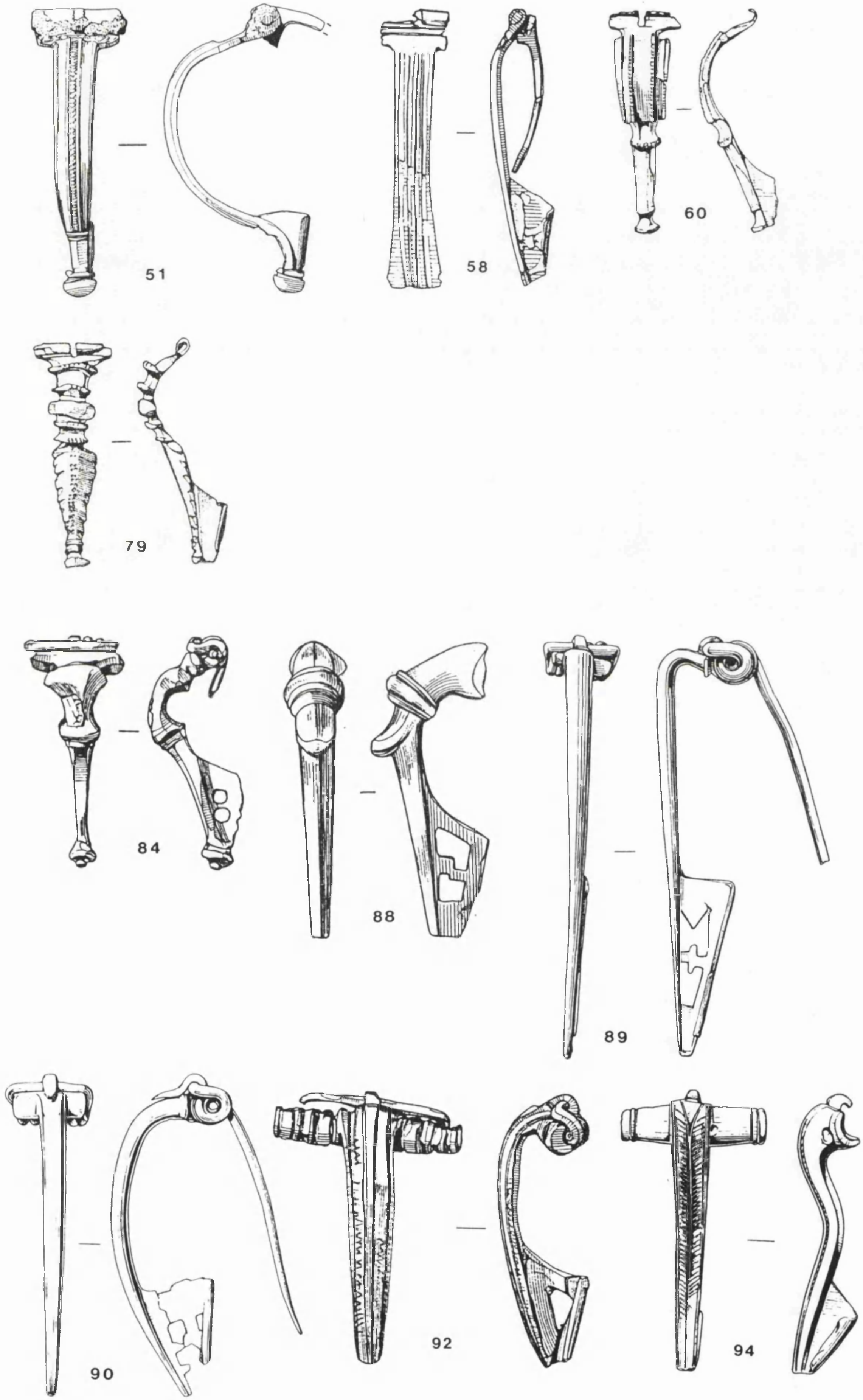
Winterton

Illustrations from Stead (1976):

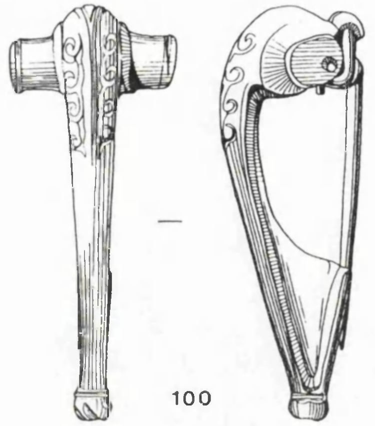
Hull Types 158C, 159A, 164.


3
10
21
26
35
36
37
40
42

Group 4B and 5 types



Group 6 and 7 types



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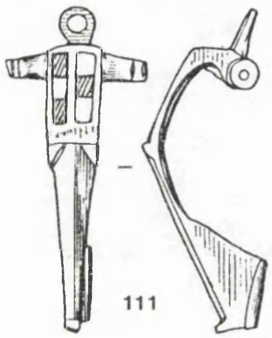

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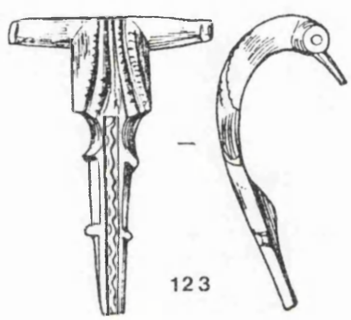

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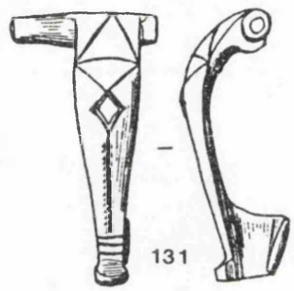

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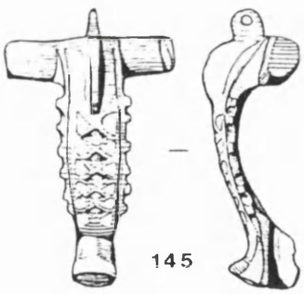

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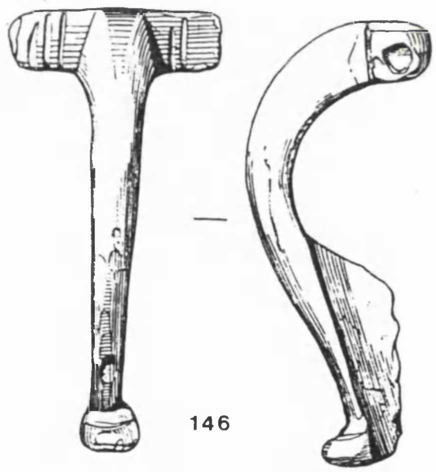

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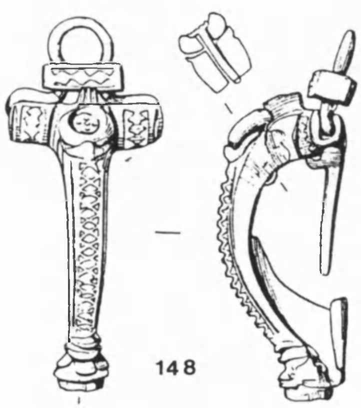

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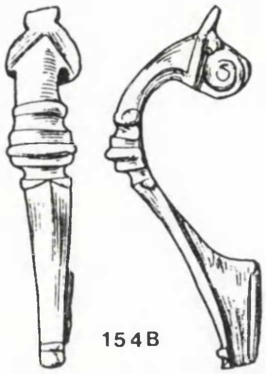
Group 8 and 9 types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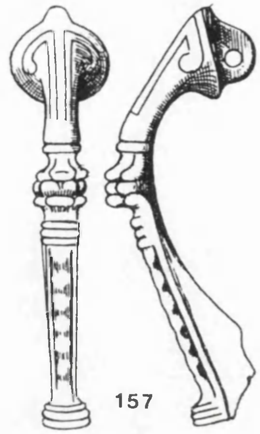
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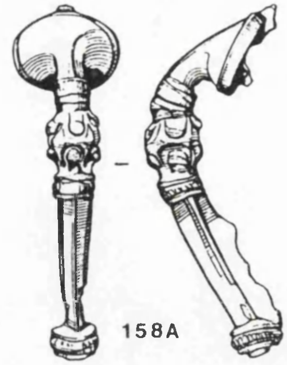
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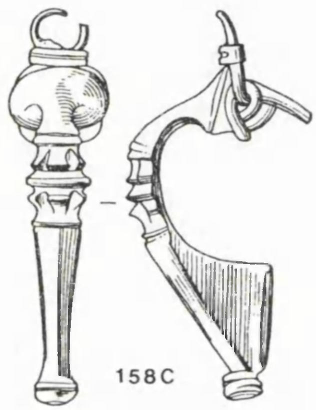
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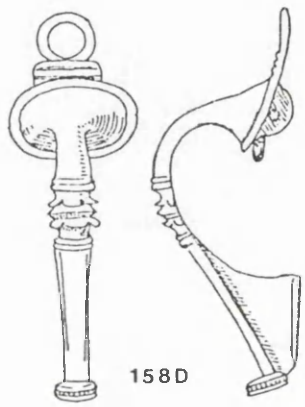
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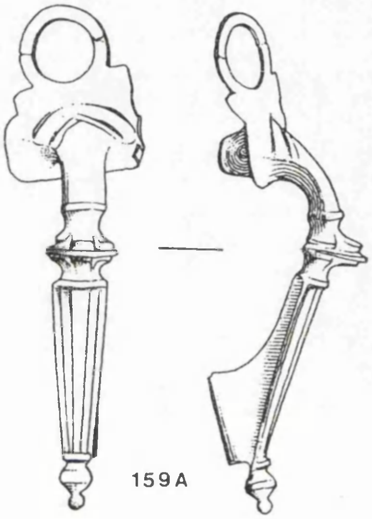
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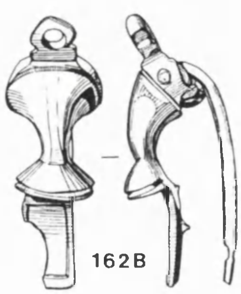
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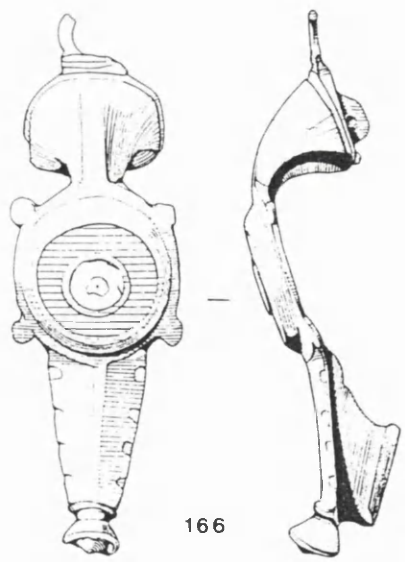
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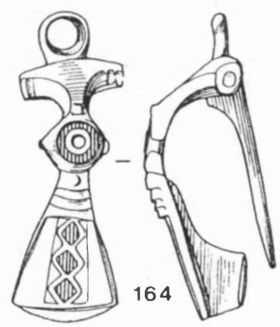
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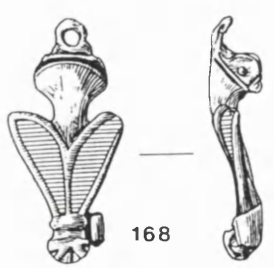
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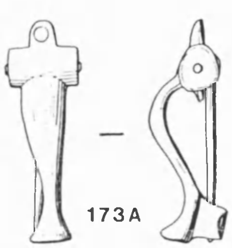
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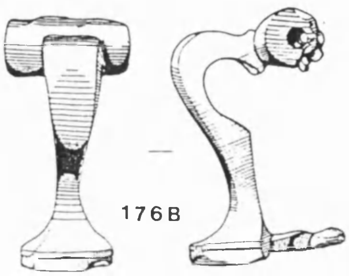
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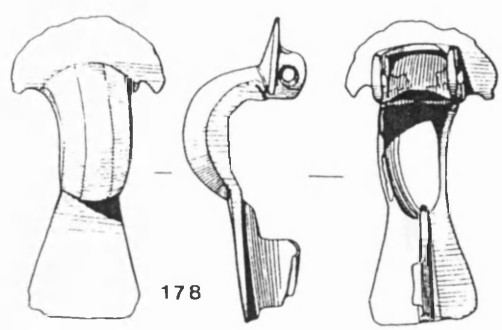
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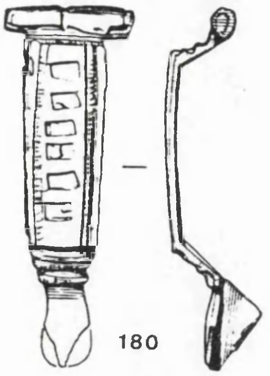

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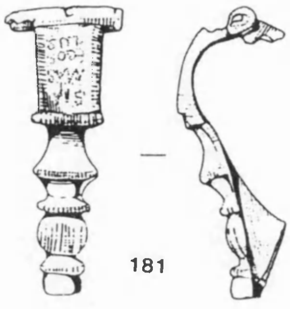

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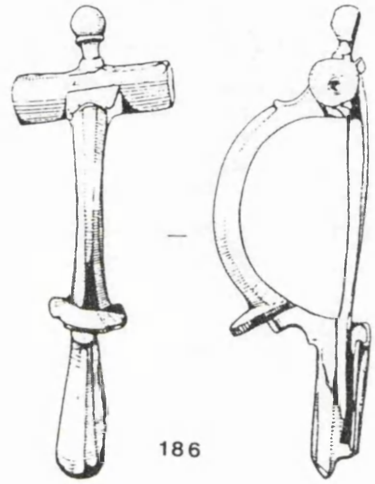

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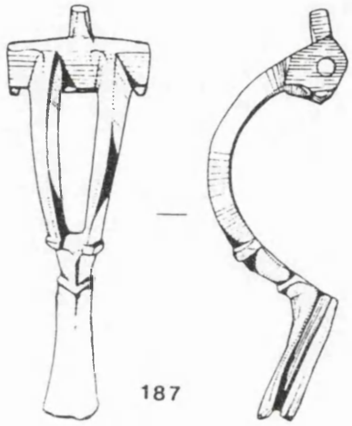

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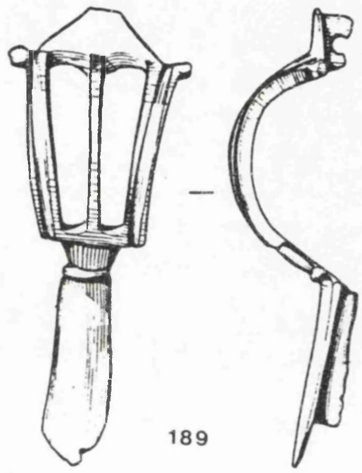

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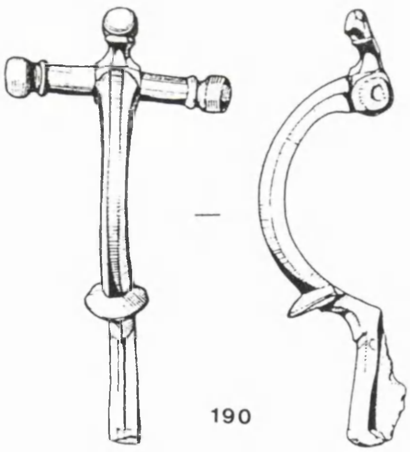

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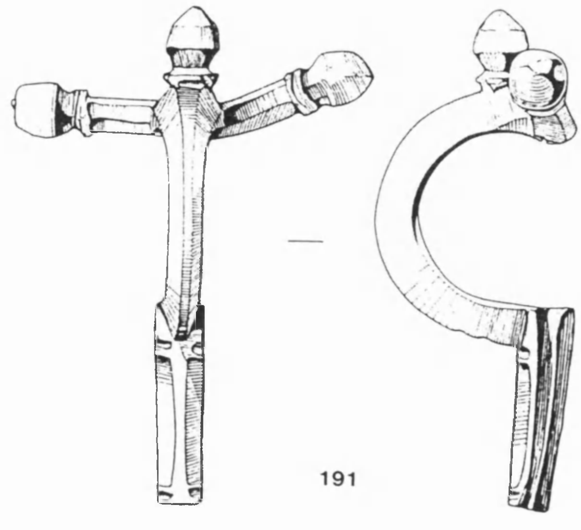

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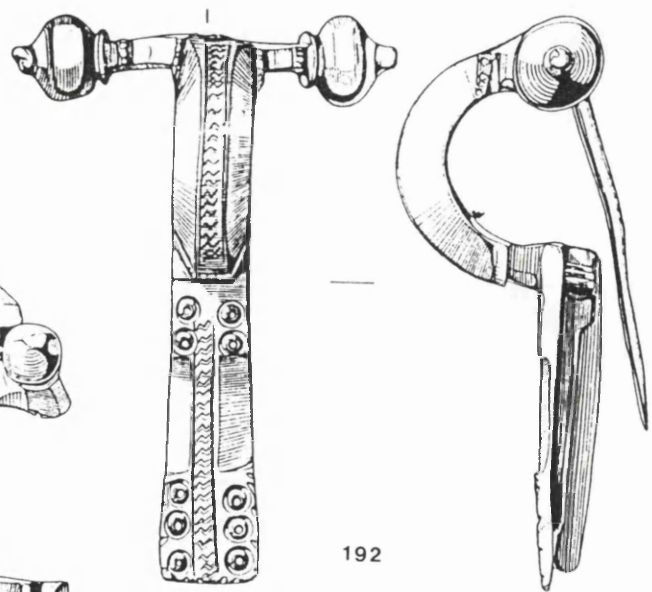

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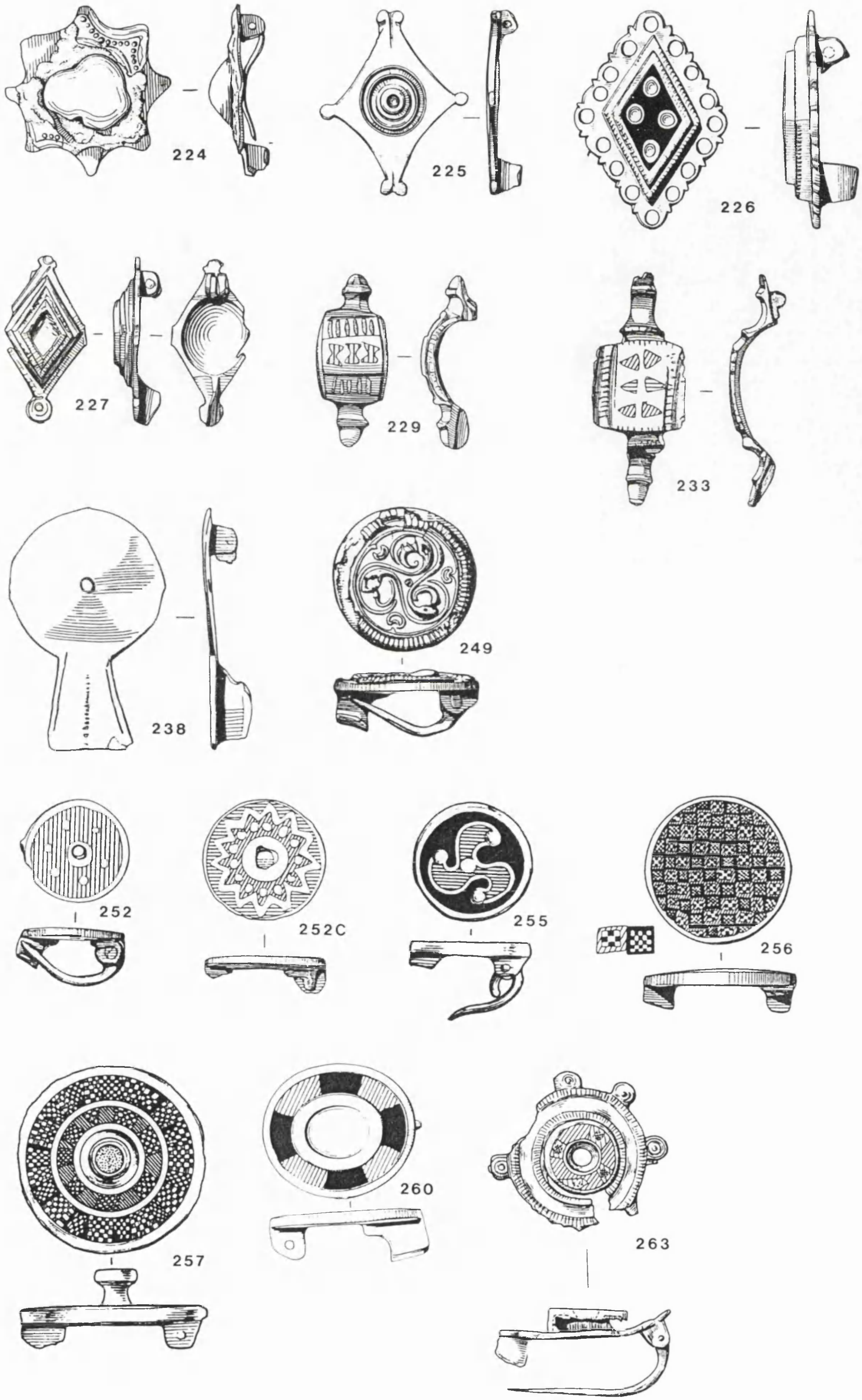
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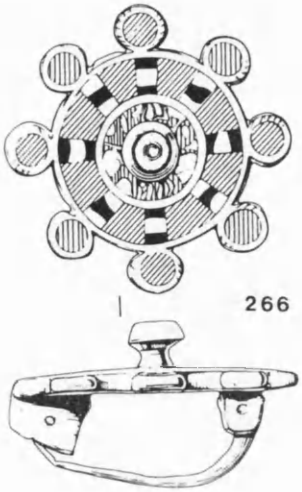

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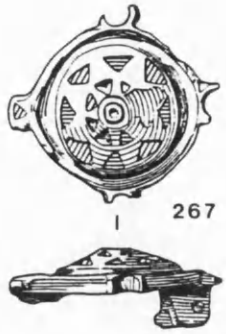

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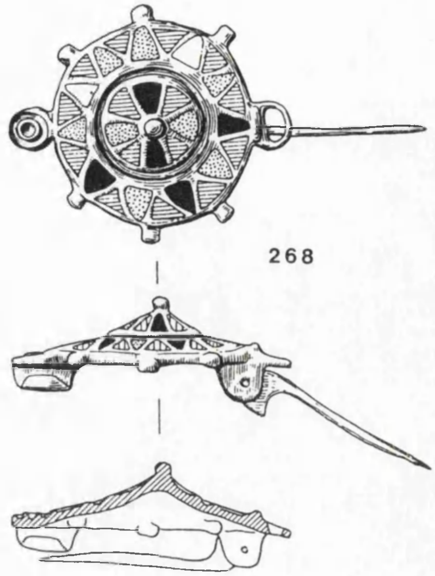

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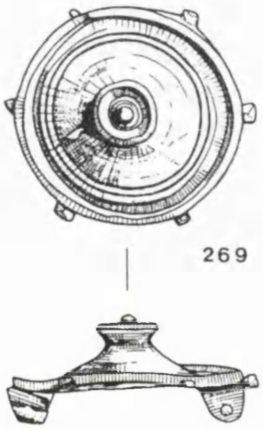

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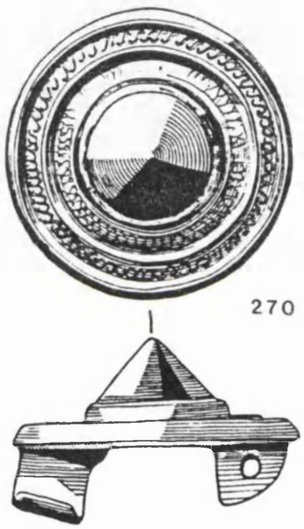

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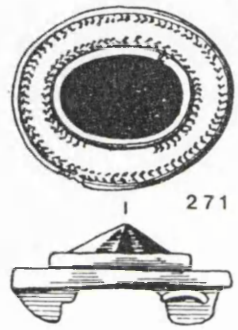

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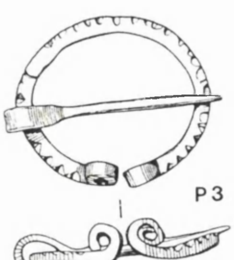

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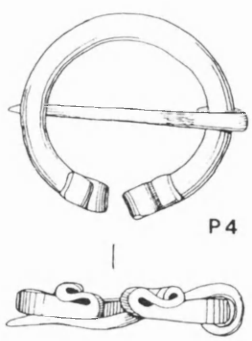

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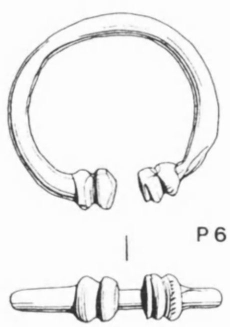

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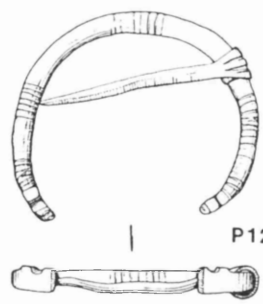

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AML 2657 BAYLEY, J. (1978) Chelmsford - the slags and other technological remains.

AML 2677 MARTIN-HOOGEWERF, A. (1978) Investigation of atomic absorption spectrophotometry and its application to the analysis of ancient copper alloy artefacts.

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AML 2811 BAYLEY, J. (1979) Rochester - Belgic coins and associated finds.

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AML 2953 * BAYLEY, J. (1979) The metalworking remains from Much Park Street, Coventry.

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AML 3032 BAYLEY, J. (1980) The crucibles from the Empire Cinema site, Bedford.

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AML 3094 BAYLEY, J. (1980) Brooches etc from Wollaston House, Dorchester, Dorset.

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AML 3113 * BAYLEY, J. (1980) The Wharram Percy disc brooch.

AML 3114 * BAYLEY, J. (1980) The crucibles and moulds from Saxon Thetford.

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AML 3153 BAYLEY, J. (1980) Note on a coin mould from Wroxeter.

AML 3155 MACALISTER, F. (1980) Dorchester - the copper alloys.

AML 3182 MACALISTER, F. (1980) Wroxeter B, Shropshire - Technology.

AML 3188 * BAYLEY, J. (1980) Colchester, Essex - analytical results for the brooches from the Sheepen excavations.

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AML 3217 BAYLEY, J. (1980) Two enamelled brooches from Hayling Island and three brooches from Lamyatt Beacon.

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AML 3283 BAYLEY, J. (1981) Two brooches from Cosgrove.

AML 3286 * BAYLEY, J. (1981) Qualitative analyses of some copper alloy objects from Sheepen, Colchester.

AML 3322 * BAYLEY, J. (1981) The finds of 'lead' from Baldock, Herts.

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AML 3425 * BAYLEY, J. (1981) Discussion of the qualitative analyses of objects from Sheepen, Colchester.

AML 3464 * BAYLEY, J. (1981) Analyses of copper alloy objects from Heybridge, Essex.

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